



Command Reference Manual

Software Version 5.12 r3

Part Numbers

004-122-000 (Standard)

004-122-100 (Cleanroom)

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Atomic Force Profiler™ (AFP™)
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Software Modes:

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Tapping™
TappingMode+™
LiftMode™
AutoTune™
TurboScan™
Fast HSG™
PhaseImaging™
DekMap 2™
HyperScan™
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StiffStage™

Hardware Options:

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Extender™
TipView™
Interleave™
LookAhead™
Quadrex™

Software Options:

NanoScript™
Navigator™
FeatureFind™

Miscellaneous:

NanoProbe®

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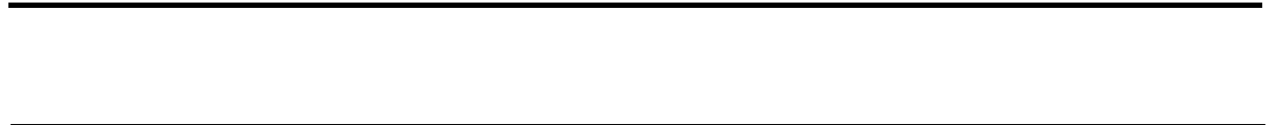
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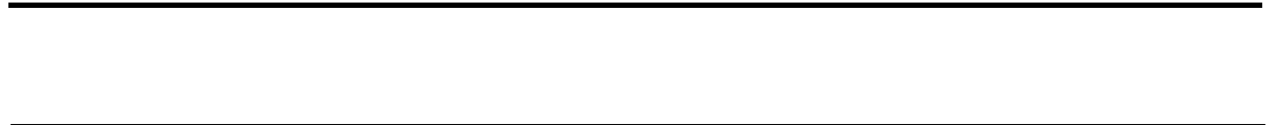
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Chapter 1 Introduction

NanoScope™ systems from Digital Instruments Veeco Metrology Group are technological leaders in the field of scanning probe microscopy (SPM). They provide fully digital software control of the SPM process, from Real time manipulation of the microscope system to Offline viewing, analysis and modification tools.

The focus of this manual is the software. It is a reference to the tasks related to your NanoScope system. The material covered provides an overview to all of the graphical interface, menus, toolbars, dialog boxes and parameters in the software for version 5.12.

This chapter includes the following topics:

- **Conventions in this Manual** [Section 1.1](#)
 - **Chapter Contents** [Section 1.1.1](#)
 - **Command Panels** [Section 1.1.2](#)
 - **NanoScope Command Icons** [Section 1.1.3](#)
- **NanoScope Software Overview** [Section 1.2](#)
- **Technical Support at Digital Instruments** [Section 1.3](#)

1.1 Conventions in this Manual

Most chapters are named for top-level menu bar commands. The organization is by software command in the order they appear on the menus and dialog boxes. Every attempt has been made to include all possible NanoScope software commands in this manual even if they may not be accessible from your particular system. Digital Instruments, Veeco Metrology Group is continually updating software and product offerings to remain at the cutting edge of the rapidly changing SPM field. Appendices contain selected advanced technical topics.

Table 1.1a shows the general organization of this manual.

Table 1.1a Command Reference Manual Organization

Category	Location	Description
System-level Information	Chapter 1	Manual Conventions
	Chapter 1	Software Overview
	Chapter 1	Hardware Overview
	Chapter 1	DI Contact and Technical Support
Real time Menu Commands	Chapter 2	DI System Menu
	Chapter 3	Panels Menu: Control Dialog Boxes
	Chapter 4	Motor Menu
	Chapter 5	View Menu
	Chapter 6	Frame and Capture Menus
	Chapter 7	Microscope Menu
	Chapter 8	Vision Menu
	Chapter 9	Stage and Recipe Menus
Offline Menu Commands	Chapter 10	File Menu
	Chapter 11	View Menu
	Chapter 12	Image Menu
	Chapter 13	Analyze Commands A-M
	Chapter 14	Analyze Commands N-Z
	Chapter 15	Modify Menu
	Chapter 16	Utility Menu
Appendices	Appendix A	Tip Selection Guide
	Appendix B	Data File Formats

1.1.1 Chapter Contents

Each chapter title signifies menu item(s) on the NanoScope software. The chapter details sub-menu commands and explanations of each dialog box accessed by selecting the command.

Note: If the menu item or subcommand is not listed on your system, it may be disabled or does not exist for your system.

Note: Parameters disabled or grayed-out may be administrator-access only.

Note: Some parameters are disabled due to mode of operation (e.g., tapping) or microscope profile (Real time > **Microscope** > **Profile**) selected.

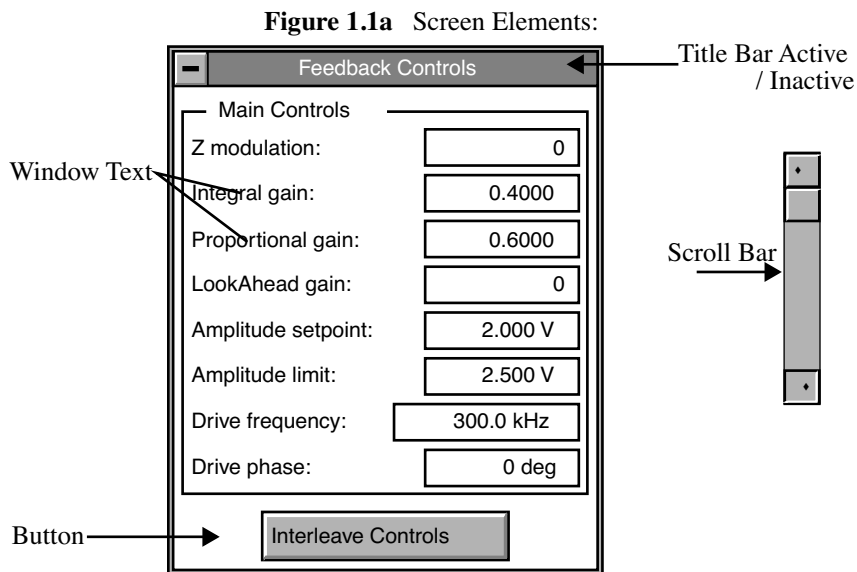
1.1.2 Command Panels

Each panel (also referred to as Dialog Box) on the Control Monitor has basic elements that enable optimized scanning or analysis. The panels are unique in that they are viewable and changeable during microscope operations.

The parameters and buttons often lead to subsequent dialog boxes. Each section in this manual describes the panels, parameters, buttons and settings. Basic knowledge of using a computer is necessary to understand the parameters.

Panel Elements

Panel elements are those portions of a dialog box that you view to adjust parameters. [Figure 1.1a](#) details general panel elements and terms used in this manual.

















1.1.3 NanoScope Command Icons

NanoScope icons in this manual correspond to the software command icons. Selecting the icon allows for an alternative method to execute a command. By clicking on the icon, certain dialog boxes appear or the system executes a command also found as a menu or sub-menu item.

Specific icons relate to Real time or Offline functions. They can be found on your Control Monitor toolbar. [Table 1.1b](#) lists the command icons on the real time and Offline toolbars.

Table 1.1b Real time NanoScope Icons

Real time Icon	Function	Offline Icon	Function
	Real time Mode		Offline Mode
	DI System Menu		DI System Menu
	Engage		Browse Mode
	Withdraw Tip		Top View
	Image Mode		Surface Plot
	Scope Mode		Section Analysis
	Frame Up		Bearing Analysis

Real time Icon	Function	Offline Icon	Function
	Frame Down		Roughness
	Force Calibrate Mode		Flatten
	Cantilever Auto Tune		Plane Fit
	Capture Image		Auto Program
	Abort		Offline Mode
	Focus Surface		
	Focus Tip		

1.2 NanoScope Software Overview

NanoScope systems provide digital software control of the SPM process, from real time manipulation of the microscope system to Offline viewing, analysis and modification tools. While the focus of this manual is the software, it is difficult to separate software from hardware, especially in integrated systems that have been designed to work as a unit.

NanoScope Scanning Probe Microscope systems consist of hardware and software elements. All hardware systems are controlled by the software elements (software dialog boxes, parameters and commands). The software displays on both a Control Monitor and a Display Monitor. More recent NanoScope SPM systems—including Dimension™ Series, MultiMode™, electrochemical scanning probe microscopes (ECs), and base-style atomic force microscopes (AFMs)—use the same basic software element, referred to as Version 5.x (i.e., 5.12 in this manual) NanoScope software.

1.2.1 System Overview

The NanoScope software system includes basic computer hardware—two-button mouse, keyboard, CPU, two monitors—and may or may not include a digital signal processor (DSP).

One monitor is configured as the Display Monitor (the NanoScope Image) and the other monitor as the Control Monitor (the NanoScope Control). All captured images display on the Display Monitor. The software mode (Offline or real time) and control panels display on the Control Monitor. Executing commands or changing parameters are done on both monitors. The design of the version 5.0+ NanoScope graphical user interface (GUI) allows you to easily move between these modes, and even to operate in more than one mode at a time.

Real time Mode Definition

The NanoScope software provides operation of the real time mode of the microscope and other hardware elements. The software also determines the type of data to be collected and how to store it.

Offline Mode Definition

The Offline software mode contains numerous commands for data analysis, modification, presentation and storage of images.

Image files for Offline analysis include:

- Data captured in real time
- Previously captured images stored as image files
- New image files created using Offline modification or analysis commands.

The user selects commands, enters and changes parameters, changes modes, selects files and otherwise interfaces with the software using a series of menu bars, drop-down menus, dialog boxes and icons.

Use the keyboard (e.g. quick keys), the mouse or a combination of both to make selections in the Control Monitor. In the Display Monitor, only the mouse may be used for selecting commands or parameters.

For additional information on executing commands or entering parameters, see [Section 1.2.4](#) and [Section 1.2.5](#).

1.2.2 Starting Up the NanoScope Software

Start the NanoScope software by double-clicking on the desktop shortcut labeled **NanoScope III 5.x**. (If your system is being used to run the DOS version of the software, start the NanoScope software by entering "Z" at the DOS prompt from the appropriate directory.) You are presented with the initial NanoScope screen on the Control Monitor and the Digital Instruments NanoScope logo screen on the Display Monitor.

The start up screens and subsequent menu items parallel the organization of the software and *NanoScope Command Reference Manual*. Chapters of the *Command Reference Manual* are organized to parallel the software's organization.

The following section "[Accessing the Start Up Screens](#)" provides more information for accessing commands and managing the flow of NanoScope software from the initial NanoScope screen.

Opening the Software

Start the NanoScope software by double-clicking on the desktop shortcut labeled **NanoScope III 5.x**. (If your system is being used to run the DOS version of the software, start the NanoScope software by entering "Z" at the DOS prompt from the appropriate directory.) You are presented with the initial NanoScope screen on the Control Monitor and the Digital Instruments NanoScope logo screen on the Display Monitor.

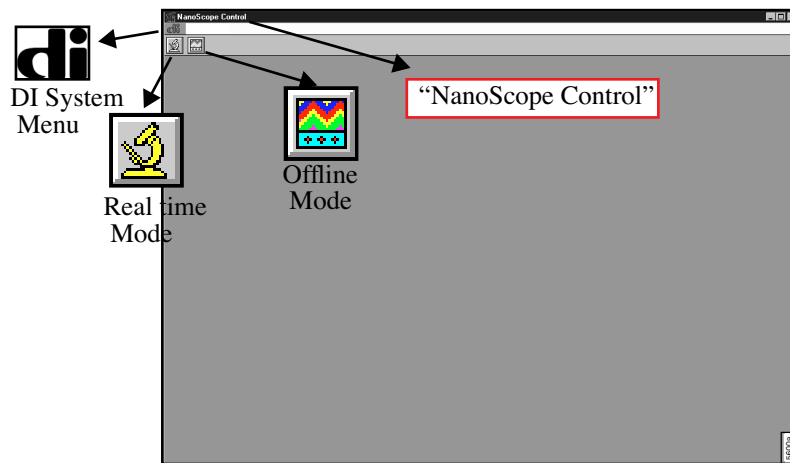
Accessing the Start Up Screens

Upon first entering the NanoScope software, the two monitors display **Start Up** screens.

The Control Monitor displays a blank screen with the three system icons. The three icons (i.e., real time mode, Offline mode and system level operations) parallel the organization of the software and *NanoScope Command Reference Manual* (See [Figure 1.2a](#)).

Note: The *NanoScope Control* is also referred as the *Control Monitor* in this manual.

Figure 1.2a Control Monitor Start Up Screen

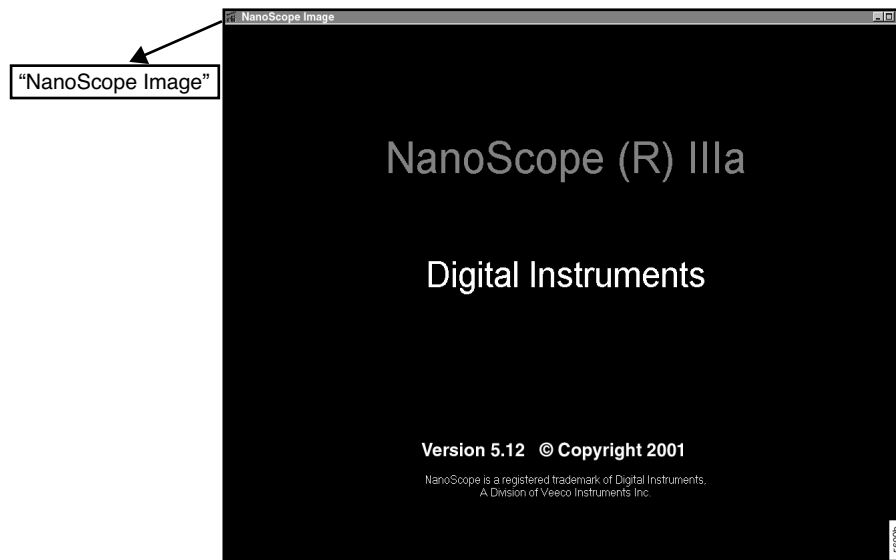


Note: The initial screen appears only once for each time you enter the software.

The Display Monitor displays the NanoScope System information (See [Figure 1.2b](#)).

Note: The *NanoScope Image* is also referred as the *Display Monitor* in this manual.

Figure 1.2b Display Monitor Start Up Screen



1.2.3 Accessing Real time

Select the real time icon to access the real time screens. Once the selection is made, a menu bar will always be present across the top of the Control Monitor. The bar displays general real time menu items and a toolbar with command icons (See [Figure 1.2c](#)).

Figure 1.2c Real time Control Monitor



Select the **DI** icon in the real time menu to make software mode selections (e.g., the **Microscope Select** command). For complete details on the commands in the **DI** menu, see **DI System Menu**, Chapter 2.

The default panels that appear on the Control Monitor have their own menu sub-command (e.g., **Channels/Interleave Controls**). Access sub-menu commands by selecting the menu item or icon. For example, access **Cantilever Tune** panels by the path: **View/Sweep/Cantilever Tune** or select the **Cantilever Tune** icon.

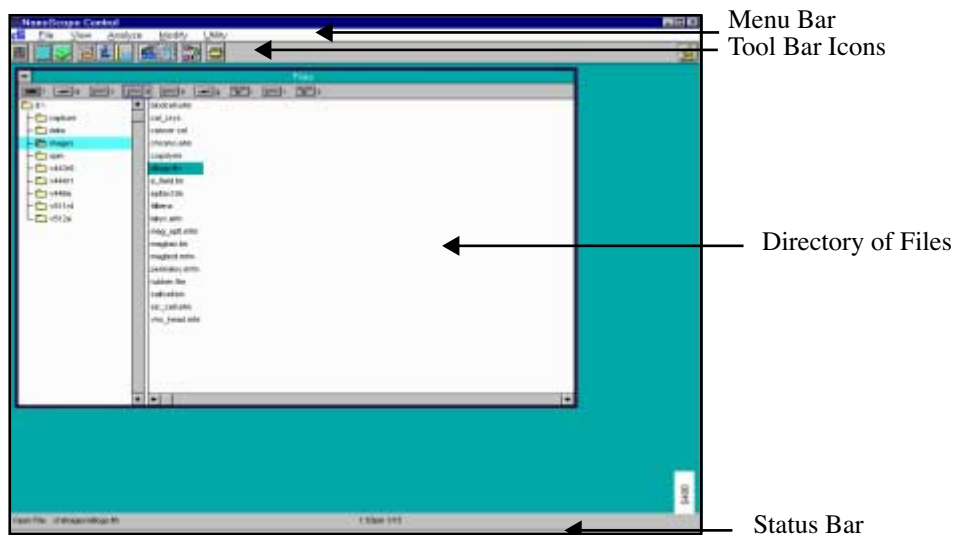
A thick black border around a button indicates a default button. Pressing **ENTER** selects the default button. A thick black border around a panel indicates that it is the active panel.

For further details on the Display Monitor, see **Interfacing with the Display Monitor Section 1.2.5**.

Offline Screens

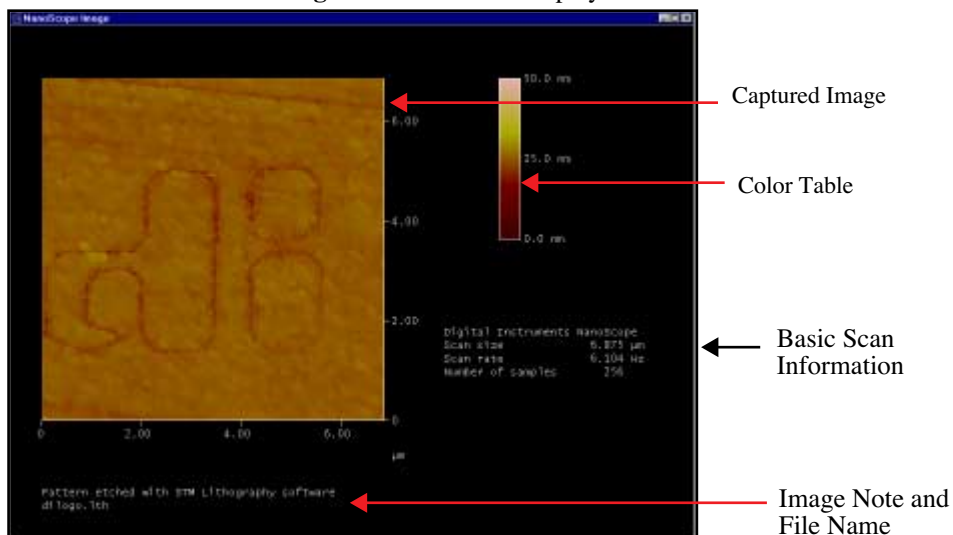
Once in the NanoScope screen, select the Offline icon to access the Offline default screens. **Figure 1.2d** shows the default Control Monitor display.

Figure 1.2d Offline Control Monitor



The Display Monitor opens the last image file in use or the first file selected on the default file list (See Figure 1.2e).

Figure 1.2e Offline Display Window



1.2.4 Control Monitor Mouse and Keyboard Functions

All movement from command-to-command and mode-to-mode on the Control Monitor can be completed exclusively from the keyboard or with a combination of mouse and keyboard actions.

Using the Mouse





Mouse actions are similar to other common GUI applications and include clicking, double-clicking, click-and-drag, as well as specific actions that can be initiated only from the right or left mouse button.

In this manual, specific mouse actions are described and indicated with the heading *Mouse Operations*. For further procedures on using the mouse, see the desired section in this manual.

Accessing and Selecting Commands Using the Keyboard

There are many keystrokes and keystroke combinations for moving through the boxes, panels, windows and commands of the Control Monitor. These can be used exclusively or in combination with mouse operations (See [Table 1.2a](#)).

Table 1.2a Control Monitor Keystrokes

Keystrokes	Action
LEFT, RIGHT  	Within a control entry: increases or decreases a value or cycles through possible values Within a menu or section: Moves the highlight left or right, or to a subordinate menu In conjunction with Move or Size: controls the direction of movement or increase/decrease
UP, DOWN  	Within a menu: Moves the highlight up or down, and enters a value In conjunction with Move or Size: controls the direction of movement or increase/decrease
ENTER	Enters a value, initiates a command or makes a selection
ESC	Closes a window, menu, or dialog box and returns control to previous level Within a dialog box, cancels an edit in progress
ALT + QUICK KEY	Jumps to appropriate menu bar command and pulls down menu
ALT + /	Opens DI System Menu
ALT + .	Opens a system menu, for example, the “- button” at the upper left of a window
SPACE BAR	For entries with preset options: brings up a menu of available options
CTRL + TAB	Cycles control from window to window
PAUSE	Activates the Abort Manager
PRINT SCRN	Prints the screen contents visible on the Display Monitor
CTRL + F4	Closes the current dialog box or window
TAB	Moves the highlight from field to field within a dialog box.
SHIFT + TAB	Reverses Tab movement

Use **UP** and **DOWN** (arrow keys) to scroll up or down the menu commands. The highlight bar indicates the currently selected command. Press **ENTER** to activate the highlighted command. Pressing **ESC** closes the open menu and returns you to the previous level.

Quick Key Commands

Many commands have **quick key** commands (series of keys to enter in place of using the mouse). Open menus, access dialog boxes and execute commands with the keys or combination of keystrokes. In the NanoScope software, the quick keys are designated by an **underlined letter** in the command name (e.g., **R** is the quick key in **Real time**).

To activate a quick key command, press the **ALT** button then the quick key, or select the command with the mouse and press the indicated quick key.

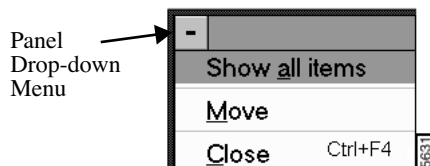
Quick keys only apply when in an *active* box, menu, dialog box or window that is currently visible on the screen. *Active* dialog boxes are designated in color with a highlight on the dialog box title or with a heavy frame around the dialog box.

Procedure to Move Dialog Boxes Using Quick Keys

Move or relocate windows or dialog boxes on the control screen as follows:

1. With the dialog box selected, press the **Alt** key and the period key simultaneously (**ALT + .**) to open the drop-down menu in the upper left corner of each dialog box (See [Figure 1.2f](#)).

Figure 1.2f The Dialog Box Drop-down Menu



Note: The dialog box drop-down menu is noted by a dark hyphen (-) within a grey box in the upper left corner of the dialog box.

2. Press **M** to activate the **Move** option.
3. When the highlight appears around the dialog box, use **LEFT**, **RIGHT**, **UP** or **DOWN** to move the highlight to the desired new position.
4. Press **ENTER** to execute the dialog box to move.

Execute other options in the menu similarly (for example, to execute the **Show All Items**, the quick key stroke is **A**).

Procedure to Resize Dialog Boxes Using Quick Keys

The **Size** option allows for *resizing* the dialog box or screen. Resizable windows have bracketed corners; for example, the **File List** screen in the **Offline** mode is resizable. Use the following procedure to resize a window:

1. Be sure the window to be resized is the active one on the monitor, (i.e. has a thick border around it or highlighted top border on windows).
2. Press the **ALT** key and the period key simultaneously (**ALT + .**) to open the system menu in the upper left corner of the dialog box .
3. With the **Move/Close** drop-down menu open, press **ALT + S** or just **S** to activate the Size function.
4. Use the arrow keys to increase or decrease the size in either direction.
5. Press **ENTER** to set the new size.

1.2.5 Interfacing with the Display Monitor

In general, use the Display Monitor for the following functions:

- Displaying images as they are being scanned.
- Browsing through smaller versions of stored images.
- Displaying stored images.
- Presenting resulting images, data tables or graphs from modification and analysis functions.
- Receiving input from the user.
- Transmitting that input to the software.
- Initiating software functions.
- Making changes to the visible images and data.

One of the major productivity features of NanoScope software is its ability to interact in Real time with the user.

Note: All user interaction with the Display Monitor requires a two-button mouse.

Images on the Display Monitor remain on the Display Monitor, even after exiting the software, or until replaced by another image, mode or application.

Information shown on the Display Monitor is function- and mode- dependent, and is normally indicated by the title at the top of the display screen.

Display Monitor Interface

A menu bar contains menu selections and commands that immediately initiate a function or action. User choices are made from the menu bar and the bar reflects choices or modes selected. When a command on a Display Monitor menu bar is the same as a button on the Control Monitor, selection can be made from either location (the resulting software activity is identical).

The Display Monitor screen includes the following components:

- Scanning Image, Captured Image or Plot - While scanning, a cursor shows Real time data collection. Some views show a plot of the data. Captured images include stored data for analysis.
- Menu Bar - Often list function commands.
- Status Bar - Bottom bar lists items in use on display.

Note: Almost always, when a menu bar is present along the top of the screen, a status bar is visible along the bottom of the screen.

- Parameter Choices - Measurements or items specified for analysis.

Note: In many cases, following selection of applicable parameters, the user must select the **EXECUTE** command before function activity begins.

- Graphs - Histogram, Correlation graphs for analysis.
- User-entered Notes and/or Date - Captured data includes this reference information.
- Interactive Cursors - Line, Box, etc. that allow for specific analysis.
- Diagrams - Allows for further analysis of a sample image.
- Measurements or information relating to the current function - Relate to Parameter choices and graphs or diagrams on the display screen.

Cursor Types

The cursor types are as follows:

- Lines
- Solid boxes
- Outlined boxes
- **Shapes** (e.g., triangles and circle)
- **Color coded**—Corresponds to other information on the screen.

When a cursor is moved by the user, it can result in: changes in the image, graph, display data, viewing perspective, or many other functionally dependent actions.

1.2.6 Mouse Operations on the Display Monitor

1. To open a drop-down menu or initiate a function from the Display Monitor, simply point and click once with the mouse.
2. Point and click once to make a parameter selection.
3. To select and move a cursor, point to it and click once with the mouse (to “pick up” the cursor, box, line, etc). Move the mouse to the desired location, and click a second time to deselect (to “drop”) the cursor.

Note: In some instances, a third mouse click “picks up” and move the entire shape (i.e., box, triangle or circle).

4. When in **Browse** mode, or when dual images are presented, point and click once with the mouse to select one or more images. The selected images are indicated with an **X** and subsequent selection of a function allows manipulation of the selected images.
5. Functions that require specific left or right button actions, or actions different from what is listed in this chapter, are described within the manual as needed.
6. For *precise* positioning with the mouse, press and hold down the **SHIFT** key while moving the mouse.

Note: This causes the mouse to move with only one-quarter of its normal speed.

1.3 Technical Support at Digital Instruments

Your satisfaction and productivity regarding Digital Instruments, Veeco Metrology Group products and documentation are absolutely essential. You can obtain technical support in a variety of ways: via telephone, send a fax, send us an e-mail, access our World Wide Web site, or send bug reports or documentation change requests through normal mail processes.

1.3.1 Submitting Bug Reports

The NanoScope software includes the capability to automatically generate a bug report if the system should abort for any reason. This bug report consists of all the information generally requested by the programmer for analysis of the problem. If the system should abort, the next time the software is initiated, a form is displayed on the Control Monitor. The user should enter their name and a brief description of the functions in use when the crash occurred. Describe the situation as accurately as possible. When transmitted, a file labeled “bug.txt” will be created. If the NanoScope system in use has a drive labeled “Q,” the bug.txt file is automatically placed there. If another bug.txt file exists, the number on the file name is incremented or the information is appended to the previous file. If there is no Q drive, the software asks you where to place the file. Once the file is created, you can put it on a floppy diskette and mail it to the address below or attach it to an e-mail message and submit it to us that way.

Note: You may not get a response to your bug submittal, but be assured that our programmers will analyze the problem and fix it in a future release if necessary.

1.3.2 Contact Information

Mailing Address:

Technical Documents(or Technical Support
Digital Instruments, Veeco Metrology Group
112 Robin Hill Rd.
Santa Barbara, CA 93117

Voice Phone:(805) 967-1400, (800) 873-9750

Fax:(805) 967-7717

World Wide Web: <http://www.di.com>

Chapter 2 DI System Menu

2.1 Overview

DI System Menu for Real-time and Off-line modes offer the same commands with the exception of the **Access Control** and **NanoScript** commands. The purpose of this menu item is to designate Microscope settings, change password levels, customize menus and interface settings. Some menu items may be unique (e.g., **Customize**) to the microscope mode, but the main functions of the DI menu include the following:

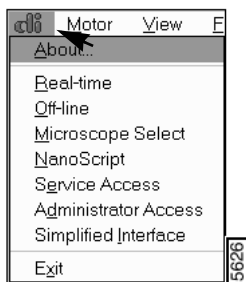
- **About... Command** [Section 2.2](#)
- **Real time and Offline Commands** [Section 2.3](#)
- **Microscope Select Command** [Section 2.4](#)
- **NanoScript Command** [Section 2.5](#)
- **Access Control Command** [Section 2.6](#)
- **Customize Command** [Section 2.7](#)

2.1.1 Di Menu



The Digital Instruments logo (DI) in the upper-left corner of the Control Monitor opens a main system menu (See [Figure 2.1a](#)).

Figure 2.1a DI Menu



2.2 About... Command

Clicking on the **About...** option displays information about the **NanoScope** software (See [Figure 2.2a](#)).

Figure 2.2a About Nanoscope Panel

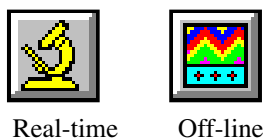


This panel provides a version number for your software, its creation date, and a copyright notice. Before contacting technical support for telephone assistance, be sure to have the version number available. This will assist in identifying the specific features of your system. To remove the panel, click on the **OK** button.

2.3 Real time and Offline Commands

Select the Real-time and Off-line submenu items to enter that microscope mode. The menu option is available in both modes. You can also switch between modes by clicking on the icon in the top right corner of the display screen (See [Figure 2.3a](#)).

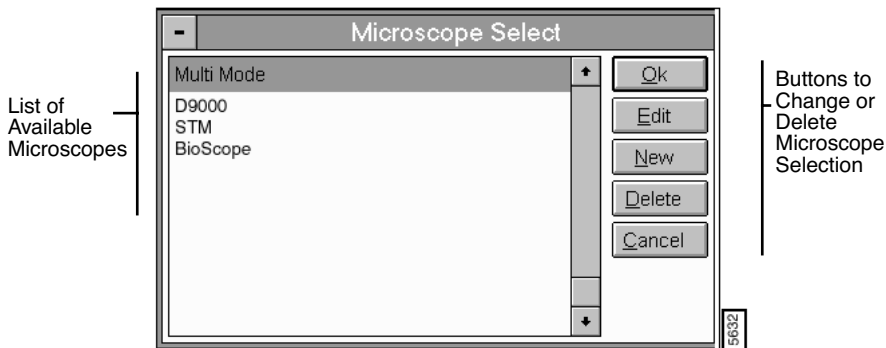
Figure 2.3a Real-time and Off-line Icons



2.4 Microscope Select Command

This option configures the software for the type of SPM used. If you have only one type of SPM, this parameter need only be configured once. Users with multiple SPMs will use this panel when switching SPMs. The panel features a list of available microscopes and a scroll bar (See [Figure 2.4a](#)).

Figure 2.4a Microscope Select Panel.



To select a microscope that has already been configured, select the appropriate microscope name, then click **Ok**.

Note: If the microscope has not yet been configured, it will be necessary to click the **EDIT** button first.

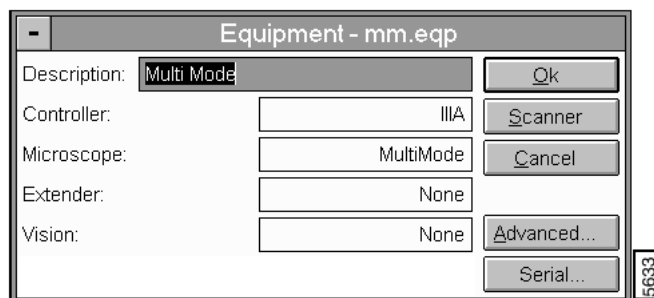
Buttons on the Microscope Select Panel

- **Edit**—Accesses the **Equipment** panel containing details of the equipment configuration. These are usually configured during the initial installation, and seldom require changing (See [Section 2.4.1](#)).
- **New**—Accesses the Equipment New panel to configure new microscope settings.
- **Delete**—Accesses an Equipment Delete warning panel.
- **Cancel**—Exits the Microscope Select panel.

2.4.1 Microscope Select/Equipment Panel

In the **Microscope Select** panel, click the **EDIT** button to access the **Equipment** panel (See [Figure 2.4b](#)).

Figure 2.4b Equipment Panel Configured for a MultiMode



Note: The panel name includes a file name for the selected microscope parameters. This file (on the **SPM/Equip directory**) contains the same parameters in a text format.

Parameters in the Equipment Panel

- **Description**—Name assigned to the equipment configuration. Many users enter the microscope type (“AFM,” “STM,” etc.); however, any label may be used (“SPM#2,” “Dale’s MultiMode,” etc.). When the **Equipment** panel is closed, this name will be listed on the **Microscope Select** panel alongside others.
- **Controller**—Type of control box connected between the SPM and computer. Typical choices include: **IIIA**, **IIIE**, **Metrology**, etc.
- **Microscope**—SPM being configured, including **AFM**, **MultiMode**, **BioScope**, etc.
- **Extender**—Mode of the installed Extender Electronics Module. *Range and Settings:* None, Basic, Capacitance, Velveeta, and Creamy Velveeta.
- **Vision**—Type of automatic vision or pattern recognition system installed (not to be confused with the standard on-axis video system installed on all Dimension Series SPMs). On systems without an automatic vision system, select **None**. Other choices include **Cognex** and **Frame Grabber**.
- **Motor Sensitivity (MultiMode only)**—Distance of movement at each step toward the surface.

Note: Changing this parameter is not recommended.

- **Zoom System**—Type of Zoom System installed on the instrument. Types include: **Motorized** and **2-Camera**.
- **Air Table**—Identifies the presence of an air table. Choices include: **None** or **Basic**.

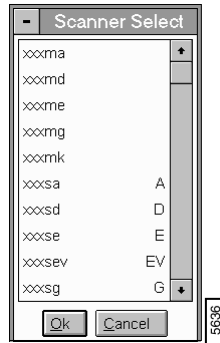
Buttons on the Equipment Panel

- **Scanner**—Accesses the **Scanner Select** panel, which lists scanner files alphabetically (See [Section 2.4.2](#)).
- **Cancel**—Exits the Microscope Select/Edit option, and closes the window.
- **Advanced**—Displays the Equipment panel parameters and additional parameters (See [Section 2.4.3](#)).
- **Serial**—Displays the **Serial Port Configuration** panel. This panel allows the user to assign and configure the serial ports (See [Section 2.4.4](#)).

2.4.2 Equipment / Scanner Panel

In the **Equipment** panel, click on the **SCANNER** button to access the **Scanner Select** panel. (See [Figure 2.4c](#)).

Figure 2.4c Scanner Select Panel



To configure a scanner, select the scanner name from the list, then click on the **OK** button. Click the **CANCEL** button to exit the panel.

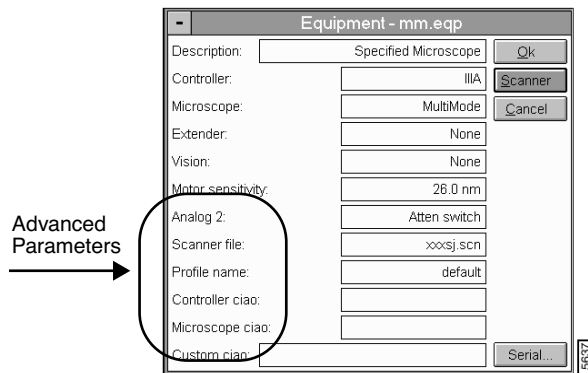
Note: Only files included within the **SPM/EQUIP** directory are listed on the **Scanner Select** panel.

See also **Real-time/Microscope/Scanner**.

2.4.3 Equipment / Advanced Panel

In the **Equipment** panel, click on the **ADVANCED** button to display additional microscope equipment parameters (See [Figure 2.4d](#)).

Figure 2.4d Advanced Equipment Panel



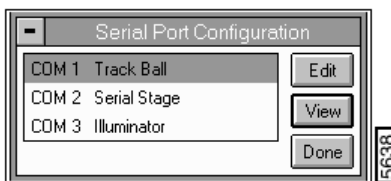
Advanced Equipment Parameters

- **Analog 2**—Configures the Analog 2 signal to switch either manually (User defined) or by the **Atten switch**.
- **Scanner file**—Name of file assigned to the scanner.
- **Profile name**—Name (alias) assigned to the microscope profile (see **Real-time / Microscope / Profile** section in this manual).
- **Controller ciao, Microscope ciao, Custom ciao**—(Reserved for future use.)

2.4.4 Equipment / Serial Port Configuration Panel

In the **Equipment** panel, click on the **SERIAL** button to access the **Serial Port Configuration** panel (See [Figure 2.4e](#)).

Figure 2.4e Serial Port Configuration Panel



This panel allows the user to assign and configure the serial ports.

Buttons in the Serial Port Configuration Panel

- **EDIT**—Accesses the **Edit Port Setup** window when the user has **Service Access** to the system. The **Port Setup Window** allows the user to quickly configure each serial port for a particular equipment type.

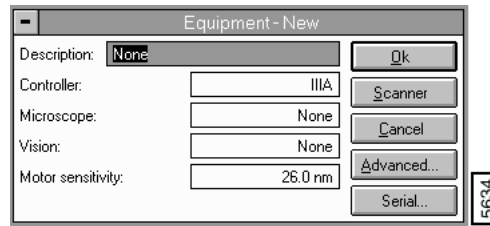
Note: Each peripheral item attached to the computer via serial port has pre-assigned default values. Altering these values may affect system performance.

- **VIEW**—Opens the view menu, which allows the user to view the configuration of the items connected to the serial ports of the computer.
- **DONE**—Closes the **Serial Port Configuration** window and saves the changes.

2.4.5 Microscope Select/New Panel

In the **Microscope Select** panel, click the **NEW** button to access the **Equipment-New** panel (See [Section 2.4g](#)).

Figure 2.4f Equipment-New Panel



The **Equipment-New** panel allows configuring new equipment on a microscope. The parameters and buttons are the same as the **Equipment** panel. For details on the parameters, see [Section 2.4.1](#).

Buttons on the Equipment-New Panel

- **OK**—Saves the new microscope settings.
- **SCANNER**—Accesses the Scanner panel to select a compatible scanner (See [Section 2.4.2](#)).
- **CANCEL**—Exits the Equipment-New panel without saving the changes.
- **ADVANCED**—Accesses additional items to configure the microscope (See [Section 2.4.3](#)).
- **SERIAL**—Displays the **Serial Port Configuration** panel. This panel allows the user to assign and configure the serial ports.

2.4.6 Microscope Select/Delete Panel

In the **Microscope Select** panel, click the **DELETE** button to access the **Equipment Delete** warning panel (See [Figure 2.4g](#)).

Figure 2.4g Equipment Delete Warning Panel



2.5 NanoScript Command

The **NanoScript** menu opens an interface to open, edit and load macro commands. Typically, this command, used for NanoLithography programming.

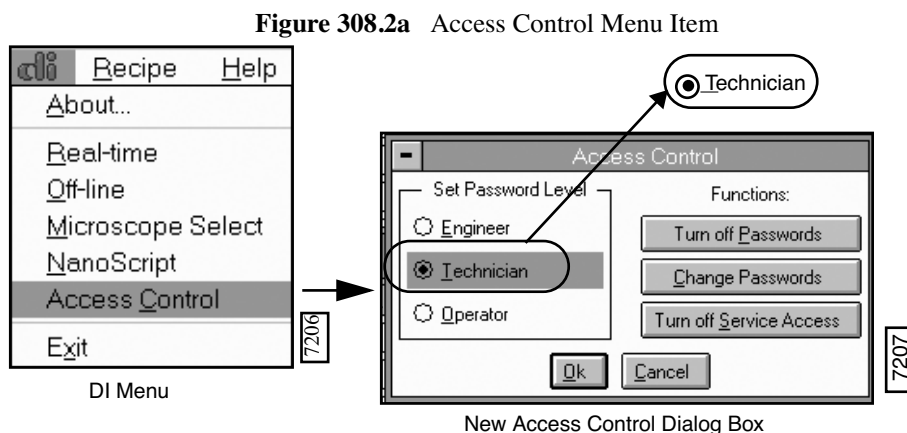
There are several familiar menus offered within the NanoScript option, including a simple file manager, edit, and a macro manager.

Note: The **NanoLithography** functionality is available as an optional package. For further information on running Lithography commands on Version 5.x software, contact your Digital Instruments, Veeco Metrology Group representative.

2.6 Access Control Command

The **Access Control** command allows for password *only* parameters or commands to be enabled. The password needs to be enabled (i.e., by an administrator) for this command to be active. Special functions, such as **Z Exclusion** and **Scaling** (Stage Menu) are also activated by logging out of Service Access.

In the DI system menu, a new menu item replaces the **Service Access** and **Administrator Access** menu items in previous software versions. The **Technician** level has been added in **Access Control**. The **Technician** level access allows access to NanoScope functionality without the ability to teach recipes (See [Figure 2a](#)).



You may enable or change passwords for either the technician or engineer levels. You may also turn on or change **Service Access** in the **Access Control** dialog box.

Engineer Access

The **Engineer** option on the Access Control panel controls user access to higher level, sensitive functions within the NanoScope environment, including calibration dialog boxes for robot alignment and automatic tip exchange. This access allows for the safeguarding of sensitive parameters from accidental or intentional damage.

Note: Special functions such as robot calibration and automatic tip exchange contain sensitive parameters used for hardware alignment. Entering parameters incorrectly may lead to

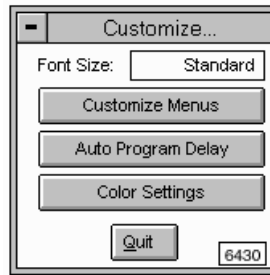
serious mechanical failures and/or damage to samples; these functions should be password protected.

When **Engineer** access is turned on, direct access to sensitive dialog boxes is allowed. When **Engineer** access is turned off, sensitive functions are disabled, appearing gray on dialog boxes.

2.7 Customize Command

The **Customize** command accesses a screen to configure the menu commands, auto program delay time and the screen display settings (e.g., screen display and font size) (See [Figure 2.7a](#)).

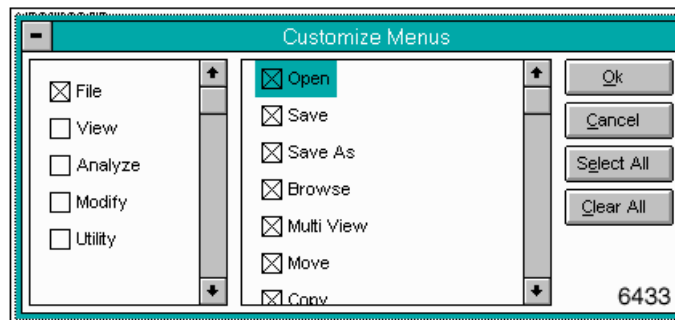
Figure 2.7a Customize Menu Panel



2.7.1 Customize Menu

Not all commands are set by default. To access the available list, use the **Customize** function (Offline/DI/Customize/View Menu). This function accesses a screen listing all main menu items in Offline mode (See [Figure 2.7b](#)). Select the Menu item to access the list of available commands to view. Select the desired commands or Select all to view all commands in the selected menu item.

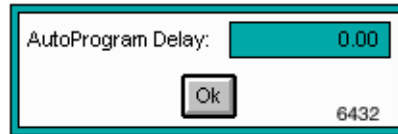
Figure 2.7b Customize Menu Panel



2.7.2 Auto Program Delay

The **Auto Program Delay** function accesses a panel to enter a time in seconds for the Auto Program commands to delay before the saved commands begin. The default is 0.

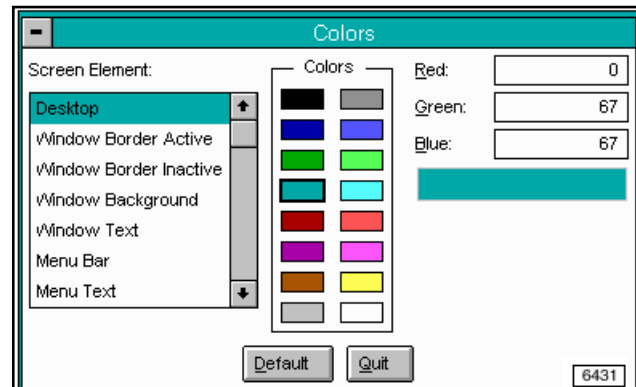
Figure 2.7c Auto Program Delay



2.7.3 Color Settings

The **Color Settings** function accesses a panel to customize the display settings (See [Figure 2.7d](#)).

Figure 2.7d Color Settings Panel



Chapter 3 Panels Menu

Real Time control **Panel** menu commands (Real Time/**Panel**) appear on the default screen upon entering Real Time mode. Each control panel contains parameters important for optimizing the scanning process. The large number of parameters (more than 2,000) allow adjustment and manipulation of the hardware.

Note: Most SPM operators use only a few of the parameters to obtain images. The parameters within each panel are often microscope-specific and may be hidden.

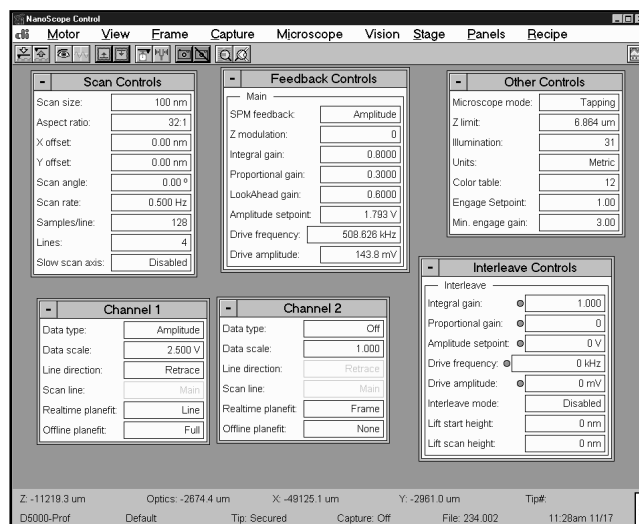
This chapter discusses the following control panel components:

- **Overview of Control Panels** [Section 3.1](#)
- **Scan Controls** [Section 3.2](#)
- **Feedback Controls** [Section 3.3](#)
- **Other Controls** [Section 3.4](#)
- **Interleave Controls** [Section 3.5](#)
- **Channel (1, 2, 3)** [Section 3.6](#)
- **Gain Adjust** [Section 3.7](#)
- **Drive Feedback Controls** [Section 3.8](#)

3.1 Overview of Control Panels

Generally, control panels are organized according to some common task. More than one panel is usually required to obtain a sought-after image. For this reason, NanoScope software allows all control panels to be viewed simultaneously (See [Figure 3.1a](#)).

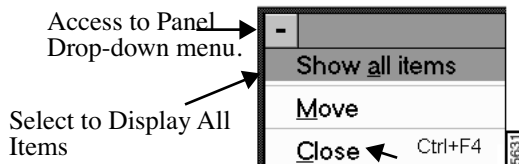
Figure 3.1a Real Time Control Panels



When a panel is selected from its menu (or by clicking on its icon), it appears on the Control Monitor. Move the panels by dragging them to desired locations within the NanoScope Control screen. To close a panel, click twice on the **HYPHEN** button at the upper-left corner, press **CONTROL+F4** (See Figure 3.1b).

Note: Each panel also has **CLOSE**, **EXIT** or **QUIT** buttons.

Figure 3.1b Panel Drop-down Menu



Control panels replace the switches, knobs, and dials required in earlier, analog versions of SPMs. For example, **Scan size**, **Scan angle**, **Scan rate**, **Feedback Gains** and other important parameters can be adjusted on the control panel with the mouse.

Clicking on a parameter and then dragging the mouse back and forth controls the parameter much like an old analog slider.

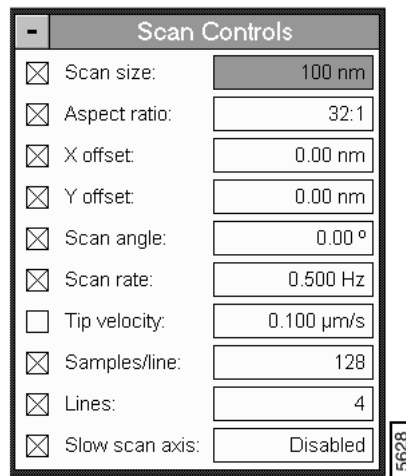
The significance, range of acceptable values, and specific information about control panel parameters are discussed in this chapter.

Parameters listed in the control panels depend on the microscope selected. Parameters necessary for one style of microscope are not applicable to another. For example, the **Drive frequency** and **Drive Amplitude** parameters are enabled on the **Feedback Controls** panel only when the microscope **AFM** mode is switched to TappingMode. Similarly, the **Bias** voltage applied to the sample only appears in the **STM** control panel.

Some users find operating an SPM less confusing if the number of parameters is limited to only the most essential ones. Parameters can be selected for display by clicking on the “close” button, then selecting the **Show all items** option (See [Figure 3.1b](#)).

In each panel, select or deselect displayed parameters by clicking on the box next to each parameter. For an example of “show all items” in the **Scan Control Parameters**, (See [Figure 3.1c](#)).

Figure 3.1c "Show All Items" in the Scan Controls Panel



3.2 Scan Controls

The **Scan Controls** panel includes parameters influencing piezo movement and data acquisition, as well as the ability to execute non-square scans. This control panel is probably the most frequently used panel, as it controls what type of scan to run, how large the scan is, its angle, scan rate, and number of samples per scan line.

Non-square scans are set using the **Aspect ratio** parameter. *Square* scans have an aspect ratio of **1:1**; therefore, any other setting (**2:1**; **4:1**; **8:1**; **16:1**, etc.) will produce a non-square scan. Once selected, scans can be modified by adjusting other parameters on the **Scan Controls** panel.

Scan size

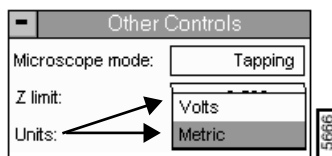
Determines the size of the scan by controlling the voltage applied to the X and Y piezos.

Range or Settings:

- **0 to 440 V**
- **0 to XX microns** (scanner-dependent)

Note: The units of this parameter are volts if the **Units** parameter (**Other Controls** panel) is set to **Volts**. The units are linear distance (nm or μm) if the **Units** parameter is set to **Metric** (See [Figure 3.2a](#)).

Figure 3.2a Units Parameter Sub-menu



Optimizing the Scan Size Parameter

- Higher voltages are required for slower piezo movement along the **Slow scan axis**. This is one reason why the maximum setting of the **Scan size** may be less than 440 volts.
- Non-zero **X** and **Y offsets** reduce the maximum **Scan size**. Each volt of **X** or **Y offset** reduces the maximum scan size by 2 volts.
- The **Scan size** and offsets can be set by using to control the **Zoom** and **Offset** subcommands on the Display Monitor.
- Having a non-zero **Scan angle** will reduce the maximum allowable **Scan size**.
- The maximum **Scan size** will also decrease as the **Scan rate** increases.

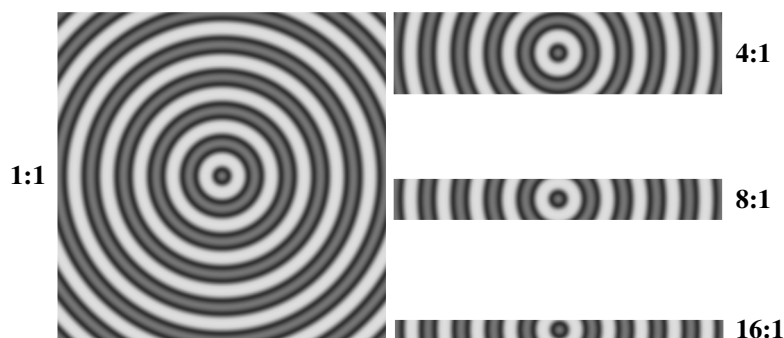
Aspect ratio

Controls the width-to-height size ratio of scans. Set **Aspect ratio** to 1:1 for square scans. An **Aspect ratio** of 2:1 yields scanned images having width equal to twice the height.

Range or Settings: (depends upon the number of scan lines)

- **1:1, 2:1, 4:1, 8:1, 16:1, 32:1, 64:1, 128:1, 256:1**

Figure 3.2b Aspect Ratio Example



X offset, Y offset

Controls the center position of the scan in the X and Y directions, respectively.

Range or Settings:

- **±220 Volts; ± XX Microns**

Hints for Optimizing the X Offset, Y Offset Parameter

- The maximum amount of **X** and **Y offset** available depends upon the scanner being used.
- Non-zero **X** and **Y offsets** reduce the maximum **Scan size**. Each volt of **X** or **Y offset** reduces the maximum scan size by 2 volts.
- These parameters use the sample as the position reference. Therefore, a more negative **X offset** value will move a feature in the current image to the *left* on the Display Monitor. Similarly, a more negative **Y offset** moves a feature in the current image *down* on the Display Monitor.
- Using the left-arrow and right-arrow keys when the cursor is in these parameters will decrement and increment these parameters by 10% of the **Scan size**.
- Using the **Zoom** or **Offset** subcommands on the Display Monitor automatically changes the value of **X** and **Y offsets**.

Scan angle

Controls the angle of the X (fast) scan relative to the sample.

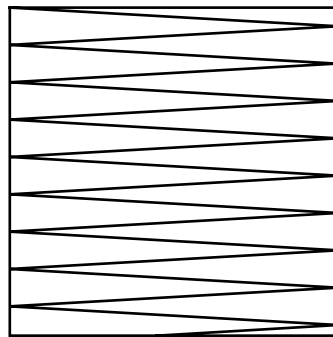
Range or Settings:

- **0—359°** (Any angular value can be entered with the keyboard)

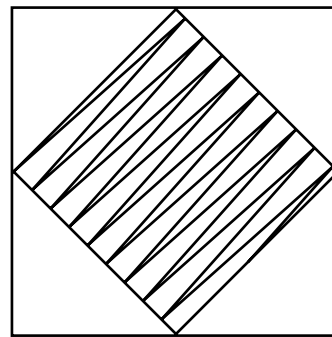
Note: Changing this parameter can dramatically affect the quality of images due to tip effects (double tips, dull faces, etc.).

Note: Setting this parameter to a non-zero setting may reduce the maximum allowable **Scan size** 10-20 percent due to corner constraints (See [Figure 3.2c](#)).

Figure 3.2c Scan Angle Rotated Example.



Original maximum **Scan size**



Scan rotated 45 degrees.
Maximum **Scan size** is reduced.

Scan rate

The Scan Rate sets the number of fast scan lines performed per second.

Range or Settings:

- 0.1—244 Hz, depending on the Number of samples per line (See [Table 3.2a](#)).

Table 3.2a Scan Rate/ Number of Samples

Number of Samples	Maximum Scan rate
128	244 Hz
256	122 Hz
512	61 Hz

Hints for Using the Scan Parameters

- The **Scan size** and height of features on the sample will affect the maximum **Scan rate** that should be used on a given sample.
- Ramping under NT is limited to approximately 27.9 Hz at 512 samples per line.

Lines

Selects the number of lines to scan in a frame. The **Lines** parameter reduces resolution along the Y axis. It also speeds imaging or "frame rate" and reduces the size of the resulting image file.

(See also,)

Range or Settings:

- **4, 8, 16, ..., maximum.** To determine the maximum number of lines allowed, divide **Samples/line** by **Aspect ratio**.

Tip velocity

Velocity of the tip (in $\mu\text{m/s}$) as it scans over the surface.

Note: When **Tip Velocity** changes, the **Scan Rate** adjusts automatically.

Samples/line

Selects the number of sample data points per scan line.

Note: When this parameter is changed, the number of scan lines per image (**Scan Controls/Lines**) are automatically adjusted to maintain the same ratio between the samples/line and lines per image.

Range or Settings:

- **128, 256, 512.** This setting influences the size of captured files and image resolution (See [Table 3.2b](#)).

Table 3.2b File Size/Samples per line

<i>Samples/line value</i>	File size (for square scans, including 8K header)
128	40 Kbytes
256	136 Kbytes
512	520 Kbytes

Samples/line should be kept at 512 for the highest resolution. To increase the frame rate (rate at which complete images are generated), the **Lines** parameter reduces. When the **Lines** parameter is reduced, file sizes in [Table 3.2b](#) are reduced accordingly.

Slow scan axis

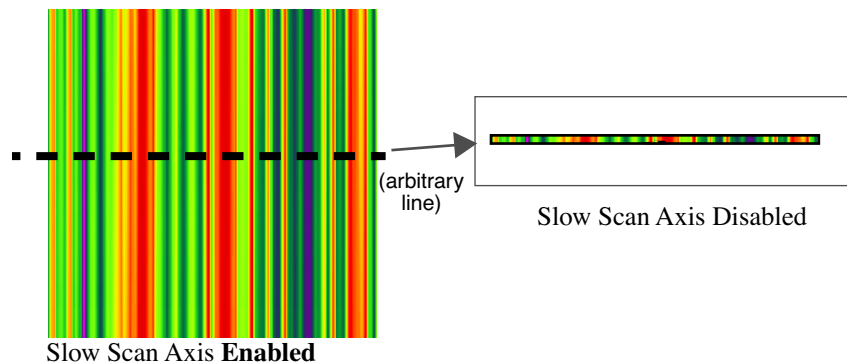
Allows the slow scan to be disabled, causing the fast scan to be repeated continuously at the same position. This means that the image displays the same line continuously. Images may be presented either as “true” X-Y renderings of the sample surface (Enabled), or as “stretched” single-line scans of length equal to the Scan size (Disabled) (See [Figure 3.2d](#)).

The advantage of using the **Slow Scan Axis/Disabled** parameter is to emphasize one area (line) to set SPM parameters accordingly. For example, an area of the image appears fuzzy (believing SPM parms are not optimized for the sample). **Disable** the **Slow Scan Axis**, view the image in **Scope** mode, and reconfigure scan parameters to optimize the scan.

For information on viewing the image in **Scope Mode**, see [Chapter 5, Scope Mode Section 5.2](#).

Note: Disabling the **Slow scan axis** and viewing the **Scope Mode** display (**View / Scope Mode**), is a convenient way of setting the **Feedback Gain** parameters.

Figure 3.2d Example of Slow Scan Axis.



The integrated circuit is scanned with the **Slow scan axis** parameter **Enabled** (left). When **Disabled** (right) the image consists of data taken along the fast scan line (dotted line). The user may arbitrarily **Disable** the **Slow scan axis** at any line along the scan.

Range or Settings:

- **Enabled**—Sample is scanned in the slow scan direction. (This is the normal setting of this parameter.)
- **Disabled**—No scanning of the sample in the slow direction is performed. The fast scan is repeated at the same position.

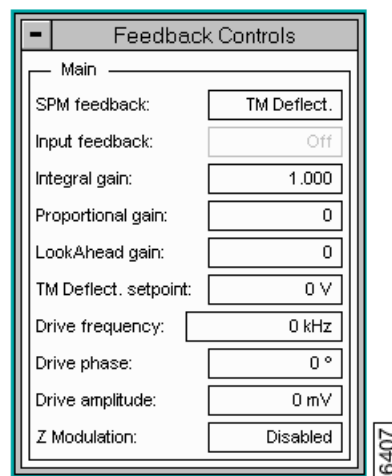
Note: Setting the **Slow scan axis** parameter to **Disable** stops the slow scanning of the piezo, but does not stop the movement of the Real Time display in Y. Lines are replicated in the Y direction.

3.3 Feedback Controls

The **Feedback Controls** parameters allow for monitoring the signals between the **NanoScope Controller** and the cantilever. These signals adjust the setpoint, oscillation frequency, drive voltage and output voltages. The purpose of the **Feedback Controls** is to maintain a constant current in the **Feedback Loop** for tip/sample control.

In the **Panels** menu, select **Feedback Controls** to access the **Feedback Controls** panel (See [Figure 3.3a](#)).

Figure 3.3a Feedback Controls Panel



3.3.1 Parameters in the Feedback Controls Panel

SPM feedback

Selects the signal to be used for tip feedback according to the selected **Microscope mode** parameter (**Other Controls** panel). For contact AFM, the choice defaults to **Deflection**; however, for TappingMode, you may select either **Deflection** or **Amplitude**. STM offers three choices of feedback: Linear, Log and Boost.

Range or Settings:

- **TappingMode—Amplitude, Deflection-**(Forcemod only)
- **Contact Mode—Deflection** only.
- **STM—Linear, Log, Boost.**

***Linear**—The linear difference between the instantaneous tunneling current and the **Setpoint** current is used in the feedback calculation.*

Log—The difference between the log of the instantaneous tunneling current and the log of the **Setpoint** current is used in the feedback calculation.

Boost—Optimizes the feedback performance for high **Scan rates** over rough surfaces. This is not intended for atomic images.

Hints to Optimize the SPM Feedback Parameters

- The **Boost** and **Log** modes are preferable for most STM samples, because the tip responds in a more symmetric manner (i.e., the same going up and coming down). **Log** and **Boost** modes tend to linearize the entire feedback loop since $Z \approx \ln(i)$. The asymmetric response of the **Lin** setting distorts data.
- Use of **Boost** mode allows the **Proportional gain** and **Integral gain** values to be reduced and is preferable for large scans having high, vertical features (e.g., integrated circuits).
- When **Boost** mode is selected, the **Integral** and **Proportional gains** are often best set to lower values than when **Log** mode is used.
- While the user is ramping Z in **Force Mode**, the feedback parameters (i.e., type, count and value) are inactive.

Input Feedback

In the **Feedback** panel, this parameter is *read only*. Use the **Input feedback** in the **Interleave Controls** panel for Frequency Modulation (MFM or EFM) and Surface Potential.

Integral gain

Controls the amount of integrated error signal used in the feedback calculation.

Range or Settings:

- 0—1024

Gain settings vary, depending upon the scanner used, the sample and scanner sensitivity. See [Table 3.3a](#) for approximate, nominal values (assumes a **Scan rate** of ≈ 2.5 Hz).

Table 3.3a Typical Integral Gain Ranges:

Scanner	Contact AFM and Forcemod	TappingMode	STM
A ^a	1.0 - 8.0	0.2 - 1.0	0.3 - 5.0

a. For atomic-scale images, scan rate must be increased to approximately 60 Hz.

Hints to Optimize the Integral Gain Parameter

- The **Integral gain** is usually the major contributor to the performance of the feedback loop due to its “long term” influence. For this reason, it is usually adjusted first.
- The integral term in the feedback calculation has the highest gain at low frequencies, and its effects diminish with increasing frequency.
- For contact AFM, a nominal **Integral gain** value may be obtained by slowly increasing the value until the piezo begins to oscillate, then decreasing the value 1-2 volts. Oscillation effects are best viewed using **Scope Mode**.

Proportional gain

Controls the amount of the proportional error signal used in the feedback calculation. The **Proportional gain** term in the feedback calculation has equal gain at all frequencies; therefore, it has a dominating effect over the **Integral gain** for high frequencies.

Range or Settings:

- 0—1024

Note: Typically, settings for the **Proportional gain** parameter are 35-100% more than **Integral gain** values.

Look Ahead Gain

Adjusts Z-axis tracking of the sample surface by “remembering” previous scan line data, then anticipating adjacent surface features on the current scan line. Look ahead gain is a valuable assist to the Integral gain parameter when scanning regular, steep features such as gratings and integrated circuits (e.g., by decreasing tip overshooting, etc.).

Range or Settings:

- 0—16

Hints for Optimizing the Look Ahead Gain Parameter

- Use **Look ahead gain** discretely. For many surfaces, **0.5—0.8** is nominal.
- Settings greater than **1.0** have a linear, multiplying effect on data. For example, a setting of **2.0** will double the tip’s anticipatory reaction to features; a setting of **3.0** will triple it, etc.
- **Look ahead gain** is applied to noise and features alike. **Look ahead gains** which are excessive for the sample surface being scanned can actually amplify noise, or lead to overdrive feedback problems.

Setpoint

The meaning of this parameter depends on the operating mode of the microscope as follows:

Amplitude Setpoint (Tapping Mode)—The Setpoint parameter in TappingMode control panel defines the amplitude of the cantilever oscillation signal to be maintained by the feedback loop.

Range or Settings:

- 0.00—10.00 volts

Note: The closer the **Setpoint** is to the maximum cantilever oscillation amplitude, the lower the amount of force applied to the surface. Therefore, larger Setpoint values decrease the force applied to the sample surface. This is opposite from the situation in the AFM contact mode where increasing the Setpoint increases the contact force.

Note: Negative values can be entered but they are not valid control points. Zero volts is not a valid control point either.

Deflection Setpoint (Contact Mode)—The **Setpoint** parameter in the AFM control panel controls the deflection-signal level used as the constant desired voltage in the feedback loop.

Range or Settings:

- **-10.00—10.00 Volts**

Note: The **Setpoint** voltage is proportional to the contact force once the base-line deflection signal level has been subtracted (i.e., increasing the setpoint, increases the contact force). This is opposite from the situation in the AFM tapping mode where increasing the Setpoint decreases the force applied to the surface.

Note: In the Real Time/View menu, **Force Mode/Calibrate** can be used to help determine the optimal setting for the **Setpoint** parameter.

Setpoint—STM.The **Setpoint** parameter in the STM control panel controls the constant current to be maintained by the feedback loop.

Range or Settings:

- **0.031 through 100.0 nA**

Hints to Optimize the Setpoint-STM Parameter:

- Typical settings for the **Setpoint** current parameter are **0.5 to 4.0 nA**.
- For large scans over surfaces with high vertical features, increasing the **Setpoint** current can improve the feedback performance since it is essentially like raising the gain.

- This parameter should be set to low values for poorly conducting surfaces.

Drive frequency (TappingMode and Force Mode only)

Selects the oscillation frequency applied to the piezoelectric crystal that vibrates the cantilever.

Range or Settings:

- **0.00** through **5.00 MHz**

Note: The **Center frequency** is adjusted with the **Cantilever Tune** command to find the resonance frequency of the cantilever. The maximum cantilever oscillation amplitude occurs at its resonant frequency. The software sets the **Drive frequency** equal to the current **Center frequency** value when the **Ok** button in the Cantilever Tune control panel is pressed.

Drive amplitude (TappingMode and Force Mode only)

Selects the amplitude of the drive voltage applied to the piezoelectric crystal that vibrates the cantilever.

Range or Settings:

- **0.00** through **20.00 Volts**

Note: The **Drive amplitude** is also adjusted with the **Cantilever Tune** command. Increasing the **Drive amplitude** increases the cantilever-oscillation amplitude. The cantilever-oscillation amplitude is increased to an appropriate level with the **Cantilever Tune** command.

Note: In **AutoTune**, the **Drive Amplitude** automatically adjusts to get a cantilever oscillation (rms amplitude) equivalent to the user's "target amplitude".

Bias (STM only)

Controls the sign and magnitude of the bias voltage applied to the sample.

Range or Settings:

- **-10.00** to **10.00 Volts**

Note: Typical settings for the **Bias** voltage parameter are **20** to **100 mV** for conductive samples and up to several volts with poorly conducting samples.

Note: Positive settings of the **Bias** voltage item correspond to negative current (electrons) tunneling from the tip into the sample on heads with the **Bias** applied to the sample.

Analog 1 [V] (STM and standard contact AFM only)

This voltage has no effect on the operation of the standard microscope, but is useful in custom applications.

Range or Settings:

- **-10.00** through **10.00 Volts**

Analog 2 [V] (STM and AFM only)

Outputs two complementary, selectable voltages from the controller (See lines labeled **AN2LV** and **AN2HV** in the “Controller-Interface Signals” matrix in Appendix B of the Control System User's Manual). One output ranges between ± 12 volts while the other output ranges between ± 220 volts. These voltages have no effect on the operation of the standard microscope, but they may be useful in custom applications.

Range or Settings:

- **± 12.00 Volts** on the low voltage channel
- **± 220 Volts** on the high voltage channel.

Note: The same digital-to-analog converter controls both the low voltage and high voltage outputs. The high voltage output simply contains another amplifier. Therefore, the voltages are complementary, but they are scaled differently.

3.4 Other Controls

The **Other Controls** parameters set the type of microscopy, Z and deflection limits, units to use in measuring and other parameters specific to microscope mode (i.e., the parameters that appear in the **Other Controls** panel will vary from one microscope to another). Not all parameters are available on all microscopes. The contents of the panel will depend on the microscope system.

In the **Panels** menu, select **Other Controls** to access the **Other Controls** panel (See [Figure 3.4a](#)).

Figure 3.4a Other Controls Panel (D5000/Tapping Mode)

Other Controls	
Microscope mode:	Tapping
Z limit:	6.864 μm
Amplitude limit:	2.500 V
Illumination:	24
Units:	Metric
Color table:	12
Engage Setpoint:	0.900
Scan line shift:	0.00
Tip serial number:	
Serial number:	1417GN
Min. engage gain:	3.00

5608

3.4.1 Parameters in the Other Controls Panel

Microscope mode

Selects the type of microscopy to be employed. Switching this parameter enables/disables other parameters. Also, on **MultiMode SPMs**, any change to the **Microscope mode** must be accompanied by use of the mode selector switch on the microscope's base.

Range or Settings: Contact, Tapping or STM

Note: Settings for this parameter will also vary according to settings in the Real Time / **Microscope** / **Profile**.

Z limit

- Permits attenuation of maximum allowable Z voltage and vertical scan range for achieving higher resolution (smaller quantization) in the Z direction.

Range or Settings:

- **11—440 Volts**

Note: Scanner dependent systems use metric measurements (*nm* and μm).

Hints for Optimizing the Z Limit Parameter

- The **Z limit** parameter allows the Z-axis digital-to-analog converter's full 16 bits to be applied to the specified range.

- The **Data scale** parameter is limited to maximum **Z Limit** value.
- Lowering the maximum scan voltage with this command is useful when performing atomic scale scans with long-range heads where the effects of quantization are greatest.
- The new **Z** range scales around the current **Z** center voltage.
- Pressing **Enter** or double-clicking on the **Z limit** parameter resets the **Z center position** value to the current **Z** average.

Deflection Limit

Use this parameter for attenuating the input voltage signal (appears only when performing contact AFM).

Range or Settings:

- 2.500 V for regular imaging
- 20.00 V in **Force Mode** *only*

Hints for Optimizing the Deflection Limit Parameter

- Attenuation was formerly adjusted using the **Input attenuation** parameter, whose settings of **1x** and **8x** correspond to settings of **2.50 V** and **20.00 V** on the **Deflection limit** parameter, respectively.

Amplitude Limit

Use this parameter for attenuating the input voltage signal (appears only for TappingMode or STM).

Range or Settings:

- 2.500 V for regular imaging
- 20.00 V in **Force Mode** *only*

FM igain

Integral gain for Frequency modulation. Controls the feedback loop that uses phase electronics.

FM pgain

Proportional gain for Frequency modulation. Controls the feedback loop that uses phase electronics.

Illumination

Controls the fiber optic illumination of the sample in **Dimension** series microscopes.

Range or Settings: **0—100**, recommended range is **20—50**

Units

Selects whether the units of certain scan parameters are in Volts or in units of Metric distance (nm, etc.). Parameters affected include Scan size, X Offset, Lift start height and Lift scan height, Y Offset, Data Scale, Z Limit, Z Scan Start, Ramp Size, Column Step and Row Step.

Range or Settings:

- **Volts**—Parameters are in **Volts**.
- **Metric**—Parameters are in units of distance (**nm**, **μm**, etc.)

Color table

Selects the range of colors used to map Z data. Color tables can be created or altered using the Color Table command in the Offline/Utility menu.

Range or Settings:

- 0—21

Bidirectional scan

When the Bidirectional scan parameter is **Enabled**, data from both Trace and Retrace scans are used to capture frames in half the normal time. Images have alternately shifted lines, which cause features to lose some of their lateral definition; however, data may be used for metrological analysis. Use to save time while capturing images.

Range or Settings:

- Enabled or Disabled

Note: When **Enabled**, features shown in images lose some lateral definition, making point-to-point measurements inadvisable. Vertical data, however, is unaffected.

Use the **Scan line shift** parameter to readjust images with the **Bidirectional scan** parameter **Enabled**. This will shift scan lines relative to one another to restore some lateral definition in features.

Scan line shift

Use the **Scan Line Shift** parameter to shift trace and retrace lines relative to one another by up to 5 pixels in either direction. Units are in pixels and range from -5 to +5. Scan line shift is used for readjusting images captured when the Bidirectional scan parameter is Enabled (see "Bidirectional scan").

Range or Settings:

- -5 to +5.

Note: This parameter is generally only for images that have been captured with the **Bidirectional scan** parameter set to **Enabled**.

Engage Setpoint (TappingMode only)

Allows the user to correct for loss of tracking on engage due to sample differences. The automatic **Engage** procedure establishes the setpoint voltage at the smallest possible value that detects the sample surface, resulting in a value that protects both the sample surface and the cantilever tip. However, this value may not be sufficient for optimal surface tracking on all samples. The setpoint voltage determined by the automatic **Engage** procedure will be multiplied by the **Engage Setpoint** value, increasing or decreasing tapping force.

Range or Settings: **0.5** through **2.0**. A value of **1.0** results in no change to the tapping force. Values less than **1.0** increase the tapping force and values greater than **1.0** decrease the tapping force. A value of **.9** is nominal for most samples.

Example. The **Engage Setpoint** for a particular sample may be empirically determined. Procedures are as follows:

1. Set the **Engage Setpoint** to **1.0** and engage on the sample.

2. After engagement, make note of the **Setpoint** parameter.
3. While watching the scan, adjust the **Setpoint** value until the tip tracks the surface correctly. Calculate the following:
 - Setpoint value/ Starting Setpoint value = Engage Setpoint
(For optimal value, take the average of several engages on a selection of samples or different areas of the same sample).

Z Modulation (Fluid TappingMode only)

Allows the user to add the drive oscillation signal to the Z piezo voltage. This parameter is used to set up fluid cell oscillation in any Dimension system for Fluid TappingMode.

Range or Settings:

- **1**—Enables Z modulation drive oscillation signal is added to Z piezo voltage. **When enabled, the Z limit must be set ≤ 420 Volts.**
- **0**—Disables the Z modulation (i.e., no additional signal is added to Z piezo voltage).

Note: The desired **Drive amplitude** and **Drive frequency** voltages (**Real Time/ View / Sweep / Cantilever Tune**) **need to be set for Fluid TappingMode operation.**

Tip Serial Number

Saves input in the image header (Ciao Scan List) for users who keep a tip filing system. This is to keep track of the tips used for certain images.

Serial Number: **Scanner Calibration** file.

Min. Engage Gain (STM only)

Allows user to engage tip in "constant height" mode. In constant height mode, the gains (feedback) is disabled. However, the **Min. Engage Gain** parameter provides for gain during engagement.

3.5 Interleave Controls

As the name implies, the **Interleave Controls** panel allows scan parameters for the main and interleaved scan lines to be set independently. Enable **Interleave Control** feedback parameters by clicking on the round "LED" enable light to the left of each highlighted interleave parameter. When the interleave parameter defaults to the same as the main parameter, the enable light appears gray.

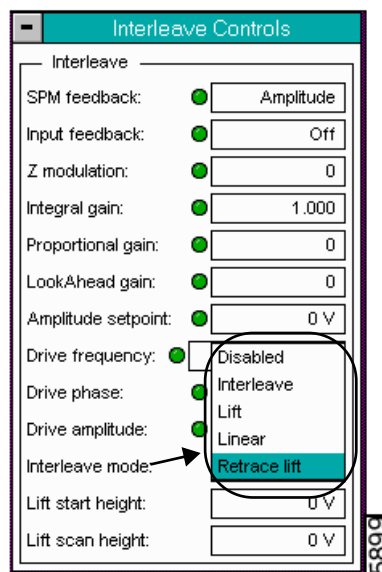
In addition to having independent feedback controls, the tip may be lifted and have its feedback turned off during the interleaved scan lines. The **Interleave Controls** panel also contains

parameters to adjust the height of the lifted tip. Although **liftmode** is used most commonly for magnetic force microscopy, it can be used in all operating modes.

When the **Interleave mode** is enabled, the system scans twice as many lines by alternating between the “main” and “interleave” scan lines. Having independent feedback controls allows a wider range of scanning possibilities.

In the **Panel** menu, select **Interleave Controls** to access the **Interleave Controls** panel (See [Figure 3.5a](#)).

Figure 3.5a Interleave Controls Panel for MultiMode TM



3.5.1 Parameters in the Interleave Controls Panel

SPM Feedback

Selects the signal used for tip feedback according to the selected microscope mode (**Other Controls** panel).

The SPM Feedback settings are as follows:

Other Controls/ Microscope Mode	Range or Setting
Tapping	Amplitude (TM Deflect only for Force Mode)
Contact	Deflection only
STM	Log, Linear, Boost

Input Feedback [For Systems configured with an Extender™ Electronics Module]

Use the **Input feedback** parameter for **Frequency Modulation** (MFM or EFM) and **Surface Potential**.

Range or Settings:

- **Off**—Disables the parameter
- **Frequency**—Enables the frequency data from oscillating TappingMode tips for MFM (Magnetic Force Microscopy) or EFM (Electric Force Microscopy) to be displayed and captured.
- **Potential**—Enables the feedback signal for electrical surface potential data (EFM) to be displayed and captured.

Z Modulation [Fluid TappingMode only]

Allows to add the oscillation signal to the Z piezo voltage used to set up fluid cell oscillation in an Dimension system for Fluid TappingMode.

Range or Settings:

- **1**—Enables Z modulation drive oscillation signal that is added to the Z piezo voltage.
- **0**—Disables the Z modulation signal.

Note: Z limit (Other Controls panel) must be set to ≤ 420 for optimizing the Z Modulation parameter.

Integral gain

Controls the amount of integrated error signal used in the feedback calculation.

Range or Settings: **0—1024**

Gain settings vary, depending upon the scanner used, the sample and scanner sensitivity. See [Table 3.3a](#) for approximate, nominal values (assumes **Scan rate** of ≈ 2.5 Hz).

Table 3.5a Typical Integral Gain Ranges:

Scanner	Contact AFM and Forcemod	TappingMode	STM
A ^a	1.0 - 8.0	0.2 - 1.0	0.3 - 5.0

a. For atomic-scale images, scan rate must be increased to approximately 60 Hz.

Hints to Optimize the Integral Gain Parameter

- The **Integral gain** is usually the major contributor to the performance of the feedback loop due to its “long term” influence. For this reason, it is usually adjusted first.
- The integral term in the feedback calculation has the highest gain at low frequencies, and its effects diminish with increasing frequency.
- For contact AFM, a nominal **Integral gain** value may be obtained by slowly increasing the value until the piezo begins to oscillate, then decreasing the value 1-2 volts. Oscillation effects are best viewed using **Scope Mode**.

Proportional gain

Controls the amount of the proportional error signal used in the feedback calculation. The **Proportional gain** term in the feedback calculation has equal gain at all frequencies; therefore, it has a dominating effect over the **Integral gain** for high frequencies.

Range or Settings:

- **0—1024**

Note: Typically, settings for the **Proportional gain** parameter are 35-100% more than **Integral gain** values.

Look Ahead Gain

Adjusts Z-axis tracking of the sample surface by “remembering” previous scan line data, then anticipating adjacent surface features on the current scan line. Look ahead gain is a valuable assist to the Integral gain parameter when scanning regular, steep features such as gratings and integrated circuits (e.g., by decreasing tip overshooting, etc.).

Range or Settings:

- **0—16**

Hints for Optimizing the Look Ahead Gain Parameter

- Use **Look ahead gain** discretely. For many surfaces, **0.5—0.8** is nominal.
- Settings greater than **1.0** have a linear, multiplying effect on data. For example, a setting of **2.0** will double the tip's anticipatory reaction to features; a setting of **3.0** will triple it, etc.
- **Look ahead gain** is applied to noise and features alike. **Look ahead gains** which are excessive for the sample surface being scanned can actually amplify noise, or lead to overdrive feedback problems.

Setpoint

The meaning of this parameter depends on the operating mode of the microscope as follows:

Amplitude Setpoint (Tapping Mode)—The Setpoint parameter in TappingMode control panel defines the amplitude of the cantilever oscillation signal to be maintained by the feedback loop.

Range or Settings:

- 0.00—10.00 volts

Note: The closer the **Setpoint** is to the maximum cantilever oscillation amplitude, the lower the amount of force applied to the surface. Therefore, larger Setpoint values decrease the force applied to the sample surface. This is opposite from the situation in the AFM contact mode where increasing the Setpoint increases the contact force.

Note: Negative values can be entered but they are not valid control points. Zero volts is not a valid control point either.

Deflection Setpoint (Contact Mode)—The **Setpoint** parameter in the AFM control panel controls the deflection-signal level used as the constant desired voltage in the feedback loop.

Range or Settings:

- **-10.00—10.00 Volts**

Note: The **Setpoint** voltage is proportional to the contact force once the base-line deflection signal level has been subtracted (i.e., increasing the setpoint, increases the contact force). This is opposite from the situation in the AFM tapping mode where increasing the Setpoint decreases the force applied to the surface.

Note: In the Real Time/View menu, **Force Mode/Calibrate** can be used to help determine the optimal setting for the **Setpoint** parameter.

Setpoint—STM.The **Setpoint** parameter in the STM control panel controls the constant current to be maintained by the feedback loop.

Range or Settings:

- **0.031** through **100.0 nA**

Hints to Optimize the Setpoint-STM Parameter:

- Typical settings for the **Setpoint** current parameter are **0.5** to **4.0 nA**.
- For large scans over surfaces with high vertical features, increasing the **Setpoint** current can improve the feedback performance since it is essentially like raising the gain.
- This parameter should be set to low values for poorly conducting surfaces.

Drive frequency (TappingMode and Force Mode only)

Selects the oscillation frequency applied to the piezoelectric crystal that vibrates the cantilever.

Range or Settings:

- **0.00** through **5.00 MHz**

Note: The **Center frequency** is adjusted with the **Cantilever Tune** command to find the resonance frequency of the cantilever. The maximum cantilever oscillation amplitude occurs at its resonant frequency. The software sets the **Drive frequency** equal to the current **Center frequency** value when the **Ok** button in the Cantilever Tune control panel is pressed.

Drive amplitude (TappingMode and Force Mode only)

Selects the amplitude of the drive voltage applied to the piezoelectric crystal that vibrates the cantilever.

Range or Settings:

- **0.00** through **20.00 Volts**

Note: The **Drive amplitude** is also adjusted with the **Cantilever Tune** command. Increasing the **Drive amplitude** increases the cantilever-oscillation amplitude. The cantilever-oscillation amplitude is increased to an appropriate level with the **Cantilever Tune** command.

Note: In **AutoTune**, the **Drive Amplitude** automatically adjusts to get a cantilever oscillation (rms amplitude) equivalent to the user's "target amplitude".

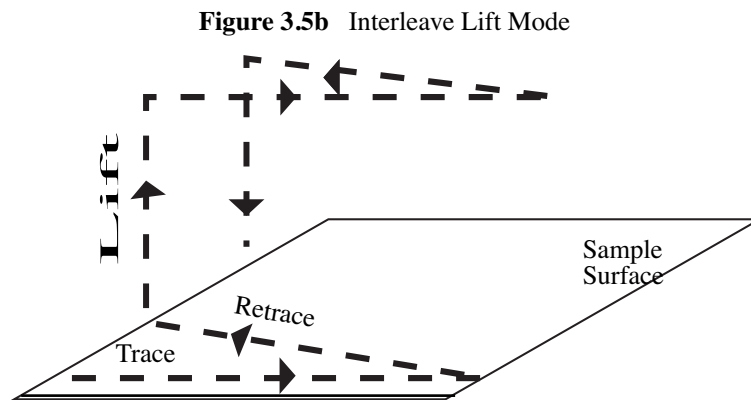
Interleave mode

The **Interleave mode** parameter enables or disables the interleave scanning function.

1. When either **Interleave**, **Lift**, **Linear**, **Retrace Lift** are chosen, the number of scan lines doubles, with the slow axis running at half the normal (single trace-retrace) speed (i.e., capture time doubles).

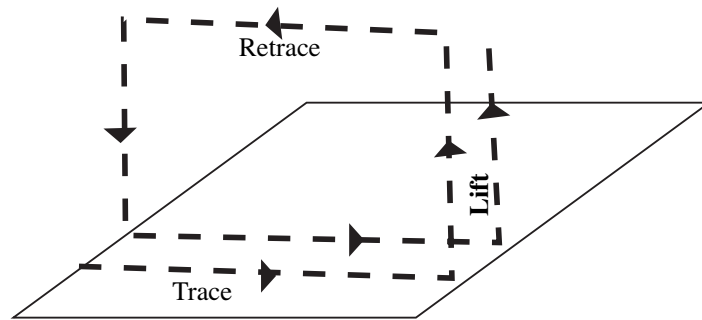
Range or Settings:

- **Interleave**—Adds a second, interleaved set of lines to the scan, which can be accessed from the Channel panel and captured as data. Invoking Interleave reduces the slow axis' speed by one-half and doubles the capture time.
- **Lift**—A variant of **Interleave**, the **Lift** option uses the first set of scan lines to detect the surface, then lifts the probe above the sample surface on the interleaved set of scan lines according to the **Lift start height** and **Lift scan height** parameter settings. During the Interleaved scan, the tip mimics the surface topography from the previous surface scan line (See [Figure 3.5b](#)).



- **Linear**—Lifts the tip to a predetermined height and runs the interleave scan at that height.
- **Disabled**—Turns off the interleave scanning.
- **Retrace Lift**—Lifts after the trace scan in the retrace direction. This parameter is optimized with the **rounding** parameter (Microscope/Calibrate/Scanner/rounding). The suggested rounding setting is **0.2**.

Figure 3.5c Retrace Lift Mode



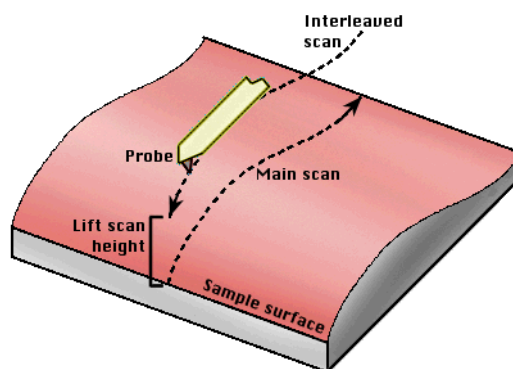
Hints for Optimizing the Interleave Mode Parameters

- Before starting an interleaved scan, be certain that parameters on the **Interleave Controls** panel are properly set to avoid crashing the probe.
- To display interleaved data, set the **Scan line** parameter on a **Channel** panel to **Interleave**. Channel panels having their **Scan line** parameters set to **Main** will display only data from the normal scan.
- The **Lift start height** and **Lift scan height** parameters control the height of the lifted scan and should be set prior to starting interleaved *lift* scanning.

Lift scan height

Specifies the tip's height above the sample surface during interleaved scans. This parameter is in effect **ONLY** when the Interleave mode parameter is set to **Lift** and **Linear**.

Figure 3.5d Lift Scan Height Illustrated



Range or Settings:

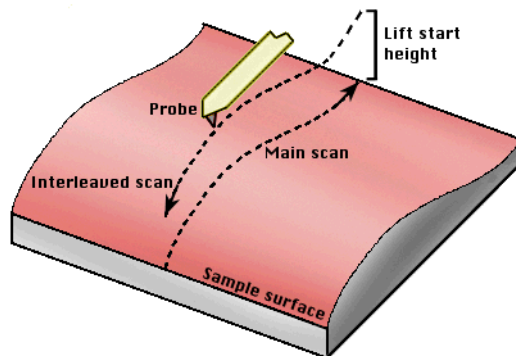
- XX μm (Scanner dependent)

Note: The maximum meaningful value of the parameter depends on the Z voltages applied in the **Main** scan line and the maximum voltage that the system can output. The maximum voltage that can be applied to the piezo is ± 220 volts. It will be lower if the Z voltage is restricted by the **Z limit** parameter.

Lift start height

Specifies the height that the tip is to be lifted above the sample surface at the start of each interleaved scan. Generally, this parameter serves to lift the tip clear of any contamination layers present on the sample before assuming its Lift scan height during interleaved scans. This parameter is in effect **ONLY** when the **Interleaved mode** parameter is set to **Lift**. This parameter defines an offset from the Z voltage, or height, applied to the piezo on the **Main** scan line.

Figure 3.5e Lift Start Height Illustrated.



Range or Settings:

- XX μm (Scanner dependent)

Hints for Optimizing the Lift Start Height Parameter

- This value can be left at zero for TappingMode and STM. It is generally only used for contact AFM to break the tip free of the adhesive force produced by the water layer before settling to the final tip height.
- The maximum meaningful value of the parameter depends on the Z voltages applied in the **Main** scan line and the maximum voltage that the system can output. The maximum voltage that can be applied to the piezo is ± 220 volts. It will be lower if the Z voltage is restricted by the **Z limit** parameter.
- The tip will go through this height at the start of every lifted scan line, then proceeds to the lift scan height for the rest of the scan line.

3.6 Channel (1, 2, 3)

Up to three data **Channels** may be opened simultaneously using the Real Time / **Panels** menu. Channels are numbered **1**, **2** and **3** and feature their own control panels. When a Data type is selected on a Channel, its image is added to the Display Monitor. It is possible to have up to three separate images from each scan. For example, a TappingMode scan might simultaneously present a **Height** image on **Channel 1**, a **Deflection** image on **Channel 2**, and an **Amplitude** image on **Channel 3**.

Parameters shown on each **Channel** control panel vary slightly, depending upon the type of microscope selected and its operating mode. For example, a MultiMode SPM imaging in TappingMode will offer six choices for its **Data type** parameter: **Height**, **Deflection**, **Amplitude**. The same microscope operating in contact AFM does not offer **Amplitude**, but offers **Friction**. Microscopes imaging with STM offer the choice of **Current**.

Parameters offered on each **Channel** panel follow. Differences are noted where pertinent.

Data type

Settings vary, depending upon the microscope selected and operating mode. The Data type parameter may receive: no data (Off); sample-height data (Height); cantilever oscillation amplitude data for TappingMode (Amplitude); cantilever deflection data (Deflection); STM current data (Current); phase data in extended AFM mode.

Range or Settings:

- **Amplitude** (TappingMode and Force Mode only)—The RMS of the cantilever amplitude signal is displayed and captured.
- **Current** (STM only)—Data displayed and captured is the tunneling current generated by the preamplifier.

Note: When this parameter is set to **Current**, the units of the data are **nA**.

- **Deflection**—Cantilever deflection signal data is displayed and captured.

Note: When this parameter is set to **Deflection**, the units of the data are in distance or volts.

- **Frequency**—Frequency data from oscillating TappingMode tips, usually used with MFM and EFM, is displayed and captured. This setting appears only when an Extender™ Electronics Module is attached to the microscope.
- **Friction**—Torsional deflection signal data is displayed and captured.
- **Height**—The Z piezo voltage set by the feedback calculation in the Digital Signal Processor (DSP) is displayed and captured.

Note: If **Height** is selected, the displayed data comes from the voltage output to the Z piezo. When this parameter is set to **Height**, the units of the data are distance (e.g., **nm**, **µm**, etc.).

- **Off**—This setting will not appear unless more than one channel is being used.
- **Phase**—Phase data from oscillating TappingMode tips, generally used with MFM and EFM, is displayed and captured. This setting appears when the microscope is configured with an Extender™ Electronics Module.
- **Potential**—Electrical surface potential data (EFM) is displayed and captured. This setting appears only when an Extender™ Electronics Module is attached to the SPM and it is hardware-configured.
- **Thermal**—Temperature data from thermal tips is displayed and captured.

Note: This setting appears only when a Thermal Head is used and the Thermal Profile is selected.

Hints for Optimizing the Data Type Parameters

- The system displays up to three Real Time images on the Display Monitor, depending on the settings of **Data type** parameters.
- The **Data type** parameter does *not* switch the operating mode of the instrument, it simply changes the source of the data displayed.
- Nanometers of deflection are calculated using the **Sensitivity** parameter in the **Force Calibrate** panel.

Contact AFM

- To run in the Constant Force mode, increase the feedback gains so that the Z piezo actually tracks the surface while keeping the deflection signal almost constant.

Set this parameter to **Height** data to image the variation in Z required to keep the deflection signal “constant.”

To run in what is referred to as the “Constant Height” mode, set the feedback gains low (so that the Z piezo would not respond very well to the variations in deflection signal, keeping the sample height almost constant), and set this parameter to **Deflection** to image the variation in deflection signal as the sample height remained “constant”.

Tapping Mode

- To produce accurate Height data in TappingMode, feedback gains should be relatively high to force the piezo height to change in an effort to keep the amplitude of the cantilever oscillation as constant as possible.
- Calculate nanometers of cantilever oscillation amplitude using the **Sensitivity** parameter in the Force Mode/Calibrate/Main panel. Finally, note that the **Setpoint** amplitude, or the nominal amplitude, is not zero, so that only the change in amplitude voltage is displayed.

STM

- To run in “Constant Current” mode, set the feedback gains relatively high so that the Z piezo actually tracks the sample surface, keeping the current almost constant.

Set this parameter to **Height** to image the variation in Z required to keep the current “constant”.

- To run in what is referred to as the “Constant Height” mode, set the feedback gains low so that the Z piezo does not respond very well to the variations in current, keeping the height almost constant. Set this parameter to **Current** to image the variation in the current as the tip height remains “constant”.
- Current, “Constant Height”, imaging should only be done for small scans (less than 0.1μ) over relatively flat surfaces; for example, atomic imaging. Otherwise, the image will appear spiky and the relatively low gains will cause the tip to strike the surface.

Data scale

The **Data Scale** controls the vertical scale corresponding to the full height of the display and color bar.

Range or Settings:

- 0.0067—440 Volts (**Data type** set to **Height**, **Units** set to **Volts**).
- XX—XXX μ m (Scanner dependent; where **Data type** set to **Height**, **Units** set to **Metric**).
- XX—XXX (Sensitivity dependent; where the **Data type** is set to **Deflection** or **Amplitude**; **Units** are set to **Metric**).
- 0.00003815 - 2.5 V or 20 V (Set to **Amplitude**; **Units** set to **Volts**).
- 0.001—XX Volts (**Data type** set to **Deflection**; **Units** are set to **Volts**).
- 0.031—200 nA (**Data type** set to **Current**; **Units** are set to **Metric**).
- 0.0003052V—20V (**Units** are set to **Volts**).

Hints for Optimizing the Data Scale Parameters

- Data beyond the setting of the **Data scale** is clipped for the Real Time display. Captured data, however, is not clipped. Independent of the settings of this parameter, the captured data will be correct, unless of course, it exceeds the maximum vertical range of the currently selected scanner.
- Retain separate settings for **Data scale** for all settings of the **Data type** parameter.
- The conversion of volts to **nm** or **nA**, is dependent on the value **Sensitivity Detector** parameters in the **Microscope/Calibrate/Detector** panel.

Data center

Offsets centerline on the color scale by the amount entered.

Note: The **Data Center** offset does *not* become a permanent part of the data.

Range or Settings:

- ± 220 V (Volts)
- $\pm XX$ nm (Metric)

Line direction

Selects the direction of the fast scan during data collection.

The feedback calculation is always performed regardless of the scan direction. This parameter simply selects whether the data is collected on the trace or the retrace. This parameter selects the relative motion of the tip to the sample.

Range or Settings:

- **Trace**—Data is collected when the relative motion of the tip is left to right as viewed from the front of the microscope.
- **Retrace**—Data is collected when the relative tip motion is right to left as viewed from the front of the microscope.

Scan line

The scan line controls whether data from the **Main** or **Interleave** scan line is displayed and captured.

Range or Settings:

- **Main** or **Interleave**

Note: This parameter is not selectable when the **Interleave mode** parameter is set to **Disable**. The system is locked on the **Main** scan lines whenever the interleaved mode is turned off.

Note: Either channel 1 or 2 can be selected for the **Main** display, but the other channel must be defined for the **Interleave** display. This setting appears only when an Extender™ Electronics Module is attached to the SPM and it is hardware-configured.

Real Time Planefit

Applies a software “leveling plane” to each Real Time image, thus removing up to first-order tilt. Five types of planefit are available to each Real Time image shown on the Display Monitor.

Range or Settings:

- **None**—Only raw, unprocessed data is displayed.
- **Offset**—Takes the Z-axis average of each scan line, then subtracts it from every data point in that scan line.
- **Line**—Takes the slope and Z-axis average of each scan line and subtracts it from each data point in that scan line. This is the default mode of operation, and should be used unless there is a specific reason to do otherwise.
- **AC**—Takes the slope and Z-axis average of each scan line across one-half of that line, then subtracts it from each data point in that scan line.
- **Frame**—Level the Real Time image based on a best-fit plane calculated from the most recent Real Time frame performed with the same frame direction (Up or Down).
- **Captured**—Level the Real Time image based on a best fit plane calculated from a plane captured with the **Capture Plane** command in the Real Time/ **Capture** menu. This selection will not appear until a valid plane is captured.

Note: The Real Time **Planefit** is applied only to *display data at the time of the scan* and does not apply to captured data. To planefit captured data, use the **Offline Planefit** parameter.

Offline Planefit

Applies a software “leveling plane” to each offline image for removing first-order tilt. Five types of planefit are available to each offline image.

Range or Settings:

- **None**—Only raw, unprocessed data is displayed.
- **Offset**—Captured images have a DC Z offset removed from them, but they are not fitted to a plane.
- **Full**—A best-fit plane which is derived from the data file is subtracted from the captured image.

Hints for Optimizing the Offline Planefit Parameter

- The **None** option should only be used in special cases. The **Offset** and **Full** options provide greater dynamic range in the data to reduce round-off and other errors in subsequent calculations.

- The **Offline / Modify / Flatten** and **Planefit** commands can also be used to level the data after it has been captured.
- The **Captured** option will not appear in the control panel until the **Capture Plane** command is used to collect a plane.

Highpass filter (Channel 1 TappingMode and contact AFM only)

The **Highpass filter** sets the cut-off frequency of a digital high-pass filter used on the Real Time and captured images. This feature is normally used only for imaging at atomic scales.

Range or Settings:

- Off
- 1–9

Hints for Optimizing the Highpass Filter Parameter

- Removes low-frequency effects from Real Time and captured images such as ripples in the image caused by torsional forces on the cantilever when the scan reverses direction.
Note: The **Height** information in the image will be distorted by the application of this filter.
- The **Off** setting results in no high-pass filtering of the image and increasing the settings from **1** through **9** increases the passband by lowering the cut-off frequency of the two-pole high-pass filter applied to the data stream.
- The keyboard can be used to turn off the **Highpass filter** by typing **0** when the parameter is highlighted.

Lowpass filter (Channel 1 TappingMode and contact AFM only)

Allows Real Time digital low-pass filtering of each line of data to remove the effects of high-frequency noise from the image without affecting the feedback.

Range or Settings:

- Off or 1 - 9

Hints for Optimizing the Lowpass Filter Parameter

- The **Off** setting results in no low-pass filtering of the image.
- Increasing the settings **1** through **9** decreases the passband by lowering the cut-off frequency of the one-pole low-pass filter applied to the data stream.

- This parameter only affects the displayed and captured data and does not affect the feedback loop.
- The keyboard can be used to turn off the low-pass filter by typing **0** when the parameter is highlighted.

3.7 Gain Adjust

Auto Gain automatically sets the feedback parameters (**Proportional** and **Integral gain**) for a given sample.

Auto Gain works by analyzing the difference between **Trace** minus **Retrace (TMR)**. The analysis is used to choose a set of feedback parameters that minimizes the **TMR** value. By specifying the starting value of the **Integral gain** sweep, the ending value, and the size of the increments, Auto Gain may be used to calculate a set of useful feedback parameters.

For the purposes of this analysis, **Proportional gain** operates as a factor of **Integral gain**. The relationship is $\text{Proportional gain} = F \times \text{Integral gain}$, where F is a factor defined as **Pro. Gain factor**.

Auto Gain only requires the input of the three **Gain** values in order to calculate an effective **Integral gain**.

In the **Panels** menu, select **Gain Adjust** to access the **Auto Gain** panel (See [Figure 3.7a](#)).

Figure 3.7a Auto Gain Panel

Auto Gain	
Gain start:	2.50
Gain end:	5.00
Gain incr:	0.0313
Pro. Gain factor:	1.50
Max shift:	0.0200
Gain offset:	0.950
Lines/gain:	8

5670

3.7.1 Parameters in the Auto Gain Panel

Gain start

The starting value of the integral gain sweep.

Range or Settings: Recommended settings are **0.10** for **TappingMode**, **0.5** for **Contact Mode**

Gain end

The ending value of the integral gain sweep.

Range or Settings: Recommended settings are **1.0** for **TappingMode**, **10.0** for **Contact Mode**

Gain incr.

The increment step for each integral gain test.

Range or Settings: **0.0—5.0**; recommended settings are **0.1** for **TappingMode**, **0.5** for **Contact Mode**.

Pro. Gain factor

Proportional gain is set to: Pro. Gain factor × Integral gain

Range or Settings: **0.0—10.0**; recommended value is **1.50**

Max shift

The percentage of pixels to shift the Retrace line to match the trace line during the correlation routine. The more closely the Trace and Retrace lines match, the lower the TMR will be, and the more effective the Auto Gain feature.

Range or Settings: **0—0.2**; recommended setting is **0.02** (or **2%**)

Gain offset

Specifies the number that determines the final, best fit Integral gain. Allows a change in the value produced by Auto Gain.

Range or Settings: **0.0—2.0**; recommended setting is **0.95** (or **95%**)

Lines/gain

The number of lines to test and average for each integral gain step. Optimal settings are between 4 and 8. This, like Max shift, allows for a more accurate determination of TMR.

Range or Settings: 1—20, with a default setting of 8

Hints for Optimizing the Lines/gain Parameter

- **Start** and **End** values should bracket the expected value, but not enough to cause damage.

- The user should perform **Auto Gain** on the actual feature of interest. If the feature is large this will usually result in an aggressive gain setting, but it is the most effective method.
- If there are no significant features, the calculated **Integral gain** is set too low because it is trying to reduce the noise in the background.

The basic procedure for using the **Auto Gain** parameter is as follows:

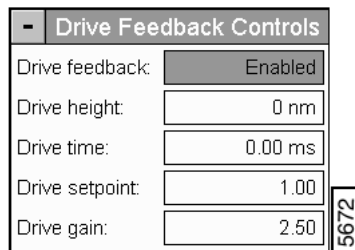
1. Take a **Trace/Retrace** pair.
2. Remove horizontal shift in the **Trace** and **Retrace** to improve the match.
3. Calculate **Trace minus Retrace (TMR)**.
4. Step the gains to the next value. **Auto Gain** repeats the process until the **End Gain value (Gain end)** is reached. The **Integral gain** value that generates the least difference between **Trace** and **Retrace** is the selected value.

3.8 Drive Feedback Controls

Many users are familiar with the difficulties of minimizing tip-sample forces on extreme surfaces (i.e., surfaces which are extremely hard or soft). Very hard surfaces tend to wear out silicon tips rapidly; very soft samples are easily damaged by the tips themselves. Minimizing tip-sample forces in TappingMode with a higher setpoint may also lead to a condition in which tips suddenly disengage from surfaces. The **Drive Feedback Controls** panel contains parameters for precisely maintaining feedback levels during TappingMode imaging. This protects tips and samples, and assists greatly in maintaining tip engagement.

In the **Panel** menu, select **Drive** to access the **Drive Feedback Controls** panel (See Figure 3.8a).

Figure 3.8a Drive Feedback Controls Panel



When enabled, **Drive Feedback** works by readjusting the drive amplitude at the beginning and end of each scan line. As the tip reaches either edge of the scan area, the tip is lifted off the surface by the **Drive height** amount and the drive amplitude is adjusted by a factor equal to the **Drive gain** times the drive error signal. This occurs for a duration of **Drive time**. The tip then turns around, descends to the surface, and resumes scanning.

3.8.1 Parameters in the Drive Feedback Control Panel

Use **Drive feedback** parameters *only* for TappingMode imaging and **Disable** during other types of imaging. Although automatic control of **Drive Feedback** is not required for most TappingMode imaging, it should be applied whenever imaging extreme surfaces and when making tip changes with automatic tip exchange.

Drive feedback

The **Drive feedback** parameter turns drive feedback parameters on and off. **Enabled** is on, **Disabled** is off.

Drive height

Distance tip is lifted during readjustment of drive feedback. Default is 5.00 nm.

Drive time

Time required for the tip to exit the scan boundary, turn off feedback, ascend to the Drive height and adjust drive feedback. Default is 10.00 ms.

Drive setpoint

Drive amplitude setpoint, expressed as a fraction of the free-air amplitude. Default is 0.90.

Drive gain

Integral gain applied to the feedback loop's drive error signal. Once the tip resumes normal scan height, Drive gain is no longer applied. Default is 1.00.

Chapter 4 Motor Menu

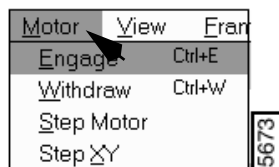
The commands in the **Motor** menu control the step motor responsible for gross movement of either tip or sample. Use the step motor to advance or retract the probe tip from the sample in the Z axis. The software takes the different microscope configurations of into account.

This chapter discusses the following **Motor** menu commands:

- **Engage** [Section 4.1](#)
- **Withdraw** [Section 4.2](#)
- **Step Motor** [Section 4.3](#)
- **Step XY** [Section 4.4](#)

On the Real-time menu bar, select **Motor** to open the **Motor** subcommands (See [Figure 4.0a](#)).

Figure 4.0a Motor Menu



4.1 Engage

The **Engage** command brings the tip into contact with the sample surface and starts the Real-time imaging process.

4.1.1 Control Monitor Actions

Engage may be initiated in one of two ways:

1. Click on the **Engage** icon on the **Real-time** tool bar.
2. Select **Motor/Engage** (CTRL-E).



4.1.2 Display Monitor Actions

- The Image of the sample appears on the Display Monitor along with a cursor. The cursor moves along the image vertically to show the engaged tip position on the surface.

Hints for Optimizing the Engage Command

- When used with stepper-motor-engagement microscopes (the Motor item in the **Microscope/Calibrate/Z** panel is set to **Forward** or **Reverse**), the tip is lowered under program control. While the tip is being engaged, the total tip travel distance is shown in the center of the status bar on the Control Monitor. For the AFM, the error signal (input - Setpoint) is also displayed in the status bar. When the surface is detected, the workstation beeps, starts the Real-time imaging process, and displays **Engaged** in the status bar on the Control Monitor.
- During automatic engagement, the tip will travel up to 250 μm for the STM A and D heads, and for the center-mounted STM G and J heads, and 125 μm for the AFM. If the sample surface is not detected in this distance, an error message will be displayed.
- If the tip is on the surface and the Z center voltage indicates that the piezo is near full extension or retraction, the tip may be withdrawn and re-engaged to center the Z center voltage. Alternatively, the *Tip Up* and *Tip Down* subcommands of the **Motor** command can be used to center the Z voltage.
- Pressing Ctrl-F after the **Engage** command has been executed will cause a false engage to occur, causing the Real-time software to start scanning independently of whether the surface has been detected or not.

4.1.3 Menu Items Affecting Results

Microscope/Calibrate panels: **Scanner**, **Z**, and **Detector** items.

4.2 Withdraw

The **Withdraw** command stops the scanning process and withdraws the tip from the surface.

4.2.1 Withdraw Control Monitor

Withdraw may be initiated in one of two ways:

1. Click on the Withdraw icon located on the Real-Time tool bar.
2. Select **Motor/Withdraw** (Ctrl-W).



4.2.2 Withdraw Display Monitor

- The cursor stops moving along the image.

ATTENTION: Do not unplug scan heads from the microscope or the microscope from the control unit when the TIP status is ENGAGED. If you do, you may damage the head, the microscope, and/or the controller, or suffer an electric shock.



4.2.3 Menu Items Affecting Results

- No menu items.

4.3 Step Motor

Step Motor may be initiated by selecting **Motor/Step Motor**. The **Step Motor** command allows the tip-to-sample spacing to be changed by incrementing the motor and leadscrew. The tip can be moved up (away from the sample) or down (towards the sample) in selectable step sizes.

4.3.1 Step Motor Control Monitor

The **Motor Control** panel allows control of the position of the tip relative to the sample (See [Figure 4.3a](#)).

Figure 4.3a Motor Control Panel



Buttons and Parameters on the Motor Control Panel

SPM Step size—The change in tip height per step.

Range and Settings:

- **25–1000 nm** for the AFM
- **50–2000 nm** for the STM "A" and "D" heads
- **25-1000 nm** for the STM "G" and "J" heads

QUIT—Exits the Step Motor mode.

TIP UP—This has the effect of moving the tip or cantilever up (away from the sample) by the amount specified by Step size.

Range and Settings:

- Specified by the **Step size** value.

TIP DOWN—Moves the tip or cantilever down (towards the sample) by the amount specified by Step size.

Range and Settings:

- Specified by the **Step size** value.

4.3.2 Display Monitor Actions

- No action items.

Hints for Optimizing Step Motor Controls

- The **Motor** field in the **Microscope / Calibrate / Z Calibration** panel can cause the meanings of **Tip up** and **Tip down** to be reversed if not set correctly for the head being used. STM heads with front mounted tips (A and D) should have this item set to **Forward**. All AFM heads and STM heads with center-mounted tips (G and J) should have this item set to **Reverse**.
- The **Step size** should be kept small (less than 200 nm) when moving the tip while it is engaged.
- There is up to 2 μm backlash in the motor-lead screw coupling; depending upon the step size, several steps may be required to see an effect when reversing step direction.
- The step sizes are not equal because the stepper motor operates in the half-step mode. If an exact step size is required, it should be an even multiple of the minimum step size.

4.3.3 Menu Items Affecting Results

Microscope/Calibrate/Z panel: **Motor direction** and **Motor sensitivity** items.

Example

1. If the Z center voltage puts the piezo near the fully extended or fully retracted position (± 220 V), use the **Step Motor** subcommands to move it closer to the center (0.0 V).

2. If the Z center voltage is too low (i.e., tip extended past center point), you would use the **Tip Down** subcommand. Likewise, you would use the **Tip Up** subcommand when the Z center voltage is too high (tip retracted above centerpoint).

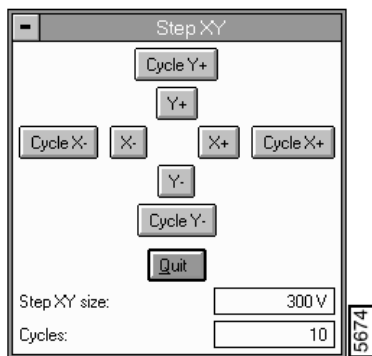
4.4 Step XY

The buttons in the **Step XY** panel move the sample in steps of approximately 25 percent of the full range of the particular scanner being used. The sample can be moved in the $\pm X$ and the $\pm Y$ directions.

Note: This command is only available for microscopes that move the sample during scanning (Small Sample, Contact AFM or MultiMode).

The **Step XY** panel allows the user to move the sample in one or ten steps in both the X and Y axes (See [Figure 4.4a](#)).

Figure 4.4a Step XY Panel



Buttons and Parameters on the Step XY Panel:

- **QUIT:** Exits the Step XY mode.
- **CYCLE Y+:** Moves the sample 10 steps in the +Y direction.
- **Y+:** Moves the sample one step in the +Y direction.
- **CYCLE X-:** Moves the sample 10 steps in the -X direction.
- **X-:** Moves the sample one step in the -X direction.
- **X+ :** Moves the sample one step in the +X direction.
- **CYCLE X+:** Moves the sample 10 steps in the +X direction.
- **Y- :** Moves the sample one step in the -Y direction.

- **CYCLE Y-:** Moves the sample 10 steps in the -Y direction.
Note: The number of steps depends on the **Cycles** parameter.
- **Step XY Size:** Adjusts the size of the stepping signal applied to the scanner. This parameter controls the effectiveness in scanning.
- **Cycles:** Number of times the stepping signal is applied to the scanner.

Chapter 5 View Menu

The commands in the **View** menu alter the form of Real-time information shown on the display menu for specific microscope modes. For example, the spectroscopic modes are not applicable to AFM, so they do not appear in the **View** menu when an AFM head is selected. Similarly, the **Force Calibrate** mode is specific to the AFM, so the **Force Calibrate** command only appears when an AFM is selected.

In some of the **View** commands (e.g., **Force Mode**), the X-Y scanning stops.

This chapter discusses the following **View** commands:

- **Image Mode** [Section 5.1](#)
- **Scope Mode** [Section 5.2](#)
- **Force Mode** [Section 5.3](#)
- **Force Calibrate** [Section 5.4](#)
- **Force Mode / Advanced** [Section 5.5](#)
- **Force Step** [Section 5.6](#)
- **Sweep** [Section 5.8](#)
- **STS Plot i(v) (STM Only)** [Section 5.9](#)
- **STS Plot i(s) (STM Only)** [Section 5.10](#)



5.1 Image Mode

The **Image Mode** command displays scan data on the display screen using a **Top View** format; this is the usual mode to select during scanning. The Control Monitor displays the default **Control** panels.

Note: When the Control Monitor panels change (e.g., in **Force Mode**), toggle back to the default screen by clicking the **Image** icon or selecting the **View** menu and then **Image Mode**.

5.1.1 Image Mode Control Monitor

Default **Control Panels** display on the Control Monitor. Panel parameters vary slightly depending upon the selected microscope (**Real-time/DI/Microscope Select**) and microscope profile (**Real-time/Microscope/Profile**). For details on each panel, see [Chapter 3](#).

General Functions of Control Panels in Image Mode

- **Scan Controls**—Affects the movement of the piezo.
- **Other Controls**—Adjusts general imaging parameters (i.e., Units).
- **Feedback Controls**—Directs the feedback response between the tip and sample.
- **Drive Feedback Controls** (TappingMode only)—Controls imaging of extremely hard or soft samples.
- **Interleave Controls**—Allows feedback parameters for interleaved, or in between, scans lines to be adjusted independently.

Up to three **Channel** panels may be displayed simultaneously, each presenting a separate image on the Display Monitor. If only one channel's **Data type** is **ON** and the others are set to **OFF**, only a single image will be displayed. Setting **Channel** panel **Data type** parameters to something other than **Off** puts the system in multi-image mode where two or three images are shown side-by-side on the Display Monitor.

5.1.2 Image Mode Display Monitor

The Display Monitor presents the Real-time image(s), a color bar for interpreting height information, a graph of the Z position, and a menu bar. The **Data type** parameter defines the number of images displayed. The menu bar contains subcommands associated with the Real-time/**Zoom In**, **Zoom Out** and **Offset** functions.

These commands enable the mouse to change the center of the scan and the **Scan size** to highlight regions of interest. The mouse may also be used to measure an X-Y distance directly on the Real-time image.

- **Distance and angle measurement**—The cursor can be placed on the image to measure the distance and angle between two points in the X-Y plane; distances and angles are displayed directly on the image. The mouse remains in this mode until another subcommand is selected.

Mouse Operations

- 1st click, left button—fixes one end of the line segment. The line segment then rubberbands out from this point.
- 2nd click, left button—fixes the other end of the line segment and displays the X-Y distance between the two points.

- 3rd click, left button—picks up the end of the line segment which is closest to the cursor.

Image Mode Menu Commands

Offset—Changes the center point of the scan. Cross hairs are used to define the new scan center point on the Real-time image.

Mouse Operations

- 1st click, left button—Drops the cross hair at its current position.
- 2nd click, left button (within the image)—Ties the cross hair to the mouse cursor.
- Click right button—Sets the cross hair position and moves the cursor to the **Execute** subcommand in the menu bar.

Note: Select **Execute** with right or left mouse button.

Zoom In—Displays an adjustable box over the Real-time image. The area within the box will fill the screen when the Execute command is given.

Zoom Out—Displays an adjustable box over the Real-time image. When the Execute command is given, the scanned area will be enlarged proportionally to the zoom box drawn on the current image.

Zoom Notes—Selecting either of the Zoom subcommands places a square box on the image. The position of the box is tied to the movement of the mouse.

Mouse Operations

- 1st click, left button—Allows the box size to be changed by moving the mouse.
- 2nd click, left button—Allows the box position to be changed by moving the mouse. Additional clicks of the left button switch between the box-translation and box-size-adjustment modes.
- Click right button—Freezes the box and moves the cursor to the Execute subcommand in the menu bar. The Execute subcommand can be given with either mouse button.
- Additional click left button—After the box is dropped, it may be “picked up” by clicking the left button within the image.

Execute—Completes the **Offset** and **Zoom** menu commands.

Clear—Removes the zoom box or cross hair from the Display Monitor.

Rotate—Rotates the image display.

Erase Image—Clears and resets the image display.

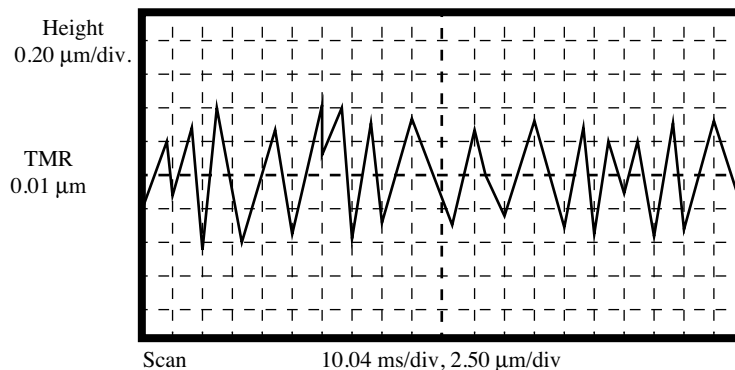
See also: Real-time/**View** menu; **Scope Mode** and **Force Calibrate** commands.

5.2 Scope Mode

The **Scope Mode** plots tip-sample interactions. Depending on the selected microscope and **Data type** (**Channel 1, 2 or 3**), the feedback signal (**Deflection**), Z data (**Height**), or auxiliary signal (**A, B or C**) displays as a plot versus the probe position in an oscilloscope-type format on the Display Monitor (See [Figure 5.2a](#)).

Note: A plot displays for each image (e.g., Two images scanning display two **Scope** plots).

Figure 5.2a TappingMode AFM Scope Trace



As with **Image Mode**, control panels for the selected microscope are available on the Control Monitor, allowing various parameters to be adjusted.

5.2.1 Scope Mode Display Monitor

The plot (or plots), Z center position graph, and menu bar appear on the Display Monitor. The “trace minus retrace” value (**TMR**) is displayed next to each scope display. **TMR** is the average distance between the trace and retrace values.

Note: The **TMR** value is a useful indicator of whether the tip is tracking the surface properly.

Scope Mode Menu Commands

The subcommands in the menu bar control the format of the Real-time scope trace display. The commands are:

- **Single Trace**—Displays a single trace corresponding to the Line direction parameter. The line will be white if Trace is selected and yellow if Retrace is selected.
- **Dual Trace**—Displays both trace and retrace where the left-to-right trace of the tip is shown in white and the right-to-left trace is shown in yellow.

5.3 Force Mode

In the **View** menu, the **Force Mode** commands include:

- **Calibrate**—See [Section 5.4](#)
- **Advanced**—See [Section 5.5](#)
- **Step**—See [Section 5.6](#)
- **Volume**—See [Section 5.7](#)

Note: X-Y scanning is halted during all **Force Calibrate**, **Advanced**, and **Force Step** operations.

The **Force Calibrate** and **Force Step** commands allow users to execute and plot controlled tip-sample interactions. **Advanced** (i.e., advanced **Force Calibrate**) allows for additional configurations in executing a Force curve for tip-sample interactions.

5.4 Force Calibrate

Also referred to as **Force Curves** or **Force Plots**, the **Force Calibrate** command modulates tip-sample separation and plots either the resulting deflection of the cantilever (contact AFM), or the amplitude of the cantilever oscillation (**TappingMode**), as a function of sample displacement. The cantilever deflection or oscillation amplitude is plotted relative to a user-designated input signal.

5.4.1 Force Calibrate Control Monitor

Clicking on the **Calibrate** command (**Real-time / View / Force Mode / Calibrate**) displays several control panels on the Control Monitor: **Main Controls** and **Channel 1, 2 and 3** (See [Figure 5.4a](#)).

Note: The **Drive frequency** and **Drive amplitude** parameters are displayed only when the microscope is switched to **TappingMode**.

Note: The **Feedback Controls** panel parameters also affect changes to the **Force Calibrate** (See [Section 5.5.2](#)).

Figure 5.4a Force Calibrate Panels

The image shows a software interface for Force Calibrate. It consists of several panels:

- Main Controls:**
 - Ramp Controls:** Ramp size: 0 nm, Z scan start: 0 nm, Scan rate: 2.03 Hz, Number of samples: 512.
 - Display:** Units: Metric, Amplitude setpoint: 0.1050 V.
- Channel 1:** Data type: Amplitude, Data scale: 2.500 V, Data center: 0 V.
- Channel 2:** Data type: Off, Data scale: 1.000, Data center: 0.
- Channel 3:** Data type: Off, Data scale: 1.000, Data center: 0.

A small box with the number 5676 is located in the bottom right corner of the interface.

5.4.2 Parameters on the Force Calibrate Main Controls Panel

Use these panels to view the force curve on the Display Monitor by manipulating various parameters found on the Control Monitor. In the **View** menu, select **Force Mode** and the subcommand **Calibrate** to access the **Main Controls** panel and specified **Channel** panels. For *advanced Force Calibrate* parameters, see [Section 5.5](#).

Ramp size

Specifies the range of the **Ramp channel**. Visible only if the **Ramp channel** parameter is set to **Z**. Settings depend on the specified units.

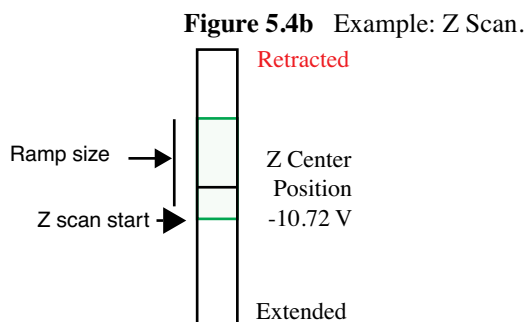
Ramp offset—Obsolete

Z scan start

Visible only if the **Ramp channel** parameter is set to **Z**.

Z scan start is the bottom position of the Z-axis scan as represented on the Display Monitor's bar graph (See [Figure 5.4b](#)). When the Force Calibrate command is first accessed during imaging, this value is automatically set to the **Z Center Position**. When returning to **Image** mode from the **Force Calibrate** command, the Z position value is initially set to this value. Z scan start is constrained such that Z scan start minus Z Scan size is greater than -220 Volts.

Note: The value of this parameter will need to be increased to move the sample closer to the cantilever in the case where there is no deflection of the cantilever for a displacement of the sample.



Range and Settings:

- **-220** through **220 V**. The units of this parameter are volts or nanometers, depending on the setting of the Units parameter.

Note: While the user is ramping Z in **Force Calibrate**, the feedback parameters (i.e., type, count and value) are inactive.

Scan rate

The rate at which the piezo extends and retracts in the Z direction (full cycle).

Note: The units for this value vary depending on the **Ramp channel** value. Very slow **Scan rates** (< 0.10 Hz) may prove too slow; the system completes the present scan before initiating parameter changes. For advanced users, this value also varies depending upon the **Forward** and **Reverse Velocities** (See [Section 5.5.1](#)).

Range or Settings:

- Min. **0.010**; maximum value depends upon **Number of samples**.

Note: Ramping under NT is limited to approximately 30 Hz at 512 samples per line.

Number of samples

Number of data points collected during each upward (retraction) and downward (extension) travel cycle of the piezo. The Number of samples parameter sets the pixel density of the force curve. This parameter does not change the Z scan size.

Range or Settings

- 4—512 data points displayed per extension and retraction cycle.

Units

Switches parameters in the control panels between units of Volts (V) or Metric units (nm or μm). Changing this parameter also changes the setting of the **Units** parameter on the AFM control panel.

Range or Settings: **Volts** (V) or **Metric** (nm)

Deflection [Amplitude] setpoint

Defines the deflection or amplitude signal, and therefore the tip-sample force, maintained by the feedback loop.

Range or Settings:

- ± 10.0 V maximum, depending upon **Deflection** or **Amplitude limit**.

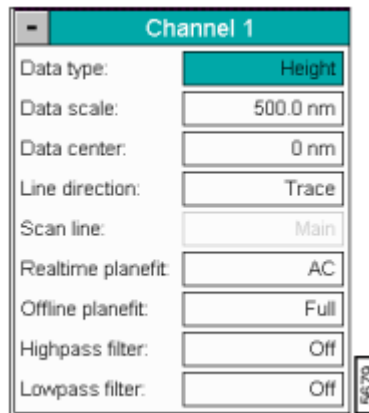
Hints for Optimizing the Deflection [Amplitude] Setpoint

- The setpoint parameter is the same as the setpoint voltage parameter on the Real-time **Feedback Control** panel. Therefore, changing the value in one place will change it in the other.
- Increasing this parameter by 1 volt has the effect of *lowering* the entire force curve by 1 volt.
- Exiting the program (DI system menu) from Force Calibration mode withdraws the tip automatically.

5.4.3 Channel Panels and Force Mode

The **Channel 1,2,3** appear on the Control Monitor in **Force Calibrate** and advanced **Force Mode** (See [Figure 5.4c](#)). For details on all of the **Channel** parameters, see [Chapter 3](#).

Figure 5.4c Control Panel—Channel 1, 2, 3



5.4.4 Channel Parameters Affecting Force Mode

The parameters in each **Channel** panel affecting **Force Calibrate** and advanced **Force Mode** is as follows:

Data type

Channels may be assigned to any input signal available including: Deflection, Amplitude, Phase, Friction, Aux A, B or C data. The Channel 3 panel displays Aux A, B or C data only. Any channel may be switched to Off, however, *at least one channel* is always on.

Data scale

Voltage range to be scaled along the vertical axis of the force curve plot.

Data center

Offsets centerline of scan by the amount entered.

Note: The Data center offset does *not* become a permanent part of the data.

Range or Settings:

- Depends upon the input signal, generally \pm one-half of **data scale** maximum.

5.4.5 Force Calibrate Control Monitor Menu Items

Along with panels, a menu bar and icon toolbar (i.e., different than the **Image Mode**) appear after selecting the **Calibrate** command (See [Figure 5.4d](#)).

Figure 5.4d Force Calibrate Menu Bar and Toolbar



Motor

The **Motor** menu controls the tip movement.

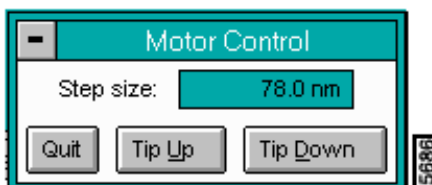
ATTENTION: Use of **Step Motor** panel is *not* recommended while the surface is engaged—the tip and/or sample surface may be damaged.



The **Motor** menu commands include:

- **Withdraw**—Retracts the tip from moving toward the surface.
- **Step Motor**—Accesses a **Motor Control** panel and allows large, motorized movements of the tip to the surface (See [Figure 5.4e](#)).

Figure 5.4e Motor Control Panel



Parameters on the Motor Control Panel

- **STEP SIZE**—Distance to move the tip.
- **TIP UP**—Executes tip move up (away from sample surface).
- **TIP DOWN**—Executes tip move down (i.e., toward sample surface).
- **QUIT**—Exits the Motor Control dialog box and returns user to the **Force Calibrate** or **Force Step** screen.

View Menu

The **View** menu contains the **Image Mode** command and returns the user to the Real-time / **Image Mode** screen. **Image Mode** may also be accessed by clicking on its icon.



Capture Menu

Stores the **Force Calibrate** or **Force Step** curve in the Capture directory. The Capture command is included among the **Force Calibrate** and **Force Step** commands to record the resulting force curve.



- **Capture**—Allows for saving the Force Curve in a directory.
- **Abort**—Exits the Capture command.
- **Continuous**—Saves multiple files of the Force Curve in a directory.
- **Capture File Name**—Designates the file name where the image is to be stored.



Probe

The **Probe** menu contains various tip control commands, including:

- **Run Continuous**—The tip is continuously lowered and raised by a distance equal to the Z scan size. This is the normal, default motion during **Force Calibrate**. “Raising” and “lowering” are relative to your system (e.g., On Dimension Series SPMs, the tip is raised and lowered to the surface; however, other SPMs raise and lower the sample beneath the tip).
- **Run Single**—Lowers and raises tip *once* by a distance equal to the Z scan size, then halts.
- **Stop**—Halts all tip movement.



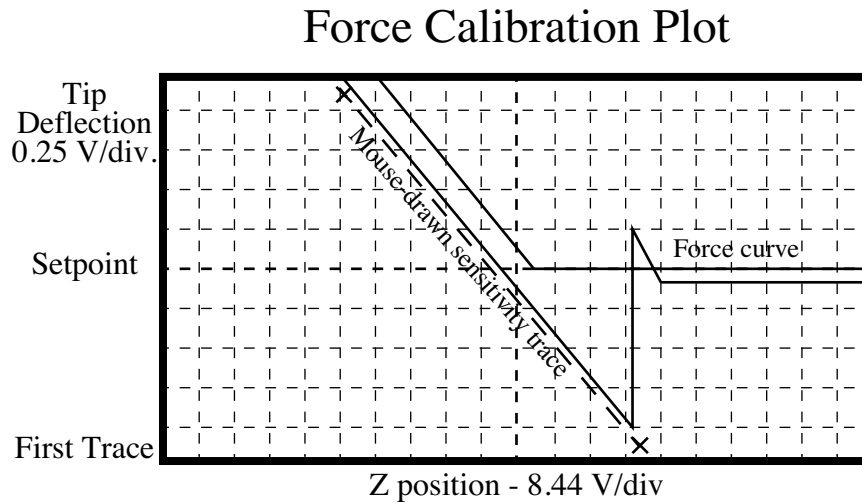
Note: View additional menu subcommands by accessing the advanced **Force Mode** command (See [Section 5.5](#)).

5.4.6 Force Calibrate Display Monitor

After selecting the **Force Calibrate** command, the Display Monitor shows a **Force Calibrate** plot. The plot is an oscilloscope-like display of the cantilever-deflection signal plotted against the Z-axis piezo voltage (sample height).

[Figure 5.4f](#) illustrates a **Force Calibration** using the mouse to set the **Sensitivity** value.

Figure 5.4f Illustration of a Force Calibration Plot.



Procedures to Set the Sensitivity Value in the Force Plot

Use the mouse to set the **Sensitivity** parameter in the **Force Calibrate** control panel by tracing a line on the sloped portion of the force curve (See Figure 5.4f). Use the **Sensitivity** value to calculate the deflection of the cantilever in nanometers.

Note: To ensure accuracy, the **Sensitivity** should be recalculated every time the laser spot position or the photodiode position is changed.

Procedures to Define the Sensitivity

Complete the following steps to define the **Sensitivity** of the cantilever deflection voltage due to the change in the piezo position:

Note: The **Sensitivity** must be defined before the **Metric** version of **Deflection** type data is available and accurate.

1. Position the cursor on the curve near the top of the sloped portion of the force curve.
2. Click on the left button to lock the cursor position. A line segment expands from this position.
3. Fit the line segment to the sloped portion of the curve. Remember that the slope of the curve is the only concern.
4. Click on the left button to define the bottom end of the line segment. The slope of the line will be calculated and automatically entered as the **Sensitivity** parameter in the Force Calibrate control panel.
5. An additional click of the left button within the limits of the graph will remove the line from the screen allowing the calibration operation to be repeated.

Procedures to Graph a Contact AFM Force Curve

This exercise demonstrates how to graph a contact AFM force curve using the **View / Force Calibration** function.

1. Prepare a Probe and Load the Calibration Standard

Samples may consist of the silicon calibration standard supplied with the microscope or a sample of some other choosing.

2. Engage the Surface

Follow the procedures to engage for contact AFM. If an experienced user is available, consult them for assistance.

3. Transfer to the **Force Calibration** Screen (Real-time/**View/Force Mode/Calibrate**)

At this point, the surface of the sample should be engaged in contact AFM; a good image of the surface should display on the monitor. Next, complete the following:

4. Align the Graph Window

To align the graph window with the active part of curve, it is necessary to make adjustments to three parameters shown on the **Force Calibration** screen:

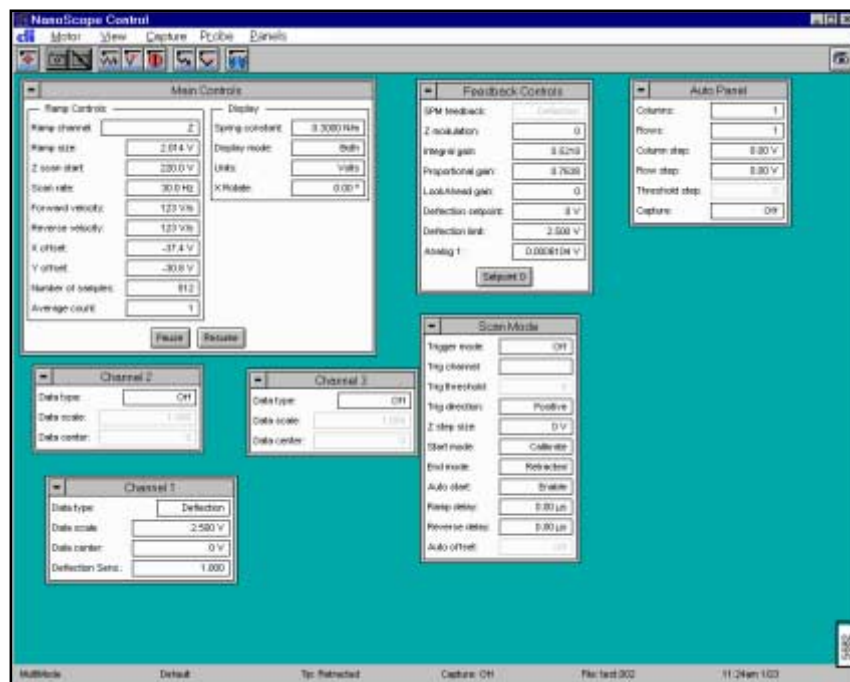
- **Z scan start**—Positions the graph horizontally on the force curve.
- **Graph range**—Scales the vertical axis of the graph to show more or less of the force curve.
- **Setpoint**—Positions the graph vertically on the force curve by setting the horizontal center line at the setpoint value indicated.

5.5 Force Mode / Advanced

Additional panels and parameters are available in the **Force Mode /Advanced** subcommand. Due to improvements in the software, it is now possible to select which output channel/signal to ramp or sweep (e.g., **Force Calibrate** ramps **Z**). The ramp channel is determined by the **Ramp Channel** parameter in the **Main Controls** panel.

After selecting the **Advanced** subcommand, a screen appears with a menu bar, toolbar, several additional parameters and a status bar (See [Figure 5.5a](#)).

Figure 5.5a Advanced Force Calibrate Screen



5.5.1 Main Controls Panel Parameters

Advanced parameters in the Main Controls panel allow for further detail in optimizing the Force Curve. See [Section 5.4.2](#) for details on the *basic* **Force Calibrate** parameters.

The *advanced* **Force Calibrate** parameters are as follows:

Ramp channel

Defines the variable to be plotted along the X-axis of the Scope Trace.

Range or Settings:

- **Z**—Plots Z
- **Analog 1**—Any analog channel. Units will vary depending on the channel output.

Bias—Appears only in STM mode.

Velocity, Forward or Reverse

For advanced users *only*; must be enabled from the di/Show all items selection. Forward and Reverse Velocity control the velocity of the piezo toward and away from the sample. These values vary depend upon the Ramp Channel and Scan Rate values. Velocities may be set at different values, however, changing the Scan Rate changes the velocities in the ratio of difference between the values. Changing the velocities adjusts the Scan Rate value.

X offset, Y offset

X, Y offset controls the center position of the scan in the X and Y directions, respectively.

Range or Settings:

- **±220 Volts; ± XX Microns** (head-dependent)

Average count

Number of force calibration curves averaged to plot the displayed and captured curve.

Spring constant

Records the spring constant of the indentation cantilever that is currently being used. This parameter is input by the user and is recorded along with each force plot captured. It is used for Off-line analysis of the force plot only. It is not critical to set the **Spring constant**, since it can be altered in the Off-line analysis of the captured force plot. Also, use the Spring constant to display a graph of force vs. separation when conducting Off-line analysis of the force plot.

Display mode

The portion of a tip's vertical motion to be plotted on the force graph.

Range or Settings:

- **Extend**—Plots only the extension portion of the tip's vertical travel.

- **Retract**—Plots only the retraction portion of the tip's vertical travel.
- **Both**—Plots both the extension and retraction portions of the tip's vertical travel.
- If a channel other than Z is chosen and the force curve is captured Off-line, **Display mode** will not be available in Off-line view.

X-rotate

X-rotate allows the user to move the tip laterally, in the X direction, during indentation. This is useful since the cantilever is at an angle relative to the surface. One purpose of X Rotate is to prevent the cantilever from plowing the surface laterally, typically along the X direction, while it indents in the sample surface in the Z direction. Plowing can occur due to cantilever bending during indentation or due to X movement caused by coupling of the Z and X axes of the piezo scanner. When indenting in the Z direction, the X Rotate parameter allows the user to add movement to scanner in the X direction. X Rotate causes movement of the scanner opposite to the direction in which the cantilever points. Without X Rotate control, the tip may be prone to pitch forward during indentation. Normally, it is set to about 22.0 degrees.

Range or Settings:

- **0 to 90 degrees**; most effective values are between **15** and **25 degrees**

Feedback type

The **Feedback type** option specifies the feedback site.

Range or Settings:

- **None**—No feedback taking place when ramping
- **Pixel**—Feedback done after every pixel encountered during the ramp (of the force curve)
- **Ramp**—Feedback takes place at the top and bottom of the ramp
- **Cycle**—One feedback takes place at the starting point after one complete cycle

Feedback counts

The **Feedback counts** option specifies the number of feedbacks to be reported at each feedback site. When **Feedback type** is set to **Ramp**, and **Feedback counts** is set to 3, then three counts are performed at each stop during the ramp cycle (i.e., A total of six).

Feedback value

The **Feedback value** is useful only in scanning tunneling microscopy (STM) and allows adjustment of the feedback value to a different **bias** than is being used in **Image Mode**.

Note: While the user is ramping Z in Force mode, the feedback parameters (i.e., type, count and value) are inactive.

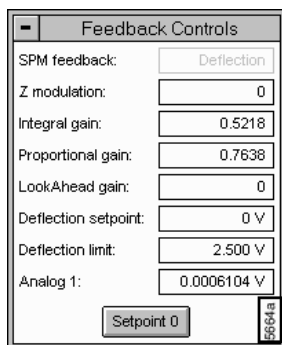
For further details on the basic **Force Calibrate** parameters, see [Section 5.4.2](#).

5.5.2 Feedback Controls Panel in Force Mode

Many parameters on the **Feedback Controls** panel are identical to those used on the Real-time / **Feedback Controls** panel. Several **Feedback Controls** parameters affect the quality of a force curve. Only parameters requiring further explanation are included in this section. For complete details on the **Feedback Controls** panel, see [Chapter 3](#).

In advanced **Force Mode** (Real-time/View/Force Mode/Advanced), the **Feedback Controls** panel appears on the Control Monitor (See [Figure 5.5b](#)).

Figure 5.5b Control Panel—Feedback Controls



5.5.3 Feedback Controls Parameters in Force Mode

For details on all of the **Feedback Controls** parameters, see [Section 3.3](#).

Integral Gain—Controls the amount of integrated error signal used in the feedback calculation.

Range or Settings for Force Mode:

- 1.0–8.0

Proportional gain—Controls the amount of the proportional error signal used in the feedback calculation. The Proportional gain term in the feedback calculation has equal gain at all frequencies; therefore, it has a dominating effect over the Integral gain for high frequencies.

Range or Settings:

- Typically, settings are 35 to 100 percent more than **Integral gain** values.

Amplitude [Deflection] limit

Available on MultiMode and Dimension SPMs. Sets the input range of the photodetector signal. (Previously called Input Atten.) If set to 2.5, the **Amplitude [Deflection] limit** parameter gives less range but better resolution. In general, use 20 V for silicon nitride tips and 2.5 for crystal silicon tips.

Analog 1, 2, 3, 4

(STM and standard contact AFM only)—Outputs a selectable voltage to the microscope (see line labeled ANA1 in the “Controller-Interface Signals” matrix in Appendix B of the Control System User's Manual). This voltage has no effect on the operation of the standard microscope, but is useful in custom applications.

Range or Settings:

- **-10.00 through 10.00 Volts**

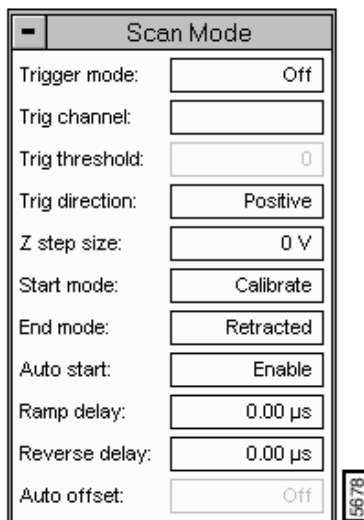
Setpoint 0 (button)

Sets the setpoint to zero (i.e., in Contact mode the deflection off the surface is no force, or 0).

5.5.4 Scan Mode Panel in Force Mode

The **Scan Mode** panel appears along with other **Advanced** panels to configure the **Force** plot (See [Figure 5.5c](#)).

Figure 5.5c Control Panel—Scan Mode



5.5.5 Parameters in the Scan Mode Panel

Trigger mode

Limits the amount of force exerted by the tip upon the sample. It is possible to operate the trigger independent of drift (Relative) or at some arbitrarily fixed point (Absolute) depending on the trigger settings.

Trig channel

Specifies on which data channel that **Trig threshold** will trigger. **Trig channel** varies depending on the selected **Ramp channel**, microscope type and mode.

Note: If a channel other than Z is chosen and the force curve is captured Off-line, **Display mode** will not be available in Off-line view.

Trig threshold

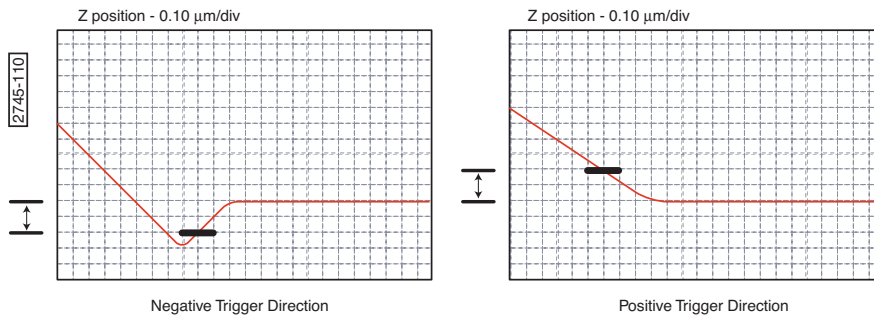
The value of the cantilever deflection, as measured by the photodetector, desired for the indentation or scratch. The **Trigger threshold** defines the maximum force applied to the sample corresponding to the upper leftmost point on the force plot.

Range or Settings:

- **0 V to 1.250 V**, but the recommended starting value depends on the **Deflection Limit**. Try 0.5 V to 1.0 V. The value may also be negative, depending on the desired deflection.

Trig direction

Determines the direction of the trigger and allows for a Positive, Negative, or Absolute trigger slope. In this way, the trigger may be configured to activate on either the positive or negative direction of the force curve.



Start mode

Start mode allows the user to switch between the various force modes without returning to image mode.

Range or Settings:

- **Indent**—The normal start mode to use for nanoindentation. This uses TappingMode to find the surface.
- **Scratch**—The normal start mode to use for nanoscratching. This uses TappingMode to find the surface.
- **Calibrate**—Produces standard Force Mode force plots. Includes the ability to continuously cycle the tip up and down.
- **Step**—Produces standard **Force Mode** force plots, with added control to step the tip towards the surface.

End mode

Determines the location of the tip when the microscope is returned to Image mode. Choices include Extended, Retracted, or Surface.

Auto start

When Enabled, autostarts **Force mode** when entering from **Image mode**. If off, user must start ramping by clicking the Continuous or Single icon, or by selecting the proper menu selection under the **Probe** pull-down menu.

Ramp delay

Specifies a delay when the tip reaches the trigger threshold or ramp end

Range or Settings:

- 0 to 250 seconds

Reverse delay

Similar to **Ramp delay**, this value specifies the duration of the delay when the piezo is at the top of the cycle (farthest away from the sample).

Range or Settings:

- 0 to 250 seconds

Auto offset

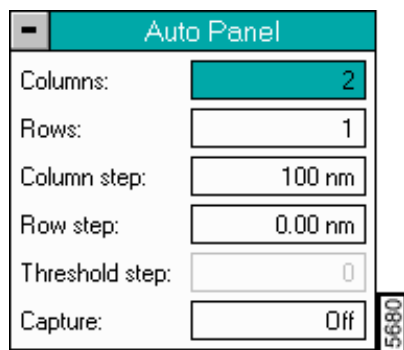
Because of Z drift (thermal drift, piezo drift, etc.), the sample will sometimes drift out of Z range. When Enabled, Auto offset uses the feedback value from Image mode to find the surface and resume Force imaging. The Auto offset feature is a form of drift correction.

5.5.6 Auto Panel in Force Mode

The **Auto Panel** allows you to define a matrix of sample points for Force Cal., STS Plot i(v), and STS Plot i(s). The Rows and Columns define the number of data acquisition points. Rows are points in the X axis, and Columns are points in the Y axis.

The **Auto Panel** appears in the Control Monitor for advanced **Force Mode** (See [Figure 5.5d](#)).

Figure 5.5d Control Panel—Auto Panel



5.5.7 Parameters in the Auto Panel

Columns—Points in the Y axis.

Rows—Points in the X axis.

Column step—Offset distance between points in the X plane.

Row step—Offset distance between points in the Y plane.

Threshold step

The trigger point at which the deflection or the current activates the position change. In STS mode, the Threshold step is measured in current.

Capture

State is either Enabled or Disabled. When Enabled, the software records and stores the data for each data point in the matrix of rows and columns.

5.5.8 Control Monitor Menu Bar and Toolbar

In addition to the advanced **Force Calibrate (Force Mode/Advanced)** parameters, new menu bar subcommands and icons appears for optimizing the **Force Calibrate** command (See [Figure 5.5d](#)).

Figure 5.5e Advanced Force Calibrate Menu Bar and Toolbar



For details on the basic **Force Calibrate** menu items and icons, see [Figure 5.4.5](#). The following additional menu items and icons appear for the advanced **Force Calibrate** command:

Probe

- **Retract**—The Z-axis piezo retracts to its limit in preparation for Approach Continuous. This command does *not* initiate motor movements.
- **Approach Continuous**—The tip lowers to the surface and raises in a controlled series of steps, then indexed by the Z step size (see Scan Mode panel) distance. This process continues downward until the tip encounters the surface. When tip deflection exceeds



the **Threshold Step** amount, **Approach Continuous** halts and the resulting force curve displays.

- **Approach Single**—The tip is lowered to the surface and raised in a single, controlled step. This process is halted if the surface is encountered by the tip, causing deflection exceeding the Step threshold amount. The resulting force curve is displayed.
- **Auto Ramp**—Begins auto ramping as defined by the parameters specified in the **Auto Panel** (See [Figure 5.5d](#))



Panels

- Ramp—Accesses the Ramp Channel parameter in the Main Controls panel.
- Feedback—Accesses the Feedback Controls panel.
- Mode—Accesses the Scan Mode panel.
- Auto—Accesses the Auto Mode panel.
- Channel (1,2,3)—Accesses up to three Channel panels.

5.6 Force Step

The **Force Step** command halts the X-Y scan and allows the user to extend the Z piezo in a highly controlled manner. It brings the tip and sample into contact one or more times, then plots either the resulting deflection of the cantilever (contact AFM) or the amplitude of the cantilever oscillation (TappingMode) as a function of sample displacement.

Force Calibrate and **Force Step** commands are similar; however, they differ slightly in the type of tip-sample interaction allowed. The main difference being that in **Force Step** the tip is carefully “stepped” down to the sample surface rather than continuously oscillated. Generally, use **Force Calibrate** to observe multiple tip-sample interactions (i.e., with the Z-axis piezo repeatedly oscillating up and down).

All commands detailed in the [Section 5.4](#) apply to **Force Step**.

Note: After selecting the **Force Step** command, the tip and sample are initially fully separated (i.e., the Z-axis piezo is fully retracted).



5.7 Force Volume

Force Volume imaging with the atomic force microscope (AFM), combines force measurement and topographic imaging capabilities. A **Force Volume** data set can be used to map in two or three dimensions the interaction forces between a sample and the AFM tip and correlate the force data with topographic information.

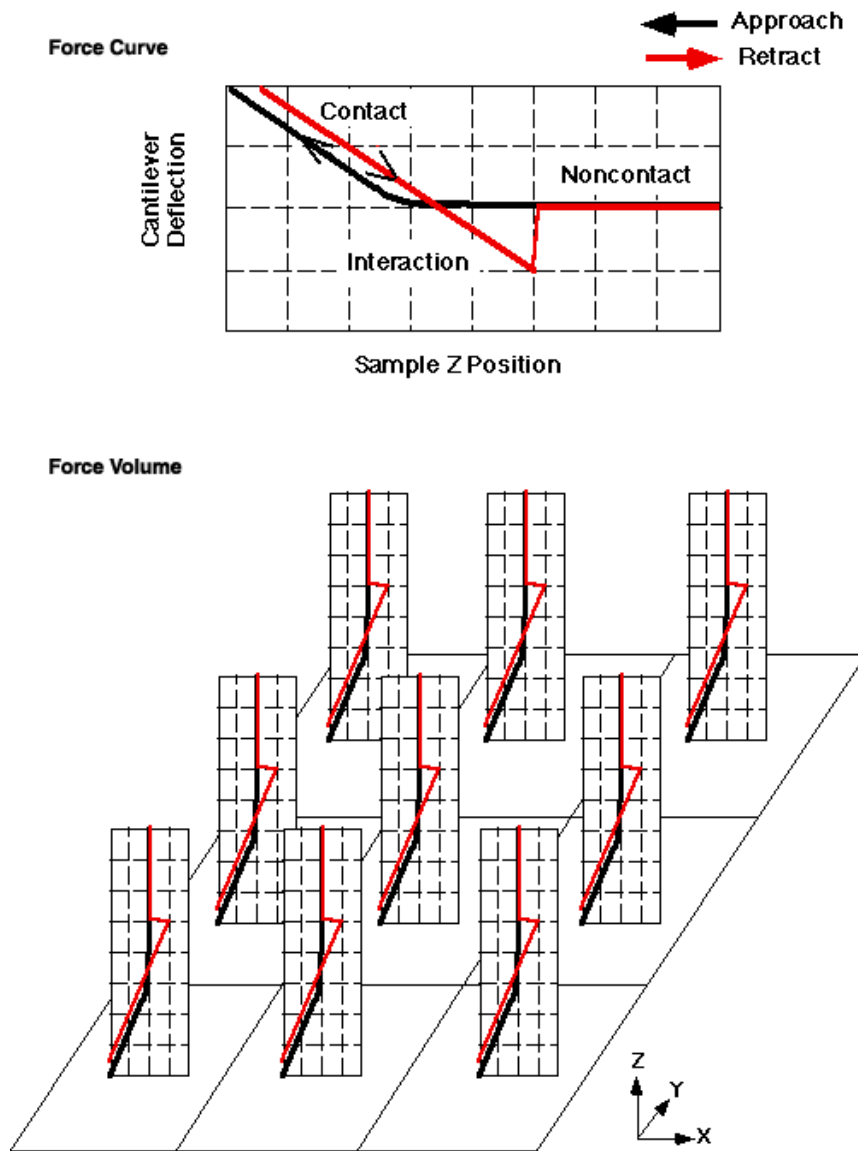
Advantages of **Force Volume** imaging include the ability to collect distributions of forces at various Z-positions and at thousands of X-Y positions during a single image scan, correlation of surface topography to interaction force, better quantization of the interaction force, and new methods of analysis.

A single **Force Curve** records the force felt by the tip as it approaches and retracts from a *point* on the sample surface. A **Force Volume** image contains a topographic image of an *area* of a sample and an *array* of force curves over the same area. Each force curve is measured at a unique X-Y position in the area, and force curves from an array of X-Y points are combined into a three-dimensional array of force data (hence the term volume).

The value at a point (X,Y,Z) in the volume is the deflection (force) of the cantilever at that position in space. Typical AFM images depict the topography of a surface by measuring the response of a feedback loop to changes in the tip-sample interactions as the tip is scanned across the surface.

The **Force Volume** data set combines simultaneously measured topographic information (a constant force map of the surface) and force information into a single data set allowing to test for correlations between forces and surface features (See [Figure 5.7a](#)).

Figure 5.7a Standard Force Curve and Force Volume Display



Note: The XYZ arrows in the graph are an addition and are not visible on screen.

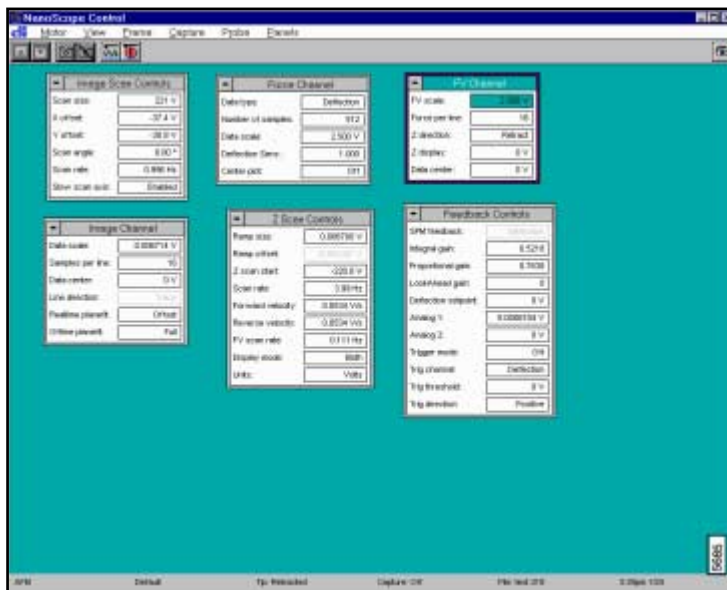
A **Force Volume** data set or an array of regularly spaced force curves yields three-dimensional force information. All the force curves are identical in the figure to simplify the diagram.

Note: In a **Force Volume** data set, the force curves will vary with XY position.

5.7.1 Force Volume Control Monitor

After selecting the **Force Volume** command a screen appears on the Control Monitor to allow for configuration of the data (See [Figure 5.7b](#)).

Figure 5.7b Force Volume Panels



5.7.2 Force Volume Control Monitor Menu Items

Motor—Withdraws or accesses the **Motor Step** panel. For details on the **Motor** menu, see [Section 5.4.5](#).

View—Toggles the screen to **Image Mode**.

Frame—Commands include: **Up**, **Down**, **Reverse** and **Line** to adjust the imaging direction in the display frame.

Capture

Commands include: **Capture**, **Abort**, **Auto Scan**, **Capture Plane**, **Capture Calibrate**, **Capture Withdraw**, **Capture Filename**. For details on the commands, see “[Image Mode Menu Commands](#)”.

Probe—Commands include: **Start** and **Stop**. Controls the tip movement.

Panels—Accesses panels on the Control Monitor

- **Scan**—Accesses the Image Scan panel similar to the main Scan Controls panel.
- **Main**—Accesses the Z Scan Controls panel similar to the Main Controls panel in Force Calibrate.
- **Feedback**—Accesses the Feedback Controls panel.
- **Channels**—Accesses three types of Channel panels: Image, Force Plot and FV Image channels. Each configures specific windows seen on the Display Monitor.

Hints to Optimize the Force Volume Parameters

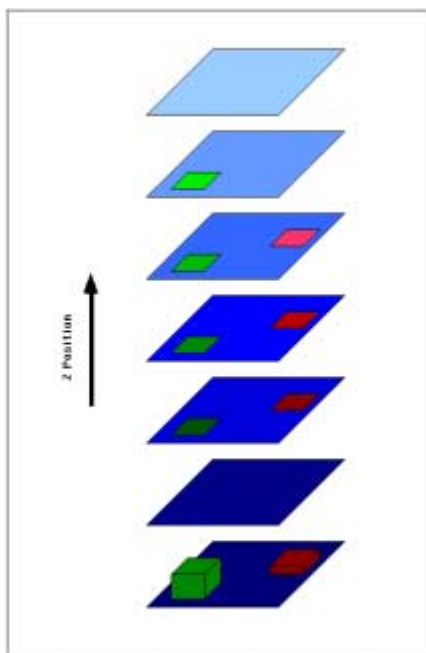
- The **Z display** parameter in the **FV Channel** panel chooses the slice of the volume displayed in the **FV Image** window. Changing this parameter during the collection of an image will allow the user to view different slices through the volume. Only the lines scanned after changing **Z display** correspond to the new slice. Lines scanned before the change correspond to the previous slice.
- Adjusting the **Volume scale** and **Volume Offset** parameters in the **FV Channel** panel allow the user to zoom in on certain force features in the **Force Volume** image. Setting these parameters in such a way as to mask all but the range of forces of interest may be helpful.
- The **Height image** adjusts the scale through the **Z range** parameter in the **Image Controls** panel. Also, the **Z direction** parameter determines whether the microscope collects the Trace or the Retrace of the scan line.
- As a rule, it is best to set the above parameters to values that allow for clear and unambiguous identification of the topographic and force features of the sample during the scan.

5.7.3 Force Volume Display Monitor

The Display Monitor includes three main parts: an image window displaying the **Height Image**, a **FV Image** window, and a **Force Curve** plot.

The windows interact to allow the user to inspect each slice in the volume (See [Figure 5.7c](#)).

Figure 5.7c Schematic of **Force Volume** Data Set



General Procedures to Display a Force Volume Slice

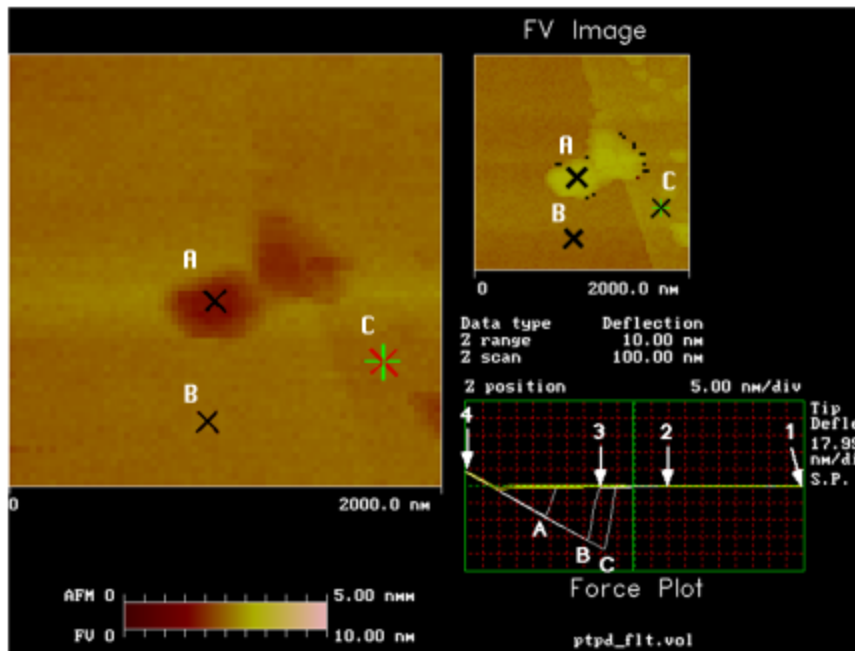
To display a **Force Volume** slice at a particular Z position complete the following:

1. Click the left mouse button on the Z position in the force plots window.

Note: The Z display parameter in the Graph dialog box contains the present Z position (the Z value of the slice, also a vertical green line in the force plots window).

2. Drag the mouse in the force plots window while holding down the left button to select consecutive slices (See [Figure 5.7d](#)).

Figure 5.7d Force Volume Display



Note: Multiple force curves, measured at points A, B, and C in the height image, display simultaneously Off-line. Also, individual curves can display.

Presently, the only way to save images of slices for later use is through the **Utility** menu. This will save (or export) an image of the Display Monitor to a directory. The images can then be modified in third party graphics software (IDL, NIH image, Canvas, etc.).

For further details on the Off-line **Utility** menu, see [Chapter 16](#).

5.8 Sweep



5.8.1 Cantilever Tune

The **Cantilever Tune** command allows determination of the cantilever resonant frequency and the setting of the operating point for TappingMode feedback. In addition, it is possible to determine the spring constant of a Contact Mode cantilever quickly and easily. **Cantilever Tune** sweeps the cantilever drive frequency over a selectable range, then displays a plot of the cantilever amplitude versus drive frequency on the Display Monitor. This command is enabled *only* when the **AFM mode** parameter on the **Other Controls** panel is set to **Tapping**. On Small Sample MultiMode SPMs, verify that the switch located on the base is toggled to **TM AFM** before selecting the **Cantilever Tune** command.

Note: The sweep channel is determined in the **Channel 1**, **Channel 2**, or **Channel 3** control panels.

Figure 5.8a Tapping Cantilever in Mid-air.

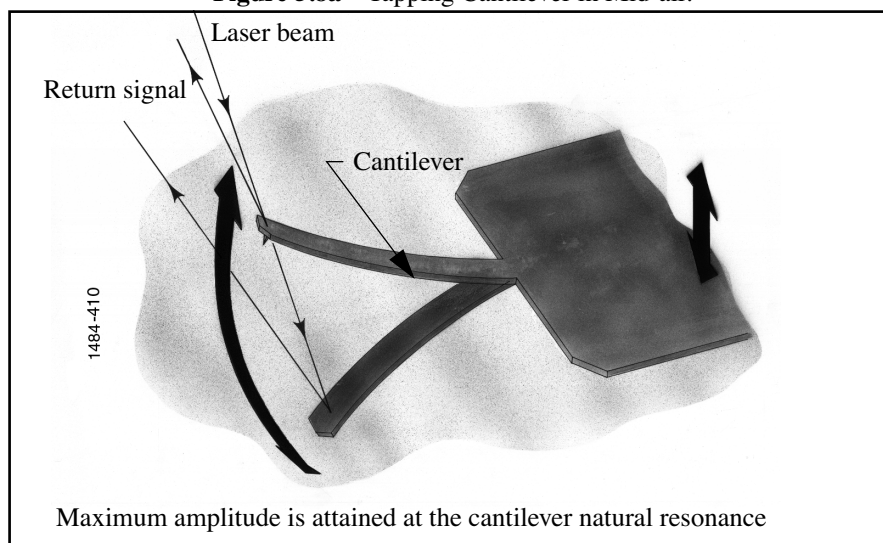
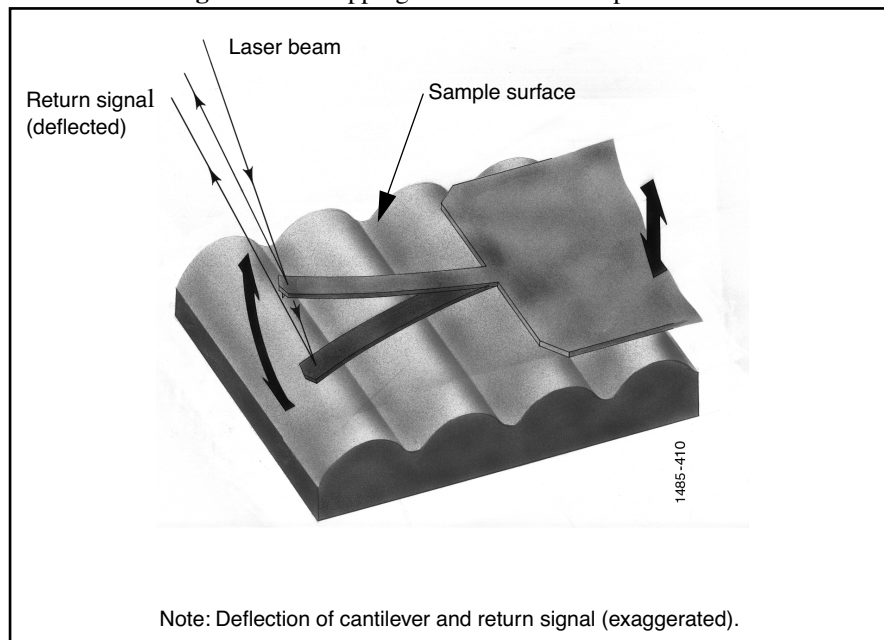


Figure 5.8b Tapping Cantilever on Sample Surface

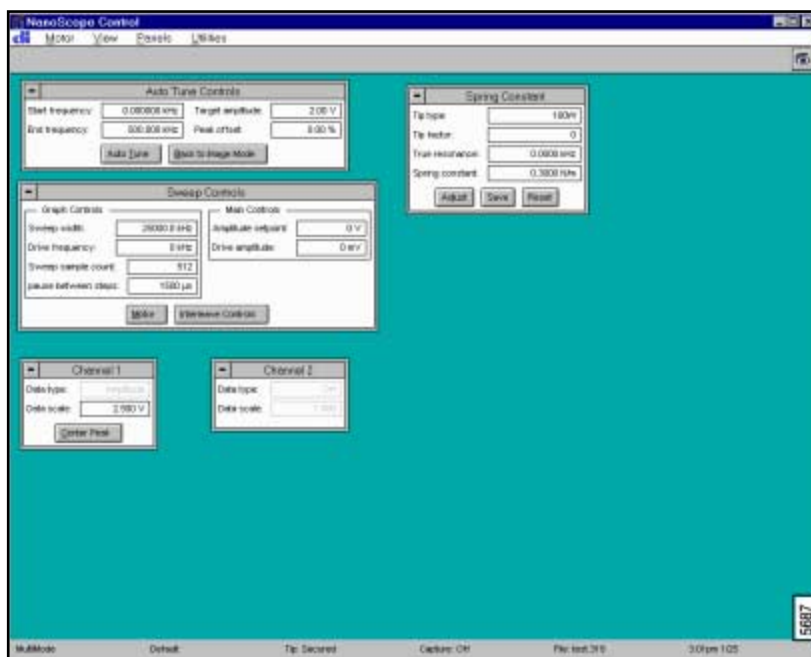


MultiMode and Dimension Series microscopes rely on an optical lever technique to map sample topography. In TappingMode, the optical lever technique reflects a laser beam off the back of the oscillating cantilever, thence to a segmented photodiode. The differential signal between the top and bottom photodiode segments provides a sensitive measure of cantilever deflection. As the sample is scanned, analog circuitry determines the RMS value of the rapidly changing cantilever deflection signal. The RMS value of the cantilever deflection signal corresponds to the amplitude of the cantilever oscillation. Changes in amplitude of the cantilever oscillation is controlled by the feedback system to track the sample surface.

5.8.2 Cantilever Tune Control Monitor

Clicking on **Panels /Auto Tune** displays the **Auto Tune Controls** screen. Along with the menu bar and status bar, up to three control panels and two channel panels appear (See [Figure 5.8c](#)).

Figure 5.8c Cantilever Tune Controls Screen



5.8.3 Panels in the Cantilever Tune Screen

To tune the cantilever at its natural resonance, click on the **Auto Tune** icon on the toolbar prior to selecting the **Cantilever Tune** command. Otherwise, select the **Cantilever Tune** command to access screens that allow for configuring parameters to tune the cantilever. The **Cantilever Tune** control panels include:

- **Auto Tune Controls**—See [Section 5.8.4](#)
- **Sweep Controls**—See [Section 5.8.5](#)
- **Spring Constant**—See [Section 5.8.6](#)

5.8.4 Auto Tune Controls Panel

The **Auto Tune** command simplifies the TappingMode tuning procedure. This command initiates a user-defined frequency sweep, then automatically determines the cantilever natural, resonant frequency and sets the **Drive frequency** to that value.

Parameters in the Auto Tune Controls Panel

Start frequency—Starting point of the Auto Tune frequency sweep.

End frequency—Ending point of the Auto Tune frequency sweep.

Target amplitude—Targeted output signal amplitude *at the photodiode detector*. This value should *not* be confused with Drive amplitude, which is the amplitude applied directly to the cantilever itself (see Drive amplitude).

Range and Settings:

- 0.00—5.00 V
- Dimension Series SPMs, nominal = **2.00 V**
- Small Sample MultiMode SPMs, nominal = **3.00 V**

Peak offset—Percentage of cantilever’s free-air resonant frequency to be automatically offset. Peak offset is used to compensate for changes in resonance before engagement due to the tip’s interaction with the surface after engagement.

Range and Settings: **0—50** percent; typical value = **1—2** percent.

Note: Positive values offset the **Drive frequency** rightward on the graph.

Minimum Q—Q is the value defined by the amount of oscillation it takes for a wave to drop to $1/e$ of its amplitude value (i.e. a wave with an amplitude of ten would have a Q of $10/e$, or 3.6788). Minimum Q establishes a minimum “width of peak” value allowed by the AutoTune function. Peaks not meeting the Minimum Q may be ignored by setting the Smash Q factor.

Smash Q factor—The width of the area beneath the wave “smashed” (set to zero) when a peak not meeting the Minimum Q requirement is found.

Buttons on the Auto Tune Control Panel

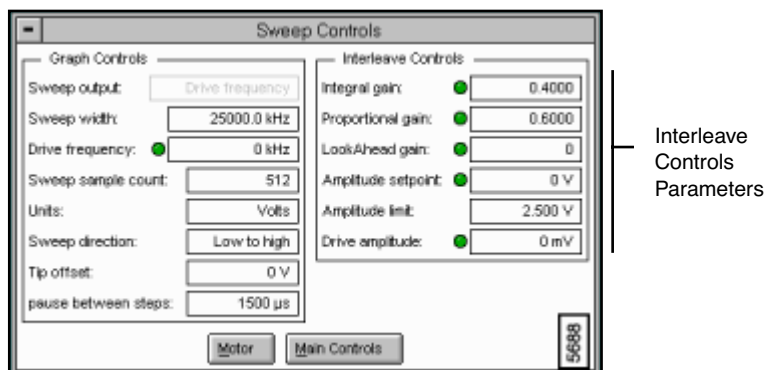
AUTO TUNE—Executes the automatic tuning procedure: the cantilever is excited through a range of frequencies beginning at the Start frequency and ending at the End frequency. A plot of the cantilever’s response curve is shown on the Display Monitor.

BACK TO IMAGE MODE—Returns the software to image mode.

5.8.5 Sweep Controls Panel

The **Sweep Controls** panel parameters adjust the frequency values applied to the cantilever. The parameters toggle to **Interleave Controls** parameters after selecting the **INTERLEAVE CONTROLS** button (See [Figure 5.8d](#)).

Figure 5.8d Sweep Controls Panel



Parameters in the Sweep Controls Panel

Graph Controls

Sweep width—Controls the range of frequencies applied to the cantilever. This value corresponds to the width of the frequency plot.

Drive frequency—Selects the oscillation frequency applied to the piezoelectric crystal that vibrates the cantilever.

Range and Settings: 0 through 25000 kHz

Sweep sample count—Controls the number of frequencies used to generate the Frequency Sweep plot on the Display Monitor.

Main Controls

Amplitude setpoint—Defines the desired cantilever oscillation amplitude voltage to be maintained by the feedback loop. The feedback loop continually compares the setpoint to the present value of the cantilever oscillation amplitude voltage to calculate the desired vertical change in the piezo position.

Range and Settings: ± 10 Volts

Drive amplitude—Selects the amplitude of the drive voltage applied to the piezoelectric crystal vibrating the cantilever.

Range and Settings: 0 through 20000 mV

Buttons on the Sweep Controls Panel

MOTOR—Displays the **Motor Control** panel used to control tip position relative to the sample with motor movements (See [Figure 5.4e](#)).

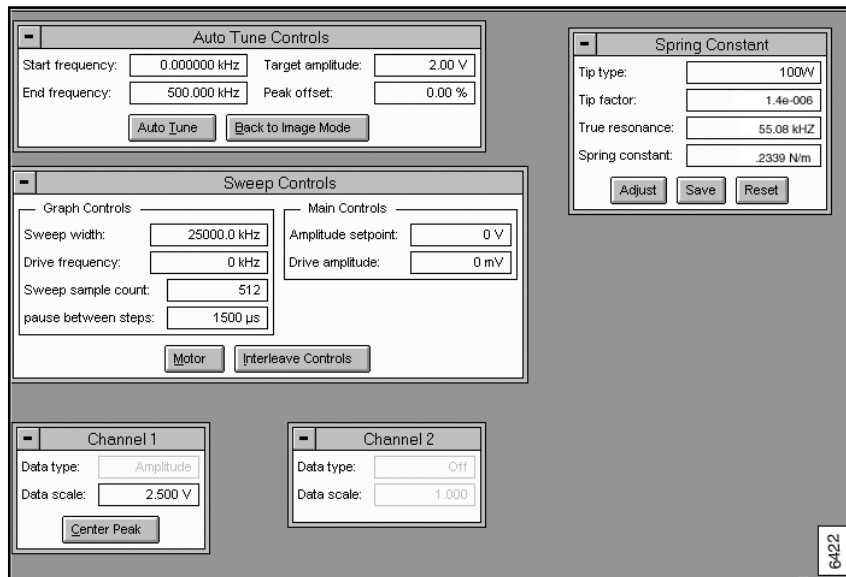
INTERLEAVE CONTROLS—Displays a duplicate set of parameters applied only to the interleaved portions of the scan (See [Figure 5.8d](#)). For further details on the **Interleave Controls** parameters, see [Section 3.5](#).

5.8.6 Spring Constant Panel

The **Spring Constant** panel is a panel in the **Cantilever Tune** screen. The parameters (**Tip factor**, **true Resonance** and **Spring Constant**) are defined by the *tip type* (e.g., 100W/100N or 200W/200N). The spring constant calculates automatically by using the equation:

$$k = \alpha_1 * f^3 \text{ (Spring Constant = Tip factor * resonant frequency)}$$

306.5g Sweep Mode Screen



Parameters in the Spring Constant Controls Panel

Tip type—The type of Contact mode tip used (e.g., 100 wide and 100 narrow).

Table 5.8a Suggested Sweep Controls Values

Tip type	Drive frequency	Sweep width
100W 100N	50	50
200W 200N	15	25

Tip factor— Value defined by the tip type; each tip has a different tip factor. Values of the coefficient for cantilever types are stored in the file `cant.ins` in the `Equip` directory.

Range and Settings: Tip type dependent

Resonant frequency— While in Sweep mode, the `ADJUST` button finds the resonant peak, measures the **Resonant frequency** value, enters this value, then recalculates the spring constant value of the cantilever.

Spring constant— Calculates automatically based on the values for Tip type, Tip factor, and Resonant frequency.

Buttons on the Spring Constant Controls Panel

ADJUST—Tunes the cantilever to the center, responsible for finding the **Resonant Frequency** and calculating the **Spring Constant** value.

SAVE—Saves the Sweep Controls values to a file.

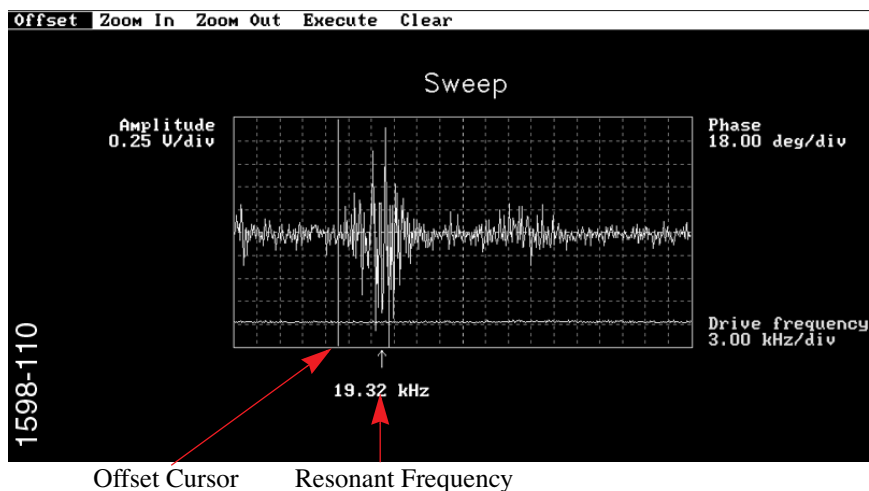
RESET—Resets the Sweep Controls values to the defaults.

5.8.8 Cantilever Tune Display Monitor

The plots shown on the Display Monitor for **Cantilever Tune** graph cantilever oscillation amplitude versus the cantilever drive frequency. This plot allows the resonance frequency of the cantilever to be determined and the operating point for the feedback loop to be set. A menu bar at the top of the monitor contains commands to help tune the drive frequency and define the operating point.

The Frequency Sweep plot does not appear after the microscope is engaged, because the frequency cannot be swept after the microscope is engaged. The following commands appear in the menu bar of the Display Monitor during the **Cantilever Tune** process:

Figure 5.8a Cantilever Tune Display



Cantilever Tune Display Menu Commands

- **Offset**—The Center frequency shifts to the position of the center vertical cursor when the command is executed. This has the effect of shifting the curve on the plot.
- **Zoom In**—The Sweep width of the graph is set to values indicated by the two yellow vertical lines when the command is executed. This command expands the plot by adjusting the Center frequency and decreasing the Sweep width. The left mouse button toggles between this command and Zoom Out. Continuing to press the left mouse button toggles between the two modes if the cursor remains in the graph area.
- **Zoom Out**—The Sweep width will increase by the ratio of the graph width and the spacing between the two yellow vertical lines when the command is executed. This command compresses the plot by adjusting the Center frequency to the center point between the cursors and increasing the Sweep width. The left mouse button toggles between this command and Zoom In. Continuing to press the left mouse button toggles between the two modes if the cursor remains in the graph area.
- **Execute**—This command initiates the previously selected command. Pressing the right mouse button moves the pointer up to this command in the command bar. Press the right button a second time (or the left button) and the previously selected command will be executed.
- **Clear**—Eliminates the cursors from the display.

Procedures To Find the Spring Constant

To find the **Spring Constant** in Contact Mode, complete the following:

1. Determine the type of cantilever being used. Standard silicon nitride Contact mode cantilever types are listed in Table 4.1.

-
2. Identify the cantilever in the **Spring Constant** control panel under **Tip type**. The **Tip factor** is a function of the cantilever type, and will appear when the cantilever type has been identified. The values are stored in the file `cant.ins` in the Equip directory.
 3. Determine the resonant frequency of the particular cantilever as follows.
 - Set the **Drive amplitude** to **0** (in the **Sweep Controls** panel)
 - Set **Sweep width** and **Drive frequency** using values defined in Table 4.1
 - Use the **Offset cursor** in the Display Monitor to center the thermal resonance noise envelope and determine the resonant frequency of the cantilever.
 4. Input the resonant frequency in the Spring Constant panel and the spring constant appears in the “Spring Constant” box. The formula used to determine an approximate spring constant is as follows: $k = \alpha_1 \times f^3$ where “k” is the spring constant, “ α ” is some coefficient stored in the NanoScope software based on **Tip type**, and “f” is the measured resonant frequency.
-

Mouse Operations

- Select the desired command (**Offset**, **Zoom In**, **Zoom Out**, **Setpoint**) by positioning the pointer on the command in the menu bar and pressing the left button of the mouse.
The command will then be highlighted (white background), and the appropriate vertical or horizontal yellow lines will appear on the graph.
- Move the mouse in the proper axis (see the particular command discussion preceding this) to obtain the desired parameter value on the graph.
- Press the right mouse button. This will cause the horizontal or vertical lines (depending upon the command) to quit moving, and the mouse pointer will jump to the **Execute** command in the command bar.
- Press the right (or left) mouse button to execute the command. The proper parameter values on the Control and Display Monitors will change to the new values.

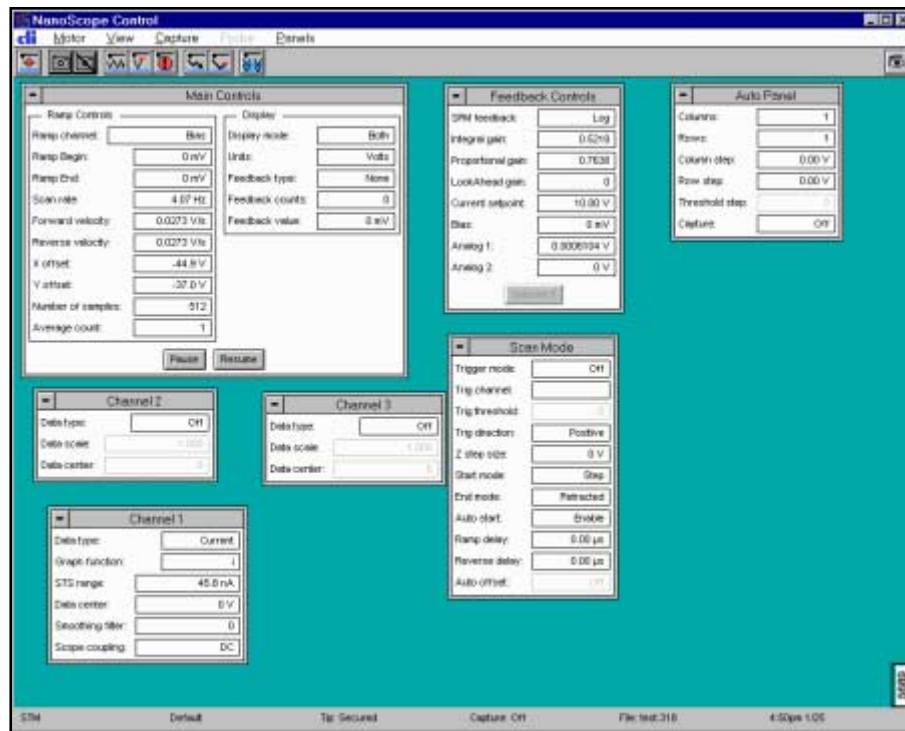
5.9 STS Plot i(v) (STM Only)

The **STS Plot i(v)** command places the STM in a spectroscopic mode. In most cases, the tip position is constant and the change in the tunneling current as a function of bias voltage is measured and plotted. However, it can also be used for BEEM (Ballistic Electron Emission Microscopy) with some additional hardware.

5.9.1 STS Plot i(v) Control Monitor

The **STS Plot i(v)** screen displays a menu bar, toolbar, up to four control panels and up to three **Channel** panels (See [Figure 5.9a](#)).

Figure 5.9a STS i(v) Plot Screen



5.9.2 STS i(v) Plot Main Controls Panel

Ramp Controls

Ramp channel—Defines the variable to be plotted along the X-axis of the Scope Trace.

Range or Settings:

Analog 1—Any analog channel. Units will vary depending on the channel output.

Bias—Appears only in STM mode.

Ramp Begin—Specifies the start of the Ramp channel scan. Units depend on the setting for Ramp channel.

Ramp End—Determines the end position of the output ramp.

Scan rate—Rate at which piezo extends in Z direction (toward surface). Note that the units for this value will vary depending on the Ramp channel value. Very slow Scan rates (< 0.10 Hz) may prove frustrating; the system completes the present scan before initiating parameter changes.

Range or Settings: min. **0.010**; maximum value depends upon **Number of samples**.

Note: Ramping under NT is limited to approximately 30 Hz at 512 samples per line.

Velocity—Forward or Reverse, units will depend on the ramp channel. Controls the velocity of the piezo.

X offset, Y offset—Controls the center position of the scan in the X and Y directions, respectively.

Range or Settings:

- **±220 Volts; ± XX Microns** (head-dependent)

Number of samples—Number of data points collected during each upward (retraction) and downward (extension) travel cycle of the piezo. The Number of samples parameter sets the pixel density of the force curve. This parameter does not change the Z scan size.

Range or Settings

- **4—60,000** data points displayed per extension and retraction cycle.

Average count—The Average count parameter in the STS Plot control panel controls how many values are averaged for each point displayed in the plot. The entire cycle repeats and the corresponding values from each cycle are averaged to reduce noise.

Range or Settings: **1 - 1024**

Hints to Optimize the Parameters in the Average count Parameter

- Increasing this parameter increases the signal-to-noise ratio by averaging out the random noise in the signal.
- Increasing this parameter also increases the total measurement time.
- This parameter defines the number of times the entire modulation cycle repeats. The cycle from **+Bias scan/2** to **-Bias scan/2** repeats **Average count** times. The corresponding data points from each scan are averaged to reduce noise.

Main Panel Display Parameters

Display mode—Portion of tip's vertical motion to be plotted on the force graph.

Range or Settings

- **Extend**—Plots only the extension portion of the tip's vertical travel.
- **Retract**—Plots only the retraction portion of the tip's vertical travel.
- **Both**—Plots both the extension and retraction portions of the tip's vertical travel.

Units—Switches parameters in control panels between units of Volts or Metric units (nm, etc.). Changing this parameter also changes the setting of the Units parameter on the AFM control panel.

Range or Settings

- Volts
- Metric

Feedback type—Specifies the feedback site.

Range or Settings:

- **None**—No feedback taking place when ramping
- **Pixel**—Feedback done after every pixel encountered during the ramp (of the force curve)
- **Ramp**—Feedback takes place at the top and bottom of the ramp
- **Cycle**—One feedback takes place at the starting point after one complete cycle

Feedback counts—Specifies the number of feedbacks to be reported at each feedback site. When Feedback type is set to Ramp, and Feedback counts is set to 3, then three feedbacks are performed at each stop during the ramp cycle (a total of six, in this case).

Feedback value—Useful only in scanning tunneling microscopy, allows user to adjust the bias value to a different bias than is being used in Image Mode.

5.9.3 Feedback Controls, Auto Panel and Scan Mode Panels

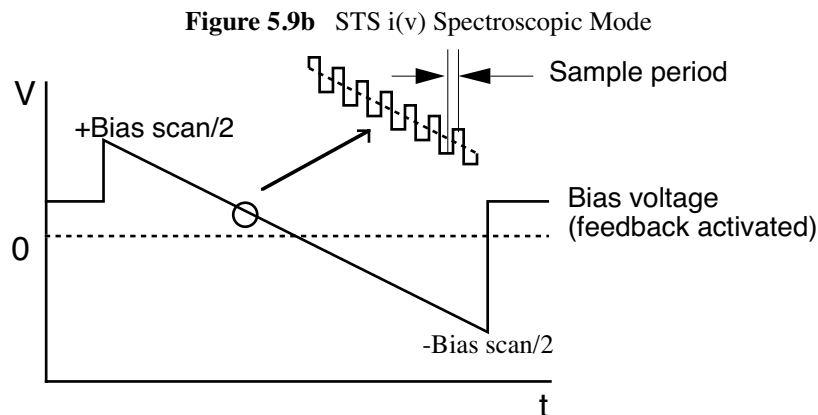
The panels in the **STS i(v) Plot** screen are similar to the advanced Force Calibrate screen panels. For further details on the parameters in these panels, see [Section 5.5](#).

5.9.4 STS i(v) Plot Display Monitor

A plot of tunneling current versus bias voltage, and the **Z Center Position** bar graph, are shown on the Display Monitor. No control operations are possible.

Hints for Optimizing the STS i(v) Plot Command

- [Figure 5.9b](#) depicts the operation of the STS i(v) spectroscopic mode when the **Feedback** parameter is set to **Off**. (See following note for the case when the **Feedback** parameter has a non-zero value).



- An STS i(v) measurement of tunneling current versus **Bias** voltage involves a few steps. First, the feedback loop runs to establish the tip-to-sample separation for the settings of **Bias** voltage and **Setpoint** current; the **Setpoint** current is sampled here. The tip-to-sample voltage is then set to $\frac{+\text{Bias scan}}{2}$ and ramped to $\frac{-\text{Bias scan}}{2}$. The tip-to-sample voltage is modulated by $\frac{\pm \text{Bias modulation}}{2}$ along the ramped portion and the following tunneling currents are measured:

$$i_+ = \text{tunneling current at } V_{\text{Bias}} = V_{\text{ramp}} + \frac{\text{Bias modulation}}{2}$$

$$i_- = \text{tunneling current at } V_{\text{Bias}} = V_{\text{ramp}} - \frac{\text{Bias modulation}}{2}$$

- The software combines these two quantities as shown to derive the various functions of $i(v)$ spectroscopy:

$$i(t) = \frac{i_+ + i_-}{2}, \text{ or } \frac{i_n + i_{n+1}}{2} \quad \text{if Bias Modulation} = 0$$

$$\Delta i = i_+ - i_-, \text{ or } i_n - i_{n+1} \quad \text{if Bias Modulation} = 0$$

$$\Delta v = \text{Bias modulation, or } \frac{\text{Bias scan}}{\text{Number of samples}} \quad \text{if Bias Modulation} = 0$$

where v = instantaneous Bias scan value

$$\frac{\delta i}{\delta v} = \frac{\Delta i}{\Delta v}$$

$$\frac{\delta i}{\delta v} = \frac{\Delta i / \Delta v}{i(t) / v}$$

$$\frac{\delta i}{\delta v} = \frac{\Delta i / \Delta v}{i(t)}$$

- If the **Feedback** parameter is set to something other than **Off**, the system responds differently. This is the setting required for BEEM (Ballistic Electron Emission Microscopy). Additional hardware is required for BEEM experiments.
- When the **Feedback** parameter is not zero, the feedback runs for each setting of the bias voltage ramp. In this way the tunneling current is kept constant throughout the bias voltage ramp.
- The signal-to-noise ratio can be increased by increasing the **Average count** parameter; however, the total measurement time is also increased. The **Average count** item controls the number of times the ramp occurs per data point. A value of four implies that the same ramp pattern occurs four times. The corresponding four data points from each ramp would be averaged to improve the signal-to-noise ratio.
- The input sensitivity must be properly defined for the auxiliary channel if the data is input through an auxiliary channel.



ATTENTION: All parameters on the STS Plot $i(v)$ control panel affect results.

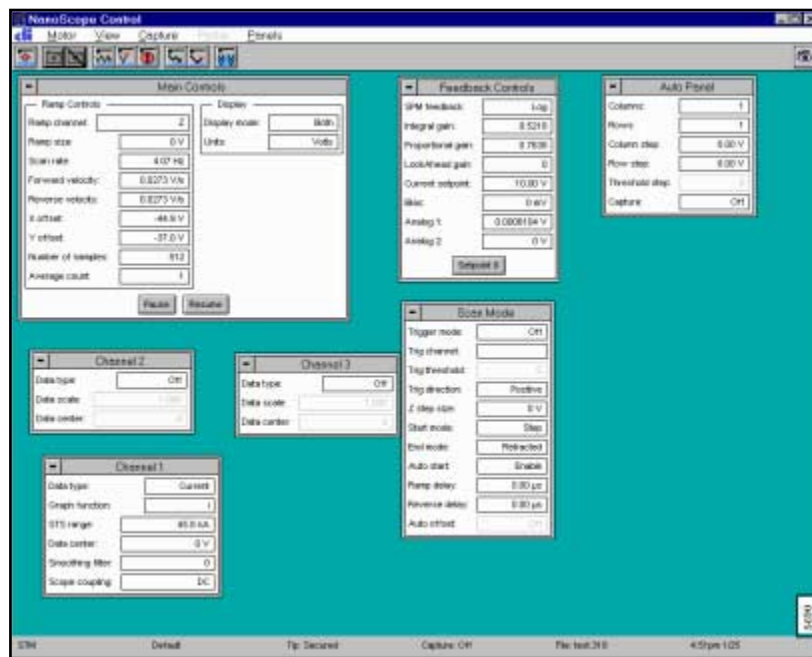
5.10 STS Plot i(s) (STM Only)

The **STS Plot i(s)** command places the STM in a spectroscopic mode. The change in the tunneling current as a function of tip-to-sample separation is measured. Many control panel parameters are common to the STS Plot $i(v)$ and STS Plot $i(s)$ control panels.

5.10.1 Control Monitor

The STS Plot i(s) control panel is shown on the Control Monitor, allowing the user to control the system operation. Each of the parameters in the **STS i(s) Plot** screen can be changed to vary the operation of the microscope. After selecting the **STS i(s) Plot** command, a new screen appears with a menu bar, toolbar, four control panels and up to three channel panels.

Figure 5.10a STS i(s) Plot Screen



5.10.2 Parameters in the Main Controls STS i(s) Panel

Ramp Controls

Ramp channel—Defines the variable to be plotted along the X-axis of the Scope Trace.

Range or Settings:

- **Z**—Plots Z
- **Analog 1**—Any analog channel. Units will vary depending on the channel output.
- **Bias**—Appears only in STM mode.

Ramp Begin—Specifies the start of the Ramp channel. Units depend on the setting for Ramp channel.

Ramp End—Determines the end position of the output ramp.

Scan rate—Rate at which piezo extends in Z direction (toward surface). Note that the units for this value will vary depending on the Ramp channel value. Very slow Scan rates (< 0.10 Hz) may prove frustrating; the system completes the present scan before initiating parameter changes.

Range or Settings:

min. **0.010**; maximum value depends upon **Number of samples**.

Ramping under NT is limited to approximately 30 Hz at 512 samples per line.

Velocity —Forward or Reverse, units will depend on the ramp channel. Controls the velocity of the piezo.

X offset, Y offset—Controls the center position of the scan in the X and Y directions, respectively.

Range or Settings:

- **±220 Volts; ± XX Microns** (head-dependent)

Number of samples—Selects the number of data points reported per STS cycle. Lower values allow faster line rates.

Range or Settings: 4 - 60,000

Average count—Controls how many values are averaged for each point displayed in the plot. The entire cycle repeats and the corresponding values from each cycle are averaged to reduce noise.

Range or Settings:

- **1 through 1024**

Hints to Optimize the Parameters in the Average Count Parameter

- Increasing this parameter increases the signal-to-noise ratio by averaging out the random noise in the signal.
- Increasing this parameter also increases the total measurement time.
- This parameter defines the number of times the entire modulation cycle repeats. The cycle from **+Bias scan/2** to **-Bias scan/2** repeats **Average count** times. The corresponding data points from each scan are averaged to reduce noise.

STS i(s) Main Panel Display Parameters

Display mode—Portion of tip's vertical motion to be plotted on the force graph.

Range or Settings:

- **Extend**—Plots only the extension portion of the tip's vertical travel.

- **Retract**—Plots only the retraction portion of the tip's vertical travel.
- **Both**—Plots both the extension and retraction portions of the tip's vertical travel.

Units—Switches parameters in control panels between units of Volts or Metric units (nm, etc.). Changing this parameter also changes the setting of the Units parameter on the AFM control panel.

Range or Settings: **Volts** or **Metric (nm)**

Feedback type—Specifies the feedback site.

Range or Settings:

- **None**—No feedback taking place when ramping
- **Pixel**—Feedback done after every pixel encountered during the ramp (of the force curve)
- **Ramp**—Feedback takes place at the top and bottom of the ramp
- **Cycle**—One feedback takes place at the starting point after one complete cycle

Feedback counts—Specifies the number of feedbacks to be reported at each feedback site. When Feedback type is set to Ramp, and Feedback counts is set to 3, then three feedbacks are performed at each stop during the ramp cycle (a total of six, in this case).

Feedback value—Useful only in scanning tunneling microscopy, allows user to adjust the bias value to a different bias than is being used in Image Mode.

5.10.3 Feedback Controls, Auto Panel, Scan Mode Panels in STS i(v) Plot

The panels in the **STS i(s) Plot** screen are similar to the advanced **Force Calibrate** screen panels. For further details on the parameters, see [Section 5.5](#).

5.10.4 STS i(s) Plot Display Monitor

A plot of tunneling current versus bias voltage, and the **Z Center Position** bar graph, are shown on the Display Monitor. No control operations are possible.

View Menu
STS Plot i(s) (STM Only)

Chapter 6 Frame and Capture Menus

The **Capture** menu allows images and parameters to be captured, then stored for future analysis. Captured image files are saved with the label assigned by the user.

The **Frame** menu (**Up, Down, Reverse and Line**) restarts the Real-time scan. These four commands facilitate data collection, especially when slower **Scan rates** are being used.

This chapter discusses the following Capture and Frame Commands:

- **Capture** [Section 6.1](#)
- **Abort** [Section 6.2](#)
- **Continuous (Movie) Capture** [Section 6.3](#)
- **AutoScan** [Section 6.4](#)
- **Capture Plane** [Section 6.5](#)
- **Capture Withdraw** [Section 6.6](#)
- **Capture Calibration** [Section 6.7](#)
- **Capture Filename** [Section 6.8](#)
- **Frame Commands** [Section 6.9](#)



6.1 Capture

The **Capture** command stores the image data of the current scan. During the image scanning process, the cursor moves up and down a square image frame (i.e., see image display in the Display Monitor). When the cursor moves across one complete frame the **Capture** is done and an image file is saved.

If the scan is in the middle of the frame, the **Capture** command waits for the beginning of the next frame to begin storing the file.

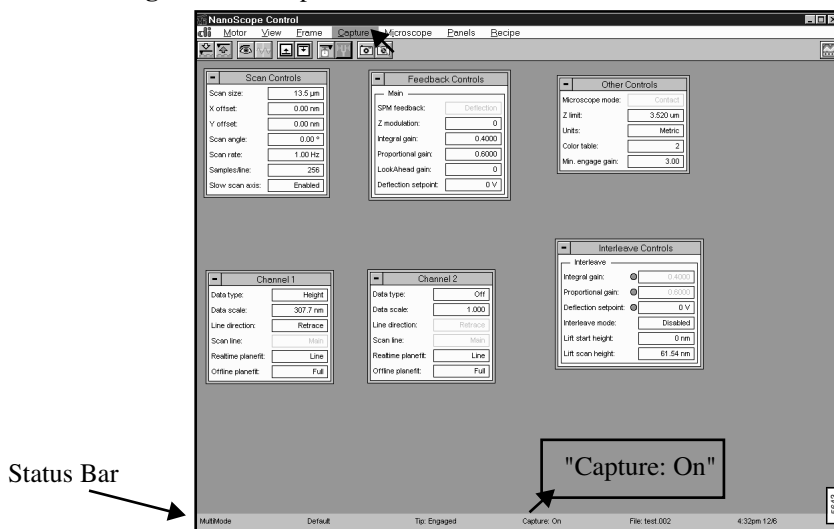
Note: For multiple images, the **Capture** command collects each frame simultaneously. However, the channel 1 image is saved in the capture file ahead of channels 2 and 3.

To begin capturing, select the **Capture** icon, the **Capture** command (**Capture/Capture**) or **CNTRL-C**.

6.1.1 Capture Control Monitor

The Control Monitor displays the main menu bar, control panels and a status bar along the bottom of the screen. The status bar reflects the state of the **Capture** operation along with the status of the scan (See [Figure 6.1a](#)).

Figure 6.1a Capture Control Monitor and Status Bar



The **Capture** status bar options include:

- **On**—Indicates that the Capture mode is in progress.
- **Off**—Indicates that the Capture has stopped.
- **Next**—Indicates that the Capture mode is waiting for the *next* frame to begin capturing.
- **Done**—Displays when the Capture finishes.
- **Movie**—Displays when the Continuous Capture mode begins (See [Section 6.3](#)).
- **Forced**—Indicates a *Forced* capture. This is done by clicking the Capture command a second time. The advantage is that the capture begins or resumes without waiting for the start of a new frame.

6.1.2 Capture Display Monitor

The **Capture** menu bar is visible on the Display Monitor. The menu bar commands allow the user to **Offset**, **Zoom In**, **Zoom Out**, **Clear**, **Rotate**, **Erase Image** and **Execute** the commands for the displayed image to (See [Figure 6.1b](#)).

Note: Initiating any command will postpone the image capture until the scan regains the beginning of the next frame.

Figure 6.1b Capture Display Menu Bar



Hints for Optimizing the Capture Command

- Captured images are modified according to the setting of the Off-line **planefit** parameter on each channel panel. See the descriptions of the control panel parameters for details about stored data options.
- If the SPM motor is moved while a capture is in progress, the capture aborts.



6.2 Abort

The **Abort** command stops the data collection of the **Capture** command. The **Abort** command stops all of the **Capture** operations except the **Auto Scan** command.

To abort the **Capture** command, press the **Abort** icon or select the **ABORT** command key (Real-time/Capture/Abort).

6.3 Continuous (Movie) Capture

The **Continuous** command allows for storing multiple images sequentially and automatically. This often proves invaluable when recording images of an evolving, dynamic process (e.g., electrochemical changes to materials).

Note: Changing a parameter aborts the **Continuous Capture** function.

6.3.1 Continuous Command Display Monitor

The menu bar is visible, but attempting operation aborts the **Continuous Capture** operation. The **Continuous Capture** mode captures and stores images until the **Abort** command is given or the system runs out of disk space in the **Capture** partition.

Note: Changing any control panel parameter or invoking the **Offset** or **Zoom** functions within the current frame will stop the **Continuous Capture** command until the next frame.

6.4 AutoScan

Use the **Auto Scan** command with any head or scanner to obtain multiple high-magnification images within the confines of the maximum allowable **Scan size** for the head or scanner.

Note: Locate the scanner parameters for your system in the EQUIPE Directory and then select filename *.scn.

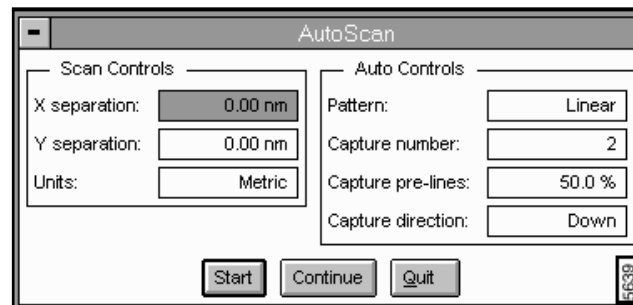
Refer to the following sections on AutoScan:

- **AutoScan Panel** [Section 6.4.1](#)
- **Buttons on the AutoScan Panel** [Section 6.4.2](#)
- **Scan Controls on the AutoScan Panel** [Section 6.4.3](#)
- **Auto Controls in the AutoScan Panel** [Section 6.4.4](#)

6.4.1 AutoScan Panel

The **AutoScan** panel displays parameters to control automatic scanning.

Figure 6.4a AutoScan Panel



6.4.2 Buttons on the AutoScan Panel

Start

The **START** button initiates **AutoScan**.

Note: If you click the **Abort** button, capture and frame incrementing should stop. Clicking **Continue** resumes with the *next* frame. If **Quit** is clicked after **Abort**, scan will reset to **X** and **Y offset** values in use before **AutoScan** was started.

Continue

The CONTINUE button resumes capturing after it has been suspended.

Quit

The QUIT button halts AutoScan and returns to the Real-time/Image mode.

6.4.3 Scan Controls on the AutoScan Panel

X Separation

Center-to-center distance between successive captures in the X (horizontal) direction.

Range or Settings:

- **0 V** through **440 V** (the allowed range is dependent on the settings of the **Scan size**, **X offset**, **Y offset**, and **Rotation** parameters on your SPM).

Y separation

Center-to-center distance between successive images in the Y (vertical) direction.

Range or Settings:

- **0** through **440 V** (the allowed range is dependent on the settings of the **Scan size**, **X offset**, **Y offset**, and **Rotation** parameters on your SPM).

Units

Selects whether X and Y separation are in Volts (V) or Metric distance units.

Range or Settings:

- **Volts**—Separation units are in volts.
- **Metric**—Separation units are in metric units of distance (nm, μm).

6.4.4 Auto Controls in the AutoScan Panel

Pattern

Selects the geometrical arrangement of the images acquired.

Range or Settings:

- **Square**—Acquires a square pattern of images with the number of images on a side equal to the **Capture number**. Specify spacing between columns by the **X separation** and spacing between rows by the **Y separation**.
- **Linear**—Acquires images in a line (not necessarily horizontal or vertical) with the **X** and **Y separations** specifying the X and Y displacements between subsequent image centers.

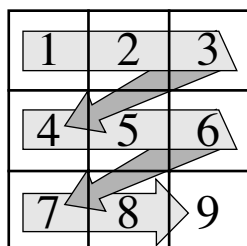
Note: The linear array can be oriented diagonally.

Note: Square patterns are acquired by row (horizontal, **X separation**), and then by column (vertical, **Y separation**) order.

Example of Using the Linear Parameter

For example, auto scanning a square pattern with the **Capture number** set to **3** would acquire nine images in the order shown in [Figure 6.4b](#). The first image captured is the left- and top-most frame for the linear array.

Figure 6.4b Square Patterns



The **X** and **Y offsets** on the Real-time / **Scan Controls** panel define the center of the scan pattern. The **X** and **Y offsets** define the center of the square when the **Pattern** parameter is set to **Square** (the center of frame 5 in the example pattern). When the **Pattern** parameter is set to **Linear**, the **X** and **Y offsets** define the center of the array.

Capture Number

Controls the number of images per side (for Square patterns), or the number of images per line (for Linear patterns). This represents the square root of the total number of images captured for square patterns.

Range or Settings:

- **2 to XX**. The number of images captured depends on the settings of the **Scan size**, **X offset**, **Y offset**, and **Rotation** parameters on the appropriate STM or AFM control

panel. The number of images captured may also be limited by the space available in the Capture directory.

Capture Pre-lines

Sets the amount of image frame to be scanned before capturing each image, expressed as a percentage of the frame lines. For example, if 75 percent is entered, the probe will scan three-quarters of the frame lines before beginning a capture. (For a scan frame having 256 Lines, this would be 192.) This allows the scanner piezo time to stabilize between frame offsets, improving image quality.

Range or Settings: **0—100** percent

Capture direction

Direction of scan while capturing images. **Capture direction** is maintained for all capture frames, regardless of **Capture number** or **Capture pre-lines** settings.

Range or Settings:

- **Up or Down.**

Example of Using the Capture Direction Parameter

To capture a series of four, adjacent 1-micron scans with a "D" head arranged in a square pattern, you would set the **Scan size** to **1000 nm**, then access the **Auto Scan** command. In the **Auto Scan** panel you would set the **Pattern** item to **Square**, the **Capture number** to **2** ($2 \times 2 = 4$ total images), and the **X** and **Y separation** parameters to **1000 nm**. Finally, click on the **Start** button to begin data acquisition. To provide a half-frame settling period between captures, set the **Capture pre-lines** parameter to **50 percent**.

6.5 Capture Plane

The **Capture Plane** command captures data from the current scan and calculates a best-fit plane for the data. The best-fit plane defines the plane for lithographic operations and to level captured real time images.

Note: For details on Lithographic operations, see *Support Note 327, NanoLithography*.

6.5.1 Capture Plane Control Monitor

The control panel is visible, but changing a parameter postpones the data capture until the scan has regained the beginning of the next frame.

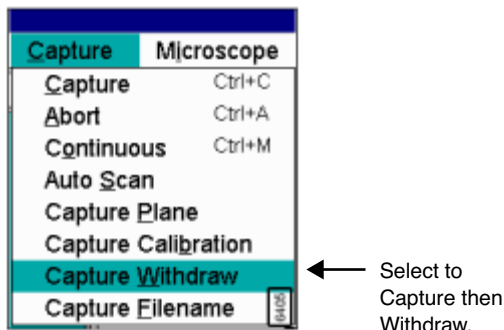
Changing any control panel parameter or invoking the **Offset** or **Zoom** functions within the current frame postpones the **Capture** operation until the scan regains the beginning of the next frame.

Note: Use the **Capture Plane** command to define the plane of the sample surface prior to lithographic operations. Lithographic operations require the tip to be at a uniform distance from the sample surface to produce consistent effects on the sample surface.

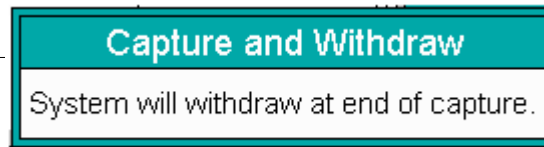
6.6 Capture Withdraw

The Capture Withdraw command captures data being scanned and withdraws the tip upon completion of the capture.

Figure 6.6a Capture Withdraw Menu



A prompt appears to show the process (See [Chapter 6.6b](#)).



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6.7 Capture Calibration

The **Capture Calibration** command stores image data for future use with the **Head Autocalibrate** command in the **Offline/Utility** menu. Images may be captured individually or in groups to calibrate: (1) sensitivities and deratings; and, (2) coupling between the slow and fast scan wave forms.

The entire set of twelve images required to calibrate the head or scanner may be captured automatically.

Note: The system must be in single image mode with the **Interleave mode** set to **Off** to capture calibration images.

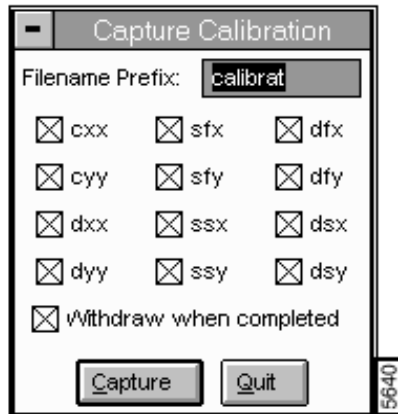
Refer to the following sections on Capture Calibration:

- **Capture Calibration Panel** [Section 6.7.1](#)
- **Parameters and Buttons in the Capture Calibration Panel** [Section 6.7.2](#)

6.7.1 Capture Calibration Panel

The **Capture Calibration** panel allows to name, select and capture the calibration images (See [Figure 6.7a](#)).

Figure 6.7a Capture Calibration Panel



6.7.2 Parameters and Buttons in the Capture Calibration Panel

Filename prefix

Defines the name prefix assigned to the calibration images. The default name is "calibrat" but any name up to eight characters in length can be entered.

cxx

Selects scan with 45° rotation to be used to calculate the X coupling terms.

cyy

Selects scan with 45° rotation to be used to calculate the Y coupling terms.

dxx

Selects scan with 19° rotation to be used to calculate the X coupling-derating terms.

dyy

Selects scan with 71° rotation to be used to calculate the Y coupling-derating terms.

sfx

Selects scan with no rotation to be used to calculate the X fast sensitivity.

sfy

Selects scan with 90° rotation to be used to calculate the Y fast sensitivity.

ssx

Selects scan with 90° rotation to be used to calculate the X slow sensitivity.

ssy

Selects scan with 0° rotation to be used to calculate the Y slow sensitivity.

dfx

Selects scan with 0° rotation to be used to calculate the X fast derating.

dfy

Selects scan with 90° rotation to be used to calculate the Y fast derating.

dsx

Selects scan with 0° rotation to be used to calculate the X slow derating.

dsy

Selects scan with 90° rotation to be used to calculate the Y slow derating.

Withdraw when completed

Acts similar to the **Capture Withdraw** command by capturing then withdrawing the tip after capturing an image.

Quit (button)

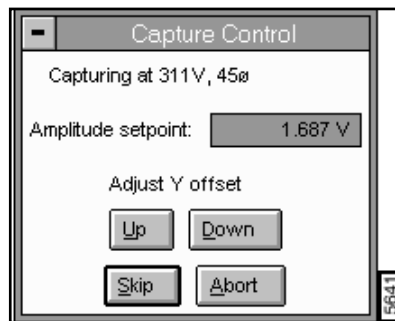
Ends the **Capture** operation.

Capture(button)

The **CAPTURE** button photographs the selected image(s) and stores them with the name defined in the Filename prefix field. The extensions "sfx", "sfy", "ssx", through "dyy" will be appended to the files. A panel similar to the one shown in Figure 6.7b appears on the screen during the Capture operation.

Note: The panel items change according to the parameter to be calibrated (i.e., y offset or x offset changes).

Figure 6.7b Capture Control Panel



Capturing at...

Defines the calibration image being captured.

Amplitude Setpoint

Adjusts the voltage applied in the Z direction for changes to the captured image.

Adjust Y Offset (Up) (Down) or Adjust X Offset (Left) (Right)

This item appears when capturing images required to calibrate the slow-fast coupling parameters. When the scan required to calibrate the X slow-fast coupling is captured, the Y scan is shut off, and this item is displayed as shown in the panel. When the scan required to calibrate the Y slow-fast coupling is captured, the X scan is shut off and this item reads `ADJUST Y OFFSET (UP) (DOWN)`. In either case, the Left / Right or Up / Down buttons should be used to align the scan to features on the sample.

Skip

Delays the **Capture** operation until the next scan. Exercise this option if an anomaly appears in the current scan.

Abort

Terminates the **Capture** operation.

Hints for Optimizing the Capture Commands

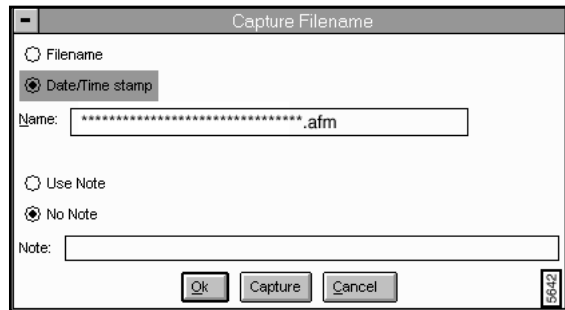
- The file name suffix appended to the file name is specific to the calibration operation performed with the **Autocalibrate** command in the **Utility** menu (Off-line/**Utility**).
- The **Capture** directory will be checked for conflicting file names before the **Capture** operation begins.
- The voltage applied during the **Capture** operations are fractions of the **Piezo cal** voltage in the microscope list. By reducing the **Piezo cal** voltage, something other than the maximum scan voltage can be used to calibrate the piezo. In most cases the **Piezo cal** parameter should be set to **440 volts**.
- Some items in the **Capture Calibration** list will not be selectable for heads that do not allow rotation.
- The status bar reflects the status of the **Capture** operation when the **Capture Calibration** command is running. To allow time for the scan to settle, two images are skipped before the calibration image is captured.
- A two-dimensional calibration standard must be used, and it must be aligned with X and Y scan directions. The **Scan angle** parameter in the control panel should be set to **0 degrees**.

6.8 Capture Filename

The **Capture Filename** command assigns file names to captured files. File names may include a user-defined name and/or date-time stamp.

The **Capture Filename** panel appears on the Control Monitor allowing a new file name and note to be entered (See [Figure 6.8a](#)).

Figure 6.8a Capture Filename Panel



Filename

Allows a custom filename to be appended to captured images. Enter the *name* in the Name field. The specified filename must be DOS compatible. The filename may now be up to 32 characters in length. A three-digit extension will be appended to the file name. The extension is sequentially numbered after each image is captured.

Note: If an extension is specified as part of the file name, the labeling will begin with the specified extension number.

The file name command checks for conflicts with existing files. The numerical extension appended to the file increments to avoid conflicts.

Date /Time stamp

The filename assigned to the captured file results from the month/day/hour/minute the file was captured. Format: MMDDHHMM.xxx

Use Note

Select to add a note to the captured file.

No Note

Deselects the option to add a note to the captured file.

Note Field

Field to add a message to the captured file.

OK

Quits the operation and saves the specified filename selection.

Capture

Resumes capturing.

Cancel

Quits the operation without saving changes to the filename selection.

Example

Specify the file name "IC.023" to continue numbering the integrated circuit data files with the extension 023. If IC.023 already exists, the new file will be given the next available extension, e.g., .024.

6.9 Frame Commands

6.9.1 Up

The **Up** command restarts the Real-time scan at the bottom of the frame.



Note: The **Up** command can be used to view an entire Real-time frame as quickly as possible. When the *Scan rates* are low, it can take a fairly long time to scan an entire frame.

Example

With the **Scan rate** set to **0.5 Hz** and the **Number of samples** set to **512**, it can take over 17 minutes to capture a single image. Using the **Up** and **Down** commands will allow you to go right to the start of the frame and not have to wait for the previous frame to end.



6.9.2 Down

The **Down** command restarts the Real-time scan at the top of the frame.

Note: The **Down** command can be used to view an entire Real-time frame as quickly as possible. When the **Scan rates** are low, it can take a long time to scan an entire frame.

6.9.3 Reverse

The **Reverse** command switches the direction of the Real-time scan.

6.9.4 Line

The **Line** Frame command allows **Frame Up/Down** to be initiated arbitrarily from any designated line in the scan. Line "0" is the bottommost line in the scan.

Chapter 7 Microscope Menu

The NanoScope system accommodates a wide range of SPM parameters that are saved in a file and interchanged. The commands in the **Microscope** menu allow microscopes with different Profiles (e.g., scan settings or tips) to be selected and calibrated then stored for later use.

Note: Changes made with any command resets the Real-time mode.

This chapter discusses the following **Microscope** menu items:

- **Profile** [Section 7.1](#)
- **Scanner** [Section 7.2](#)
- **Microscope/Calibrate** [Section 7.3](#)
- **Calibrate/Scanner** [Section 7.4](#)
- **Calibrate/Detector** [Section 7.5](#)
- **Calibrate/Z** [Section 7.6](#)
- **Tapping Engage** [Section 7.7](#)
- **Leakage (STM and EC STM Only)** [Section 7.8](#)
- **Offset (STM Only)** [Section 7.9](#)
- **Sensitivity Calibration** [Section 7.10](#)
- **Auto Gain Adjust** [Section 7.11](#)

- [Replace Tip \(MM AFM Only\) Section 7.13](#)
-

7.1 Profile

The **Profile** command in the **Microscope** menu works with the **Microscope Select** command (Real-time/DI/**Microscope Select**) to configure the microscope for specific imaging modes (e.g., **Contact** mode, **Tapping** mode or **STM**).

Note: The **Profile** command is similar to the **Microscope/Settings** command used in earlier software versions.

A Profile is a file that includes all the Real-time parameter settings. There are two copies of each Profile, a master copy and a temporary copy. The master copy can only be modified by selecting the **SAVE AS MASTER** button and accessing the **Save as Master Profile** panel.

The temporary copy is updated whenever the user exits the software or enters Off-line mode. Access the temporary copy using the **LOAD** button. Once the **Load** button is selected, the Master Profile overwrites the temporary copy.

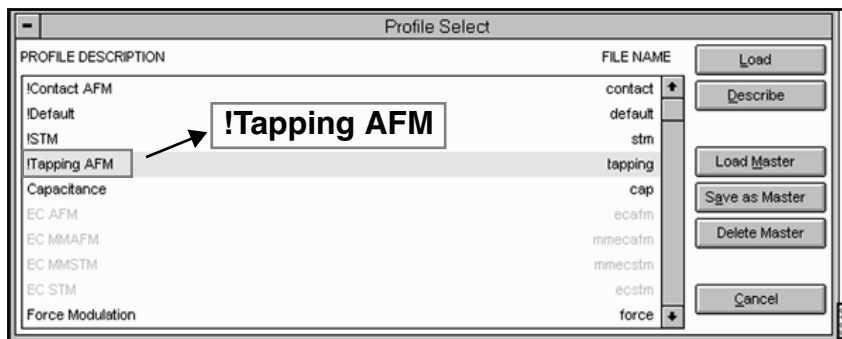
Refer to the following sections on using the Profile functions:

- [Profile Select Panel Section 7.1.1](#)
- [Enabling Profile Commands Section 7.1.2](#)

7.1.1 Profile Select Panel

In the **Microscope** menu, select **Profile** to access the **Profile Select** panel (See [Figure 7.1a](#)).

Figure 7.1a Profile Select Panel



The **Profile Select** panel includes a two-column window and command buttons. In the window, the left column names the profile description for reference.

The right column lists the corresponding file name for the Profile. The file includes settings for each Profile (e.g., parameter values, display and placement of panels).

The Profiles marked with an exclamation mark (!) designate *read only* master files and can not be modified by the user (See [Figure 7.1a](#)).

Note: Changing the Master Profile **File Name** to *Contact*, *STM*, or *Tapping* also changes the **Microscope Mode** setting in the **Other Controls** panel.

Once changes are made, they may be easily saved to the Profile, then recalled later. This avoids any need for readjusting parameters each time the microscope is switched to a new imaging mode.

Buttons on the Profile Select Panel

The buttons allow for loading the Profile, including a description of the file, saving the file in the SPM/Equip directory, deleting the file or exiting from the **Profile** command.

Load

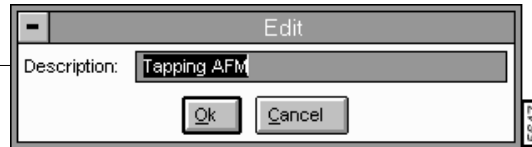
The **LOAD** button loads the selected temporary copy of the Profile file from the **di/SPM/par** directory and sets panels and setting parameters to their preset values. Select Profiles with the mouse from the scroll bar list on the **Profile Select** panel.

Note: If a different scanner is being used along with the new microscope profile, use the Real-time/**Microscope/Scanner** option to install the appropriate scanner file. For details on **Scanner** selections, see [Section 7.2](#).

Describe

The **DESCRIBE** button accesses the **Edit** panel to enter the file name description (i.e., the left column description in the **Profile Select** panel). The description attaches a user-defined note to each profile for easy identification. Descriptions may be up to 40 characters in length (See [Figure 7.1b](#)).

Figure 7.1b Profile Edit panel



Select **OK** to incorporate the description in to the profile .

Load Master

The **LOAD MASTER** button loads a Master Profile from the `D : /SPM/PAR` directory, which acts as a template and overwrites the temporary copy of the Profile of the same name. Selecting the **LOAD MASTER** button accesses the **Delete Confirm** panel (See [Figure 7.1c](#)).

Figure 7.1c Delete Confirm Panel



Save As Master

The **SAVE AS MASTER** button saves the Profile as a Master Profile. The new file name appears in the **Profile Select** panel (right column) and saves a preset file in the `d:/` directory.

Note: The system also saves a temporary copy of the Master Profile.

In the **Save Master Profile** panel, enter the *Name* in the **Name** field (See [Figure 7.1d](#)).

Figure 7.1d Save Master As Panel



Note: If a previously used **Name** is entered, the old Profile will be updated.

Select the **OK** button to enter the description and corresponding file name to the Master Profiles.

Delete Master

The **DELETE MASTER** button deletes a Master Profile from the **Profile Select** panel and the D : / SPM / PAR directory.

Cancel

The **CANCEL** button exits the **Profile Select** panel (or/and any changes) and returns to the Real-time menus.

7.1.2 Enabling Profile Commands

Some profiles may appear disabled (i.e., greyed) in the Profile Select panel. This is due to the equipment restrictions for this profile that are set up in the *.pan files. Locate the *.pan files in your EQUIP directory and view the allowable configurations that enable viewing the profile.

To view the restrictions, complete the following:

1. Locate the EQUIP directory in Windows Explorer (e.g., c:\spm\equip).
2. Select the profile name (e.g., MFM.pan).
3. Locate the restrictions at the top of the profile.
4. To view the profiles in the **Profile Select** panel, enable these configurations.

Example: MFM.pan file

Restrictions: Extender = Quadrex Microscope = D3000

Therefore, in order to view the *MFM* profile on the **Profile** panel, you must be on a *D3000* microscope configured with a *Quadrex* extender.

7.2 Microscope Menu Scanner

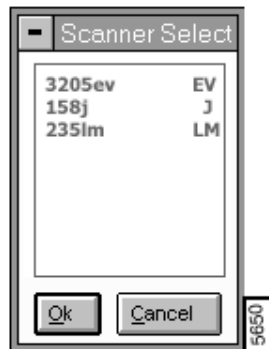
Use the **Scanner** command to select a scanner calibration file. The **Microscope/Scanner** option displays the **Scanner Select** panel, which lists all available scanner files located within SPM/EQUIP directory that are compatible with the selected microscope configuration.

The SPM/EQUIP directory contains separate parameter files for each microscope and scanner. Files having an ".eqp" extension contain information about your microscope hardware and configuration. Files having a ".scn" extension contain information for a specific scanner. For example, if you operate a MultiMode SPM with a *J* scanner, there should be a MM.EQP file for the microscope base, and a XXXXJ.SCN file for the scanner (i.e., where XXXX is the serial number of the scanner).

To select a scanner listed in the SPM/EQUIP directory, open the **Scanner Select** panel. The scanners are listed alphabetically and are selected using the mouse (See [Figure 7.2a](#)).

Note: If a required scanner file is not listed, its *.scn file needs to be added to the SPM/EQUIP directory manually.

Figure 7.2a Scanner Select Panel



7.3 Microscope/Calibrate

The **Calibrate** menu provides access to the scanner calibration and signal gains. The **Scanner** and **Z** submenus allow the scanner calibration parameters to be viewed and changed. The **Detector** submenu allows various signal sensitivity and polarity settings to be viewed and changed.

The calibration parameters for the heads and scanners purchased with the instrument are set prior to shipment. Calibration parameters for heads and scanners purchased after installation can be loaded directly from the disk shipped with these added parts.

Some parameters appear on panels according to the microscope selected (Real-time/**DI/Microscope Select**) and the microscope profile settings (Real-time/**Microscope/Profile**); however, every attempt has been made to include all parameters, including some from earlier software versions.



ATTENTION: Changes made to parameters in any of the **Calibrate** panels, immediately affects the operation of the microscope.

The parameters are saved in the appropriate microscope parameter file after selecting the **OK** button to exit the panel.

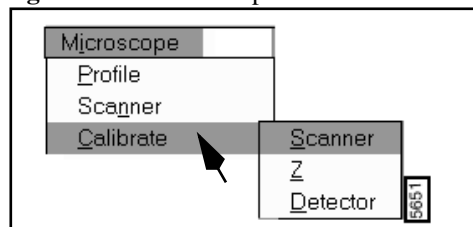
Note: All **Calibrate** parameters can only be changed by typing in a numeric value. Unlike parameters in other windows, it is not possible to change the values by scrolling the mouse OR incrementing with the arrow keys on the keyboard.

See also: **Off-line/Utility** menu: **Auto calibration** command.

7.3.1 Calibrate Submenu Commands

In the **Microscope** menu, select the **Calibrate** command to access the submenu items (See [Figure 7.3a](#)).

Figure 7.3a Microscope/Calibrate Submenu



7.4 Calibrate/Scanner

7.4.1 Calibrate/Scanner

For optimizing the scanner, parameters set the sensitivity, applied voltage, limits on scan rate, etc. for specific scanner types. The parameters vary by the scanner serial number entered.

The **Scanner** command accesses the **Scanner Calibration** panel (See [Figure 7.4a](#)).

Refer to the following Calibrate/Scanner sections:

- **Buttons on the Scanner Calibration Panel** [Section 7.4.1](#)
- **Parameters in the Scanner Calibration Panel** [Section 7.4.2](#)

Figure 7.4a Scanner Calibration Panel

Scanner Calibration			
Serial number:	<input type="text"/>		
X fast sens:	<input type="text" value="30.00 nm/V"/>	Y fast sens:	<input type="text" value="30.00 nm/V"/>
X fast derate:	<input type="text" value="0.02000 nm/V<sup>2</sup>"/>	Y fast derate:	<input type="text" value="0.02000 nm/V<sup>2</sup>"/>
X slow sens:	<input type="text" value="35.00 nm/V"/>	Y slow sens:	<input type="text" value="35.00 nm/V"/>
X slow derate:	<input type="text" value="0.03000 nm/V<sup>2</sup>"/>	Y slow derate:	<input type="text" value="0.03000 nm/V<sup>2</sup>"/>
Xs-Xf coupling:	<input type="text" value="0.05000 nm/V<sup>2</sup>"/>	Ys-Yf coupling:	<input type="text" value="0.05000 nm/V<sup>2</sup>"/>
Xs-Xf coup der:	<input type="text" value="0.02000 pm/V<sup>3</sup>"/>	Ys-Yf coup der:	<input type="text" value="0.02000 pm/V<sup>3</sup>"/>
Xs-Yf coupling:	<input type="text" value="0.005000 nm/V<sup>2</sup>"/>	Ys-Xf coupling:	<input type="text" value="0.005000 nm/V<sup>2</sup>"/>
Xs-Yf coup der:	<input type="text" value="0.000 pm/V<sup>3</sup>"/>	Ys-Xf coup der:	<input type="text" value="0.000 pm/V<sup>3</sup>"/>
X offset sens:	<input type="text" value="35.00 nm/V"/>	Y offset sens:	<input type="text" value="35.00 nm/V"/>
Fast mag0:	<input type="text" value="1.20"/>	Slow mag0:	<input type="text" value="1.25"/>
Fast mag1:	<input type="text" value="0.500"/>	Slow mag1:	<input type="text" value="0.600"/>
Fast arg:	<input type="text" value="2.50"/>	Slow arg:	<input type="text" value="2.50"/>
Fast arg derate:	<input type="text" value="0.00 1/V"/>	Slow arg derate:	<input type="text" value="0.00 1/V"/>
Fast cal freq:	<input type="text" value="2.44 Hz"/>	Slow cal freq:	<input type="text" value="4.77 mHz"/>
Piezo cal:	<input type="text" value="440 V"/>	Rounding:	<input type="text" value="0.00"/>
Allow rotation:	<input type="text" value="Allow"/>	Orthogonality:	<input type="text" value="0.00 °"/>
Minimum scan rate:	<input type="text" value="0.0200 Hz"/>		
<input type="button" value="Ok"/> <input type="button" value="Print"/> <input type="button" value="Cancel"/>			

7.4.1 Buttons on the Scanner Calibration Panel

Ok—The OK button exits the Calibrate/Scanner command and saves the changes made to the parameters.

Print— Accesses the Print panel, which allows printing of scanner calibration parameters on the system printer. Once parameters are satisfactorily set, it will prove helpful to print a copy of the parameters list and store it with the scanner as a future reference. Note that some parameters need to be altered slightly as the scanner ages.

7.4.2 Parameters in the Scanner Calibration Panel

The heads and scanners are factory calibrated. The values for this item are entered into the calibration panels for all heads and scanners shipped with the system. Sensitivity values are listed on the back of the head or scanner.

Following are parameters for calibrating typical scanners:

X fast sens

Sets the piezo deflection per volt when the fast scan waveform is applied to X-axis electrodes (as when the **Scan angle** parameter in the **Scan Controls** panel is set to 0.00 degrees).

Table 7.4a Typical Parameter Values (nm/V)

Scanner	"A"	"D"	"E"	"G"	"J"
X fast sensitivity	2.00	35.0	30.0	200	300

X fast derate

Sets the rate of decrease in the X fast sensitivity as the fast scan voltage applied to the X-axis is reduced.

Table 7.4b Typical Parameter Values

Scanner	"A"	"D"	"G"	"J"
X fast derating	0.00	0.020	0.20	0.25

X slow sens

Defines the deflection in nanometers produced in the piezo per volt applied when the slow scan waveform is applied to the X electrodes (as when the **Scan angle** parameter in the **Scan Controls** panel is set to 90 degrees).

Table 7.4c Typical Parameter Values

Scanner	"A"	"D"	"G"	"J"
X slow sensitivity	NA	NA	300	400

Note: The values listed in the table are typical values; the sensitivities of individual scanners often vary.

X slow derate

The rate of decrease in the X sensitivity when the slow scan voltage applied to the X electrode is reduced from the maximum.

Table 7.4d Typical Parameter Values (nm/V²)

Scanner	"A"	"D"	"G"	"J"
X slow derating	0.00	0.020	0.35	0.45

Xs-Xf coupling

Defines the degree of coupling between the slow and fast scan waveforms when they are both applied to the X electrode (as when the scan angle parameter in the control panel is set to a non-orthogonal angle).

Values are in units of nanometers/volt/volt.

Note: This item has no effect if the **Scan angle** parameter in the **Scan Controls** panel is set to **0, 90, 180, or 270 deg.**

Note: This number is defined by the **Off-line/Utility/Auto calibration** command.

Xs-Xf coup der

The **Xs-Xf coupling derate** compensates for the decrease in the X coupling between the slow and fast waveform when the fast-scan voltage applied to the X electrode is reduced from the maximum (e.g., when the scan is rotated).

Values are in units of picometers/volt/volt/volt.

Note: This item has no effect if the **Scan angle** parameter in the **Scan Controls** panel is set to **0°**, **90°**, **180°**, or **270** degrees.

Note: This number is defined by the **Off-line/Utility/Autocalibration** command.

Xs-Yf coupling

Xs-Xf coupling defines the degree of coupling between the slow X waveform and the fast Y waveform. The fast Y waveform enhances the effect of the slow waveform applied to the Y axis. This item compensates for that effect.

Values are in units of nm/V³.

Note: This number is defined by the **Off-line/Utility/Autocalibration** command.

Xs-Yf coupling derate

The **Xs-Yf coupling derate** compensates for the decrease in coupling between the slow X and the fast Y waveforms when the fast-scan voltage applied to the Y electrode is reduced from the maximum.

Values for the heads and scanners are in units of pm/V³.

Note: This number is defined by the **Off-line/Utility/Autocalibration** command.

Fast mag0, Fast mag1, Fast arg

These are correction factors which improve the linearity of the fast-scan waveform.

Table 7.4e Typical Values for Nonlinear Correction Factors

Scanner Type	Fast mag0	Fast mag1	Fast arg
A	0.00	0.00	1.00
D, E	0.75	0.35	2.50
G	1.35	0.65	2.75
J	1.3	0.80	3.65

Note: A patented, nonlinear ramp is applied to the piezo to produce linear scans. A linear voltage ramp applied to many piezo scanners will not generate a linear response. The scan waveform applied to the piezo consists of a linear ramp added to a decaying exponential of varying magnitude and argument. The parameters **Fast mag0**, **Fast mag1**, and **Fast arg** define the magnitude and argument of the exponential. **Fast arg** determines the exponential decay of the

nonlinear term while **Fast mag0** and **Fast mag1** determine the amount of the exponential term to use and how that amount varies with **Scan size**.

Fast arg derate

The **Fast arg derate** creates fine adjustment of the Fast arg parameter as a function of the scan size. The value of the argument for a given scan size is as follows:

$$\text{arg} - (\text{Piezo cal} - \text{scan size}) \times \text{arg derate}$$

Therefore, the value of the argument used is actually **arg** when the scan size is equal to the **Piezo cal**, and is reduced for smaller scan sizes.

Note: This parameter is used only under very special circumstances and should normally be set to **0.00** (zero).

Fast cal freq

Fast cal freq is the frequency of the slow waveform when the scanner was calibrated.

Range and Settings:

- **2.44 Hz** (typical value)

Note: This number is assigned by the **Off-line/Utility/Autocalibration** command.

Piezo cal

Piezo cal is the voltage used to calibrate the head or scanner.

Range and Settings:

- **1 V–440 V.**

Note: For large area scanners this value will usually be **440 V**.

Allow rotation

Allow rotation allows the scan direction to be rotated relative to the sample by using the Scan angle parameter on the **Scan Controls** panel.

Range and Settings: **Allow** or **Disallow**

Note: Only the STM "A" and "D" heads, which have front-mounted tips, require the **Disallow** setting. Scan rotation is allowed for all other STM heads and all AFM scanners.

Minimum scan rate

The **Minimum scale rate** sets a lower limit for the Scan rate parameter on the Scan Controls panel.

Range and Settings:

- **0.001—10 Hz; default = 0.100 Hz**

Y fast sens

Y fast sens defines the deflection in nanometers produced in the piezo per volt applied when the fast scan waveform is applied to the Y electrodes (as when the Scan angle parameter in the control panel is set to 90.0 degrees).

Table 7.4f Typical Values (nm/V)

Scanner Type	"A"	"D"	"G"	"J"
Y fast sensitivity	2.20	30.0	200	300

Y fast derate

Y fast derate is the rate of decrease in the Y sensitivity when the fast scan voltage applied to the Y electrode is reduced from the maximum.

Table 7.4g Typical Values (nm/V²)

Scanner	"A"	"D"	"G"	"J"
Y fast derating	0.00	0.020	0.20	0.25

Y slow sens

Y slow sens defines the deflection in nanometers produced in the piezo per volt applied when the slow scan waveform is applied to the Y electrodes (as when the scan angle parameter in the control panel is set to 0.00 degrees).

Table 7.4h Typical Values (nm/V)

Scanner type	"A"	"D"	"G"	"J"
Y slow sensitivity	2.20	40.0	300	400

Y slow derate

Y slow derate is the rate of decrease in Y sensitivity when the slow scan voltage waveform applied to the Y electrode is reduced from the maximum.

Table 7.4i Typical Values (nm/V²)

Scanner type	"A"	"D"	"G"	"J"
Y slow derating	0.00	0.020	0.35	0.45

Ys-Yf coupling

Ys-Yf coupling defines the coupling between the slow and fast waveform when both waveforms are applied to the Y piezo electrode (e.g., when the scan is rotated).

Values are in units of nm/V².

Note: This parameter has no effect if the **Scan angle** parameter in the **Scan Controls** panel is set to **0, 90, 180, or 270** degrees.

Note: This number is defined by the **Off-line/Utility/Autocalibration** command.

Ys-Yf coup der

Ys-Yf coupling derate compensates for the decrease in the Y coupling between the slow and fast waveform when the fast scan voltage applied to the Y electrode is reduced from the maximum (e.g., while rotating the scan). Values for heads and scanners are in units of pm/V³.

Note: This item has no effect if the **Scan angle** parameter in the **Scan Controls** panel is set to **0, 90, 180, or 270** degrees.

Note: This number is defined by the **Off-line/Utility/Autocalibration** command.

Ys-Xf coupling

Ys-Xf coupling defines the degree of coupling between the slow Y waveform and the fast X waveform.

Values for scanners are in units of nm/V².

Note: The fast X waveform enhances the effect of the slow waveform applied to the Y axis. This parameter compensates for that effect.

Note: This number is defined by the **Off-line/Utility/Autocalibration** command.

Ys-Xf coup der

Ys-XF coupling derate compensates for the decrease in the coupling between the slow Y and the fast X waveforms when the fast-scan voltage applied to the X electrode is reduced from the maximum (e.g., when the scan is rotated).

Values for scanners are in units of pm/V².

Note: This number is defined by the **Off-line/Utility/Autocalibration** command.

Slow mag0, Slow mag1, Slow arg

These items are correction factors which improve the linearity of the slow-scan waveform.

Table 7.4j Typical Values for Nonlinear Correction Factors

Scanner Type	Slow mag0	Slow mag1	Slow arg
A	0.00	0.00	1.00
D, E	0.75	0.35	2.50
G	1.35	0.60	2.75
J	1.3	0.80	3.65

Note: A patented nonlinear ramp is applied to the piezo to produce linear scans. A linear voltage ramp applied to many piezo scanners will not generate a linear response. The scan waveform applied to the piezo consists of a linear ramp added to a decaying exponential of varying magnitude and argument. The parameters **Slow mag0**, **Slow mag1**, and **Slow arg** define the magnitude and argument of the exponential. **Slow arg** determines the exponential decay of the nonlinear term while **Slow mag0** and **Slow mag1** determine the amount of the exponential term to use, and how that amount varies with **Scan size**.

Slow arg derate

Slow arg derate makes fine adjustment of the **Slow arg** parameter as a function of the the scan size. The value of the argument for a given scan size is as follows:

$$\text{arg} - (\text{Piezo cal} - \text{scan size}) \times \text{arg derate}$$

Therefore, the value of the argument used is actually **arg** when the scan size is equal to the **Piezo cal**, and is reduced for smaller scan sizes.

Note: This parameter is used only under very special circumstances and should normally be set to **0.00** (zero).

Slow cal freq [mHz]

Microscope Slow cal freq is the frequency of the slow scan waveform used when the selected scanner was **Calibrate/Scanner** calibrated. The units are millihertz (i.e., thousandths of Hertz). This value represents the frequency of the slow waveform when the head or scanner was calibrated.

Range and Settings:

- **4.77 mHz** represents a typical value.

Note: This number is in millihertz. This number is calculated by dividing the **Fast cal freq** by the number of data points (or scan lines), then dividing the result by two.

Note: This number is assigned by the **Off-line/Utility/Autocalibration** command.

Rounding

Rounding defines the percentage of the fast scan time not captured or shown on the Display Monitor. This function allows mechanical systems to stabilize after the scan direction changes. This function distorts the linearity corrections made on the head or scanner.

Range and Settings:

- 0 - 50%

Note: This parameter should be zero for long, slow scans and increased only for short, fast scans.

Note: This parameter should be set to **0.00** when using the LFM.

Orthogonality

Orthogonality is the angular value added or subtracted to achieve an X-Y axis orthogonality of 90.00 degrees.

Range and Settings:

- ± 10.0 deg


Note: X- and Y-axis piezo crystals cannot always be assembled at precisely 90 degrees to one another. This parameter is designed to compensate for whatever orthogonality error exists in the assembled scanner.

The **Microscope/Calibrate/Detector** panel allows the gain, polarity and units of some signals to be viewed and /or changed. The standard setting for most signals is 1.0.

CAUTION: Changing the sensitivity settings changes your data! An incorrect polarity setting can affect feedback operation.



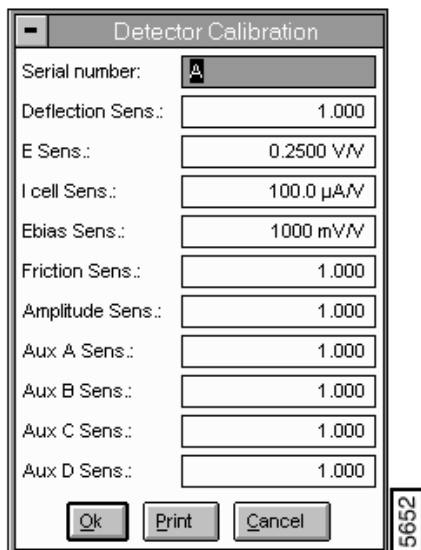
Note: Listed items vary depending upon the configuration of the microscope.

 **ATTENTION:** In version 4.42 and later software versions, units and polarity are entered directly by the user and conveyed to other panel parameters. For example, **Deflection sens** is normally entered in units of volt-per-volt (**Volt/Volt**).

In version 4.42 and later software, however, the user also has the option of entering whatever units they wish to use. Units should be entered directly with the numeric value (e.g., "2.54 Volt/Volt"). To set polarity, simply enter a positive value or insert a minus sign ("-") before the value to make it negative. Positive values are generally assigned to all normal settings (i.e., normal motor direction, normal piezo polarity). Negative values are generally assigned to abnormal settings (e.g., reverse polarized scanners, reverse motor direction, etc.).

7.5.1 Detector Calibration Panel

Figure 7.5a Detector Calibration Panel



Buttons on the Detector Calibration Panel

Ok

The **OK** button exits the **Detector** command and saves changes made to parameters.

Print

The **PRINT** button accesses the **Print** panel, which allows printing of **Detector** parameters on the system printer.

The **Calibrate/Z** allow to set the Z-axis piezo and leadscrew motor (MultiMode only)

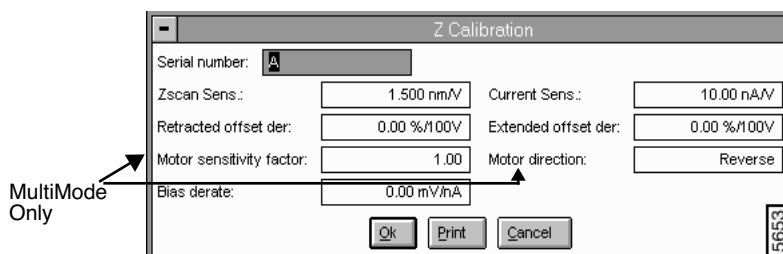
Refer to the following sections:

- **Z Calibration Panel** [Section 7.6.1](#)
- **Buttons on the Z Calibration Panel** [Section](#)
- **Parameters in the Z Calibration Panel** [Section](#)

7.6.1 Z Calibration Panel

Parameters are microscope and scanner-type dependent.

Figure 7.6a Z Calibration Panel



Buttons on the Z Calibration Panel

Ok

Exits the **Z Calibration** command and saves changes made to parameters.

Print

Accesses the **Print** panel, which allows printing of **Z Calibration** parameters on the system printer.

Parameters in the Z Calibration Panel

Serial number

The serial number is visible upon entering the panel.

Zscan sens

Z scan sens is the sensitivity of the piezo tube in the Z direction. The values are in units of nanometers of extension per volt applied to the electrodes.

Table 7.6a Typical Sensitivity Values (nm/V)

Scanner type	"A"	"D"	"E"	"G"	"J"
Z Scan sensitivity	1.50	9.00	7.00	12.5	12.5

Note: Almost all SPM heads produced by **Digital Instruments** require positive **Zscan sens** values. A positive **Zscan sens** value extends the piezo element with positive voltage. In very rare instances, a Z piezo may exhibit reverse polarity properties (i.e., a positive voltage retracts the piezo element.) In these instances, a negative **Zscan sens** value should be entered.

Contact Digital Instruments/Veeco Metrology Group for more information on the **Z scan sens**.

Current Sens. [STM mode only]

Current Sens. specifies the current sensitivity in STM mode.

Range and Settings:

- Defaults to **10.00 nA/V** (i.e., appropriate gain for standard STM pre-amp).

Retracted [Extended] offset der

Derating applied to the Z scan sensitivity as the Z piezo is offset by fixed voltages. This parameter corrects for Z-axis errors due to the piezo's increased sensitivity at higher voltages, and is expressed as a percentage of the scanner's Z-axis voltage above-below zero.

Range and Settings:

- **0—100%**

Suggested Values:

- **Retracted offset derating = 2.5 percent**
- **Extended offset derating = 7 percent**

Bias derate [mV/nA] (STM only)

Corrects for the bias voltage drop which exists in some STM preamplifiers used on the NanoScope. This parameter only appears when an STM head is selected.

Range and Settings:

- **1 mV/nA** for the standard preamplifier circuit
- **0 mV/nA** for trans impedance low-noise preamplifier circuit

Note: This item ensures the accuracy of the **Bias** voltage parameter on the Real-time STM control panel.

For further instructions on calibrating offset deratings, see the *Calibration* chapter of your system manual.

7.7 Tapping Engage

The **Calibrate/Tapping Engage** commands are designed to assist users in controlling key parameters associated with surface engagement during TappingMode. In former software editions, these parameters were not subject to operator control, being optimized for engagement speed and tip safety *under most conditions*. By using the **Calibrate/Tapping Engage** panel, however, users may minimize engagement times or tapping forces for specific conditions (e.g., TappingMode in fluids, etc.).

CAUTION: Adjustment of the **Tapping Engage** parameters can decrease engagement times during **TappingMode** by speeding the tip's travel to the surface and decreasing the number of test probes. Although this may save time, it also endangers the tip. You should always default to more conservative settings when in doubt; otherwise, you risk breaking tips.



7.7.1 Tapping Engage Panel

The Tapping Engage panel shown in [Figure 7.7a](#) illustrates recommended parameter values for most conditions. These settings yield an engagement time of 20 - 40 seconds.

Figure 7.7a Tapping Engage Panel

Tapping Engage	
Engage delta setpoint:	0.0200
Engage final delta setpoint:	0.00
Engage test threshold:	100
Engage min setpt [%]:	25
TM engage gain:	3.00
Sew tip:	Yes
Sewing trigger [%]:	98
Trigger safety:	20.0 μ m
Pre engage setpoint [%]:	90
Trig channel:	Off
Trig threshold:	0
Scan rate:	TM Deflect
Ramp step:	1.00 μ m

5654

Setpoint values represent percentages of a setpoint established internally by the software for engagement purposes (generally, about 90 percent of the tip's free-air amplitude). These values should *not* be confused with the **Setpoint** value indicated on the **Feedback Controls** panel.

7.7.2 Parameters in the Tapping Engage Panel

Engage delta setpoint

Amount the setpoint is adjusted during each false engage test.

Note: While in **TappingMode**, this tests for false engagement assist in engaging the tip on the sample surface. Tests for false engagement help to avoid artifacts produced by light scatter, fluid film damping, etc. Therefore, a setting of **0.00** (no test for false engagement) is not recommended.

Range and Settings:

- **± 0—0.10** (default: **0.02**) A value of 0.10 (corresponds to ±10%) is the recommended maximum. If set to 0.00, the system will not test for false engagement.

Engage final delta setpoint

Percentage of setpoint value (internally set) to be used *after* tests for false engagement are concluded. This is the amount of temporary "overdrive" used by the system to verify whether the sample is, in fact, engaged by the tip. If this test is passed, the setpoint is restored to the last value used during false engagement tests.

Range and Settings:

- **0.00—0.10** (corresponding to 0 to 10 percent)

Note: This value is usually set equal to the **Engage delta setpoint**. It represents a cumulative value which is eventually reached in a series of **Engage delta setpoint** increments (rather than one, single test). For example, with an engage delta setpoint of 0.02 and a final delta of 0.10, five extra tests will be run after "engagement" to verify that the tip is actually on the surface ($0.10 \div 0.02 = 5$).

Note: If problems persist with false engagement, set the **Engage final delta setpoint** to a value that is 2-3 times the engage delta setpoint.

Engage test threshold

Slope value obtained by dividing the change in Z piezo voltage by the change in setpoint, which ultimately represents an envelope within which engagement is detected.

Range and Settings:

- **100—1000** (default: **100**)

Note: Because changes in Z piezo voltage units occur approximately 200 times per unit change of setpoint, slope values tend to be between **100—1000**.

Note: The higher the slope value, the greater the chance of "false engagement." Lower values are recommended for most applications. Using much lower values may reduce tip life.

Engage min setpoint [%]

Lowest allowable percentage of setpoint value (internally set) used during engagement, representing the "last word" in tip-sample force. This value overrides other parameters determining setpoint during engagement.

Range and Settings:

- **10—90.** (typical value: **25**).

Note: Lower values may endanger the tip and/or sample, as higher tip-sample forces will be employed.

Note: Higher values represent lower, more conservative tip-sample forces; however, very high values will increase false engagements.

TM engage gain

Integral gain value used during TappingMode engagement. Once the surface is engaged, gain values revert to those displayed on the **Feedback Controls** panel.

Range and Settings:

- **0.0100—10.00** (typical values: **0.5-2**)

Hints for optimizing the TM Engage Gain

- As **TM engage gain** is increased, the tip's vertical velocity downward increases. This parameter may be used to speed the engagement process and save time; however, if set too high, the tip and sample may be damaged.
- During engagement, gain values (**Integral** and **Proportional**) displayed on the **Feedback Controls** panel are *not* utilized. Instead, the software sets its own integral gain based on this parameter.
- With normal (non-fluid) samples, higher values tend to accelerate engagement speed at the cost of endangering tips and samples. Use of a higher gain may be recommended for TappingMode scanning of hard samples in fluid; however, gain should be increased cautiously.
- Use of lower gain values will tend to increase engagement times; however, lower values are recommended for soft, delicate samples where impact is to be minimized.

Sew tip

Controls use of sewing during the engagement process to detect the surface. Sewing consists of moving the tip vertically with the Z piezo while lowering it toward the surface. If the surface position is well known, Sewing may be triggered to save time.

Range and Settings:

- **Yes**—Turns sewing on. This is the normal, default mode.
- **No**—Turns sewing off.

Note: Only used for testing purposes; typically results in a damaged tip.

- **Triggered**—Turns sewing on when the RMS amplitude reaches the specified Sewing trigger value. The Triggered switch is used to protect tips and samples and to decrease engagement time.
- **Ramped**-Specifies the distance the motor travels toward the sample.

Sewing trigger [%]

Percentage of oscillation amplitude required to trigger sewing. This parameter is enabled *only* when the Sew tip parameter has been set to Triggered. Default setting is 98; not recommended at values less than 90.

Range and Settings:

- **1—100**; default setting = **98**.

Note: Regardless of setting, this parameter may be overridden by the **Trigger safety** parameter.

Trigger safety [for Dimension series microscopes only]

Minimum height above sample surface at which sewing is turned on. This parameter overrides the Sewing trigger parameter.

Range and Settings:

- **0—100 μm** ; typical setting = **20 μm**

ATTENTION: To avoid damaging the tip or sample, the **Trigger safety** should be set to a value greater than the height of the tip, or the maximum peak-to-valley distance of surface features, whichever is greater. This parameter consists of a height above the surface as determined during the Real-time/**Stage/Focus Surface** command.



Pre engage setpoint [%]

Used to set the setpoint of the tip prior to engagement by reducing the setpoint relative to the RMS amplitude.

Range and Settings

- **50—100**; default = **90**.

Note: The usable range of this parameter is generally from **85** to **95**. This represents the starting value for the engagement cycle (see beginning of this section).

Trig channel

Microscope. Only active when the set top is set to ramped. The **Trip channel** specifies the data channel on **Tapping Engage** **Trig threshold** trigger. Trig channel choices will vary depending on the available inputs. Possible settings include **Off** (which disables the Trigger function), **Deflection**, **Amplitude** and **Phase**.

Trig threshold

Only active when the set top is set to ramped. The **Trigger threshold** is the change in value of the trigger channel that will determine when the tip contacts the surface.

Range and Settings:

- Dependent on selected channel.

Scan rate

Rate at which piezo extends in Z direction (toward surface). Very slow Scan rates (< 0.10 Hz) may prove frustrating; the system completes the present scan before initiating parameter changes.

Range or Settings:

- Min. **0.010**; maximum value depends upon **Number of samples**; normal: 5-10Hz.

Note: Ramping under NT is limited to approximately 30 Hz at 512 samples per line.

Ramp step

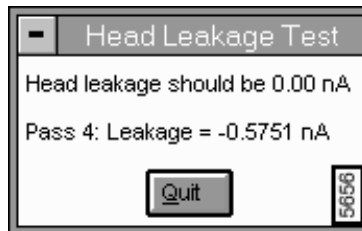
Specifies the distance the motor will travel towards the sample when trying to find the surface (when **Sew tip** has been set to **Ramped**). This feature is used to increase the motor steps when ramped sewing has been activated.

7.8 Leakage (STM and EC STM Only)

The **Leakage** command measures any current leakage between the tip and the Y electrode on the piezo tube of STM heads.

The **Leakage** test display appears on the Control Monitor:

Figure 7.8a Head Leakage Test Panel



As leakage tests are executed, the panel will display the results:

ATTENTION: Quit the panel when a sufficient number of tests have been run.



Hints for Optimizing the Leakage Command

- This command can only be executed if the head is withdrawn. Make sure the tip is not touching the sample when this command is executed.
- Null the preamplifier offset using the Real-time/**Microscope/Offset** command prior to running this command; otherwise, a **Y offset** will appear doubly as leakage.
- Select the **Quit** subcommand to exit the **Leakage** command.
- Head leakage is usually caused by an excess of moisture buildup in the area where the tip holder mounts to the piezoelectric scanner. This problem is greatest where etched tips (which can have some residual salts from the etching process) are used.
- If the measured leakage is greater than 0.2 to 0.5 nanoamps, then clean the area around the tip holder with a cotton swab and alcohol.

Note: Do not use more reactive solvents (i.e., acetone), as they will eat away the protective coating applied to the piezo scanner and tip holder.

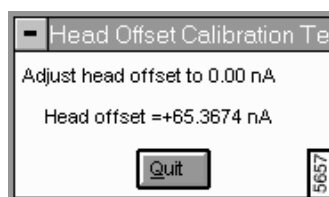
- Head leakage can cause effects such as making the Z center voltage go off-scale when the **Scan size** is increased past a certain point. This is caused by domination of the tunneling current by the leakage current as the **Y scan** voltage increases.
- Each pass takes 8 seconds.

7.9 Offset (STM Only)

The **Offset** command measures the voltage offset of the STM head preamplifier when the tip is withdrawn from the surface. This command allows the voltage offset to be measured and trimmed to zero for standard preamps. Low-noise preamps and Tipview preamps are not adjustable.

The **Offset Calibration Test** panel appears on the Control Monitor, allowing the offset in the head preamplifier to be nulled with the pot on the preamp board (See [Figure 7.9a](#)).

Figure 7.9a Head Offset Calibration Test Panel



Note: Execute only when the tip is withdrawn (use the **Motor/Withdraw** command several times).

Note: Unusually high offsets indicate that the tip is contacting the sample, that the head is disconnected from the base, the microscope is disconnected from the controller, or the controller is turned off or disconnected from the workstation.

See also: Real-time/**Motor** menu: **Withdraw** command. Real-time/**Microscope** menu: **Leakage** command.

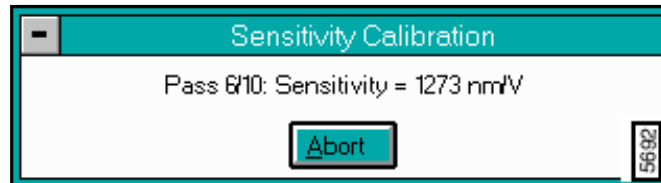
Procedure to Adjust Head Offset

To adjust the preamplifier offset of a head, you would make sure the system is withdrawn, so that there are no high voltages applied to the head (using the **Withdraw** command several times). Connect the desired head to the microscope and make sure the tip was well away from the surface. Finally, after invoking the **Offset** command, adjust the head-offset potentiometer (accessible through the hole in the cover of the head) until the reading is close to zero.

7.10 Sensitivity Calibration

The **Sensitivity** command measures the voltage offset of the STM head preamplifier when the tip is withdrawn from the surface. The **Sensitivity Calibration Test** panel appears on the Control Monitor, showing the sensitivity calibration (See [Figure 7.10a](#)).

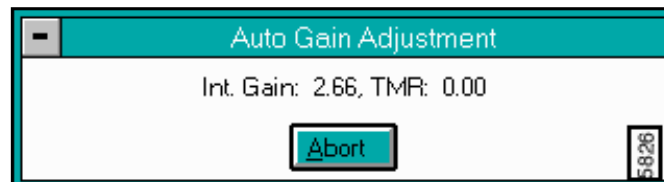
Figure 7.10a Sensitivity Calibration Pane



7.11 Auto Gain Adjust

The **Auto Gain Adjust** command measures Integral Gain of STM head preamplifier when the tip is withdrawn from the surface. The Auto Gain Adjustment panel appears on the Control Monitor, displaying the measurements (See [Figure 7.11a](#)).

Figure 7.11a Auto Gain Adjustment Panel



7.12 Reset

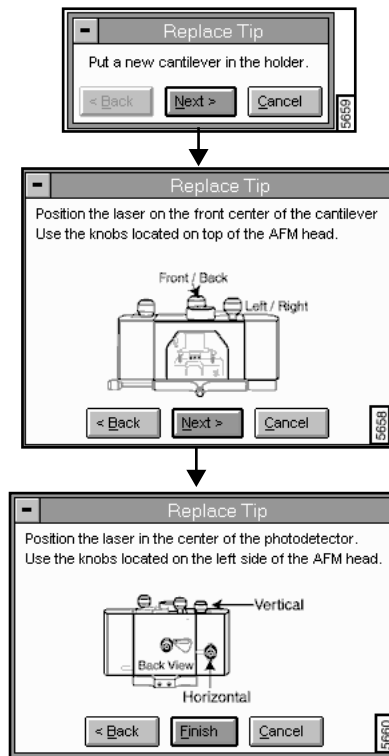
The **Reset** command renews the **Microscope** settings to the default parameters. If the controller is turned off/on without restarting the software, this command needs to be executed.

7.13 Replace Tip (MM AFM Only)

The **Replace Tip** command opens instruction panels when replacing a tip. The function of the panels is to assist the user with the hardware knobs and levers to optimize the tip replacement.

Selecting the **Replace Tip** command accesses a series of **Replace Tip** prompts (See [Figure 7.13a](#)).

Figure 7.13a Replace Tip Prompt Panels



See also: Real-time/Stage/Replace Tip for Dimension series microscopes.

Chapter 8 Vision Menu

This chapter describes the vision system hardware and software components for locating features on sample surfaces using a video camera.

The vision system components discussed in this chapter include:

- **Vision Hardware:** [Section 8.1](#)
- **Vision System Requirements:** [Section 8.2](#)
- **Vision System Interface:** [Section 8.3](#)
- **Vision Control Menu Command:** [Section 8.4](#)

For additional *automated* functions of the Vision System, see the *Automation Supplement Rev A*.

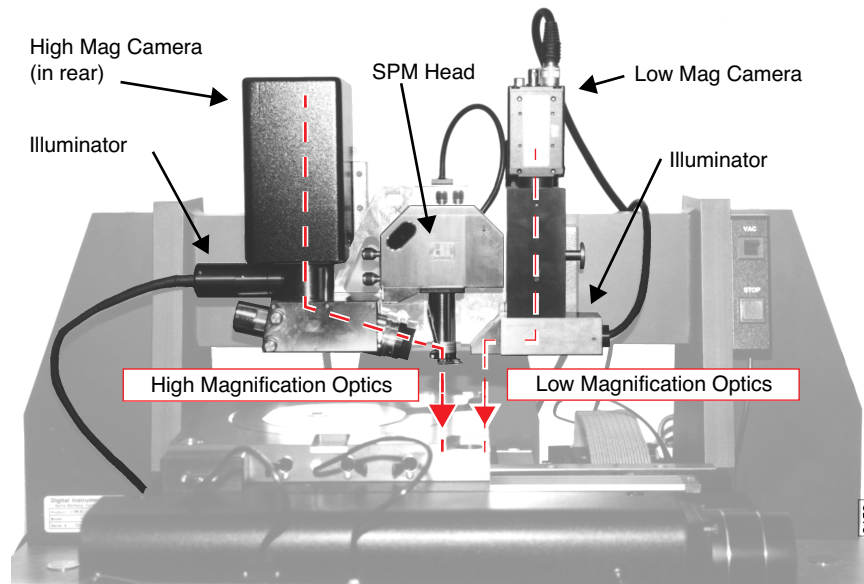
8.1 Vision Hardware

The standard on-axis, high magnification optical system supplied with all Dimension series SPMs is designed to align the probe with sample sites; however, these optics are unsuitable for conducting wide-angle searches. Therefore, a second, wide-angle, low magnification camera is added (as an option) to some microscopes for locating larger patterns with the **Pattern Recognition** option. The low magnification camera is used to align wafers with the microscope stage and to perform other wide-field tasks.

After large patterns are identified using the low magnification camera, the vision control system switches to the microscope's high magnification camera to zoom in on finer features. These finer features are used to determine the wafer's X-Y coordinate system and serve as reference points in all subsequent navigation of the sample.

In [Figure 8.1a](#) the high magnification system shown on the left side of the SPM is supplied with all Dimension series SPMs. Low magnification optics shown on the right side are supplied as a special option.

Figure 8.1a Vision Hardware



8.1.1 Hardware Additions Requirements

Meteor Frame Grabber Board

The Frame Grabber board processes the output from up to four CCD (circuit cable devices) color NTSC cameras residing in the microscope and sends it to the display for viewing.

Low Magnification Optics

An optional set of low magnification optics is added to the right dovetail. The field of view of these optics is large enough ($\sim 8000 \times 6500 \mu\text{m}$) to handle the maximum wafer positioning error of the autoloader ($< 1000 \mu\text{m}$). The low mag optics are offset from the tip high mag optics by about 1.25 inches.

Illumination System

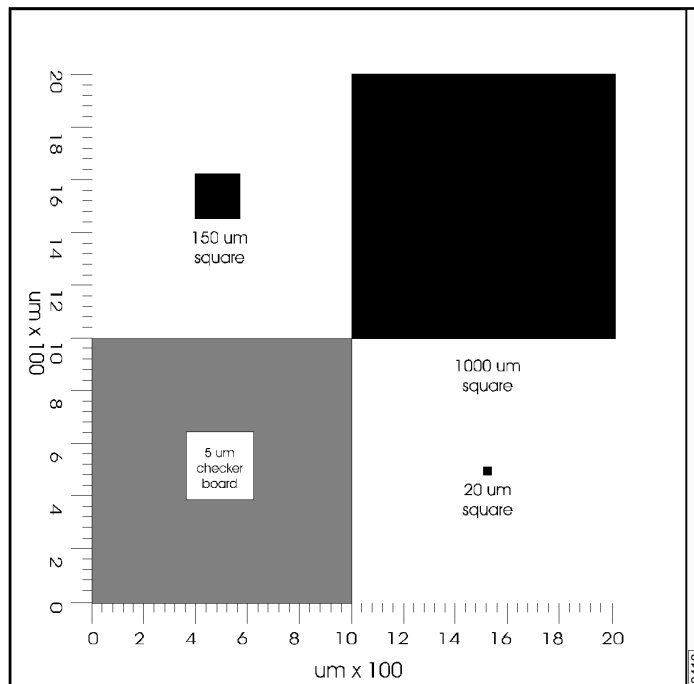
A computer-controlled illumination system is added. This allows the system to save light levels during the macro teach process and restore them during the macro run process. The illumination system consists of a single halogen bulb illuminating two fiber bundles, one for each set of optics. The intensity of the bulb is controlled by a 6811 microprocessor. The 6811 communicates with the PC and NanoScope software through an RS-232 serial port.

Miscellaneous Hardware

Several small system changes have been made to accommodate the vision system:

- An Optical Standard is mounted to the right-rear of the chuck to provide a reference for calibrating both sets of optics. Note that the image is optically inverted (negative) from what is seen through the optics (See [Figure 8.1b](#)).

Figure 8.1b Optical Standard



- The illumination optics are upgraded to improve the contrast of the high magnification optics.
- A hard stop is added to the zoom to improve the repeatability of the zoom.

8.2 Vision System Requirements

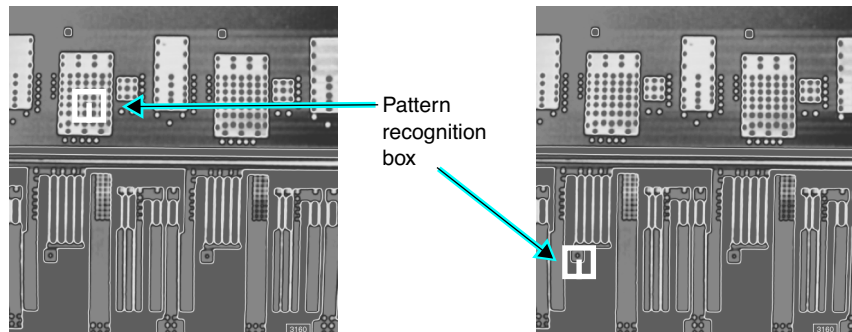
8.2.1 Recognizable Patterns

The Cognex vision control system is capable of recognizing high-contrast features having a distinct, local appearance. These are referred to as “visual models”.

Many wafers are etched with distinct marks to serve as reference points. Corners, contact pads, trace intersections, etc. may all be used as visual models; however, they must be distinct from their surroundings.

Examples of poor visual models include non distinct pads located within a field of identical pads; wafer edges; parallel, identical traces, etc. [Figure 8.2a](#) shows one such example. Features within the box in the left illustration might easily be confused with each other. Features within the box in the right illustration are distinct from those immediately surrounding it.

Figure 8.2a Selection of Visual Model



A good visual model should have few transitions between dark and light, and the transitions should be far apart. The model should have a distinct, local appearance that cannot be confused with any other area nearby.

When teaching a model, the upper-right of the video display shows the position (X-Y) and size (X-Y) of the model, and the total pixels within the model. Model size is limited to 65535 pixels or less. An error message is displayed if the model is 65536 pixels or greater. The optimum size of a model is in the range of 75 to 200 pixels on a side. A model that is too large takes a long time to save and load. A model that is too small requires a longer search time.

8.2.2 Illumination Control

Both the high magnification camera and the low magnification camera are equipped with on-axis, fiber optic illumination supplied by the same halogen lamp. The halogen lamp's intensity is controlled by the **Illumination** software parameter. When a visual model is saved, the level of illumination is saved along with it.

The illumination intensity is crucial to the ability of the vision control system to distinguish features:

- The lower the magnification, the lower the illumination intensity required. Too much light at low magnification washes out features, making them impossible to see. Conversely, higher magnification requires more light.

- Illuminate features as brightly as possible *without washing them out*. You want features to be imaged with adequate contrast against their backgrounds and reduced tonal differences between one visual model and another.

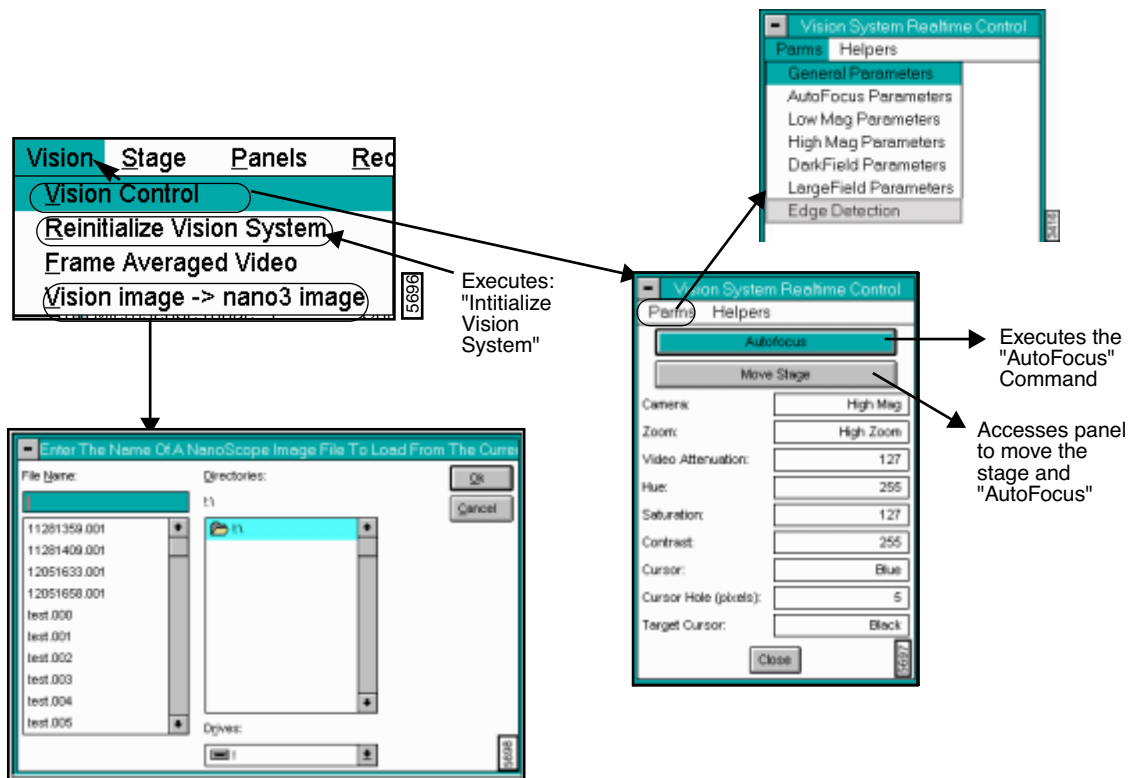
8.2.3 Rotational Alignment of Features

The Cognex recognition system allows most features to be recognized within angular orientations of ± 7.5 degrees. The robot employed with Dimension series SPMs is designed to locate samples with an angular accuracy of ± 0.25 degrees. Therefore, rotation is normally not a problem with automatically loaded samples. When manually loading samples, you can reduce rotational alignment problems by ensuring that the samples are squarely positioned.

8.3 Vision System Interface

Figure 8.3a illustrates the Vision menu panels and parameters associated with typical MultiMode and Dimension series microscopes. Additional parameters and menus appear for systems configured with automated features (i.e., robot functions).

Figure 8.3a Navigating in the Vision Menu



8.4 Vision Control Menu Command

From the **Vision** menu item, select **Vision Control** to display the **Vision System Real Time Control** panel. The purpose of the **Vision System Control** panel includes :

- Adjusts parameters for the currently selected camera and monitor.
- Assigns and recalls filenames for visual models and parameters.

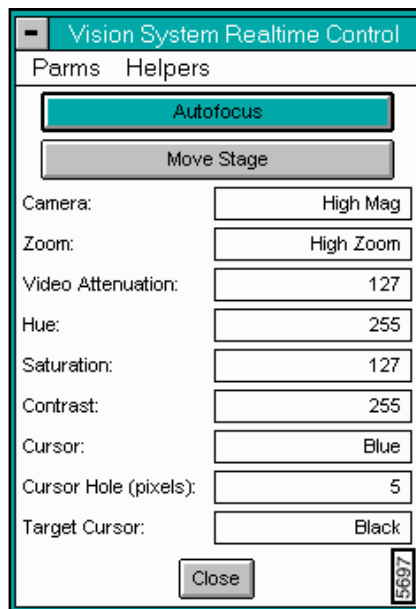
Note: On a Dimension series microscopes that include a stage and the pattern recognition option, a number of additional parameters are available. See, *The Automation Supplement* (Version 5.13) for details on the parameters associated with automated systems.

Refer to the following Vision Control sections:

- **Vision Control Panel:** [Section 8.4.1](#)
- **Buttons on the Vision System Realtime Control Panel:** [Section 8.4.2](#)
- **Parameters on the Vision System Real-time Control Panel:** [Section 8.4.3](#)
- **Parms Submenu:** [Section 8.4.4](#)
- **General Parameters:** [Section](#)
- **AutoFocus Button [Auto Focus Parms Panel]:** [Section](#)
- **Helpers Submenu on the Vision Control Panel:** [Section 8.4.5](#)

8.4.1 Vision Control Panel

Figure 8.4a Vision Control Panel

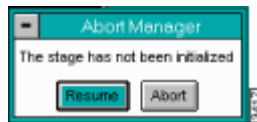


8.4.2 Buttons on the Vision System Realtime Control Panel

AutoFocus

Executes the Auto Focus command. If the stage is not initialized, you are informed of this condition and given the opportunity to **ABORT** or **RESUME** (See [Figure 8.4b](#)).

Figure 8.4b Abort Prompt



Selecting the **ABORT** button discontinues Vision Control and returns you to the Real Time environment (scan controls, channel controls, etc.). Selecting the **RESUME** button opens the **Vision Control** panel, but any vision system functions that require stage motion (e.g., **Camera** selection, **MOVE STAGE** button) do not operate properly.

Move Stage

The **MOVE STAGE** button accesses a panel allowing trackball stage control, stage control using the panel buttons and direct camera control.

8.4.3 Parameters on the Vision System Real-time Control Panel

Camera—Defines the current camera selection and allows the user to select a different camera.

Range or settings: **Low Mag.** or **High Mag.**

Zoom—Shows the current zoom setting and allows the user to select a different zoom setting.

Range or settings: **Low Zoom** or **High Zoom**

Illumination—Shows the current illumination (light) level and allows the user to select a different illumination setting.

Range or settings: **0** (min. light) - **100** (max. light).

Video Attenuation—Shows the current value of the video attenuation (hardware control over the video signal strength similar to the “Brightness” knob on a TV set) and allows the user to change the attenuation.

Range or settings: **0** attenuation is very bright - **100** attenuation (maximum) is very dark.

Hue—Controls the color value of the displayed image.

Saturation—Sets the value of the color intensity.

Contrast—Enhances or degrades the contrast in the image.

Range or settings: **0** (min. contrast) - **255** (max. contrast)

Cursor—Defines the color of the main cursor. Also allows the cursor to be disabled.

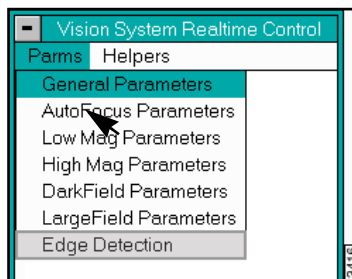
Cursor Hole (pixels)—Sets the number of pixels open at the center of the cursor where the horizontal and vertical lines meet.

Target Cursor—Defines the color of the “target cursor”. The target cursor controls the color of the box used to define models for pattern recognition.

8.4.4 Params Submenu

The **Params** pull-down menu on the **Vision System Real-time Control** panel provides access to additional parameter panels.

Figure 8.4c Params Submenu on Real-time Control Panel

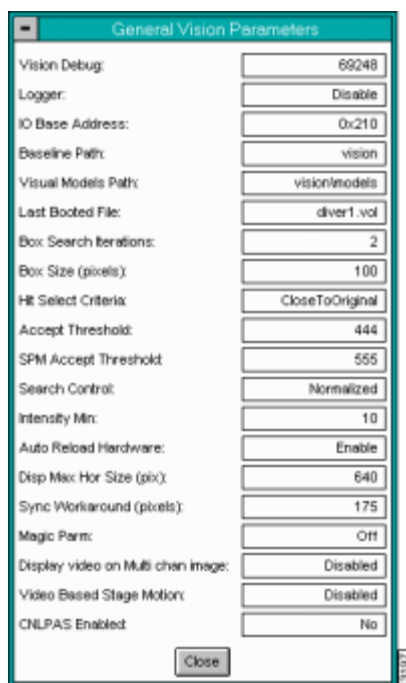


General Parameters

The **General Vision Parameters** dialog box contains parameters for controlling vision paths and general vision functions.

Note: All of the fields display, even if a particular parameter is not available.

Figure 8.4d General Vision Parameters Dialog Box



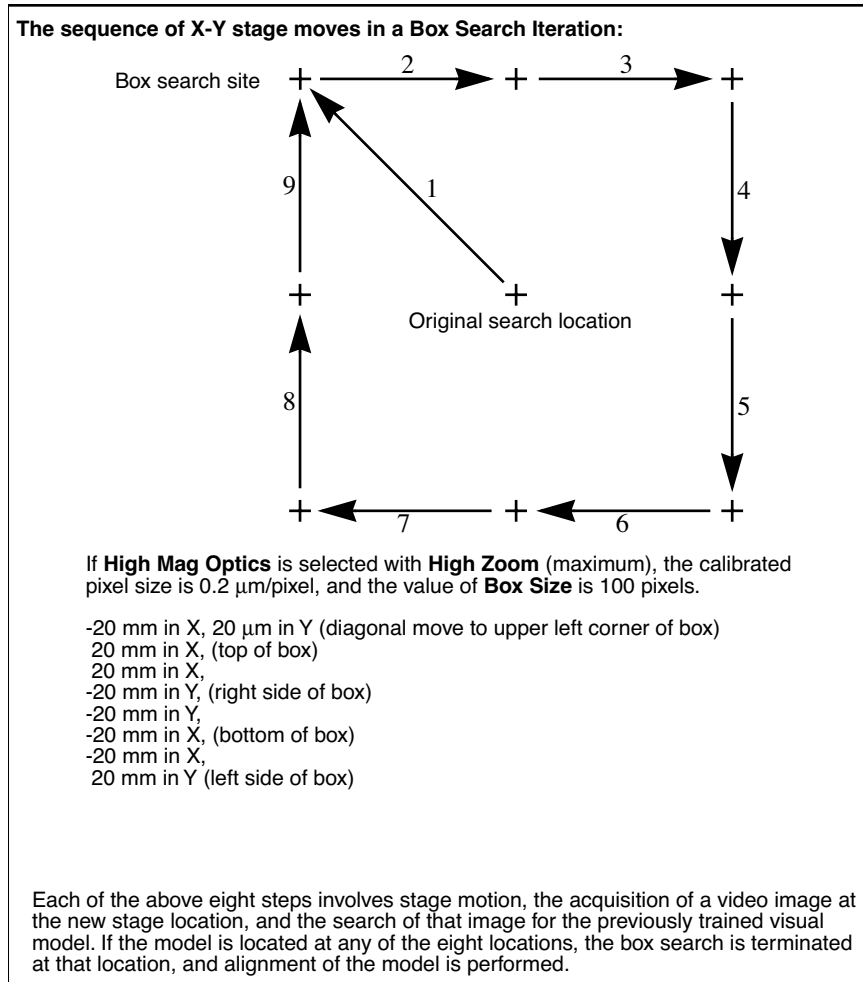
Parameters on the General Vision Parameters Panel

- **Vision Debug**
 - The **Vision Debug** parameter is a diagnostic tool for controlling the quantity of information that is displayed in the **Vision Debug** box (**Ctrl-Alt-V**). The default value is **0** (no debug information). Increasing values cause more information to be displayed in the **Vision Debug** box when commands are sent to the vision system.
- **Logger**
 - The **Logger** parameter allows you to enable or disable the logging function. If enabled, the **Logger** enters the vision errors in the **Vision Debug** file. If disabled, vision errors are not logged.
- **IO Base Address**—This field is obsolete.
- **Baseline Path**
 - The **Baseline Path** parameter defines where the boot files for initializing the vision system are located on the NanoScope hard disk. The default directory is `c:\spm\vision`.
- **Visual Models Path**

- The **Visual Models Path** parameter defines the path for loading and saving visual models. The default path is `c:\spm\vision\models`.
- **Last Booted File**—This field is obsolete.
- **Box Search Iterations**
- The **Box Search Iterations** parameter defines the maximum number of boxes around the original search location which are allowed during a box search. A box search is conducted during a look if 1) the visual model is not found at the initial search location, and 2) the **Box Search** parameter is enabled for that look.
- The default is **2** boxes, with options of **0** to **10** boxes.
- With **Box Search Iterations** set to **1**, the X-Y stage moves to obtain a series of images with the centerpoints of the images forming a square box (in the X-Y plane) around the original image center. The length of each side of the depicted box is twice the value of the **Box Size (pixels)** parameter. See the example in [Figure 8.4e](#).
- The actual size of the box in microns depends on the camera, zoom, and the associated calibration parameter (microns per pixel) as set in the **Low Mag Optics** or **High Mag Optics Parameters** (See and).
- When the parameter **Box Search Iterations** is greater than 1, each successive box increases in size such that the length of the side increases by:
- $2 \times \text{Box Size (pixels)} \times \text{microns per pixel}$

Figure 8.4e Box Search Iterations Example

- **Box Size (pixels)**
- The **Box Size** parameter defines the X or Y distance in pixels of two successive looks during a box search. The size of the box through which the stage moves is defined by twice the value of **Box Size (pixels)**. See the discussion of “[Box Search Iterations](#)” on [page 8-183](#).
- **Hit Selection Criteria**
- The **Hit Selection Criteria** parameter determines the method used by the vision system when it finds multiple locations during the search for a model (i.e., two or more areas of the video correlate with the model).
- **Best Score**—Selects the location with the highest score. This is the default and is appropriate for most applications.
- **Close to Original**—Selects the location closest to the screen position of the model when the model was taught. This method is appropriate for regular use of pattern recognition on images that have repeated or ambiguous features. While pattern



recognition can dither between the ambiguous locations when aligning the pattern, the **Close to Original** option consistently uses the model closest to the original alignment.

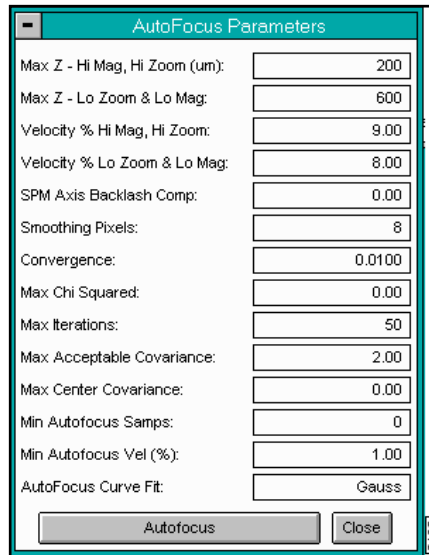
- **Accept Threshold**
- When the software compares a location to the model it was taught, it uses the **Accept Threshold** minimum correlation score to determine if the location is acceptable.
- The default is **500**, with a range of **1** to **1000**.
- **SPM Accept Threshold**
- When the software compares a location to the model it was taught, it uses the **SPM Accept Threshold** minimum correlation score to determine if it is an acceptable SPM location.

- The default is **500**, with a range of **1** to **1000**.
- **Search Control**
- The **Search Control** parameter establishes the type of correlation values used to determine acceptability.
- **Normalized**—Correlation values are acceptable from **0** to **1000**. This is the default value.
- **Absolute**—The absolute value of the correlation score is acceptable; therefore, the software recognizes locations that are inverted or optical negative of the original model.
- **Intensity Min**
- The **Intensity Minimum** parameter determines the acceptable threshold for a location's average pixel intensity (brightness).
- The default is **10**, with a range of **0** to **255**.
- **Auto Reload Hardware** —This field is obsolete.
- **Disp Max Hor Size (pix)**—This field is obsolete.
- **Sync Workaround (pixels)**—This field is obsolete.
- **Magic Parm**—This field is obsolete.
- **Display video on Multi chan image**
- When capturing images in multi channels, the **Display video on Multi channel image** parameter enables or disables the video. If **Disabled** (default), only the channel captures display. If **Enabled**, the channel captures and the video screen are sized to display simultaneously.
- **Video Based Stage Motion**
- The **Video Based Stage Motion** parameter determines whether or not you can indicate stage position from the video screen. If **Enabled**, double-clicking on a point in the video display causes the stage to move so that the indicated point is aligned beneath the video display cross hair. To work well, this option requires good pixel calibration.
- The default is **Disabled**.

AutoFocus Parameters Panel [Parms Submenu Item]

Access the **AutoFocus Parameters** panel in the **Vision System Control / Parms** submenu. Select **AutoFocus Parameters**.

Figure 8.4f AutoFocus Parameters Panel



Max Z - Hi Mag, Hi Zoom (μm)

- This parameter defines the total Z (SPM) axis excursion during **AutoFocus** for the high mag camera at high zoom setting. The actual downward movement is half the value set in the parameter, after which it raises the full value gathering focus data. The default value is **200** μm , with a range of **0** to **2000** microns.
- At the default setting, the **AutoFocus** algorithm moves the SPM axis 50 μm down at maximum velocity, then move the SPM axis up slowly (defined by the **Velocity % Hi Mag, Hi Zoom** parameter) 100 μm during which focus data is gathered. If an optimum focus point is detected, the SPM axis is moved down to that point at maximum velocity.

Max Z - Lo Zoom & Lo Mag

- This parameter defines the maximum Z (SPM) axis excursion during **AutoFocus** when either the **Low Mag** camera is selected or the **High Mag** camera is selected at the **Low Zoom** setting. The default is **600** μm , with a range of **0** to **2000** microns.

Velocity % Hi Mag, Hi Zoom

- This parameter defines the Z (SPM) axis velocity for the data collection phase of **AutoFocus** when the **Hi Mag** camera and **Hi Zoom** settings are selected. The velocity is specified as a percentage of the maximum SPM axis velocity. The default is **7%** (of maximum velocity), with a range of **0** to **100%**

Velocity% Lo Zoom & Lo Mag

- This parameter defines the Z (SPM) axis velocity for the data collection phase of **AutoFocus** as a percentage of the maximum velocity when either **Low Mag** optics or **High Mag** optics is selected at the **Low Zoom** setting. The default is **25%** (of maximum velocity), range of **0** to **100%**

SPM Axis Backlash Comp

- This parameter defines the backlash compensation in microns during **AutoFocus** for the downward -Z (SPM) axis movement. The default value is **0.0** μm (no compensation), with a range of **0.0** to **100.0** μm .

Smoothing Pixels

- During data collection the **AutoFocus** algorithm repeatedly performs the following operations: 1) video acquisition, 2) windowing of acquired data, 3) smoothing of the windowed data, and 4) calculation of the differential-sum (sharpness) of the smoothed data.
- The number of pixels over which the data is smoothed is defined by the **Smoothing Pixels** parameter. The default is **8** pixels, with a range of **0** to **8**.

Convergence

- After the **AutoFocus** data collection phase is complete, the resulting data relates focus (sharpness) to SPM axis position. This data is then fit to a Gaussian function using an iterative non-linear algorithm. The **Convergence** parameter determines how closely the Gaussian curve must fit. The default is **0.01**, with a range of **0.00** to **1.00**.

Max Chi Squared

- The **Maximum Chi Squared** parameter originally provided an iterative look for **AutoFocus** to aid in asymmetrical curves. This parameter is now *obsolete*.

Max Iterations

- The **Max Iterations** parameter defines the maximum number of attempts to make the **AutoFocus** data fit a Gaussian curve. If **Convergence** does not occur within this number of iterations, then the covariance of each of the Gaussian function parameters (height, width, center) is checked to determine if a fit has been obtained.
- The default is **100** iterations, range: up to **1000**.

Max Acceptable Covariance

- At the completion of a curve fit, the covariance of the height, width, and center of the Gaussian function are provided by the curve fit algorithm. The **Max Acceptable Covariance** parameter defines the greatest tolerable covariance for a successful curve fit. If any of the three covariance are greater than the value of this parameter, **AutoFocus** fails.

Max Center Covariance

- The **Maximum Center Covariance** parameter defines the greatest tolerable covariance for a successful curve fit relative to *only* the center value. At the completion of a curve fit, the covariance of the height, width, and center of the Gaussian function are provided by the curve fit algorithm. The default is **0** iterations, range: **0** to **100**.

Min Autofocus Samps

- The **Minimum AutoFocus Samples** parameter defines the number of pictures snapped during the **AutoFocus** routine. This parameter works in conjunction with the **Minimum AutoFocus Velocity** parameter. The higher the number of samples requested, the slower the **AutoFocus**.
- The default is **0** samples, with a range of **0** to **100**.

Min Autofocus Vel (%)

- The **Minimum AutoFocus Velocity** parameter defines the minimum speed of the **AutoFocus** routine. This parameter works in conjunction with the **Minimum AutoFocus Samples** parameter. The slower the velocity, the slower the **AutoFocus**.
- The default is **0%**, with a range of **0** to **100%**.

AutoFocus Curve Fit

- The **AutoFocus Curve Fit** parameter determines the type of curve to apply to the data during **AutoFocus**.
- **Gaussian**—Fits the data to a smooth, symmetrical curve. This is the default value.
- **Asymmetric**—Recognizes asymmetry and fits the data appropriately to recognize the asymmetry. Use this type if the curve is known to be asymmetrical or if dealing with a dramatic step.

AutoFocus Button [Auto Focus Params Panel]

The **AUTOFOCUS** button provides you with the ability to execute the **AutoFocus** algorithm from within the parameters adjustment box.

AutoFocus performs the following operations using the values set in **AutoFocus Parameters** panel:

AutoFocus moves the Z (SPM) axis down X microns, where X is determined by the **Max Z** parameter for the currently selected optics. The actual downward movement is half the value set in the parameter, after which it raises the full value gathering focus data.

Backlash compensation is used if the **SPM Axis Backlash Comp** parameter is non-zero (i.e., downward motion is 150 percent of the parameter's value, then the Z axis moves upward by the amount of the backlash parameter).

AutoFocus commands the stage to move upward by **Max Z** amount at the percentage of maximum velocity defined by the appropriate **Velocity %** parameter.

Simultaneously, the vision system hardware repeatedly executes the following:

- Saves stage Z position for this pass.
- Acquires image in frame buffer.
- Identifies appropriate window of frame buffer image—center quarter of image for **Low Mag** optics or **High Zoom, High Mag** optics, or center (vertical), left (vertical) quarter of image for **Low Zoom, High Mag** optics.
- Checks window contrast and generates error if too low (<1.0).
- Smooths window according to **Smoothing Pixels** parameter value.
- Executes differential-sum algorithm on smoothed window (sharpness calculation).
- Repeats until stage motion completes.

AutoFocus then fits the acquired stage Z and sharpness data pairs to a Gaussian curve using the Levenberg-Marquardt method (nonlinear, steepest descent) and checks for convergence while iterating (**Convergence** and **Max Iterations** parameters).

AutoFocus verifies that the variances of the values that define the Gaussian curve (height, width, center) are sufficiently low (**Max Acceptable Covariance** parameter) and verifies that the computed center is within the range of motion through which the stage moved (**Max Z**).

If the settings for AutoFocus are met, the stage is moved downward in Z to the “sharpest” point, the center of the Gaussian curve. The downward motion includes backlash compensation if the backlash parameter is non-zero.

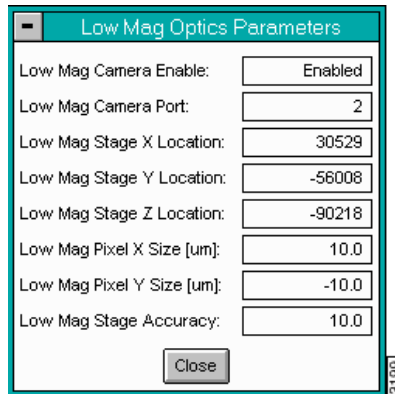
If any single constraint is not met, the Z stage is sent back to the position at which **AutoFocus** was initiated, and a failure message is displayed.

Low Mag Parameters [Parms Submenu]

Low magnification is available on systems with the Pattern Recognition option.

The **Low Mag Optics Parameters** panel provides access to parameters related to the behavior of the **Low Mag** optics within the vision system.

Figure 8.4g Low Mag Optics Parameters Panel



Low Mag Camera Enable

- The **Low Mag Camera Enable** parameter allows you to enable and disable the low mag optics. If set to **Disabled**, the other **Low Mag Parameters** are unavailable.

Low Mag Camera Port

- This parameter designates the port (either **1** or **2**) to which the low mag camera is connected. Changes to this parameter take effect on initialization only (restart `z.exe`). The default is port **2**.

Low Mag Stage X Location

- This parameter defines the X position (absolute) of the X-Y stage when the stage is at the **Low Mag** optics calibration position. The parameter is set when the **Low Mag** optics calibration function is executed or taught. This parameter is usually grayed-out and cannot be directly modified.
- The default is **0** counts (microns) range of -1000000 to 1000000 μm .

Low Mag Stage Y Location

- This parameter defines the Y position (absolute) of the X-Y stage when the stage is at the **Low Mag** optics calibration position.
- The parameter is set when the **Low Mag** optics calibration function is executed or taught. This parameter is usually grayed-out and cannot be directly modified.
- The default is **0** counts (microns) range of -1000000 to 1000000 μm .

Low Mag Stage Z Location

- This parameter defines the Z position (absolute) of the Z stage when the stage is at the **Low Mag** optics calibration position. The parameter is set when the **Low Mag** optics calibration function is executed or taught. This parameter is usually grayed-out and cannot be directly modified.
- The default is **0** counts (microns) range of -1000000 to 1000000 μm .

Low Mag Pixel X Size [μm]

- This parameter defines the size of a pixel in μm in the X direction for the low mag camera. The default is **10.0** μm , with a range from **-1000** to **1000** μm .
- When coarse alignment occurs, the vision system determines the number of pixels along the X axis between the current location of the model and the taught location of the model. Using the value of this parameter, the number of pixels is converted to μm for subsequent stage motion to correct the alignment error in the X direction.
- You calculate this number by converting the video image of the 1000 μm square on the Optical Standard to a NanoScope image using the vision system function **Video image->Nano3 image**. Use the **Off-line/View/Top View** utility to measure the apparent width of the square, calculate the percent of error, and modify this parameter accordingly.

Low Mag Pixel Y Size [μm]

- This parameter defines the size of a pixel in μm in the Y direction for the **low mag** camera. The default is **-10.0** μm , with a range from **-1000** to **1000** μm .
- When coarse alignment occurs, the vision system determines the number of pixels along the Y axis between the current location of the model and the taught location of the model. Using the value of this parameter, the number of pixels is converted to μm for subsequent stage motion to correct the alignment error in the Y direction.

- You calculate this number by converting the video image of the 1000 microns square on the Optical Standard to a NanoScope image using the vision system function **Video image->Nano3 image**. Use the Off-line/**View/Top View** utility to measure the apparent width of the square, calculate the percent of error, and modify this parameter accordingly. This number is generally negative, because the positive Y direction of the X-Y stage is opposite that of the vision system.

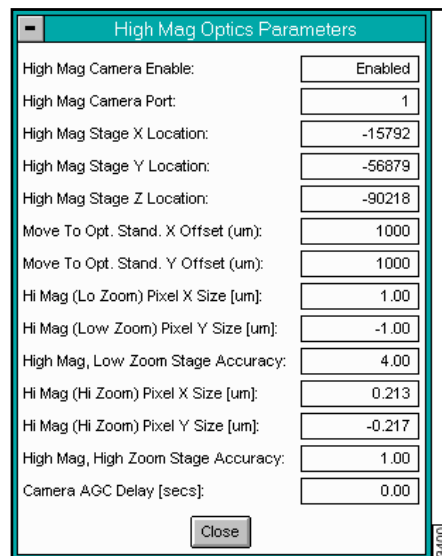
Low Mag Stage Accuracy

- This parameter defines the accuracy threshold the vision system must meet when attempting to null errors during registration between the current screen location of the model and the taught location of the model.
- For example, if the vision system determines that the error between the current screen location of the video model and the taught location of the video model is 5 microns, and the **Low Mag Stage Accuracy** is set to 10 microns, then no error correction is attempted.
- This parameter applies to both the X and Y axes. Typically, the **Low Mag Stage Accuracy** should be greater than or equal to the pixel size of the camera.

High Mag Parameters [Parms Submenu]

The **High Mag Optics Parameters** panel gives you access to parameters related to the behavior of vision system **High Mag** optics (See [Figure 8.4h](#)).

Figure 8.4h High Mag Optics Parameters Panel



High Mag Optics Parameters	
High Mag Camera Enable:	Enabled
High Mag Camera Port:	1
High Mag Stage X Location:	-15792
High Mag Stage Y Location:	-56879
High Mag Stage Z Location:	-90218
Move To Opt. Stand. X Offset (um):	1000
Move To Opt. Stand. Y Offset (um):	1000
Hi Mag (Lo Zoom) Pixel X Size [um]:	1.00
Hi Mag (Low Zoom) Pixel Y Size [um]:	-1.00
High Mag, Low Zoom Stage Accuracy:	4.00
Hi Mag (Hi Zoom) Pixel X Size [um]:	0.213
Hi Mag (Hi Zoom) Pixel Y Size [um]:	-0.217
High Mag, High Zoom Stage Accuracy:	1.00
Camera AGC Delay [secs]:	0.00
Close	

High Mag Camera Enable

- The **High Mag Camera Enable** parameter allows you to enable and disable the high mag optics. If set to **Disabled**, the other **High Mag Parameters** are unavailable.

High Mag Camera Port

- This parameter designates the port (either **1** or **2**) to which the high mag camera is connected. Changes to this parameter take effect on initialization only (restart `z.exe`). The default is port **1**.

High Mag Stage X Location

- This parameter defines the X position (absolute) of the X-Y stage when the stage is at the **High Mag** optics calibration position.
- (continued on next page...)
- The parameter is set when the **High Mag** optics calibration function is executed or taught. This parameter is usually grayed-out and cannot be directly modified.
- The default is **0** counts (microns), range of -1000000 to 1000000 μm .

High Mag Stage Y Location

- This parameter defines the Y position (absolute) of the X-Y stage when the stage is at the **High Mag** optics calibration position. The parameter is set when the **High Mag** optics calibration function is executed or taught. This parameter is usually grayed-out and cannot be directly modified.
- The default is **0** counts (microns), range: 1000000-1000000 μm

High Mag Stage Z Location

- This parameter defines the Z position (absolute) of the Z stage when the stage is at the **High Mag** optics calibration position. The parameter is set when the **High Mag** optics calibration function is executed or taught. This parameter is grayed-out and cannot be directly modified.
- The default is **0** counts (microns), range of -1000000 to 1000000 μm .

Move To Opt. Stand. X Offset (μm)

- The **Move to Optical Standard X Offset (μm)** parameter defines the X distance in microns from the center of the optical standard to the point which the stage must move after selecting the **Move to Optical Standard** command.
- The default is **1000 μm** , range of **-2000 to 2000**

Move To Opt. Stand. Y Offset (μm)

- The **Move to Optical Standard Y Offset (μm)** parameter defines the Y distance in microns from the center of the optical standard to the point which the stage must move after selecting the **Move to Optical Standard** command.
- The default is **-1000 μm** , with a range of **-2000 to 2000**.

High Mag (Lo Zoom) Pixel X Size [μm]

- This parameter defines the **High Mag (Low Zoom)** camera's X axis pixel size. The default is **1.0 μm** , with a range from **-1000 to 1000 μm** .
- When coarse alignment occurs, the vision system determines the number of pixels along the X axis between the current location of the model and the taught location of the model. Using the value of this parameter, the number of pixels is converted to μm for subsequent stage motion to correct the alignment error in the X direction.
- You calculate this number by converting the video image of the 150 μm square on the Optical Standard to a NanoScope image using the vision system function **Video image->Nano3 image**. Use the **Off-line/View/Top View** utility to measure the apparent width of the square, calculate the percent of error, and modify this parameter accordingly.

High Mag (Low Zoom) Pixel Y Size [μm]

- This parameter defines the **High Mag (Low Zoom)** camera's Y axis pixel size. The default is **-1.0 μm** , with a range from **-1000 to 1000 μm** .
- When coarse alignment occurs, the vision system determines the number of pixels along the Y axis between the current location of the model and the taught location of the model. Using the value of this parameter, the number of pixels is converted to μm for subsequent stage motion to correct the alignment error in the Y direction.
- You calculate this number by converting the video image of the 150 μm square on the Optical Standard to a NanoScope image using the vision system function **Video image->Nano3 image**. Use the **Off-line/View/Top View** utility to measure the apparent width of the square, calculate the percent of error, and modify this parameter accordingly. This number is generally negative because the positive Y direction of the X-Y stage is opposite the vision system.

High Mag, Low Zoom Stage Accuracy

- This parameter defines the accuracy threshold the vision system must meet when attempting to null errors during registration between the current screen location of the model and the taught location of the model. The default is **4.0 μm** , with a range of **0 to 1000000** microns.
- For example, if the vision system determines that the error between the current screen location of the video model and the taught location of the video model is 2 microns, and the **High Mag, Low Zoom Stage Accuracy** is set to 4 microns, then no error correction is attempted.
- This parameter applies to both the X and Y axes. Typically, the **High Mag, Low Zoom Stage Accuracy** should be greater than or equal to the pixel size of the camera.

High Mag (Hi Zoom) Pixel X Size [μm]

- This parameter defines the **High Mag (High Zoom)** camera's X axis pixel size. The default is **0.214 μm** , with a range from **-1000 to 1000 μm** .
- When fine alignment occurs during registration, the vision system determines the number of pixels along the X axis between the current location of the model and the taught location of the model.
Using the value of this parameter, the number of pixels is converted to μm for subsequent stage motion to correct the alignment error in the X direction.
- You calculate this number by converting the video image of the 20 μm square on the Optical Standard to a NanoScope image using the vision system function **Video image->Nano3 image**. Use the Off-line/**View/Top View** utility to measure the apparent width of the square, calculate the percent of error, and modify this parameter accordingly.

High Mag (Hi Zoom) Pixel Y Size [μm]

- This parameter defines the **High Mag (High Zoom)** camera's Y axis pixel size. The default is **-0.214 μm** , with a range from **-1000 to 1000 μm** .
- When fine alignment occurs during registration, the vision system determines the number of pixels along the Y axis between the current location of the model and the taught location of the model.
Using the value of this parameter, the number of pixels is converted to μm for subsequent stage motion to correct the alignment error in the Y direction.
- Calculate this number by converting the video image of the 20 μm square on the Optical Standard to a NanoScope image using the vision system function **Video image->Nano3 image**. Use the Off-line/**View/Top View** utility to measure the apparent width of the square, calculate the percent of error, and modify this parameter accordingly. This number is generally negative because the positive Y direction of the X-Y stage is opposite the vision system.

High Mag, High Zoom Stage Accuracy

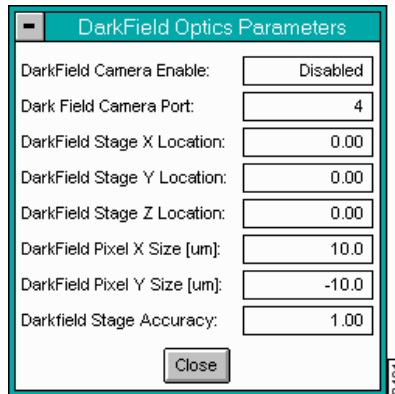
- This parameter defines the accuracy threshold the vision system must meet when attempting to null errors during registration between the current screen location of the model and the taught location of the model. The default is **1.0 μm** , with a range of **0** to **1000000** microns.
- For example, if the vision system determines that the error between the current screen location of the video model and the taught location of the video model is 0.5 microns, and the **High Mag, High Zoom Stage Accuracy** is set to 1 micron, then no error correction is attempted.
- This parameter applies to both the X and Y axes. Typically, the **High Mag, High Zoom Stage Accuracy** should be greater than or equal to 1 μm , the step size of the X-Y stage.

Camera AGC Delay (Secs)

- The **Camera Automatic Gain Control** parameter controls the time allowed for the camera iris and processor to determine acceptable brightness of the image.
- The default is **0 seconds**, with a range of **0** to **1000**.

DarkField Parameters [Parms Submenu]

Figure 8.4i DarkField Optics Parameters Panel

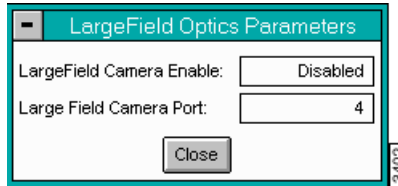


The DarkField parameters are similar to those for low magnification, as described on [Page 190](#).

Large Field Parameters [Parms Submenu]

The Large Field parameters allow you to enable/disable the Large Field camera and to specify the port to which the Large Field camera is connected.

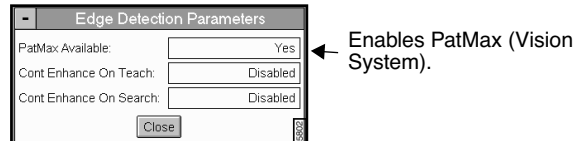
Figure 8.4j LargeField Optics Parameters Panel



Edge Detection

This function accesses a panel to enable the **Vision** system type (See Figure 8.4k).

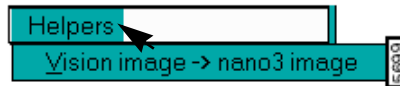
Figure 8.4k Edge Detection Parameters Panel



8.4.5 Helpers Submenu on the Vision Control Panel

Several functions are available in the **Helpers** pull-down menu on the **Vision System Real-time Control** panel.

Figure 8.4l Helpers Submenu on Vision System Real-time Control Panel



Vision Image->Nano3 Image

The **Vision Image->Nano3 Image** function translates the vision image to a NanoScope compatible image for analysis.

For example, you can calculate a number by converting the video image of the 1000 μm square on the Optical Standard to a NanoScope image using the vision system function **Video image->Nano3 image**.

Then use the **Off-line / View / Top View** utility to measure the apparent width of the square, calculate the percent of error, or modify the image.

Vision Menu

Vision Control Menu Command

Chapter 9 Stage and Recipe Menus

The commands in the **Stage** menu pertain to the movement and calibration of stage systems. The commands in the **Recipe** menu control teaching the microscope to perform automated functions. For further details on the **Recipe** menu commands, see *The Automation Supplement* or your system manuals.

This chapter details the following **Stage** and **Recipe** commands:

- **Overview of the Stage Command:** [Section 9.1](#)
- **Stage Menu Interface:** [Section 9.2](#)
 - **Load New Sample** [Section 9.3](#)
 - **Locate Tip** [Section 9.4](#)
 - **Focus Surface** [Section 9.5](#)
 - **Move To (x, y) (Dimension Series only)** [Section 9.6](#)
 - **Set Reference (Dimension Series only)** [Section 9.7](#)
 - **Programmed Move (Dimension Series Only)** [Section 9.8](#)
 - **Replace Tip (D3000 Series)** [Section 9.9](#)
 - **Scaling** [Section 9.10](#)
 - **Set Image Center (Dimension 5000/9000 only)** [Section 9.11](#)
 - **Initialize** [Section 9.12](#)
 - **SPM Parameters** [Section 9.13](#)
 - **Set Z Exclusion** [Section 9.14](#)
- **Recipe Commands** [Section 9.15](#)

9.1 Overview of the Stage Command

The **Stage** menu appears whenever Dimension™ Series microscopes are selected using the **Microscope / Select** command. The Dimension 3000 features two stage types: a manual (hand-cranked) version; and an open-loop, motorized version. Dimension 9000 microscopes feature a large sample stage having high-precision, closed-loop positioning for such materials as silicon wafers and computer hard drive media. These stages consist of stacked, perpendicular X- and Y-axis slides.

9.1.1 Mounting Samples

Stages come equipped with vacuum chucks, which are the usual choice employed for securing samples; an outside source of vacuum is required. Operators should be cautious when handling larger samples with the vacuum chuck—an 8-inch wafer held using 5 psi vacuum sustains a loading of 250 lbs. If debris is trapped between the stage and wafer, the wafer may become scratched or broken. Keep the stage clean at all times using isopropyl alcohol. When cleaning dust from the stage area, use a vacuum cleaner with a soft brush. DO NOT clean stages using compressed air.

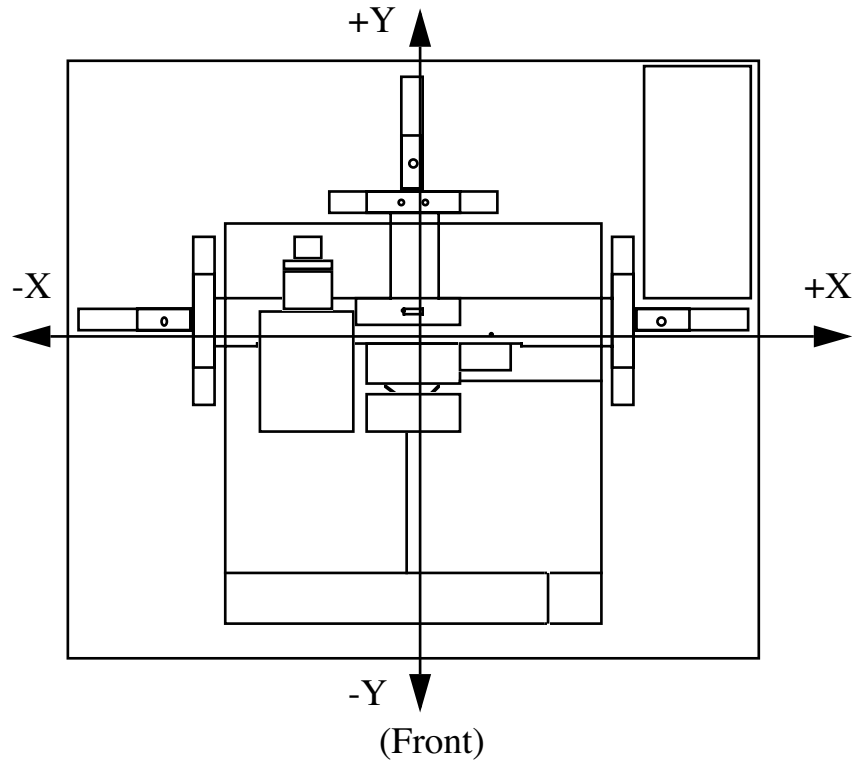
Samples may also be secured to the stage using magnetic pucks, which are themselves magnetically attached to the stage. This system allows for easy mounting and removal of small samples.

Regardless of the method used, operators should verify that samples are mounted flat and parallel to the stage. This is especially important for larger samples being inspected over more than one site. Grossly tilted samples may require raising the head higher whenever the sample is indexed, increasing cycle time and the risk of probe-sample collision. Similarly, large numbers of identical samples should be mounted the same way whenever possible; this allows use of the same settings between samples.

9.1.2 Axis Orientation—X-Y Stages

Viewing the SPM from the front, stage movements are defined over two axes of motion: X (left-right), and Y (front-back). For X-axis movements, lesser (decreasing) coordinates are located to the left. For Y-axis movements, positive (increasing) coordinates are located toward the rear of the machine, negative values are located forward (see [Figure 9.1a](#) of a Dimension 5000/7000 stage; Dimension 3000 is similar).

Figure 9.1a Dimension Series Stage, X-Y Axis Coordination

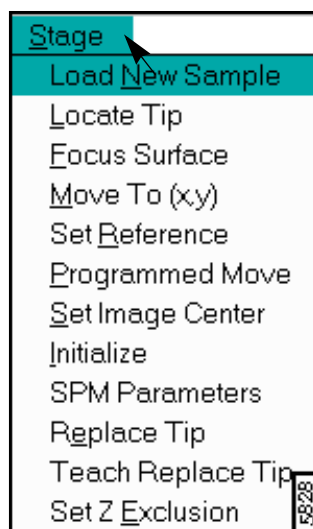


9.2 Stage Menu Interface

Stage software allows for manual or taught movement of the stage prior to scanning.

The stage menu allows for setting up stage parameters for optimal scanning. Prior to initializing the stage, menu commands appear disabled. This is to avoid head crashes and to properly set up locations for scanning. Enable some commands by entering the Service Access (e.g., Z exclusion) and enable the parameters set by logging out of Service Access. The software guides and prompts the user to complete the functions of each **Stage** command.

Figure 9.2a Stage Menu



9.3 Load New Sample

The **Load New Sample** command programs the probe to automatically lift from the sample surface, then index the stage to a preprogrammed location (usually front-center) from which samples may be rapidly reloaded.

Once a new sample has been placed on the stage and secured, the stage software is used to quickly and accurately relocate the sample to the previously used site. It is possible to establish a series of separate sites on any one sample, then repeatedly inspect these same sites on identical samples. This is the preferred method for inspecting integrated circuits and magnetic media

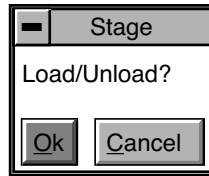
Refer to the following sections:

- **Procedures to Load or Unload a Sample** [Section 9.3.1](#)

9.3.1 Procedures to Load or Unload a Sample

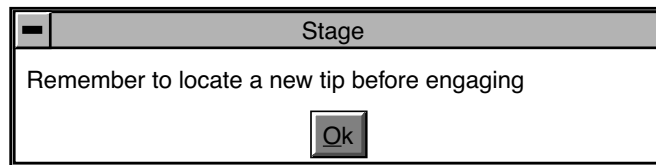
1. Click on the **Stage / Load New Sample** option. The screen will display a panel:

Figure 9.3a Stage Panel



2. To load the new sample, click the **Ok** option. The head will first be raised to the Load/Unload height, then the stage will index to the front-center position. The screen will display a reminder:

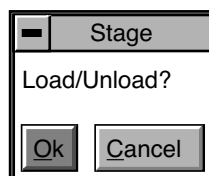
Figure 9.3b Stage Prompt



Note: Operators are advised to verify that the head's tip is still usable. If the tip has been used for a lengthy period, or if damage is suspected, change the tip now per instructions provided in your Dimension Series manual.

3. When the tip has been changed, or if a tip change is not required, click **Ok** in the panel.
4. To release the vacuum chuck's hold on a previous sample, use the pneumatic toggle switch located on the right side of the beam. The vacuum will be released; remove the sample.
5. Verify that the stage and vacuum chuck are clean of debris. If debris is noticed, clean using a lint-free wipe and isopropyl alcohol.
6. Place the new sample on the stage. Check that the sample is seated flat against the chuck's contact points and centered. Actuate the vacuum chuck by toggling the vacuum chuck switch.
7. Click on the **Stage / Load New Sample** option. The screen will display an execute panel:

Figure 9.3c Stage Prompt



8. To load the new sample, click the **Ok** option. The stage will return the sample to its most recent position.

9.4 Locate Tip

This function is used as a prelude to focusing on the sample surface, and should be executed whenever new tips are installed before proceeding with engagement. It enables the operator to find the probe tip using the optical system.

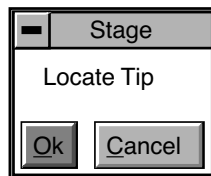
Refer to the following sections:

- **Procedure to Locate Tip** [Section 9.4.1](#)

9.4.1 Procedure to Locate Tip

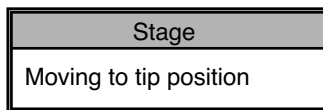
1. Verify that a tip has been installed into the probe tipholder, then click on the **Stage / Locate Tip** option. The screen will prompt the operator to continue:

Figure 9.4a Stage Prompt



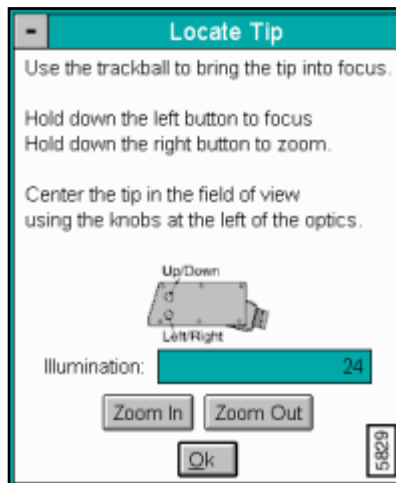
2. Click on **Ok** to continue. The screen will display a caution to the operator, indicating that the microscope objective is being maneuvered:

Figure 9.4b Stage Prompt



As the objective is positioned, the tip may begin to come into focus. When the focus position is attained, the screen will then display trackball instructions for achieving a focus:

Figure 9.4c Locate Tip Instructions Panel



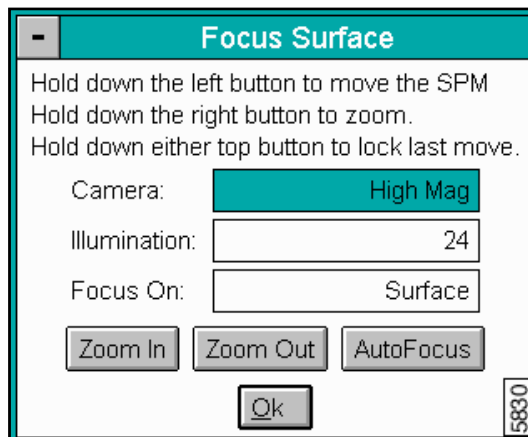
3. Bring the tip into focus by holding down the left button while turning the trackball. The tip may be off from the center of the field of view (particularly if a new type of tip has been installed); however, this will be corrected shortly.
4. To center the tip in the field of view, rotate the small, metal knobs located on the front of the camera casing as indicated in the screen prompt. The tip should be centered in the frame's field of view. You should verify that a sufficiently large field of view is being utilized to locate the tip. If locating the tip proves difficult, turn the metal knobs CW until they stop, then turn back CCW approximately 1.5 turns.
5. When the tip has been brought into focus and centered in the field of view, click on **Quit** in the Locate Tip panel.

9.5 Focus Surface

The **Focus Surface** command accesses a panel to control the stage and view the surface. The purpose of this command is to optimize placement of the tip on the sample surface. Also, use this command for setting the **Z-exclusion** limit, (See [Section 9.14](#)).

In the **Stage** menu, access the **Focus Surface** panel (See [Figure 9.5a](#)).

Figure 9.5a Focus Surface Panel



9.5.1 Focus Surface Panel

Parameters on the Focus Surface Panel

Camera—Sets the level of magnification for viewing the surface (i.e., High Mag or Low Mag).

Illumination—Value for viewing the surface (i.e., 0 is darkest and 100 is brightest).

Focus On—Sets the focus designator (i.e., **Surface** or **Tip**).

Zoom In—Moves optics closer to the surface to enlarge a specified *point* on the sample surface.

Zoom Out—Distances the optics to enlarges the *area* on a sample surface.

Auto Focus—Automatically adjusts optics to find a position relative to the sample surface for setting engage values and SPM parameters.

Ok—Set the focus surface values and exits the Focus Surface command.

9.6 Move To (x, y) (Dimension Series only)

This option enables the operator to quickly index the stage to a defined X-Y coordinate. If the origin has not been preset using the Stage / Set Reference menu, the stage will automatically default to using its center point as the origin. (All subsequent X-Y moves are done from the origin).

Refer to the following sections:

- **Procedure to Move the X-Y Stage** [Section 9.6.1](#)
- **CAUTION:**, [Page 9](#)

9.6.1 Procedure to Move the X-Y Stage

1. Verify that the stage origin (position 0, 0) is either: a) at the default, center stage position; or, b) has been reset to a new position using the Stage / Set Reference menu.
2. Click on the **Stage / Move To (x,y)** option. The screen will present a panel having four parameters:

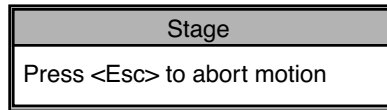
Figure 9.6a Move to (x, y) Panel

Move To (x,y)	
X position:	-49850 μm
Y position:	49967 μm
X position change:	0.00 μm
Y position change:	0.00 μm
<input type="button" value="Quit"/> <input type="button" value="Move"/> <input type="button" value="Focus Surface"/>	

Note: The first two parameters define absolute moves relative to the currently set origin (0,0). The third and fourth parameters define relative moves from the *current position*.

3. Enter the X and Y coordinates of the position to be moved to, then click **Move**. The stage will move to the new position; meanwhile, the screen reminds the operator to monitor the **Esc** button:

Figure 9.6b Stage Screen



4. Should it become necessary to halt movement, press the **Esc** button.

Note: The software permits stage movement while the tip is engaged (using **Focus Surface** trackball controls); however, this is not generally advised.

CAUTION: Always verify that the tip is off the surface before attempting stage movements. If manual stage movements are attempted during engagement, the tip and/or sample may be damaged.

ATTENTION: Il est impératif de toujours s'assurer que la pointe ne touche pas la surface avant de bouger la platine porte-échantillons. Si le déplacement de la platine porte-échantillons est effectué manuellement, la pointe et/ou l'échantillon pourrai(en)t être endommagés.

WARNHINWEIS: Überprüfen Sie immer zunächst, daß die Meßspitze nicht mehr auf der Oberfläche ist, ehe Sie den XY-Verschiebetisch bewegen. Wenn der XY-Verschiebetisch von Hand bewegt wird, während sich das Mikroskop im Engage-Zustand befindet, können Meßspitze und/oder Probe beschädigt werden.



9.7 Set Reference (Dimension Series only)

Use the **Set Reference** command to set the origin point on the sample surface for all subsequent **Move To** and **Programmed Move** operations. Operators should verify the reference point (0,0) with programmed move sequences, since all moves are relative to the current origin. For example, a program designed to move the stage to the four corners of a square sample when the origin (0, 0) is set to the upper-left corner will not probe the same positions if the origin is changed to the lower-right corner. It will avoid confusion to select a standard position as the usual origin reference (e.g., lower-left corner), then reuse the same reference position with all samples.

On samples having a grid-like aspect (e.g., integrated circuits), the reference is initially defined from a line (two points) rather than a single point. The reference line is defined parallel to some feature on the sample surface (e.g., an electronic trace on an integrated circuit). This is done by defining two points: an origin and a second point.

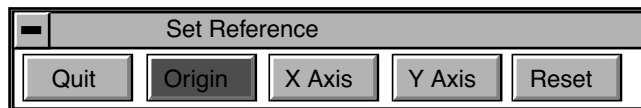
Refer to the following sections:

- **Procedure to Set a Reference** [Section 9.7.1](#)

9.7.1 Procedure to Set a Reference

1. Select the **Stage / Set Reference** option. The screen will offer four options to the operator:

Figure 9.7a Set Reference Screen



2. Verify that the sample surface is in focus on the Display Monitor, then use the trackball to move the sample until the monitor cross-hairs are on the intended origin. Click **Origin** in the Set Reference panel; this is the first of two points to be used for defining a reference line on the coordinate grid.
3. Next, use the **Focus Surface** option and trackball to either:
 - a. Move the stage rightward to a second point on the linear feature. (This second point, along with the point set in [Step 2](#), will define the X-axis.) Now, click on the **X Axis** option. This will establish the ($Y = 0$) reference line.
 - b. Move the stage upward to a second point on the linear feature. (This second point, along with the point set in [step 2](#), will define the Y-axis.) Now, click on the **Y Axis** option. This will establish the ($X = 0$) reference line.

Note: Accuracy will be improved if the two points defining a reference line are located at some distance to each other. For maximum angular accuracy, the two points should be located at opposite sides of the sample (See [Figure 9.7b](#)).

Figure 9.7b Stage Illustration

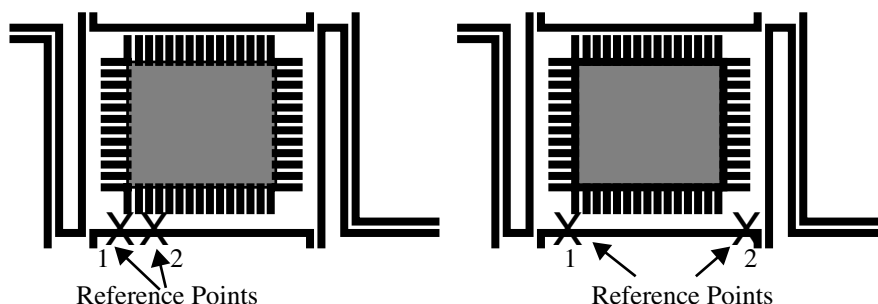
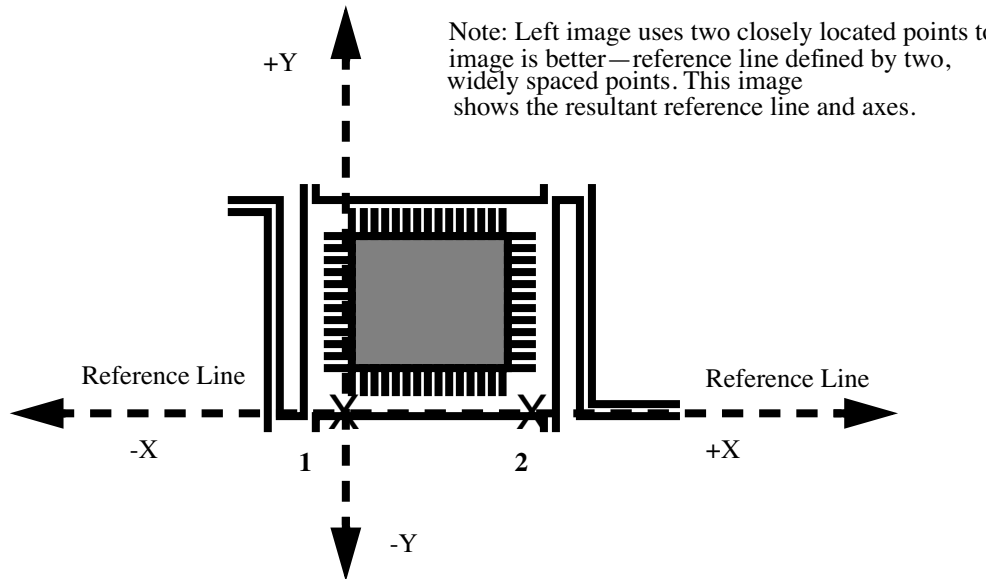


Figure 9.7c Scanning illustration



9.8 Programmed Move (Dimension Series Only)

The Stage / Programmed Move function allows the stage to be automatically positioned at a series of memorized positions. These positions are programmed into the controller's computer, then called out automatically in sequence. The operator may run either the entire memorized sequence, or skip positions, as desired. This function is particularly useful for statistical quality assurance runs on large numbers of identical samples, and as a basic inspection aid.

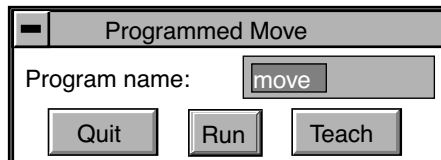
Refer to the following sections:

- **Programmed Move Panel** [Section 9.8.1](#)
- **Procedure for Teaching a Programmed Move** [Section 9.8.2](#)
- **Procedure to Remove a Programmed Option** [Section 9.8.3](#)
- **Procedure to Insert a Step into an Existing Program Sequence** [Section 9.8.4](#)
- **Procedure To Run a Series of Programmed Moves** [Section 9.8.5](#)

9.8.1 Programmed Move Panel

To access this option, select on **Stage / Programmed Move**. The screen will display a panel of short options:

Figure 9.8a Programed Move Panel



Definitions

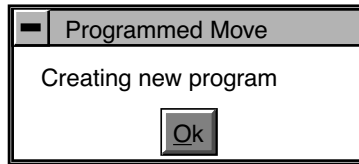
- **Program Name Field**—Provides the name of the move program currently loaded (in this example, the program is called “move”). Moves are first programmed using the **Teach** option. Later they may be executed using the **Run** option.
- **Quit (button)**—Exits the Programmed Move panel.
- **Run (button)**—Executes the specified program name.
Once a program sequence has been taught to the computer, the program can be run from the Programmed Move panel. The stage will move to each position in the same order it was taught, relative to the current origin point. At each program position, the sample will be scanned for 1.5 frames, captured, then indexed to the next position. Captured data from each position is stored on the hard disk; there should be sufficient memory to record 100 frames at 256 samples each.
- **Teach (button)**—Accesses a panel to crate a new program.
- *Origin Points—Current origin at the time of programming.*
Programmed Move positions are memorized relative to the *current origin at the time of programming*. If the origin has been shifted from its original position since the time of programming, it will be necessary to reestablish the original origin point to locate the same positions on the sample. When generating maps of programmed moves, the origin point should always be indicated.

9.8.2 Procedure for Teaching a Programmed Move

To program (teach) a series of moves, do the following:

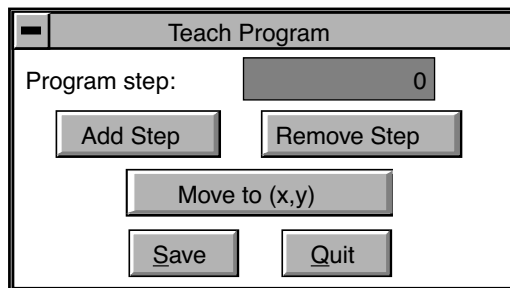
1. Click on the **Program name** option in the panel, then enter the name to be used. (Program names should be eight characters or less and follow DOS protocol.) From the Programmed Move panel, click on the **Teach** option. The screen will prompt with:

Figure 9.8b Programmed Move Panel



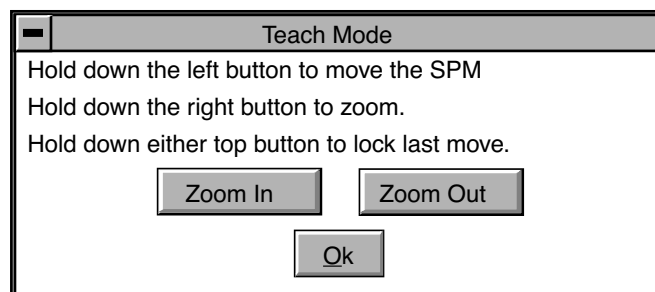
2. Click on **Ok** to proceed with programming moves. A new panel will be displayed, featuring the basic teaching commands:

Figure 9.8c Teach Program Panel



3. To add a first step, click on the **Add Step** option; this will, in turn, access the **Teach Mode** panel:

Figure 9.8d Teach Mode Panel



The operator may now use the controls to position the stage and sample to the desired location(s) to be programmed into the computer. (These controls are identical to the **Focus Surface** controls explained in Chapter 5 of this manual.)

4. The **Move To (X,Y)** command offers an alternative method to move the stage. Click on the **Move To (X,Y)** to access the **Move To** panel:
5. When the stage has been moved to a desired position, press **Quit** on the Teach Mode panel; to add another position, click again on the **Add Step** option. The Teach Mode panel will be displayed again, and the operator may again position the stage at the desired location, quit the Teach Mode panel, and click on **Add Step**. Each time the Teach Program panel is reentered, the **Program step** will increment by another count. This procedure may be repeated until all the desired positions have been programmed up to a maximum of 100 steps. Each position will be automatically assigned a program step number.

It will prove helpful to draw a simple map of the sample, along with each programmed position, before programmed moves are entered. If reducing cycle time is important, position order should be optimized to reduce stage travel. Also, note the origin point at the time of programming.

6. When all stage positions have been entered into the program, click on **Save** in the Teach Program panel, then **Quit**. The program should now be entered and saved under the name entered in [Step 1](#).

Note: The operator must save steps before using Quit to exit the Teach Program panel; otherwise, programmed steps will be lost.

7. Additional programs are entered in the same manner, using a separate program name for each.

9.8.3 Procedure to Remove a Programmed Option

To remove a step from the programmed sequence:

1. Click on the **Stage / Programmed Move / Teach Program** panel.
2. Click on **Program step** field in the **Teach Program** panel.
3. Enter the step number to be removed into the keyboard, or drag the mouse to index to the step number. The stage will simultaneously move to the new step position.
4. Click on the **Remove Step** option. When individual program steps are removed, all subsequent steps are “moved up” by one count. (For example, after removing step #2 from a program, step #3 would become the new step #2, step #4 would become the new step #3, etc.)
5. Click on **Save** to save the edited version of program.

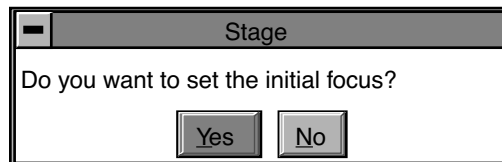
9.8.4 Procedure to Insert a Step into an Existing Program Sequence

1. Click on the **Stage / Programmed Move / Teach Program** option.
2. Click on **Program step** in the Teach Program panel.
3. Enter *one less* than the step number to be added to the sequence, or drag the mouse to index to the desired step number. (For example, if the operator wishes to add a new program step #7, while leaving all preexisting steps intact, they would enter “6” in the **Program step** field. The stage will simultaneously move to the preexisting step position #6.)
4. Click on the **Add Step** option. The Teach Mode panel will appear; at this point the operator should use the trackball to move the stage to the new position to be added. When new program steps are added, all preexisting steps beyond the new entry are “moved up” by one count.
5. Click on **Quit** to exit the Teach Mode panel. The new position should now be added.
6. Click on **Save** to save the edited version of program.

9.8.5 Procedure To Run a Series of Programmed Moves

1. Click on the **Stage / Programmed Move** panel.
2. Click on the **Program name** field, then enter the name of the program to be run.
3. Click on the **Run** option. If the program is being loaded and run from the beginning, the screen will prompt the operator whether to refocus the screen:

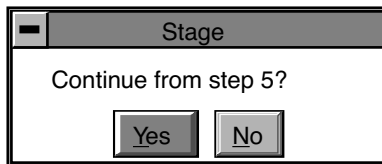
Figure 9.8e Stage Panel



4. Clicking on **Yes** will transfer the user to the **Focus Surface** panel; the user may then make focusing adjustments to better view the surface. Clicking on **No** will initiate the programmed move from step #1.

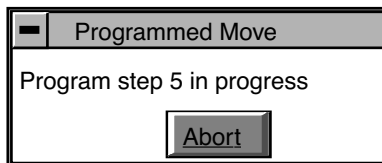
If the program was previously run without finishing (aborted), the screen will request whether to begin the program sequence at the aborted step; for example, if the operator left off at step #5:

Figure 9.8f Stage Panel



5. The operator may wish to run the entire program from its beginning (step #1); if this is the case, click **No**. Otherwise, click on **Yes**. The screen will display the current program step in progress:

Figure 9.8g Programmed Move Panel



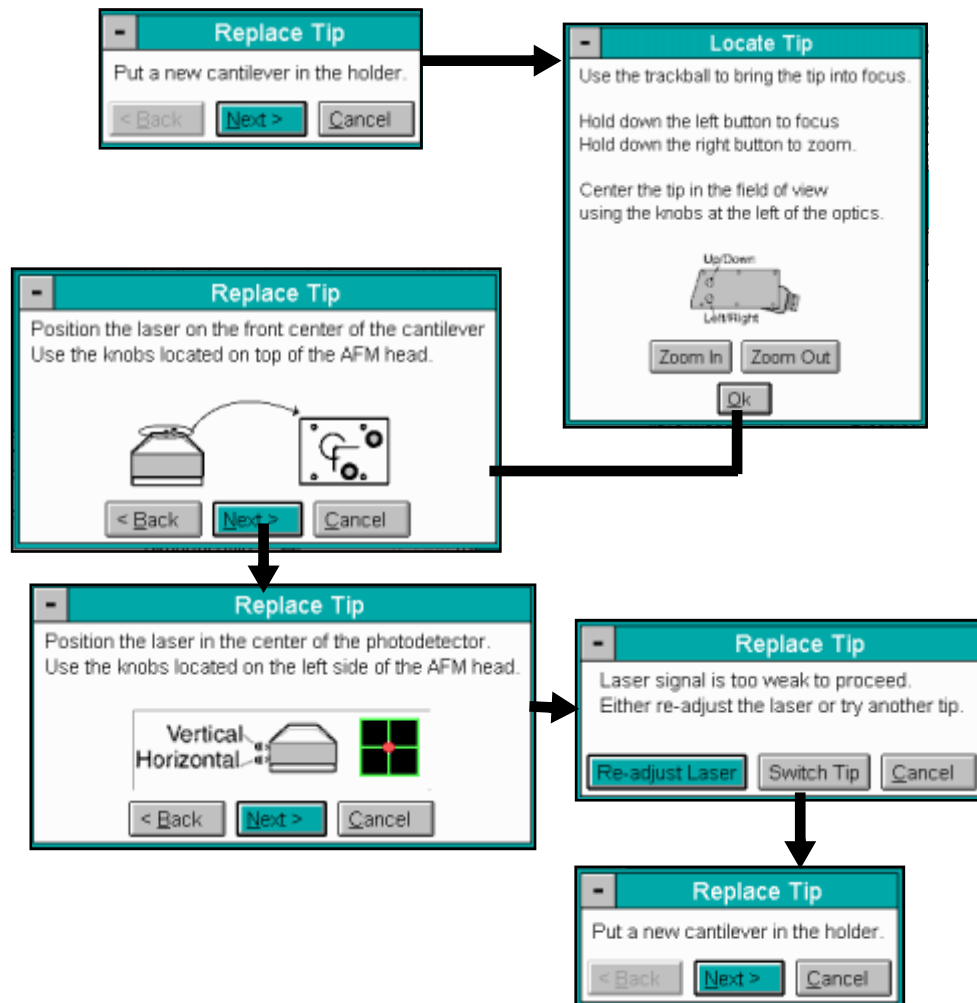
If the operator wishes to initiate the program sequence from another starting point, it will be quickest to simply use the **Teach Program** panel to remove any unwanted step(s), then run the program again from the new "step 1" position.

9.9 Replace Tip (D3000 Series)

The **Replace Tip** command opens instruction panels when replacing a tip. The function of the panels is to assist the user with the hardware knobs and levers to optimize the tip replacement. Each prompt guides you through the process of replacing a tip on the Dimension 3000 series microscopes.

Select the **Replace Tip** command to access a series of **Replace Tip** prompts (See Figure 9.9a).

Figure 9.9a Replace Tip Prompts for the Dimension Series Microscopes



9.10 Scaling

Sets values according to the proportions of an established scale of measurement (e.g., wafer x, y or x and y dimensions). This function allows for locating features on the sample surface.

Refer to the following topics on **Scaling**:

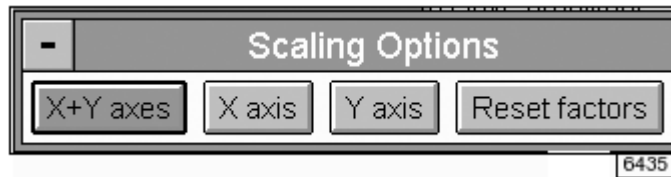
- **Procedures for Scaling** [Section 9.10.1](#)
- **Navigating in the Scaling Panels and Parameters** [Section 9.10.2](#)

9.10.1 Procedures for Scaling

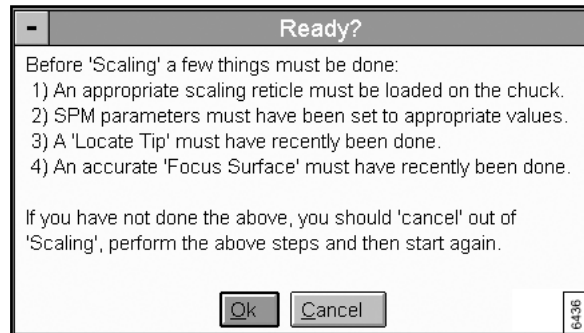
1. Select **DI/SERVICE ACCESS** and enter your Service password.

Note: Scaling is only available to engineers with Service Access.

2. Select **Real-time/STAGE/SCALING**. Select the coordinate(s) to be rescaled: **X**, **Y** or **X+Y**. Click **OK**.

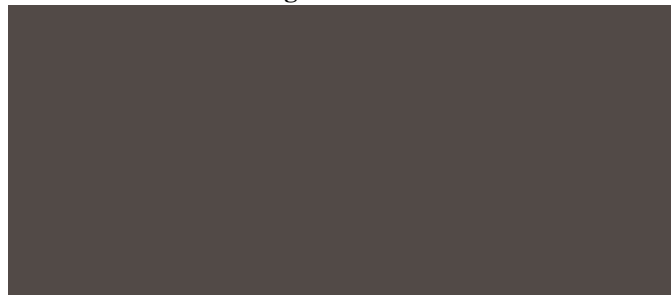


3. Read the **Ready?** panel and select **OK** . Proceed or **CANCEL** to set up.



4. In the **Scaling** panel, enter X- and Y-coordinates for the **FIRST REGISTRATION POINT**, and X- and Y-coordinates of the **SECOND REGISTRATION POINT**, so that they are separated by the reference distance.

Figure 9.10a .



Note: If the two registration points are ≤ 50 mm apart, a warning is displayed; select **OK** and proceed, or **CANCEL** and return to item 4.

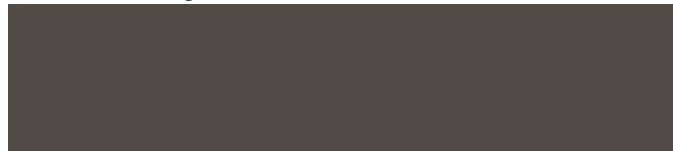


5. Move to and align the crosshairs on the first target. Click **OK**.



6. Move to and align the crosshairs on the second target. Click **OK**.

7. Click **OK** to acknowledge the reminder.



8. Click **OK** to go to the Service Access log-off panel.

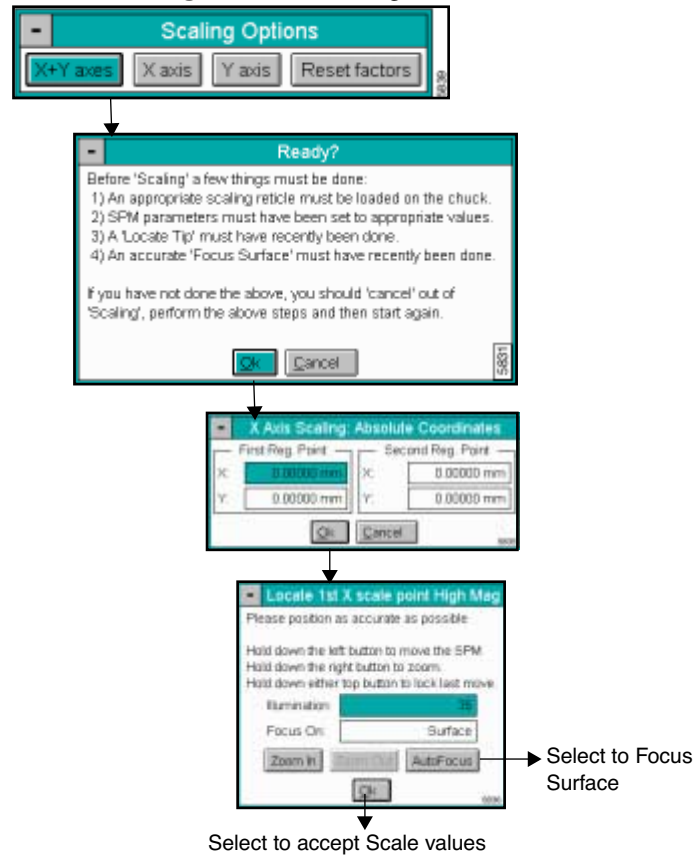


9. Log-off Service Access.

9.10.2 Navigating in the Scaling Panels and Parameters

A series of panels and prompts opens to set the X and Y registration points

Figure 9.10b Scaling Panels



9.10.3 Buttons on the Scaling Options Panel

- X + Y AXIS:** Sets the scale based on both X and Y coordinates.
- X AXIS:** Sets the scale based on the X coordinates only.
- Y AXIS:** Sets the scale based on the Y coordinates only.
- RESET FACTORS:** Resets the scale to previously saved values or default values.

9.11 Set Image Center (Dimension 5000/9000 only)

Ideally, operators should be able to locate features on the surface of a sample using the optical system's monitor, then engage the exact site of interest. Usually, this requires adjustment due to offsetting between camera optics, the tip, and the sample surface. The Set Image Center function of the Stage menu allows the operator to align images seen with the optical system with the SPM image seen on the Display Monitor. This requires scanning a frame, noting the offset difference between the optical system's center and the scanned image's center, then using the Set Image Center option to make a stage offset correction; subsequent engagements should locate the tip at the exact location(s) chosen from the optical system monitor.

9.11.1 General Procedures for Using Set Image Center

1. Verify that the tip has been located.
2. From the **Stage / Focus Surface** panel, use the SPM's optical system to locate a prominent feature on the sample surface which is suitable for scanning. Examples include prominent holes and cornered features, etc. The camera should be zoomed out to maximum.
3. Center the screen's cross-hairs exactly over the feature to be scanned, then click on **Quit** to exit the Focus Surface panel.
4. Verify that the **X offset** and **Y offset** values on the Main Controls screen are set to zero (0). Engage the sample surface and begin scanning until a full-frame view of the surface is obtained. The **Scan size** field should be sufficiently large (50—90 μm) to completely image the prominent feature(s) selected.

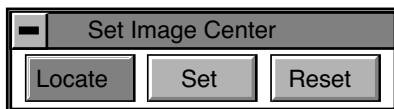
Survey the location of the prominent centering feature on the Display Monitor's scanned image.

Note: If the feature is located at the center of the Display Monitor, the SPM is centered and will require no further adjustment. The operator may skip the **Set Image Center** procedure.

Note: If the feature is off-center, proceed to step #5.

5. Click on the **Stage / Set Image Center** option. A panel will display the various options for Set Image Center:

Figure 9.11a Set Image Center



6. Click the **Locate** option in the Set Image Center panel; a caution will be displayed on the screen:

Figure 9.11b Set Image Center



Note: The prompt in Figure 9.11b is designed to remind operators *not* to use the **Execute** option at the top of the Display Monitor. If **Execute** is used, the computer will attempt centering the image with X and Y offsets, rather than by correcting from the stage; this will *not* correct the offset error.

7. Click on OK in the prompt panel to continue; a cursor (cross-hairs) will then appear on the Display Monitor.
8. Use the mouse to move the Display Monitor cursor (cross-hairs) onto the feature, then click the mouse to lock the cursor in place. Click on the **Set** option in the Set Image Center panel. This will establish the stage's correction offset between the images centered in both the optical system and SPM Display Monitors; subsequent engagement of the surface should occur beneath the tip as viewed from the optical system monitor.

Clear an Image and Center Stage Offset

If the previously selected image center offset is no longer accurate due to tip replacement, etc., the operator may clear the offset by clicking the **Clear** option in the Set Image Center panel. This can be done before setting a new image center.

9.12 Initialize

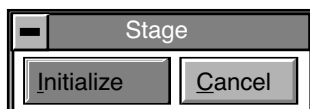
The Initialize option is used by the system software to locate home pulses on the stage slides' linear encoders. When executed, the stages are exercised to their limits of travel and the stage is parked in the center position. Initialization must be executed under the following conditions:

- a. Use Initialize whenever the computer has been turned off.
- b. Use Initialize whenever the stage has been manually moved while not under software control.

9.12.1 Procedures for Using the Initialize Command

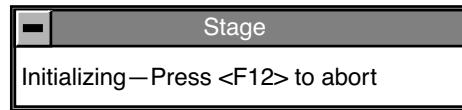
1. Click on the **Stage / Initialize** option. The screen will offer a menu of short options:

Figure 9.12a Stage Panel



2. Before beginning initialization, check that the stage is clear of loose items and debris, and that operators are clear. To begin initialization, click on **Initialize**. As the stage begins a series of motorized movements, the screen will indicate operating status:

Figure 9.12b Stage Panel



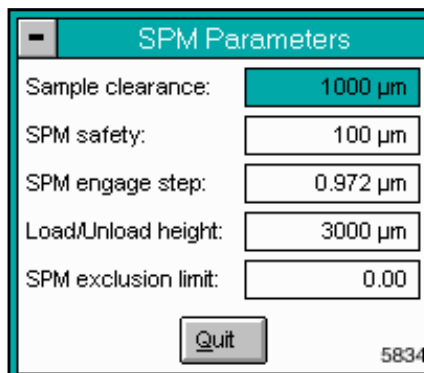
3. The initialization sequence may be aborted at any time by pressing the **F12** key. When the stage has completed its initialization sequence, it will park at the load/unload position.

9.13 SPM Parameters

The SPM Parameters menu lists the most important Z-axis parameter values for loading/unloading the stage and engaging samples.

Select the **SPM Parameters** command to access the **SPM Parameters** panel (See [Figure 9.13a](#)).

Figure 9.13a SPM Parameters



Parameters on the SPM Parameters Panel

Sample Clearance: Sets the distance that the tip should be above the surface to allow reasonable clearance above the sample when moving the trackball.

*Range or Settings:*1000

SPM safety: Sets the distance of the tip above the sample surface where the *fast* approach segment of the engage process ends, and the *slow* approach begins.

*Range or Settings:*100

- SPM engage step:** Sets the step size (in microns) that is used while approaching the surface, during the *slow* engage portion of the engage (i.e., $-1.0\mu\text{m}$ is safest).
Range and Settings: **Less than $1\mu\text{m}$**
- Load/Unload height:** Sets the distance the tip should withdraw to, above the surface, when loading or unloading a sample (See [Section 9.3](#)).
- SPM exclusion limit (Read-only):** Value in counts below the focus surface height (i.e., Sample Clearance height) below which trackball motion is excluded (disabled) to help protect against accidentally driving the tip in to the surface or tip-x cassette. This value is set by the Set Z Exclusion command (See [Section 9.14](#)).

9.14 Z Exclusion for Two Substrate Thicknesses [5.12 r1]

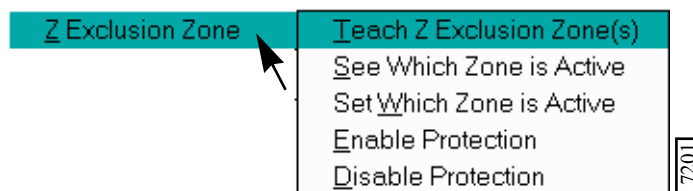
The **Z Exclusion Zone** feature allows you to set two independent trackball protection, or exclusion, zones. You can run two thickness samples and teach an exclusion zone for each sample. When changing from one sample thickness to another, you can enable or set which exclusion zone setting is *active*.

There is a distinct menu option for enabling (that is, **Enable Protection**) and disabling (that is, **Disable Protection**) the **Z Exclusion Zone** settings (see [Figure 9.14a](#)).

9.14.1 Z Exclusion Submenu Items

The new **Z Exclusion Zone** functionality adds five submenu items to the **Z Exclusion** command (see [Figure 9.14a](#)).

Figure 9.14a Z Exclusion Menu After Stage Initialization and Service Access



- **Teach Z Exclusion Zone(s)**—Accesses the **Set Z Exclusion** dialog box.
- **See Which Zone is Active**—Accesses a dialog box to show the active zone.
- **Set Which Zone is Active**—Accesses a dialog box to change the active zone.
- **Enable Protection**—Activates the settings taught for Zone 1 or Zone 2.
- **Disable Protection**—Disables the settings taught for Zone 1 or Zone 2.

9.14.2 Z Exclusion Warning Prompts

Upon entering the system, a warning prompts you to enable the **Z Exclusion Zone** settings. Also, if a thick and thin zone have been taught, a warning appears as a reminder to verify which sample is loaded.

Procedures to Disable the Warning Prompts

An added feature disables the warning prompts that appear when opening your NanoScope software. To disable these prompts complete the following:

1. In your NanoScope System files, locate the **Par/STAGE.PAR** file.
2. Locate the **Exclusion Warning Level** option.
3. Set the option to **0** for suppressing the warning prompts for Z Exclusion.
4. Setting the option to **1** enables the warning prompts.

9.14.3 Procedures to Enable Z Exclusion

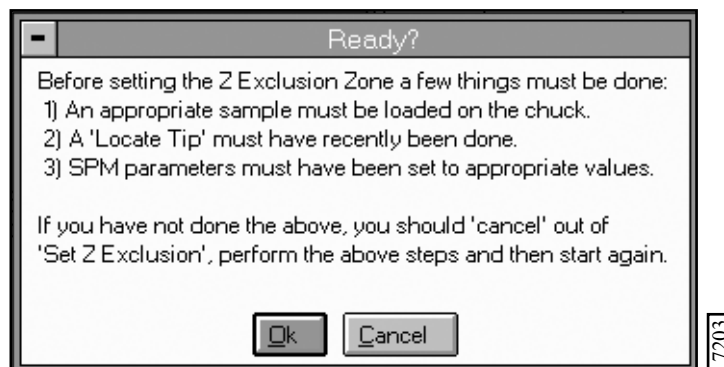
1. Initialize the stage (Real Time > **Stage** > **Initialize**).
2. In the **Stage** menu, select **Z Exclusion** > **Teach Z Exclusion Zone** > **Zone 1**.

Figure 9.14b Teach Zone 1



Note: A reminder to load a sample and initialize the stage appears (see Figure 9.14c).

Figure 9.14c Teach Z Exclusion Prompt



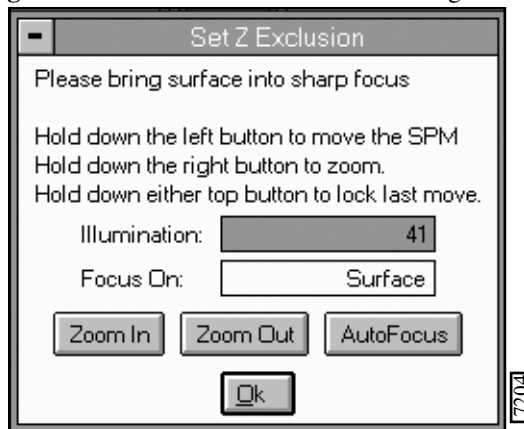
3. Verify that your sample is on the chuck or stage.

4. Verify that **Locate Tip** is complete.
5. Set the **SPM parameters** (Stage menu > **SPM Parameters**) appropriate for your sample.

Move the Tip with the Trackball

1. While looking at the probe and surface to verify a safe distance of tip to sample, roll the trackball slowly (that is, toward you) to lower the probe to approximately **5 mm** above the surface.
2. Select the Focus Surface command (**Stage > Focus Surface**) (See [Figure 9.14d](#)).

Figure 9.14d Auto Focus/Trackball Settings Enabled



3. Set the **Illumination** setting (that is, percentage of lightness) to view the cantilever in your vision window.
4. Lower or raise the probe (that is, using the trackball) slowly to focus on the surface.



CAUTION: Tip crashes can occur with the trackball fully enabled. Be careful when moving the tip toward the sample in focusing on the surface.

5. Bring the surface into sharp focus to set the **Z Exclusion Zone** level.

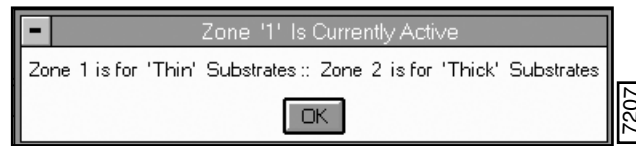
Note: This setting enables the system to remember the accepted level as the lowest point which the trackball can safely travel.

6. Click **OK** to accept this distance.
7. Select **Z Exclusion > Enable Protection**.

Verify Which Zone is Active

1. Select **Z Exclusion > See Which Zone is Active**.
2. Verify that **Zone 1** is active.

Figure 9.14e Verify Zone 1 is Active Prompt



For additional substrate thicknesses, follow the [9.14.3](#) for Setting the second Z distance (that is, Zone 2).

Chapter 10 Offline File Menu

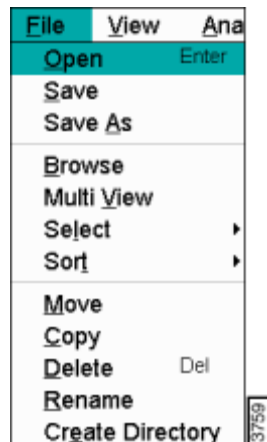
The pull-down **File** menu features a number of basic commands to facilitate the preview, transfer, copy, and deletion of files. **File** commands in this chapter include:

- **Browse** [Section 10.2](#)
- **Multi View** [Section 10.3](#)
- **Select** [Section 10.4](#)
- **Sort** [Section 10.5](#)
- **Move** [Section 10.6](#)
- **Copy** [Section 10.7](#)
- **Delete** [Section 10.8](#)
- **Rename** [Section 10.9](#)
- **Create Directory** [Section 10.10](#)

10.1 Overview

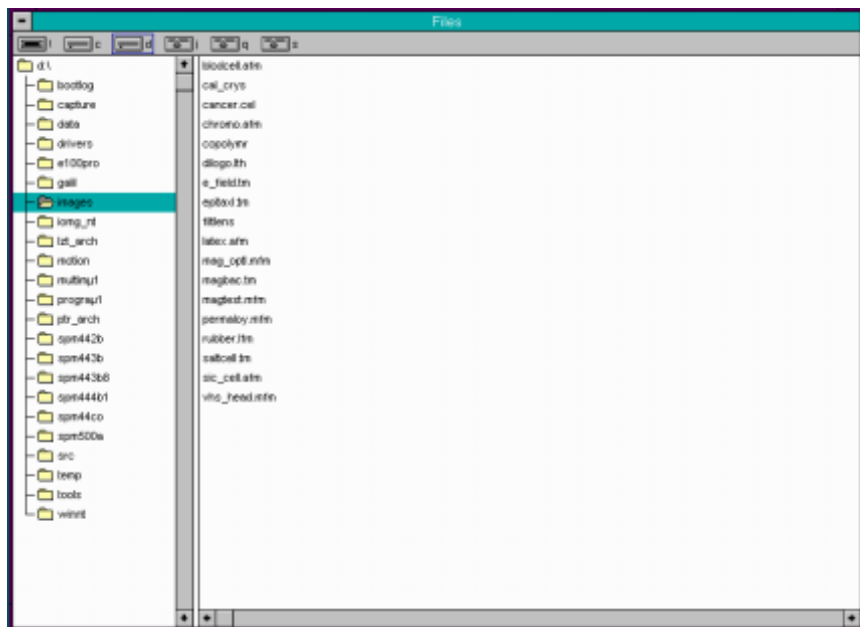
Select the **File** menu to execute commands to open, save, copy, rename or move to a specific folder menu (See [Figure 10.1a](#)).

Figure 10.1a Off-line File Drop-down Menu



Off-line files are displayed on the Control Monitor using the **Files** screen shown in [Figure 10.1b](#). At the top of the panel, all available disk drives are displayed; drives are selected by clicking on them with the mouse. On the left side of the **Files** panel is a directory tree for the selected disk drive. A slider bar permits you to navigate through the tree and select directories. Files contained within the current directory display on the right side of the screen.

Figure 10.1b Off-line Files Screen



In the **File** commands, select individual files by clicking on them with the mouse. To select more than one file, press the **SHIFT** or **CONTROL** keys simultaneously. The procedure for these functions are as follows:

Shift Key Function for Selecting Files

To select a serialized group of files, hold down the **SHIFT** key while dragging the mouse over the files to be selected. All selected files are highlighted. Release the mouse and **SHIFT** key after all selected files are highlighted.

Control Key Function for Selecting Files

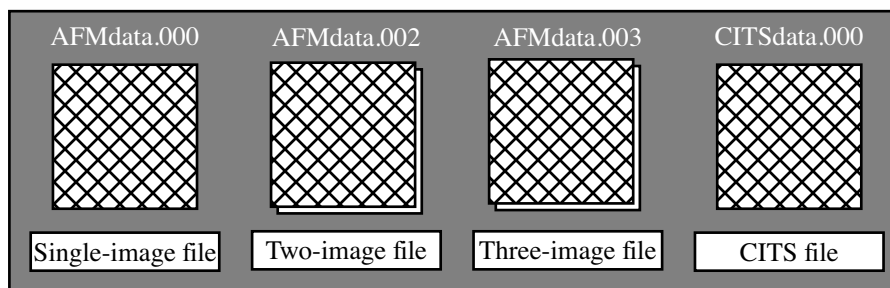
To select a composite group of files, hold down the **CONTROL** key and click on individual files one-by-one with the mouse. All selected files are highlighted. Release the mouse and **CONTROL** key after all selected files are highlighted.

10.2 Browse



The **Browse** command previews up to twenty-four image files on the Display Monitor. Image files may take the form of single, dual, or triple images, depending on how many channels were enabled during **Capture**. The **Browse** command allows isolating and comparing two or three images within a single file, or comparing separate images from separate files.

Figure 10.2a Browse Image Files Types



Note: The *two-image* and *three-image* files are not distinguishable from each other on the browse screen.

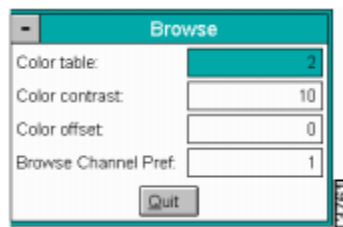
Refer to the following Browse sections:

- **Browse Panel** [Section 10.2.1](#)
- **Browse Display Monitor** [Section 10.2.2](#)
- **File Menu Command** [Section 10.2.3](#)
- **Select Menu Command** [Section 10.2.4](#)
- **View Menu Commands** [Section 10.2.5](#)
- **Auto Menu Commands** [Section 10.2.6](#)
- **Page up Menu Command** [Section 10.2.7](#)
- **Page down Menu Command** [Section 10.2.8](#)
- **Hints to optimize the Browse Command** [Section 10.2.9](#)
- **Procedure to Use the Browse Command** [Section 10.2.10](#)

10.2.1 Browse Panel

The following panel is displayed on the Control Monitor, allowing the **Color table**, **Color contrast**, and **Color offset** of images to be adjusted (See [Figure 10.2b](#)).

Figure 10.2b Browse Panel



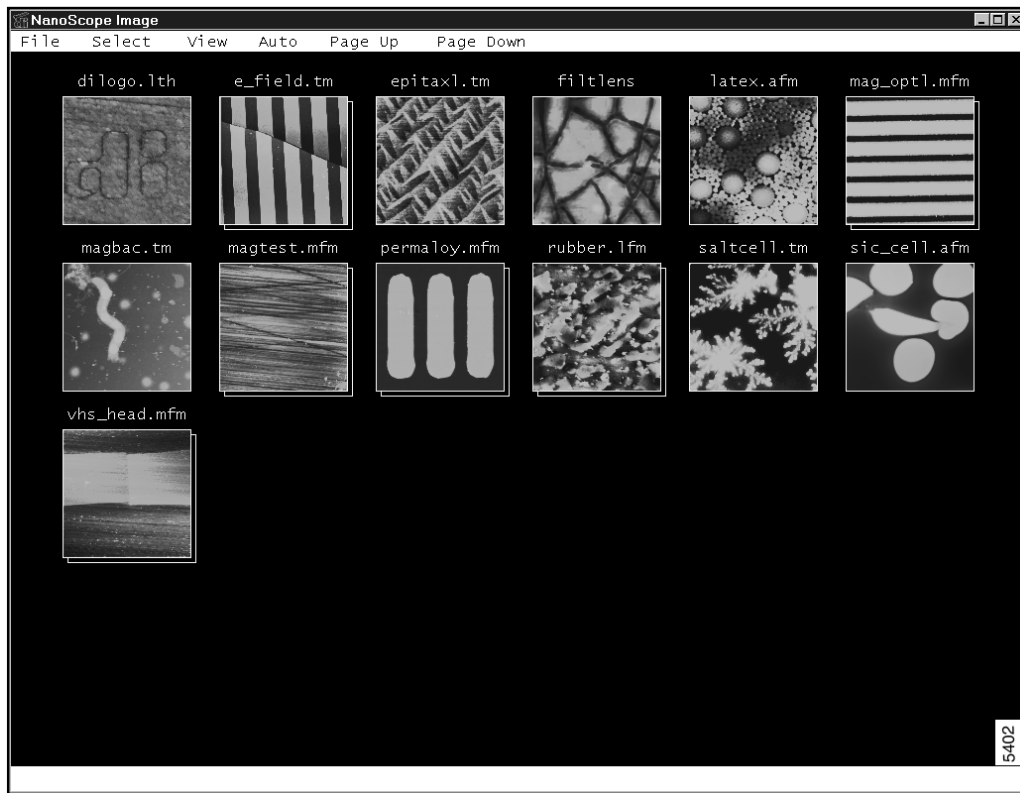
Parameters in the Browse Panel

- **Color Table**—Number (0 - 21) designates color for the displayed images (e.g. 0 shows black and white image).
- **Color Contrast**—Number (0 - 10) designates contrast of colors in displayed image (e.g., 0 shows little change, while 10 shows highest contrast).
- **Color Offset**—Number (0 - 120) designates offset of colors in displayed image (e.g., 120 shows illuminated background on image).
- **Browse Channel Pref**—For multiple images, selects which channel image appears on top of the **Browse** Display Monitor.

10.2.2 Browse Display Monitor

Image files can be previewed quickly using **Browse**; the subcommands allow files to be selected and configured. The Display Monitor includes: menu bar, up to 24 thumbnail images and menu commands including (See [Figure 10.2c](#)): **File, Select, View, Auto, Page Up, Page Down**

Figure 10.2c Browse Display Window



10.2.3 File Menu Command

Move—Accesses the **Move** panel, allowing files to be moved from the current directory and/or disk to another directory (See Figure 10.2d).

Figure 10.2d Move File Panel

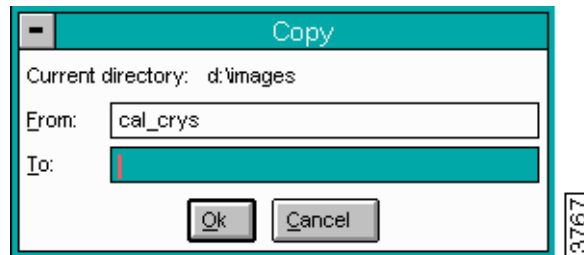


Parameters in the Move Panel

- **From** and **To**—**From** refers to the current file name; **To** allows entry of the path where the file will be moved. The current directory displays at the top of the panel.

Copy—Accesses the **Copy** panel, allowing files to be copied (See [Figure 10.2e](#)).

Figure 10.2e Copy Files Panel



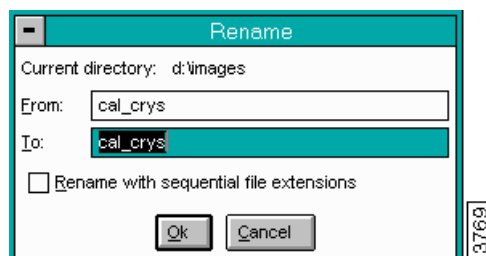
Parameters in the Copy Panel

- **From** refers to the current file name; **To** allows entry of the path where the file will be copied. The current directory displays at the top of the panel.

Delete—Removes selected image file(s) from the current directory.

Rename—Accesses the Rename panel. The Rename panel allows you to rename selected files (See [Figure 10.2f](#)).

Figure 10.2f Rename Panel



Parameters in the Rename Panel

- **From** refers to the current file name; **To** allows entry of the new file name. The current directory displays at the top of the panel.
- **Rename with sequential file extensions**—Names file extensions with sequential extensions (i.e., *.000, *.001, *.002)

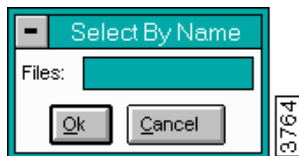
10.2.4 Select Menu Command

Contains the file handling subcommands **All**, **None**, **Page**, **Name**, and **Invert**.

- **All**—Selects all of the images within the directory.

- **None**—Deselects (removes the X marker) all of the images within the directory.
- **Page**—Selects the twenty-four images currently displayed on the page.
- **Name**—The **Select By Name** panel appears on the Control Monitor, allowing the selection of images by name (See [Figure 10.2g](#)).

Figure 10.2g Select By Name Panel



Note: Using one of the DOS “wild card” symbols allows you to select more than one file at a time. The * symbol allows selection of files with matching name strings. For example, typing **image*.*** selects all of the files beginning with the word “image”.

- **Invert**—Reverses the current command. For instance, if all the images in the directory are selected, the **Invert** command deselects all the images (removes the X marker).

10.2.5 View Menu Commands

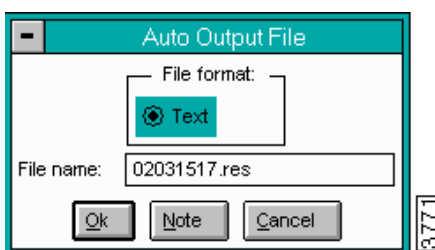
Contains the file-handling subcommands **Dual** and **Multi**.

- **Dual**—Two images may be selected and displayed side-by-side in the dual-screen display. The two selected files may be composed of either single or dual images. If dual images are selected, only the front images is used.
- **Multi**—Displays from two to six images on the Display Monitor in 256 x 256 format. If more than six images are selected, the first six images are displayed in the selected order.

10.2.6 Auto Menu Commands

Initiates the currently selected **Auto Program** file. The file can be selected with the **Auto Program File** command in the **Utility** menu. The **Auto Program** file should be created by selecting the **AUTO PROGRAM** button in the desired commands in the desired order.

The panel in [Figure 10.2h](#) appears on the Control Monitor, allowing you to select the format of the output file.

Figure 10.2h Auto Output File Panel

The form of the output file selected depends on the type of printer that is available. If a Postscript compatible printer is to be used, select **Postscript**; otherwise **ASCII** is a more appropriate selection.

Note: If a *custom* report macro file is loaded on the system, the **Auto Output File** panel includes a **Custom** format.

The **NOTE** button accesses a panel to insert a message to be inserted in the output file.

10.2.7 Page up Menu Command

Pages to the previous images (twenty-four maximum).

10.2.8 Page down Menu Command

Pages to the next images (twenty-four maximum).

10.2.9 Hints to optimize the Browse Command

- Select the desired image(s) **before** selecting a command.
- Clicking on selected images a second time removes the X marker.
- DOS file conventions apply to filenames and directories.
- When renaming images, the extension can be specified to begin numbering at any specified value. For example, if the new base name “.055” is specified, the first image is renamed “.055,” the second “.056”...to the end of the images.
- Sequential images listed after the selected image are displayed. To view files out of sequential order, use the **Multi View** command described in [Section 10.3](#).
- Spectroscopic and force plots are not displayed unless in **Force Calibrate** mode.
- Up to twenty-four images can be selected across page boundaries.

- The **ESC** key or space bar may be used to interrupt the preview of all twenty-four images. This can save time if the desired image previews early in the list.
- A **Browse** subdirectory is created in the currently selected directory. This subdirectory contains low-resolution forms of the browsed images to speed up subsequent browses.

10.2.10 Procedure to Use the Browse Command

To perform any **Browse** command displayed on the Display Monitor's menu bar, complete the following:

1. Select the first image in the file list on the **Control Monitor**.
2. Click the **Browse** command to view all the images in the directory (i.e., twenty-four maximum).

Note: Image selection can be performed across pages.

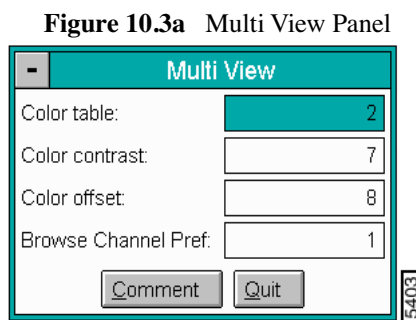
3. Using the mouse, select the image or images that you want to configure.
4. Select the desired command.

See also: **Off-line/View/Topview** panel: **Color table**, **Color offset**, **Color contrast**, and **Z range** parameters; **Offline /Image** panel.

10.3 Multi View

The **Multi View** command is similar to the **Browse** command; however, Multi View allows you to choose specific files to preview rather than viewing all of the images after the selected file. Multi View previews up to six image files (256 x 256 format) on the Display Monitor. Use the **CTRL** key to choose single files and the **SHIFT** key to choose file ranges.

Figure 10.3a shows the **Multi View** panel, allowing you to adjust the **Color table**, **Color contrast**, **Color offset** and **Browse Channel Pref**.



Parameters in the Multi View Panel

- **Color Table**—Number (0 - 21) designates color for the displayed images (e.g. 0 shows black and white image).
- **Color Contrast**—Number (0 - 10) designates contrast of colors in displayed image (e.g., 0 shows little change, while 10 shows highest contrast).
- **Color Offset**—Number (0 - 120) designates offset of colors in displayed image (e.g., 120 shows illuminated background on image).
- **Browse Channel Pref**—For multiple images, selects which channel image appears on top of the **Browse** Display Monitor.
- **Comment**—Appends a comment to the saved Multi View images.
- **Quit**—Exits the Multi View panel.

10.3.1 Multi View Display Monitor

Up to six images in the 256 x 256 format are shown on the Display Monitor. The images are displayed without rotation and with the default **Z range** for that image.

If more than six images are selected, the first six images are displayed in the selected order.

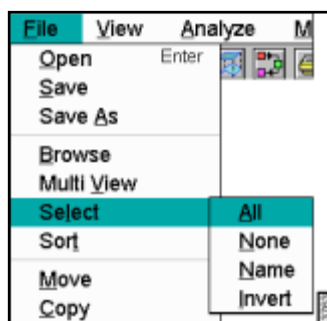
Example of Multi View Function

To quickly preview the images in a directory, use the **CTRL** key to select the desired images in the file list and use the **Multi View** command to view the selected images, up to six at a time.

10.4 Select

The **Select** command (**File/Select**) selects images within the open directory by using one of the Select subcommands (See [Figure 10.4a](#)).

Figure 10.4a File/Select Drop-down Menu



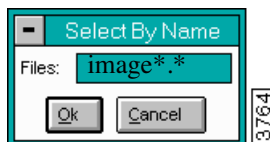
10.4.1 Select Subcommand Menu

All—Selects (highlights) all of the files in the directory.

None—Deselects any selected files in the directory.

Name—The Select By Name panel appears on the Control Monitor, allowing you to select images by name. Using one of the DOS “wild card” symbols to select more than one file at a time (e.g., Typing `image*.*` selects all of the files beginning with the word “image”) (See [Figure 10.4b](#)).

Figure 10.4b Select By Name Panel



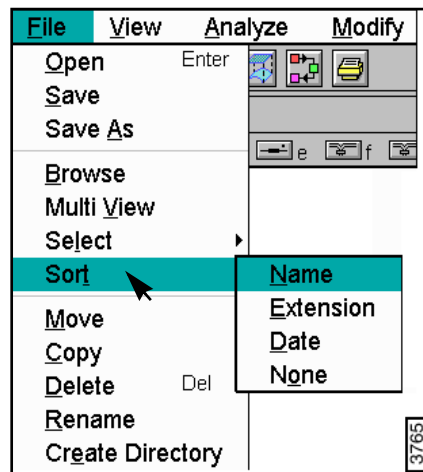
Invert

Reverses the current file selection. For instance, if one file is selected, the **Invert** command deselects that file and selects all of the remaining files in the directory. This command performs the **opposite** command.

10.5 Sort

The **Sort** command sorts images within the open directory by using one of the **Sort** subcommands.

Figure 10.5a File/Sort Drop-down Menu



10.5.1 Sort Subcommand Menu

Name—Sorts files alphabetically by filenames.

Extension—Sorts files alphabetically by their three letter file suffix.

Date—Sorts files by file creation date.

None—Returns the files to their original order before using the **Sort** command.

10.6 Move

The **Move** command functions almost exactly the same as **Copy**; however, it also deletes moved files from their source directory. The **Move** command transfers the selected image to the drive and/or directory you specify.

The **Move** panel allows you to move a file.

Figure 10.6a Move Panel



From—The source drive\directory\filename to be moved.

To—The new location of the drive\directory\filename being moved.

Ok—Completes the **Move** command.

Cancel—Aborts the **Move** command.

Hints for Optimizing the Move Command

The following are hints to optimize the **Move** function:

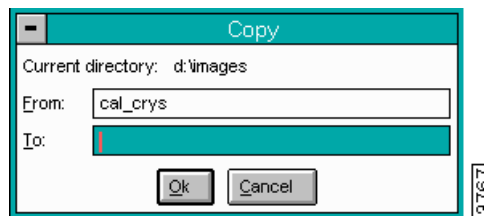
- The default **To** filename is the same as the **From** filename. This default filename can be changed by selecting the **To** field and typing a new name.
- The desired partition and directory can be entered directly for the **To** directory; however, the entered directory must already exist, and the partition must be valid. The entry form should be `partition:\directory`.
- If a file with the same name already exists, the software asks whether to overwrite or supply a different filename.

10.7 Copy

The **Copy** command duplicates the selected image and results in two identical images. An identical image with a new name can be created in the current directory, or a copy can be created in a new directory and/or partition with the same name or a new name.

Use the **Copy** panel shown in [Figure 10.7a](#) to copy files to/from any directory accessible by the microscope computer. Normal DOS file conventions should be observed.

Figure 10.7a Copy Panel



10.7.1 Parameters in the Copy Panel

From—The directory and name of file to be copied (e.g., C:\images\fileorig.001).

To—The directory and name of the file being assigned the file copy (e.g., C:\images\filecopy.001).

Ok—Completes the **Copy** command.

Cancel—Aborts the **Copy** command.

Hints for Optimizing the Copy Command

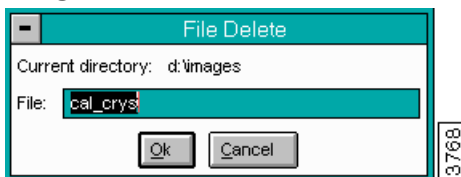
- The default **To** filename is the same as the source filename. When copying an individual file, the name of the copy can be changed by selecting the **To** field, then typing a new name.
- The desired partition and directory can be entered directly for the **To** directory; however, the entered directory must already exist, and the partition must be valid. The entry form should be `partition:\Directory`.
- If a file with the same name already exists, you are asked whether to overwrite or supply a different filename.
- You can also use the **Copy** subcommand of the **Browse** command to copy files.

10.8 Delete

The **Delete** command eliminates the selected image from the disk.

The **Delete** panel allows you to delete a selected filename. Normal DOS file conventions should be observed.

Figure 10.8a File Delete Panel



Hints for Optimizing the File Delete Command

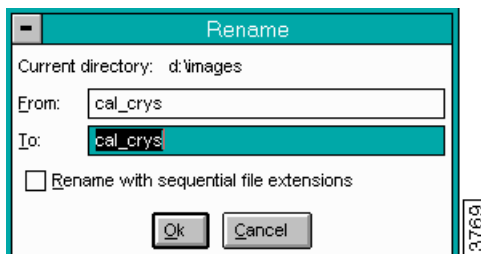
- Confirmation is requested for the Delete command to prevent accidental removal of files.
- The default name is the file selected when the command was given. A different file can be entered by selecting the filename and typing in another filename.
- The **Delete** command may also be used to delete empty directories.
- You can also use the **Delete** subcommand of the **Browse** command to delete files.

10.9 Rename

The **Rename** command changes the name of the selected file.

The **Rename** panel allows you to rename selected files.

Figure 10.9a Rename Panel



10.9.1 Parameters in the Rename Panel

From—Refers to the old file name.

To—Names the new file name.

Rename with sequential file extensions—If the **To** filename is given a numeric extension, subsequent files with the same filename are assigned incremental, sequential extensions.

Ok—Completes the name change.

Cancel—Aborts the **Rename** command, leaving the filename unchanged.

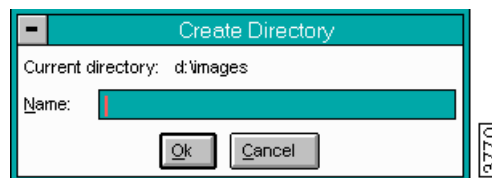
See also: **Offline /File** menu: **Delete**, **Copy**, and **Move** commands.

10.10 Create Directory

The **Create Directory** command allows creation of additional directories in the **Current directory**. Directories created with this command are subsequently recognized by all MS-DOS commands.

The **Create Directory** panel shown in [Figure 10.10a](#) is displayed on the Control Monitor. Enter the directory to be added into the **Name** field, then click on the **OK** button.

Figure 10.10a Create Directory Panel



New directories are placed in the **Current directory** shown in the panel. If the new directory is to go to a different drive or directory other than the one displayed, **Cancel** the **Create Directory** panel, and use the **Files** panel on the Offline screen to specify a new **Current directory**. Reenter the **Create Directory** panel and enter the new directory name.

Note: You can also create a directory on a different drive by specifying the path as part of the directory name, using the format
`drive:\directory\filename`

Chapter 11 Offline Image Menu

The **Image** menu commands allow the user to view two- or three-image files, and then select a single image for further analysis (e.g., **Select Left Image**, **Subtract**, and **Offset**).

Note: The **Image** menu *only* appears after multiple image files are selected.

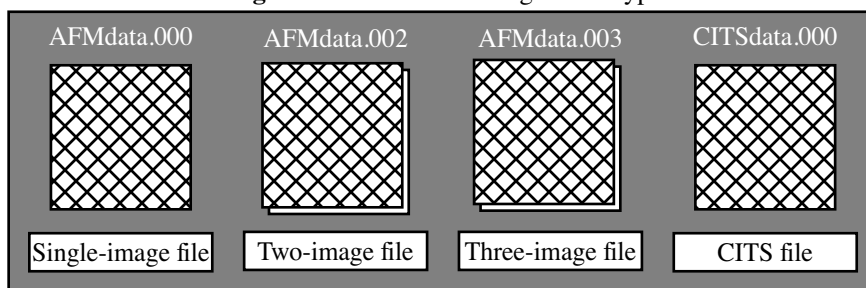
This chapter includes the following **Image** commands:

- **Dual Section** [Section 11.2](#)
- **Select Left** [Section 11.3](#)
- **Select Right** [Section 11.4](#)
- **Subtract Image** [Section 11.5](#)
- **Amp/Phase to Amp SinPhase/Amp Cosphase** [Section 11.6](#)
- **Split Images** [Section 11.7](#)
- **Offset** [Section 11.8](#)

11.1 Image File Types

Image files may take the form of single, dual, or triple images, depending upon how many channels were enabled during **Capture**. It is sometimes necessary to isolate and compare two or three images within a single file, or to compare separate images from separate files. The commands in the **Off-line/Image** menu make image isolation and comparison possible. Look for the *layered* display of boxes denoting multiple images (See [Figure 11.1a](#)).

Figure 11.1a Browse Image Files Types



Displayed menu commands depend on the type of image file(s) selected (See [Table 11.1a](#)).

Table 11.1a Image File Types and Menu Commands

Image File Type Selected	Image Menu Commands Displayed
Two-image files, or two single-image files selected simultaneously using the Browse command.	Dual Section Select Left Image Select Right Image Subtract Images AmpPHase to amp Sinphase/ampCosphase Split Images Offset
Three-image files	Select First Image Select Second Image Select Third Image Amp Phase to amp Sinphase/amp Cosphase

Note: The **Image** menu *only* appears in the **Off-line** mode when selecting the following:

- multiple (two or three) image files
- two (simultaneous) single-image files using the **Browse** screen

[Figure 11.1b](#) shows the menu for *two-image* files.

Figure 11.1b Dual-Image Drop-down Menu

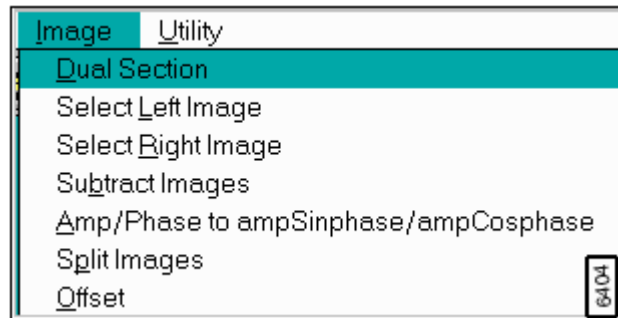


Figure 11.1c shows the drop-down menu for *three-image* files.

Figure 11.1c Three-Image Drop-down Menu



11.2 Dual Section

The **Dual Section** command allows you to analyze surface profiles. When sectioning two images, the section profile is identical in each image (i.e., when cursor moves on one image, the identical position and size moves on the second image). This feature is similar to **Section Analysis**. For complete details on **Section Analysis**, see [Chapter 14](#).

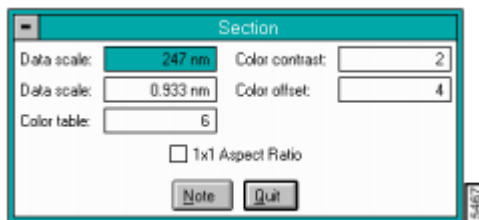
Refer to the following Dual Section topics:

- **Section Panel** [Section 11.2.1](#)
- **Section Display Monitor** [Section 11.2.2](#)
- **Section Display Monitor Menu Commands** [Section 11.2.3](#)

11.2.1 Section Panel

The **Section** panel appears to control the image colors and aspect ratio (See [Figure 11.2a](#)).

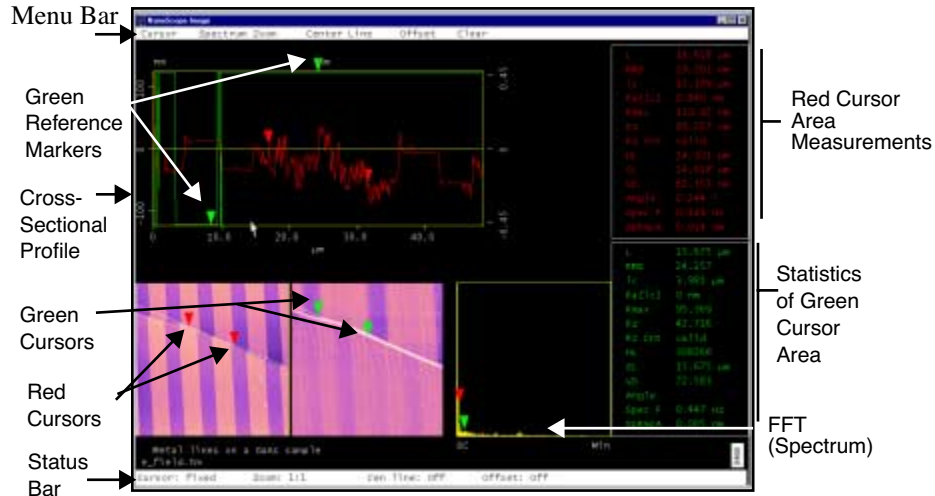
Figure 11.2a Section Panel



11.2.2 Section Display Monitor

The **Section** monitor includes: the two images, a spectrum graph, two statistic boxes, a cross-sectional profile, a menu bar and a status bar (See Figure 11.2b).

Figure 11.2b Image Section Display



11.2.3 Section Display Monitor Menu Commands

The menu bar commands control specified areas of the image to be analyzed. The menu commands include:

Cursor

- **Fixed**— Allows a fixed line cursor to be drawn in area and displays this data in the Cross-sectional profile and Spectrum Graph.
- **Moving**— Allows a fixed-position line to be drawn on the images and places a moving reference line perpendicular to the fixed line. The **Cross-sectional profile** and **FFT (Spectrum Graph)** displays data from the reference line.
- **Average**— Allows a fixed-position reference line to be drawn on the image and places a box parallel to the reference line.

Spectrum Zoom

Controls the magnification of the **Spectrum** window:

- **8:1**—Interpolates data between reference markers in an 8 to 1 ratio
- **4:1**—Interpolates data between reference markers in a 4 to 1 ratio
- **2:1**—Interpolates data between reference markers in a 2 to 1 ratio
- **1:1**—Interpolates data between reference markers in a 1 to 1 ratio

Center Line

Displays the calculated center line (local RMS) between cursors on the **Cross-sectional profile**. The center line displays in white with green and red reference markers.

Range and Settings:

- **On** and **Off**—Switches the center line on or off between cursors. If the **Center Line** subcommand is **ON**, each time the markers are repositioned a line appears (i.e., the first line is red for the red markers, then green and the last is white).

Offset

Allows the center line cursor to be arbitrarily moved so the viewing window can be shifted relative to the data. To move the center line, drag with the mouse:

Offset Range and Settings:

- **On**—Turns Offset on by displaying the t-cross reference markers positioned in the images.
- **Off**—Turns **Offset** off by anchoring the center line at “0.”
- **Cursor Clear**—Anchors the center line at its currently set position.

Clear

Removes the Profile and Spectrum windows and clears the reference marker measurements to allow new reference lines to be selected.

*See also, **Offline/Analyze/Section**.*

11.3 Select Left

The **Select Left** command appears only when dual-image files are selected. It places only the left image from the current file on the Display Monitor.

The **Off-line** menu bar appears when the single image is selected and displayed for individual analysis.

11.4 Select Right

The **Select Right** command appears *only* when dual-image files are selected. It places only the right image from the current file on the Display Monitor.

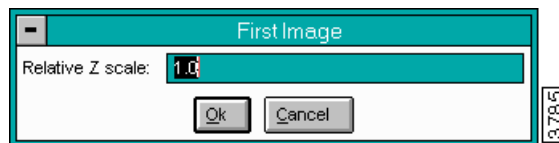
The **Off-line** menu bar appears when the single image is selected and displayed for individual analysis.

11.5 Subtract Image

The **Subtract** command appears when either a dual image file is selected, or two single-image files are selected by executing the **Dual** command from the **Browse** screen. It allows one image to be subtracted from another.

If the **Data type** for the images is different, panels appear, allowing you to enter **Relative Z scale** values for each image. In either case, another panel appears so the resultant file can be named and stored.

Figure 11.5a Image Relative Z Scale Pane



Hints for Optimizing the Subtract Command

- When **Data types** are the same, the second (right) image is subtracted from the first (left) image.

- When **Data types** are not the same, the calculation is performed as follows:

First (left) **Relative Z scale** * first (left) image – second (right) **Relative Z scale** * second (right) image = New Image
- The images must be the same **Scan size** and contain the same number of data points (i.e., **Number of samples** must be equal).
- The **Relative Z scale** parameter must be less than 10,000 and greater than 0.0001.
- Two separate images can be put together for the sake of this command with the **Dual** subcommand under the **Off-line / Browse** command.
- Limitations built into the command are not that stringent. Just because the command subtracts two images does not mean that the result is useful.

See also: **Off-line/File** menu: **Browse/Dual** subcommand.

11.6 Amp/Phase to Amp SinPhase/Amp Cosphase

In this function, dual images, which were obtained in **Force Modulation** appear on the Display Monitor. The left image is an amplitude image and the right is a phase image (i.e., Amp/Phase). The command creates two new images:

1. The left image is the amplitude image multiplied by the sine of the phase image.

$$\text{New left Image} = \text{old left point} * \sin(\text{old right point}) \quad (\text{EQ 1})$$

2. The new right image is the amplitude image multiplied by the cosine of the phase image.

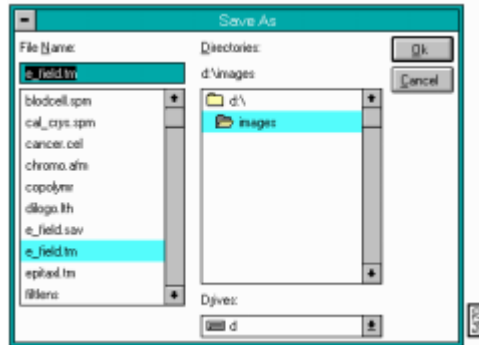
$$\text{New right image} = \text{old left point} * \cos(\text{old right point}) \quad (\text{EQ 2})$$

11.6.1 Control Panel

After **Amp/Phase to Amp Sinphase/Amp Cophase** is selected, a **Save As** file panel appears to store the two new images (See [Figure 11.6a](#)).

Note: Open the new files in Windows Explorer using your local simpletext editor.

Figure 11.6a Save As File Panel



11.7 Split Images

The **Split Images** command appears only when a two or three image file is selected. It places all images from the current multiple image file on the Display Monitor in two- or three-image format. These separated images may then be saved as separate files.

Note: The Off-line menu bar is truncated by this command, because images must be processed individually.

Figure 11.7a Split Images Panel



11.8 Offset

The **Offset** command displays in the two or three-image file menus and allows for a comparison of visual data. Clicking on this function creates a center line reference marker on each image. Position a marker and drag the mouse to reposition markers for comparing data in the multiple images.

Chapter 12 Offline View Menu

View menu commands allow previously captured files to be displayed in various formats. This chapter includes the following **View** functions:

- **Top View** [Section 12.1](#)
- **Line Plot** [Section 12.2](#)
- **Quick Surface Plot** [Section 12.4](#)
- **Parameter** [Section 12.5](#)
- **Graph** [Section 12.6](#)

Not all commands are set by default. To access the entire list available, use the **Customize** function (**Off-line/DI/Customize/View Menu**).

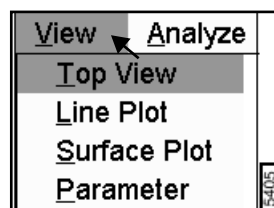
Commands providing a top view and selectable oblique views are available for image files. The **Graph** command appears when force calibration curves are selected. The **Image** command appears when you select dual image files.

12.1 Top View



The **Top View** command displays the selected image from a top-down perspective. The X and Y information is in the plane of the monitor, and the height information is represented by the color at a given point. You can calculate the distance and angle between features, as well as the angle between planar features. Access **Top View** by clicking on the icon below the menu bar or entering the following path: **Off-line/View/Top View**.

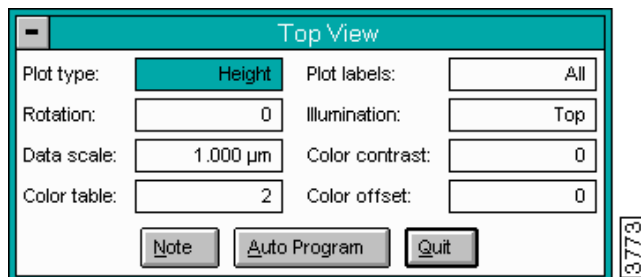
Figure 12.1a View Menu



12.1.1 Top View Control Monitor

The **Top View** panel is displayed on the Control Monitor, allowing the appearance of the image on the Display Monitor to be adjusted to your preference (See [Figure 12.1b](#)).

Figure 12.1b Top View Panel



12.1.2 Parameters in the Top View Panel

Plot type

Selects the mode in which the data is displayed: **Height**, **Illuminate**, or the contrast-enhanced **Equal area** mode.

Range and Settings:

- **Equal area**—Applies a contrast-enhancing function to the data.
- **Height**—The image is displayed with the height values at each point encoded according to the color table.
- **Illuminate**—The image is displayed as if a light source is shining on the sample surface from a selectable direction.

Note: In the **Equal area** mode, the **Z range** and **Illuminate** parameters have no effect on the display.

Note: The **Illumination** parameter on the **Top View** panel affects the display only if **Illuminate** is selected as **Plot type**.

Rotation

Selects the angular orientation of the displayed image relative to the captured image.

Range & Settings:

- **0**—No rotation.
- **90**—Rotates image 90 degrees counterclockwise.
- **180**—Rotates image 180 degrees counterclockwise.
- **270**—Rotates image 270 degrees counterclockwise.

Data scale

Controls the vertical range of the image, corresponding to the full extent of the color table.

Range & Settings:

- This parameter is head- and scanner-dependent, and the units vary according to the type of image (e.g., nm, nA, etc.).
- This parameter applies only to height data.

Color table

Selects which color table is used by the display commands to encode the Z information.

Range & Settings:

- **0–21**

Note: Color tables 0 through 3 are built into the NanoScope software. Tables 4 through 21 are from color table files you can access and modify with the **Offline/Utility/Color table** command.

Note: This parameter has an immediate effect on the image and any visible color bar.

Plot labels

Selects which axes and labels display with the image. This parameter is useful for generating hard copies for presentation. You can display and print images with the amount of information you choose to include.

Range & Settings:

- **All**—Includes plot axes, color bar, file name, and information label.
- **Axes**—Includes the plot axes and the color bar.
- **None**—Displays image by itself.

- **Big Note**—Includes plot axes, color bar, and a double-sized label.

Illumination

Selects the position of the imaginary light source used to highlight features if you have selected **Illuminate** as the **Plot type**.

Range & Settings:

- **Top**—Illumination is from directly above the image.
- **Right**—Illumination is from above and to the right of the image.
- **Front**—Illumination is from above and to the front of the image.
- **Left**—Illumination is from above and to the left of the image.
- **Back**—Illumination is from above and to the back of the image.

Note: This parameter only takes effect when the **Plot type** parameter in the **Top View** panel is set to **Illuminate**.

Color contrast

Compresses or expands the color table about its center, effectively increasing or decreasing the image contrast.

Range & Settings:

- ± 10

Note: This parameter has an immediate effect on the image and any visible color bar.

Color offset

Adds or subtracts a constant offset from each color table index, shifting the color scale up or down.

Range & Settings:

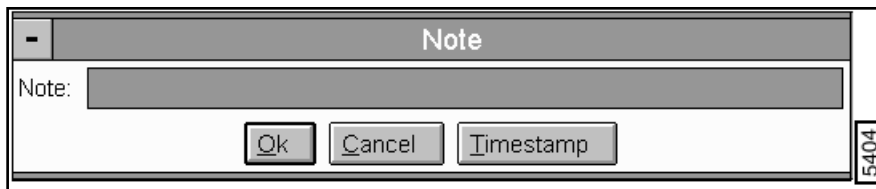
- **± 120** As the color table shifts upward or downward, the bottom or top color continues to fill in the offset.

12.1.3 Buttons on the Top View Panel

Note

Allows a descriptive message and time stamp to be added to the display (See [Figure 12.1c](#)). The note can be up to 32 characters.

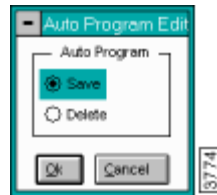
Figure 12.1c Note Panel.



Auto Program

The **AUTO PROGRAM** button accesses the **Auto Program Edit** panel. In this panel, the **Top View** command is saved or deleted from the currently selected **Auto Program** file (See [Figure 12.1d](#)).

Figure 12.1d Auto Program Edit Panel



Note: The **Auto Program File** command in the **Utility** menu must be used to select or create an auto program file.

Use the **Auto** subcommand under the **Browse** command to select files to be processed and to execute the Auto Program file.

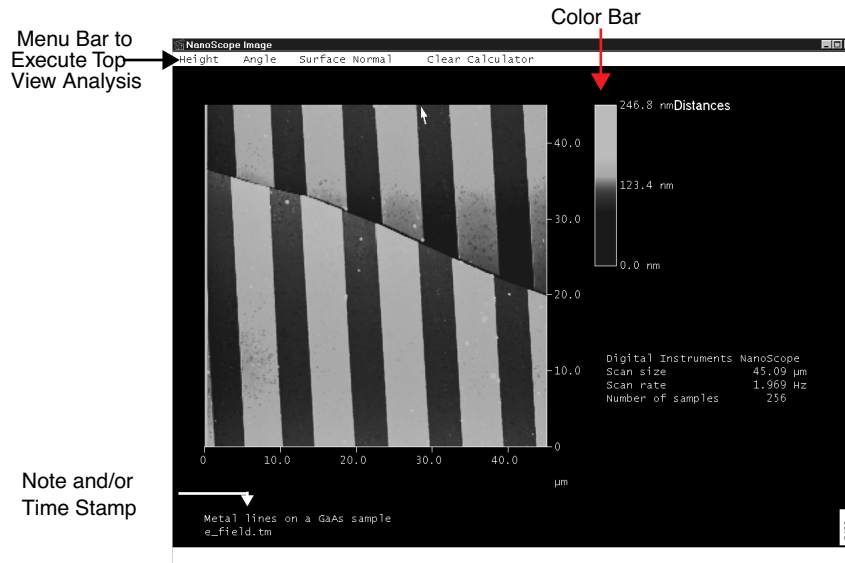
Quit

Exits the **Top View** command.

12.1.4 Top View Display Monitor

The Display Monitor includes the image, the color bar used to encode the height information, a menu bar, and a status bar (See [Figure 12.1e](#)).

Figure 12.1e Top View Display Monitor.



Top View Menu Bar Commands

The commands in the menu bar let you use the mouse to determine point-to-point distances and angles on the captured image.

Height

Allows you to measure the change in height and the distance between points on an image. When more than one line is drawn, the sum of the line lengths and the average line length are reported in the status bar on the Display Monitor.

Mouse Operations

- 1st click, left button—Fixes the position of the first point. A line segment “rubberbands” from the point as the mouse is moved.
- 2nd click, left button—Fixes the position of the second point.
- Subsequent clicks—Pick up the end of the line closest to the cursor. A second click fixes the point.
- Click on **Height** again to remove line cursor.

Angle

Allows angular features to be measured on the image.

Mouse Operations

- 1st click, left button—Defines the vertex of the angle. A line segment expands from the point as you move the mouse.
- 2nd click, left button—Defines one leg of the angle. The other leg swings out as the mouse is moved.
- 3rd click, left button—Fixes the position of the second leg of the angle.
- Subsequent clicks—Pick up the leg of the angle closest to the cursor. Another click fixes the leg.
- Click on **Angle** again to remove angle from image.

Surface Normal

Calculates the angle between two planes you define. This subcommand performs a least-squares plane fit on the data in the two boxes, then calculates and reports the angle between vectors perpendicular to the calculated planes.

Mouse Operations

- 1st click, left button—Defines the corner of the first box (shown with red perimeter lines). A box expands from the point as the mouse is moved.
- 2nd click, left button—Defines and expands the opposite corner of the first box.
- 3rd click, left button—Defines the corner of the second box (shown with green perimeter lines). A box expands from the point as the mouse is moved.
- 4th click, left button—Defines and expands the opposite corner of the second box.
- Subsequent clicks—With cursor inside a box, picks up the entire box. With cursor on edge or corner, resizes box. Another click fixes the box position.
- Click on the **Surface Normal** command again to remove the boxes from the displayed image.

Clear Calculator

Zeros the sum and average values reported for the **Height** subcommand.

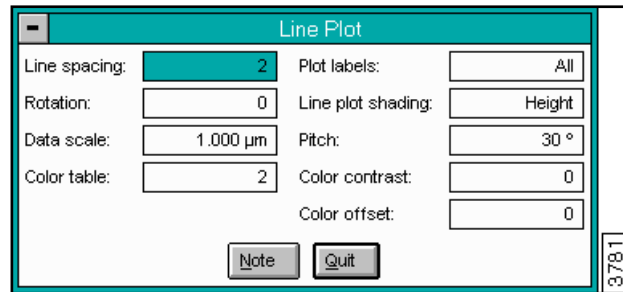
Note: In the typical color table, lighter colors represent taller positions while darker shades represent lower positions on the sample. However, this is flexible. A wide variety of color tables is available, and almost any color scheme can be used.

See also: **Off-line/View** menu: **Line Plot** and **Surface Plot** commands.
Off-line/Utility menu: **Color table** command.

12.2 Line Plot

The **Line Plot** command displays the selected image as a series of cross sections in an oblique view. Select **View/Line Plot** to access the **Line Plot** panel (See [Figure 12.2a](#)).

Figure 12.2a Line Plot Panel



12.2.1 Parameters on the Line Plot Panel

Line spacing

Controls the horizontal distance between lines in the displayed image.

Range & Settings:

- 2–16

Rotation

Selects the angular orientation of the displayed image relative to the captured image.

Range & Settings:

- 0—No rotation.
- 90—Rotates image 90 degrees counterclockwise.
- 180—Rotates image 180 degrees counterclockwise.
- 270—Rotates image 270 degrees counterclockwise.

Data scale

Defines the vertical range of the color table used to encode the height information in the image.

Range & Settings:

- This parameter is head- and scanner-dependent, and the units vary according to the type of image (e.g., nm, nA).

Color table

Selects the color table used to encode the Z information.

Range & Settings:

- **0—21** (Color schemes are numbered in no particular order.)

Hints for Optimizing the Color Table Command

- Colors used to construct images are rendered electronically and often bear little resemblance to the actual sample color. Most scan sizes are below the wavelengths of visible light.
- Color tables 0 through 3 are built into the NanoScope software. Tables 4 through 21 are from color table files which can be accessed and modified with the **Off-line/Utility/Color table** command.
- This parameter has an immediate effect on the image and any visible color bar.

Plot labels

Selects which axes and labels are displayed with the image.

Range & Settings:

- **All**—Includes plot axes, color bar, file name, and information label.
- **Axes**—Includes the plot axes and the color bar.
- **None**—Displays image by itself.
- **Big Note**—Includes plot axes, color bar, and a double-sized label.

Note: Regardless of the setting of this parameter, the color bar is not displayed when the **Line plot shading** parameter on the **Line Plot** panel is set to **White**.

Line plot shading

Allows the lines to be displayed in plain white or in color with the color representing the height at a given point in the image.

Range & Settings:

- **White**—The cross sectional lines displayed are white.
- **Height**—The color table is applied to the cross sectional lines which form the image.

Pitch

Selects the pitch of the Y axis in the three-dimensional Line Plot image.

Range & Settings: **30** and **60**

Color contrast

Compresses or expands the color table about its center, effectively increasing or decreasing the image contrast.

Range & Settings:

- **±10**

Note: This parameter only has an effect when the **Line plot shading** parameter on the **Line Plot** panel is set to **Height**.

Color offset

Adds or subtracts a constant offset from each color table index, shifting the color scale up or down.

Range & Settings:

- **±120** This parameter has an immediate effect on the image and any visible color bar. As the color table is shifted upward or downward, the bottom or top entry is replicated to fill in the offset.

Note: This parameter only has an effect when the **Line plot shading** parameter on the **Line Plot** panel is set to **Height**.

12.2.2 Buttons in the Line Plot Panel

Note

Allows a descriptive message and/or a time stamp to be added to the displayed image.

Quit

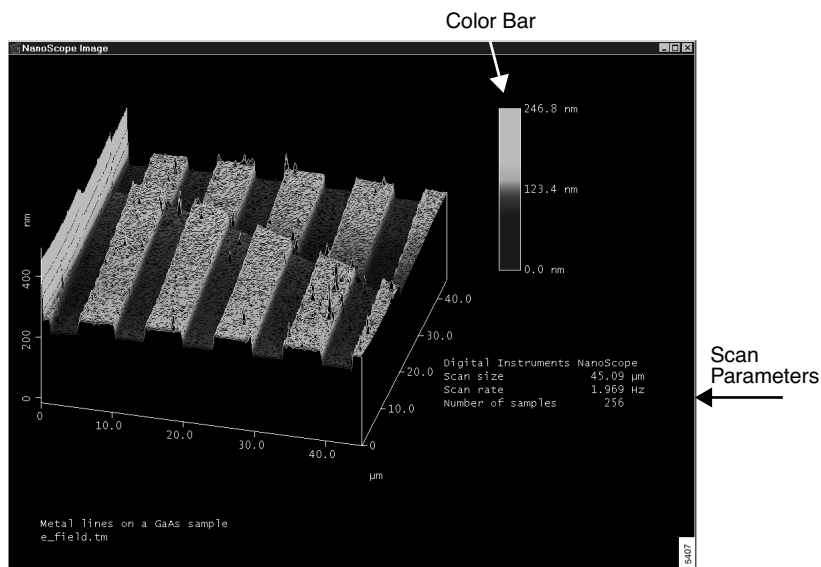
Exits the Line Plot command.

See also: **Off-line/View** menu: **Top View** and **Surface Plot** commands.

12.2.3 Line Plot Display Monitor

The Display Monitor includes an image, a color bar and a list of scan parameters (See [Figure 12.2b](#)). No menu items exist since the commands execute by using the Line Plot panel.

Figure 12.2b Line Plot Display



12.2.4 Using the Line Plot Command

To produce a hardcopy line plot of an image, complete the following:

1. Select the image with the mouse.
2. Access the **Line Plot** command.
3. Adjust the display parameters until the presentation is satisfactory.
4. Quit the **Line Plot** command and click on the **Print** subcommand (**Off-line/Utility/Print**) to print the displayed image.

12.3 Surface Plot

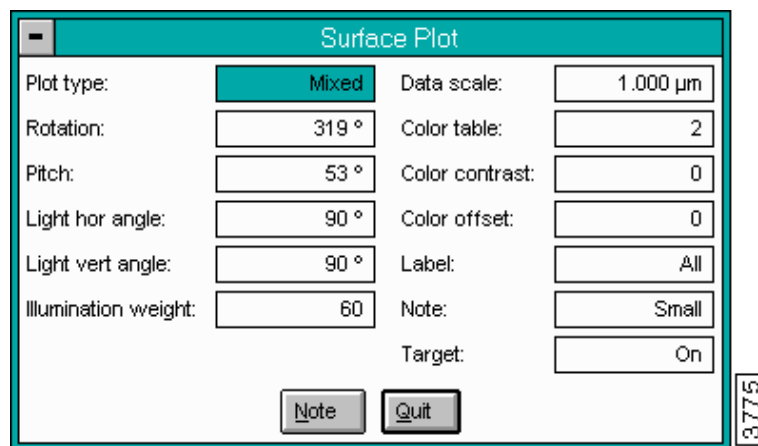


The **Surface Plot** command displays the selected image with color-coded height information in a three-dimensional, oblique perspective. You can select the viewing angle and illumination angle for a modeled light source.

View the **Surface Plot** by clicking on the **Surface Plot** icon, or enter the following path: **Off-line/View/Surface Plot**.

The **Surface Plot** panel appears and allows formatting of image data on the Display Monitor (See Figure 12.3a).

Figure 12.3a Surface Plot Panel



12.3.1 Buttons and Parameters in the Surface Plot Panel

Plot Type

Selects data type displayed in **Height**, **Illuminate**, or a combination of the two.

Range & Settings:

- **Height**—Displays image with the height values encoded according to the color table.
- **Illuminate**—Displays image as if a light source is shining on the sample surface from a selectable direction.
- **Mixed**—A combination of height and illumination encoding is used on the displayed image. The relative weights of the height and illumination are determined by the **Illumination weight** parameter on the **Surface Plot** panel.

Note: The **Illumination weight** parameter only affects the display when the **Plot type** is set to **MIXED**.

Rotation

The **Rotation** parameter in the **Surface Plot** panel changes the viewing angle by rotating the displayed image about the Z axis relative to its captured orientation.

Range & Settings:

- 0—360°

Pitch

The **Pitch** parameter in the **Surface Plot** panel changes the viewing angle by selecting the pitch (in degrees) of the Y axis in the three-dimensional Surface Plot image.

Range & Settings:

- 0—90°

Light Hor Angle

The **Light hor(izontal) angle** parameter in the **Surface Plot** panel rotates the modeled incident light source in the horizontal plane (along the Z axis).

Range & Settings:

- 0—360°

Light Ver Angle

The **Light ver(tical) angle** parameter in the **Surface Plot** panel selects the vertical angle (in degrees) for the modeled, incident light source.

Range & Settings:

- 0—90°

Illumination Weight

Selects the percentage of the imaginary light source mixed with the color-encoded height information when the **Plot type** is set to **Mixed**.

Range & Settings:

- 0—100

Note: This parameter applied for **Plot type** set to MIXED.

Data Scale

The **Data scale** parameter in the **Surface Plot** panel defines the full range of the color bar used to encode the height information applied to the displayed image.

Range & Settings:

- This parameter is head- and scanner-dependent, and the units vary according to the type of image (e.g., nm, nA).

Color Table

The **Color table** parameter in the **Surface Plot** panel selects which color table is applied to the Z-axis data.

Range & Settings:

- **0—21:** Color tables 0 through 3 are built into the NanoScope software. Tables 4 through 21 are from color table files which can be accessed and modified with the Off-line/Utility/Color table command.

Color Contrast

The **Color contrast** parameter in the **Surface Plot** panel compresses or expands the color table about its center, effectively increasing or decreasing the image contrast.

Range & Settings:

- ± 10

Note: This parameter has an immediate effect on the image and any visible color bar.

Color Offset

The **Color offset** parameter in the **Surface Plot** panel changes the image color by shifting the range of the color table used to display the image. It adds/subtracts a constant offset from each color table index, shifting the color scale up/down.

Range & Settings:

- ± 120

Note: As the color table is shifted upward or downward, the bottom or top entry continues to fill in the offset.

Label

The **Label** parameter in the **Surface Plot** panel selects whether labels, axes, and the view/illumination controller are displayed with the image.

Range & Settings:

- **All**—Includes the plot axes, scan parameters, and scale.
- **Axes**—Includes the plot axes and scale.
- **None**—Only the image is displayed.

Note

The **Note** parameter in the **Surface Plot** panel enables/disables the note appended to the image and changes its size on the Display Monitor.

Range & Settings:

- **Big**—Large font.
- **Small**—Small font.
- **None**—No message.

Target

The **Target** parameter in the **Surface Plot** panel turns the Display Monitor view/illumination controller on or off.

Range & Settings:

- **On**—Displays illumination controller with the image.
- **Off**—Does not display illumination controller.

Note

Allows a descriptive message to be added to the control monitor.

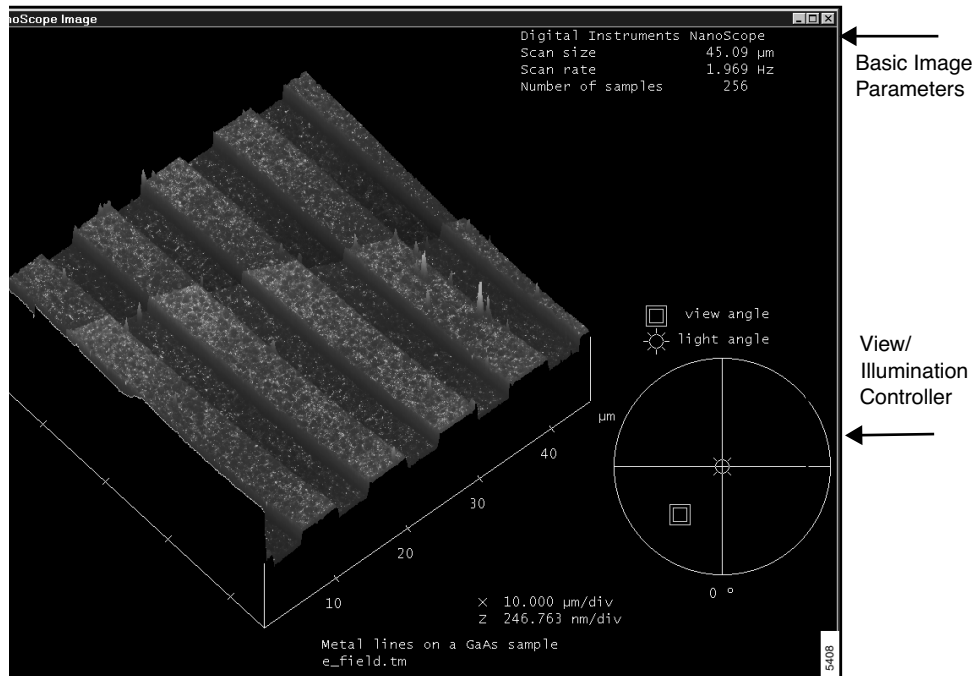
Quit

Exits the **Surface Plot** mode.

12.3.2 Surface Plot Display Monitor

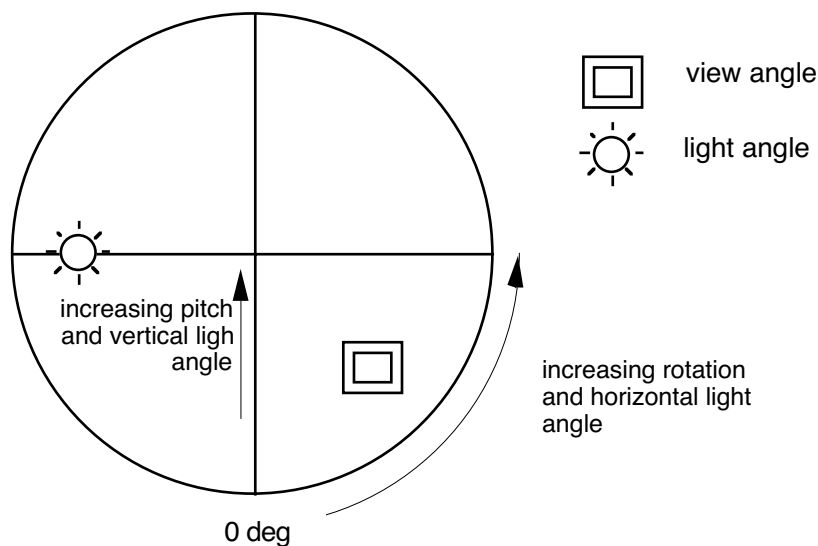
The Display Monitor includes an image, a list of scan parameters and a **View/Illumination** controller (See [Figure 12.3b](#)).

Figure 12.3b Surface Plot Display



The **View/Illumination** controller, which consists of cross hairs in a circle, can be used to set the viewing angle and the angle of incidence from an imaginary light source (See [Figure 12.3c](#)).

Figure 12.3c View/Illumination Controller Operation



12.3.3 The View/Illumination Parameter

The light icon, which is used to position the angle of incidence of the imaginary light source, is the circle with radial lines. It affects the image if the **Plot type** is set to either **Illuminate** or **Mixed** (if the **Illumination weight** in the panel is greater than zero). Placing the light icon at the cross hairs in the center of the view/illumination controller places the light source directly above the sample. Moving the light icon toward the circumference of the circle moves the light source toward the horizon.

The nested square boxes constitute the view angle icon. Placing the view angle icon in the center of the view/illumination controller provides a top view perspective of the image. Moving the view angle icon radially toward the circumference of the circle reduces the pitch angle. Rotating the view angle icon around the circle changes the rotation of the sample.

Hints for Optimizing the Surface Plot Command

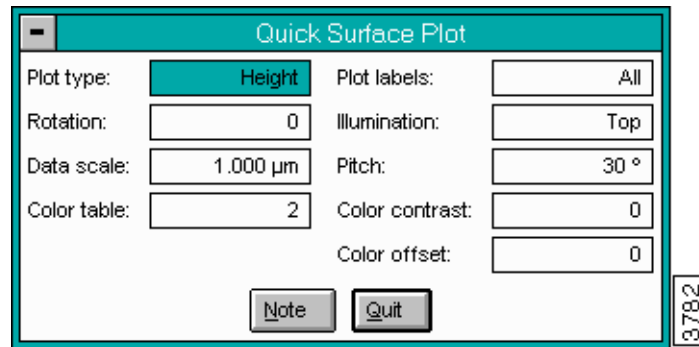
- Height-encoded surface plots (**Plot type** parameter set to **Height**) are less susceptible to high frequency noise and tend to look better than slope-shaded plots (**Plot type** parameter set to **Illuminate**) for images with a large number of features.
- The **Rotation**, **Pitch**, **Light hor angle**, and **Light ver angle** can be changed by changing the position of the appropriate symbol on the view/illumination controller or by changing the values in the **Surface Plot** panel.

See also: **Off-line/View** menu: **Surface Plot**, **Top View**, and **Line Plot** commands.

12.4 Quick Surface Plot

The **Quick Surface Plot** command is similar to the **Surface Plot** command but has fewer parameters displayed.

Figure 12.4a Quick Surface Plot Panel



12.4.1 Buttons and Parameters on Quick Surface Plot Panel

Plot Type

Selects whether the data is displayed in the **Height** or **Illuminate** mode.

Range & Settings:

- **Height**—The image is displayed with the height values encoded according to the color table.
- **Illuminate**—The image is displayed as if a light source is shining on the sample surface from a selectable direction.

Rotation

The **Rotation** parameter in the **Quick Surface Plot** panel changes the viewing angle by rotating the displayed image about the Z axis relative to its captured orientation.

Range & Settings:

- **0–360°**

Data Scale

The **Data scale** parameter in the **Quick Surface Plot** panel defines the vertical range of the color table used to encode the height information in the image.

Range & Settings:

- This parameter is head- and scanner-dependent, and the units vary according to the type of image (e.g., nm, nA).

Color Table

The **Color table** parameter in the **Quick Surface Plot** panel selects which color table is applied to the Z-axis data.

Range & Settings:

- **0–21**

Note: Color tables 0 through 3 are built into the NanoScope software. Tables 4 through 21 are from color table files you can access and modify with the **Color table** command.

Plot Labels

The **Plot labels** parameter in the **Quick Surface Plot** panel selects whether labels, axes, the view/illumination controller, or a note are displayed with the image.

Range & Settings:

- **All**—The plot axes, scan parameters, and scale are displayed with the image.
- **Axes**—The plot axes and scale are displayed with the image.
- **None**—Only the image is displayed.
- **Big Note**—A note with large font is appended to the image.

Illumination

Images displayed with the **Illuminate Plot type** appear to be illuminated by a light source. This parameter varies the position of the light source relative to the sample.

Range & Settings:

- **Top**—Places the light source directly above the sample.
- **Right**—Places the light source on the right side of the sample.
- **Front**—Places the light source in front of the sample.

-
- **Left**—Places the light source on the left side of the sample.
 - **Back**—Places the light source behind the sample.
-

Pitch

The **Pitch** parameter in the **Surface Plot** panel changes the viewing angle by selecting the pitch (in degrees) of the Y axis in the three-dimensional **Surface Plot** image.

Range & Settings:

- **30°, 60°**

Color Contrast

The **Color contrast** parameter in the **Quick Surface Plot** panel compresses or expands the color table about its center, effectively increasing or decreasing the image contrast.

Range & Settings:

- **±10**

Note: This parameter has an immediate effect on the image and any visible color bar.

Color Offset

The **Color offset** parameter in the **Quick Surface Plot** panel changes the image color by shifting the range of the color table used to display the image. It adds/subtracts a constant offset from each color table index, shifting the color scale up/down.

Range & Settings:

- **±120**

Note: This parameter has an immediate effect on the image and any visible color bar. As the color table is shifted upward or downward, the bottom or top entry continues to fill in the offset.

Note [button]

Offline View Menu descriptive message and/or time stamp to the displayed image.

Parameter

Quit

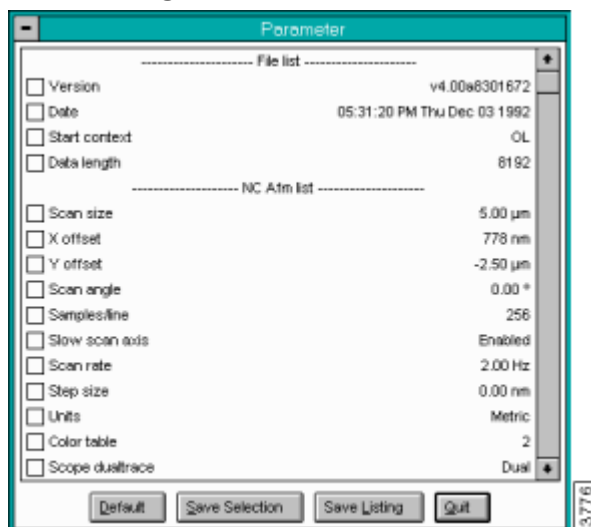
Exits the **Quick Surface Plot** mode.

12.5 Parameter

The **Parameter** command allows you to select a limited number of parameters which are subsequently shown on the Display Monitor with the image or force curve in all **View** formats.

A representative panel is shown in [Figure 12.5a](#). The actual parameters listed depend on the type of file selected. The panel shows lists of parameters and their configured setting.

Figure 12.5a Parameter Panel



12.5.1 Measurements in the Parameter Panel

The **Parameter** panel displays parameters to be displayed with the image. All of the parameters from the header to the image file are shown, but only selected parameters may be displayed. You can scroll through the list of parameters by using the **Page Up** and

12.5.2 Buttons on the Parameter Panel

Default

The selection defaults to a predefined set of parameters (**Scan size**, **Setpoint**, **Scan rate**, and **Number of samples**).

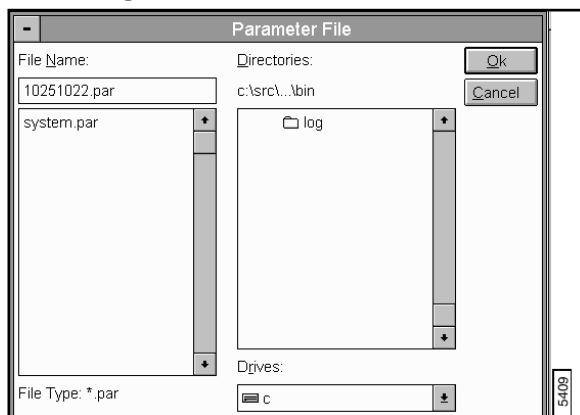
Save Selection

The selected parameters are displayed in a list with the image the next time a **View** command is used to display the image.

Save Listing

Accesses the **Parameter File** panel to create a new file that contains all of the parameters in the entire list (See [Figure 12.5b](#)).

Figure 12.5b Parameter File Panel.



Quit—Exits the **Parameter** command.

12.5.0 Parameter Display Monitor

Graph

In several cases, the same parameter appears twice in the list, but the values may be different. Always use the parameter from the **AFM** or **STM** list for different values.

Note: For dual image files, the **Parameter** command is not available until one of the images is selected. The header for a dual image contains two image lists, one for each image. Both of the image lists are available with the **Parameter** command even after one image has been separated. The first image list corresponds to the left image while the second image list relates to the right image.

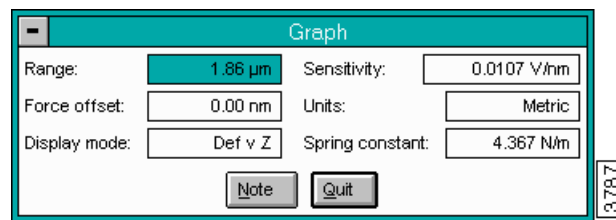
12.6 Graph

The **Graph** command appears in the **View** menu when a **Force Calibrate** function (also referred to as **Force Curve**) or **Scope Trace** is selected. For the **Force Curve** function, several formats of the graph axes can be selected.

12.6.1 Graph Control Monitor

The **Graph** panel displays on the Control Monitor, allowing you to adjust the appearance of the plot, sensitivity values, displayed units and Spring Constant value. For additional information on Force Curves, see [Chapter 5, Force Mode Section 5.3](#).

Figure 12.6a Graph of Force Plot Panel



12.6.2 Buttons and Parameters in the Graph Panel

Range

Force Offset

The distance to offset the plot along the deflection or force axis. This can be set with the **Offset** subcommand in the Display Monitor menu.

Display Mode

Changes the format of the displayed data. Several combinations of axes are available. The selections vary depending on the type of data.

Use the following **Display mode** options for TappingMode data:

- **Amp v Z**—Displays the RMS cantilever amplitude versus the Z position of the scanner.
- **Amp v Sep(aration)**—Displays the RMS cantilever amplitude versus the sample-to-tip separation.
- The following are for contact mode data:
- **Def v Z**—Displays the cantilever deflection versus the Z position of the scanner.
- **Def v Sep(aration)**—Displays the cantilever deflection versus the sample-to-tip separation.
- **Frc v Sep(aration)**—Displays the force on the cantilever versus the sample-to-tip separation. By first placing the cursor at the point of the start of deflection, the **Frc v Sep** mode gives a load versus penetration plot of the distance the tip moves versus force applied to the surface.

Sensitivity

Allows **Sensitivity** parameter to be determined graphically. Displays change in the cantilever deflection voltage-versus-piezo — — — voltage applied to the Z axis (the slope of the force curve between the cursors) when the probe is on the surface. This value has several important functions within the **Graph** command. It must be determined accurately before any data can be accurately represented.

Offline View Menu. The Tip Force also depends on the
Graph Sensitivity. The tip-to-sample separation is defined by removing this slope from the deflection data.

Note: Both cursors should be placed on the sloped portion of the curve.

Mouse Operations:

Two arrow cursors appear on the plot. A left button click on either cursor picks it up. A second left button click drops the cursor. When a cursor stops, or is dropped, **Sensitivity** parameter changes to the slope of the least-squares fit of the data points between the cursors. The cursors should be positioned on the downward sloping section of the plot where the tip is in firm contact with the sample, encompassing as much good data as possible.

Units

Sets the units for all measurements.

Range & Settings:

- **Volts or Metric**

Spring Constant

Use the **Spring Constant** for converting deflection to force. This value must be set accurately to use the **Frc v Sep** display mode.

Note

Allows a descriptive message to be added to the display.

Quit

Exits the operation.

12.6.3 Display Monitor Graph Commands

Sensitivity

Allows the Sensitivity parameter to be changed graphically.

Direction

This subcommand changes the plot line (trace or retrace) tracked by the Sensitivity and Offset cursors.

Offset

Allows the Offset parameter to be changed graphically.

Zoom in / Zoom out

Zooms the graph inward or outward.

Z Offset

Activates the center vertical cursor. Moving the cursor and Executing the move shifts the center of the plot to the cursor.

Execute

Completes the Z Offset command.

Reset

Resets the plot to its original display (erases any offsets and zooms).

Clear

Clears any offset lines (center vertical lines) in the Display Monitor.

Offline View Menu
Graph

Chapter 13 Analysis Commands (A-L)

The commands in the **Analyze** menu provide methods for quantifying the surface properties of samples. You may skip through different sections of this chapter, according to your immediate interests. Commands beginning with the letters M-Z are listed in [Chapter 14](#).

This chapter includes the following **Analyze** commands:

- **Autocovariance** [Section 13.2](#)
- **Auto Stepheight** [Section 13.3](#)
- **Bearing** [Section 13.4](#)
- **Bearing Compare** [Section 13.5](#)
- **Depth** [Section 13.6](#)
- **Grain Size** [Section 13.7](#)
- **Grain Size Average** [Section 13.8](#)

Note: Instructions for highly specialized Off-line **Analyze** commands (such as **LZT Analysis**) are not included in this manual. For more information on these features, please contact your local sales representative.

13.1 Theory

See Table 13.1a to review **Analyze** features and its applications in this chapter.

Table 13.1a Analyze Commands & Applications

Analyze Command	Measure Depth	Measure Roughness	Measure Power Spectrum	Grain Size
Autocovariance			√	√
Auto Stepheight	√			
Bearing	√	√		
Bearing Compare	√	√		
Bump Analysis				
Depth	√	√		
Grain Size	√			√
Grain Size Average				√

Numerous books are available which describe image processing with matrices, Fourier analysis and statistical methods such as autocovariance. Digital Instruments recommends two excellent books on the subject of image processing by John C. Russ—*The Image Processing Handbook* (1992, CRC Press, Inc., Boca Raton) and *Computer-Assisted Microscopy, The Measurement and Analysis of Images* (1992, Plenum Press, New York). You are also referred to author Jean M. Bennett as an excellent source of books and articles on Fourier analysis and statistical methods. Digital Instruments recommends her *Introduction to Surface Roughness and Scattering* (co-authored with Lars Mattsson, 1989, Optical Society of America, Washington, D.C.), among others.

13.1.1 FFTs, PSDs, Autocovariance and RMS

Two off-line NanoScope commands, **Power Spectral Density (Analyze/PSD)** and **2D Spectrum (Modify/2D Spectrum)**, use Fourier analysis to extract information from images. A third method, **Autocovariance (Analyze/Autocovariance)**, uses a related, discrete method for analyzing images. Applications of all three features are discussed briefly in this section to assist the reader. Features are discussed further in their own sections.

Relating FFTs, PSDs, Autocovariance and Root Mean Square (RMS)

Fast Fourier transforms (FFTs), power spectral densities (PSDs), autocovariance and Root Mean Square (RMS) roughness are interrelated mathematically. Their relationship may be stated as follows:

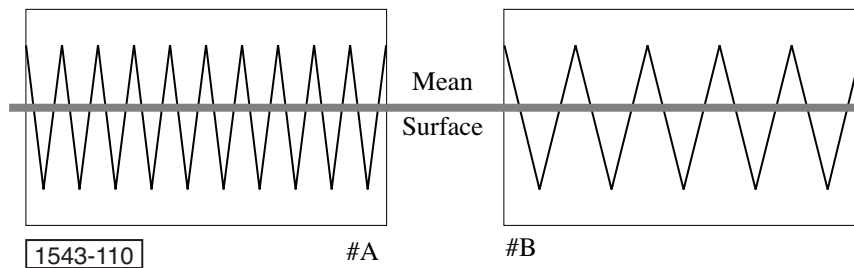
$$\text{PSD} = \text{FFT}^2 = \text{FFT}\{\text{ACF}\} = \text{RMS}^2$$

The (one-dimensional) power spectral density (PSD) of a surface is equal to the square of its Fourier transform (FFT) and is also equal to the Fourier transform of its autocovariance function (ACF), or the RMS value squared. Both one- and two-dimensional PSDs are calculated automatically and displayed by the **Analyze/ Power Spectral Density** function; however, the spectral plot is presented only for the two-dimensional PSD.

13.1.2 Why a Power Spectrum?

Surfaces illustrated in [Figure 13.1a](#) may be characterized with roughness analysis, commonly using the RMS roughness, or R_a value. In the surfaces represented here, peaks and valleys are equidistant from the mean surface centerline. Although surface #A contains noticeably more peaks than surface frequency or wavelength also distinguish them apart for characterizing each surface's feature. It would be helpful to know which wavelengths occur most often and which impart the greatest influence or "power" to the surface's topography. This is presented in a *power spectral density* analysis.

Figure 13.1a Sample Surfaces Example



13.1.3 Example

Figure 13.1b is a synthetic image of an idealized, sinusoidal waveform having a wavelength of 63 nanometers. The waveform is pure and noise-free, and is not observed on natural surfaces; however, analysis is helpful in understanding spectral plots.

Figure 13.1b "Rules" Image

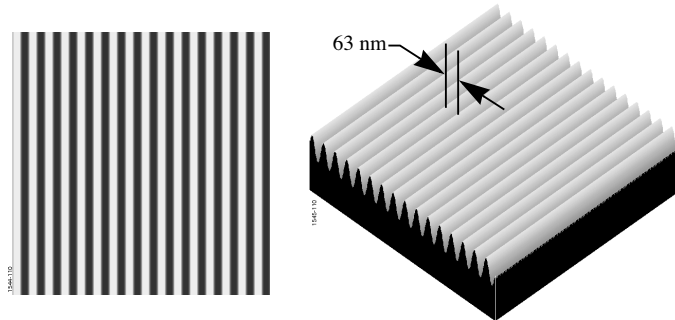
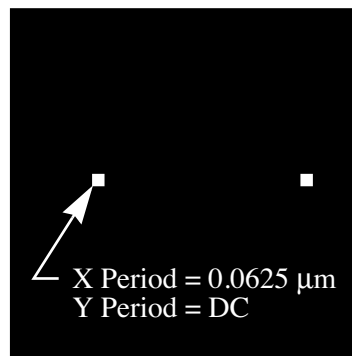


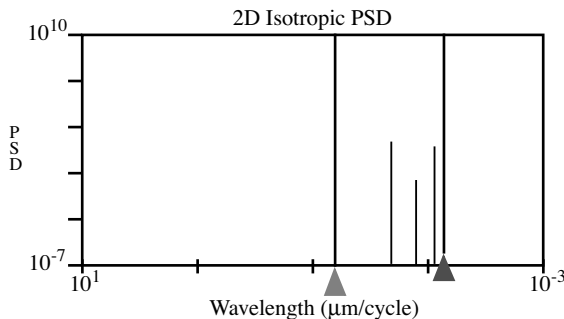
Figure 13.1c X and Y Period (Wavelength)



Notice that there is no Y component (the rules are perfectly parallel), and the **Y Period** is equal to **DC** (direct current). That is, the Y axis in this case cannot be expressed as a sinusoidal wave form and is, therefore, a flat wave form—as though produced by a fixed, direct current signal.

To further analyze, click on **Analyze/ Power Spectral Density**. The plot is shown on the Display Monitor (See Figure 13.1d).

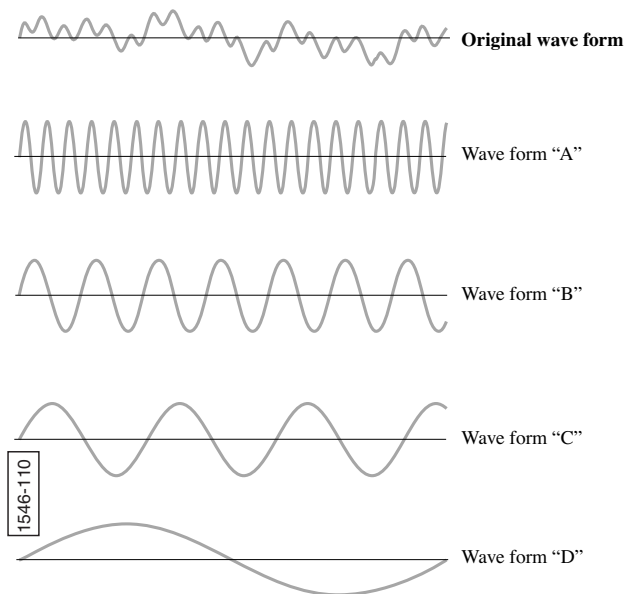
Figure 13.1d Power Spectral Density Plot



The left (green) cursor is automatically positioned at the wavelength with the greatest power. The right (red) cursor is positioned rightward of the data plots. Specifications for both the green and red cursors are displayed below the plot. Notice that the most powerful wave form is detected at 62.5 nm, corresponding to the dominant wave form of the image. Additional spectra are plotted at shorter wavelengths (21, 13 and 9 nm); however, these contribute virtually no power to the image.

When considering complex images, the spectrum quickly broadens to include multiple wavelengths, see [Figure 13.1e](#).

Figure 13.1e Wave Forms

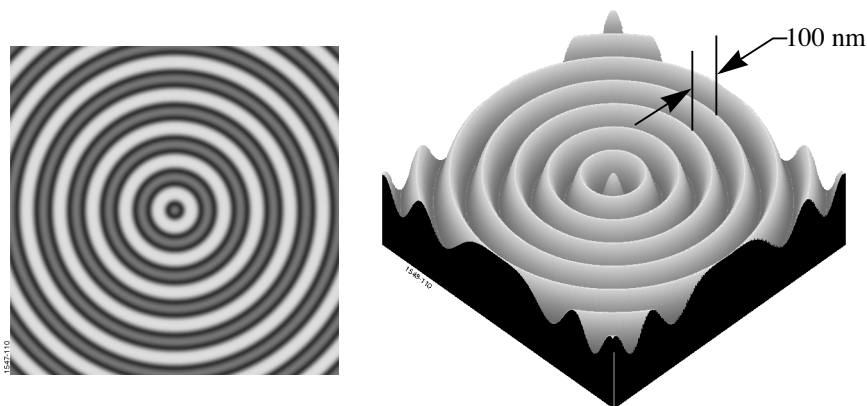


The two-dimensional wave form at the top of [Figure 13.1e](#) (“Original wave form”) is an additive composite of the wave forms below it (“A” through “D”). A Fast Fourier Transform (FFT) algorithm separates the original wave form into its constituent parts, mapping each wavelength on the 2D spectral plot. Since SPM images are three dimensional, wave forms mapped on the **2D Spectrum** may be oriented at any angle and density (power) to reconstruct the original image. Moreover, since the entire image is digitally comprised of a finite number of pixels, a finite number of wave forms suffice to reconstruct the image *in toto*. This and other aspects of FFT analysis are

discussed in a voluminous literature. Further reading is recommended to those seeking additional information.

Figure 13.1f shows another synthetic image having a wavelength of 100 nanometers. **2D Spectrum** analysis of this image reveals a broad plot, consisting of many wavelengths.

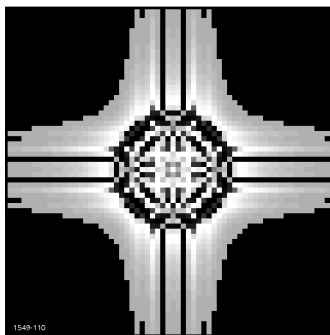
Figure 13.1f “Rings” Image



Note: To better view the plot, use the **Zoom** command on the Display Monitor.

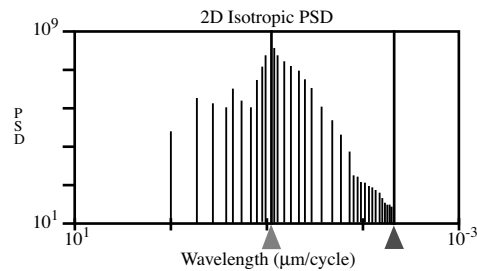
Figure 13.1g reflects the concentric symmetry of the data, with various wavelength densities plotted through 360° of rotation. As the cursor is positioned to various points on the plot, the **X**, **Y** and **R Period** and **Angle** reveal each wavelength's position on the plot. Notice that wavelength values range from the original scan size ($1 \mu\text{m}$) to about $0.02 \mu\text{m}$, and occur in various powers represented on the screen in terms of brightness and/or color.

Figure 13.1g “Rings” Image 2D Spectrum Plot



Power on the **2D Spectrum** plot displays in pixel brightness and color, the **Power Spectral Density** plots each wavelength on a logarithmic scale. A **Power Spectral Density** (PSD) plot of the image confirms that the image consists of a composite of multiple wave forms (See Figure 13.1h).

Figure 13.1h Power Spectral Density Plot of “Rings” Image



Notice that an exact wavelength of 100 nanometers is not plotted on the PSD. This is because the scan clip portions of the outermost annular waves, reducing the overall average. (The PSD’s most powerful wave form peaks at 91.4 nm.) Users of PSD should bear in mind that the graph includes *all* features within the image, not just those of immediate interest.

Relating PSDs, FFTs and Autocovariance

In the NanoScope III software environment, the FFT is the chief subroutine called in **2D Spectrum**, **Power Spectral Density** and **Autocovariance** software routines.

The FFT function consists of a common algorithm specially adapted to the NanoScope environment. It may be summarized as follows:

$$\text{FFT} = \sum_{j=0}^{N/2-1} e^{\frac{2\pi i k j}{N/2}} f_{2j} + W^k \sum_{j=0}^{N/2-1} e^{\frac{2\pi i k j}{N/2}} (f_{2j} + 1)$$

where $W \equiv e^{\frac{2\pi i}{N}}$ and k varies from 0 to N . The expression is divided into two terms—one for even-numbered data points, the other for odd-numbered data points.

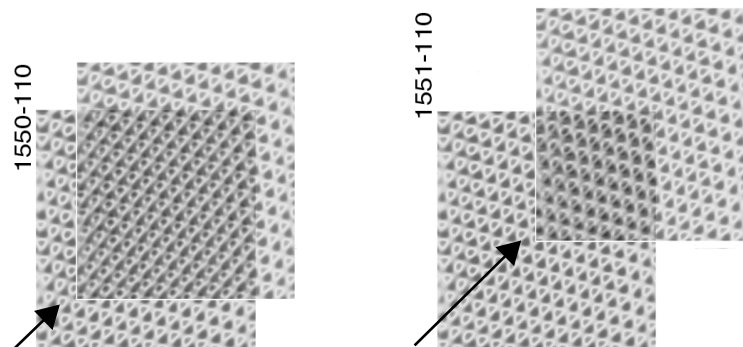
13.1.4 Autocovariance Theory

The **Autocovariance** function initiates an incremental correlation of the image data with itself. It is the product of two exact copies of the image data as they are shifted relative to one another. The amount of lateral shift between the two profiles is the *lag length*.

A related function of interest is the **Analyze/ Autocovariance** command. This runs a statistical covariance of the image data, yielding an image which highlights inherent, periodic features. Analysis of a sectioned autocovariance image provides information about the average size and separation of surface features. By comparing the lag-lengths and angular orientation of features in the autocovarianced image, it is possible to obtain information about “hidden” regularities in the surface.

The image in [Figure 13.1i](#) ([graf01](#) on the tutorial disk) is shifted diagonally by the **Autocovariance** command until only one pixel is compared between the two copies.

Figure 13.1i “Graf01” Image Autocovariance Example

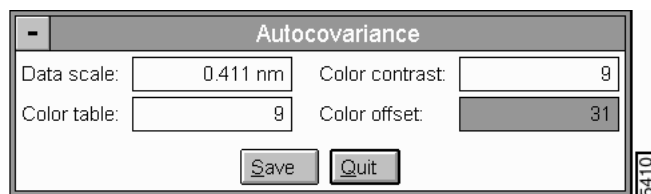


13.2 Autocovariance

The **Autocovariance** command calculates the autocovariance function of the image and displays the results on the Display Monitor. The autocovariance function is calculated by taking the inverse Fourier transform of the product of the FFT of the image and the complex conjugate of the FFT. The **Autocovariance** command is performed on the currently loaded image when selected. To undo the command, **Quit** the panel and reload the image.

The **Autocovariance** panel displays parameters adjustable to the preferences of the user (See [Figure 13.2a](#)).

Figure 13.2a Autocovariance Panel



13.2.1 Parameters on the Autocovariance Panel

Data scale

Controls the vertical range of the image corresponding to the full extent of the Color table. The units of this item vary according to the type of image (e.g., nm, nA, etc.).

Color table

Color contrast

Controls the contrast in the image by compressing or expanding the Color table.

Color offset

Shifts the Color table used to display the image.

Save

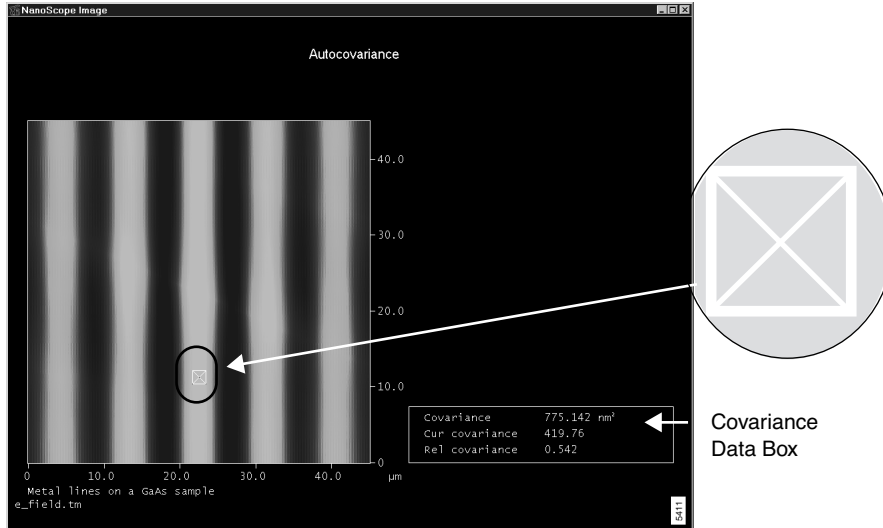
Stores the autocovariance file to the specified directory, allowing it to be reviewed and processed.

Quit—Exits the Autocovariance command.

13.2.2 Autocovariance Display Monitor

The Autocovariance display includes an image, a note and/or time stamp and a **Covariance Data Box** (See [Figure 13.2b](#)).

Figure 13.2b Autocovariance Display



Mouse Operations:

A measurement cursor with the cross hair inside a box appears within the covariance image when the image is displayed.

- 1st click, left button—Attaches the measurement cursor to the cursor. As the cursor is moved around the image, the value of the relative covariance updates.
- 2nd click, left button—Drops the measurement cursor.
- Right mouse button—Clicking the right mouse button moves the mouse cursor out of the covariance window.

Note: The message prompt, `AUTOCOVARIANCE IN PROGRESS - PLEASE WAIT`, appears while the **Autocovariance** is calculated.

Covariance Data Box

- **Covariance**—Peak value of the Autocovariance command in μm^2 or nm^2 .
- **Cur[sor] covariance**—Covariance value at the cursor (on Display Monitor).
- **Rel covariance**—Ratio of the covariance and the peak covariance at any point.

13.3 Auto Stepheight

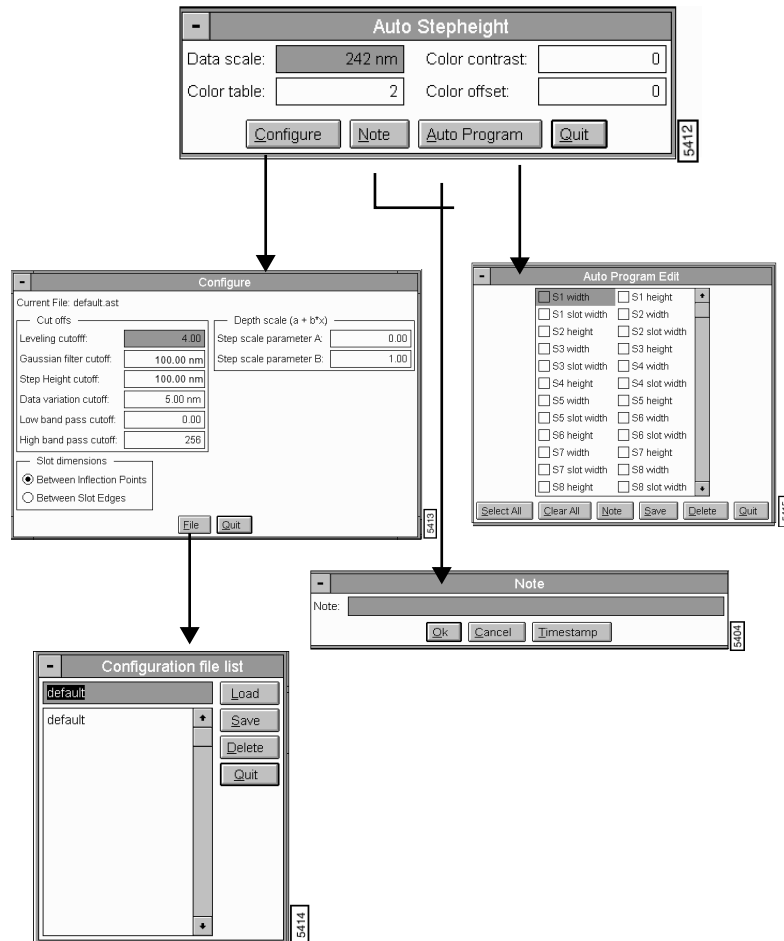
The **AutoStepheight** command automatically makes relative height measurements between two levels (steps) on sample surfaces based on the entered parameters in the **Configure** panel (See [Section 13.3.4](#)).

AutoStepheight displays a top view of the image and two plots for displaying the averaged **Height Profile** and a derivative of the height value. For further details on the image display and the two plots, see [Section 13.3.7](#).

Accessing Auto Stepheight Panels

In Off-line mode, select the image you want to measure. Then select **Analyze/ AutoStepheight**. The **Auto Stepheight** panel appears (See [Figure 13.3a](#)).

Figure 13.3a Navigating in Auto Stepheight Analysis



Refer to the following Auto Stepheight sections:

- **Auto Stepheight Control Monitor** [Section 13.3.1](#)
- **Step Results Window** [Section 13.3.2](#)
- **Auto Stepheight Panel** [Section 13.3.3](#)
- **Auto Stepheight Configure Panel** [Section 13.3.4](#)
- **Parameters in the Auto Stepheight Configure Panel** [Section 13.3.5](#)
- **Auto Stepheight Auto Program Panel** [Section 13.3.6](#)
- **Auto Stepheight Display Monitor** [Section 13.3.7](#)
- **Using the AutoStepheight Command** [Section 13.3.8](#)

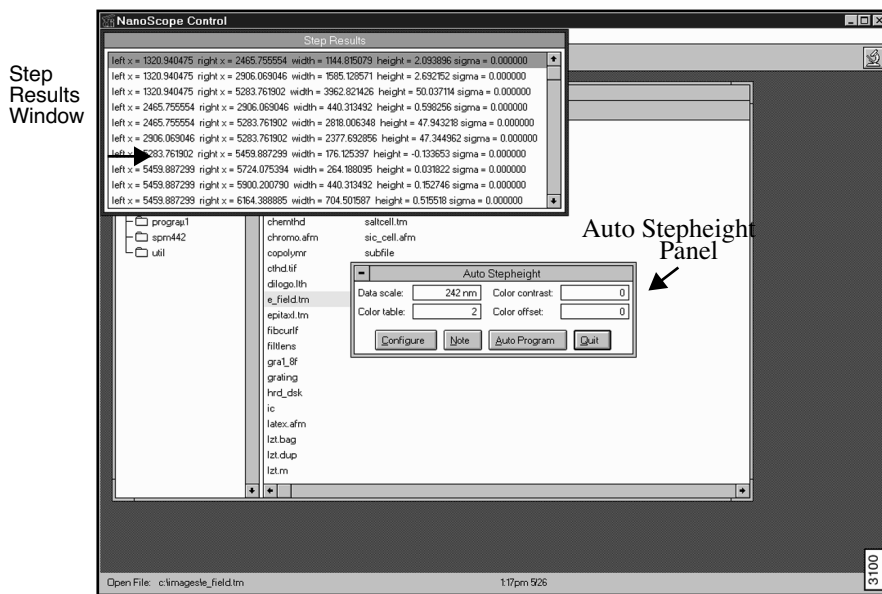
Analysis Control Auto Stepheight Control Monitor

Auto Stepheight

Along with the Offline list of files, the following panels appear in the control monitor for analyzing **Auto Stepheight** (See [Figure 13.3b](#)):

- **Auto Stepheight** panel, [Section 13.3.3](#)
- **Step Results** window, [Section 13.3.2](#)

Figure 13.3b Step Results Window and Auto Stepheight Panels



13.3.2 Step Results Window

The **Step Results** window shows all cursor placements measured in nanometers that fall within the parameters set in the **Configure** panel (See [Section 13.3.4](#)). These are measured from the left side of the profile. Highlighting a line of data in this window causes cursors representing this data to appear in the two image plots (e.g., **Height Profile**) on the Display Monitor (See [Figure 13.3f](#)).

Each line in the **Step Results** window contains the following data:

- **Left x**—The average of the placement of the two red cursors (i.e., the mid point between the red cursors).

- **Right x**—The average of the placement of the two green cursors (i.e., the mid point between the two green cursors).
- **Width**—The distance between the **Left x** and the **Right x**.
- **Height**—The z distance between the average of the data between the red cursors, and the average of the data between the green cursors.
- **Sigma**—The +/- error resulting from using averaged data to establish the z height.

13.3.3 Auto Stepheight Panel

The parameters in the **Auto Stepheight** panel are the same as in the **Stepheight** command (See [Chapter 14](#)).

Buttons on the Auto Stepheight Panel

Configure—Accesses parameters to adjust settings (See [Section 13.3.4](#)).

Note—Accesses a **Note** panel to append a note and/or time stamp to the displayed image.

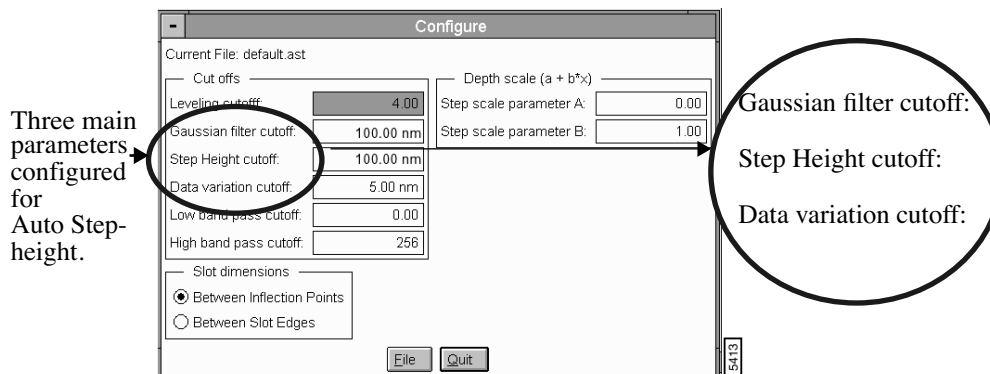
AutoProgram—Accesses the **Auto Program** panel to add the **Stepheight** command to the **Auto Program** file (See [Section 13.3.4](#)).

Quit—Exits the **Auto Stepheight** command.

13.3.4 Auto Stepheight Configure Panel

The **Configure** panel contains six **Cut-off** parameters, but usually requires only the **Step height cutoff**, **Data variation cutoff**, and **Gaussian filter cutoff** parameters.

Figure 13.3c Auto Stepheight Configure Panel



13.3.5 Parameters in the Auto Stepheight Configure Panel

Analysis Commands (A-L)

Auto Stepheight

Cut Offs

Leveling Cutoff—Specifies a cutoff value for a low pass filter that is used to level the profile automatically. Most images are auto leveled with the default value (i.e., 4). Some types of images may require adjusting this parameter with a value of 2 or 3 (low pass at one-half or one-third of the profile length) to make the auto level work precisely.

Range and Settings—

- **0 to 512** (Default is **4**)

Gaussian filter cutoff—Smooths the profile so that noise or small changes in the profile do not get identified as steps. The effective value is dependent on the profile and can be determined only by your experimentation.

Range and Settings—

- **0 nm to Scan Size value in nm** (Default—**100 nm.**)

Step height cutoff—Specifies the minimum step height to be identified. Values below this cutoff are ignored in the data.

Range and Settings—

- **1 nm to infinity** (Default—**100 nm.**)

Data variation cutoff—Sets the distance between the two cursors of a cursor pair. After finding the beginning of a step, the second cursor moves to one side (away from the step) and keeps going as long as the variation in the data encountered is not larger than the value of this parameter. If the cutoff value is 5 nm, the cursor continues moving until it encounters a variation greater than 5 nm, at which point the boundary of the cursor pair is set.

Note: All the data between the respective cursor pairs is averaged to determine the **Left x** and the **Right x** values.

Range and Settings—

- **0 nm to Scan Size value** (Default—**0 nm.**)

Low band pass cutoff and **High band pass cutoff**—Profiles with nested steps, multiple levels of steps, or steps that do not have approximately horizontal levels may require a band pass filter to define the steps and place the cursors.

Complicated profiles seems to respond to a **Low band pass cutoff** set to 2 (i.e., one-half scan length) and a **High band pass cutoff** set to 8 (i.e., one-eighth scan length). However, the optimum settings are dependent on the profile and must be determined through experimentation.

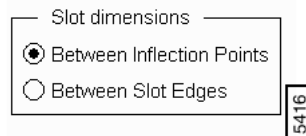
Range and Settings:

- **0 to 512** (Default—Low=0, High=256)

Slot Dimensions in the Auto Stepheight Configure Panel

The **Slot dimensions** appear below the **cut off** parameters in the **Configure** panel (See Figure 13.3d).

Figure 13.3d Slot Dimensions



The **Slot Dimension** parameters include:

- **Between Inflection Points**—Specifies the measurements to include data between the points on a curve that separates an arc concave upward from one concave downward and vice versa.
- **Between Slot Edges**—Specifies the measurements to include data between the openings in a groove on the sample surface.

Depth Scale (a + b*x) Parameters

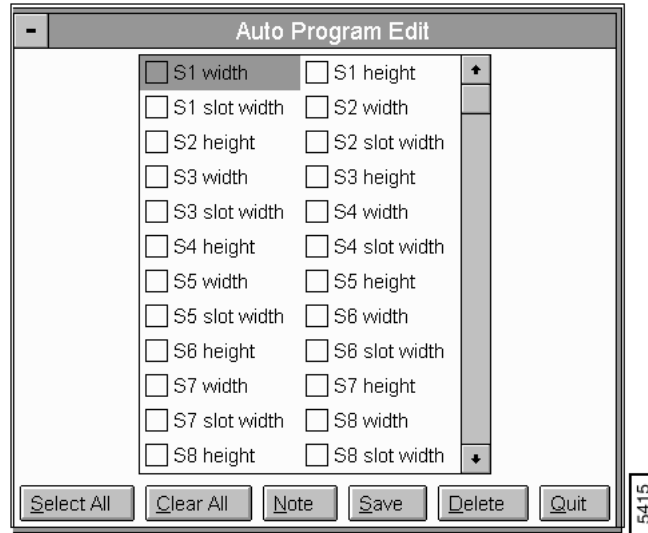
Where **a** is usually 0 nm and **b** is a multiplier (usually 1 or 2) for the stepheight value **x**

- **Step Scale Parameter a**—Value of stepheight offset (default is **0 nm**).
- **Step Scale Parameter b**—Value of multiplier (default is **1.00**) for the reported stepheight value.

13.3.6 Auto Stepheight Auto Program Panel

The **Auto Program Edit** panel displays parameters to add to the **Auto Program** file (See Section 13.3e). Select parameters manually or by clicking the function buttons: **SELECT ALL** or **CLEAR ALL**.

Figure 13.3e Auto Stepheight Auto Program Edit Panel



Buttons on the Auto Stepheight Auto Program Edit Panel

- **Select All**—Selects all of the parameters in the Auto Program Edit panel.
- **Clear All**—Removes all of the selected parameters in the Auto Program Edit panel.
- **Note**—Appends a note to the **Auto Program** file for reference.
- **Save**—Accesses a panel to save selected parameters to the **Auto Program** file (*.prg).
- **Delete**—Deletes selected parameters.
- **Quit**—Exits the **Auto Program Edit** panel.

The lower graph displays the average of the line values. The position of the cursor pairs in the sample image are shown in the chart. The upper graph displays the derivative of the data shown in it.

13.3.8 Using the AutoStepheight Command

1. Select **Off-line**.
2. Select the image to be measured.
3. Click on **Analyze/ AutoStepheight** on the menu bar.
4. Left click on the image, release and draw a reference line on the sample image, which appears in the lower-left of the image screen.

Note: Remember that image data is averaged perpendicular to the reference line. Therefore, you can draw the line in any direction.

5. In the sample image select the side border to size and position the box cursor to include the area you want measured
6. Configure the **Auto Stepheight** panel parameters.
7. Click on **Configure** and enter the appropriate parameters for your sample (See [Section 13.3.4](#) for a description of these parameters).

Note: Notice that one pair of cursor lines is over the peak, and the other pair is over the pit. The data between the respective cursor pairs is averaged. Then the two averages are subtracted to calculate the step height. Refer to [Figure 13.3f](#) for an illustration of the relationship between the control screens and the image screens.

8. Click **File** to save the parameters; otherwise, click **Quit**.



13.4 Bearing

Analyze/ Bearing provides a method of plotting and analyzing the distribution of surface height over a sample. This form of analysis may be applied to the entire image, or to selected areas of the image, using a rubberband box. Moreover, regions within the selected area can be blocked out by using “stopbands” to remove unwanted data from the analysis.

13.4.1 Theory

Bearing analysis reveals *how much of a surface lies above or below a given height*. This measurement provides additional information beyond standard roughness measurements. (Surface roughness is generally represented in terms of statistical deviation from average height; however, this gives little indication of height distribution over the surface.) By using bearing analysis, it is possible to determine what percentage of the surface (the “bearing ratio”) lies above or below any arbitrarily chosen height. In industries where materials are polished or chemically etched, this is a particularly useful tool. For example, bearing analysis is frequently used in silicon etching processes to observe changes in etched features over an interval of time.

Figure 13.4a Bearing Analysis Illustration

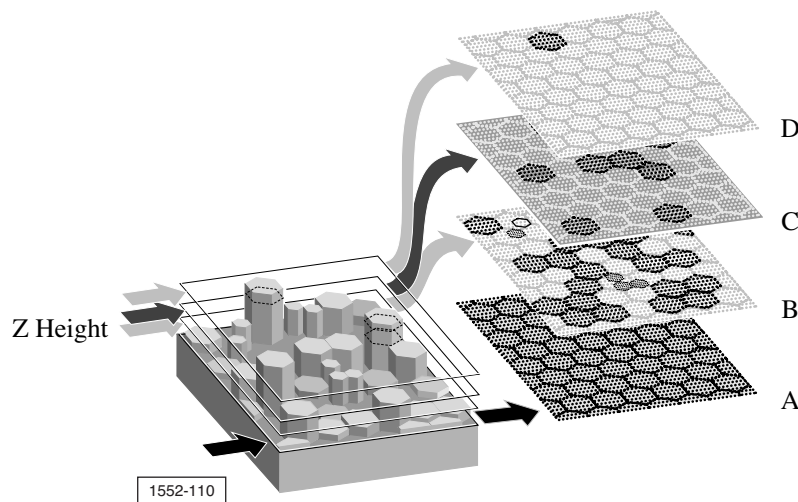


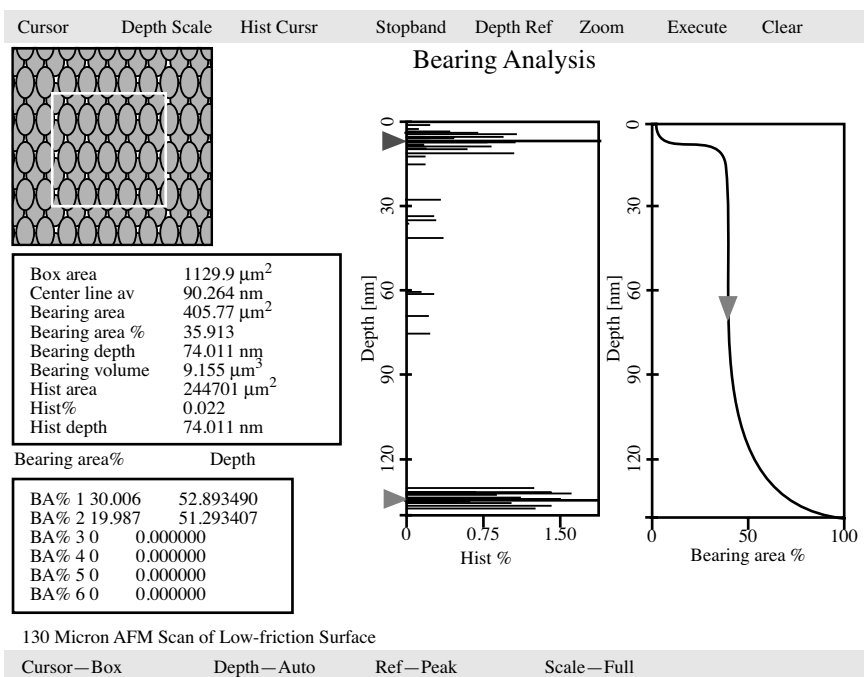
Figure 13.4a represents how **Bearing** analysis generates a histogram of feature height based upon the occurrence of pixels at various Z heights. At Z height “A,” virtually all of the surface is included (corresponding to a **Bearing ratio** of 100, or 100 percent of the area). At Z height “D,” the pixel count is much reduced, representing a smaller **Bearing ratio** (approximately 2-5 percent of area). By using **Bearing Compare** (See Section 13.5), you may compare sample regions before and after processing to reveal relative changes in surface height.

13.4.2 Preparation for Use

Use **Modify/Plane Fit** to remove all tilt before running **Analyze/ Bearing**. When running **Bearing Compare** between two or more files, make certain that Z-scales are roughly equal; otherwise, comparisons cannot be generated.

The **Bearing** command displays a top view of the image, then calculates and displays bearing ratio curves and surface height histograms for lines or areas drawn on the image (See [Figure 13.4b](#)).

Figure 13.4b Bearing Analysis Display



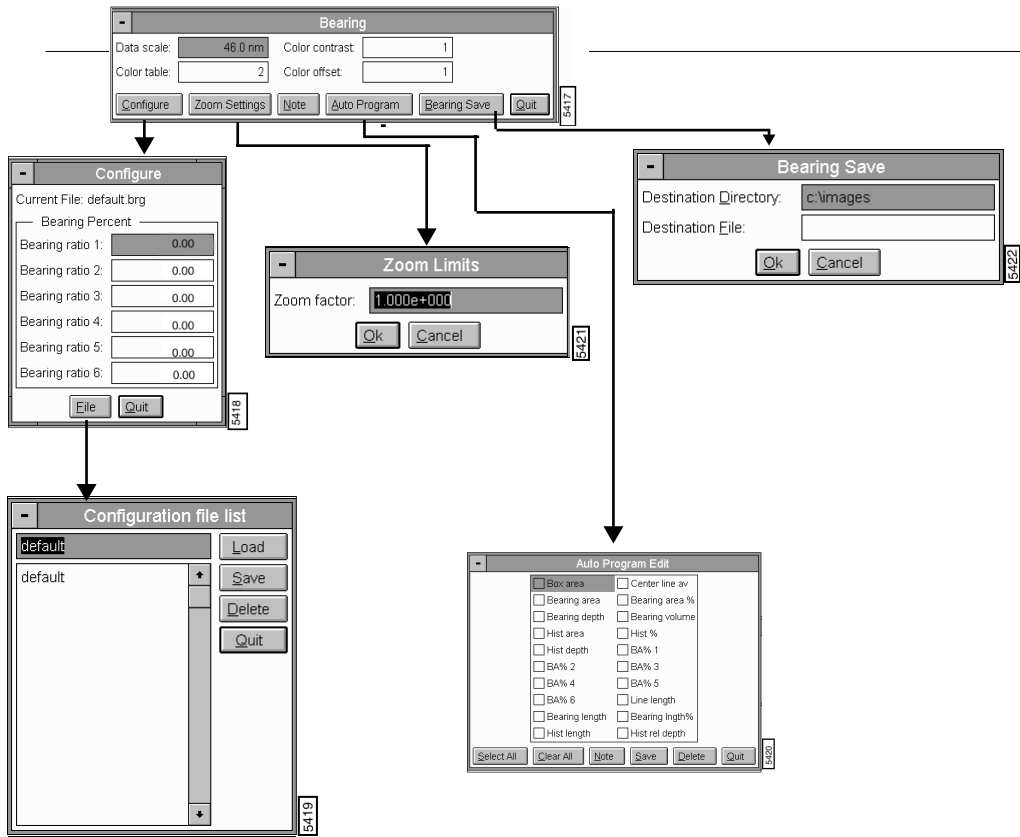
The word *bearing* means the relative roughness of a surface in terms of high and low areas. The bearing *ratio curve* is the integral of the surface height histogram and plots the percentage of the surface above a reference plane as a function of the depth of that plane below the highest point in the image.

Plotted data includes all data points, noise spikes and holes. If noise is to be filtered out, it should be removed *before* using the **Bearing** command by executing one of the various filtering commands in Off-line/ **Modify** (e.g., **Gaussian**, **Lowpass**, **Median**).

13.4.3 Bearing Control Monitor

The **Bearing** panel displays on the Control Monitor. Each button on the panel leads to another panel to adjust bearing parameters to the preferences of the user. See [Figure 13.4c](#) for navigating in **Bearing** analysis.

Figure 13.4c Navigating in Bearing Analysis



13.4.4 Bearing Panel

The **Bearing** panel sets the image display parameters (See [Figure 13.4d](#)).

Figure 13.4d Bearing Panel



Parameters on the Bearing Panel

- **Data scale**—Controls the vertical range of the image corresponding to the full extent of the Color table. The units of this item vary according to the type of image (e.g., nm, nA, etc.).
- **Color table**—Selects the Color table used to encode the Z information.
- **Color contrast**—Controls the contrast in the image by compressing or expanding the Color table.
- **Color offset**—Shifts the Color table used to display the image.

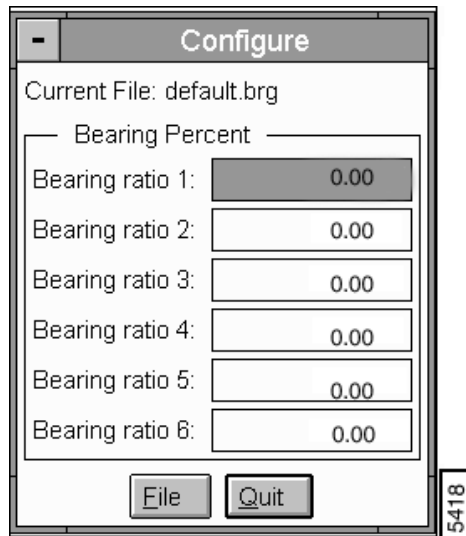
Buttons on the Bearing Panel

- **Configure**—Allows the input of various bearing ratios (See [Section 13.4.5](#)).
- **Zoom Settings**—Expands or contracts the range about the center of data (See [Section 13.4.7](#)).
- **Note**—Allows you to add a descriptive message and time stamp to the display.
- **Auto Program**—Allows the Bearing command to be added to, or deleted from, the currently selected Auto Program file (See [Section 13.4.8](#)).
- **Bearing Save**—Saves the current bearing measurements (See [Section 13.4.9](#)).
- **Quit**—Cancels Bearing analysis and returns screen to Off-line mode.

13.4.5 Bearing Configure Panel

The **Configure** panel allows the input of Bearing ratios (See [Figure 13.4e](#)).

Figure 13.4e Bearing Configure Panel



Parameters and Buttons on the Bearing Configure Panel

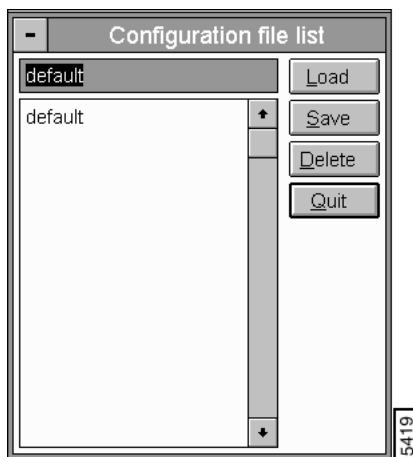
- **Bearing Percent** (1, 2, 3, 4, 5, 6)—Displays depth data for specifically entered bearing ratios. For example, if *50* is entered for the ratio, the box displayed on the image screen measures the depth above which 50% of the data points are above.

Up to six different ratios may be entered simultaneously. A red, triangular cursor is automatically located on the bearing area histogram to indicate the last entered **Bearing ratio** value.

- **File** (button)—Opens the **Configuration file list** panel (See [Section 13.4.6](#)) and allows for saved files to be opened.

13.4.6 Configuration File List Panel

Figure 13.4f Bearing Configuration File List Panel



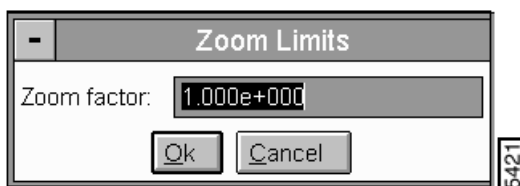
Buttons on the Configuration File List Panel

- **Load**—Loads the specified **Bearing Configure** file
- **Save**—Saves the current settings as a **Bearing Config** file
- **Delete**—Deletes the specified **Bearing Configure** file
- **Quit**—Exits the **Configuration file list** panel.

13.4.7 Zoom Settings

Expands or contracts the range about the center of data. For instance, if the Zoom factor is set to 2 and the current range is 100 nm (centered at 50 nm), the resulting zoomed range is 200 nm and extends from -50 to 150 nm (still centered at 50 nm). The Zoom factor is always applied to the current range; therefore, if the Zoom factor is set to 0.25 and applied to a range of 200, the new range is 50 (200×0.25) and extends from 25 to 75 nm (See [Figure 13.4g](#)).

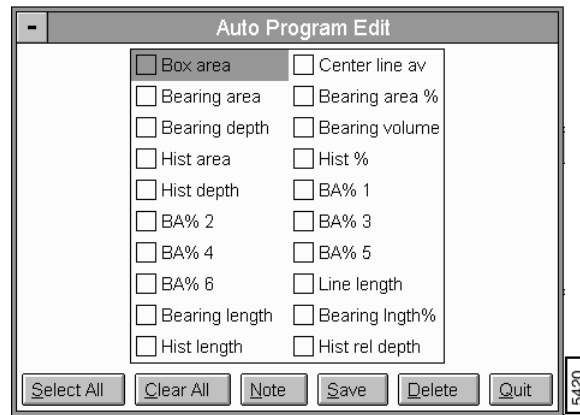
Figure 13.4g Bearing Zoom Limits Panel



13.4.8 Auto Program

The **Auto Program** panel allows the **Bearing** command to be added to, or deleted from, the currently selected Auto Program file. A selection of reportable values displays in the Bearing Auto Program panel (See [Figure 13.4h](#)).

Figure 13.4h Bearing Auto Program Panel



Buttons on the Bearing Auto Program Edit Panel

- **Select All**—Selects all of the parameters in the Auto Program Edit panel.
 - **Clear All**—Removes all of the selected parameters in the Auto Program Edit panel.
 - **Note**—Appends a note to the **Auto Program** file for reference.
 - **Save**—Accesses a panel to save selected parameters to the **Auto Program** file (*.prg).
- Note:** A prompt appears to overwrite the existing **Bearing** program if the file is the same name.
- **Delete**—Deletes selected parameters.
 - **Quit**—Exits the **Auto Program Edit** panel.

13.4.9 Bearing Save

Accesses the **Bearing Save** panel shown in [Figure 13.4i](#) to save the currently selected Bearing file to the Destination Directory and Destination File specified by the user. Files may be compared using **Analyze/ Bearing Compare** function (See [Section 13.5](#)).

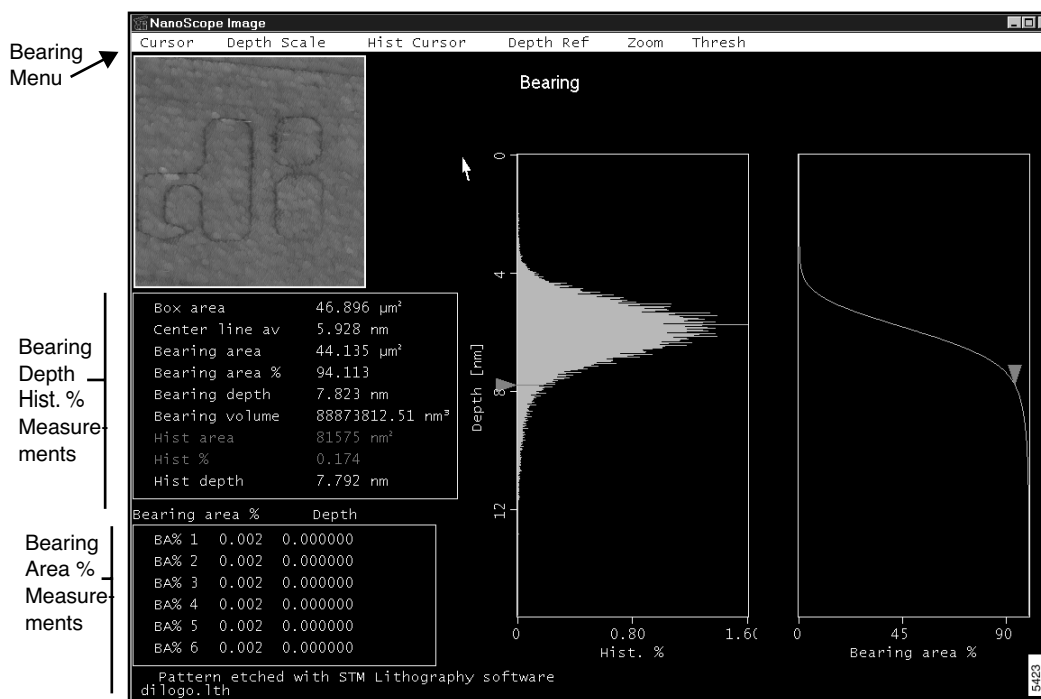
Figure 13.4i Bearing Save Panel



13.4.10 Bearing Display

The Display Monitor includes: a menu bar, status bar, an image, two sets of measurements and two histograms. The histograms show the Z values in the image and the bearing ratio curve (See [Figure 13.4j](#)).

Figure 13.4j Bearing Display



13.4.11 Bearing Display Menu Commands

The menu bar provides subcommands which modify and control the operation of the **Bearing** command.

Cursor

Determines whether the histogram and bearing ratio are calculated along a line or within a box.

- **Line**—Puts the system into line mode, allowing a reference line to be drawn on the image. The data along the line is used in the calculation of the bearing and histogram curves.

Mouse operations:

- 1st click, left button—Fixes one end of the reference line and “rubberbands” from the selected position, allowing the reference line to be drawn in any direction.
- 2nd click, left button—Fixes the position of the reference line and displays the Bearing Ratio and Histogram curves for the data along the line.
- **Box**—Puts the system into area mode, allowing a rectangular box to be drawn on the image. The data within the box is used in the calculation of the bearing and histogram curves.

Mouse operations:

- 1st click, left button—First, locate a corner or edge of the image and click once to allow the rectangle to be formed by moving the mouse.
- 2nd click, left button—Fixes the position of the box and displays the Bearing Ratio Curve and the Histogram for the enclosed area.
- 3rd click left button—The effect of the third depends on the position of the cursor when the click occurs.
- On box edge—Clicking the left button when the cursor is on an edge of the box allows that edge of the box to be repositioned by moving the mouse.
- On box corner—Clicking the left button when the cursor is on a corner of the box allows that corner of the box to be repositioned by moving the mouse.
- Inside the box—Clicking the left button when the mouse is inside the box allows the entire box to be repositioned by moving the mouse.
- Another click of the left button freezes the position and size of the box.
- **Stop Add**—This creates a user-defined rectangle (a “stopband”), having an “X,” whose area is not included in the bearing calculation. Click and drag on the image to draw the stopband. The stopband can be any size with any rectangular shape.
- **Stop Remove**—Removes stopbands which have already been drawn. Click on the particular rectangle to be removed.
- **Stop Clear**—Removes all currently drawn stopbands.

Depth Scale

Sets the Z-axis scales (depth) of height histogram and bearing ratio curves.

- **Z Scale**—Scales the Z-axis on the height histogram and bearing ratio curves to the **Data scale** value entered in the panel on the control monitor. The lowest depth datum point is set to zero.
- **Auto Scale**—Automatically scales the Z-axis on the height histogram and bearing ratio curves over the entire data range.

Hist[ogram] Cursor

When the **Hist Cursor** subcommand is **On**, two reference markers are generated—one is red and the other is green.

Mouse and Cursor Operation—Clicking the left button when the cursor is on a reference marker attaches the reference marker to the cursor. Moving the mouse causes the reference marker to move and the relevant histogram values to be updated in the measurement chart. A second click of the left button drops the reference marker.

Depth Ref[erence]

Sets the Z-axis scale relative to one of two references—the peak (highest) height; or, the median (center line) height.

- **Peak**—When Peak is selected, the values are the difference between the tallest point in the selected region (i.e., the zero point of the Bearing Curve) and the cursor position.
- **Center Line**—When Center Line is selected, the values are the difference between Center line av (median height) and the cursor position.

Zoom

After executing **Bearing** analysis, subcommands under **Zoom** menu allow the height histogram between two green cursor lines to be magnified, and/or normalized. Zoomed plots may be zoomed again and again.

- **On**—Generates two green Zoom cursor lines on the height histogram. The portion to be zoomed lies between the green cursor lines. To adjust the zoom, drag the lines above and below the plotted data to be zoomed.
- **Off**—Removes the green Zoom cursor lines from the height histogram.
- **Zoom**—Expands the height histogram region between the green cursor lines to occupy the height histogram; vertical and horizontal axes are rescaled accordingly. This option may be used repeatedly for any given bearing data set. If the **Zoom** function is used

without first activating the red cursor lines, the area zoomed lies above the triangular cursor indicated on the Bearing Area histogram.

- **Normalize**—Readjusts the bearing area% curve (horizontal axes) to fit to the zoomed height histogram.
- **Full scale**—Restores the height histogram and bearing ratio curve to their original forms (zoom range at 100%). Equivalent to another **Execute** of the bearing curve.

Thresh

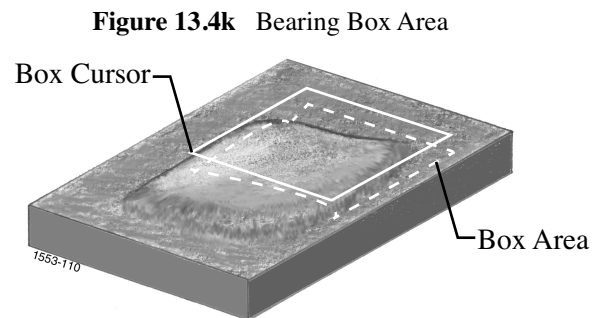
Analysis tool, used to illustrate depths in the image. When activated, the percent (%) value indicates the top % of pixels that are turned red. 2% is the top two percent of pixels, 25% is the top twenty-five percent, etc.

13.4.12 Bearing Terms

Depending on the image cursor selection, values for up to eight of the following terms are listed in the measurement windows:

Box area

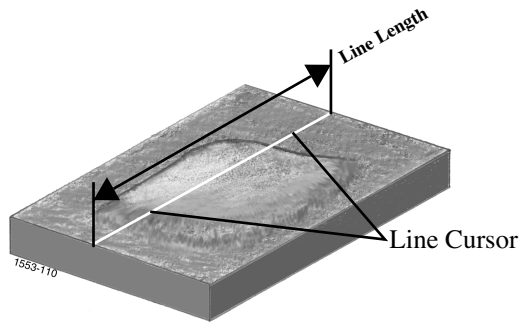
Area of the box. This value is only displayed when the box cursor is selected.



Line length

Length of the line. This value is only displayed when the line cursor is selected.

Figure 13.4l Bearing Line Length



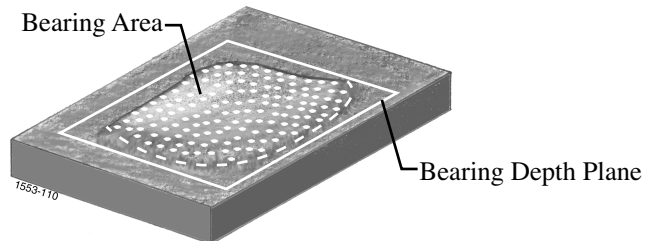
Center line av

Depth at which the number of points above and below the depth point are equal. This is the 50% point on the Bearing Curve.

Bearing area

Area covered by all of the points above the selected **Bearing depth**. This value is only displayed when the box cursor is selected.

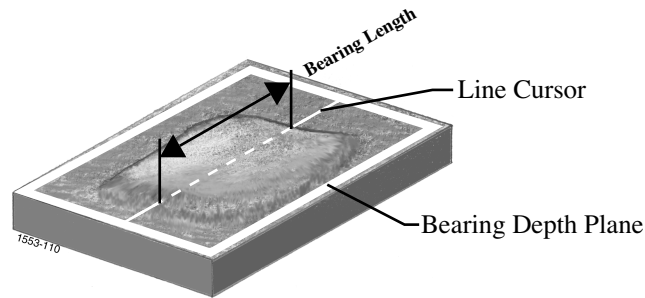
Figure 13.4m Bearing Area



Bearing length

Length of cursor line above the selected **Bearing depth**. This value is only displayed when the line cursor is selected.

Figure 13.4n Bearing Length



Bearing area %

The bearing area % curve is the integral of the Histogram curve. The bearing area % reported in the measurement list defines the percentage of the surface above the reference plane defined by the green cursor.

Bearing length %

When using the line cursor in the cursor menu, this value returns the length data along the line. Performs the same function as **Bearing area %**, but reduced to points along a line.

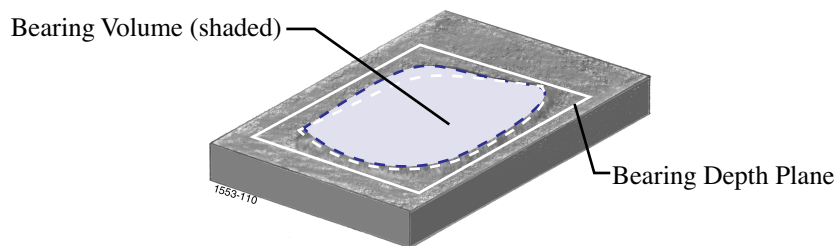
Bearing depth

The depth at the green bearing area cursor position relative to highest point in the image when **Peak** is selected in the **Depth** reference command and relative to the **Center line av** when **Center Line** is selected in the **Depth** reference command.

Bearing volume

Sample volume defined above the bearing depth plane.

Figure 13.4o Bearing Volume



Histogram area

The area covered by the points at the depth indicated by the red histogram cursor. This value is only displayed when the box cursor is selected.

Histogram length

The length of points along the cursor line at the depth indicated by the red histogram cursor. This value is only displayed when the line cursor is selected.

Histogram %

The percentage of the total number of points at the depth indicated by the red histogram cursor.

Histogram depth

The depth at the red histogram cursor position relative to highest point in the image when **Peak** is selected in the **Depth** subcommand and relative to the **Center line av** when **Center Line** is selected in the **Depth** subcommand. When both cursors are present, this value represents the depth difference between the two cursors, and this item is titled **Hist rel depth**.

Histogram relative depth

When the second histogram cursor is activated (in the **Hist Cursor** menu on *Display Monitor*), this value reports the distance between the two cursors.

Note: The **Bearing** command only operates on buffers with a “height” vertical scale.

13.5 Bearing Compare

Once **Bearing** analysis has been completed on two or more images, it becomes possible to compare results using the **Bearing Compare** function. This generates a composite height histogram and bearing ratio curve for the images being compared, and makes obvious any height differences between them.

13.5.1 Theory

Bearing Compare is designed to assist those interested in assessing height/depth changes on similar samples that have undergone a process, or for comparing dissimilar samples having surface features within a similar Z-axis scale. The Bearing feature is particularly useful for evaluating etched surfaces.

13.5.2 Preparation

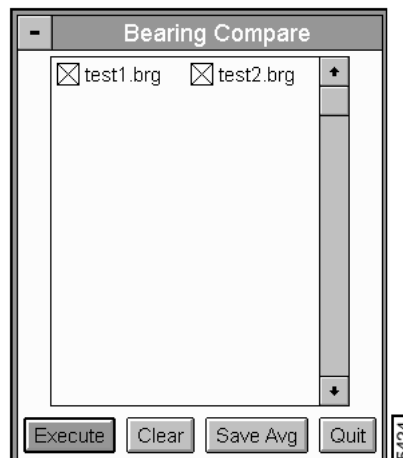
Images to be compared must first undergo **Bearing** analysis (See [Section 13.4](#)) to obtain height histograms and bearing ratio curves. After Bearing analysis is obtained, files to be compared are saved to a common directory using the **Bearing/ Bearing Save** option.

Note: To ensure accurate comparisons between files, *always* prepare images to undergo **Bearing** analysis with **Plane Fit** modification first; otherwise, the surfaces to be compared may be at different attitudes. (That is, sample #1 may be “flat and level,” while sample #2 may appear wedged, “tilted, running downhill.” Whereas heights on the first, level sample appear relatively uniform, the second, wedged sample appears to have heights which diminish from one edge to the other. Use **Modify/ Plane Fit (Auto or Manual)** to correct this).

13.5.3 Bearing Compare Panel

On the **Analyze** menu, select **Bearing Compare** to access the **Bearing Compare** panel (See [Figure 13.5a](#)).

Figure 13.5a Bearing Compare Panel



Buttons in the Bearing Compare Panel

Execute—Executes Bearing Compare analysis between the files selected from the current directory.

Clear—Clears currently selected files in the Bearing Compare panel (removes all “X”s) without quitting the panel.

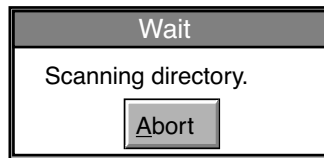
Save—Avg[average]—Saves the average values of compared files to a directory and file named by the operator.

Quit—Exits the Bearing Compare analysis without saving.

13.5.4 Bearing Compare Procedure

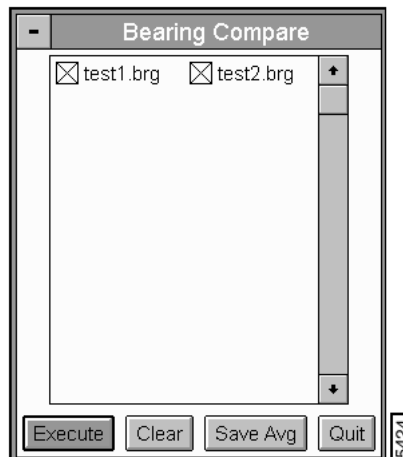
1. Analyze images to be compared using the **Analyze/ Bearing** function. Each image file should be saved to a common directory using **Bearing Save** in the **Bearing** panel. (See [Section 13.4](#) for instructions on using **Bearing Save**.)
2. Exit the **Bearing** panel. Using the **Files** window, transfer to the directory where the bearing files to be compared are saved.
3. Click on **Analyze/ Bearing Compare**. The control screen displays a prompt during bearing file location (See [Figure 13.5b](#)).

Figure 13.5b Bearing Compare Advisory



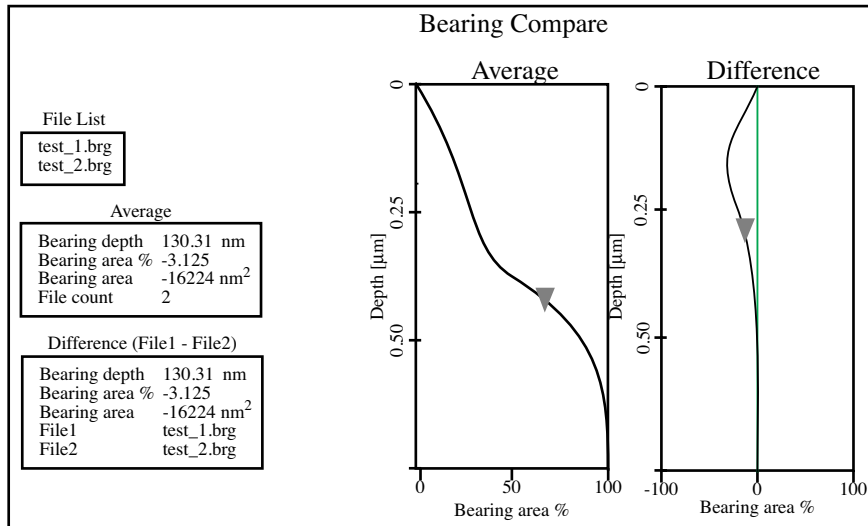
When all bearing files are located, the control monitor then displays the **Bearing Compare** panel (See [Figure 13.5c](#)).

Figure 13.5c Bearing Compare Panel



4. Use the mouse to select all files to be compared. An “X” appears in the box of each file selected. When all desired files are selected, click on the **Execute** button.
5. The Display Monitor displays the results of the **Bearing Compare** analysis shown in [Figure 13.5d](#).

Figure 13.5d Bearing Compare Analysis Display



The two files compared are listed in the **File List** box near the upper-left corner of the screen (i.e., “test_1.brg” and “test_2.brg” in Figure 13.5d). The Display Monitor includes **Average** values and **Difference** values for the first two files compared. On the right half of the screen are displayed the Average and Difference bearing ratio curves.

The Difference bearing ratio curve is computed as file #1 minus file #2; thus, curves to the left of the green center line represent areas where file #1 was *lower* than file #2, curves to the right of the green center line represent areas where file #1 was *higher* than file #2.

By manipulating the triangle cursors with the mouse, it is possible to change the **Bearing depth**, **Bearing ratios**, and **Bearing areas** for Average and/or Difference curves, then obtain bearing ratios for any given depth.

6. To exit the **Bearing Compare** panel, click on **Quit**.

13.6 Depth

To analyze the depth of features you have numerous choices which measure the height difference between two dominant features that occur at distinct heights. Depth was primarily designed for automatically *comparing* feature depths at two or more similar sample sites (e.g., when analyzing etching depths on large numbers of identical silicon wafers). The depth commands are also useful on unique samples.

The **Section** (Section 14.7) and **Bearing** (Section 13.4) commands are designed for analyzing unique samples. It is recommended that those tools be examined as well to determine which analysis is most appropriate for a particular image or sample.

13.6.1 Theory

The term “depth” often proves troublesome when analyzing features which undergo change. For example, silicon wafers undergo a cyclical building-up of deposition, etching, planarization, etc. to create multiple layers. Evaporated films on surfaces often alternate between one material and another to yield a multi-layer of many films. With normal probing to such surfaces, the SPM sometimes has no base-line reference from which to judge feature depth, giving rise to the question, “How deep is the feature, relative to *what?*”

One solution is to saw sections from samples to reveal layering, then scan the entire cross-section; this is accurate but destructive. Another is to compare all depths to some feature of unchanging depth (e.g., a substrate); however, such datum features are not always available, or may be located too far away from the imaging site to be of use.

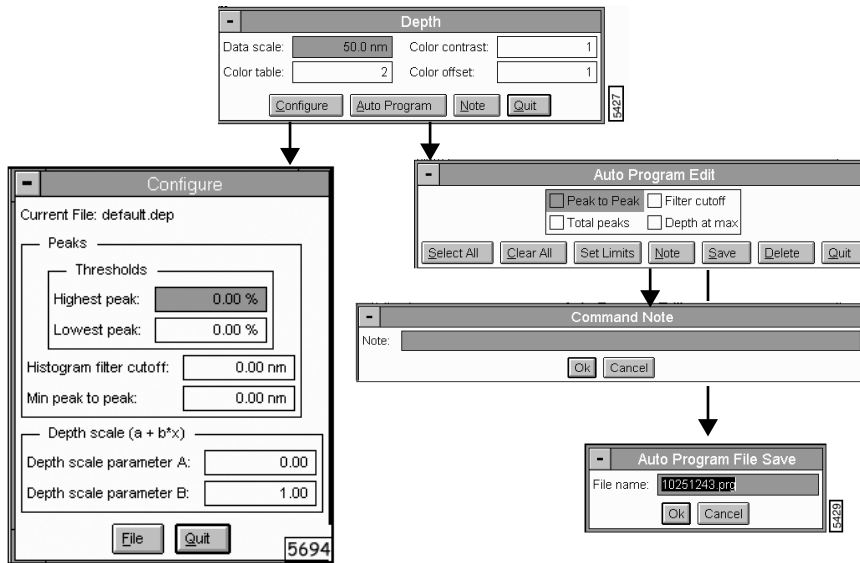
The **Depth** command is designed to accumulate depth data within a specified area, apply a Gaussian low-pass filter to the data to remove noise, then rapidly obtain depth comparisons between two or more dominant features (for example, the depth of a single feature and its surroundings). Although this method of depth analysis does not substitute for direct, cross-sectioning of the sample, it does afford a means for comparing feature depth between two or more similar sites in a consistent, statistical manner.

13.6.2 Depth Panels and Parameter

In the **Analyze** menu, select the **Depth** command to access the **Depth** panels and parameters (See Figure 13.6a).

Note: Always plane fit images *before* performing **Depth** analysis.

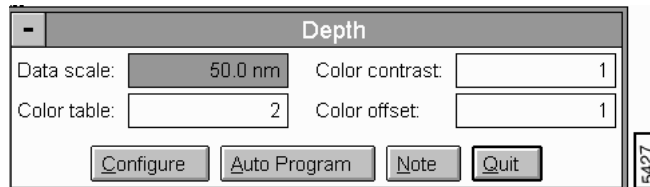
Figure 13.6a Navigating Panels in Depth Analysis



13.6.3 Depth Panel

The **Depth** panel parameters set the image display parameters (See [Figure 13.6b](#)).

Figure 13.6b Depth Panel



Parameters in the Depth Panel

- **Data scale**—Controls the vertical range of the image corresponding to the full extent of the Color table. The units of this item vary according to the type of image (e.g., nm, nA).
- **Color table**—Selects the Color table used to encode the Z information.
- **Color contrast**—Controls the contrast in the image by compressing or expanding the Color table.
- **Color offset**—Shifts the Color table used to display the image.

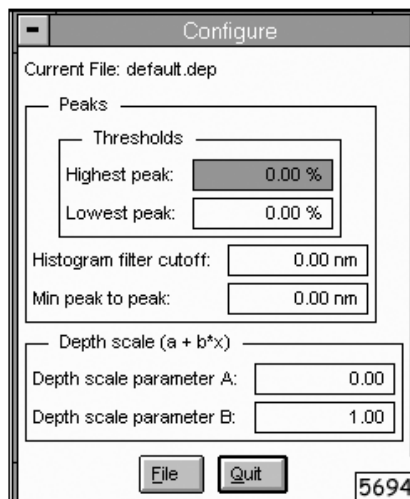
Buttons on the Depth Panel

- **Configure**—Accesses the **Configure** panel (See [Section 13.6.4](#)).
- **Auto Program**—Accesses the **Auto Program** panel (See [Section 13.6.5](#)).
- **Note**—Allows for a descriptive message to be added to the display (up to 32 character).
- **Quit**—Exits the **Depth** command.

13.6.4 Depth Configure Panel

Cursors applied to the filtered data histogram serve two functions—1) to identify surface features for measurement and comparison; 2) to facilitate rapid recognition of curve components by the computer. The **CONFIGURE** button in the **Depth** panel accesses the **Configure** panel. This box displays, loads and deletes preexisting configuration files, and initiates new ones (See [Figure 13.6c](#)).

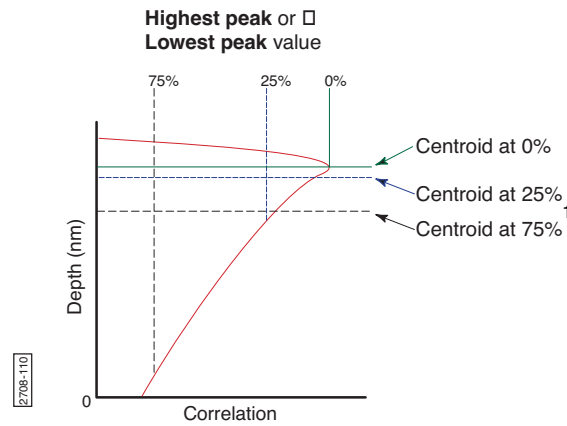
Figure 13.6c Depth Configure Panel



Parameters in the Depth Configure Panel

Peaks—Controls the smoothing of the data in the Correlation Histogram. Also controls the method of how the exact depth of the peaks is chosen. See [Figure 13.6d](#) for determining the exact depth of a Correlation Histogram.

Figure 13.6d Determining the Exact Depth of a Peak

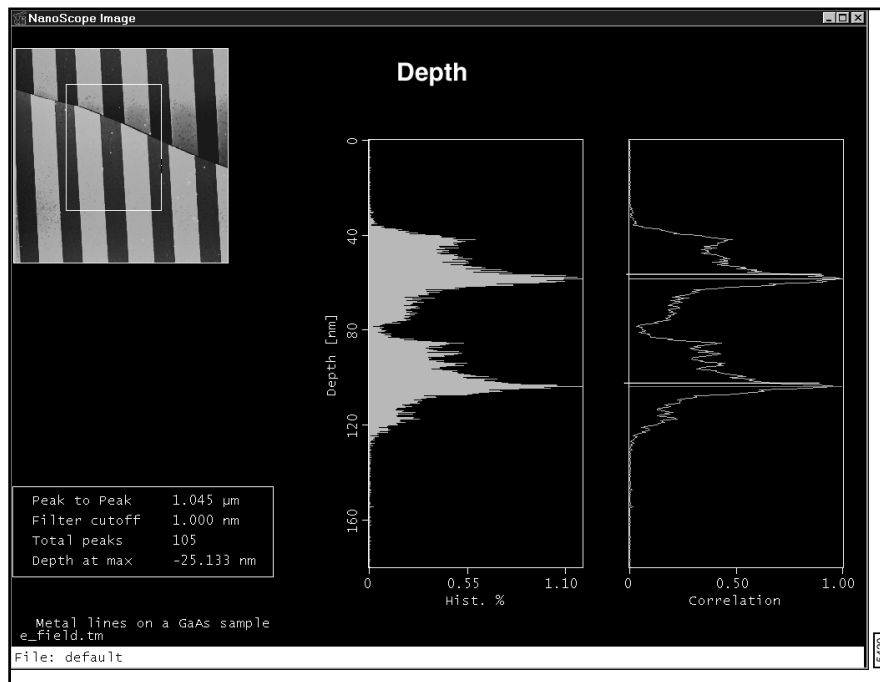


1. Centroid—A weighted average of points on a curve.

Thresholds—Sets how much of a peak is used when calculating the centroid to determine its depth (or position)

- **Highest Peak**—Topmost peak in the Correlation Histogram. Value used to define how much of the **Highest peak** is included when calculating the centroid. At 0 percent, only the maximum point on the curve is included. At 25 percent, only the maximum 25% of the peak is included in the calculation of the centroid.
- **Lowest Peak**—Peak closest to the bottom in the Correlation Histogram. Value used to define how much of the **Lowest peak** is included when calculating the centroid. At 0 percent, only the maximum point on the curve is included. At 25 percent, only the maximum 25% of the peak is included in the calculation of the centroid.

Figure 13.6e Depth Thresholds Display



Histogram filter cutoff—Lowpass filter which smooths out the wavelengths below the cutoff. Use to reduce noise in the Correlation histogram.

Min peak to peak—Sets the minimum distance between the maximum peak (green cursor) and the second peak (red cursor). The second peak is the next largest peak to meet this distance criteria.

Depth Scale (a + bx)—Modifies the height data where **A** is the offset and **B** is the multiplier to the height data. Adjustments to the default values changes the data. Use this feature with caution unless manipulated data is desired.

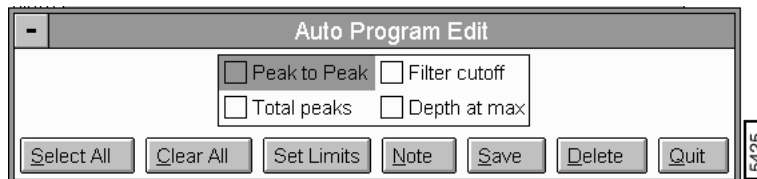
- Depth scale parameter **A**—Offset value.
- **Depth scale parameter B**—Multiplier to the height data x .

Ranges and Settings: A=0, and B=1.0 (Changed values from the default values, modifies the data.)

13.6.5 Depth Auto Program Edit Panel

The **Auto Program Edit** panel adds or deletes the **Depth** command from the currently selected Auto Program file. A panel listing measurements reported by the **Depth** command is displayed (See Figure 13.6f). Selecting a measurement stores it in the Auto Results file when Auto Program is run.

Figure 13.6f Auto Program Edit Pane



Parameters in the Auto Program Edit Panel

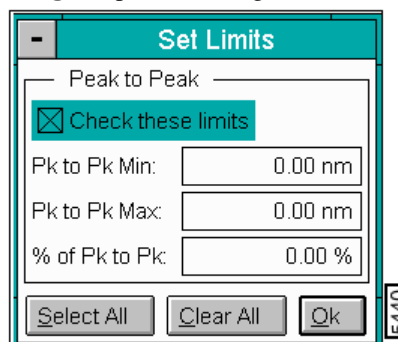
- **Peak to Peak**—Depth between the two data peak centroids as shown by the green and red line cursors.
- **Total Peaks**—Total number of peaks included within the data histogram.
- **Filter Cutoff**—Reports the value from Histogram filter cutoff in the Configure menu.
- **Depth at Max.**—Depth of maximum (lowest) pixel from shallowest pixel.

Buttons in the Auto Program Edit Panel

- **Select All**—Selects all the parameters.
- **Clear All**—Clears all the parameters.
- **Note**—Allows you to insert a command note in the Auto Program file.
- **SET LIMITS**—Sets specific limits on the peak to peak measurements in an Auto Program (See [Figure 13.6g](#)).

Note: The **Set Limit** panel only appears if **PEAK TO PEAK** on the **Auto Program Edit** panel is enabled.

Figure 13.6g Depth Auto Program Set Limits Panel



Parameters and Buttons in the Set Limits Panel

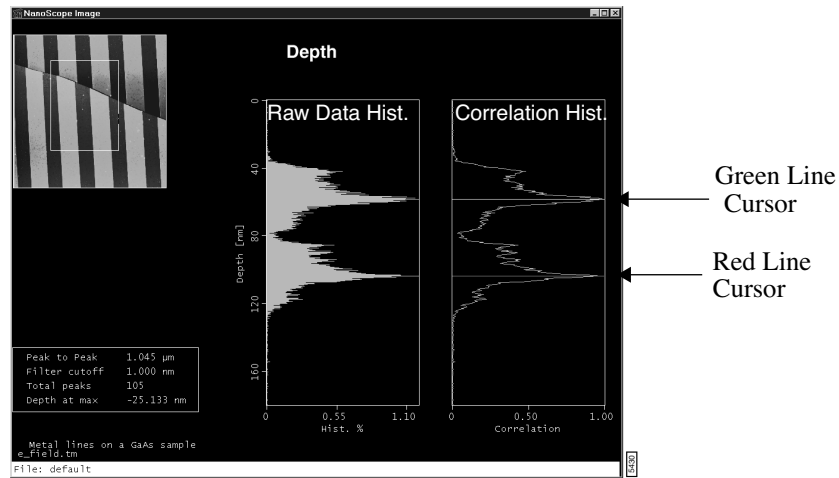
Peak to Peak

- **Check these limits**—If enabled, the limits specified in the **Set Limits** panel apply to the Auto Program. If not selected, the limits are ignored.
- **Pk to Pk Min**—If the measured peak to peak value of a file analyzed in an Auto Program is *less* than the peak to peak *minimum*, then that measurement is not included in the calculation of the peak to peak statistics (average standard deviation, minimum). The measurement is then reported in the Auto Result file with an *L-* before the file name indicating that is was *below* the limit).
- **Pk to Pk Max**—If the measured peak to peak value of a file analyzed in an Auto Program is greater than the peak to peak *maximum*, then that measurement is not included in the calculation of the peak to peak average standard deviation. The measurement is then reported in the Auto Result file with an *L+* before the file name indicating that is was *above* the limit.
- **Percent of Pk to Pk**—The peak to peak minimum and maximum
- **Save**—Saves selected measurements to the Auto Program file. If the **Depth** command is already in the current Auto Program file, it retains its position in the file.
- **Delete**—Removes the **Depth** command from the Auto Program file.
- **Quit**—Exits the Auto Program Edit mode without making changes to the Auto Program file.

13.6.6 Depth Display Monitor

The display screen includes a top view image and two histograms; depth data is displayed near the lower-left corner of the screen. Unconfigured files are displayed with a presized, white cursor box on other edge of the image. The mouse is used to resize and position the box cursor over the area to be analyzed. The left histogram displays the raw depth data. The right histogram displays a Gaussian-filtered version of the same data. In both histograms, depth data is distributed proportional to its occurrence within the defined bounding box. For example, in [Figure 13.6h](#), the data peak indicates large numbers of features at a depth of about 60 nm.

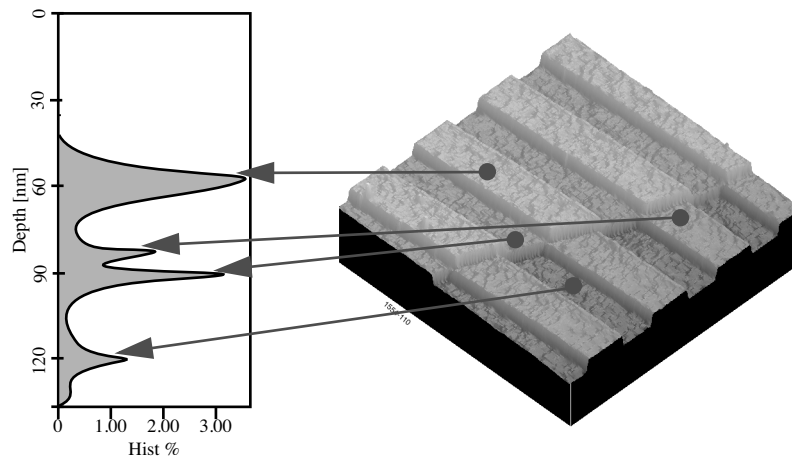
Figure 13.6h Depth Display



Raw Data Histogram

The leftmost histogram displays raw depth data. Depending upon the range and size of depth data, the curve may appear jagged in profile, with noticeable levels of noise. Data spikes on the histogram correspond to specific depths of features on the sample surface. (See Figure 13.6i).

Figure 13.6i Depth Histogram



Correlation Histogram

The Correlation Histogram is a filtered version of the Raw Data Histogram. Filtering is done using the **Histogram filter cutoff** parameter in the **Depth Configure** panel. The larger the filter cutoff, the more data is filtered into a Gaussian (bell-shaped) curve. Large filter cutoffs average so much of the data curve that peaks corresponding to specific features are unrecognizable. On the other hand, if the filter cutoff is too small, the filtered curve may appear noisy.

The Correlation Histogram presents a lowpass, Gaussian-filtered version of the left histogram. The low-pass Gaussian filter removes noise from the data curve and averages the curve's profile. Peaks which are visible in the curve correspond to features in the image at differing depths.

Peaks do not show on the correlation curve as discrete, isolated spikes; instead, peaks are contiguous with lower and higher regions of the sample, and with other peaks. This reflects the reality that features do not all start and end at discrete depths.

When using the **Depth** command for analysis, each peak on the filtered histogram is measured from its statistical centroid (i.e., its statistical center of mass).

Green Line Cursor—The green line cursor identifies the centroid of the largest (maximum) peak.

Red Line Cursor—The red line cursor identifies the centroid of the next largest (minimum) peak that is no closer to the maximum peak than the distance specified by the **Min peak to peak** value set in the **Configure** panel.

Note: Both line cursors may be moved using the mouse to manually select their positions.

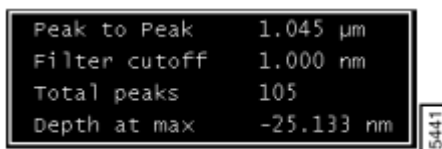
The **Configure** panel generates a *configuration* file, which sets parameters within the **Depth** feature that control many important aspects of the analysis (See [Section 13.6.4](#)) It records where the box cursor is located and how big it is sized, and records the selection of data peaks.

Because configuration files are so closely tied to the location of feature(s) within the image, it is imperative that images be carefully located the same way each time. If **Depth** analysis is being used to compare identical image files (such as captured from magnetic media and integrated circuits) for monitoring purposes. It is important that each image be captured with features of interest located in the same area where the cursor is drawn on the configuration file. For automated SPMs, this can be achieved by registering a representative sample and using a macro routine to process identical samples. On other SPMs, image sites need to be located manually. It may prove helpful to scan a larger-than-necessary site, then use the Off-line/ **Modify/ Zoom** feature to crop the scan to the same size each time before analyzing it.

13.6.7 Interpreting *Depth* Data

The Display Monitor lists all depth analysis results within the data box (See [Figure 13.6j](#)).

Figure 13.6j Depth Display Data Box



Peak to Peak	1.045 μm
Filter cutoff	1.000 nm
Total peaks	105
Depth at max	-25.133 nm

5441

Note: Any or all of these values may be incorporated into the **AutoProgram** feature (See [Section 13.6.5](#)).

Parameters in the Depth Display Data Box

Peak to peak

Depth between two data peak centroids as selected using the horizontal, green line cursors.

Filter cutoff

Reports the value from **Histogram filter cutoff** in the **Configure** menu. **Histogram filter cutoff** acts as a lowpass filter which smooths out the wavelengths that lie below the cutoff. Used to reduce noise in the **Correlation** histogram.

Total peaks

Total number of peaks included within the data histogram.

Depth at max

Depth of maximum (lowest) pixel from shallowest pixel.

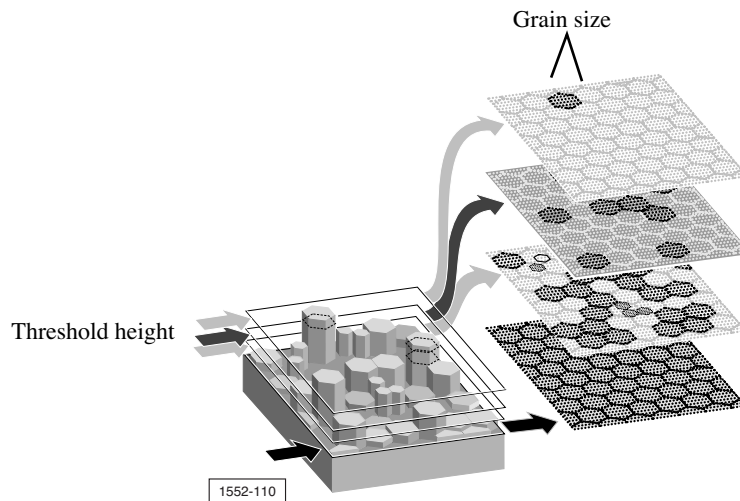
Note: Be aware of an image shifting on automatically captured images. If image features are shifted outside of the configured cursor box, results are inconsistent. To automate **Depth** analysis with optimal results, try using the **Off-line/Analysis/ Pattern Recognition** feature to ensure proper location of all image features.

13.7 Grain Size

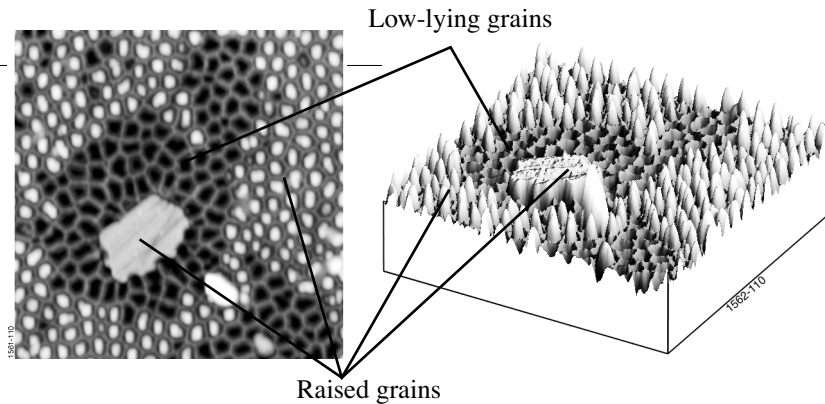
The **Grain Size** command defines grain boundaries based on the height of pixel data. A histogram of grain size can be produced and used to identify specific grains by size. The mean area and standard deviation of the grain sizes, and the total number of grains are calculated and displayed. Grains may be analyzed singly or in aggregates. *Grains*, as used here, are defined in terms of conjoined pixels having a height above or below a given **Threshold height**.

Figure 13.7a Grain Size Illustration

Figure 13.7b



The illustration in [Figure 13.7a](#) reflects how grains can be isolated by height. This is especially true of certain materials where grain size or type is linked to height. Consider the chemically etched hard disk shown in [Figure 13.7c](#).



Materials which exhibit grain structure but which are very flat (e.g., polished refractories) may require pre-processing to assist the **Grain Analysis** software. The **Contrast Enhance**, or **Invert** functions on the modify menu are often useful. The software analyzes grains by height thresholding from above (normal, default setting) or below (enable **Reverse Thresholding** within the **Limits** window). Grains may also be differentiated by manually drawing lines to separate them (**Cursor/ Line**), and by using digital erosion (**Erode**) and dilation (**Dilate**) to further separate or conjoin them.

13.7.1 Erosion and Dilation

As applied to the **Grain Size** function in digital NanoScope images, erosion and dilation are used to clump grains together (dilation), or separate them (erosion). Pixels comprising an image are evaluated in square matrices (i.e., neighborhoods), sized according to the **Erode Neighborhood size** and **Dilate Neighborhood size** parameters shown on the **Limits window** (See [Section 13.7.4](#)).

Erosion—The effect of digital erosion is to separate grains which otherwise touch or conjoin one another. If all values in a neighborhood are **ON**, erosion is not applied. If N pixels are **OFF** in a neighborhood of ON pixels (where N is specified by the **Num. pix. off for erode** parameter), the center pixel is turned **OFF** and the result written to the eroded image file.

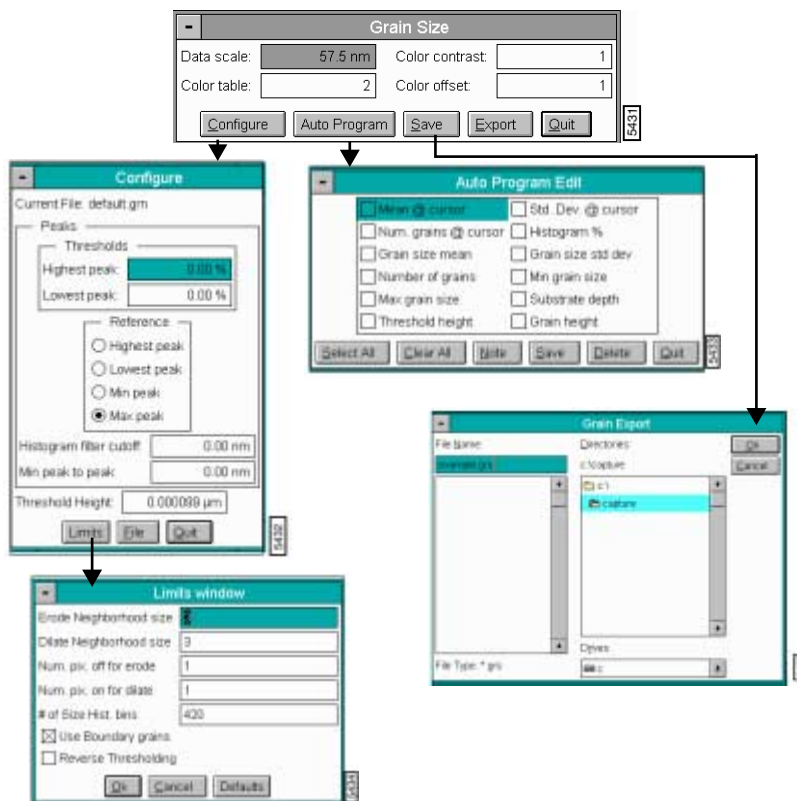
If the **Num. pix. off for erode** parameter is set to **1**, the erosion process is triggered if even one pixel is off, making erosion more sensitive at a setting of **1**. Furthermore, if the **Erode Neighborhood size** is large, erosion is applied to larger areas of the image. Therefore, maximum erosion is obtained with a large **Erode Neighborhood size** setting and a small **Num. pix. off for erode** setting.

Analysis Commands (A) is attained with a small **Erode Neighborhood size** setting and a large **Grain Size Num. pix. off for erode** setting.

Dilation—The effect of digital dilation is to conjoin otherwise separate grains, and to mend broken grains. If all values in a neighborhood are “off,” dilation is not applied. If N pixels are “on” in a neighborhood of “off” pixels (where N is specified by the **Num. pix. on for dilate** parameter), the center pixel is turned “on” and the result written to the dilated image file. Note that if the **Num. pix. on for dilate** parameter is set to **1**, the dilation process is triggered if even one pixel is on, making dilation more sensitive at a setting of **1**. Furthermore, if the **Dilate Neighborhood size** is large, dilation is applied to larger areas of the image. Therefore, maximum dilation is attained with a large **Dilate Neighborhood size** setting and a small **Num. pix. on for dilate** setting. Minimum dilation is attained with a small **Dilate Neighborhood size** setting and a large **Num. pix. on for dilate** setting.

For navigating in the **Grain Size** panels, see [Figure 13.7d](#).

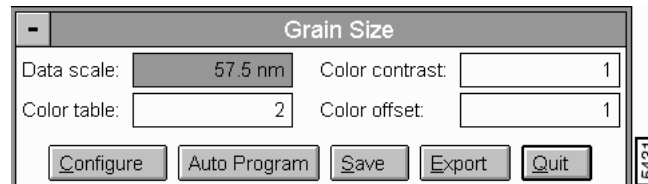
Figure 13.7d Navigating Grain Size Analysis



13.7.2 Grain Size Panel

The **Grain** panel appears and sets the image display parameters (See [Figure 13.7e](#)).

Figure 13.7e Grain Size Panel



Parameters in the Grain Size Panel

Data scale

Controls the vertical range of the image corresponding to the full extent of the Color table. The units of this item vary according to the type of image (e.g., nm, nA, etc.).

Color Table

Selects the color table used to encode the Z information.

Color Contrast

Controls the contrast in the image by compressing or expanding the Color table.

Color Offset

Shifts the Color table used to display the image.

Buttons in the Grain Size Panel

Configure

Accesses the **Configure** panel and defines the values to be applied in the various grain size functions. For details on the **Configure** panel, see [Section 13.7.3](#).

Auto Program

Accesses the **Auto Program Edit** panel and adds or deletes the **Grain Size** command from the currently selected Auto Program file. For details on the **Auto Program** panel, see [Section 13.7.6](#).

Save—Saves Grain Size data to a directory and file name specified by the user.

Note: Saves only the image of the grains and not the numeric information. To save any numeric results, use the **Export** command.

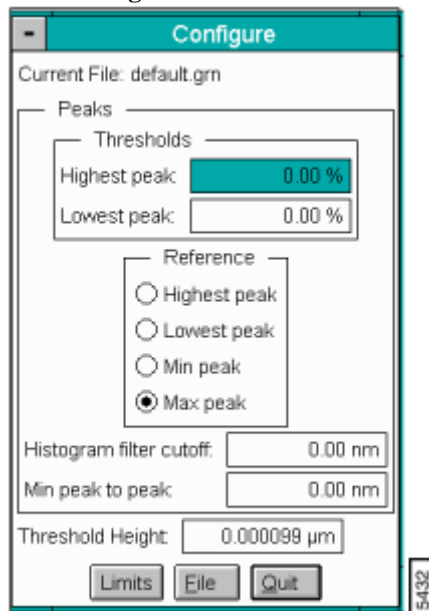
Analysis Command (A) Exports (A) Exports Grain Size data in ASCII format to a directory and file name defined by **Grain Size** the user.

TQuit—Exits the Grain Size analysis feature.

13.7.3 The Grain Size Configure Panel

The **Configure** panel defines the values to be applied in the various grain size functions. In the **Grain Size** panel, click on the **CONFIGURE** button to access the **Configure** panel (See Figure 13.7f).

Figure 13.7f Grain Size Configure Panel



Parameters in the Grain Size Configure Panel

Thresholds

Sets amount of a peak is used for calculating the centroid (weighted average of points on a curve).

- **Highest Peak**—Value used to define how much of the *highest peak* (i.e., topmost peak in the Correlation histogram) is included when calculating the

centroid. At 0%, only the maximum point on the curve is included. At 25%, only the maximum 25% of the peak is included in the calculation of the centroid.

- **Lowest Peak**— Value used to define how much of the *lowest peak* (i.e., peak closest to the bottom in the Correlation histogram) is included when calculating the centroid. At 0 percent, only the maximum point on the curve is included. At 25 percent, only the maximum 25 percent of the peak is included in the calculation of the centroid.

Reference

- **Highest Peak**—Topmost peak in the Correlation histogram
- **Lowest Peak**—Peak closest to the bottom in the Correlation histogram
- **Min peak**— Shortest (smallest) peak in the curve
- **Max peak**—Tallest peak in the Correlation histogram

Figure 13.7g Grain Size Display

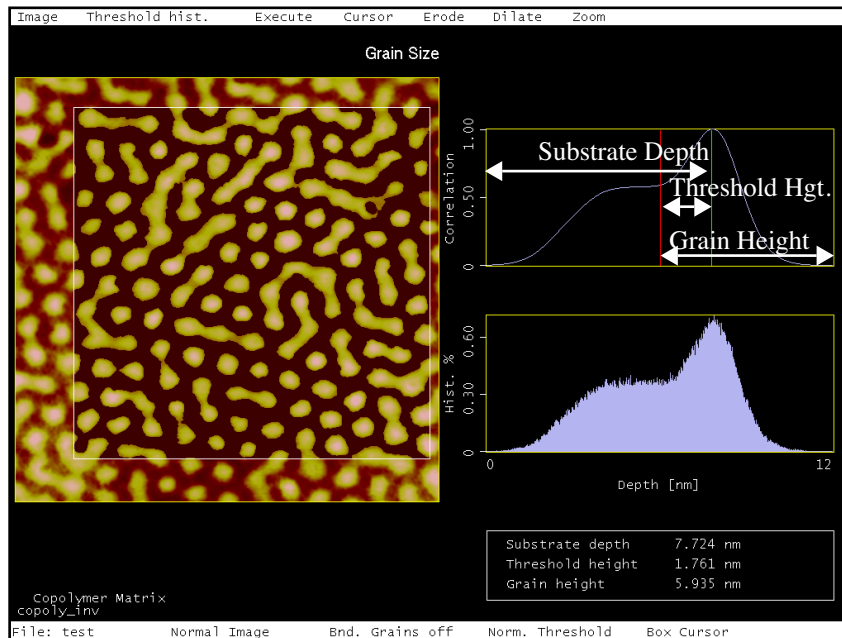
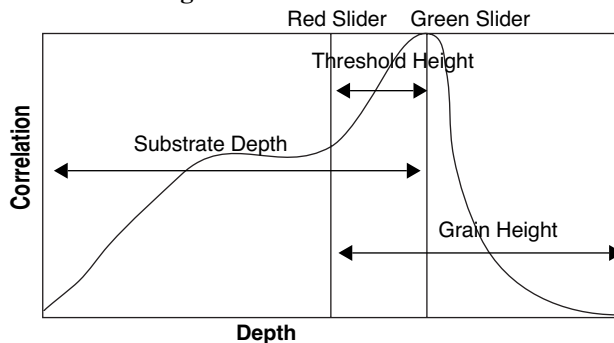


Figure 13.7h represents the data box measurements in Figure 13.7g.

Figure 13.7h Grain Size Correlation Histogram



Histogram filter cutoff

Lowpass filter which smooths out the wavelengths that lie below the cutoff. Used to reduce noise in the Correlation histogram.

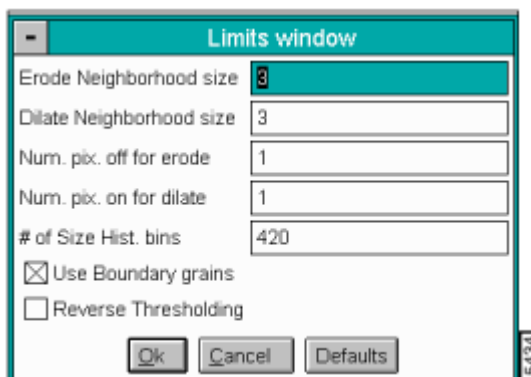
Threshold height

Sets threshold height used to differentiate grain boundaries, exactly as the cursor slider does on the height histogram. Unlike the slider cursor, this parameter allows for precise pinpointing of threshold values.

13.7.4 Limits Window

In the **Configure** panel, click on the **LIMITS** button to access the **Limits Window** panel. The **Limits Window** parameters define limits to be applied to the various **Grain Size** functions (See Figure 13.7i).

Figure 13.7i Limits Window Panel

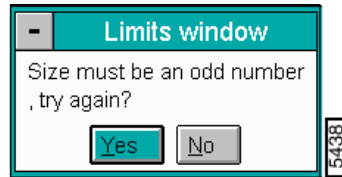


Parameters in the Limits Window

Erode Neighborhood size— $N \times N$ square pixel matrix used to erode a binary image where N equals the **Erode Neighborhood size**. (E.g., an **Erode Neighborhood size** of **3** uses a 3×3 matrix to evaluate local erosion in the binary image).

If even numbers are entered in **Erode** and **Dilate** parameters, an error panel appears (See [Figure 13.7j](#)).

Figure 13.7j Limits Window Error Message



Dilate Neighborhood size—Pixel size of matrix used to define image dilation. E.g., a value of **3** uses a 3×3 matrix to evaluate local dilation in the binary image. If all values in a 3×3 neighborhood are off, no change is effected. If any one pixel is on, the center pixel is turned on and the result is written to the dilated image file. The larger the neighborhood size, the less “tolerant” the dilation process becomes.

Num. pix. off for erode—Number of “off” pixels required in a square matrix of **Erode Neighborhood size** to apply erosion.

Num. pix. on for dilate—Number of “on” pixels required in a square matrix of **Dilate Neighborhood size** to apply dilation.

of Size Hist. bins—Number of histogram points used to plot grain size data, varying from **1** to **370**. As this parameter is reduced, histogram shape becomes coarser and grain sizes are clustered together into larger and larger (and fewer and fewer) data “bins” or “buckets,” with a correspondingly larger standard deviation.

Use Boundary grains—When selected, includes grains along the boundary of the cursor box. When not selected, includes only those grains which fall entirely within the boundary of the cursor box.

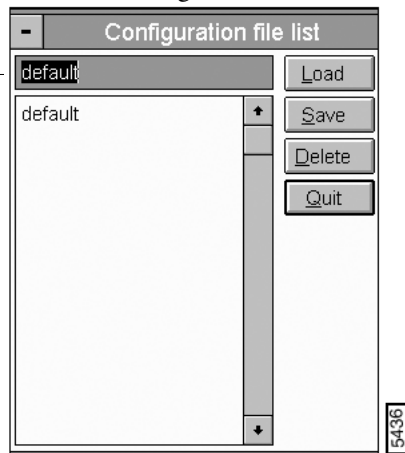
Reverse Thresholding—Selects sample areas *below* the height histogram, rather than above; this parameter should be selected when analyzing low-lying grains.

Note: Another way to analyze low-lying grains is to apply the **Off-line/ Modify/ Invert** command to the image first, then use **Grain Size** analysis in the normal fashion.

13.7.5 Configuration File List Panel

In the **Configure** panel, click on the **FILE** button to access the **Configuration file list** menu (See [Figure 13.7k](#)).

Analysis Commands (A-L)**Figure 13.7k** Configuration File List Menu
Grain Size



The panel allows saved **Configure** files to be opened, deleted or created.

Buttons on the Configuration File List Panel

LOAD—Loads the specified **Grain Size Configure** file.

SAVE—Saves the current settings as a **Grain Size Config** file.

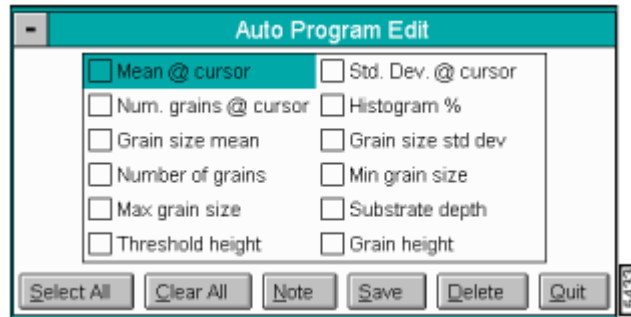
DELETE—Deletes the specified **Grain Size Configure** file.

QUIT—Quits the **Configuration file list** window .

13.7.6 Auto Program Edit Panel

Adds or deletes the Grain Size command from the currently selected Auto Program file. A panel listing measurements reported by the Grain Size command is displayed (See [Figure 13.71](#)).

Figure 13.71 Grain Size Auto Program Edit Panel



Note: See the end of this section for a definition of the measurements reported in Grain Size (Mean @ cursor, Number of grains, Max grain size, etc.).

Parameters and Buttons on the Auto Program Edit Panel

A list of parameters (i.e., measurements) add or delete to the grain size specifications. Selecting a measurement stores it in the Auto Result file when **Auto Program** is run.

Select All

Selects all the measurements simultaneously.

Clear All

Clears all the measurements simultaneously.

Note

Allows a command prompt to be inserted into the AutoProgram file. Text input is printed in the result file with the measurements.

Save

Saves selected measurements to the Auto Program file. If the **Grain Size** command is already in the current Auto Program file, it asks to retain or append the new grain size.

Delete

Removes the **Grain Size** command from the Auto Program file.

Quit

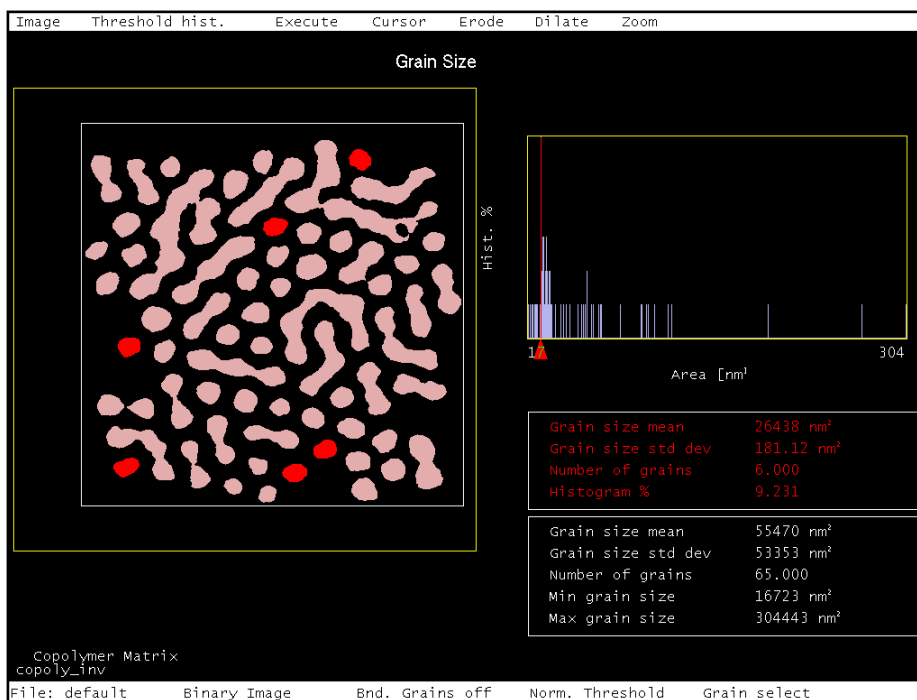
Exits the Auto Program Edit mode without making changes to the Auto Program file.

Note: The **Auto Program File** command in the **Utility** menu must be used to select, or create, an Auto Program file. The **Auto** subcommand under the **Browse** command selects the files to be processed and executes the Auto Program file.

13.7.7 Grain Size Display Monitor

When **Grain Size** is applied to an image, the image and an area histogram are first displayed on the Display Monitor (See [Section 13.7g](#)). The area histogram allows you to select individual grain sizes by sliding the red, triangular cursor horizontally. The measurement values of the selected grain(s) are displayed in red; measurements for all the grains in a given analysis are displayed in white.

Figure 13.7m Grain Size (Executed) Display



13.7.8 Menu Commands on the Grain Size Display Monitor

Image

Switches the displayed image between either a **Binary** or **Normal** mode. In the **Binary** mode, grains are shown in white against a black background. In the **Normal** mode, grains are assigned their normal, **Color table** hues against a black background. While adjusting the **Threshold histogram**, it is generally best to view the image in Binary mode to more easily differentiate grains.

Threshold hist[ogram]

Displays pixel height correlation and a pixel height histogram on the right side of the screen. The height correlation has two sliders that determine the thresholds of grain size. In the normal, default mode (with **Reverse Thresholding** disabled) as the red slider is moved to the right, sample areas below the threshold are removed from the image (black), leaving only the raised area of the grains behind.

This effect *reverses* when **Reverse Thresholding** is enabled, blacking out image features *above* the threshold.

Again in normal, default mode, the green slider shows the position of the centroid of the largest peak (See [Section 13.7g](#)).

After grains are defined with the red threshold slider, the **Execute** command should be selected to obtain information about the grains.

Execute

Initiates grain size analysis and displays statistics for the grains defined by the height threshold on the area histogram. The default position of the red line cursor on the area histogram is the area bin containing the most grains.

Cursor

Offers several different types of cursors, which may be applied to the sample image.

- **Box**—Box cursor for selecting rectangular regions of the image. When **Execute** is selected, only the region within the box is analyzed.
- **Grain select**—Selects one specific grain from the analyzed region. The selected grain is highlighted in red, its dimensions are displayed in red characters, and its corresponding plot is indicated on the grain size histogram by a red line cursor.
- **Grain remove**—Removes selected grains from the image. This feature may be used to eliminate unwanted grains and noise.
- **Grain accumulate**—Restricts analysis to selected grains. As more grains are chosen, the display reflects the new *accumulated* statistics.
- **Line**—The line cursor may be used to cut portions of fragmented grains.
- **Clear**—Removes all cursors from the image and recalculates the grains and the grain-size histogram.

Erode

Performs a digital erosion on the image. For a definition of **Erode**, see [Section 13.7.1](#).

Dilate

Performs a digital dilation on the image. For a definition of **Dilate**, see [Section 13.7.1](#).

Zoom

Applies a “zoom in” to the grain size histogram by rescaling its horizontal axis to display only plots included within a green box cursor. Unzoomed portions of the histogram are not displayed and their corresponding grains are removed from the image. For a description of using **Zoom**, *see also* [Section 13.7.10](#).

- **On**—Enables the **Zoom** command. A red zoom box cursor is displayed on the grain size histogram. To zoom a portion of the histogram, use the mouse to stretch and position the cursor box over the selected region of the plot, then click on **Zoom/Zoom**. When **Zoom** is on, the data in the lower display reflects those grains within the **Zoom** lines.
- **Off**—Disables the **Zoom** command.
- **Zoom**—Applies the **Zoom** command to the portion of the histogram included within the green box cursor.
- **Full scale**—Restores the grain size histogram to its original (“zoomed out”) form, showing all plots.

Mouse Operations on the Display Monitor

Red Slider (cursor)—Defines the threshold.

Green Slider (cursor)—Defines the substrate

Using the slider

- 1st click, left button—Placing the cursor on the red, triangular slider and clicking the left mouse button frees the slider horizontally. The slider can then be dragged by rolling the mouse left and right.
- 2nd click, left button—Fixes the slider and height histogram threshold.

Within the image

- 1st click, left button—Fixes one corner of a box cursor (or one end of a line cursor) and “rubberbands” to the opposite corner or end. Also enables the various **Cursor** options.
- 2nd click, left button—Fixes the opposite end of the box or line cursor.

The **Off-line/Analysis/Grain Size** function is designed to detect and measure granularity on sample surfaces.

1. Load image.
2. Select area of interest in image by drawing a box cursor (**Cursor/ Box**).
3. Use **Threshold hist.** to define grain boundaries by manipulating the height thresholds in the correlation box (move the red slider). If the grains to be analyzed are low-lying areas of the image (e.g., pits), select the **Reverse Thresholding** command within the **Limits** window.
4. If more grain definition is required, apply **Erode** or **Dilate** to the image. Separate conjoined grains using **Erode**, or manually separate them using the **Cursor/Line** feature.
5. Click on **Execute** to perform grain analysis and generate data.
6. Use **Zoom** to isolate grains of a specific size. Use **Cursor/Grain Select**, **Grain Accumulate** or **Grain Remove** to manually isolate grains of interest and obtain data.

After grain size analysis is executed, statistics are displayed below the histogram for each plot pointed to by the sliding cursor. If statistics are sought for more than one grain, use the **Zoom** command to specify the size range to be analyzed (See [Section 13.7.10](#)).

In [Figure 13.7g](#), a white box cursor has been drawn with the mouse to define the area of interest. **Grain Size** is performed by clicking on **Execute**.

A histogram of the various grains is displayed to the right of the image, and various statistics such as average size are displayed in the lower-right corner.

By sliding the cursor laterally along the bottom of the histogram, you can highlight each grain plotted. If the **Cursor/Grain** option is selected, the mouse may be used to manually select specific grains from the image; the histogram slider automatically moves to the corresponding plot

(See [Figure 13.7m](#)).

13.7.10 Using the Zoom Function

Once an image has been analyzed using the **Grain Size** function, it is possible to isolate grains of a particular size range and compile statistics by using the **Zoom** function. In **Grain Size** analysis, *size zooming* enables you to isolate grains of a specified size range. To use the **Zoom** function, complete the following:

1. Load the image to be analyzed and execute the **Grain Size** function.

Analysis Commands (A-L)

Grain Size Click on the **Zoom/ On** option. Two red, vertical lines (line cursors or sliders) are displayed on the histogram.

3. Use the mouse to move the red, vertical lines on the histogram. The lines should encompass the grain size range of interest. Simultaneously, the sample image highlights all grains falling within the selected range.

Note: No extra plane fitting is applied to the data during the grain-size calculations. Some type of plane fitting may be needed beforehand.

Note: You can divide a grain into multiple grains by drawing edit lines (**Cursor/ Line**) through the grains on the image.

13.7.11 Interpreting *Grain Size* Data

The data is divided into two sets, separated by boxes. The data set for a specific grain or group of grains identified by the red arrow slider in the area histogram is shown in red. The data for the entire area enclosed by the box cursor is shown at the bottom in white.

Data for a specific (highlighted) grain or group of grains:

- **Grain size mean**—Mean size of all highlighted grains in the group
- **Grain size std dev**—The standard deviation of the grain size for all the highlighted grains
- **Number of grains**—Number of grains in the group.
- **Histogram %**—percent of total number of grains

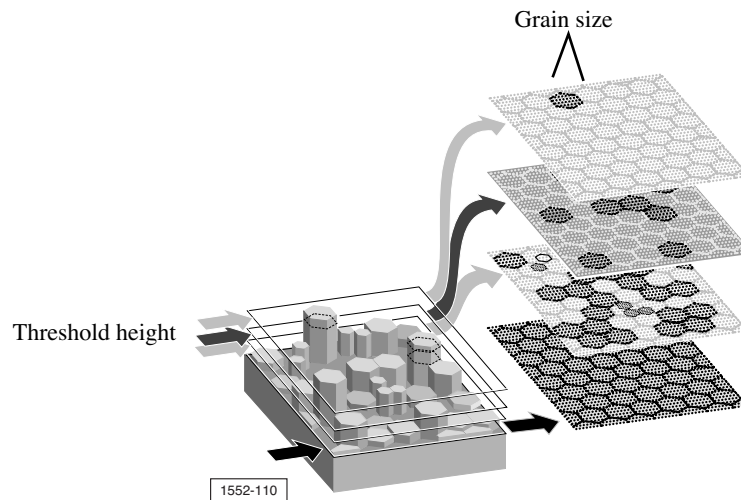
Data for the area enclosed by the box cursor:

- **Grain size mean**—Mean size of all grains enclosed in the box cursor (data set)
- **Grain size std. dev.**—Standard deviation for all the grains enclosed in the box cursor
- **Number of grains**—Total number of grains enclosed in the box cursor
- **Min grain size**—The size of the smallest grain in the data set
- **Max grain size**—The size of the largest grain in the data set

13.8 Grain Size Average

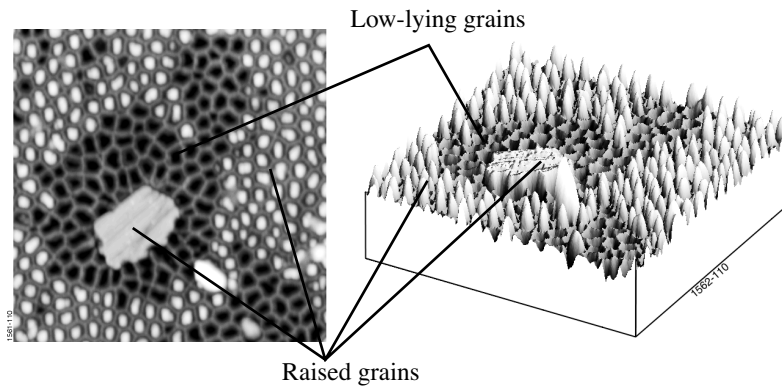
The **Grain Size Average** command defines grain boundaries based on the height of pixel data. It is nearly identical to the **Grain Size** command, although it returns a more true and accurate measurement of all the grains. Grain Size is used to measure and analyze individual grains. **Grain Size Average** is better suited for analyzing larger numbers of grains and grain groups. It does this by making calculations based on two thresholds. One threshold contains the maximum number of grains, and another is the maximum surface area (above a user-defined threshold plane). A histogram of grain size can be produced and used to identify specific grains. The mean size and diameter, total number of peaks, and the total number of grains are calculated and displayed. Grains may be analyzed singly or in aggregates. “Grains,” as used here, are defined in terms of conjoined pixels having a height above or below a given **Threshold height**.

Figure 13.8a Grain Size Average Illustration



Grains can be isolated by height. This is especially true of certain materials where grain size or type is linked to height. Consider the chemically etched hard disk shown in [Figure 13.8b](#).

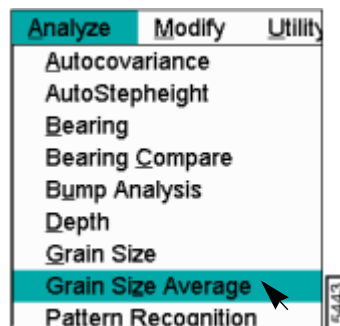
Figure 13.8b Chemically Etched Hard Disk Image



Materials which exhibit grain structure but which are very flat (e.g., polished refractories) may require pre-processing to assist the **Grain Size Average** software. The contrast enhance, or invert functions on the **Modify** menu are often useful. The software analyzes grains by height thresholding from above (normal, default setting) or below (enable **Reverse Thresholding** within the **Limits** window). Grains may also be differentiated by manually drawing lines to separate them (**Cursor/Line**), and by using digital erosion (**Erode**) and dilation (**Dilate**) to further separate or conjoin them.

To access **Average Grain Size**, select the **Analyze/Average Grain Size** command (See [Figure 13.8c](#)).

Figure 13.8c Grain Size Average Menu

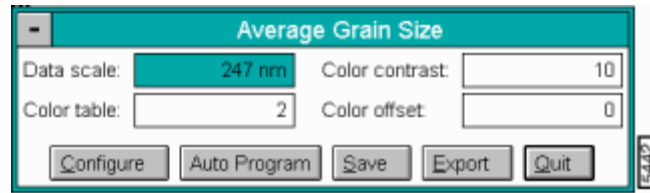


The **Average Grain Size** panel is displayed allowing the display parameters to be adjusted to the preferences of the user (See [Figure 13.8d](#)).

13.8.1 Average Grain Size Panel

For details on the panels and parameters in the Average Grain Size command, refer to **Grain Size Section 13.7**.

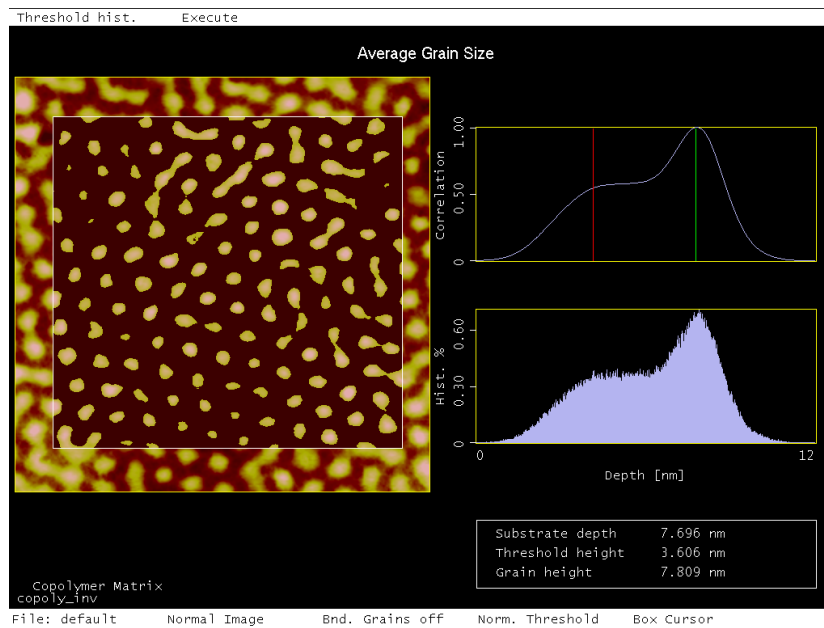
Figure 13.8d Average Grain Size Panel



13.8.2 Display Monitor

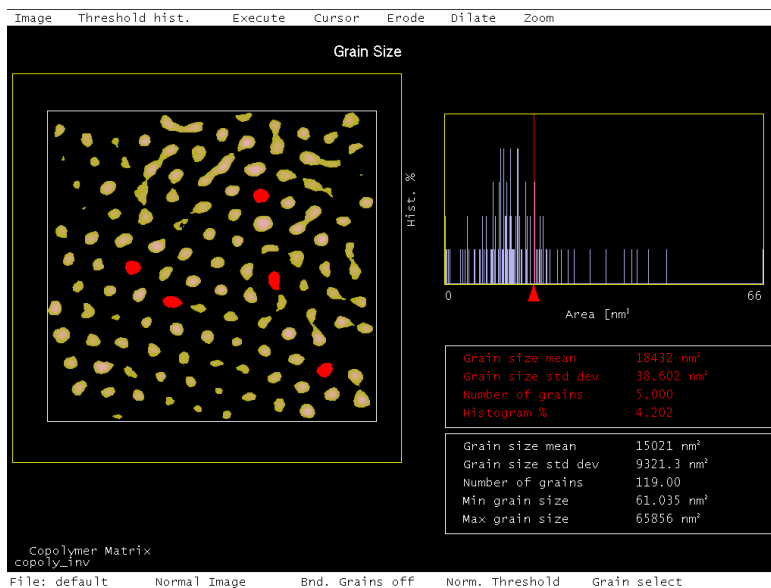
When **Grain Size Avg** is applied to an image, the image and an area histogram are first displayed on the Display Monitor (See [Figure 13.8e](#)). The area histogram allows you to select individual grain sizes by sliding the red, triangular cursor horizontally.

Figure 13.8e Grain Size Average Display



The measurement values of the selected grain(s) are displayed in red; measurements for all the grains in a given analysis are displayed in white (See [Figure 13.8f](#)).

Figure 13.8f Grain Size Average (Executed) Display



Menu Commands in the Display Monitor

Threshold hist[ogram]

Displays pixel height correlation and a pixel height histogram on the right side of the screen. The height correlation has two sliders that determine the thresholds of grain size. In the normal, default mode (with **Reverse Thresholding** disabled) as the red slider is moved to the right, sample areas below the threshold are removed from the image (black), leaving only the raised area of the grains behind. This effect is reversed when **Reverse Thresholding** is enabled, blacking out image features *above* the threshold.

Again in normal, default mode, the green slider determines the maximum threshold height of the grains.

The histogram filter cutoff in the **Configure** panel determine the size of the Gaussian distribution. A larger cutoff value produces a more gaussian (bell-shaped) curve.

After grains are defined with the red threshold slider, the **Execute** command should be selected to obtain information about the grains.

Execute

Initiates grain size analysis and displays statistics for the grains defined by the height threshold on the height histogram. The default position of the red line cursor on the area histogram is the area bin containing the most grains.

Using the slider:

- 1st click, left button—Placing the cursor on the red, triangular slider and clicking the left mouse button frees the slider horizontally. The slider can then be dragged by rolling the mouse left and right.
- 2nd click, left button—Fixes the slider and height histogram threshold.

Using the cursor within the image:

- 1st click, left button—Fixes one corner of a box cursor (or one end of a line cursor) and expands to the opposite corner or end. Also enables the various **Cursor** options.
- 2nd click, left button—Fixes the opposite end of the box or line cursor.

13.8.3 Using Average Grain Size

The **Off-line/Analysis/Grain Size Average** function is designed to measure the true size of grains on the sample surface. Generally, the procedure for using **Grain Size Average** is as follows:

1. Load image.
2. Select area of interest in image by drawing a box cursor (**Cursor/ Box**).
3. Use **Threshold hist.** to define grain boundaries by manipulating the height thresholds in the correlation box (move the red and green sliders). If the grains to be analyzed are low-lying areas of the image (e.g., pits), select the **Reverse Thresholding** command within the **Limits** window.
4. Click on **Execute** to perform grain analysis and generate data.

After grain size analysis is executed, statistics are displayed below the histogram for each plot pointed to by the sliding cursor.

A histogram of the various grains is displayed to the right of the image, and various statistics such as average size are displayed in the lower-right corner.

By sliding the cursor laterally along the bottom of the histogram, you can highlight each grain plotted. If the **Cursor/Select** grain option is selected, the mouse may be used to manually select specific grains from the image; the histogram slider automatically moves to the corresponding plot.

Note: You can divide a grain into multiple grains by drawing edit lines (**Cursor/Line**) through the grains on the image.

13.8.4 Interpreting *Grain Size Average* Data

The data is divided into two sets, separated by boxes. The data set for a specific grain or group of grains identified by the red arrow slider in the area histogram is shown in red. The data for the entire area enclosed by the box cursor is shown at the bottom in white.

Data for a specific (highlighted) grain or group of grains

- **Grain size mean**—Mean size of all highlighted grains in the group
- **Grain size std dev**—The standard deviation of the grain size for all the highlighted grains
- **Number of grains**—Number of grains in the group (minimum of 1)
- **Histogram %**—Percent of the total area comprised by the selected grain

Data for the area enclosed by the box cursor

- **Number of grains**—Number of grains enclosed in the box cursor
- **Grain height**—Average height of grain relative to **Threshold plane**
- **Mean size**—The average size (area) of all the grains enclosed in the box cursor
- **Mean diameter**—The average diameter of all the grains enclosed in the box cursor
- **Number of peaks**—Number of peaks in the **Correlation** histogram used to calculate the true **Grain size average**.

Chapter 14 Analysis Commands (M-Z)

The commands in the **Analyze** menu provide methods for quantifying the surface properties of samples. See [Chapter 13](#) for referencing commands beginning with the letters A-L.

Refer to the following sections:

- **Analyze Commands M-Z Overview** [Section 14.1](#)
- **Particle Analysis** [Section 14.2](#)
- **Pattern Recognition** [Section 14.3](#)
- **Power Spectral Density** [Section 14.4](#)
- **PSD Compare** [Section 14.5](#)
- **Roughness** [Section 14.6](#)
- **Section** [Section 14.7](#)
- **Stepheight** [Section 14.8](#)
- **Auto Tip Qualify** [Section 14.9](#)
- **Trench** [Section 14.10](#)
- **Width** [Section 14.11](#)
- **MSM and HFMM** [Section 14.12](#)

14.1 Analyze Commands M-Z Overview

See [Table 14.1a](#) to review the **Analyze** features and its applications in this chapter.

Table 14.1a Analyze Commands and Applications

Analyze Command	Measurement/Applications				
	Depth	Roughness	Power Spectrum	Width	Area
Particle Analysis	X			X	X
Pattern Recognition					
Power Spectral Density			X		
PSD Compare			X		
Roughness		X			
Section	X	X		X	X
Stepheight					
Auto Tip Qual					
Width	X			X	X
Trench	X			X	X

14.2 Particle Analysis

The **Particle Analysis** command defines particles based on the height of pixel data. This analysis was designed for analyzing well isolated particles. Particles may be analyzed singly or in quantities. *Particles* in this context, are conjoined pixels above or below a given threshold height. The **Particle Analysis** functions are similar to analyzing grains (Analyze menu/Grain Size). .

The analysis includes a histogram of particle size, which can be used to identify specific particles by size. Measurements on this analysis include: the mean area and standard deviation of the particle sizes, the total number of particles, a correlation histogram, a bearing ratio curve and a depth histogram.

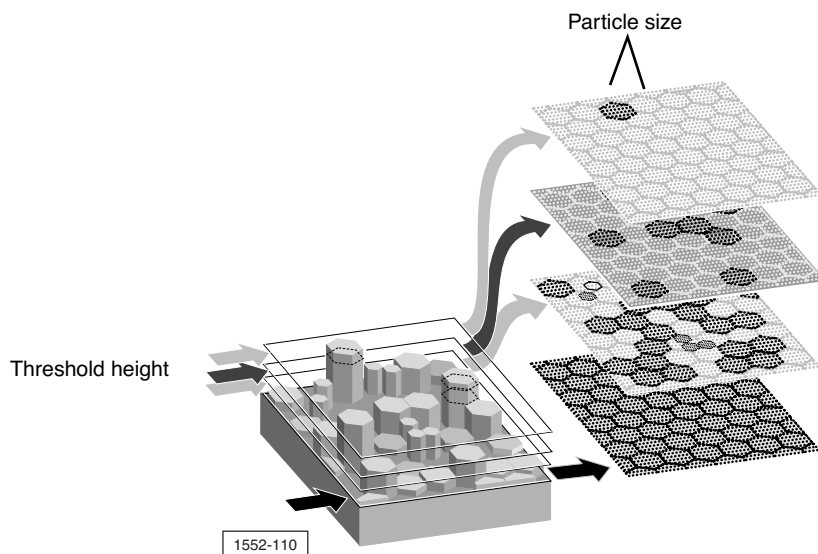
Refer to the following sections on Particle Analysis:

- **Example of Particle Analysis and Area** [Section 14.2.1](#)
- **Erosion and Dilation** [Section 14.2.2](#)
- **Particle Analysis Panels Overview** [Section 14.2.3](#)
- **Particle Analysis Panel** [Section 14.2.4](#)
- **Particle Analysis Configure Panel** [Section 14.2.5](#)
- **Limits Window Panel** [Section 14.2.6](#)
- **Configuration File List** [Section 14.2.7](#)
- **Auto Program Edit Panel** [Section 14.2.8](#)
- **Particle Analysis Display Monitor** [Section 14.2.9](#)
- **Procedure for Using Particle Analysis** [Section 14.2.10](#)
- **Interpreting Particle Analysis Data** [Section 14.2.11](#)

14.2.1 Example of Particle Analysis and Area

The illustration in [Figure 14.2a](#) reflects how particles can be isolated by height. This type of analysis works well on materials in which particle size or type is linked to height.

Figure 14.2a Particles Isolated by Height



14.2.2 Erosion and Dilation

As applied to the **Particle Analysis** function in digital NanoScope images, erosion and dilation are used to clump particles together (dilation), or separate them (erosion). Pixels comprising an image are evaluated in square matrices (“neighborhoods”), sized according to the **Erode Neighborhood size** and **Dilate Neighborhood size** parameters shown on the **Limits window**.

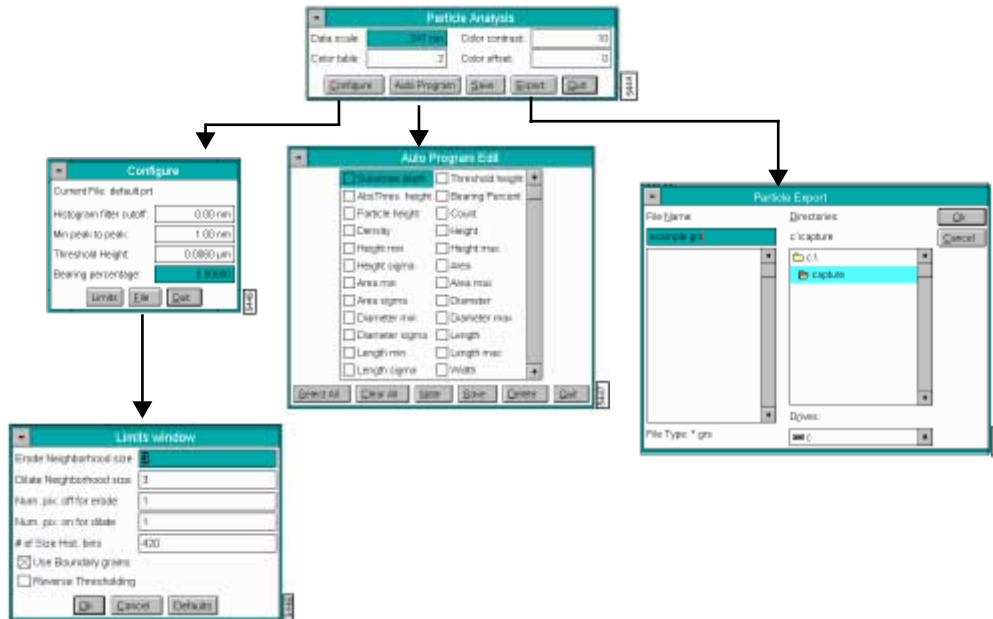
Erosion—The effect of digital erosion is to separate particles which otherwise touch or conjoin one another. If all values in a neighborhood are “on,” erosion is not applied. If N pixels are “off” in a neighborhood of “on” pixels (where N is specified by the **Num. pix. off for erode** parameter), the center pixel is turned “off” and the result written to the eroded image file. Note that if the **Num. pix. off for erode** parameter is set to **1**, the erosion process is triggered if even one pixel is off, making erosion more sensitive at a setting of **1**. Furthermore, if the **Erode Neighborhood size** is large, erosion is applied to larger areas of the image. Therefore, *maximum erosion is obtained with a large **Erode Neighborhood size** setting and a small **Num. pix. off for erode** setting. Minimum erosion is attained with a small **Erode Neighborhood size** setting and a large **Num. pix. off for erode** setting.*

Dilation—The effect of digital dilation is to conjoin otherwise separate particles, and to mend broken particles. If all values in a neighborhood are “off,” dilation is not applied. If N pixels are “on” in a neighborhood of “off” pixels (where N is specified by the **Num. pix. on for dilate** parameter), the center pixel is turned “on” and the result written to the dilated image file. Note that if the **Num. pix. on for dilate** parameter is set to **1**, the dilation process is triggered if even one pixel is on, making dilation more sensitive at a setting of **1**. Furthermore, if the **Dilate Neighborhood size** is large, dilation is applied to larger areas of the image. Therefore, *maximum dilation is attained with a large **Dilate Neighborhood size** setting and a small **Num. pix. on for dilate** setting. Minimum dilation is attained with a small **Dilate Neighborhood size** setting and a large **Num. pix. on for dilate** setting.*

14.2.3 Particle Analysis Panels Overview

For navigating in **Particle Analysis**, see [Figure 14.2b](#).

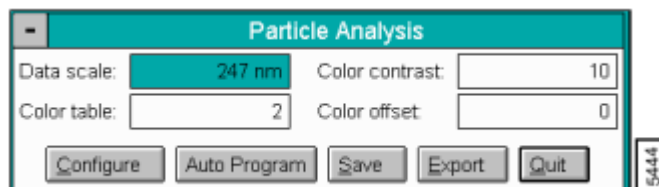
Figure 14.2b Navigating in Particle Analysis



14.2.4 Particle Analysis Panel

Access the **Particle Analysis** panels by selecting Off-line/**Analyze/Particle Analysis** (See [Figure 14.2c](#)).

Figure 14.2c Particle Analysis Panel



Parameters in the Particle Analysis Panel

Data scale—Controls the vertical range of the image corresponding to the full extent of the color table. The units of this item vary according to the type of image (e.g., nm, nA, etc.).

Color table—Selects the color table used to encode the Z information.

Color contrast—Controls the contrast in the image by compressing or expanding the color table.

Color offset—Shifts the color table used to display the image.

Buttons on the Particle Analysis Panel

Configure—Defines the values to be applied in the various particle size functions (See [Section 14.2.5](#)).

Auto Program— Adds or deletes the **Particle Analysis** command from the currently selected **Auto Program** file (See [Section 14.2.8](#)).

Save—Saves **Particle Analysis** image to a directory and filename you specify.

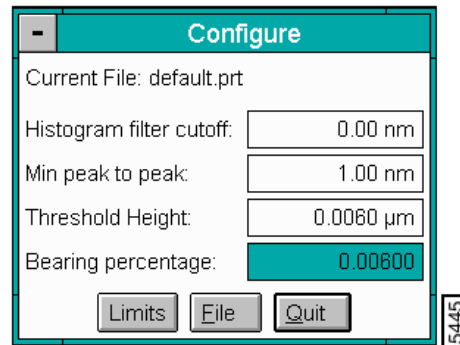
Export—Exports **Particle Analysis** data in ASCII format to a directory and file name you define.

Quit— Exits the **Particle Analysis** command.

14.2.5 Particle Analysis Configure Panel

In the **Particle Analysis** panel, click the **CONFIGURE** button to access the **Configure** panel (See [Figure 14.2d](#)).

Figure 14.2d Particle Analysis Configure Panel



Parameters in the Particle Analysis Configure Panel

Histogram filter cutoff—Lowpass filter which smooths out the wavelengths that lie below the cutoff in the depth correlation histogram. Used to reduce noise in the Correlation histogram.

Min Peak to Peak—Specifies a minimum placement of the green and red cursors for particles configured to the specified distance (nm) between the red and green cursors (threshold height distance).

Threshold Height—Sets threshold height (distance between the green “substrate” and red “threshold” slider cursors) used to differentiate particle boundaries, exactly as the Red Slider cursor does on the Correlation histogram. Unlike the slider cursor, this parameter allows for precise pinpointing of threshold values.

Bearing Percentage—Displays the percentage of the surface that lies above the threshold height indicated by the red arrow on the bearing ratio curve.

Buttons on the Configure Panel

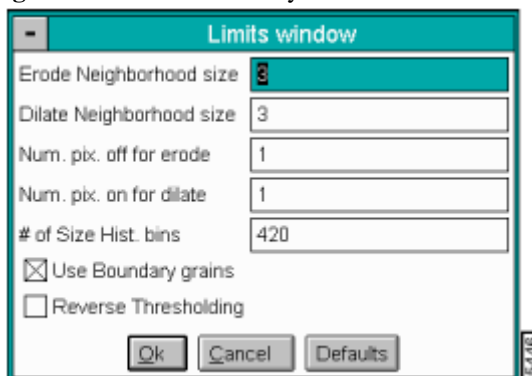
Limits—The Limits Window parameters define limits to be applied to the various Particle Analysis functions. For details on the Limits Window panel, see [Section 14.2.6](#).

File—Opens a Configuration File List panel to save configure parameters. Allows saved Configure files to be opened and saved. For details on the Configuration File List, see [Section 14.2.7](#).

Quit—Exits the Configure panel

14.2.6 Limits Window Panel

Figure 14.2e Particle Analysis Limits Window Panel



Parameters in the Limits Window

Erode Neighborhood size— $N \times N$ square pixel matrix used to erode a binary image where N equals the **Erode Neighborhood size**. (For instance, an **Erode Neighborhood size** of 3 uses a 3×3 matrix to evaluate local erosion in the binary image.) For details on **Erosion**, see [Section 14.2.7](#).

Dilate Neighborhood size—Pixel size of matrix used to define image dilation. E.g., a value of 3 uses a 3×3 matrix to evaluate local dilation in the binary image. If all values in a 3×3 neighborhood are off, no change is effected. If any one pixel is on, the center pixel is turned on and the result is written to the dilated image file. The larger the neighborhood size, the less “tolerant” the dilation process becomes. For details on **Dilation**, see [Section 14.2.7](#).

Num. pix. off for erode—Number of “off” pixels required in a square matrix of **Erode Neighborhood size** to apply erosion.

Num. pix. on for dilate—Number of “on” pixels required in a square matrix of **Dilate Neighborhood size** to apply dilation.

of Size Hist. bins—Number of histogram points used to plot particle size data (default is 420).

Note: As this parameter is reduced, histogram shape becomes coarser and particle sizes are clustered together into larger and larger (and fewer and fewer) data “bins” or “buckets,” with a correspondingly larger standard deviation.

Use Boundary grains—When selected, includes particles along the boundary of the cursor box. When deselected, includes only those grains which fall entirely within the boundary of the cursor box.

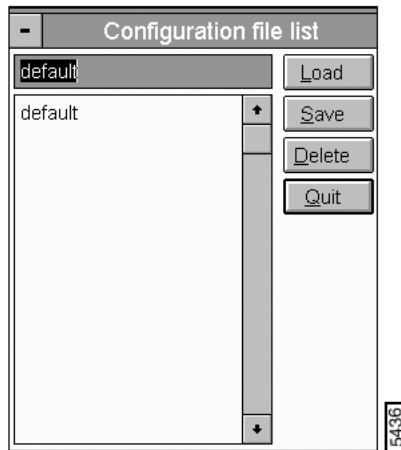
Reverse Thresholding—Selects sample areas *below* the height histogram, rather than above; this parameter should be selected when analyzing low-lying areas or depressions rather than particles.

Note: Another way to analyze depressions is to apply the **Off-line / Modify / Invert** command to the image first, then use **Particle Analysis** in the normal fashion.

14.2.7 Configuration File List

The **FILE** button in the **Configure** panel, opens the **Configuration file list menu** in [Figure 14.2f](#). The panel allows saved **Configure** files to be opened.

Figure 14.2f Configuration File List



Buttons on the Configuration File List Panel

Load—Loads the specified **Configure** file.

Save—Saves the current settings as a Particle Analysis Configure file (*.prt).

Delete—Deletes the specified Configure file (*.prt).

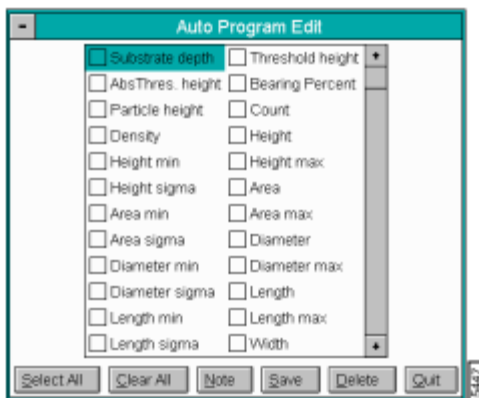
Quit—Exits the **Configuration file list** window.

14.2.8 Auto Program Edit Panel

Adds or deletes the **Particle Analysis** command from the currently selected **Auto Program** file. A panel listing measurements reported by the **Particle Analysis** command is displayed (See [Figure 14.2g](#)). Selecting a measurement stores it in the results file when Auto Program is run.

Note: Measurements not shown: **Width min**, **Width max**, and **Width sigma**.

Figure 14.2g Auto Program Edit Panel



Buttons on the Auto Program Edit Panel

Select All—Selects all the measurements simultaneously.

Clear All—Clears all the measurements simultaneously.

Note—Allows a descriptive message to be added to the display and the Auto Program Results file.

Save—Saves selected measurements to the Auto Program file. If the **Particle Analysis** command is already in the current Auto Program file, it retains its position in the file.

Note: An option exists to overwrite the command or add this as a second particle analysis command in the program.

Delete—Removes the **Particle Analysis** command from the Auto Program file.

Quit—Exits the **Auto Program Edit** mode without making changes to the Auto Program file.

Note: The **Auto Program File** command in the **Utility** menu must be used to select, or create, an Auto Program file. The **Auto** subcommand under the **Browse** command selects the files to be processed and executes the Auto Program file.

14.2.9 Particle Analysis Display Monitor

In addition to a menu bar and status bar, Particle **Analysis** displays a selected image, a Bearing Ratio Curve (Bearing area %) and Correlation (pixel height) histogram to execute particle analysis (See Figure 14.2h).

Figure 14.2h Particle Analysis Display

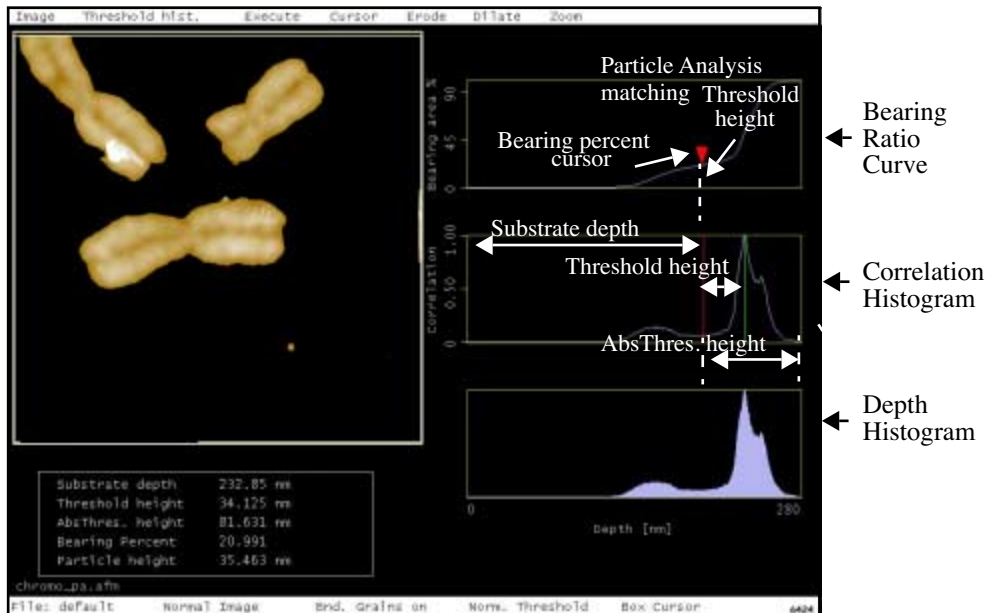


Figure 14.2h displays three histograms on the right side of the display screen. The top histogram is a Bearing area percent or Bearing Ratio curve showing the Bearing percent or data to be analyzed *above* this percent (e.g., for a Bearing percent = 20, the top 80% of data is included in the analysis).

The middle correlation histogram shows data in pixel height for measuring the substrate depth, threshold height and the absolute threshold height. This histogram has two sliders that determine the thresholds of particle size. In the normal, default mode (with **Reverse Thresholding** disabled) as the red slider is moved to the right, sample areas below the threshold are removed from the image (black), leaving only the raised area of the particles behind. This effect is reversed when **Reverse Thresholding** is enabled, blacking out image features *above* the threshold.

The green line in the height histogram determine the size of the gaussian distribution. A larger area within the box produces a more gaussian (bell-shaped) curve.

The bottom graph displays the depth histogram % for *read only* analysis.

Measurements Calculated in the Display Monitor

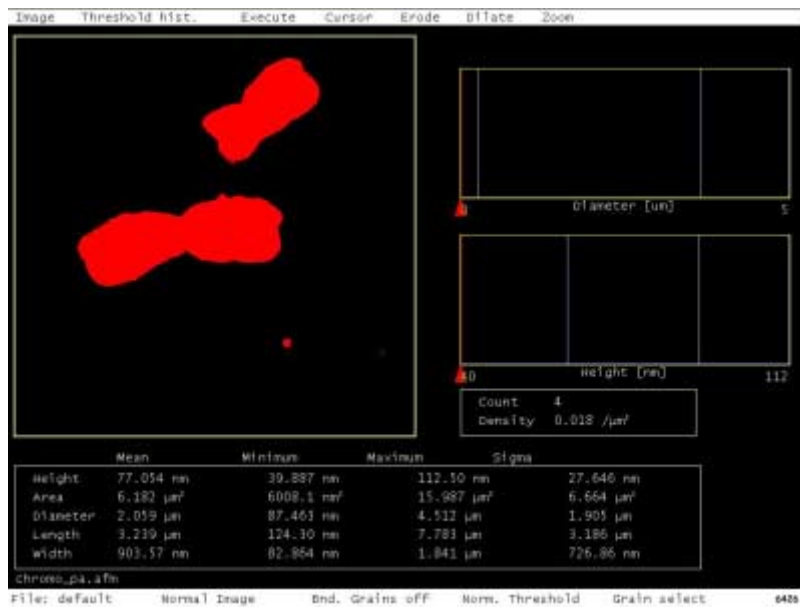
As the cursor highlights a specific particle (or group of particles), measurements for that particle are displayed at the bottom of the screen.

- **Substrate depth**—Distance between the the substrate peaks (green slider cursor) and the highest peak.
- **Threshold height**—Distance between the threshold (red cursor) and the substrate (green cursor) peaks.
- **Abs Thres. height**—Distance between the threshold (red cursor) and the lowest peak.
- **Bearing Percent**—Percent of data that has occurred above the depth indicated by the Bearing cursor.
- **Particle height**—Height of specific particles or group of particles for the cursor placements.

Display Monitor after Executing Particle Analysis

After selecting a group of particles to analyze, click **Execute** to calculate the Mean, minimum, maximum and sigma values of the isolated particles. A new screen appears that includes a menu bar, the selected particles, a Diameter histogram, a Height histogram and two data boxes (See Figure 14.2i).

Figure 14.2i Particle Analysis Image



Menu Bar Commands

Image

Switches the displayed image between either a **Binary** or **Normal** mode. In the **Binary** mode, grains are shown in white against a black background. In the **Normal** mode, grains are assigned their normal, color table hues against a black background. While adjusting the **Threshold histogram**, it is generally best to view the image in **Binary** mode to more easily differentiate particles.

Threshold hist[ogram]

Returns the display to the original Particle Analysis Display (See [Figure 14.2h](#)) where the threshold is set on the depth correlation histogram.

Execute

Initiates particle analysis and displays statistics for the particles defined by the height threshold on the height histogram. Red arrows below the diameter and height histograms default to most numerous particle type (See [Figure 14.2i](#)).

Cursor

Offers several different types of cursors applicable to the sample image.

- **Box**—Use for selecting rectangular regions of the image. When **Execute** is selected, only the region within the box is analyzed. The cross-hair cursor defines the center of the pattern.
- **Grain select**—Selects one specific particle from the analyzed region. The selected particle is highlighted in red, its dimensions are displayed in red characters, and its corresponding position on the diameter and height histograms indicated by a red arrow cursor.
- **Grain remove**—Removes selected grains from the image. This feature may be used to eliminate unwanted particles.
- **Grain accumulate**—Restricts analysis to selected particles. As more particles are chosen, their accumulated statistics are displayed.
- **Line**—Used to divide a particle in to 2 pieces. Two particles are created from the original “cut” particle.
- **Clear**—Removes all cursors from the image and recalculates the particle and the particle-size histogram.

Erode

Performs a digital erosion on the image (For definitions of erosion, see [Section 14.2.2](#)).

Dilate

Performs a digital dilation on the image (For definitions of dilation, see [Section 14.2.2](#)).

Zoom

Applies a “zoom-in” to the particle height histogram by rescaling its horizontal axis to display only plots included within a white box cursor. Unzoomed portions of the histogram are not displayed and their corresponding grains are removed from the image For details on using the **Zoom** command, see **Procedures for Using the Zoom Function**.

- **On**—Enables the **Zoom** command. A red zoom box cursor is displayed on the particle height histogram. To zoom a portion of the histogram, use the mouse to stretch and position the cursor box over the selected plots, then click on **Zoom / Zoom**.
- **Off**—Disables the **Zoom** command.

- **Zoom**—Applies the **Zoom** command to the portion of the histogram included within the white box cursor. Particles within the zoomed height box are highlighted in red and the statistical data reflects only the selected particles.
- **Full scale**—Restores the particle histogram to its original (“zoomed out”) form, with all particles showing on the plots.

Mouse operations on the Display Monitor:

Using the slider:

- 1st click, left button—Placing the cursor on the red, triangular slider and clicking the left mouse button frees the slider horizontally. The slider can then be dragged by rolling the mouse left and right.
- 2nd click, left button—Fixes the slider position on the histogram.

Within the image:

- 1st click, left button—Fixes one corner of a box cursor (or one end of a line cursor) and “rubberbands” to resize the box as the mouse is rolled. Also enables the various **Cursor** options.
- 2nd click, left button—Fixes the opposite corner of the box or end of the line cursor.

Procedures for Using the Zoom Function

Once an image has been analyzed using the **Particle Analysis** function, it is possible to isolate particles of a particular size range and compile statistics by using the **Zoom** function. In **Particle Analysis**, size zooming enables you to isolate particles of a specified size range. To use the **Zoom** function, do the following:

1. Load the image to be analyzed and execute the **Particle Analysis** function. The particle diameter and height histograms appear to the right of the image.
2. Click on the **Zoom / On** option. Two red, vertical lines are displayed on the histogram.
3. Use the mouse to move the red, vertical lines on the histogram. The lines should be set to either side of the particle size range to be zoomed. Simultaneously, the sample image highlights all particles falling within the zoomed size range. The data displayed in the box below the histogram changes, depending upon the width of the zoom.
If a single histogram plot is zoomed on, the *number of particles* (displayed as **Count** in the data box below the height histogram) is set to **1**; if seven histogram plots are zoomed on, the *count* is set to **7**, etc.

For images having a broad range of particle sizes, the **Zoom / Zoom** function expands the histogram scale for plots lying between the vertical, red cursors.

14.2.10 Procedure for Using Particle Analysis

The **Off-line/Analysis/Particle Analysis** function is designed to detect and measure the lateral and vertical dimensions of isolated particles on the sample surfaces. Generally, the procedure for using **Particle Analysis** is as follows:

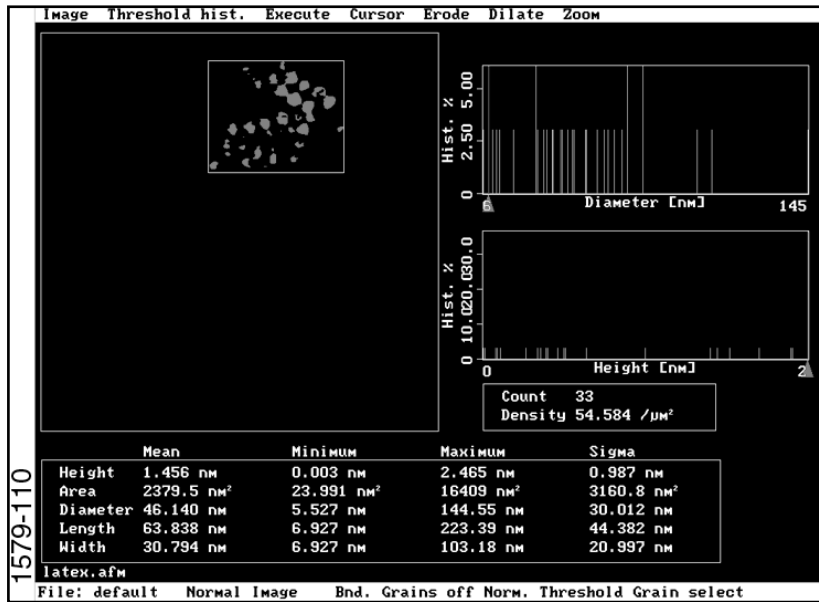
1. Load image.
2. Select area of interest in image by drawing a box cursor (**Cursor/Box**).
3. Define particle boundaries by sliding the red and green sliders in the correlation box. If the particles to be analyzed are low-lying areas of the image (e.g., pits), select the **Reverse Thresholding** command within the **Limits** window.
4. Click on **Execute** to perform particle analysis and generate data.
5. Use **Zoom** to isolate particles of a specific size. Use **Cursor/Grain Select**, **Grain Accumulate** or **Grain Remove** to manually isolate particles of interest and obtain data.
6. Separate conjoined particles using the **Cursor/Line** feature.

After particle analysis is executed, statistics are displayed below the histogram for each plot pointed to by the sliding cursor. If statistics are sought for more than one particle, use the **Zoom** command to specify the size range to be analyzed or use the **Grain Accumulate** function (Analyze menu/Grain Size)

In the image below, a white box cursor has been drawn with the mouse to define the area of interest. **Particle Analysis** is performed by clicking on **Execute**. The diameter and height histograms of the various particles are displayed to the right of the image, and various statistics such as average height are displayed at the bottom of the screen.

By sliding the cursor laterally along the bottom of the histogram, you can highlight each particle plotted. If the **Cursor/Select Grain** option is selected, the mouse may be used to select specific grains from the image; the histogram slider automatically goes to the corresponding plot. Data for each particle is displayed in [Figure 14.2j](#).

Figure 14.2j Example of Particle Data Display



14.2.11 Interpreting Particle Analysis Data

	Mean	Minimum	Maximum	Sigma
Height	Average height of all particles in data set	Minimum height of all particles in data set	Maximum height of all particles in data set	Standard deviation of height of all particles in data set
Area	Average area of all particles in data set	Minimum area of all particles in data set	Maximum area of all particles in data set	Standard deviation of area of all particles in data set
Diameter	Average diameter of all particles in data set	Minimum diameter of all particles in data set	Maximum diameter of all particles in data set	Standard deviation of diameter of all particles in data set
Length *	Average length of all particles in data set	Minimum length of all particles in data set	Maximum length of all particles in data set	Standard deviation of length of all particles in data set
Width **	Average width of all particles in data set	Minimum width of all particles in data set	Maximum width of all particles in data set	Standard deviation of width of all particles in data set

* Length = the longest axis in a particle.

** Width = the perpendicular bisector to the length.

14.3 Pattern Recognition

Analysis Commands (M-Z) conditions between samples and repeatability errors on stage microscopes, no **Pattern Recognition** images ever appear exactly the same. The **Pattern Recognition** command is able to adjust itself to find patterns wherever they appear within an image.

You can specify a maximum allowable X-Y shift between one image and another, and the software indicates when patterns have shifted a distance greater than this acceptable distance. This shift amount is specified using the **Max Allowable** parameters on the **AFM Pattern Recognition** panel.

After the software locates the pattern and detects that the shift exceeds **Max Allowable** parameters, the actual shift is limited to the **Max Allowable** value in either X, Y, or both.

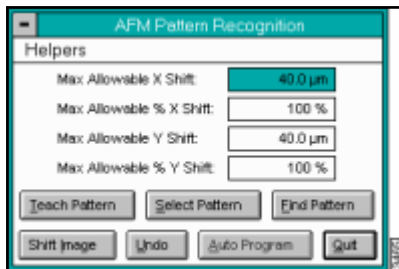
Refer to the following **Pattern Recognition** sections:

- **Pattern Recognition Panel** [Section 14.3.1](#)
- **Parameters in the Pattern Recognition Panel** [Section 14.3.2](#)
- **Buttons in the Pattern Recognition Panel** [Section 14.3.3](#)
- **Helpers Drop-Down Menu** [Section 14.3.4](#)

14.3.1 Pattern Recognition Panel

The **AFM Pattern Recognition** panel appears on the Control Monitor to adjust the X-Y shift between one image and another in locating patterns. The panel includes buttons to teach patterns, manually shift locating within the image, undo changes and add these functions to an Auto Program file.

Figure 14.3a AFM Pattern Recognition Panel



14.3.2 Parameters in the Pattern Recognition Panel

Max Allowable X Shift

This parameter sets the maximum amount of shift on the X axis that is acceptable for locating a model from image to image. It is specified in microns.

Changes to the **Max Allowable % X Shift** parameter (described below) automatically adjust this parameter.

Max Allowable % X Shift

This parameter defines the maximum acceptable X axis shift for locating a model from image to image as a percentage of the **Scan size** (displayed in the **Scan Controls** panel on the control monitor). For instance, an image with a **Scan size** of **10 μm** and a **Max Allowable % X Shift** value of **25%** would be acceptable if the image shift did not exceed 2.5 microns.

Changes to the **Max Allowable X Shift** parameter (described above) automatically adjust this parameter.

Max Allowable Y Shift

This parameter sets the maximum amount of shift on the Y axis that is acceptable for locating a model from image to image. It is specified in microns.

Changes to the **Max Allowable % Y Shift** parameter (described below) automatically adjust this parameter.

Max Allowable % Y Shift

This parameter defines the maximum acceptable Y axis shift for locating a model from image to image as a percentage of the **Scan size** (displayed in the **Scan Controls** panel on the control monitor). For instance, an image with a **Scan size** of **10 μm** and a **Max Allowable % Y Shift** value of **25%** would be acceptable if the image shift did not exceed 2.5 microns.

Changes to the **Max Allowable Y Shift** parameter (described above) automatically adjust this parameter.

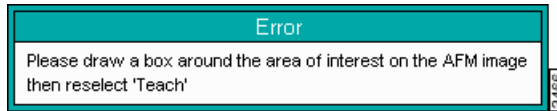
14.3.3 Buttons in the Pattern Recognition Panel

Teach Pattern

If the pattern you wish to locate has not been taught, draw a box around the desired feature, then select the **TEACH PATTERN** button.

An **Error** prompt appears asking you to specify the area of interest on the image if you select the **TEACH PATTERN** button before drawing the box (See [Figure 14.3b](#)).

Figure 14.3b Teach Pattern Alert Box



Troubleshooting Teach Pattern:

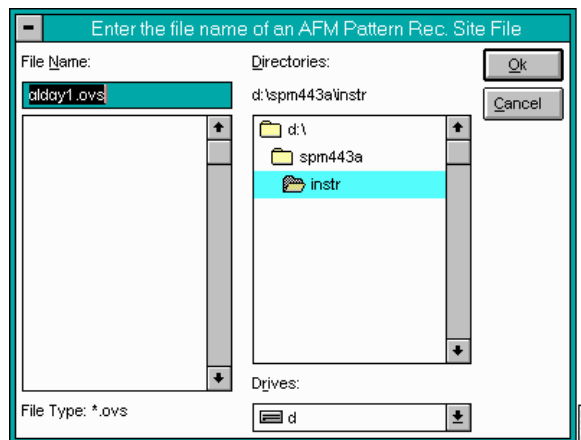
1. Use the mouse to draw a box around the feature to be used as the pattern. The cursor box should encompass the specific feature of interest.
2. After locating the pattern and sizing the box appropriately, click again on the **TEACH PATTERN** button.
3. Return to the **AFM Pattern Recognition** panel (See [Figure 14.3a](#)).

Select Pattern

If the pattern you wish to locate has already been taught, click on the **SELECT PATTERN** button to find it and other patterns that have previously been taught. The control monitor displays a listing of all saved pattern files (See [Figure 14.3c](#)).

Note: Pattern Recognition files have an *.ovs (Off-line Vision Site) file extension.

Figure 14.3c Pattern Recognition Site File Panel

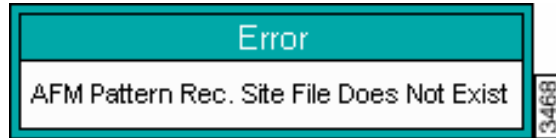


Find Pattern

After designating the pattern you wish to find (using **SELECT PATTERN**, above), click on the **FIND PATTERN** button to locate it in the image. A cursor box identifies it in the currently loaded image.

You may find it necessary to use the **SHIFT IMAGE** button to make minor adjustments to the image center (See [“Shift Image”](#) on [page 14-343](#)).

Figure 14.3d Unidentified Pattern Error Box



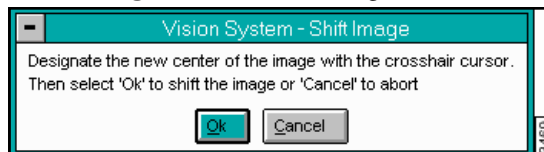
If the recognition system does not find the pattern, but you are sure it is within the image, check for the following conditions:

- The pattern may provide a poor visual model because of bad definition or contrast. Patterns must have a distinct, local appearance while remaining relatively simple. Remember, a plain square or cross is a better pattern than a complex curvilinear pattern. The pattern is rejected if the model does not satisfy the **Accept Threshold** parameter located in the **Advanced Features** found on the **Helpers** menu of the **AFM Pattern Recognition** panel (See **Advanced Features**).
- The sample may be rotated so that its pattern presents an unrecognizable model to the vision system. Be sure that samples are loaded each time with the same angular orientation. Autoloaded samples rarely have this problem, but manually loaded samples can be loaded at any angle. The use of registration pins or a stage jig on manually loaded stages helps maintain consistent angular orientation.

Shift Image

Use the **SHIFT IMAGE** button to make minor adjustments to the image's center if it has been captured away from an ideal center point for your pattern. When you select the **SHIFT IMAGE** button, an instruction panel appears (See [Figure 14.3e](#)).

Figure 14.3e Shift Image Panel



Use the mouse to move the crosshair cursor to the desired image center, then click on **Ok**. The captured image is shifted on the Display Monitor to place the new image center point at the center of the scan's field of view.

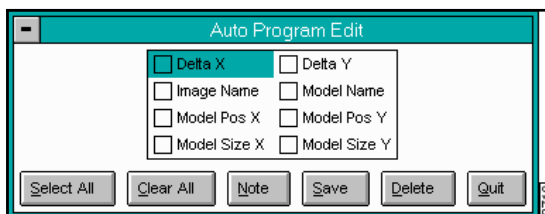
Undo

The **Undo** button restores the currently loaded image to its saved version. The image is cleared of any cursors and returned to its unshifted position (if you have used the **SHIFT IMAGE** command or the image was shifted during execution of **FIND PATTERN**).

Auto Program

The **Auto Program** command appends the pattern recognition routine to the list of automatic routines performed on captured images. When the button is selected, the **Auto Program Edit** panel (See [Figure 14.3f](#)) appears.

Figure 14.3f Auto Program Edit Panel

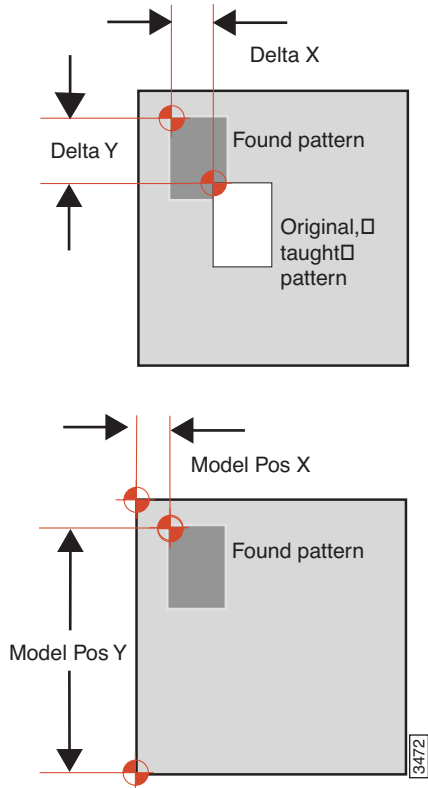


This panel can also be used to update the current Auto Program. If, after you click the **SAVE** button, the software finds an Auto Program step, you are asked if you want to update it. If not, the software appends the routine.

The **Auto Program Edit** panel contains several parameters that may be written to the auto result file during **Auto Program** execution. Click on the box next to each of the parameters you want written to the results file.

The **Auto Program Edit** parameters are illustrated in [Figure 14.3g](#).

Figure 14.3g Auto Program Edit Parameters



- **Delta X**—The distance (μm) along the X axis over which the found pattern has shifted from the location of the original, taught pattern.
- **Delta Y**—The distance (μm) along the Y axis over which the found pattern has shifted from the location of the original, taught pattern.
- **Image Name**—The name of the image used to teach the pattern recognition step in the Auto Program.
- **Model Name**—The filename of the model.
- **Model Pos X**—The X axis location of the pattern relative to the left side of the image.
- **Model Pos Y**—The Y axis location of the pattern relative to the bottom of the image.
- **Model Size X**—Width (X-axis dimension) of the model.
- **Model Size Y**—Height (Y-axis dimension) of the model.

Buttons on the Auto Program Edit Panel

Select All—Selects all parameters on the panel.

Clear All—Deselects all parameters on the panel.

Note—Allows you to make notations to the file.

Save—Saves the pattern recognition data to the Auto Program file.

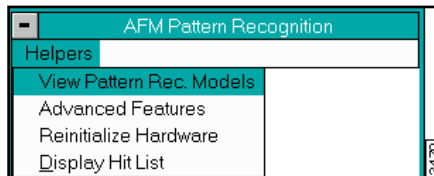
Delete—Deletes the pattern recognition data from the Auto Program file.

Quit—Exits the **Auto Program Edit** panel.

14.3.4 Helpers Drop-Down Menu

The **Helpers** drop-down menu (See [Figure 14.3h](#)) on the **AFM Pattern Recognition** panel provides access to functions that configure and modify the pattern recognition process.

Figure 14.3h Helpers Menu on Pattern Recognition Panel



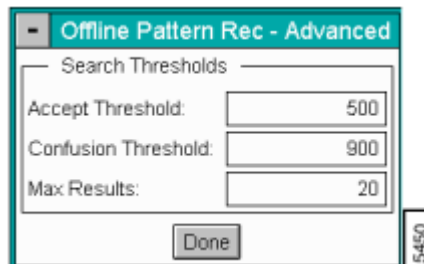
View Pattern Recognition Models

Loads a previously taught video model and displays it on the video monitor.

Advanced Features

The **Off-line Pattern Rec - Advanced** panel (See [Figure 14.3i](#)) enables you to change threshold parameters.

Figure 14.3i Off-line Pattern Rec - Advanced Panel



Display Hit List

A list of X-Y coordinate positions at which the pattern was found in the image the last time **Find Pattern** was run.

14.4 Power Spectral Density

The Power Spectral Density (PSD) function is useful in analyzing surface roughness. This function provides a representation of the amplitude of a surface's roughness as a function of the spatial frequency of the roughness. Spatial frequency is the inverse of the inplane spatial wavelength of the roughness features.

The PSD function reveals periodic surface features that might otherwise appear "random" and provides a graphic representation of how such features are distributed. On turned surfaces, this is helpful in determining speed and feed data, sources of noise, etc. On ground surfaces, this may reveal some inherent characteristic of the material itself such as grain or fibrousness. At higher magnifications, PSD is also useful for determining atomic periodicity or lattice.

Refer to the following Power Spectral Density sections:

- **NanoScope PSD Measurements** [Section 14.4.1](#)
- **PSD and Surface Features** [Section 14.4.2](#)
- **PSD and Flatness** [Section 14.4.3](#)
- **Power Spectral Density Panel** [Section 14.4.4](#)
- **Parameters in the Spectral Density Panel** [Section 14.4.5](#)
- **Buttons on the Spectral Density Panel** [Section 14.4.6](#)
- **Power Spectral Density Display Monitor** [Section 14.4.7](#)

14.4.1 NanoScope PSD Measurements

The **Power Spectral Density** function computes the following information for the image:

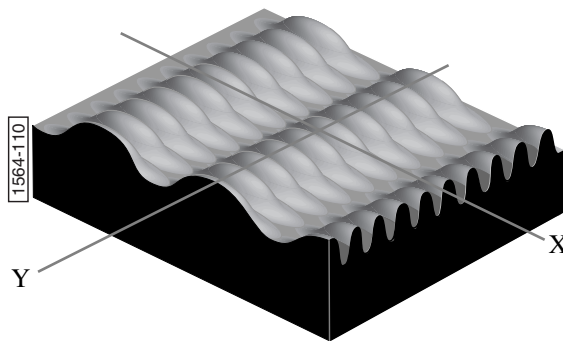
- **Total power spectrum** - Power is roughness amplitude squared, so power is in units of length squared. Power spectrum is a plot of power as a function of spatial wavelength or frequency.
- **1D PSD** - A one dimensional power spectral density. Power spectral density is a plot of the density, in spatial frequency space, of the power spectrum. Its units are length squared divided by a one dimensional frequency, or 1 over length, which is length cubed. A 1D PSD can be calculated in either the X direction of the data or in the Y direction.
- **1D isotropic PSD** - A different version of a one dimensional power spectrum.
- **2D isotropic PSD** - A two dimensional power spectral density. Its units are length squared divided by a two dimensional frequency, or 1 over length squared, which is length to the fourth power. This is isotropic in the sense that it is an average taken over all directions in the data.

- **RMS roughness values** - Since the RMS roughness is the square root of the integral of the PSD, over some wavelength or frequency interval, this calculation can be conveniently done when one has the PSD.

14.4.2 PSD and Surface Features

Consider the image in [Figure 14.4a](#).

Figure 14.4a Waveform Surfaces



This synthetic surface consists of essentially two dominant wave forms: a long period waveform along the X-axis, and a shorter period waveform along the Y-axis. A 2 dimensional power spectral density plot consists of two dominant spikes (one for each dominant wavelength), plus some number of extra wavelengths inherent within the image. (These extra wavelengths may appear due to fine surface features and/or side bands of the dominant wave forms.) Because of the sinusoidal nature of the composite wave form, a relatively small set of spectral frequencies suffices to describe the entire surface. By contrast, an image comprised of angular (saw-toothed or square) waveform contains more spatial frequency components.

Over a given range of spatial frequencies the total power of the surface equals the RMS roughness of the sample squared.

The frequency distribution for a digitized profile of length L , consisting of N points sampled at intervals of d_0 is approximated by:

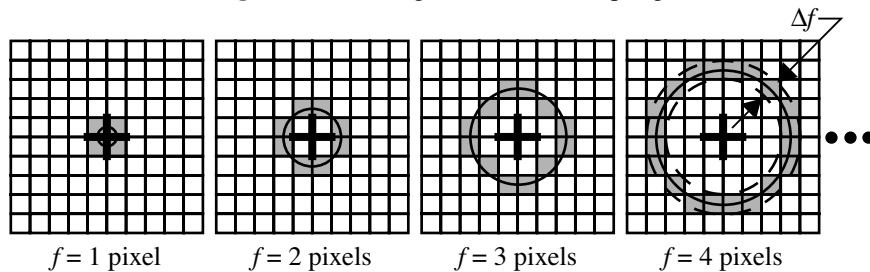
$$\text{PSD}(f) = \frac{2d_0}{N} \left| \sum_{n=1}^N e^{i \frac{2\pi}{N}(n-1)(m-1)} z(n) \right|^2 \quad \text{for } f = \frac{m-1}{Nd_0}$$

Where $i = \sqrt{-1}$, and frequencies, f , range from $\frac{1}{L}$ to $\frac{N/2}{L}$. Practically speaking, the algorithm used to obtain the PSD depends upon squaring the FFT of the image to derive the power. Once the power, P , is obtained, it may be used to derive various PSD-like values as follows:

$$\begin{aligned} \text{1D PSD} &= \frac{P}{\Delta f} \\ \text{1D isotropic PSD} &= \frac{P}{2\pi f} \\ \text{2D isotropic PSD} &= \frac{P}{2\pi f(\Delta f)} \end{aligned}$$

The terms used in the denominators above are derived by progressively sampling data from the image's two-dimensional FFT center (See [Figure 14.4b](#)).

Figure 14.4b Progressive Data Sampling



Each sampling swings a “data bucket” of given frequency f . Since samples are taken from the image center, the sampling frequency, f , is limited to $\frac{N/2}{L}$, where N is the scan size in pixels. This forms the upper bandwidth limit (i.e., the highest frequency) of the PSD plot. The lower bandwidth limit is defined at $1/L$.

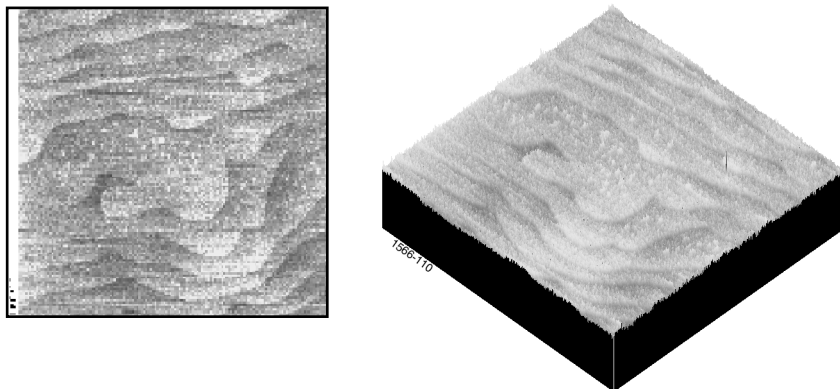
14.4.3 PSD and Flatness

PSD is used increasingly as a metrology tool for evaluating extremely flat surfaces, such as polished or epitaxial silicon. Generally, the desired surface is expected to adhere to certain PSD thresholds, signifying it meets a specified flatness criterion.

The main advantage gained over traditional RMS specifications is that PSD flatness is qualified through the full spectral range of interest. For example, one may specify spectral thresholds at frequencies measured on the atomic scale, thus ensuring surfaces consist largely of uniform lattices. Setting the precise thresholds for various materials remains a matter of debate.

Consider the image of epitaxial gallium arsenide in [Figure 14.4c](#) (See file “**gaas.epi**” on the images disk).

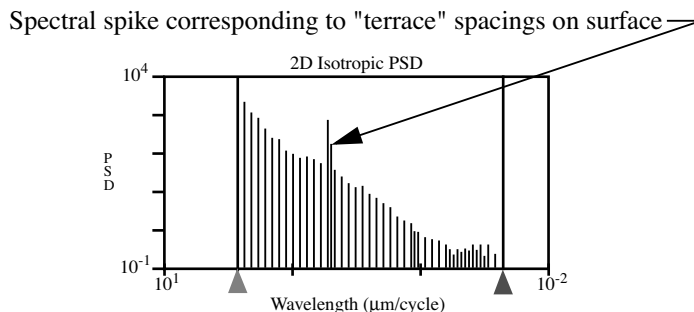
Figure 14.4c Epitaxial Gallium Arsenide Image



This surface is comprised of “terraces” formed from the material’s natural lattice structure; each terrace is one atomic monolayer thick and is spaced at fairly regular intervals. This degree of flatness is handily evaluated with PSD, as the terraces produces a spectral spike corresponding to their spacing wavelength.

A PSD plot for this type of surface generally takes the form shown in [Figure 14.4d](#).

Figure 14.4d PSD Plot for Terraced Sample

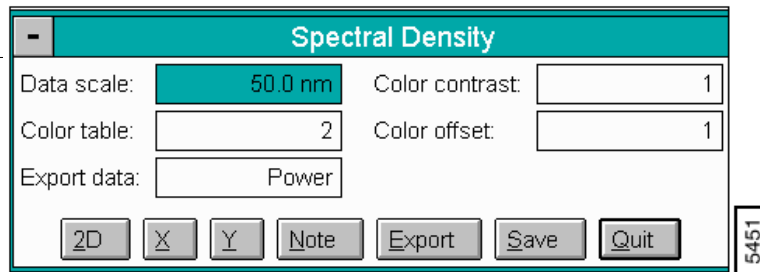


This tapered PSD plot is characteristic of flat, isotropic surfaces. Longer wavelengths are present up to the scan width, and are accompanied by uniformly decreasing powers of shorter wavelengths down to 2 pixels. On the plot shown above a spike stands out, corresponding to the wavelength spacing of the terraced features. Depending upon the qualitative standards of the person evaluating such a plot, this spike may exceed a threshold standard of flatness.

14.4.4 Power Spectral Density Panel

The **Spectral Density** panel allows items on the Display Monitor to be adjusted to your preferences.

Figure 14.4e Spectral Density Panel



14.4.5 Parameters in the Spectral Density Panel

Data Scale

Controls the vertical range of the image corresponding to the full extent of the color table.

Color Table

Selects the color table used to encode Z information.

Export Data

Sets the type of data to be exported from the display screen parameters. Data is exported in a spreadsheet format readable by most third-party applications. Generally, data is exported in two-column x N/2 rows, where N equals the scan size in pixels. Each row is separated by a carriage return; columns are separated with a space.

Range and Settings:

- **Power, 1D PSD, 1D iso PSD, 2D iso PSD**

Color Contrast

Controls the contrast in the image by compressing or expanding the color table.

Color Offset

Changes the image color by shifting the range of the color table used to display the image.

14.4.6 Buttons on the Spectral Density Panel

2D—Executes a two-dimensional Power Spectral Density analysis.

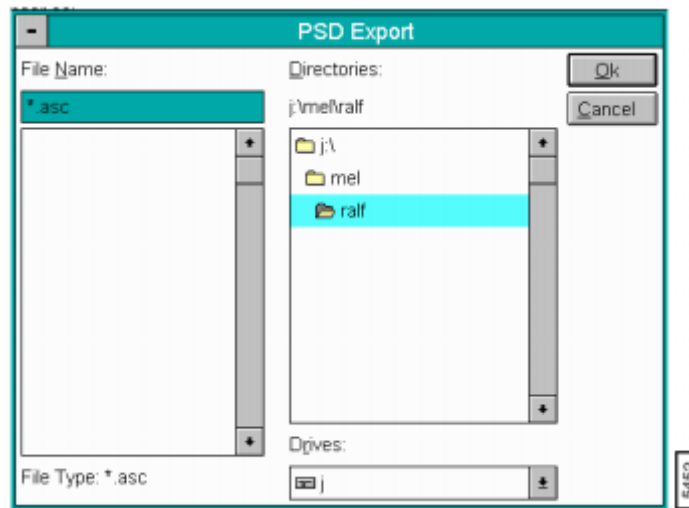
X—Executes a one-dimensional Power Spectral Density analysis along the X-axis.

Y—Executes a one-dimensional **Power Spectral Density** analysis along the Y-axis.

Note—Allows a descriptive message to be added to the display.

Export—Saves current PSD data to a directory and file name you define (See [Figure 14.4f](#)).

Figure 14.4f Power Spectral Density Export Panel



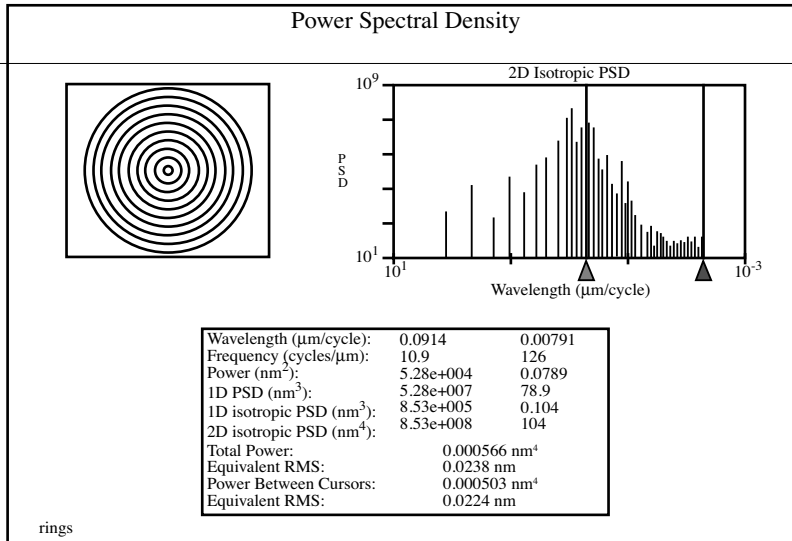
Save—Saves current PSD analysis to a directory and file you specify.

Note: The **PSD Compare** function may only be performed on PSD data files that have been saved to a common directory.

Quit—Exits the Power Spectral Density function.

14.4.7 Power Spectral Density Display Monitor

The Display Monitor generates a histogram of wavelength versus power. Both wavelength and power are indicated on logarithmic scales (See [Figure 14.4g](#)).

Figure 14.4g Power Spectral Density Display

The calculation begins as soon as the command is selected from the menu. The PSD and a table of values from the graph are shown on the Display Monitor.

Display Table Parameters

- **Wavelength**—The wavelength in $\mu\text{m}/\text{cycle}$ units at current cursor positions.
- **Frequency**—The frequency in cycles per μm at current cursor positions.
- **Power**—Power measured in nm^2 at current cursor positions.
- **1D PSD**—One-dimensional power spectral density. (See [Section 14.4.2](#) for mathematical definition.) Power measured in nm^3 at current cursor positions.
- **1D isotropic PSD**—One-dimensional, isotropic power spectral density. (See [Section 14.4.2](#) for mathematical definition.) Power measured in nm^3 at current cursor positions.
- **2D isotropic PSD**—Two-dimensional, isotropic power spectral density. (See [Section 14.4.2](#) for mathematical definition.) Power measured in nm^4 at current cursor positions.

Note: The **2D isotropic PSD** is the power function that is plotted on the Display Monitor histogram.

- **Total power**—The sum of the power contained in the entire spectrum.
- **Equivalent RMS**—The root-mean-square (RMS) roughness of the sample. It is calculated as the square root of the total power.
$$\text{RMS} = \sqrt{\int W(p,q) \delta p \delta q}$$
- **Power Between Cursors**—The sum of the power contained in the portion of the spectrum between the cursors.
- **Equivalent RMS**—The root-mean-square (RMS) roughness of the sample contributed by the frequencies between the cursors. It is calculated as the square root of the integral of the **Power Between Cursors** (above).

Plot

Specifies the vertical axis of the PSD plot.

- **Power**—Power (nm² units) is plotted against wavelength.
- **1D PSD**—One-dimensional power (nm³ units) is plotted against wavelength.
- **1D ISO**—One-dimensional, isotropic power (nm³ units) is plotted against wavelength.
- **2D ISO**—Two-dimensional, isotropic power (nm⁴ units) is plotted against wavelength.

Mouse operations on the Display Monitor

The cursors in the power spectrum can be moved by clicking on a cursor and dragging the mouse.

Note: The ASTM E-42.14 STM/AFM Subcommittee report on “Standard Practices for Analyzing and Reporting Surface Roughness as Measured by STM/AFM” describes the basic method for quantifying the surface roughness of materials imaged by STM and AFM.

14.5 PSD Compare

The **PSD Compare** command permits one-to-one comparison between PSD data files (as saved from the **Analyze/Power Spectral Density** command). The power spectral density plot for each compared file is presented on a graph so that overlapping power data may be directly compared; PSD data is displayed in a table below. Plots are displayed and compared for: power, 1-dimensional PSD, 1-dimensional isotropic, or 2-dimensional isotropic data.

To utilize **PSD Compare**, it is necessary to collect all PSD files in a common directory and transfer to that directory beforehand. When the **PSD Compare** command is accessed, the software searches

the current directory for PSD files. If none are found, an error message (“**Warning: Directory has no files with .psd extension**”) displays.

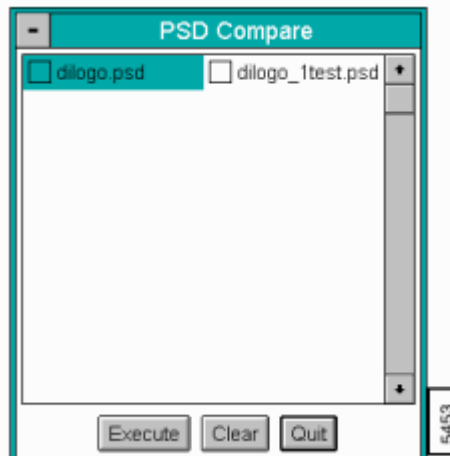
Refer to the following PSD Compare sections:

- **PSD Compare Panel** [Section 14.5.1](#)
- **Buttons on the PSD Compare Panel** [Section 14.5.2](#)
- **PSD Compare Display Monitor** [Section 14.5.3](#)
- **Reference Data** [Section 14.5.4](#)

14.5.1 PSD Compare Panel

Clicking on the **Analyze / PSD Compare** command displays the **PSD Compare** panel (See [Figure 14.5a](#)).

Figure 14.5a Power Spectral Density Compare Panel



All saved PSD data files are listed for the current directory and feature a “.psd” extension. To change directories, use the Off-line file manager panel. To select files for comparison, click on the box to the left of each file; an “X” indicates that the file is to be compared. Up to six PSD data files may be selected and compared at one time.

14.5.2 Buttons on the PSD Compare Panel

Execute—Plots the selected data (where an “X” has been placed) to the Display Monitor histogram and displays each data set’s PSD information.

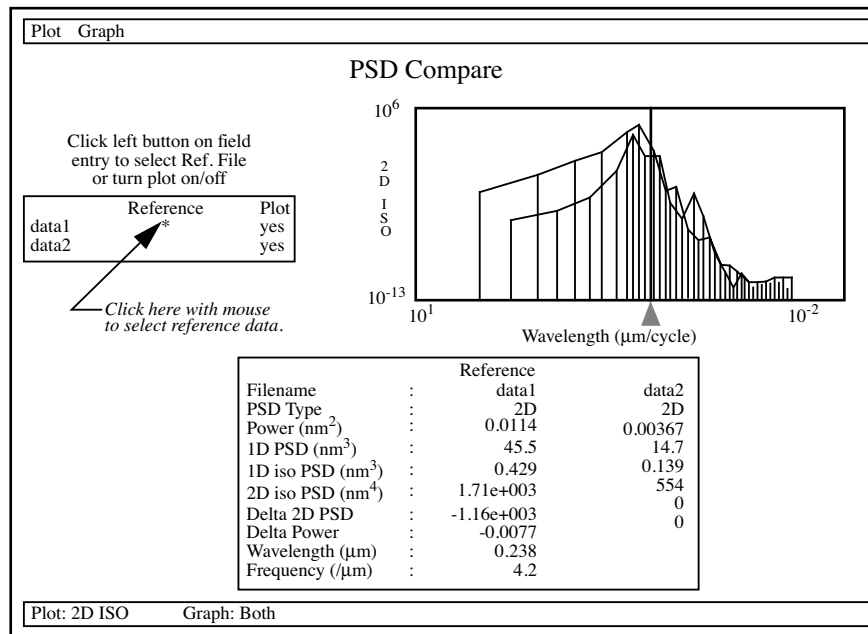
Clear—Deselects all previously selected files (removes all “X”s).

Quit—Quits **PSD Compare** command.

14.5.3 PSD Compare Display Monitor

On the Display Monitor, the selected files are plotted relative to one another. If the PSD data is similar between files, plots may be overlapping.

Figure 14.5b PSD Compare Display



Sliding the line cursor back and forth on the plot histogram displays new data for each point. Where a plot has no data, the value reads “NA” (not available).

Display Monitor Commands

Plot

Commands listed here present different types of data histograms on the Display Monitor. Choices are outlined below.

- **Power**—Total PSD power data is plotted.
- **1D PSD**—One-dimensional PSD data is plotted.
- **1D ISO**—One-dimensional isotropic PSD data is plotted.
- **2D ISO**—Two-dimensional isotropic PSD data is plotted.

Graph

Commands listed here determine the manner in which data is plotted to the histogram. Choices are outlined below.

- **Curves**—Plots data as a series of curves.
- **Lines**—Plots data as a series of lines (bar graph).
- **Both**—Plots data with both curves and lines simultaneously.

14.5.4 Reference Data

Clicking on the **Reference** column in the upper-left corner of the Display Monitor allows a file to be designated as the reference data set. An asterisk (*) is placed alongside the selected file name and `REFERENCE` is displayed above the data column. Each data set is also assigned a separate color to assist in organization. Two values are generated from the reference data:

- **Delta 2D PSD**—Difference in two-dimensional PSD value between reference data and selected data.
- **Delta Power**—Difference in total power between reference data and selected data.

14.6 Roughness



The **Roughness** command generates a wide variety of statistics for surfaces, including classical roughness values, peak and summit (texture) data and surface area calculations. “Image” statistics are reported for the entire image. “Box” statistics are reported only for the region you define within a cursor box. In addition, the area included within a box cursor can be augmented with passbands and stopbands to isolate specific features.

Most industrial standards for roughness measurement call for plane-fitting of data *before* values are calculated. Digital Instruments’ **Roughness** routine applies a temporary, first-order plane-fit before calculating roughness statistics. On many surfaces, especially those which are tilted, this yields different values from those seen in raw (unplane-fitted) data. Moreover, peripheral features included within the analyzed region may produce cumulative results uncharacteristic of the feature(s) of interest. To ensure the best results, you should observe the following rules when using **Roughness** analysis:

- If the image shows signs of second- or third-order distortion (e.g., bow due to large scans areas on large scanners), apply a second- or third-order **Flatten (Off-line/Modify/Flatten)** and **Plane-fit (Off-line/Modify/Plane-fit)** to the image *before* using **Roughness** analysis.
- Isolate your analysis to specific areas of the image. This may be accomplished by using **Off-line / Modify / Zoom** to limit the entire image, or by using the box cursor in **Roughness** to analyze only select portions of the image.

For further details on the Roughness panels and parameters, refer to the following sections:

- **Roughness Parameters** [Section 14.6.1](#)
- **Navigating Control Panels in Roughness Analysis** [Section 14.6.2](#)
- **Roughness Panel** [Section 14.6.3](#)
- **Auto Program Edit Panel** [Section 14.6.4](#)
- **Screen Layout Panel** [Section 14.6.5](#)
- **Roughness Display Monitor** [Section 14.6.6](#)
- **Troubleshooting the Roughness Function** [Section 14.6.7](#)
- **Roughness Data Definitions** [Section 14.6.8](#)
- **Example of Using Roughness Analysis** [Section 14.6.9](#)

14.6.1 Roughness Parameters

There are currently forty-five parameters available from the **Roughness** routine; however, only parameters selected from the **Screen Layout** menu are actually displayed and reported. In addition,

some parameters are reported only when certain subroutines are turned on from the command bar of the Display Monitor. For example, **Surface area** is displayed only when it has been selected from the **Screen Layout** panel AND the “Surface Area” subroutine is turned **On**.

[Table 14.6a](#) lists all parameters available within the **Roughness** routine, along with subroutines required (if any) to be turned **On** for their display.

To display a parameter, select it from the **Screen Layout** panel first, then turn **On** the required subroutine.

Note: Only 21 parameters can be selected on at one time. If the box gets too big, the image statistics after 21 do not display.

Refer to [Section 14.6.8](#) for **Roughness** parameter definitions.

Table 14.6a Roughness Parameters

Parameter	Required Subroutine		
	“Peak”	“Surface Area”	“Summit”
10 pt mean (Rz)			
Area Thresh abs		X	
Area Thresh ref		X	
Area Thresh (%rms)		X	
Av max depth (Rvm)	X		
Av max ht (Rpm)	X		
Box x dimension			
Box y dimension			
Img. Mean			
Img. Ra			
Img. Raw mean			
Img. Rmax			
Img. RMS (Rq)			
Img. Srf. area			
Img. Srf. area diff			
Img. Z range			
Kurtosis			
Line density			
Max depth (Rv)	X		
Max height (Rmax)			
Max peak ht (Rp)	X		
Mean			
Mean roughness (Ra)			
Peak count	X		
Peak Threshold	X		

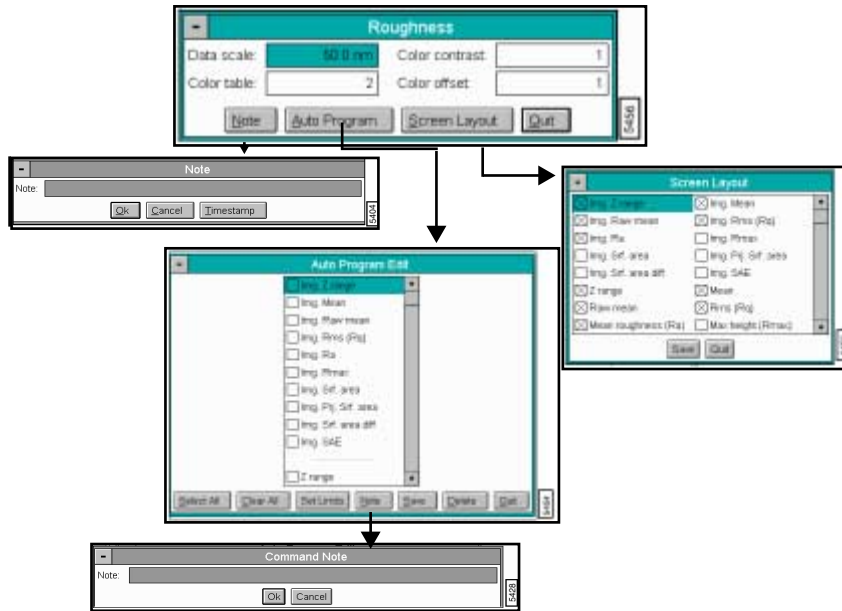
Table 14.6a Roughness Parameters

Parameter	Required Subroutine		
	“Peak”	“Surface Area”	“Summit”
Peak Thresh ref	X		
Peak Thresh (%rms)	X		
Raw mean			
RMS (Rq)			
Skewness			
Summit count			X
Summit curvature			X
Summit Cutoff			X
Summit Cutoff ref			X
Summit Cutoff (%rms)			X
Summit density			X
Summit diameter			X
Summit Threshold			X
Summit Thresh ref			X
Summit Thresh (%rms)			X
Summit rad. curv.			X
Summit slope			X
Surface area		X	
Surface area diff		X	
Z range			

14.6.2 Navigating Control Panels in Roughness Analysis

Off-line/Analyze/Roughness accesses the **Roughness** panel. After selecting the captured image, you can configure and program commands that allow for specific **Roughness Analysis**. For an overview of the navigational path in this analysis, see [Figure 14.6a](#).

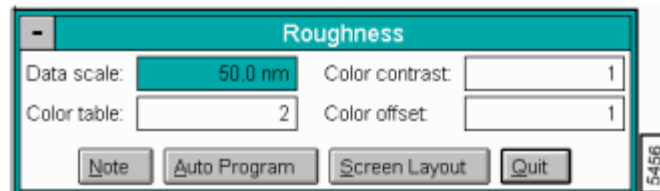
Figure 14.6a Navigating in Roughness Analysis



14.6.3 Roughness Panel

The Roughness panel includes familiar display parameters and buttons to control the image display and set parameters (See [Figure 14.6b](#)).

Figure 14.6b Roughness Panel.



Parameters in the Roughness Panel

Data Scale

Controls the vertical range of the image corresponding to the full extent of the color table. This is the difference between the highest and lowest points within the image.

The units of this item vary according to the type of image (e.g., nm, nA, etc.).

Note: This value does not correct for tilt in the plane of the data; therefore, plane fitting or flattening the data changes the data while the data scale remains the same value.

Color Table

Selects the color table used to encode the image (e.g., Z information).

Color Contrast

Controls the contrast in the image by compressing or expanding the color table.

Color Offset

Shifts the color table used to display the image.

Buttons in the Roughness Panel

Note—Appends a descriptive message to the image file and the bottom of the displayed image.

Auto Program—Accesses the **Auto Program Edit** panel and allows **Roughness** parameters to be selected and stored in the Auto Program file list. For details on the **Auto Program Edit** panel, see [Section 14.6.4](#).

Screen Layout—Accesses the **Screen Layout** panel and allows you to select the **Roughness** parameters to display. For details on the **Screen Layout** panel, see [Section 14.6.5](#).

Quit—Exits the Roughness command.

14.6.4 Auto Program Edit Panel

The **Auto Program Edit** panel allows **Roughness** parameters to be selected and stored in the Auto Program file list. When the Auto Program file is run, the selected **Roughness** parameters are computed and listed in a report file along with any other functions selected (See [Figure 14.6c](#)).

Figure 14.6c Auto Program Edit Panel



Note: Select up to 21 parameters to be added to the output result file.

Buttons in the Auto Program Edit Panel

Select All—Selects all the measurements simultaneously.

Clear All—Clears all the measurements simultaneously.

Set Limits—Sets specific measurement limits for an AutoProgram result. You may specify the **Min**, **Max**, and **% of Section** values for each result available in the **Set Limits** window.

Note—Allows a descriptive message to be added to the display and the Auto Program Results file.

Save—Saves selected measurements to the Auto Program file. If the **Roughness Analysis** command is already in the current Auto Program file, it retains its position in the file.

An option exists to overwrite the command or add this as a second particle analysis command in the program.

Delete—Removes the **Roughness** command from the **Auto Program** file.

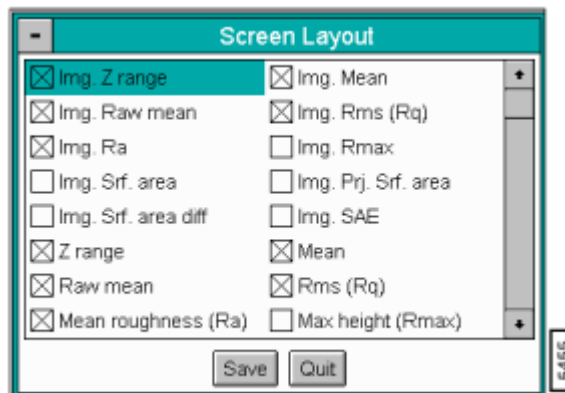
Quit—Exits the **Auto Program Edit** mode without making changes to the Auto Program file.

Note: The **Auto Program File** command in the Off-line/ **Utility** menu must be used to create and edit Auto Program files. The **Auto** subcommand under the **Browse** command selects the currently selected files to be processed and executes the Auto Program file (Utility menu/Auto Program File).

14.6.5 Screen Layout Panel

The **Screen Layout** panel allows you to select which **Roughness** parameters display. Because of the limited size of the Display Monitor, it shows a maximum of twenty-one parameters at any one time; however, the current Auto Program files still contains all selected parameters.

Figure 14.6d Screen Layout Panel



Buttons and Parameters on the Screen Layout Panel

To select a parameter, use the mouse to place an “X” in the box next to it. Deselect a parameter by removing its “X” with the mouse.

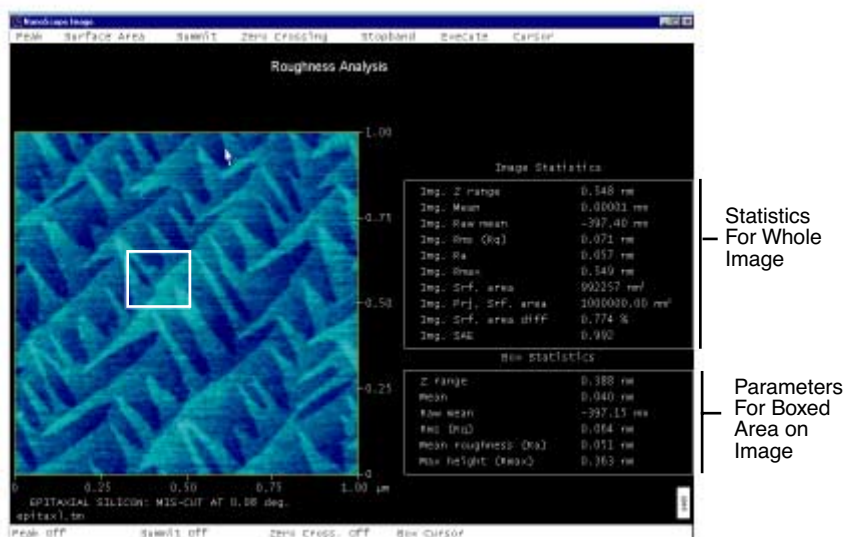
Save—Finalizes the selected **Roughness** parameters. Once the **Save** button is clicked, the selected parameters appear on the Display Monitor.

Quit—Exits the **Screen Layout** panel without changing the parameter selection.

14.6.6 Roughness Display Monitor

The Display Monitor shows the image alongside **Roughness** parameters selected from the **Screen Layout** panel. Parameters chosen from the **Screen Layout** panel are displayed in two data boxes (i.e., **Box Statistics** and **Image Statistics**). Values listed in the **Box Statistics** apply only to the area within the box cursor; if no box cursor is drawn, no values appear there. **Image Statistics** apply to the entire image. Commands on the menu bar control the operating mode (See [Figure 14.6e](#)).

Figure 14.6e Roughness Display



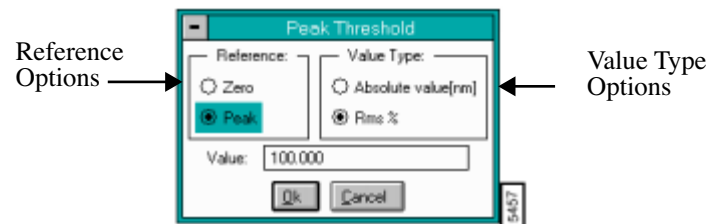
Roughness Display Menu Bar Commands

Peak

The **Peak** feature, when switched **On**, isolates specified height portions of the image (peaks) from background data. Peaks are specified using the **Peak Threshold** panel, either in terms of their absolute height or their deviation from the RMS value of all surface data, and relative to either the highest data point (Peak) or the lowest (Zero). When **Peak** is turned **On**, portions of the image contained within the box cursor and falling within the specified boundaries are retained; all other data is removed.

- **On**—The following statistical parameters are turned on: **Peak Threshold**; **Peak Thresh ref.**; **Peak Thresh (%rms)**; **10 Pt Mean (R_z)**; **Peak count**; **Max peak ht (R_p)**; **Ave. Max ht (R_{pm})**; **Max depth (R_v)**; and, **Ave. max depth (R_{vm})**. All **Peak** parameters are calculated from the threshold you define with the **Threshold** subcommand.
- **Off**—**Peak** statistics are not calculated.
- **Threshold**—Defines a height threshold for the **Peak** measurement (See Figure 14.6f).

Figure 14.6f Peak Threshold Panel



Peak Threshold Panel

The Reference options select whether the threshold is defined relative to the Zero (lowest) value, or the tallest Peak in the selected region.

The **Value Type** options select whether the threshold is defined as an absolute distance (**Absolute value**) from the reference point or a percentage of the root-mean-square (**RMS %**) of the Z values.

Surface Area Menu Command

Controls the surface area statistical calculations. Disable **Surface Area** functions on the **Area Threshold** panel (i.e., unlike **Peak** functions that are enabled in the Menu commands).

Range and Settings:

- **On**—The following statistical parameters are turned on: **Surface area**; **Surface area diff**; **Area Thresh (% rms)**; and, **Area Thresh abs**. Parameters are calculated based on the threshold you define with the **Threshold** subcommand.
- **Off**—Surface area statistical parameters are not calculated.
- **Threshold**—The **Area Threshold** panel allows a height threshold for surface area statistics (See Figure 14.6g).

Figure 14.6g Area Threshold Panel.



Area Threshold Panel

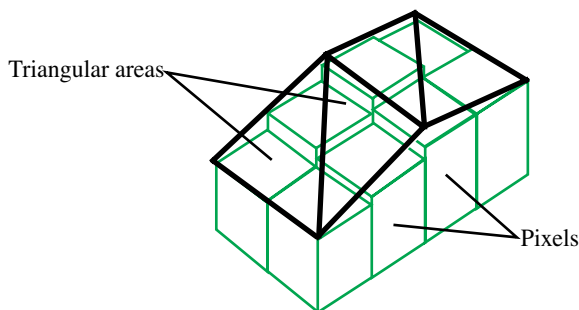
When Threshold is **On**, the surface area is calculated for the surface above the threshold. The threshold is applied according to the Reference and Value Type parameters in the panel. When **Threshold** is **Off**, the surface area of the *entire* selected area is calculated.

The **Reference** options determine whether the threshold is defined relative to the **Zero** value of the data or the tallest **Peak** within the selected region.

The **Value Type** options determine whether the threshold is defined as an absolute distance from the reference point in nanometers (**Absolute value**) or a percentage of the root-mean-square (**RMS %**) of the Z values.

Note: Surface area is calculated as a sum of triangles over the surface of the analyzed area defined within two-by-two pixel kernels (See [Figure 14.6h](#)).

Figure 14.6h Surface Area Calculation



Summit

A *summit* is any surface data point which is higher than its four nearest neighbors by a height you specify. The **Summit** subroutine allows you to isolate summits according to the **Threshold** settings.

See also, [Section 14.6.8](#) for specific descriptions of summit parameters.

Range and Settings:

-
- **On**—The number of summits within the box cursor is determined based on the threshold you define with the **Threshold** subcommand. The number of summits is reported as the **Summit count**. The number of summits is divided by the area of the box cursor and reported as the **Summit density**.
 - **Off**—The Summit determination is not performed.
 - **Threshold**—The **Summit Threshold** panel appears on the control monitor, allowing a height threshold for the summit determination to be defined.
 - The Reference selection defines whether the threshold is defined relative to the zero value of the data or the tallest peak in the selected region.
 - The Value Type selects whether the threshold is defined as an absolute distance from the reference point or a percentage of the root-mean-square of the Z values.
 - **Cutoff**—The **Summit Cutoff** panel appears on the control monitor, allowing a cutoff threshold for the summit determination to be defined.
 - **Summit disp. on/off**—Allows you to display the summit.

Zero crossing

A zero crossing is a point where the Z values go through zero regardless of slope. This value is the total number of zero crossings along both the X and Y center lines divided by the sum of the box dimensions.

Range and Settings:

- **On**—The number of zero crossings along the X and Y center lines of the box cursor is determined.
The number of zero crossings is divided by the sum of the lengths of the X and Y center lines and reported as the **Line density**.
- **Off**—The zero crossing determination is not performed.

Stopband

Excludes covered regions of the image from analysis.

Range and Settings:

- **Add**—This creates a rectangle you define containing an *X* whose area is excluded from the roughness calculation. Click on the image to create the stopband.
- **Remove**—Removes stopbands which have already been drawn. Click on the stopband(s) to be removed.
- **Clear**—Removes all stopbands.

Execute—Calculates roughness values for the region you define.

Cursor—Controls the type of cursor to be used.

- **Clear**—Removes all cursors from the image.
- **Box**—Places the cursor into box mode, which is the normal, default cursor mode. Boxes are defined by dragging the cursor from one corner to another. To switch the cursor to summit mode, select the **Summit** option.
- **Summit**—Allows summits to be selected and analyzed individually. Selected summits are distinguished by a small *X*. **Summit** statistics on the Display Monitor pertain only to the selected summit. To switch the cursor back to box mode, select the **Box** option.

Mouse Operation on the Display Monitor

Within the image

- 1st click, left button—Locates a corner of a rectangle and allows the rectangle to be formed by moving the mouse.
- 2nd click, left button—Fixes the position of the opposite corner of the box. After selecting the **Execute** command, the 2nd click, left button calculates the roughness values for the area confined by the box, and displays the values in the measurement chart.
- 3rd click, left button—The effect of the third depends on the position of the cursor when the click occurs.
- On box edge—clicking the left button when the cursor is on an edge of the box allows that edge of the box to be repositioned by moving the mouse.
- On box corner—Clicking the left button when the cursor is on a corner of the box allows that corner of the box to be repositioned by moving the mouse.

- Inside the box—Clicking the left button when the mouse is inside the box allows the entire box to be repositioned by moving the mouse.
- 4th click, left button—Freezes the position and/or size of the box.
- Right mouse button—Clicking the right mouse button when the cursor is in any of the windows moves the cursor to the menu bar.

14.6.7 Troubleshooting the Roughness Function

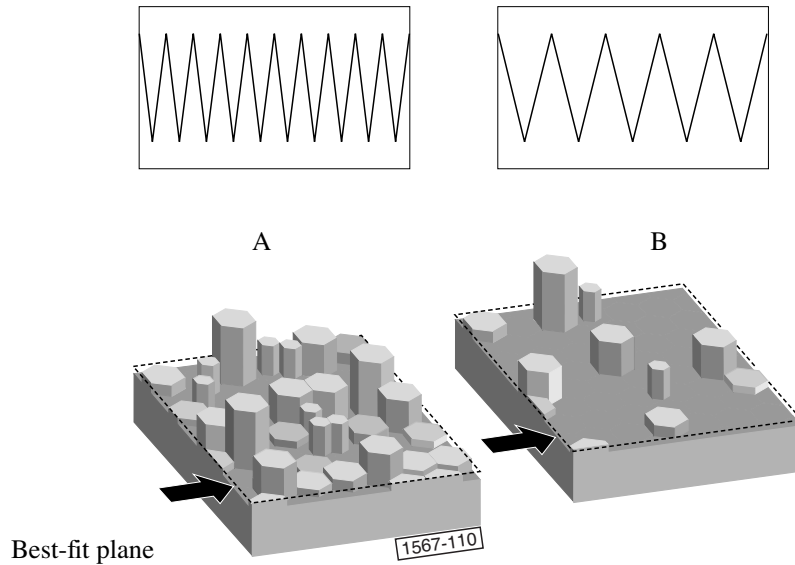
- All **Roughness** parameters are affected by offline filters applied to the data beforehand. When qualifying roughness statistics, be certain to evaluate the impacts of previous operations.
- Some statistics calculated by the **Roughness** routine are also calculated by other routines. (For example, RMS roughness is also calculated by the **Offline / Analyze / Section** and **PSD** routines).

If statistics differ slightly from routine-to-routine, it may be because they are calculated for a line rather than an area, or because planefitting was utilized. Check the appropriate sections in this manual to determine how values are calculated.

- Regarding the Effects of Planefitting on Roughness Statistics—When **Roughness** analysis is applied to an image, statistical values are calculated according to the relative heights of each pixel in the image.
 Planefitting—used to correct images for tilt and bow—reorients these pixels in a manner which can affect roughness statistics dramatically on some surfaces. This is especially true of surfaces having broad, coplanar features. Planefitting can be applied at the time of file capture using Real-time **planefit** and Off-line **planefit** from a **Channel** panel, or via either of the two **Modify / Plane Fit** functions.
- When **Roughness** analysis is applied to an image, the image data is automatically planefit beforehand. This is done to accord with ASME and ISO metrological standards. (Only the **Raw mean** parameter is exempt from this operation, being calculated from raw data only.) To avoid unexpected results due to planefitting, be certain to apply **Roughness** analysis only to the surface(s) of interest by utilizing a cursor box, or by scanning just the specific site of interest. Including peripheral features within an analyzed area may produce cumulative results uncharacteristic of the feature(s) of interest.
- The relationship between the zero plane and the data also changes according to the setting of the Off-line **planefit** parameter. If the Off-line **planefit** parameter is set to **None** the offset is not removed from the data and it is very possible that the zero plane does not intersect the data. The other settings of the parameter subtract the average Z value from every point in the image so the data varies around the zero plane.
- Regarding Basic Roughness Measurements—Average roughness (R_a) is one of the most commonly used roughness statistics. [Figure 14.6i](#) represents two surfaces having the same “average roughness”.

Similarly, a number of other roughness values are based upon least-squares calculations (e.g., RMS roughness, or R_q), and their algorithms are more concerned with a best fit of all height points than with the spatial frequency of features.

Figure 14.6i Basic Roughness Measurements



The surface of image A is represented as having a high frequency profile of features. Image B represents a separate surface having the same average feature height, but distributed at wider (lower-frequency) intervals. In terms of average and RMS roughness, both surfaces are “equally rough.” If you are interested in differentiating between the two, you must rely upon more precise statistical parameters. Refer to the Analyze / Bearing and Power Spectral Density functions, which analyze surface features in terms of depth-versus-occurrence and wavelength-versus-power, respectively.

14.6.8 Roughness Data Definitions

Statistics used by the Roughness routine are defined in this section. The terms are listed *alphabetically*. Most are derived from ASME B46.1 (“Surface Texture: Surface Roughness, Waviness and Lay”) available from the American Society of Mechanical Engineers, which should be consulted.

10 pt mean (R_z)

This is the average difference in height between the five highest peaks and five lowest valleys relative to the **Mean Plane**. In cases where five pairs of peaks and valleys do not exist, this value is based on fewer points.

The threshold absolute value in terms of height.

Area Thresh ref

The reference point for the area threshold.

Area Thres (%rms)

The threshold value as a percentage of the root-mean-square of the Z values.

Av max depth (R_{vm})

Average distance between the five lowest profile points and the mean data plane.

Av max ht (R_{pm})

Average distance between the five highest profile points and the mean data plane.

Box x dimension

The width of the L_x box cursor you define.

Box y dimension

The length of the L_y box cursor you define.

Img. Mean

Mean value of data contained within the image.

Img. R_a

Arithmetic average of the absolute values of the surface height deviations measured from the mean plane.

$$R_a = \frac{1}{n} \sum_{j=1}^n |Z_j|$$

Img. Raw mean

Mean value of image data without application of plane fitting.

Img. R_{max}

Maximum vertical distance between the highest and lowest data points in the image.

Img. RMS R_q

Root mean square average of height deviations taken from the mean data plane, expressed as:

$$\sqrt{\frac{\sum Z_i^2}{n}} = R_q$$

Img. Srf. area

The three-dimensional area of the analyzed region. This value is the sum of the area of all of the triangles formed by three adjacent data points.

Img. Srf. area diff

Difference between the image's three-dimensional **Surface area** and its two-dimensional, footprint area.

Img. Z range

Maximum vertical distance between the highest and lowest data points in the image. (Same as Img. R_{max}).

Kurtosis

This is a non dimensional quantity used to evaluate the shape of data about a central mean. It is calculated as follows:

$$\text{Kurtosis} = \frac{1}{R_q^4} \frac{1}{n} \sum_{j=1}^n Z_j^4$$

Graphically, **kurtosis** indicates whether data are arranged flatly or sharply about the mean.

Line Density

The number of zero crossings per unit length on the X and Y center lines of the box cursor. A zero crossing is a point where the Z values go through zero regardless of slope. This value is the total number of zero crossings along both the X and Y center lines divided by the sum of the box dimensions.

Max Depth (R_v)

Lowest data point in examined region.

Max height (R_{max})

Maximum vertical distance between the highest and lowest data points within the cursor box.

Max peak ht (R_p)

Maximum peak height within the analyzed area with respect to the mean data plane.

Mean

The average of all the Z values within the enclosed area. The mean can have a negative value because the Z values are measured relative to the Z value when the microscope is engaged. This value is not corrected for tilt in the plane of the data; therefore, plane fitting or flattening the data changes this value.

Mean Roughness (R_a)

Arithmetic average of the absolute values of the surface height deviations measured from the mean plane within the box cursor:

$$R_a = \frac{1}{n} \sum_{j=1}^n |Z_j|$$

Peak Count

The number of **Surface peaks** taller than the threshold.

Peak Threshold

The threshold value in terms of height.

Peak Thresh ref

The reference point for the peak threshold.

Peak Thresh(%rms)

The threshold value as a percentage of the root-mean-square of the Z values.

Raw Mean

Mean value of image data within the cursor box you define without application of plane fitting.

RMS (R_q)

This is the standard deviation of the Z values within the box cursor and is calculated as:

$$R_q = \sqrt{\frac{\sum (Z_i)^2}{n}}$$

where Z_i is the current Z value, and N is the number of points within the box cursor. This value is not corrected for tilt in the plane of the data; therefore, plane fitting or flattening the data changes this value.

Skewness


Measures the symmetry of surface data about a mean data profile, expressed as:

$$\text{Skewness} = \frac{1}{R_q^3} \frac{1}{n} \sum_{j=1}^n Z_j^3$$

where R_q is the RMS roughness. Skewness is a non dimensional quantity which is typically evaluated in terms of positive or negative. Where **Skewness** is zero, an even distribution of data around the mean data plane is suggested. Where **Skewness** is strongly non-zero, an asymmetric, one-tailed distribution is suggested, such as a flat plane having a small, sharp spike (> 0), or a small, deep pit (< 0).

Summit Count

Number of summits within the analyzed area having the defined “Threshold” and “Cutoff” values.

Note: Summits are identified on the image with special markers: 

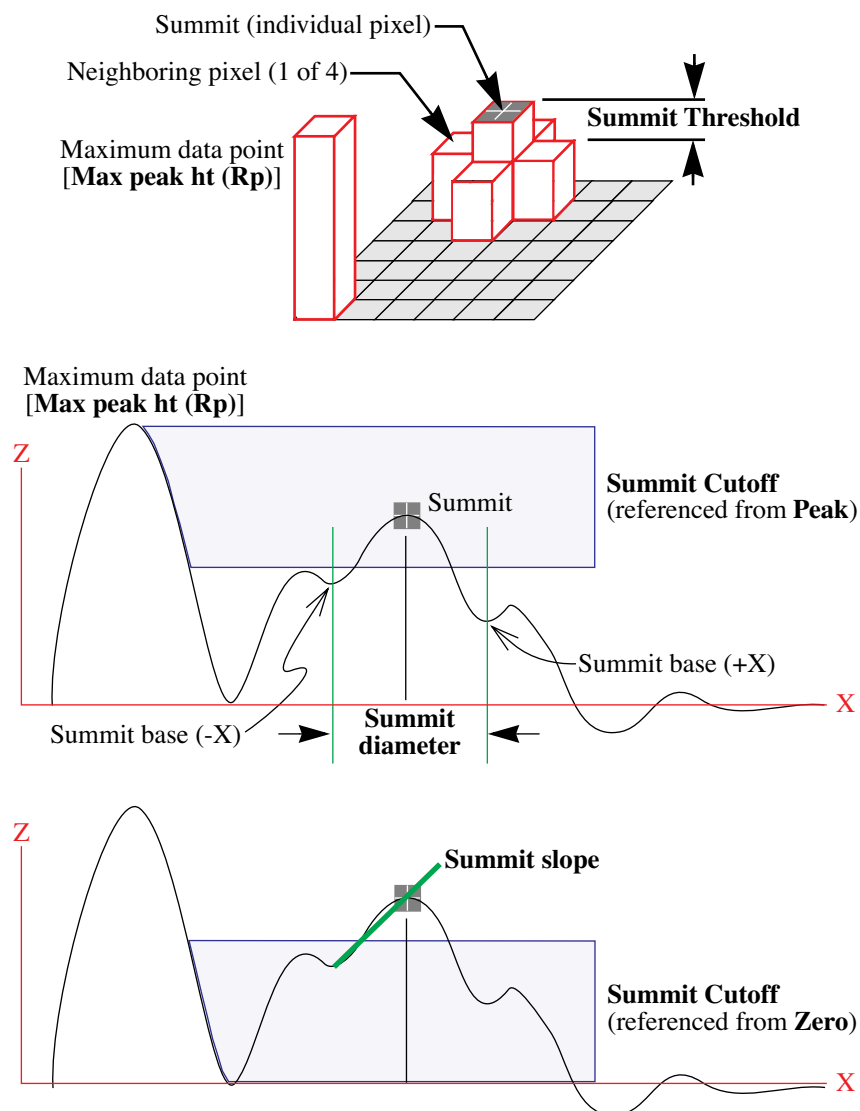
Summit Curvature

Measure of the peak's sharpness using the summit and one of its nearest neighbors.

Summit Cutoff

Distance where a summit is recognized, referenced either from the mean **Zero** data plane or the highest **Peak**. The cutoff is measured in terms of an **Absolute value**, or as a percentage of the total data range (**% of Range**) within the analyzed area.

Figure 14.6j Summit Illustrations



Summit Cutoff ref

Analysis Commands (M-Z) which the **Summit Cutoff** is measured. There are two choices: the **Zero Roughness** data plane, and the **Peak** (maximum) data point.

Summit Cutoff (%rms)

Summit Cutoff measured in terms of a percentage of the root mean square.

Summit Density

Number of summits found within the analyzed image area expressed as peaks per square micron.

Summit Diameter

Diameter of summit as measured from one summit base to another.

Summit Threshold

Minimum distance a pixel must rise above all four of its nearest neighbors to be identified as a summit.

Note: Usually, this value must be small to work effectively (e.g., **< 500 nm Absolute value**, or **< 2% of Range**), as many summits prove to be relatively flat on top.

Summit Thresh ref

Reference from which the **Summit Threshold** is measured.

Summit Thresh (% range)

Summit Threshold expressed as a percentage of height range.

Summit Rad. Curv.

Radius of curvature expressed as the inverse of the summit curvature found by using a summit and one of its nearest neighbors.

Summit Slope

Slope of a line connecting a summit and one of its bases along one of its axes.

Surface Area

The three-dimensional area of the region enclosed by the cursor box. This value is the sum of the area of all of the triangles formed by three adjacent data points.

Surface Area Diff

Difference between the analyzed region's three-dimensional **Surface area** and its two-dimensional, footprint area.

Surface Area Ratio

The percentage of the three-dimensional surface area (as defined above) to the two-dimensional surface area produced by projecting surface onto the threshold plane. The calculation is as shown below.

$$\text{surface area diff} = \left[\frac{\Sigma(\text{surface area}_i)}{\Sigma(\text{projected area}_i)} - 1 \right] \times 100\%$$

When the threshold is lower than the lowest point in the image, the projected area equals the two-dimensional image area for the image calculations and the area of the box cursor for the box calculations.

Z Range

Peak-to-valley difference in height values within the analyzed region.

14.6.9 Example of Using Roughness Analysis

For general **Roughness Analysis**, complete the following procedures:

1. Select the captured image in the list of files.
2. Select the **Roughness** command (**Off-line/Analyze/Roughness**).
3. When the **Roughness** panel appears, configure the image display settings for desired color settings.

Note: The color settings are computer generated and should not be confused with actual sample colors.

4. Set **Auto Program** settings for multiple task settings and to save settings in a file for later use.
5. In **Display Monitor**, select **Cursor** commands to enable or disable desired areas to be calculated (e.g., enable box cursor to create a box area within image).
6. In **Display Monitor**, select **Execute** to calculate roughness statistics.
7. Note calculations and continue process of **Roughness Analysis**.

14.7 Section



The **Section** command displays a top view image, upon which three types of reference lines may be drawn. The cross-sectional profiles and fast Fourier transform (FFT) of the data along those reference lines are shown in separate windows on the Display Monitor. Roughness measurements are made of the surface along the reference line(s) you define.

Section is probably the most commonly used **Analyze** command; it is also one of the easiest commands to use. To obtain consistently accurate results, ensure your image data is corrected for tilt, noise, etc. *before* analyzing with **Section**.

If you wish to analyze the depth of features, you have three choices from the **Analyze** menu: **Bearing**, **Depth** and **Section**. *This portion of the chapter is devoted to the **Section** command, which is designed for analyzing unique, one-of-a-kind surfaces.*

To *compare* feature depth at two or more similar sample sites (e.g., when analyzing etched depths on large numbers of identical silicon wafers), use the **Depth** command (See **Depth Section 13.6**).

For statistical analysis (histograms) of depth data, use the **Bearing** command (See **Bearing Section 13.4** and **Bearing Compare Section 13.5**).

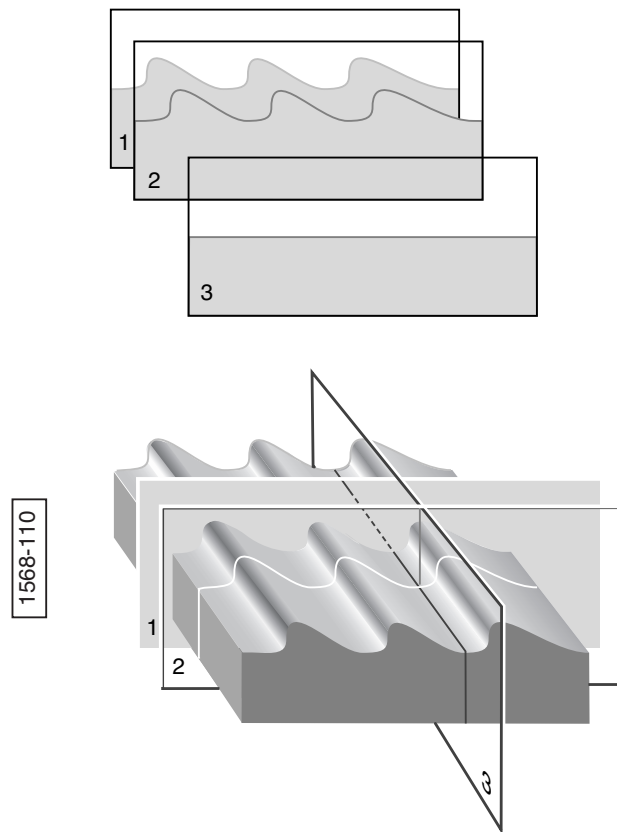
For further information, refer to the following sections on Section Analysis:

- **About Sectioning of Surfaces** [Section 14.7.1](#)
- **Navigating Control Monitor Panels in Section Analysis** [Section 14.7.2](#)
- **Section Panel** [Section 14.7.3](#)
- **Section Auto Program Edit Panel** [Section 14.7.4](#)
- **Section Display Monitor** [Section 14.7.5](#)
- **Troubleshooting the Section Command** [Section 14.7.6](#)
- **Example—Section Analysis of a Diffraction Grating** [Section 14.7.8](#)

14.7.1 About Sectioning of Surfaces

Samples are sectioned to learn about their surface profiles. The **Section** command does not reveal what is *below* the surface—only the profile of the surface itself. When sectioning samples, you should first ascertain surface topology. Depending upon the topology and orientation of the sample, the results of **Section** analysis may vary tremendously (See [Figure 14.7a](#)).

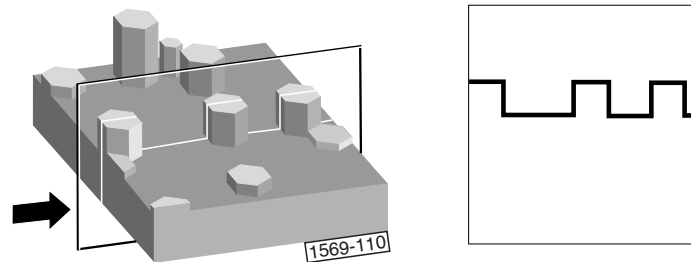
Figure 14.7a Section Analysis Illustrated



In [Figure 14.7a](#), the sample surface (a diffraction grating) is sectioned along three axes. Sections 1 and 2 are made perpendicular to the grating's rules, revealing their blaze and spacings. (Sections 1 and 2 may be compared simultaneously using two fixed cursor lines, or checked individually with a moving cursor.) Section 3 is made parallel to the rules, and reveals a much flatter profile because of its orientation.

The **Section** command produces a profile of the surface, then presents it on the Display Monitor.

Figure 14.7b Section Command Profile



Generally, **Section** analysis proves most useful for making direct depth measurements of surface features. By selecting the type of cursor (fixed, moving, or average), and its orientation to features, you may obtain the following analysis:

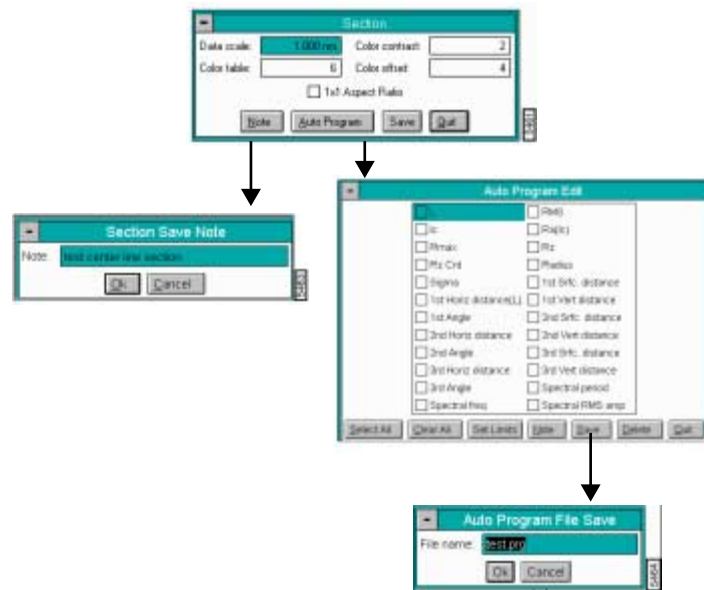
- Vertical distance (depth), horizontal distance and angle between two or more points.
- Roughness along section line: RMS, R_a , R_{max} , R_z .
- FFT spectrum along section line

See also, Section Data Definitions Section 14.7.7 and Roughness Section 14.6 for additional information on Section data and information regarding roughness calculations.

14.7.2 Navigating Control Monitor Panels in Section Analysis

The **Section** panels allow for definitions of image display, changing data for specific analysis of the sample surface. For an overview in navigating in this analysis, see [Figure 14.7c](#).

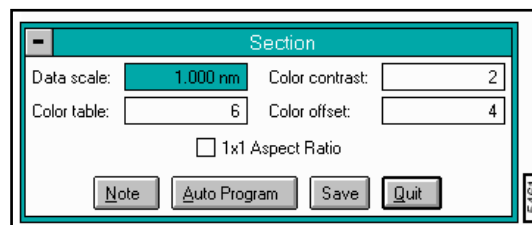
Figure 14.7c Navigating in Section Analysis



14.7.3 Section Panel

The **Section** panel displays parameters to define the image display.

Figure 14.7d Section Panel



Parameters in the Section Panel

1 x 1 Aspect Ratio

Selecting this option adjusts the Data scale to display the section profile with its true X-Y-Z aspect and proportions. On very flat samples, profiles may be imperceptible with 1 x 1 Aspect Ratio selected; however, section cursors and other functions may still be used.

Data scale

Controls the vertical range used to display the top view image and the cross-sectional profile along the reference line. The units of this item vary according to the type of image (e.g., nm, nA, etc.).

Color table

Selects the color table used to encode Z information.

Color contrast

Controls image contrast by compressing or expanding the color table.

Color offset

Changes image color by shifting the image's color table range.

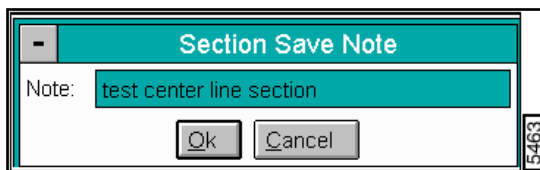
Buttons on the Section Panel

Note—Appends a note to the display. The note may include a time stamp.

Auto Program—Adds or deletes the Section command from the currently selected Auto Program file. For details on the **Auto Program** panel, see [Section 14.7.4](#).

Save—Saves **Section** data to a directory and file name you specify. Once the Section file is saved, the screen prompts you whether to append the file name with a note (See [Figure 14.7e](#)).

Figure 14.7e Section Save Note Panel



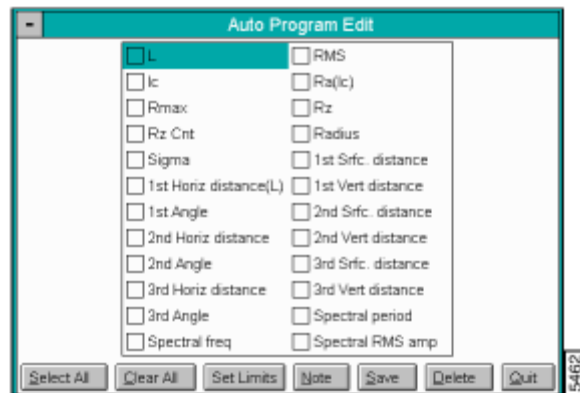
Note: Comments may be up to 32 characters in length.

Quit—Exits the Section command.

14.7.4 Section Auto Program Edit Panel

The **Auto Program** panel adds or deletes the **Section** command from the currently selected **Auto Program** file. A panel listing measurements reported by the **Section** command is placed on the screen. Selecting a measurement stores it in the data file when Auto Program is run (See [Figure 14.7f](#)).

Figure 14.7f Section Auto Program Edit Panel



Buttons on the Auto Program Edit Panel

Select All—Selects all the measurements simultaneously.

Clear All—Clears all the measurements simultaneously.

Set Limits—Sets specific limits for the peak result. You may specify the Rmax Min (high peak), Rmax Max (low peak) , and % of Section Rmax values.

Note: If the data does not fit within the set limits, the file is flagged with an “L” in the Auto Result file.

Note: For Section data definitions, see [Section 14.7.7](#).

Note—Allows you to insert a command note in the Auto Program file.

Save—Saves selected measurements to the Auto Program file. If the **Section** command is already in the current Auto Program file, and option appears to overwrite the current file or add a new Section analysis to the Auto Program file.

Delete—Removes the **Section** command from the Auto Program file.

Quit—Exits the Auto Program Edit mode without making changes to the Auto Program file.

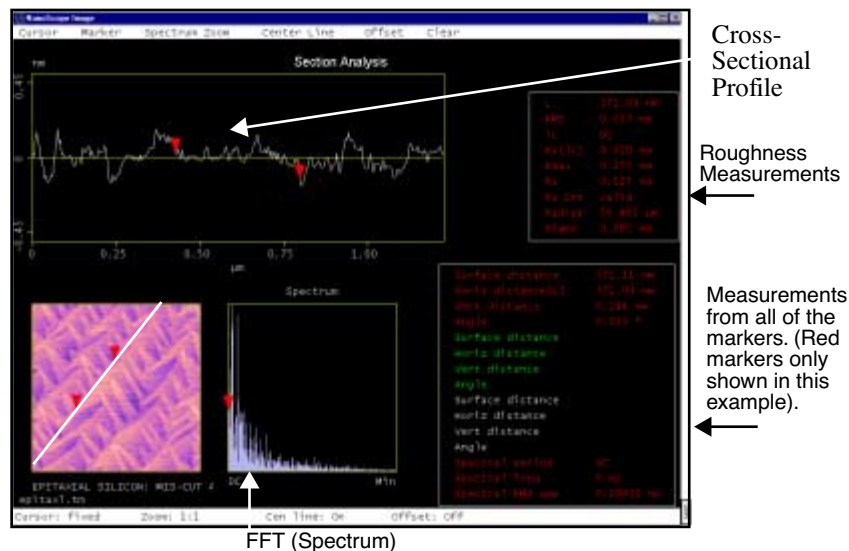
Note: The **Auto Program File** command in the **Utility** menu can be used to select, or create, an Auto Program file. The **Auto** subcommand under the **Browse** command selects the files to be processed and executes the Auto Program file.

14.7.5 Section Display Monitor

The **Display Monitor** includes (See [Figure 14.7g](#)):

- Menu Bar (Cursor, Marker, Spectrum Zoom, Center Line, Offset, Clear)
- Cross-Sectional Profile
- Small image (lower left corner)
- Spectrum (FFT) (Next to image)
- Upper-right date box (defined by reference markers)
- Lower-right data box (defined by all reference markers in the Cross-sectional profile and Spectrum).
- Status bar

Figure 14.7g Section Display Monitor



Display Monitor Explanation. The menu, status bar and five windows are shown on the Display Monitor.

An image is displayed in the lower-left window, allowing the cross-sectional line you specify to be drawn on the image. When the line is drawn, the cross-sectional profile is displayed in the upper-left window, and the FFT (**Spectrum**) along the line is displayed in the lower-center window. The extra points are generated by interpolation.

The upper-right window lists roughness information based on the position of the presently selected reference markers. The lower-right window displays measurements from all of the reference markers in the **Cross-sectional Profile** window and the **Spectrum** window. The menu bar provides the subcommand list for the Section mode while the status bar reflects the subcommands that have been selected.

Display Monitor Menu Commands

Cursor

Five cross-sectional line types are available:

- **Fixed**—Allows a fixed-position line to be drawn on the image and shows the cross-sectional profile and FFT of the data along that line.
- *Mouse operations for a **Fixed** cursor are as follows:*
- 1st click—Anchors the origin of the reference line and expands from the selected position, allowing a reference line to be drawn in any direction.
- 2nd click—Anchors the terminal point of the reference line, then displays the cross-sectional profile and the FFT of the data along this line.
- **Moving**—Allows a fixed-position line to be drawn on the image and places a moving reference line perpendicular to the fixed line on the screen. The cross-sectional profile and FFT of the data along the moving reference line is displayed.
- *Mouse operations for a **Moving** cursor:*
- 1st click—Anchors the origin of a line segment and expands from the selected position, allowing a line segment to be drawn in any direction.
- 2nd click—Anchors the terminal point of the first (dashed) line segment and draws a moving reference line perpendicular to the fixed-line segment. The cross-sectional profile and the FFT along the reference line are displayed at this time. The position of the moving reference line tracks the movements of the mouse. When the mouse is stationary, the cross-sectional profile and the FFT of the data along the moving reference line is updated on the Display Monitor.
- 3rd click—Fixes the position of the reference line.
- 4th click—Recouples the reference line to the movement of the mouse.
- **Average**—Allows a fixed-position reference line to be drawn on the image and places a box parallel to the reference line.

The average of all the cross-sectional profiles perpendicular to the reference line and constrained by the box is displayed. The FFT of the average profile is also displayed.

- *Mouse Operations for **Average***

- 1st click—Anchors the origin of a line segment and “rubberbands” from the selected position, allowing the line segment to be drawn in any direction.
- 2nd click—Anchors the terminal point of the first line segment and draws a box along the fixed-line segment. The average profile of the lines perpendicular to the segment and confined by the box is displayed. The FFT along the average cross-section is also displayed at this time.
- As a reference, the cursor positions also show up as red lines in the box.
- 3rd click—Allows the box to be moved (cursor inside box), or resized (cursor on edge of box). Clicking on the corner allows the box to be resized in two directions.
- 4th click—Fixes the box position or size.
- **Fixed Two**—Allows two fixed-position reference lines to be drawn on the image, showing the cross-sectional profiles of the data along those lines. Cross-sectional profiles may be shifted relative to one another by dragging the profile’s handle (tiny box on reference line) with the mouse.
- **Fixed Three**—Allows three fixed-position reference lines to be drawn on the image, showing the cross-sectional profiles and FFTs of the data along those lines. Cross-sectional profiles may be shifted relative to one another by dragging the profile’s handle (tiny box on reference line) with the mouse.

Marker

Adds or deletes pairs of reference markers (inverted colored triangles) from the cross-sectional profile window.

- **Draw**—Adds another pair of reference markers on the cross-sectional profile window if all three pairs are not already visible. Reference markers are added in the following order: Red-Green-White.
- **Erase**—Removes a pair of reference markers from the cross-sectional profile window. Reference markers are removed in the opposite order that they are added: White-Green-Red.

Spectrum Zoom

Controls the magnification of the Spectrum window. Eight-to-one, four-to-one, two-to-one, and one-to-one options are available.

Center Line

Displays the calculated center line (RMS) between cursors on the cross-sectional profile window. The center line is displayed in red with equal areas above and below.

Range and Settings:

- **On**—Switches the center line on between cursors. The cutoff length (lc) defined on the FFT plot, changes the calculation of the center line.
- **Off**—Switches the center line off between cursors.

Offset

Allows the center line cursor in the **Section** plot on the Display Monitor to be arbitrarily moved up-down so the viewing window can be shifted relative to the data. To move the center line, drag with the mouse.

Range and Settings:

- **On**—Turns Offset on by making center line available for moving (green center line).
- **Off**—Turns Offset off by anchoring the center line at “0” (yellow center line).
- **Cursor Clear**—Anchors the center line at its currently set position.

Mouse Operations for Offset:

- 1st click—Once the **Offset** subcommand is **On**, clicking on the green center line cursor in the section plot picks up the green line. Moving the mouse moves the green line cursor and defines the value of the new center line. When the mouse movement stops, the values on the vertical axis shift to make the position of the green line the new center of the graph.
- 2nd click—Fixes the center line of the plot.

Clear

Removes the cross-sectional profile window and the Spectrum window and clears the reference-marker measurements to allow new reference lines to be selected.

14.7.6 Troubleshooting the Section Command

- **Reference (Triangle) Markers**—When in the cross-sectional profile window or **Spectrum** window, reference markers can be 'picked-up' by clicking the left button when the cursor is on the desired marker. Moving the mouse changes the position of the marker. A second click drops the marker. The horizontal separation, vertical separation, and angle between the reference markers in the cross-sectional profile window are listed in the lower-right measurement window.
- **Jumping between Windows**—After selecting a cursor type from the **Cursor** menu, the cursor jumps to the image window. After selecting **Marker / Draw**, the cursor jumps to the cross-sectional profile window and is attached to one of the added reference markers. When **Spectrum Zoom** is selected, the cursor jumps to the Spectrum window and is attached to the reference marker.

- Clicking the right mouse button when the cursor is in one of the windows moves the cursor to the menu bar.

14.7.7 Section Data Definitions

Roughness Measurements

The standard deviation (RMS), mean Roughness (R_a), the maximum height (R_{max}), and the 10-point roughness (R_z) for the segment between the reference markers are also listed in the measurement (upper right) window. This is the roughness data.

These four parameters are calculated based upon the following definitions and criteria:

- L —Length of the roughness curve.
- RMS (Standard Deviation)—Standard deviation of the Z values between the reference markers, calculated as follows:

$$RMS = \sigma = \sqrt{\frac{\sum (Z_i - Z_{ave})^2}{n}}$$

- where Z_i is the current Z value, Z_{ave} is the average of the Z values between the reference markers, and N is the number of points between the reference markers.
- l_c —Cutoff length (in nanometers) of the high-pass filter used in creating the roughness curve. The FFT period is equal to l_c .
- R_a (Mean Roughness)—Mean value of the roughness curve relative to the center line, calculated as:

$$R_a = \frac{1}{L} \int_0^L |f(x)| dx$$

- where L is the length of the roughness curve and $f(x)$ is the roughness curve relative to the center line.
- R_{max} (Maximum Height)—Difference in height between the highest and lowest points on the cross-sectional profile relative to the center line (not the roughness curve) over the length of the profile, L .
- R_z (Ten-Point Mean Roughness)—Average difference in height between the five highest peaks and five lowest valleys relative to the center line over the length of the profile, L . In cases where five pairs of peaks and valleys do not exist, this is based on fewer points.

Profile

Cross-sectional data between the two reference markers.

Roughness Curve

Cross-sectional data between the two reference markers that have been high-pass filtered with a two-pole filter having a gain of 75% at the cutoff length, l_c .

Mean Line of Profile

Calculated straight line based upon the profile that has a minimum variance about this line.

Center Line of Roughness Curve

Calculated straight line based upon the roughness curve data that has equal area (bounded by the roughness curve) above and below the line.

Profile Peak, Profile Valley

Continuous area above and below the mean line of the profile, respectively. Bounded by the profile and between the two intersection points.

Peak, Valley

Highest and lowest points, respectively, in the profile peaks and profile valleys.

Changing the cursor on the FFT changes l_c , the cut-off length of the high-pass filter applied to the data. The filter is applied before the roughness data is calculated; therefore, the position of the cut-off affects the calculated roughness values.

14.7.8 Example—Section Analysis of a Diffraction Grating

This example uses **Section** to analyze a diffraction grating (file name “**grating**” on the images disk). The **Section** command profiles peaks and valleys, as well as the blaze angle and other features in the grating.

Note: The file “**grating**” is included with the images disk which accompanies this manual. It may be loaded from the B: floppy drive.

1. Transfer to the Off-line screen, then use **File / Open** to access the image **grating** on the images disk.
2. Open the file by double-clicking on **grating**, or using Off-line/**File/ Open** to load the file. The image should appear on the display screen.
3. Use **View / Surface Plot** (or click on the Surface Plot icon) to obtain a surface plot view of the grating surface. Study the image—notice that the grating consists of parallel, ruled lines which are etched into the surface. These lines are used to diffract white light into light having



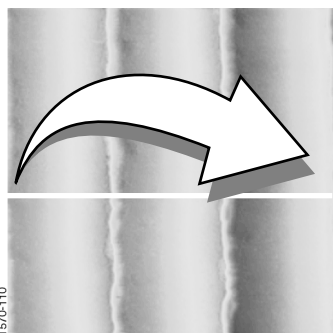
narrower wavelengths. (You may have seen diffraction gratings used as colorful reflectors on ornaments and packages.)

Depending upon the incident angle of the light falling on the grating's surface and spacing between rules, different colors are produced. Manufacturers of gratings are especially concerned with maintaining a fixed, definite spacing between lines and the angle (or "blaze") of the rulings.

4. Click on the **Quit** button to exit from the **Surface Plot** panel.
5. Before doing a sectional analysis of the grating, ensure that the image is properly oriented by removing any tilt or bow. This is especially important if a high level of precision is to be employed in measuring the blaze angle.
6. To remove any tilt which might be present, click on **Off-line / Modify / Plane Fit Auto**. Set the **Planefit order** parameter in the panel to **1**, then click on the **Execute** button. The image is fitted to a plane ("leveled") by fitting each scan line to a first-order equation, then fitting each scan line to others in the image. At this point, the image has not been appreciably altered, it has only been reoriented slightly.
7. Click on the **Quit** button to exit from the Plane Fit Auto panel.
8. To use the **Section** command, click on **Offline / Analyze / Section**, or use the **Section** icon. The **Section** panel is displayed on the control monitor, and the "grating" image is displayed on the Display Monitor.
9. To make a single-line section of the image, use the mouse to draw a line through the image, as in [Figure 14.7h](#).



Figure 14.7h Mouse Drawing Line



Use the mouse to drag a line cursor across the image.

See also, **Dual Section** [Section 11.2](#) for Section Analysis on two and three images simultaneously.

14.8 Stepheight

The **Stepheight** command makes relative height measurements between two regions (steps) on sample surfaces. Typical applications include measuring film thickness and etch depths. **Stepheight** works similarly to a **Section** command with an averaging box cursor, but its operation is simplified.

Stepheight displays a top view of the image, then a reference line is drawn across the regions to be measured. A height profile is generated from averaged data on either side of the reference line. Cursors—which are moved along the profile—define specific regions (steps). These may be measured (**Measure** button) relative to each other, with or without data leveling (**Level** button).

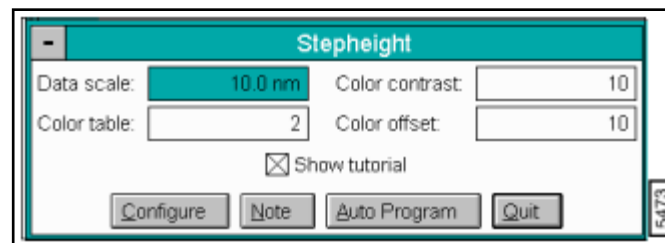
Refer to the following Stepheight sections:

- **Stepheight Panel** [Section 14.8.1](#)
- **Parameters on the Stepheight Panel** [Section 14.8.2](#)
- **Buttons on the Stepheight Panel** [Section 14.8.3](#)
- **Stepheight Configure Panel** [Section 14.8.4](#)
- **Configuration File List Panel** [Section 14.8.5](#)
- **Auto Program Edit Panel** [Section 14.8.6](#)
- **Stepheight Display Monitor** [Section 14.8.7](#)
- **Example—Stepheight Analysis of a Thin Film** [Section 14.8.8](#)

14.8.1 Stepheight Panel

The **Stepheight** panel displays parameters for adjusting the image display, as well as buttons to **Configure** and **Auto Program** the **Stepheight** analysis.

Figure 14.8a Stepheight Panel



14.8.2 Parameters on the Stepheight Panel

Data scale

Controls the vertical range used to display the top view image and the cross-sectional profile along the reference line. The units of this item vary according to the type of image (e.g., nm, nA, etc.).

Color table

Selects the color table used to encode Z information.

Color contrast

Controls image contrast by compressing or expanding the color table.

Color offset

Changes image color by shifting the image's color table range.

Show tutorial

When selected, this displays a help box on the Display Monitor. The help box consists of several pages of useful information describing how to use the Stepheight command.

14.8.3 Buttons on the Stepheight Panel

Configure—Accesses the Configure panel and displays the *Current File* being used in the Stepheight function (See [Section 14.8.4](#)).

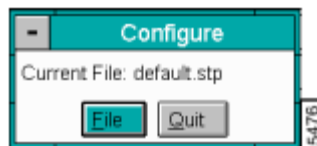
Note—Appends a note or timestamp to the display. The note may include a time stamp.

Auto Program—Adds or deletes the **Stepheight** command from the currently selected Auto Program file. For details on the **Auto Program Edit** panel, see [Section 14.8.6](#).

Quit—Exits the **Stepheight** command.

14.8.4 Stepheight Configure Panel

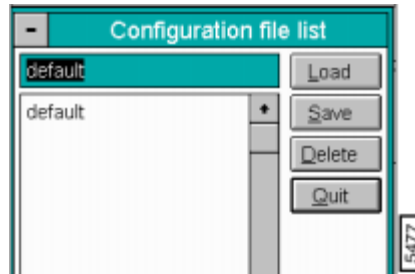
Figure 14.8b Stepheight Panel



The **Configure** panel opens and shows the `CURRENT FILE` for running the **Stepheight Analysis** function. Click the **FILE** button to access a new file in the **Configuration File List** panel (See [Section 14.8.5](#)) or **QUIT** to exit the **Configure** panel.

14.8.5 Configuration File List Panel

Figure 14.8c Configuration File List Panel



Buttons in the Configuration File List Panel

Load—Loads the specified Stepheight Configure file.

Save—Saves the current settings as a Stepheight Configure file.

Delete—Deletes the specified Stepheight Configure file.

Quit—Exits the Configuration File List panel.

14.8.6 Auto Program Edit Panel

The **Auto Program Edit** panel adds or deletes the **Stepheight** command from the currently selected Auto Program file. The **Auto Program Edit** panel is displayed. To include **Stepheight** within the auto program file, click on the box next to `STEP HEIGHT`, then click on the **SAVE** button (See Figure 14.8d).

Note: If you do not place an “X” within the “Step height” box, the command is executed but no results are recorded.

Figure 14.8d Auto Program Edit Panel



Note: The **Auto Program File** command in the **Utility** menu must be used to select, or create, an Auto Program file. The **Auto** subcommand under the **Browse** command selects the files to be processed and executes the Auto Program file.

Buttons on the Auto Program Edit Panel

Select All—Selects all the measurements simultaneously.

Clear All—Clears all the measurements simultaneously.

Note—Allows you to insert a command note in the Auto Program file.

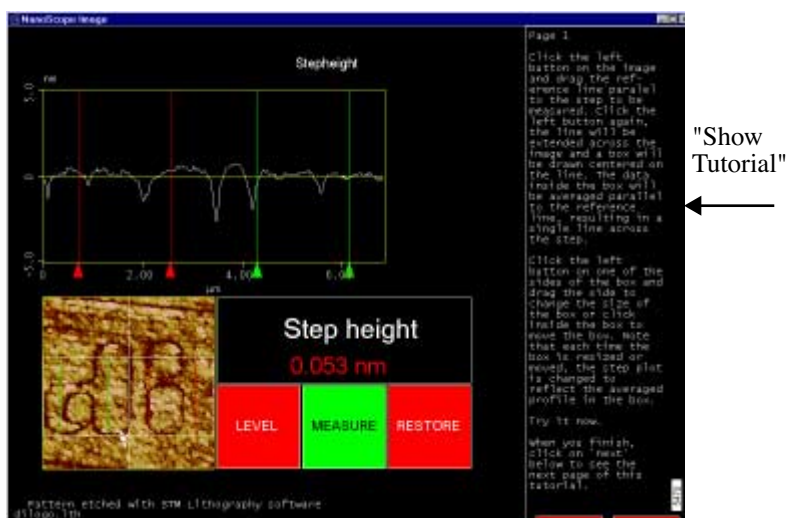
Save—Saves selected measurements to the Auto Program file. If the **Section** command is already in the current Auto Program file, it retains its position in the file.

Delete—Removes the **Section** command from the Auto Program file.

Quit—Exits the Auto Program Edit mode without making changes to the Auto Program file.

14.8.7 Stepheight Display Monitor

Figure 14.8e Stepheight Display



The image appears in the lower-left corner of the display screen. The mouse is used to draw a reference line across the image, which orients a white box cursor. The box is sized and positioned to define the measured area.

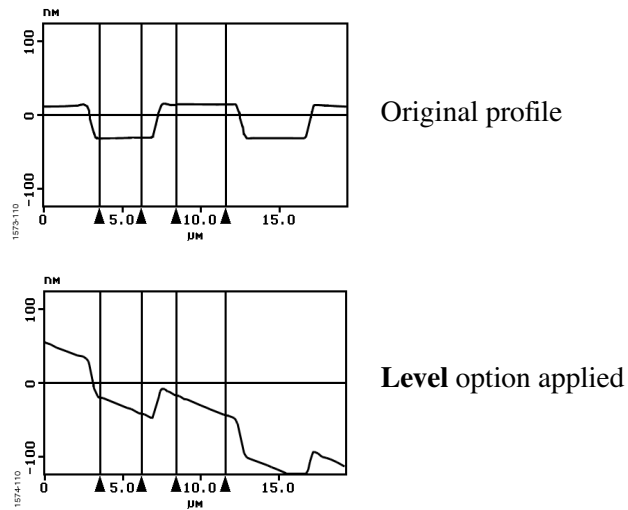
In the profile above the image, the averaged height of features lying within the box are shown. Two pairs of cursors (one red and one green) are moved across the profile to define the steps to be measured. (The region between each cursor pair defines a “step.”) In the box labeled “Step height,” the relative height between steps is displayed in large numerals.

Stepheight Display Menu Commands

Level

Reorients the profile so that the average height of each step region is equal.

Figure 14.8f Level Option Profile



Measure

Displays the relative height between steps.

Restore

Returns the profile to its original, unleveled form. (Deselects the Level option.)

Mouse Operation (within image)

- 1st click—Anchors the origin of a line segment and “rubberbands” from the selected position, allowing the line segment to be drawn in any direction.
- 2nd click—Anchors the terminal point of the first line segment and draws a box along the fixed-line segment. The average profile of the lines perpendicular to the segment and confined by the box is displayed.
- As a reference, the cursor positions also show up as red and green lines in the box.
- 3rd click—Allows the box to be moved (cursor inside box), or resized (cursor on edge of box). Clicking on the corner allows the box to be resized in two directions.
- 4th click—Fixes the box position or size.

14.8.8 Example 4-Stepheight Analysis of a Thin Film

Stepheight

This example uses **Stepheight** to analyze metal lines on a gallium arsenide substrate. The **Stepheight** command is used to profile adjacent lines and measure their height above the substrate.

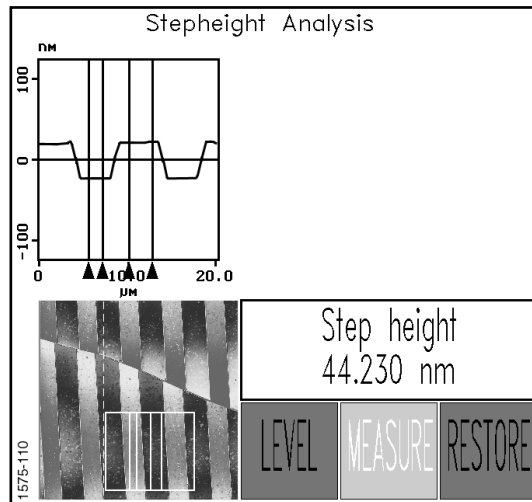
Note: This example uses the file "gaas" included with the images disk which accompanies most recent software versions and may be loaded from the B: floppy drive. You may also download it from Digital Instrument's "Public" FTP site folder.

1. Transfer to the Off-line screen, then use **File / Open** to access the image "gaas" on the images disk.
2. Open the file by double-clicking on "gaas," or using **Off-line / File / Open** to load the file. The image should appear on the display screen.
3. Use **View / Surface Plot** (or click on the Surface Plot icon) to obtain a surface plot view of the grating surface. Study the image—notice that the image consists of parallel, metal lines atop a gallium arsenide substrate. The lines and substrate have been fractured through the center of the image, making two sets of juxtaposed lines.
4. Click on the **Quit** button to exit from the **Surface Plot** panel.
5. Before doing a **Stepheight** analysis of the image, it may prove helpful to ensure that the image is properly oriented by removing any tilt or bow. To remove any tilt which might be present, use the **Off-line / Modify / Plane Fit Auto** command. At this point, the image has not been appreciably altered, it has only been reoriented slightly.
6. To use the **Stepheight** command, click on **Offline / Analyze / Stepheight**. The image appears in the lower-left corner of the display screen. Use the mouse to draw a *vertical* reference line on the image between two parallel lines. (Remember, image data is averaged perpendicular to this line, which is why we are drawing it vertically.) Next, use the mouse to size and position the box cursor to include at least one complete line and a substrate region.

The image should appear similar to the one in [Figure 14.8g](#).



Figure 14.8g Stepheight Analysis Image



Notice that one pair of cursor lines have been moved over the substrate; another pair are centered on a line. The measured height difference is displayed prominently. (The step height in the example above indicates a relative height difference of 44.230 nm.)

7. You may continue to experiment with other images. Characteristics of a good image for **Stepheight** analysis include prominent, flat (planar) features. The **Stepheight** command is less useful for measuring features having rounded or uneven surfaces.

14.9 Auto Tip Qualify

Auto Tip Qualify

The **Off-line / Analyze / Auto Tip Qual** function actually incorporates two separate capabilities in one software feature: tip estimation and tip qualification. *Tip estimation* generates a composite image of the tip (as seen looking straight down on to the apex) based upon the tip's interaction with a sample, and is displayed in the lower-left corner of the display screen. *Tip qualification* uses the estimate to determine whether the tip is acceptable for use. This is useful in at least two ways:

- Tips may be checked periodically for signs of wear, then changed when found to be unacceptably worn.
- By using tip estimation and qualification to enforce an envelope of tip acceptability, metrological values can be compared from image to image, ensuring consistent, long-term analysis of samples.

The **Auto Tip Qualify** command allows the user to qualify a tip before proceeding with the **Real-time** scan.

For Auto. Tip Exchange and Auto Tip Qual, *see also*, the *Automation Supplement* (Version 5.13).

Refer to the following Auto Tip Qualify sections:

- **Using macros to run Auto TipQual and Tip Exchange** [Section 14.9.1](#)
- **Selection of Probes** [Section 14.9.2](#)
- **Tip Artifacts** [Section 14.9.3](#)
- **Tip Estimation Theory** [Section 14.9.4](#)
- **Auto Tip Qual Display Monitor** [Section 14.9.5](#)
- **Auto Tip Qual Panel** [Section 14.9.6](#)
- **Auto Tip Qual Display Monitor** [Section 14.9.7](#)
- **Tip Qualification Parameters** [Section 14.9.8](#)
- **Example: Using the Auto Tip Qualification Command** [Section 14.9.9](#)
- **Running ETD-based Tip Qualification** [Section 14.9.10](#)

14.9.1 Using macros to run *Auto TipQual* and *Tip Exchange*

When run under macro control, the Auto TipQual software can be combined with **Automatic Tip Exchange**.

If ETD-based tip qualification is selected while teaching the macro program, then when the tip qualification software determines that a tip is worn or bad, it will cause the system to execute an **Exchange Tip** function, which replaces the used cantilever with a fresh one or, if the system does not have Automatic Tip Exchange, it prompts the user to change the tip manually.

14.9.2 Selection of Probes

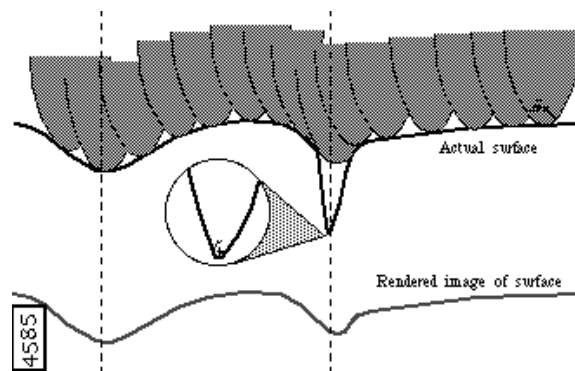
An important prelude to tip estimation and qualification is the correct choice of a suitable tip. There will be little gained in estimating and qualifying a tip if it is improperly sized for the features it will encounter. Specifically, a tip cannot resolve the linear and angular aspects of any feature sharper than itself.

Note: Even a blunt tip can still resolve height accurately. Therefore, select a tip which is sufficiently sharp, depending upon what you are attempting to measure with it.

14.9.3 Tip Artifacts

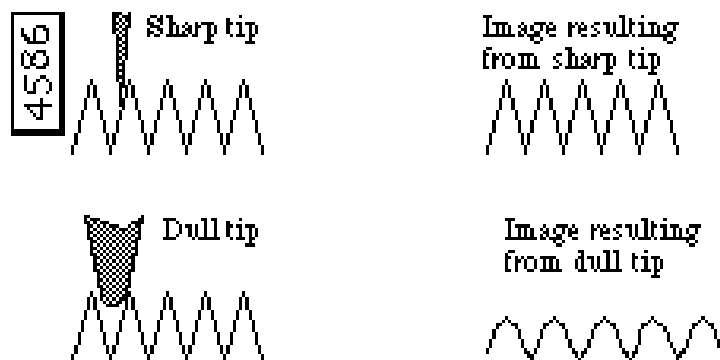
AFM measurements are limited by the shape of the tip used to probe the sample surface. Depending upon sample features, this may lead to “tip artifacts” in the image. In the simplest case, the finite size of the AFM tip will not let it probe narrow, deep features on a sample as shown in [Figure 14.9a](#) where the tip’s radius R , is greater than the radius of the recess, r .

Figure 14.9a Example of Dull Probe on a Deep Feature



In addition, sharp sample features will appear broadened in AFM images due to the finite width of the tip. Consequently, image measurements such as surface roughness and surface area are affected by the shape of the AFM tip. An image captured with a very sharp tip will show a greater roughness and a larger surface area than an image captured with a dull tip (See [Figure 14.9b](#)).

Figure 14.9b Tip/Image Relationship



Note: It is often desirable to discard a tip when it is no longer sufficiently sharp.

The **Tip Estimation** software provides tools for characterizing the apparent size and shape of the tip, based on captured sample images. **Tip Qualification** software can then use the apparent size and shape of the tip to decide whether or not a tip and/or the image data should be discarded.

Based on thresholds set by the user, the Tip Qualification software will usually return one of the following tip statuses: **GOOD**, **WORN**, or **BAD**. A tip status of **GOOD** indicates that the tip is still sufficiently sharp and that the image data should be acceptable. A tip status of **WORN** indicates that the tip is becoming dull and should be changed, but previous image data taken with this tip should still be acceptable. If a **BAD** status is returned, the tip should be changed and the current image data discarded. In cases where imaging errors are suspected, Tip Qualification may return one of two other statuses: **SUSPECT** or **NO TIP**.

Auto Tip Qual describes multiple operations, including:

- Estimation of tip shape from measured samples and designated characterizers.
- Qualifying tips as “good,” “worn,” or “bad,” depending upon their estimated shapes.

14.9.4 Tip Estimation Theory

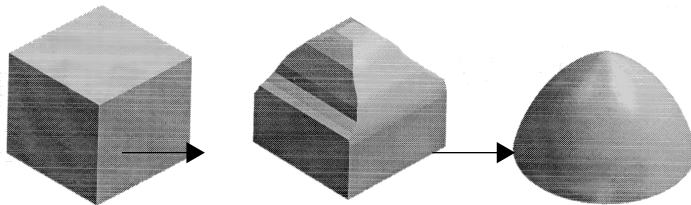
Tip Estimation uses measured images of a sample to construct a 3-dimensional estimate of the apparent tip shape. The model of the tip is constructed by analyzing a collection of different features from the image data. The software first identifies a series of local peaks (neighborhood maxima) in the image data and then successively analyzes each peak, refining the tip estimate as it does so. At the top of each of these peaks, the software effectively determines the rate at which surrounding data slopes down in all directions. The degree of the slope determines the tip sharpness, as no data in the image can have a slope steeper than the slope of the tip. As this basic process is repeated for each local peak, any feature sharper than corresponding features from all previously analyzed peaks will cause the tip model to update to a new, sharper estimate.

A Physical Analogy: Carving a Wooden Model of the Tip

Try to carve a wooden model of the tip based on collected image data. Start with a simple wooden block. Now consider a sample image that has a series of small peaks (bumps) in the image data. This is the typical image for many samples with grain-like structure. Pick one of the peaks in the image data and measure the shape of the peak in all directions as you move down from the top of the peak. The tip must be at least as sharp as this measured shape. So your first estimate of the tip shape is to carve the same shape as the first peak into the wooden block.

Now, move on to the next peak in the image data and compare this to the wooden model. If there are any features that are duller than the current model (that is, they fall away more slowly), ignore them.

Figure 14.9c Wooden Block Analogy



You already know that the tip is sharper than the dull parts of the second feature. But if there are any regions of the second peak that are sharper than on the last peak, you will carve away regions of the tip model that have the smaller slopes of the previous peak. You will repeat this for each peak in the image data.

Each peak will typically make the model of the tip more and more accurate since different peaks will often reflect contact between the sample and different parts of the tip. You keep carving away material from the model as necessary based on the sharpness of each new peak. The final model is the aggregate of all the shapes of all the peaks found in the image. Mathematically, the result is called the geometric intersection of all the individual peaks analyzed in the image data. A simplified progression of constructing the tip model is shown above. (You can see this same basic process occurring dynamically while running the Tip Estimation software—turn on the **Dynamic Tip Update** function described later in this chapter).

The Tip Model is Sample-dependent

The model generated by **Tip Estimation** is not, in general, the actual shape of the tip. Since the tip model is constructed by analyzing the shapes of peaks in the image data, the accuracy of the model is limited by the sharpness of features on the sample. A surface with infinitely sharp features will produce an accurate model of the tip. Conversely, a surface having large rounded features will impart its shape to the tip's estimation. Here are a few examples:

Figure 14.9d A perfect spike on the sample surface yields a perfect tip estimate.

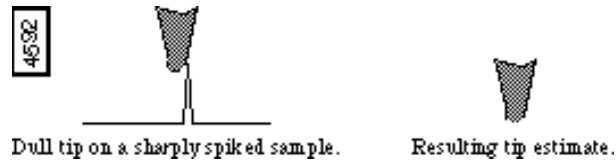
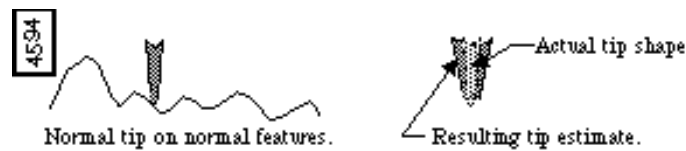


Figure 14.9e A sample with no sharp features yields a dull tip estimate.



Figure 14.9f A sample with feature sizes similar to the tip size yields a tip estimate that combines tip and sample geometry.



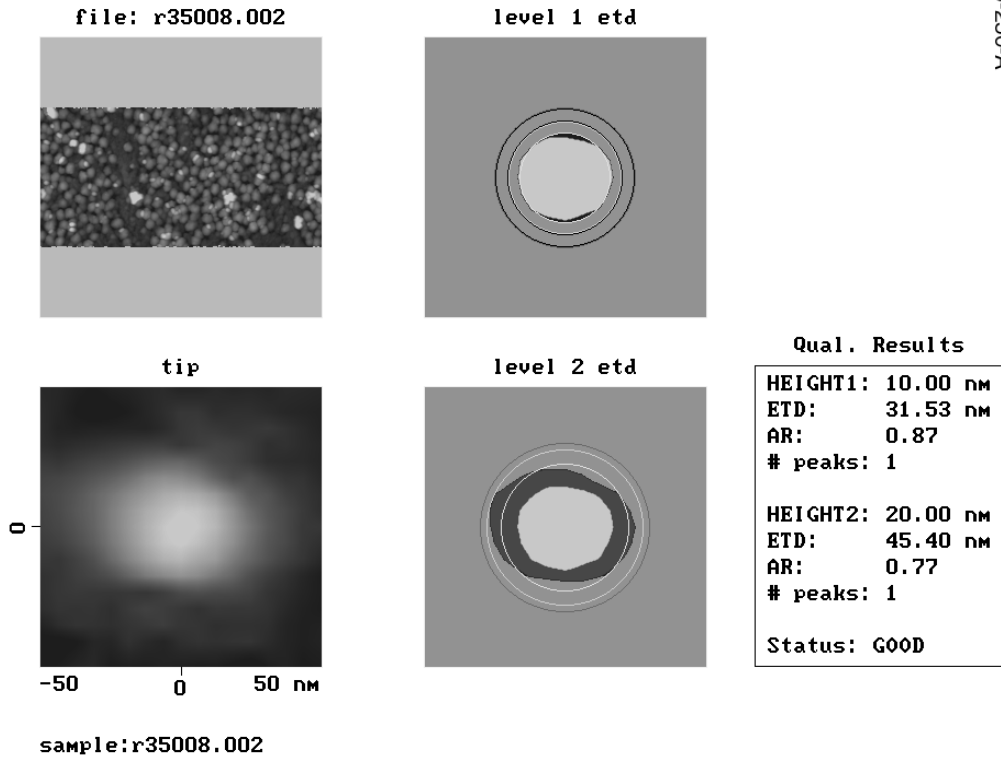
For this reason it is always important to consider the effects of the sample features on the calculated tip model. Samples that provide the most accurate estimate of tip size and shape are those with many fine protrusions. Very flat samples will not provide a very useful estimate of tip shape.

Despite the dependence on the sample characteristics, Tip Estimation and Tip Qualification software can often provide a reliable method of tracking tip wear and ensuring that probes are changed when they become dull.

Example: When making repeated measurements on suitable rough samples, **Tip Estimation** can provide very reproducible estimates of tip size and shape, which change in a predictable and consistent fashion as the tip wears.

14.9.5 Auto Tip Qual Display Monitor

Figure 14.9g Typical Tip Qualification Display Monitor
 Auto Tip Qualification

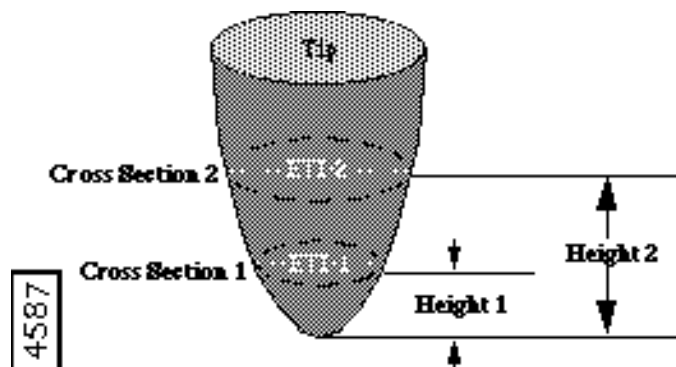


The top-left frame is the image data being analyzed. The lower-left frame is a top view image of the software model of the tip (looking down onto the apex).

Once a tip model has been generated, the **Tip Estimation** software extracts quantitative measurements of the tip's size and shape.

The software cuts cross-sections at two different heights through the tip model as shown in [Figure 14.9h](#).

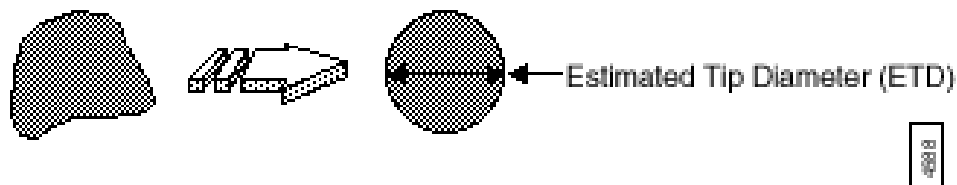
Figure 14.9h Cross Sections on Tips



These cross-sections show the apparent size and shape of the tip at two different distances from the apex of the tip. Typical cross-sections are shown in the two right frames labeled “level 1 etd” and “level 2 etd.” In the level 1 cross-section, the apparent tip shape is shown as a light gray shape (in this case, roughly circular). In the lower-right frame, the level 1 cross-section is shown again (light gray) and the additional tip area in the cross-section at level 2 is shown as a darker color. (The actual colors of the tip cross-section depend on the color table selected).

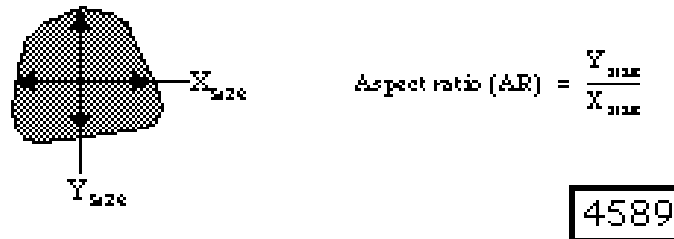
The **Tip Estimation** software then provides two numerical measurements of the tip size and shape: Estimated Tip Diameter (ETD) and aspect ratio (AR). The Estimated Tip Diameter is the diameter of a circle having the same *area* as the measured tip cross-section (See Figure 14.9i).

Figure 14.9i Tip Estimation



The **Aspect Ratio** (AR) is calculated as the ratio of the vertical (y) and horizontal (x) size of the tip as shown in Figure 14.9j.

Figure 14.9j Aspect Ratio



Tip Qualification Status

The **Tip Qualification** software will generate a tip status, depending on the calculated values of Estimated Tip Diameter (ETD), the Aspect Ratio (AR) and user-selected threshold and limit values. For the ETD values, there are two thresholds that affect the tip status:

- **Good/Worn ETD Threshold**— If the ETD is smaller than this number, the tip will usually be characterized as **GOOD**. The threshold diameters are shown as *green* circles on the Display Monitor.
- **Bad/Worn ETD Threshold**— If the ETD is smaller than this threshold, but bigger than the **Good/Worn ETD Threshold**, it is characterized as **WORN**. If the ETD is larger than this number, it is characterized as **BAD**. These threshold diameters are shown as *red* circles on the Display Monitors.

There are two separate sets of ETD thresholds for the two tip levels (ETD 1 at Height 1, and ETD 2 at Height 2). There are also minimum and maximum limits for the tip Aspect Ration (AR) at each level. These limits will detect when the image data produces a tip model of an oblong shape that is not likely to be physically correct. (Usually, induced by an imaging artifact, such as a noise streak not removed by discontinuity rejection.) In most cases these thresholds should not require adjustment.

Setting ETD Thresholds

It takes some experimentation with a particular tip and sample type to find appropriate values for the various thresholds. The basic idea is to find the maximum ETDs (the diameters of the dullest tips) that provide reliable image data. Then set the Bad/Worn ETD Thresholds based on these diameters. Then it is usually desirable to set the Good/Worn ETD Thresholds slightly smaller than the Bad/Worn ETD thresholds.

An additional limit `MIN ETD SIZE` is used to reject Tip Qualification results if the estimated tip shape is unreasonably small (indicating a tip that is sharper than physically likely). This is usually induced by imaging artifacts, such as noise spikes which were not removed by spike rejection. In most cases, this can be set at or near the same value as the Height (from Apex) for each different level. So, if Height 1 = 10 nm, a reasonable value for the Min ETD size is also 10 nm.

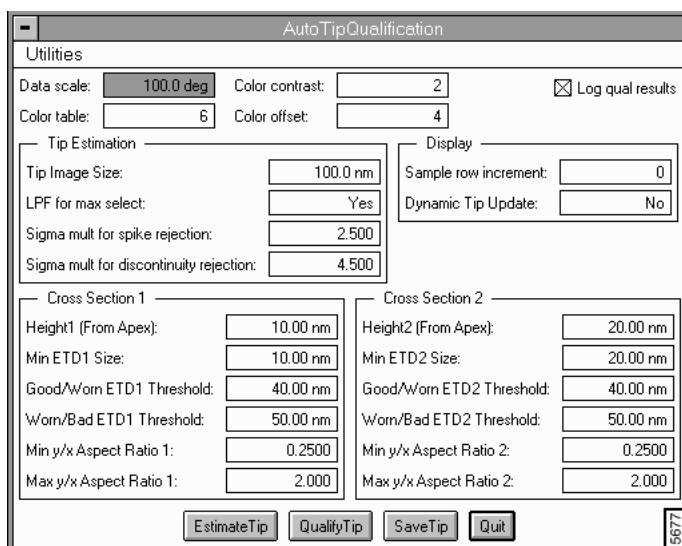
Since the tip estimate is valid only where the tip contacted the sample, ETD heights should be selected to ensure that the tip made “frequent” contact with the sample at those heights. Thus, the ETD heights should be below the sample’s peak-to-valley values. If the ETD heights are too high for the sample, the resultant ETD will tend to be very large and multiple apparent peaks will be found at that height.

14.9.6 Auto Tip Qual Panel

Access the **Automatic Tip Qualification** panel by using the **Off-line / Analyze / Auto Tip Qual** command. However, before accessing the **Auto Tip Qual** command, a qualification image must be loaded first. The sample image must have sufficient surface relief to make tip qualification possible, and produce an ETD that changes in a consistent and predictable fashion as the tip wears.

After the image is loaded, the **Auto Tip Qualification** panel is used to analyze image data and qualify the tip based on parameters set by the user. In the **Off-line/Analyze** menu, select **Auto Tip Qual** to access the **AutoTip Qualification** panel (See [Figure 14.9k](#)).

Figure 14.9k Auto Tip Qualification Panel



Parameters in the Auto Tip Qualification Panel

Parameters at the top of the panel control how the top view image on the left side of the Display Monitor is presented. These function the same as with other **Off-line** features.

Data Scale— Controls the vertical range of the image corresponding to the full extent of the Color Table. The units of this item vary according to the type of image (e.g., nm, μm , etc.).

Color Contrast— Controls the contrast in the image by compressing or expanding the Color Table.

Color Table— Selects the color scheme used to render Z-axis data.

Color Offset— Shifts the Color Table used to render Z-axis data up and down.

Buttons on the Auto Tip Qualification Panel

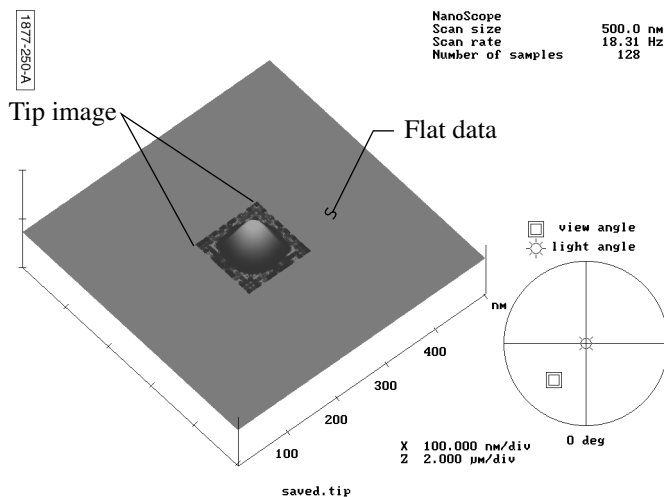
Estimate Tip— Performs a new tip estimation. A rendering of the tip as seen looking down on to the apex is shown in the lower left-hand corner of the Display Monitor. In the upper left hand corner of the screen is shown the original image, with green markers (+) indicating the data peaks used for the estimation. If the Save Tip button is selected, the estimated tip image is saved to a directory. This image can be loaded and analyzed the same as other NanoScope images.

Qualify Tip— Selecting this button results in the following actions:

1. If any “Tip Estimation” parameter or the analysis region has been changed, a new tip estimation is performed.
2. The tip cross sections and qualification results are displayed on the graphics window.
3. Tip status is determined based upon the estimated tip shape.

Save Tip— This saves the estimated tip image as a NanoScope image file, allowing it to be analyzed using the standard NanoScope Off-line / Modify and Analyze functions. Because tip images have fewer data points than a standard image, saved tip images are centered in a large, uniform field of flat data (See Figure 14.91).

Figure 14.91 Tip Image Display



Quit— This will cause the current parameter settings to be written out to the `ATIPQUAL.PAR` file and exit the **AutoTip Qualification** panel.

Tip Estimation Parameters

Tip Image Size— The **Tip Image Size** sets the size of the image displayed in the lower-left corner of the Display Monitor. The calculated tip size will be the smallest size greater than or equal to **Tip Image Size**, as determined by the sample resolution. For example, **Tip Image Size = 120 nm** will result in a tip image approximately 120 nm x 120 nm square.

Tip Image Size also defines the neighborhood size which is used to select the maxima points used for the tip calculation. For example, for **Tip Image Size = 120 nm**, each selected maxima point is the maximum of approximately 120 nm x 120 nm centered about that point. Therefore selected maxima have to be at least 120 nm apart.

Note: Larger **Tip Sizes** results in a smaller number of selected points.

Because more points provide more tip information, it is best to select **Tip Image Size** to be as small as possible while still satisfying the following conditions:

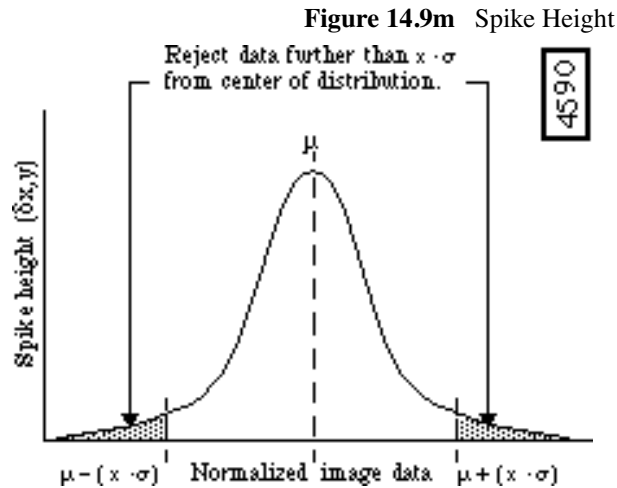
- **Tip Image Size** should encompass a tip shape as far up the shaft of the tip as required to obtain measurements. This can be determined experimentally by varying the **Tip Image Size** and observing the image which results in the lower-left corner of the Display Monitor.

Note: A good starting point for this value is the sum of the maximum allowable tip diameter plus the diameter of a typical feature in the characterizer.

- If and when “double tip” peaks arise due to rough wear, their apexes should be no farther apart than one-half the **Tip Image Size**. This ensures that multiple peaks from a “double tip” feature are not treated as separate features from the same peak (which would produce erroneous results and no longer guarantee an outside tip envelope).

LPF [low pass filter] for max select— Determines whether a Gaussian lowpass filter is applied to the data before identifying selected points. The filtered data is only used for point selection, not for the actual tip calculation. This filter has the effect of reducing noise sensitivity. It is recommended that the filter be turned on (Yes).

Sigma mult[plier] for spike rejection— Sets a threshold for rejection of isolated (upward) noise spikes by distributing data over a Gaussian curve, then rejecting that portion of the data lying beyond $x\sigma$ of the average, where x is the Sigma mult[plier] for spike rejection value and σ is equal to the standard deviation of the spike heights. (See [Figure 14.9m](#)).



In Figure 14.9m, image data is shown normalized in a Gaussian distribution. With the **Sigma mult for spike rejection** value set to 1, all outlying data beyond one standard deviation (shaded regions) would be rejected for purposes of tip estimation.

If **Sigma mult for spike rejection = 0**, noise spike rejection is not performed. If the parameter is > 0, noise spike rejection is performed as follows: for each point x,y in the selected region, the difference $\delta_{x,y}$ between that point and the average of its 8 neighbors is determined. The mean (μ) and standard deviation (σ) of all such positive differences $\delta_{x,y}$ is calculated and all outliers are rejected via the following formula:

$$\delta_{x,y} > \mu + M \cdot \sigma$$

where x,y is a noise spike datum and M is the specified sigma multiplier. A point identified as a noise spike is disqualified from the selected point set S .

Sigma Mult[plier] for Discontinuity Rejection— Similar to Sigma mult for spike rejection (above), this parameter is used to set a threshold for rejection of an entire line of data where a statistical discontinuity is detected, such as when a tip “trips” over features. If Sigma mult for discontinuity rejection = 0, discontinuity rejection is not performed.

If the parameter is > 0, discontinuity rejection is performed as follows: for each row y in the selected region, the average absolute difference δ_y between each point and its immediate neighbor on the next line is calculated. The mean (μ) and standard deviation (σ) of all such average differences δ_y is calculated and all outliers are rejected via the following formula:

$$\delta_y > \mu + M \cdot \sigma$$

where row y is a discontinuity and M is the specified sigma multiplier.

Points which fall within a (tip-sized) neighborhood centered on a discontinuity row are disqualified from the selected point set S . Thus detected discontinuities cannot contribute to the tip estimation. Discontinuity rows are displayed as red horizontal lines on the image display.

Note: Tip Qualification returns **SUSPECT** status whenever discontinuities are detected. In this case, the ETD values will provide additional tip size information.

14.9.7 Auto Tip Qual Display Monitor

Parameters on the Display Monitor control how the graphics display looks whenever tip estimation is performed (See Section 14.9.5). During tip estimation the tip is successively refined as each point in the selected point set S is analyzed. For diagnostic purposes it is often helpful to see the tip shape evolve as it is refined and/or have a visual indication of which selected points in the image are contributing to certain features in the estimated tip shape.

Sample Row Increment— This parameter controls how frequently the row marker is incremented during the tip calculation on the image display. This marker is a yellow line which is updated every I th line, where I is the specified Sample Row Increment. The line corresponds to the current line being analyzed; any selected points in S on this line will be analyzed when the marker is on this line. If this parameter is set to zero, no row marker is displayed.

Dynamic Tip Update— If this option is selected (Yes) the tip display updates after processing each image line. If this option is deselected (No) the tip shape is displayed only after it has been completely estimated. Dynamic Tip Update slows down the tip estimation process but when used in conjunction with Sample Row Increment it is possible to get a good idea of which features in the image are contributing to significant tip features.

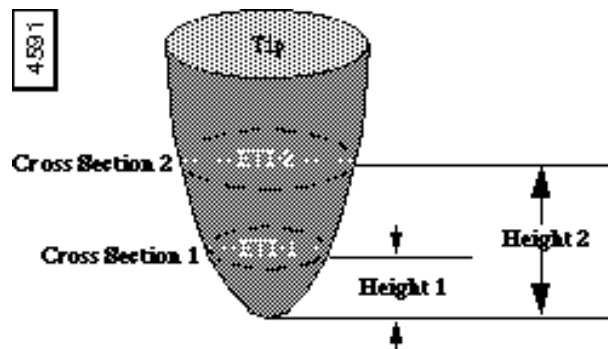
14.9.8 Tip Qualification Parameters

Tips are cross-sectionally analyzed by the software at two separate heights above the apex to determine the tip **Status**. These heights occur at **Cross Section 1** and **Cross Section 2**. Parameters are appended with either a “1” or a “2,” depending upon which cross section they describe, (e.g., **Height 1** and **Height 2**, respectively).

Note: If cross-sectional analysis is desired at only one height, set **Height 1** to **0.00 nm**, and set **Height 2** to the desired value.

Height 1 [Height 2] (From Apex)— Height above the tip apex at which the cross section is defined.

Figure 14.9n Height from Apex



Min ETD1 [ETD2] Size— Minimum estimated tip diameter (ETD) at Cross Section 1 [2]. If the calculated ETD is smaller than Min ETD Size, then TipStatus = SUSPECT.

Good/Worn ETD1 [ETD2] Threshold— If ETDX is smaller than Good/Worn ETD1 [ETD2] Threshold (but greater than Min ETD Size) then Tip Status = GOOD (assuming that no other conditions such as a bad aspect ratio or the presence of discontinuities result in a SUSPECT TipStatus).

Worn/Bad ETD1 [ETD2] Threshold— If ETDX is greater than Good/Worn ETD Threshold but smaller than Worn/Bad ETD Threshold then TipStatus = WORN. If ETDX is greater than Worn/Bad ETD Threshold then TipStatus = BAD.

Min y/x Aspect Ratio 1 [Ratio 2]— If ARX is less than Min y/x Aspect Ratio X, then TipStatus = SUSPECT.

Max y/x Aspect Ratio 1 [Ratio 2]— If ARX is greater than Max y/x Aspect Ratio X, then TipStatus = SUSPECT.

14.9.9 Example: Using the Auto Tip Qualification Command

1. Select Tip Size and Filtering

With the image loaded, enter the **Tip Image Size** desired for the currently loaded tip and characterizer image. Next, select whether or not to apply a low pass filter to the image by selecting either **Yes** or **No** from the **LPF for max select** parameter. **NOTE:** It is generally a good idea to use a low pass filter to ensure that small noise artifacts are removed beforehand. If noise is left in the image, the software may mistake it for an actual feature and render a poor image of the tip. Additionally, large noise artifacts can be selectively removed by adjusting the **Sigma mult for spike rejection** and **Sigma mult for discontinuity rejection** parameters.

2. Enable “Display” Parameters (Optional)

Optionally, parameters within the “Display” box may be used to: 1) detect which features in the image contribute to significant tip features; or, 2) assist with diagnosing any problems that derive from the image. The **Dynamic Tip Update** parameter, in conjunction with the **Sample row increment**, identifies which portion of the image is being analyzed during the **Estimate Tip** command using a horizontal line. Meanwhile, tip shape is dynamically rendered within the “tip” window on the Display Monitor. If a sudden, abrupt change is noted in tip shape, the user should note which portion of the image was being analyzed at the time, then closely examine this portion of the image for noise. If noise is noted, it may be excluded by moving the cursor box to another, noise-free portion of the image, or by adjusting the **Sigma mult for spike rejection** and **Sigma mult for discontinuity rejection** parameters and rerunning the **Estimate Tip** command.

Sample Row Increment— Spacing of rows used to dynamically display the tip estimate.

Range and Settings: **0–100** (in multiples of **5** rows).

Dynamic Tip Update— Enables dynamic tip updating.

Range and Settings: **Yes** = enabled, **No** = disabled.

3. Select **Cross Section 1** and **2** parameters

The selection of tip qualification parameters must be researched beforehand by the user. Each parameter will influence how the tip is qualified and whether or not it is rejected. Depending upon how parameters are set, they will result in one of the following flags. Evaluated in the following order:

- **SUSPECT**— Tips will be qualified as SUSPECT under any of the following conditions:
 - A discontinuity has been found in the data that exceeds the **Sigma mult**[iplier] for discontinuity rejection.
 - One of the aspect ratios of the tip exceeds Y/X or X/Y thresholds.
 - One of the ETDs (ETD1 or ETD2) is smaller than its minimum threshold.
- **GOOD**— Both ETDs are less than the **Good/Worn ETD Threshold** parameter setting.
- **BAD**— At least one of the ETDs is greater than its WORN/BAD threshold or one of the cross-sections intersects a large portion of the tip image boundary.
- **WORN**— At least one of the ETDs falls between its GOOD/WORN and WORN/BAD limits.

14.9.10 Running ETD-based Tip Qualification

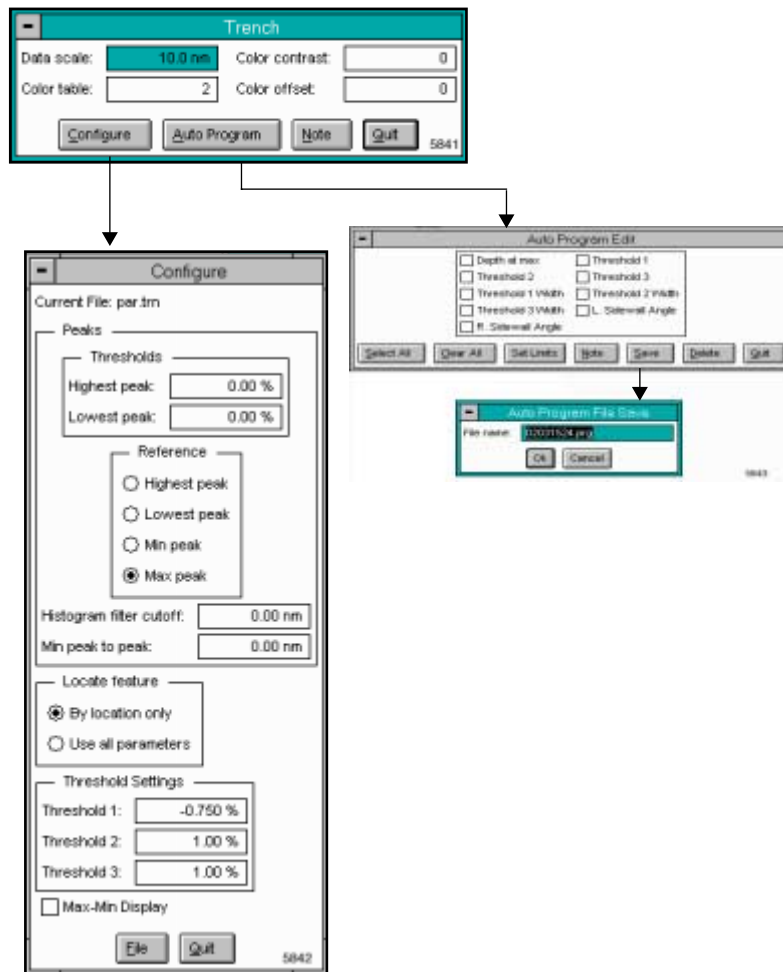
ETD-based tip qualification may be run either manually using the **Off-line / Analyze / Auto Tip Qual** function above, or from a recipe file. For more information on automated capabilities using this feature, see the *Automation Supplement* (Version 5.13) or your system manual.

14.10 Trench

Trench is designed to measure long narrow features on the sample image. The parameter functions are similar to the **Depth** command (See [Section 13.6](#)) and the **Width** command (See [Section 14.11](#)).

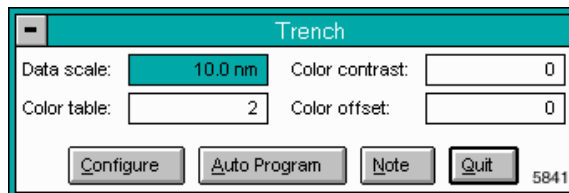
For navigating in the **Trench** panels, see [Figure 14.10a](#).

Figure 14.10a Main Trench Analysis Panels



14.10.1 Trench Panel

Figure 14.10b Trench Panel



Parameters and Buttons on the Trench Panel

Data scale

Controls the vertical range of the image corresponding to the full extent of the color table. The units of this item vary according to the type of image (e.g., nm, nA, etc.).

Color table

Selects the color table used to encode the Z information.

Color contrast

Controls the contrast in the image by compressing or expanding the color table.

Color offset

Shifts the color table used to display the image.

Configure—Accesses the **Width Configure** panel (See [Section 14.11.2](#)).

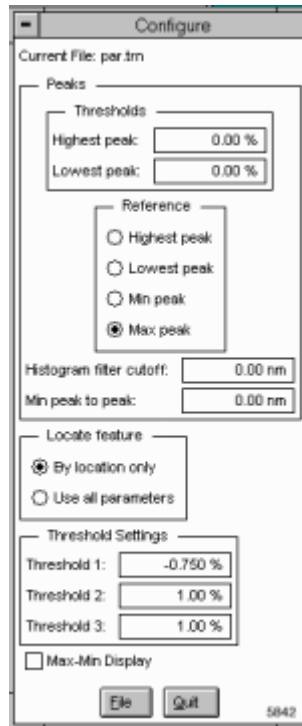
Auto Program—Accesses the **Auto Program Edit** panel ([Section 14.11.4](#)).

Note—Adds a descriptive message and time stamp to the display.

Quit—Exits the **Width** analysis feature.

14.10.2 Trench Configure Panel

Figure 14.10c Trench Configure Panel

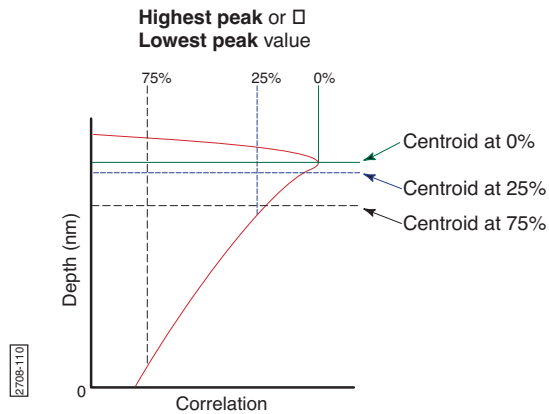


Peaks

Adjusts the minimum and maximum search values in the **Trench** Correlation histogram by adjusting the threshold heights
(See [Figure 14.10d](#)).

Note: The Correlation histogram defines which peak to use for a reference height.

Figure 14.10d Peaks Correlation Histogram



Thresholds

Establishes the height and depth thresholds when calculating the centroid.

- **Highest Peak**—Value defines how much of the **Highest peak** is included when calculating the centroid. At 0%, only the maximum point on the curve is included. At 25%, only the maximum 25% of the peak is included in the calculation of the centroid.
- **Lowest Peak**—Value used to define how much of the **Lowest peak** is included when calculating the centroid. At 0%, only the maximum point on the curve is included. At 25%, only the maximum 25% of the peak is included in the calculation of the centroid.

Reference

You may specify a reference point for the green cursor. This feature is useful for repeated, identical measurements on similar samples. For example, the green slider cursor is moved to a specific point on the Correlation histogram. That point is remembered (saved) as a distance from whatever reference peak you choose.

- **Highest Peak**—Topmost peak in the Correlation histogram
- **Lowest Peak**—Peak closest to the bottom in the Correlation histogram
- **Min peak**—Shortest (smallest) peak in the curve
- **Max peak**—Tallest peak in the Correlation histogram

Histogram filter cutoff

Lowpass filter which smooths out the wavelengths that lie below the cutoff. Used to reduce noise in the Correlation histogram.

Min peak to peak

Sets the minimum distance between the maximum peak (green cursor) and the second peak (red cursor). The second peak is the next largest peak to meet this distance criteria.

Locate Feature

Saves location information to a configuration file.

- **By location only**—Saves location information only in one parameter (location in X, Y, and Z). Note that this function analyzes the feature CLOSEST to the feature position established during the original configuration.

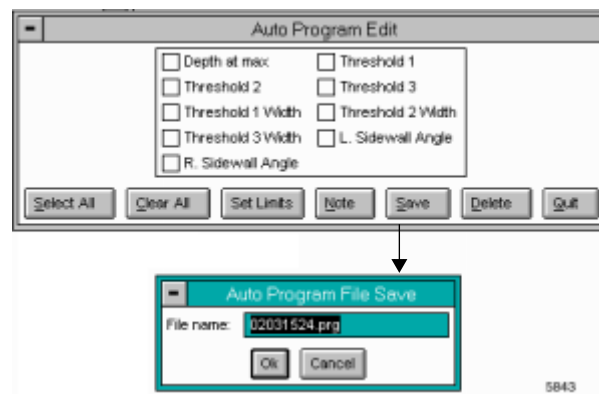
Use all parameters—Saves location information based on several parameters, including: location, area, width, length, and height. This function searches the entire image and finds the feature most closely matching the size of the feature established during the original configuration.

14.10.3 Trench Auto Program Edit Panel

Adds or deletes the **Trench** command from the currently selected **Auto Program** file. A panel listing measurements reported by the **Trench** command is displayed. Selecting a measurement stores it in the data file when **Auto Program** is run.

Note: The measurement selections vary depending on the setting of the **Measure** feature in the display screen.

Figure 14.10e Trench Auto Program Edit Panel



Buttons in the Auto Program Edit Panel

Select All—Selects all the measurements simultaneously.

Clear All—Clears all the measurements simultaneously.

Note—Allows you to insert a command note in the Auto Program file.

Set Limits—Sets specific limits for a given value, as well as a % limit on the total. Limits may be set only for non-planar, non-circular **Width** measurements.

Save—Saves selected measurements to the Auto Program file. If the **Trench** command is already in the current Auto Program file, it retains its position in the file.

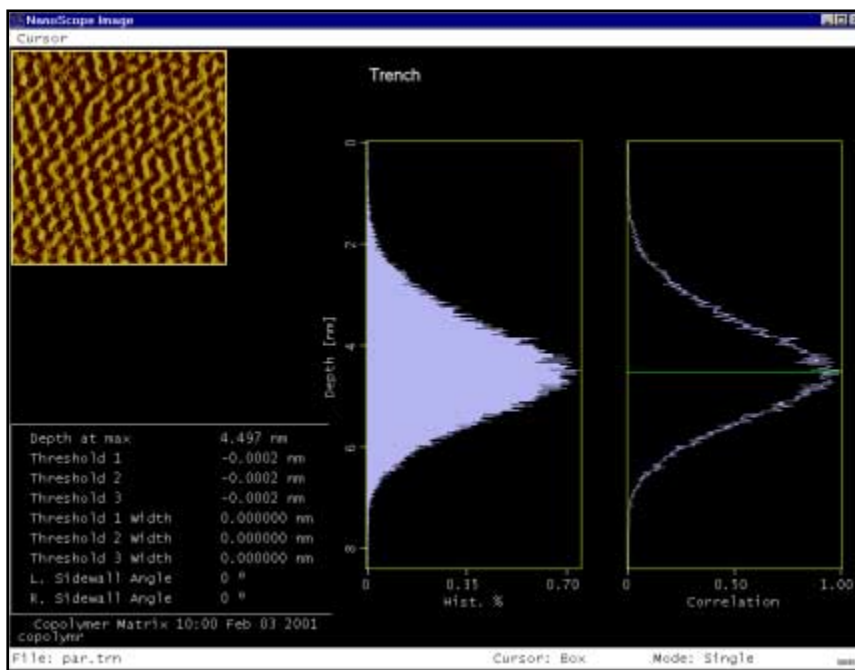
Delete—Removes the **Width** command from the Auto Program file.

Quit—Exits the Auto Program Edit mode without making changes to the Auto Program file.

14.10.4 Trench Display Monitor

The **Trench** Display Monitor includes a menu bar command (**Cursor**) for selecting features on the image to analyze, two Histograms, a data box and status bar. The histograms include a Correlation and Trench Histogram for determining the exact measurements for specified features (e.g., **Depth at Max[imum]** and **Width**) (See [Figure 14.10f](#)).

Figure 14.10f Trench Display Monitor



14.11 Width

To analyze the width of features, you have two choices from the **Analyze** menu: **Width** and **Section**. It is also possible to measure features on images loaded into the **Off-line / View / Top**

View feature. This portion of the chapter is devoted to the **Width** command, which is designed to automatically measure the width of features on large numbers of identical images (e.g., silicon wafers). The **Section** command (discussed in the “Section” portion of this chapter) is better suited for analyzing unique, one-of-a-kind sample surfaces.

The **Width** command is designed to automatically measure width between features distinguished by height, such as trenches and raised features.

This algorithm utilizes many of the same functions found in **Depth** and **Grain Size** analysis by accumulating height data within a specified area, applying a Gaussian low-pass filter to the data (to remove noise), then rapidly obtaining height comparisons between two dominant features. For example, 1) the depth of a single feature and its surroundings; or, 2) depth differences between two or more dominant features. Although this method of width measurement does not substitute for direct, cross-sectioning of the sample, it does afford a means for comparing feature widths between two or more similar sites in a consistent, statistical manner.

The **Width** command is best applied when comparing similar features on similar sites. Width measurement on dissimilar sites is better performed using the **Section** command, or from **View / Top View**.

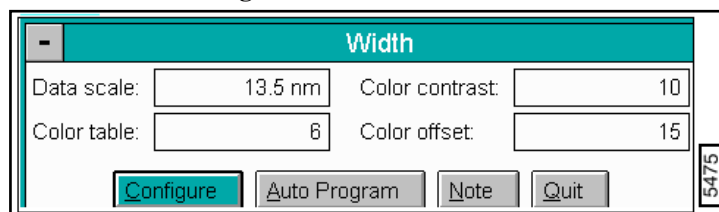
Refer to the following section on Width analysis:

- **Width Panel** [Section 14.11.1](#)
- **Width Configure Panel** [Section 14.11.2](#)
- **Auto Program Edit Panel** [Section 14.11.4](#)
- **Width Display Monitor** [Section 14.11.5](#)
- **Width Example** [Section 14.11.6](#)
- **Interpreting Width Data** [Section 14.11.7](#)

14.11.1 Width Panel

Clicking on the **Analyze / Width** command accesses the **Width** panel.

Figure 14.11a Width Panel



Parameters on the Width Panel

Data scale

Controls the vertical range of the image corresponding to the full extent of the color table. The units of this item vary according to the type of image (e.g., nm, nA, etc.).

Color table

Selects the color table used to encode the Z information.

Color contrast

Controls the contrast in the image by compressing or expanding the color table.

Color offset

Shifts the color table used to display the image.

Buttons on the Width Panel

Configure—Accesses the **Width Configure** panel (See [Section 14.11.2](#)).

Auto Program—Accesses the **Auto Program Edit** panel ([Section 14.11.4](#)).

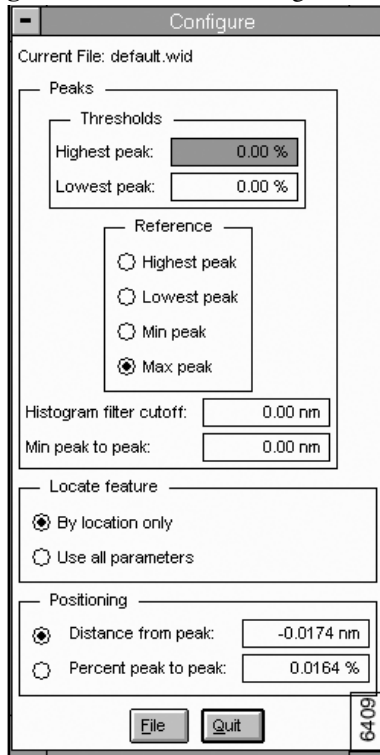
Note—Adds a descriptive message and time stamp to the display.

Quit—Exits the **Width** analysis feature.

14.11.2 Width Configure Panel

Cursors applied to the filtered data histogram serve two functions: 1) to identify surface features for measurement and comparison; 2) to facilitate rapid recognition of curve components by the computer. The Configure button in the Width panel accesses the Configure panel. This box displays, loads and deletes preexisting configuration files, and initiates new ones (See [Figure 14.11b](#)).

Figure 14.11b Width Configure Panel



Buttons on the Width Configure Panel

File—Accesses the **Configuration file list** panel. The list button commands are as follows:

- **Load**—Loads the specified **Depth Configure** file.
- **Save**—Saves the current settings as a **Depth Config** file.
- **Delete**—Deletes the specified **Depth Configure** file.
- **Quit**—Quits the **Configuration file list** window.

Quit—Exits the width **Configure** panel.

14.11.3 Parameters on the Width Configure Panel

Locate Feature

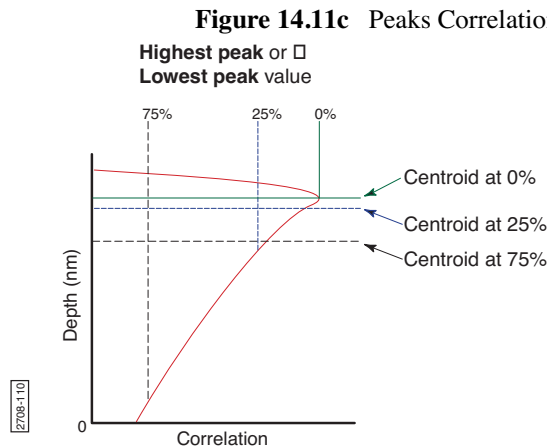
Saves location information to a configuration file.

- **By location only**—Saves location information only in one parameter (location in X, Y, and Z). Note that this function analyzes the feature CLOSEST to the feature position established during the original configuration.
- **Use all parameters**—Saves location information based on several parameters, including: location, area, width, length, and height. This function searches the entire image and finds the feature most closely matching the size of the feature established during the original configuration.

Peaks

Adjusts the minimum and maximum search values in the **Width** Correlation histogram by adjusting the threshold heights (See [Figure 14.11c](#)).

Note: The Correlation histogram defines which peak to use for a reference height.



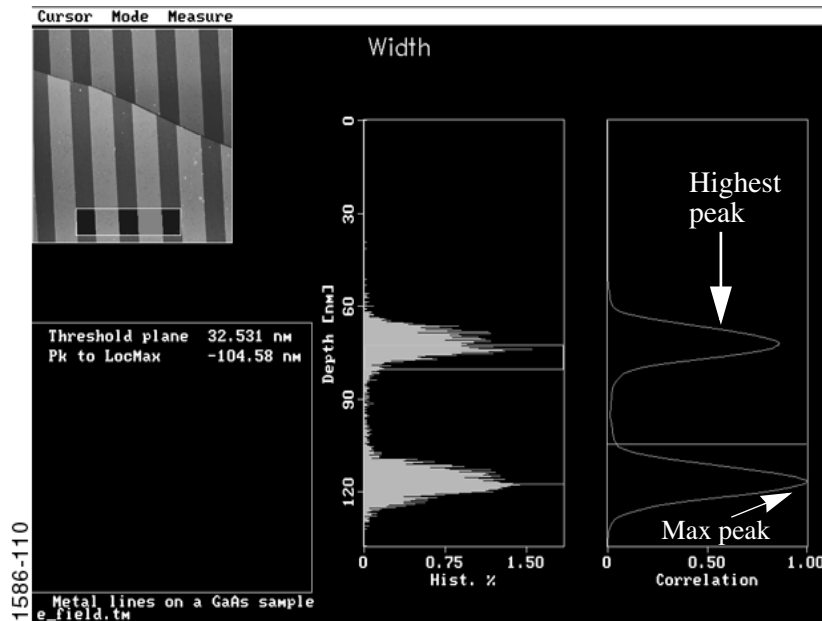
Note: Centroid is a weighted average of points on a curve.

Thresholds

Establishes the depth threshold when calculating the centroid.

- **Highest Peak**—Value defines how much of the **Highest peak** is included when calculating the centroid. At 0%, only the maximum point on the curve is included. At 25%, only the maximum 25% of the peak is included in the calculation of the centroid (See [Figure 14.11d](#)).

Figure 14.11d Width Display



- **Lowest Peak**—Value used to define how much of the **Lowest peak** is included when calculating the centroid. At 0%, only the maximum point on the curve is included. At 25%, only the maximum 25% of the peak is included in the calculation of the centroid.

Reference

You may specify a reference point for the green cursor. This feature is useful for repeated, identical measurements on similar samples. For example, the green slider cursor is moved to a specific point on the Correlation histogram. That point is remembered (saved) as a distance from whatever reference peak you choose.

- **Highest Peak**—Topmost peak in the Correlation histogram
- **Lowest Peak**—Peak closest to the bottom in the Correlation histogram
- **Min peak**—Shortest (smallest) peak in the curve
- **Max peak**—Tallest peak in the Correlation histogram

Histogram filter cutoff

Lowpass filter which smooths out the wavelengths that lie below the cutoff. Used to reduce noise in the Correlation histogram.

Peak Average Factor

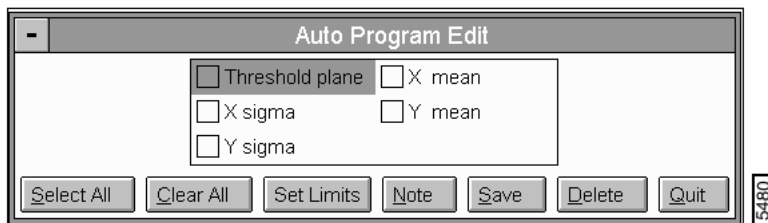
Analysis Commands (M-Z) of averaging the height histogram data to eliminate extraneous peaks.
Width When Peak Avg. Factor is set to 4, the height histogram data of four peaks is averaged out and displayed as one peak in the correlation data.

14.11.4 Auto Program Edit Panel

Adds or deletes the **Width** command from the currently selected **Auto Program** file. A panel listing measurements reported by the **Width** command is displayed. Selecting a measurement stores it in the data file when **Auto Program** is run.

Note: The measurement selections vary depending on the setting of the **Measure** feature in the display screen. The following values are for the *Linear Dimensions* setting (See [Figure 14.11e](#)).

Figure 14.11e Width Auto Program Edit Panel



Buttons in the Auto Program Edit Panel

SELECT ALL—Selects all the measurements simultaneously.

CLEAR ALL—Clears all the measurements simultaneously.

NOTE—Allows you to insert a command note in the Auto Program file.

SET LIMITS—Sets specific limits for a given value, as well as a % limit on the total. Limits may be set only for non-planar, non-circular **Width** measurements.

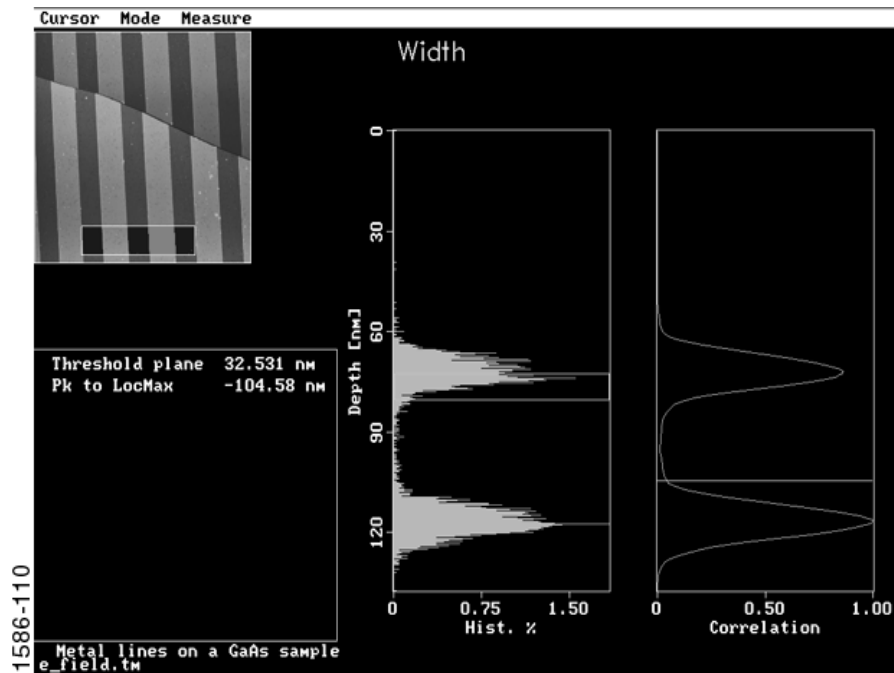
SAVE—Saves selected measurements to the Auto Program file. If the **Width** command is already in the current Auto Program file, it retains its position in the file.

DELETE—Removes the **Width** command from the Auto Program file.

QUIT—Exits the Auto Program Edit mode without making changes to the Auto Program file.

14.11.5 Width Display Monitor

Figure 14.11f Width Display Screen



The display screen includes a top view image and two histograms. Statistical width data is displayed near the lower-left corner of the screen. By using the mouse, the topview image allows a bounding box to be superimposed over it, defining the area where width is to be analyzed. The left histogram displays the raw depth data as depth-vs-histogram area. The right histogram displays a Gaussian-filtered version of the same data. In both histograms, depth data is distributed proportional to its occurrence within the defined bounding box. For example, in the example shown above, most of the surface (where the histogram peaks horizontally) lies near a depth of approximately 75 and 120 nm.

When the **Width** command is opened, the most recent configuration file sets the **Threshold plane** and measure a feature. Temporary adjustments to the **Width** measurement functions may be made by adjusting the box cursor and/or sliders on the Display Monitor.

These adjustments are not saved and are immediately reset to the current configuration file while in the function. If these settings need to be saved, a new configuration file may be created.

Width Display Menu Commands

Cursor

Allows to select different types of cursors for different types of image data selection.

- **Box cursor**—The mouse draws a white box on the image. Area within the box is analyzed.
- **Feature select**—The mouse is used to include a feature in **Width** analysis.
- **Feature de-select**—The mouse is used to exclude a feature from **Width** analysis.
- **Line**—Allows you to cut a portion of a feature or allows you to divide one feature in to two parts.

Mode

Switches **Width** analysis between single and multiple features.

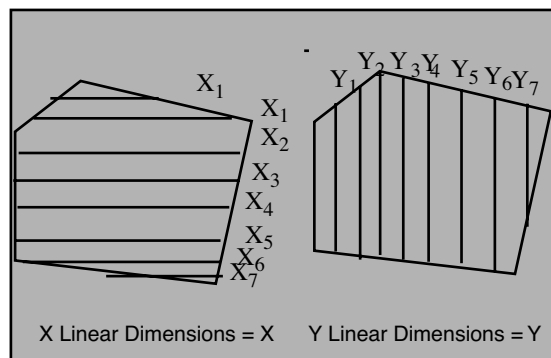
- **Single feature**—**Width** analysis is performed on one feature only.
- **Multiple feature**—**Width** analysis is performed on two or more features.

Measure

Determines the manner in which features are to be measured using **Width** analysis.

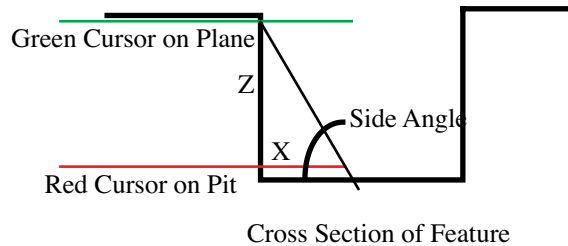
- **Circular dimensions**—Measures features in terms of area and diameter. This form of measurement may be preferable for certain types of features, such as grains and holes.
- **Linear dimensions**—Measures features in the X or Y direction (width and length) and calculates the mean value.

Figure 14.11g Linear Measurement



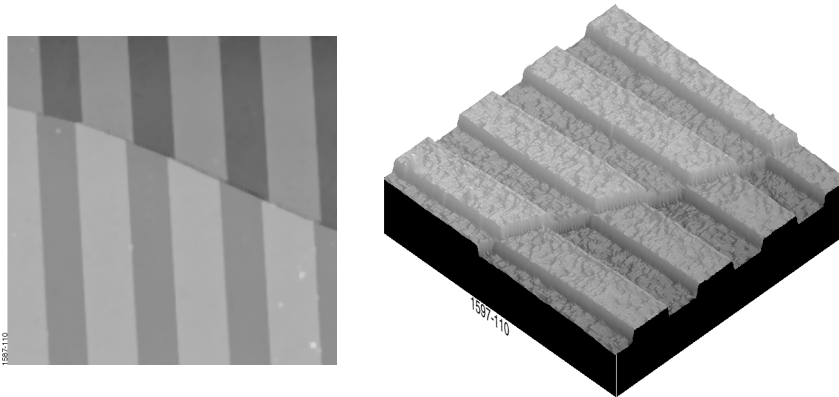
- **Height**—For raised features (bumps)—measures vertical distance between highest point of the selected feature and the reference peak. For depressed features (holes, trenches)—measures vertical distance between lowest point of the selected feature and the reference peak.
- **Side angle**—Measures angles on right and left sides selected feature (See

Figure 14.11h Side Angle Measurement



14.11.6 Width Example

Figure 14.11i Electric Field Image



The 35.12-micron image above reveals metal lines on a gallium arsenide sample. The sample is broken, creating four separate height levels. For this example, we are measuring a series of lines in the upper portion of the image. **Width** is to be measured from the left to right sides of a raised feature.

Sample Width Procedures for Electric Field Sample

1. Load the image “**e_field.tm**” in the images directory.

Note: The file “**e-field.tm**” is included with the images disk which accompanies most recent software versions.

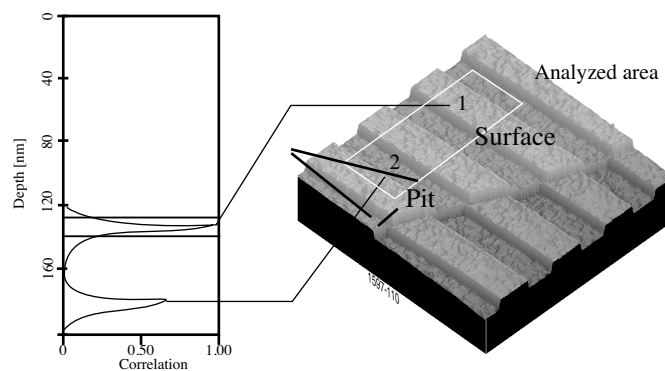
2. Before doing any **Width** analysis, first ensure the image is plane fit by clicking on **Modify / Plane Fit** (Manual or Automatic). Use a plane fit along the image’s X- and Y-axes (**Planefit order = 1**).

Note: To obtain accurate depth comparisons between two or more identical images, each image must be plane fit before commencing **Width** analysis. Tilted images introduce inconsistencies to measurements.

3. Next, load the plane fitted image into the **Analyze / Width** function by clicking on **Analyze / Width**.
4. Click on the **Configure** button to begin configuring for the image. Select the appropriate parameters for measurement (See [Figure 14.11b](#)).
5. Click on **Measure/Linear** dimensions and then select **Mode/Multiple** features.
6. Use the mouse to move the cursor to the Display Monitor, then draw a box cursor on the top view image similar to the one in the example figure above.

Histograms for depth data are presented on the right side of the screen. The histogram peaks correspond to the different parts of the image (See [Figure 14.11j](#)).

Figure 14.11j Width Histogram Analysis



7. Move the green cursor in the right Gaussian Filtered histogram to define a threshold where the desired raised lines are separated from the lower areas between the lines.
8. Select **Cursor** in the display menu, then select **Feature select**. Click on the desired lines (features) to be measured.
The linear width values (X mean) display in the lower-left data box.

14.11.7 Interpreting Width Data

The Display Monitor lists all information regarding width analysis within the bounding box. The information varies depending on the selection in the **Measure** menu (at the top of the Display Monitor).

Note: Define the **Threshold plane** value. Except for the Side Angle value, all other values in the **Measure** menu are calculated or measured values. If no **Threshold plane** is set, a default value is set by the software.

Height

- **Threshold plane**—Depth from the selected peak to the plane which defines the cutoff level of continuous features.
- **Pk to LocMax**—Depth from reference peak to the highest point in the feature selected by the Threshold plane and Feature select.
- **Pk to LocMin**—Depth from reference peak to the lowest point in the feature selected by the Threshold plane and Feature select.

Side Angle

- **Threshold plane**—Depth from the selected peak to the plan which defines the cutoff level of continuous features. Also defines one pair of X-Z data points for slope calculation.
- **Bottom plane**—Depth from selected peak to the level at which the second set of X-Z data points are measured.
- **Left side angle**—Left wall angle of feature
- **Right side angle**—Right wall angle of feature

Linear Dimensions

- **Threshold plane**—Depth from the selected peak to the plan which defines the cutoff level of continuous features.
- **X mean**—The average of all the highlighted X values within the enclosed area.
- **X sigma**—The standard deviation of the measured X values.
- **Y mean**—The average of all the highlighted Y values within the enclosed area.
- **Y sigma**—The standard deviation of the measured Y values.

Circular Dimensions

- **Threshold plane**—Depth from the selected peak to the plan which defines the cutoff level of continuous features.
- **Area**—The area of the circle defined by the feature.

Analysis Commands **Diameter**—Diameter of the circle defined by the feature.

Width

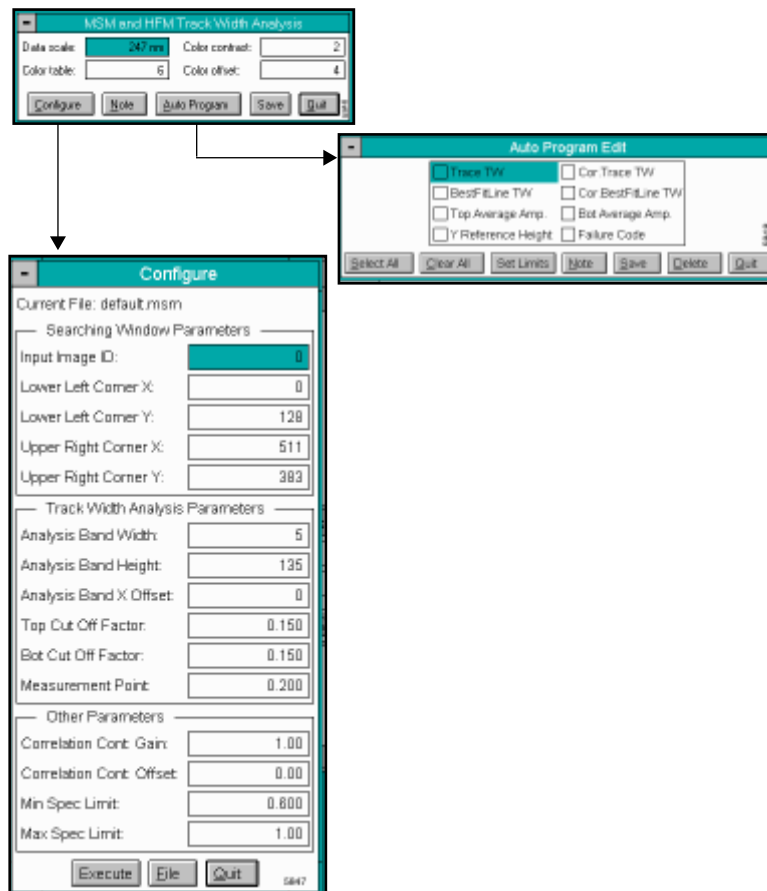
14.12 MSM and HFMM

MSM and HFMM are AFM measurement tools typically used to measure magnetic field characteristics and the Magnetoresistive (MR) read sensitivity of data storage products (write/read heads used in disk and tape mass storage).

14.12.1 MSM and HFMM Panels

In the **Analyze** menu, select **MSM and HFMM** for navigating in the MSM and HFMM Track Width Analysis (See Figure 14.12a).

Figure 14.12a MSM and HFMM Main Panels



MSM and HFMM Track Width Analysis Panel

This panel allows to configure the display image colors, contrast and offset of colors for interpreting the analysis. The buttons on the panel access a **Configure** panel to define an area to

analyze (See Section 14.12.2), save trace and correlation parameters, and set limits in an Auto Program file.

14.12.2 MSM and HFMM Configure Panel

Figure 14.12b MSM Configure Panel

Configure

Current File: 2to1msm.msm

Searching Window Parameters

Input Image ID: 3

Lower Left Corner X: 0

Lower Left Corner Y: 127

Upper Right Corner X: 511

Upper Right Corner Y: 383

Track Width Analysis Parameters

Analysis Band Width: 10

Analysis Band Height: 200

Analysis Band X Offset: 0

Top Cut Off Factor: 0.200

Bot Cut Off Factor: 0.200

Target Threshold: 0.500

Other Parameters

Correlation: Slope: 1.00

Correlation: Offset: 0.00

Min Spec Limit: 0.100

Max Spec Limit: 1.00

Use 0 (Zero) As Low Reference

Use Top_Average As High Reference

Use Best_Fit_Line TW' With Spec Limits

Search Target Y Position First

Execute File Quit 5847

Parameters and Buttons on the Configure Panel

Searching Window Parameters—Defines the area of data to be analyzed for Reader width and amplitude within a 1:1 aspect ratio image. A rectangular window is determined from the coordinates assigned by the **Lower Left Corner X-Y** to the **Upper Right Corners X-Y** (See Figure 14.12c).

- **Input Image ID**—Selects the image to be analyzed. 0 is default, 1 is the left image, 2 and 3 are the middle and right images.

- **Lower Left Corner X**—The pixel location of the lower left corner of the search window on the X-axis. *Range:* 0-512
- **Lower Left Corner Y**—The pixel location of the lower left corner of the search window on the Y-axis. *Range:* 0-512.
- **Upper Right Corner X**—The pixel location of the upper right corner of the search window on the X-axis. *Range:* 0-512.
- **Upper Right Corner Y**—The pixel location of the upper right corner of the search window on the Y-axis. *Range:* 0-512.

Figure 14.12c MSM Defining Window Parameters

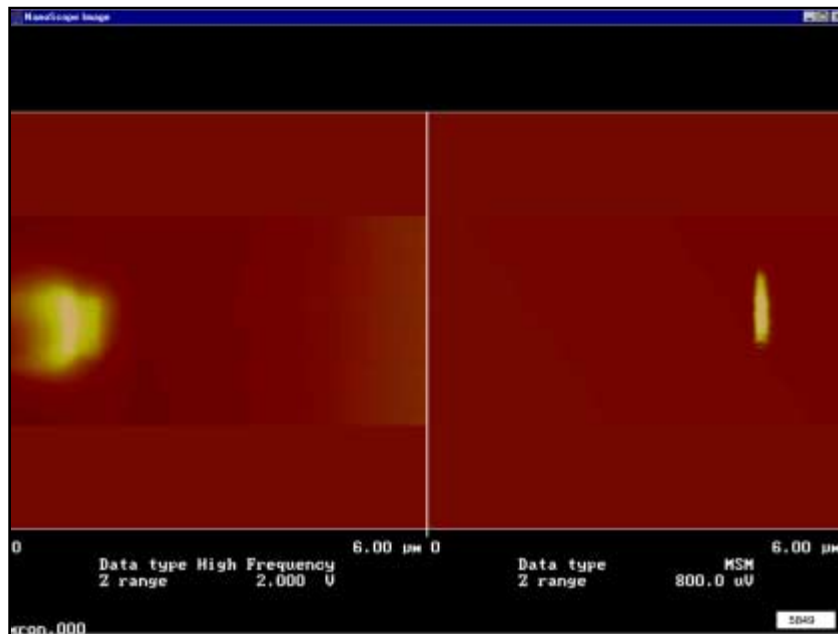


Figure 14.12c represents **HF MFM** and **MSM** images captured in a single scan of an active GMR disk head with the inductive write portion of the head indicated by the left image and the Magneto Resistive reader indicated by the right. **MSM and HF MFM Analysis (Off-line / Analyze / MSM and HF MFM)** is used to analyze both scans individually and return width, amplitude and position information. Position information is useful in determining Y offset values between the write and read elements of the head.

Track Width Analysis Parameters—Defines the location of the top edge of the Mid Shield (See Figure 14.12d).

- **Analysis Band Width**—Width of the searching box in pixels. *Range:* 1-512.
- **Analysis Band Height**—Height of the searching box in pixels. *Range:* 10-512.

- **Analysis Band X Offset**—Offsets the analysis band in the X direction, by the number of pixels specified. A negative number offsets the band to the left of the peak value. *Range:* 0-512.
- **Top Cut Off Factor**—Percent of data excluded at top for best-fit line calculation from high reference to low reference. *Range:* 0.05-0.950.
- **Bot Cut Off Factor**—Percent of data excluded at bottom for best-fit line calculations from the low reference to high reference. *Range:* 0-1.00.
- **Target Threshold**—Threshold, in percent, to find the edge between the high and low reference levels. *Range:* 0.05-0.950.

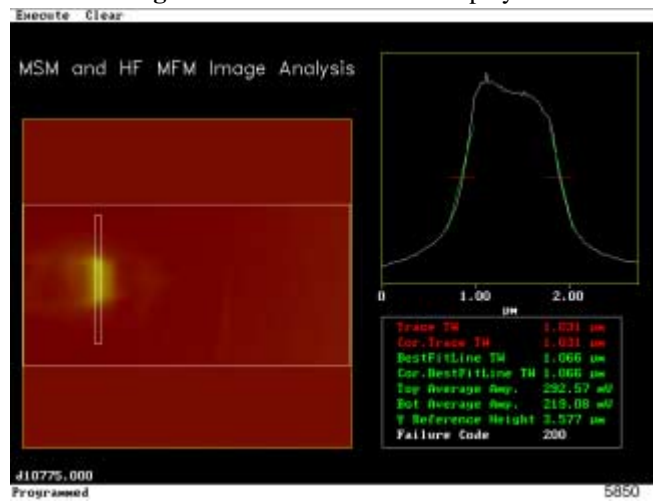
Other Parameters

- **Correlation Slope**—A gain value that can be applied to track width results to fine tune different systems into agreement. The ‘M’ in $MX+B$. *Range:* -1000-1000.
- **Correlation Offset**—An offset value that can be applied to track width results to fine tune different systems into agreement. The ‘B’ in $MX+B$. *Range:* -2000-2000.
- **Min Spec Limit**—Acceptance criteria lower value. *Range:* 0-1000.
- **Max Spec Limit**—Acceptance criteria upper value. *Range:* 0-1000.

Reference Preferences

- **Use 0 (Zero) As Low Reference**—If selected, the low reference value is the average of the two end values of the analysis band.
- **Use Top_Average As High Reference**—If selected, the high reference value is the average of the data in the area of the Analysis Band determined by Top Cut Off Factor (2d). If unchecked, the high reference value is the maximum data value in the Analysis Band.
- **Use Best_Fit_Line TW With Spec Limits**—If selected, the specification limits set in 3c,d are applied to best-fit line track width for failure codes. If unchecked o, the specification limits are applied to trace track width.
- **Search Target Y Position First**—If selected, the system searches the image for the peak value of each scan line in the Y direction. If not selected, images are searched in the X direction.
For example in [Figure 14.12d](#) X direction search is appropriate (i.e., not selected) if the image was rotated 90°, Y direction (selected) search would be appropriate.

Figure 14.12d MSM Data Display



Failure Codes on the MSM and HFMM Display Monitor

- **0**—Failed to find a target in any of the search windows or analysis bands.
- **20**—Failed to derive a Track Width result.
- **100**—Failed the lower Spec. Limit.
- **200**—Failed the upper Spec. Limit.

Chapter 15 Modify Menu

The commands in the **Modify** menu enhance image features, eliminate noise, correct for bow and tilt and isolate specific features. These operations process the captured/stored image, then produce another (modified) version.

Note: Before modifying images, *always* make a backup copy of the original. This allows more freedom to experiment with images without the risk of losing them.

A number of books have been written on the subject of image processing. **Digital Instruments Veeco Metrology Group** recommends two excellent books on the subject by John C. Russ: *The Image Processing Handbook*, 1992, CRC Press, Inc., Boca Raton; and, *Computer-Assisted Microscopy, The Measurement and Analysis of Images*, 1992, Plenum Press, New York.

15.1 Overview of the Modify Commands

15.1.1 Contents of the Modify Menu

This chapter discusses the following **Modify** menu commands:

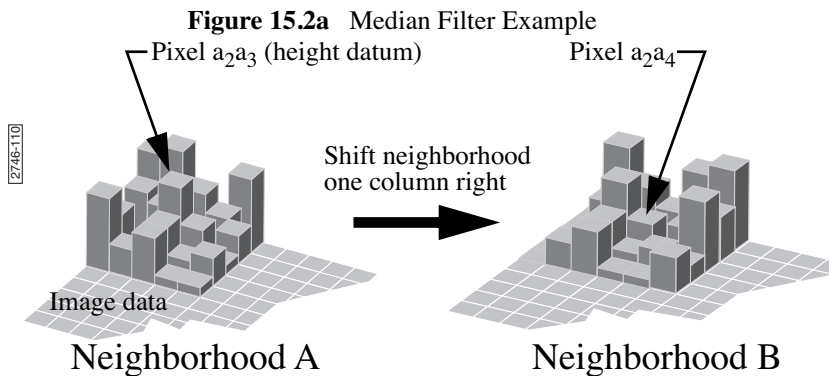
- **Clean Image** [Section 15.3](#)
- **Contrast Enhancement** [Section 15.4](#)
- **Convolution** [Section 15.5](#)
- **Detrend** [Section 15.6](#)
- **Edge Enhance** [Section 15.7](#)
- **Erase Scan Lines** [Section 15.8](#)
- **Flatten** [Section 15.9](#)
- **Gaussian** [Section 15.10](#)
- **Geometric** [Section 15.11](#)

15.2 Image Filtering using Data Matrix (Kernel) Operations

A number of **Offline / Modify** image filters use matrix operations to achieve their effects. The matrix operations include:

- Clean Image
- Convolution
- Gaussian
- Highpass
- Lowpass
- Median

In each of these commands, data is analyzed in kernels (matrices), with every pixel individually recalculated based upon its neighboring values. For example, data which is undergoing a **Median** filter applies a 3 x 3 or 5 x 5 matrix operation to each image pixel. (Most filters utilize 3 x 3 matrices.)



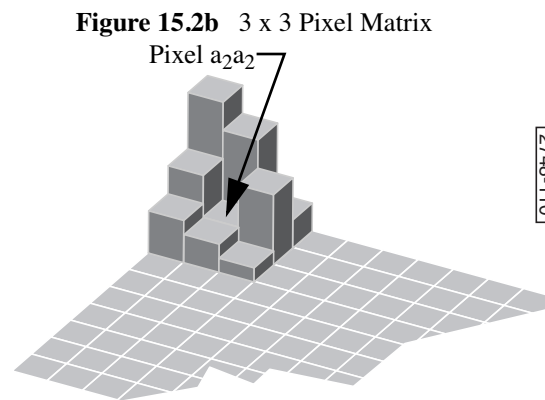
In the example in [Figure 15.2a](#), each pixel is individually evaluated within its own local, 5 x 5 “neighborhood.” Neighborhood “A” has pixel a_{2a_3} at its center. For a **Median** filter, the 25 pixels in neighborhood A are evaluated to locate the median value pixel. The median value of neighborhood A is then mapped to a

The matrix is shifted over one column to define a new neighborhood (“B”) with pixel a_{2a_4} at its center.

The median value for neighborhood “B” is found, then mapped to pixel a_{2a_4} in the separate data set. The filtering process is repeated until all pixels have been remapped.

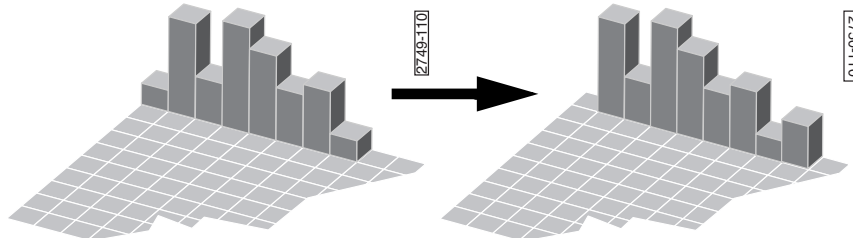
Note: In this and all other matrix operations, pixels are mapped to the new, separate data set without changing pixel values in the original image data until saved. (Matrices do not operate cumulatively on previously filtered data.) Filters include averaging (e.g., **Lowpass** filter) and non-averaging (e.g., **Highpass**) types.

Most filters utilize 3 x 3 pixel matrixes, which tend to confine any averaging effects to smaller areas. They process image data in a manner similar to the 5 x 5 matrix example in [Figure 15.2b](#).



Gaussian filters utilize a 1 x N matrix, where N is determined by the **Filter size** parameter. In this instance, image data is analyzed in two-dimensional matrices which are shaped to a Gaussian curve where the sigma value (σ) is determined by the **Filter cutoff** parameter. (See [Section 15.10](#).)

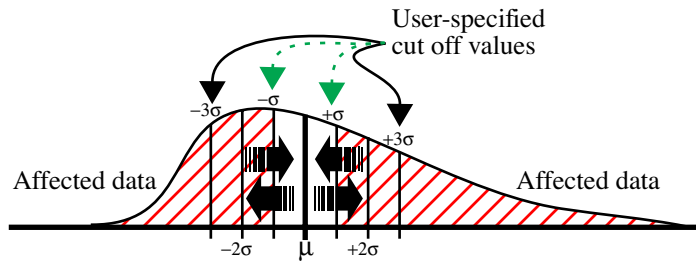
Figure 15.2c Gaussian Filter Example



15.3 Clean Image

The **Clean Image** command is used to smooth noisy image data within the cursor box you specify. The **Spike cut off** and **Streak cut off** commands define sigma cut-offs for spikes and streaks, respectively. Data points lying beyond the mean \pm designated sigma values (σ) are replaced with the mean data value.

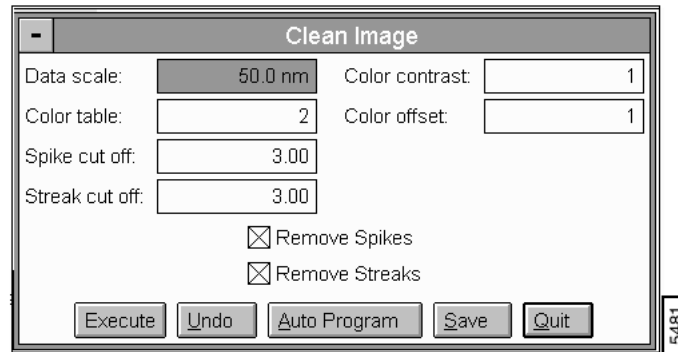
Figure 15.3a Clean Image Diagram



15.3.1 Clean Image Panel

The **Clean Image** panel allows filter and display parameters to be adjusted (See [Figure 15.3b](#)).

Figure 15.3b Clean Image Panel



Parameters on the Clean Image Panel

Data scale

Controls the vertical range of the image corresponding to the full extent of the color table. The units of this item vary according to the type of image (e.g., nm, nA, etc.)

Color table

Selects the color table used to encode the Z information.

Color contrast

Controls the contrast in the image by compressing or expanding the **Color Table**.

Color offset

Shifts the color table used to display the image.

Spike cut off

Number of sigma values to use as the cut off point for spike data. Data points lying outside the mean \pm Spike cut off sigma value(s) are replaced by the mean data value.

Range and Settings:

- **0—10**

Streak cut off

Number of sigma values to use as the cut off point for streak data. Data points lying outside the mean \pm Streak cut off sigma value(s) are replaced by the mean data value.

Range and Settings:

- **0—10**

Remove Spikes

Enables the **Spike cut off** value and applies it to data within the cursor box you specify.

Remove Streaks

Enables the Streak cut off value and applies it to data within the cursor box you specify.

Buttons on the Clean Image Panel

Execute—Executes the filter.

Undo—Restores the image to its original form.

Auto Program—Accesses the Auto Program Edit panel on the Control Monitor, allowing the **Clean Image** command to be added to, or deleted from, the currently selected Auto Program file (See [Section 15.3.2](#)).

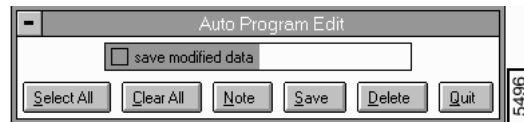
Save—Allows the converted image to be saved to the disk.

Quit—Exits the **Clean Image** command.

15.3.2 Clean Image Auto Program Edit Panel

The **Auto Program Edit** panel allows the **Clean Image** command to be added or deleted to the currently selected Auto Program file (See [Figure 15.3c](#))

Figure 15.3c Auto Program Edit Panel



Buttons on the Auto Program Edit Panel

Select All—Selects all the measurements simultaneously.

Clear All—Clears all the measurements simultaneously.

Note—Allows you to insert a command note in the Auto Program file.

Save—Saves selected measurements to the Auto Program file. If the **Lowpass** command is already in the current Auto Program file, it retains its position in the file.

Delete—Removes the **Clean Image** command from the Auto Program file.

Quit—Exits the Auto Program Edit mode without making changes to the Auto Program file.

Note: The Auto Program File command in the **Utility** menu must be used to select or create an Auto Program file.

Note: The **Auto** subcommand under the **Browse** command selects the files to be processed and executes the current Auto Program file.

15.4 Contrast Enhancement

The **Contrast Enhancement** command runs a statistical differencing filter on the current image. This filter can bring all the features of an image to the same height and equalize the contrast between all the features. This allows all features of an image to be seen simultaneously. **Contrast**

Enhancement distorts height information, so quantitative measurements performed after running this filter are inaccurate.

15.4.1 Contrast Enhancement Panel

The **Contrast Enhancement** panel allows filter and display parameters to be adjusted (See [Figure 15.4a](#)).

Figure 15.4a Contrast Enhancement Panel



Buttons on the Contrast Enhancement Panel

Execute—Executes the filter.

Undo—Restores the image to its original form.

Save—Allows the converted image to be saved to the disk.

Auto Program—Allows the **Contrast Enhancement** command to be added or deleted to the currently selected Auto Program file (See [Section 15.4.2](#)).

Quit—Exits the **Contrast Enhancement** command.

Parameters in the Contrast Enhancement Panel

Data scale

Controls the vertical range of the image corresponding to the full extent of the color table. The units of this item vary according to the type of image (e.g., nm, nA, etc.)

Color table

Selects the color table used to encode the Z information.

Color contrast

Controls the contrast in the image by compressing or expanding the Color Table.

Color offset

Shifts the color table used to display the image.

Contrast equalization

Degree to which the filter attempts to equalize the image contrast. The Contrast equalization parameter is a filter coefficient which is trying to drive the standard deviation of each neighborhood to the same value. The larger the number, the more aggressively it is driven. Values as low as 2 and 3 can have dramatic effects. This processes an image with tall features in some areas and shorter features in other areas so that all the features become closer to the same size and can be seen simultaneously. It can also have many other effects, including edge enhancement.

Range and Settings:

- 0—9

Background removal

Amount of background to be removed. The Background removal parameter is a filter coefficient which brings the mean of each neighborhood towards the same value. A value of 0 has no effect and a value of 9 makes the mean for each neighborhood the same. This allows an image that has small features on large features to be essentially stripped of the larger features so that all of the smaller features can be seen simultaneously. The neighborhood size should be set larger than the size of the features you wish to preserve.

Range and Settings:

- 0—9

Neighborhood size

Sets the size in pixels of the neighborhoods to used for background removal and contrast equalization. The Neighborhood size parameter specifies the size in pixels of square regions (kernels) the image is divided into for Contrast equalization and Background removal. This should be set near to, or larger than, the pixel size of features in the image you are trying to enhance.

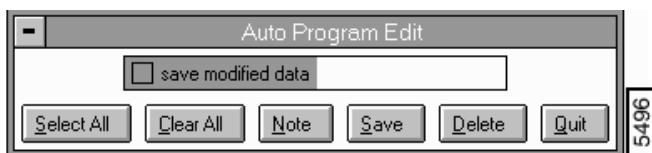
Range and Settings:

- 2, 4, 8, 16, 32, 64

15.4.2 Contrast Enhancement Auto Program Edit Panel

The **Auto Program Edit** panel allows the **Contrast Enhancement** command to be added or deleted to the currently selected Auto Program file (See [Figure 15.4b](#)).

Figure 15.4b Auto Program Edit Panel



Buttons on the Auto Program Edit Panel

Select All—Selects all the measurements simultaneously.

Clear All—Clears all the measurements simultaneously.

Note—Allows you to insert a command note in the Auto Program file.

Save—Saves selected measurements to the Auto Program file. If the **Contrast Enhancement** command is already in the current Auto Program file, it retains its position in the file.

Delete—Removes the **Contrast Enhancement** command from the Auto Program file.

Quit—Exits the **Auto Program Edit** mode without making changes to the Auto Program file.

Note: The Auto Program File command in the **Utility** menu must be used to select or create an Auto Program file.

Note: The **Auto** subcommand under the **Browse** command selects the files to be processed and executes the current Auto Program file.

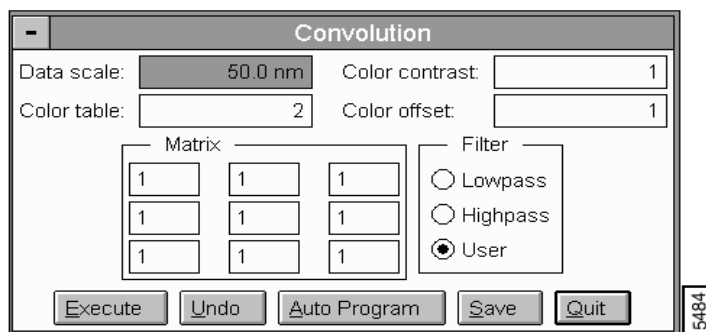
15.5 Convolution

The **Convolution** filter incorporates filters similar to the **Highpass** and **Lowpass** commands (See [Section 15.12](#) and [Section 15.14](#)), plus a third, **User** filter having an assignable 3 x 3 kernel. This third option enables you to apply a custom-designed, non-averaging filter to the image data and can prove very useful in enhancing edge features. Filter kernels are applied to the image data pixel-by-pixel to construct an entirely new image.

Selecting the **Convolution** function displays a panel shown in [Figure 15.5a](#) featuring a 3 x 3 kernel (matrix). The kernel values alter, depending upon which filter is selected in the **Filter** option box. A brief discussion of each filter follows.

15.5.1 Convolution Panel

Figure 15.5a Convolution Pane



Buttons on the Convolution Panel

Execute—Executes the filter.

Undo—Restores the image to its original form.

Save—Allows the converted image to be saved to the disk.

Auto Program—Allows the **Convolution** command to be added or deleted to the currently selected Auto Program file (See [Section 15.5.2](#)).

Quit—Exits the **Convolution** command.

Parameters in the Convolution Panel

Filter—Lowpass

This is the only averaging filter in the **Convolution** command and is similar to the **Modify/Lowpass** function (See [Section 15.14](#)). It is designed to filter out high frequency noise, and imparts

a “smoothing” effect to surface features, averaging each pixel with the pixels around it. When selected, its kernel defaults to the following values:

1	1	1
1	1	1
1	1	1

This filter treats each pixel of the image data according to the following algorithm:

$$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \Rightarrow \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$

$$a'_{22} = \frac{\sum_{i=1}^3 a_{ii}}{9}$$

Each pixel in the image data, a_{22} , is incrementally multiplied by every pixel immediately adjacent to it; the product is divided by 9 (averaged), and the result, a'_{22} , is plotted to the modified image. This averaging effect removes high frequency noise from the image and has a “smoothing” effect on sharp surface features.

Filter—Highpass

This filter is similar to the Modify / Highpass function (See [Section 15.14](#)). It is designed to filter out low frequency noise and accentuate high frequency features. When selected, its kernel defaults to the following values:

-1	-1	-1
-1	8	-1
-1	-1	-1

This filter treats each pixel of the image data according to the following algorithm:

$$\begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix} \Rightarrow \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$

$$a'_{22} = \sum_{\substack{i=1 \\ a_{21}}}^{a_{11}} -a_{ii} + 8a_{22} + \sum_{\substack{i=1 \\ a_{33}}}^{a_{23}} -a_{ii}$$

Each pixel in the image data, a_{22} , is multiplied by eight (8) and incrementally added to every pixel immediately adjacent to it, then the result, a'_{22} , is plotted to the modified image. Notice that this

algorithm is non-averaging; therefore, it accentuates differences in adjacent pixels rather than smooth them (as does the **Lowpass** filter).

Filter—User

The third filter option is labeled User. This option allows you to custom-design the image filter by assigning values to the 3 x 3 kernel. When this option is selected, its values default to those of the Highpass option. To change the filter, click on any of nine kernel values with a cursor, then enters the new value.

Note: Whole numbers (integers) must be used for all values.

Note: If any negative values are entered into the **User** kernel, the sum of all values must equal zero (0).

The user-defined kernel operates upon the image data in a manner similar to the Highpass filter:

— User-defined kernel

$$\begin{bmatrix} x_{11} & x_{12} & x_{13} \\ x_{21} & x_{22} & x_{23} \\ x_{31} & x_{32} & x_{33} \end{bmatrix} \Rightarrow \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$

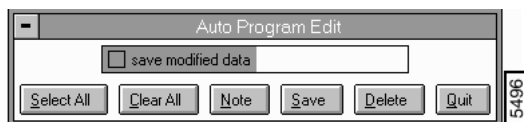
$$a'_{22} = \sum_{\substack{a, x_{11} \\ a, x_{33}}} x_{ii} a_{ii}$$

Experimentation with various values on a known sample surface provide the best indication of how the user-defined kernel impacts image data.

15.5.2 Convolution Auto Program Edit Panel

The **Auto Program Edit** panel allows the **Convolution** command to be added or deleted to the currently selected Auto Program file (See

Figure 15.5b Convolution Auto Program Edit Panel



Buttons on the Auto Program Edit Panel

Select All—Selects all the measurements simultaneously.

Clear All—Clears all the measurements simultaneously.

Note—Allows you to insert a command note in the Auto Program file.

Save—Saves selected measurements to the Auto Program file. If the **Convolution** command is already in the current Auto Program file, it retains its position in the file.

Delete—Removes the **Convolution** command from the Auto Program file.

Quit—Exits the **Auto Program Edit** mode without making changes to the Auto Program file

15.6 Detrend

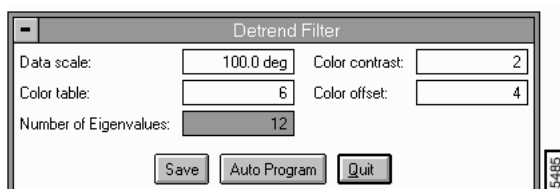
The **Detrend** command modifies the displayed image by accessing spatial frequency data for imaging features with slowly changing topography and for viewing the image for sharp changes in topography. The lower spatial frequency includes data at a “lower frequency” and correlates to a lower **Eigenvalue** input in the **Detrend Filter** panel.

The original image can be thought of as a sum of 100 **Eigenvalues** numbered from 1 (lowest spatial frequencies) to 100 (highest spatial frequencies).

15.6.1 Detrend Filter Panel

Select **Modify/Detrend** to access the **Detrend** panel (See [Figure 15.6a](#)).

Figure 15.6a Detrend Panel



Parameters and Buttons on the Detrend Panel

Save—Saves the modified data.

Auto Program—Allows the **Detrend** command to be added or deleted to the currently selected Auto Program file (See [Section 15.6.2](#)).

Quit—Exits the **Detrend** command without saving.

Data scale

Controls the vertical range of the image corresponding to the full extent of the color table. The units of this item vary according to the type of image (e.g., nm, nA, etc.)

Color table

Selects the color table used to encode the Z information.

Color contrast

Controls the contrast in the image by compressing or expanding the Color Table.

Color offset

Shifts the color table used to display the image.

Number of Eigenvalues

Controls the displayed image when entered and **Execute** is the Display Monitor is run.

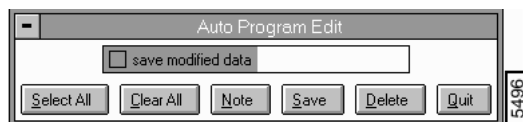
Range and Settings:

- **1**—Displays the lowest spatial frequency data.
- **2-100**—Displays increasing spatial frequency data of the original image.

15.6.2 Detrend Auto Program Edit Panel

The **Auto Program Edit** panel allows the **Detrend** command to be added or deleted to the currently selected Auto Program file (See [Figure 15.6b](#)).

Figure 15.6b Detrend Auto Program Edit Panel



Parameters and Buttons on the Auto Program Edit Panel

Select All—Selects all the measurements simultaneously.

Clear All—Clears all the measurements simultaneously.

Note—Allows you to insert a command note in the Auto Program file.

Save—Saves selected measurements to the Auto Program file. If the **Detrend** command is already in the current Auto Program file, it retains its position in the file.

Delete—Removes the **Detrend** command from the Auto Program file.

Quit—Exits the Auto Program Edit mode without making changes to the Auto Program file.

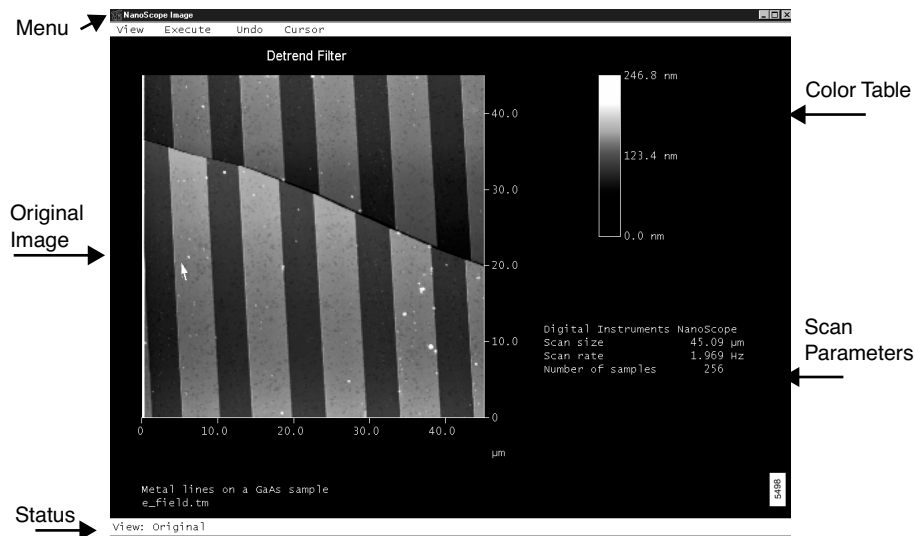
15.6.3 Detrend Display Monitor

The Display Monitor displays the original image, the scan parameters and a command menu.

Detrend Display Menu Commands

View—Displays the **Original** image, **Trend** (image based on Eigenvalues) and the **Detrended Image** (the sum of the detrended image and the trended image and the Eigenvalues equals the original image) (See [Figure 15.6c](#)).

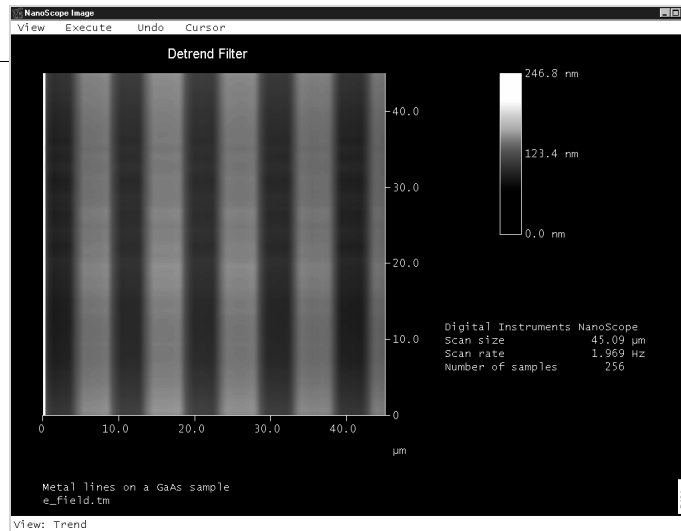
Figure 15.6c The Original Image in Detrend Image Display



Note: For 1 Eigenvalue, the image displays lower spatial frequency data (i.e., the image shows slower changes in topography) (See [Figure 15.6d](#)).

Figure 15.6d Filtered Detrend Image

Image change with "1" Eigenvalue shows low frequency image.



Execute—Runs the **Detrend** command.

Undo—Resets the **Detrend** settings to the original image without saving.

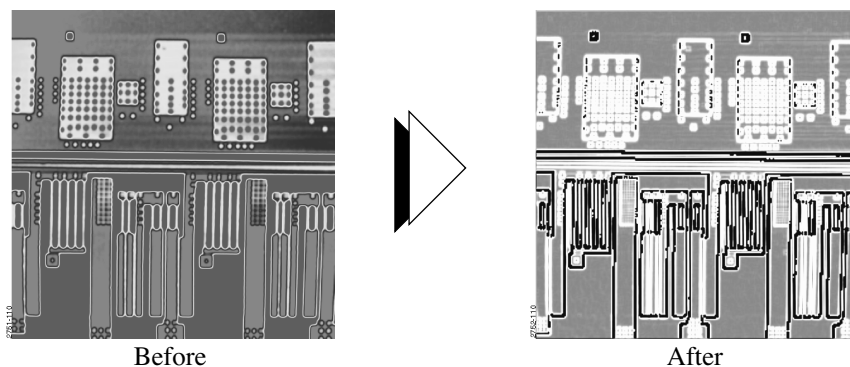
Cursor—Allows a box cursor to specify an area on the image to be modified. The **Delete** command *detrends* the specified area. The **Clear** command clears the cursor box(es).

Note: To reset the image, select the **Undo** command.

15.7 Edge Enhance

Edge Enhance is used to accentuate boundaries (edges) between dissimilar areas of an image. This is accomplished at some loss of height resolution; therefore, images should be copied and processed with edge enhancement separately if height data needs to be preserved.

Figure 15.7a Edge Enhance Example



The **Edge Enhance** routine detects edges in images by applying Sobel kernels to 3 x 3 pixel cells. These kernels are of the form where edge enhancement is achieved by summing the absolute value of the results of both kernels. This routine is applied to the center pixel in each 3 x 3 kernel of the image (See Figure 15.7b).

Figure 15.7b Sobel Kernel in 3 x 3 Pixels

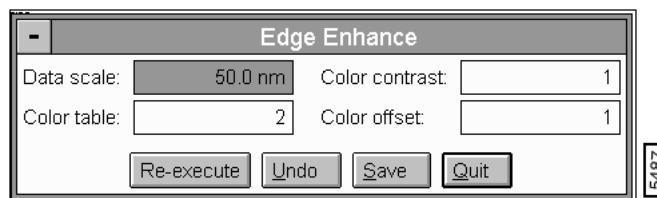
-1	-2	-1
0	0	0
1	2	1

-1	0	1
-2	0	2
-1	0	1

There are no parameter controls associated with the **Edge Enhance** command; however, the command may be applied repeatedly to the same image by clicking on the **Re-execute** button. Images may be restored by clicking on the **Undo** button.

The **Edge Enhance** panel allows display parameters to be adjusted to your preferences (See Figure 15.7c)

Figure 15.7c Edge Enhance Panel



Re-execute—Reapplies edge enhancement.

Note: **Edge Enhance** may be applied as many times as desired; however, image definition may be lost if used excessively.

Undo—Restores the image to its original form.

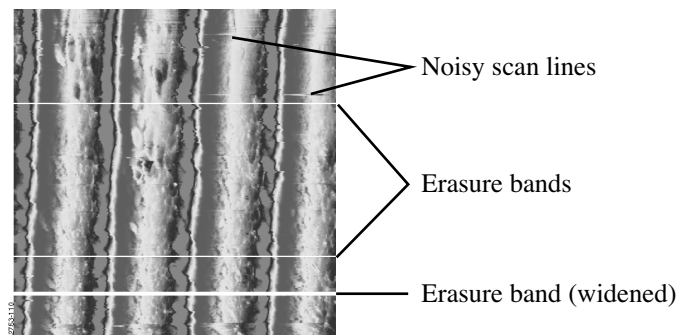
Save—Allows the converted image to be saved to the disk.

Quit—Exits **Edge Enhance**.

15.8 Erase Scan Lines

The **Erase Scan Lines** command removes noisy scan lines from an image. This operation replaces the specified line or lines by interpolation. For example, the image in [Figure 15.8a](#) includes noisy scan lines. Erasure lines are positioned over the noisy lines to remove them. Where noise is larger, the erasure line is widened (bottom).

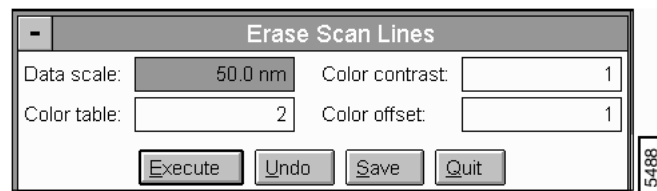
Figure 15.8a Erase Scan Lines Example



15.8.1 Erase Scan Lines Panel

The **Erase Scan Lines** panel allows display parameters to be adjusted to your preferences (See [Figure 15.8b](#)).

Figure 15.8b Erase Scan Lines Panel



Parameters and Buttons in the Erase Scan Lines Panel

Execute—Initiates the command.

Undo—Restores the image to its original form.

SAVE—Allows the converted image to be saved to the disk.

Quit—Exits the operation.

Data scale

Controls the vertical range of the image corresponding to the full extent of the color table. The units of this item vary according to the type of image (e.g., nm, nA, etc.).

Color table

Selects the color table used to encode the Z information.

Color contrast

Controls the contrast in the image by compressing or expanding the Color Table.

Color offset

Shifts the color table used to display the image.

15.8.2 Erase Scan Lines Display Monitor

The standard top view of the image, plus the menu and status bar are shown on the Display Monitor.

Erase Scan Lines Menu Bar Commands

Add

Allows a horizontal reference line to be placed over a scan line to remove it from the image. Reference lines can also be moved in the Add mode by clicking on a previously placed line. The first click ties the line to the mouse movement; the second click drops the line.

Mouse Operations—Add mode

- Use the left button.

- 1st click—Places a horizontal line which is tied to the mouse on the image. The line can be positioned by moving the mouse.
- 2nd click—Drops the line generated by the first click.

Delete

Removes a line previously placed with the Add subcommand.

Mouse Operations—Delete mode

- Position the cursor over a previously added line and click the left button to remove the line.

Move

Moves a reference line previously placed with the Add subcommand.

Mouse Operations—Move mode

- Use the left button.
- 1st click—Position the cursor over a previously added line and click the left button to tie the line to the movement of the mouse. The line can be repositioned by moving the mouse.
- 2nd click—Drops the line picked up by the first click.

Widen

Increases the width of a reference line previously placed with the Add subcommand.

Mouse Operations—Widen mode

- Position the cursor over a previously added line and click the left button to increase the width of the line in both directions.

Clear

Removes all of the reference lines from the image.

Execute

Removes the scan line or lines beneath the reference lines added to the image.

Undo

Restores the image to its original form.

Mouse Operations—All modes

- A click of the right mouse button completes the operation and positions the cursor over the **Execute** subcommand in the menu bar. At this point, clicking either mouse button executes the command. Therefore, once the lines are positioned properly, two clicks of the right mouse button execute the command.

Note: The operating modes, **Add**, **Delete**, **Move**, or **Widen**, are shown in the status bar. Once a mode has been selected, repeated operations can be performed. For example, after the **Delete** subcommand has been selected, any number of lines can be deleted with multiple clicks of the left button. The **Add** mode is the default mode for this command.

Note: The data for the adjoining scan lines is used to interpolate new data for the removed scan lines. Therefore, this command does not change the number of scan lines in the image.

See also: **Off-line / Modify** menu: **Median**, **Lowpass**, and **Spectrum 2D** commands.

15.8.3 Procedure in Using the Erase Scan Lines Command

1. Load a captured image from the `SPM/IMAGES DIRECTORY`.
2. Click on the **Offline / Modify / Erase Scan Lines** command.
3. Move the cursor to the Display Monitor, then click on **Add**. Next, move the cursor to the top view image.
4. Locate a *noisy* scan line (See [Figure 15.8a](#) for locating *noise* on an image), then use the cursor to click on it. A white erasure line is drawn.
5. Drag the white erasure line to a position where it is covering the offending scan line, then click the mouse again to drop the line.
6. Click on **Add** again and place another white erasure line over a wider noisy scan line. Drop the line and click on **Widen**, then return to the line once more and click on it. The erasure line is widened. (You may continue to widen the line by clicking on it again and again.)
7. To erase the covered lines, click on **Execute** (use either the display or Control Monitor). The covered lines is reconstructed (“erased”) by interpolating from neighboring data.

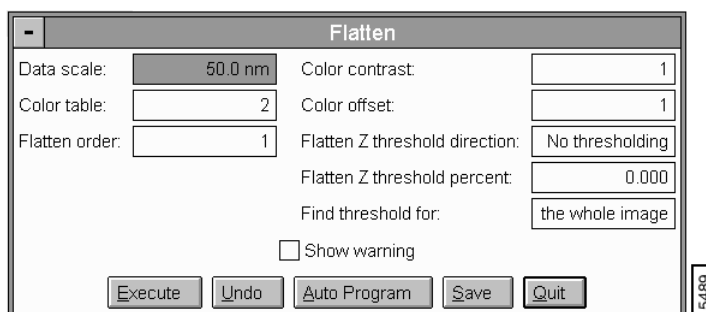
15.9 Flatten

The **Flatten** command eliminates unwanted features from scan lines. It uses all unmasked (stopbanded) portions of scan lines to calculate individual least-squares fit polynomials. The polynomials are subtracted from each scan line. This is useful for samples that have sporadic, tall features in predominantly flat areas. (Only featureless area of the scan should be used to calculate the polynomial. All other features should be covered with a stopband.)

15.9.1 Flatten Panel

The **Flatten** panel is displayed, allowing the order of the equation to be selected and display parameters to be adjusted to your preferences.

Figure 15.9a Flatten Panel



Parameters and Buttons on the Flatten Panel

Execute—Initiates the command.

Undo—Restores the image to its original form.

Auto Program—Allows the **Flatten** command to be added or deleted to the currently selected Auto Program file (See [Section 15.9.2](#)).

Save—Allows the converted image to be saved to the disk.

Quit—Exits the operation.

Flatten order

Selects the order of the polynomial calculated and subtracted from each scan line.

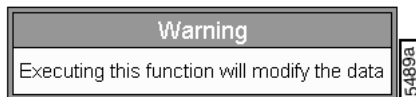
Range and Settings:

- Zero order (**0**) removes the Z offset between scan lines by subtracting the average Z value for the selected segment from every point in the scan line.
- First order (**1**) removes the Z offset between scan lines, and the tilt in each scan line, by calculating a first order, least-squares fit for the selected segment then subtracting it from the scan line.
- Second order (**2**) removes the Z offset between scan lines, and the tilt and bow in each scan line, by calculating a second order, least-squares fit for the selected segment then subtracting it from the scan line.
- Third order (**3**) removes the Z offset between scan lines, and the tilt and bow in each scan line, by calculating calculates a third order, least-squares fit for the selected segment and subtracts it from the scan line.

Show warning

When enabled (click on the box to place an “X”), the following warning is displayed before access to the **Flatten** panel is granted (See [Figure 15.9b](#)).

Figure 15.9b Flatten Warning



Data scale

Controls the vertical range of the image corresponding to the full extent of the color table. The units of this item vary according to the type of image (e.g., nm, nA, etc.).

Color table

Selects the color table used to encode the Z information.

Color contrast

Controls the contrast in the image by compressing or expanding the color table.

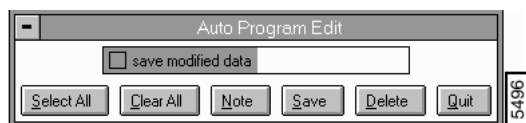
Color offset

Shifts the color table used to display the image.

15.9.2 Flatten Auto Program Edit Panel

The **Auto Program Edit** panel allows the **Flatten** command to be added or deleted to the currently selected Auto Program file (See [Figure 15.9c](#)).

Figure 15.9c Flatten Auto Program Edit Panel



Parameters and Buttons in the Flatten Auto Program Edit Panel

Select All—Selects all the measurements simultaneously.

Clear All—Clears all the measurements simultaneously.

Note—Allows you to insert a command note in the Auto Program file.

Save—Saves selected measurements to the Auto Program file. If the **Flatten** command is already in the current Auto Program file, it retains its position in the file.

Delete—Removes the **Flatten** command from the Auto Program file.

Quit—Exits the **Auto Program Edit** mode without making changes to the Auto Program file.

15.9.3 Flatten Display Monitor

The standard top view of the image, and the menu and status bars, are shown on the Display Monitor.

Flatten Menu Bar Commands

Clear

Removes stopband(s) from the image.

Execute

Initiates the flattening operation.

Undo

Restores the image to its original form.

Mouse Stopband Operations

- 1st click, left button—Drops the first corner of the stopband.
- 2nd click, left button—Drops the second corner of the stopband.
- Subsequent clicks, left button—Additional clicks can be used to draw additional stopbands, or pick up, resize or reposition.
- Clicking the right button moves the cursor to the **Execute** subcommand in the top menu bar.

Note: The **Flatten** command uses only those data points which have not been stopbanded to generate each least-squares fit polynomial; however, all data is subtracted from polynomials.

Note: Use of the **Flatten** command modifies the file's height information. If you need to keep the height information, save a separate, unflattened copy of the image file before using **Flatten**.

See also: **Off-line / Modify** menu: **Geometric**, **Plane Fit Auto**, and **Plane Fit Manual** commands.

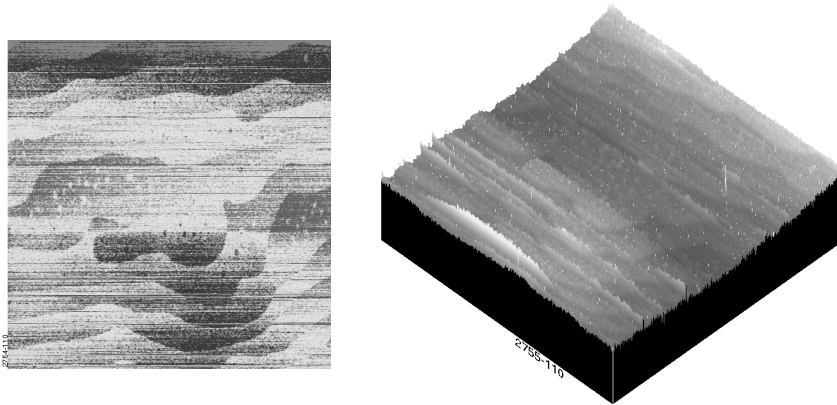
Procedures for the Flatten Command

For an image that contains a number of noisy scan lines, use the **Flatten** command to correct the problem.

1. Load the image. Before using **Flatten**, examine the image using **Surface Plot**. Click on **View / Surface Plot**, or use the **Surface Plot** icon. Notice that the image contains disjointed scan lines which are misaligned along the Z-axis (some are high and some are low). This effect somewhat resembles an unshuffled deck of cards when viewed on-edge. The image also has bow along its Y-axis. When finished examining the image, click on **Quit**.

Note: [Figure 15.9d](#) shows an image file “gaas.epi” in its original, raw form as an example for the **Flatten** command. Many of the image's scan lines are disjointed along the Z-axis. The image also has a slight bow along the Y-axis.

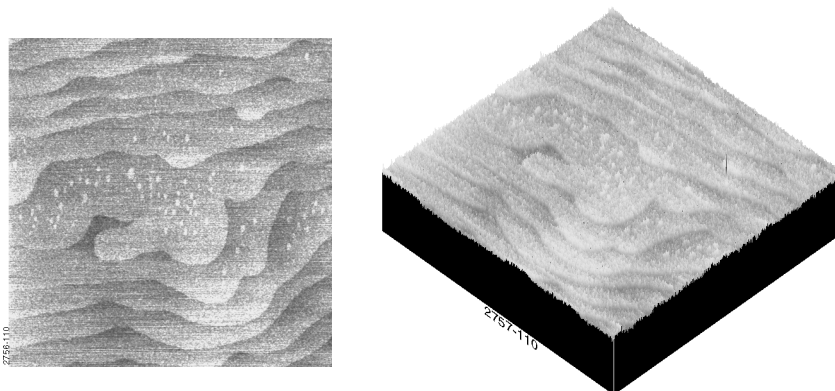
Figure 15.9d Raw Image Epitaxial Gallium Arsenide



2. Click on **Flatten**. Set the **Flatten order** value to **2**. This removes both the scan line misalignment and the Y-axis bow.
3. Click on **Execute** to initiate the **Flatten** command. The flattened image appears on the display screen.

Note: Figure 15.9e shows the same image file after using a second-order **Flatten** (Flatten order = 2). The scan lines are now aligned and the Y-axis bow is removed.

Figure 15.9e Flattened Image Epitaxial Gallium Arsenide



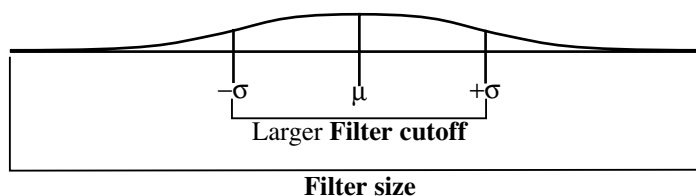
4. To see a variety of effects using the **Flatten** command, enter different **Flatten order** values. Each new version may be undone by clicking on the **Undo** button.

15.10 Gaussian

The **Single Axis Gaussian Filter** permits analysis of images along either the X or Y axis with a 1-by-X kernel you define specified in Gaussian terms. The **Filter size** value in the panel corresponds to the kernel size, with the symmetric Gaussian curve centered over the operated-upon pixel. The **Filter cutoff** value corresponds to the sigma (σ) value of the Gaussian curve, encompassing approximately 68 percent of the data. By varying these two values, you are able to effectively shape the Gaussian curve.

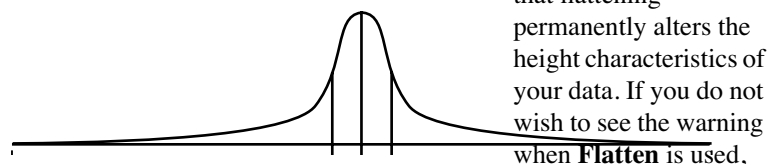
Larger **Filter cutoff** values distribute the curve broadly (See [Figure 15.10a](#)). During **Lowpass** filtering, this lends greater weight to values farther away from the pixel and increases the Gaussian filter's averaging effects upon the image. During **Highpass** filtering, this subtracts a decreased average from each pixel, lessening the filter's impact.

Figure 15.10a Larger Filter Cutoff



Smaller **Filter cutoff** values concentrate curve data around the center value (See [Figure 15.10b](#)).

Figure 15.10b Smaller Filter Cutoff



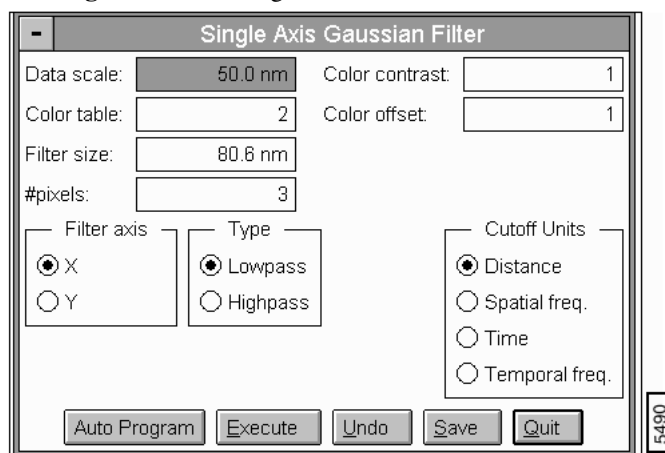
During **Lowpass** filtering, this lends less weight to pixels distant from the center, decreasing the Gaussian filter's ability to average local pixels with distant ones—the filter's impact is lessened. During **Highpass** filtering, the larger and more localized pixel average being subtracted from the operated-upon pixel value yields an enhanced impact upon the image.

Note: **Filter size** and **Filter cutoff** are specified in units of **Distance**, **Spatial frequency**, **Time**, **Temporal frequency**, and **Pixel size**.

15.10.1 Single Axis Gaussian Filter Panel

The **Single Axis Gaussian Filter** panel is shown in [Figure 15.10c](#).

Figure 15.10c Single Axis Gaussian Filter Panel



Parameters and Buttons in the Gaussian Filter Panel

Auto Program—Allows the Gaussian command to be added or deleted to the currently selected Auto Program file (See [Section 15.10.2](#)).

Execute—Applies the **Single Axis Gaussian Filter** to the currently loaded image.

Undo—Undoes the **Single Axis Gaussian Filter** command and restores the file to its original form.

Save—Saves the filtered image file to the directory and file name you specify.

Quit—Quits the **Single Axis Gaussian Filter** panel.

Data scale

Controls the vertical range of the image corresponding to the full extent of the color table. The units of this item vary according to the type of image (e.g., nm, nA, etc.).

Color table

Selects the color table used to encode the Z information.

Color contrast

Controls the contrast in the image by compressing or expanding the Color Table.

Color offset

Shifts the color table used to display the image.

Filter size

Size of the scan line to be operated upon by the Gaussian filter kernel. This value is expressed in the Cutoff units specified (See below).

Range and Settings:

- **Minimum** = 3 pixels
- **Maximum** = one-half scan size

#pixels

The current Filter size in pixel units. This value may be used to both enter and monitor the Filter size.

Range and Settings:

- **Minimum** = 3
- **Maximum** = one-half scan size.

Filter cutoff

Portion of the scan line to be included within filtered computations. This value represents a statistical sigma (σ) value and is applied to both sides of the center, average data point (i.e., $\mu \pm \sigma$); therefore, the filtered area equals twice the Filter cutoff value.

Range and Settings:

- ≥ 0.01 nm

Cutoff units

Selected units are applied simultaneously to both the Filter size and the Filter cutoff. (The #pixels field displays the pixel equivalent of the current Filter size value.)

Range and Settings:

- Distance
- Spatial frequency
- Time
- Temporal frequency

Type: Low Pass and High Pass

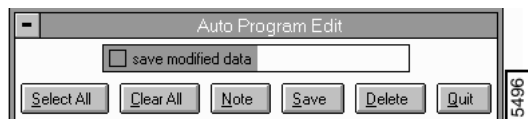
Low Pass filtering allows through longer wavelength features while filtering out shorter wavelength features. The net effect is to remove noise in the form of spikes and fuzz on the image. (For a more thorough discussion on **Low Pass**, See [Section 15.14](#).)

Conversely, **High Pass** filtering allows shorter wavelength features through while filtering out longer wavelength features. (For a more thorough discussion, See [Section 15.12.](#))

15.10.2 Gaussian Auto Program Edit Panel

The **Auto Program Edit** panel allows the **Gaussian** command to be added or deleted to the currently selected Auto Program file (See [Figure 15.10d](#)).

Figure 15.10d Gaussian Auto Program Edit Panel



Buttons on the Gaussian Auto Program Edit Panel

Select All—Selects all the measurements simultaneously.

Clear All—Clears all the measurements simultaneously.

Note—Allows you to insert a command note in the Auto Program file.

Save—Saves selected measurements to the Auto Program file. If the **Gaussian** command is already in the current Auto Program file, it retains its position in the file.

Delete—Removes the **Gaussian** command from the Auto Program file.

Quit—Exits the **Auto Program Edit** mode without making changes to the Auto Program file.

15.10.3 Gaussian Kernel Algorithm

The general equation used to generate a 1-by-(N+1) Gaussian kernel is as follows:

$$\left(f_i = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{i}{\sigma}\right)^2} \right)$$

Where i , is in units of pixels, and σ is set by the **Filter cutoff** value. Using this kernel, the filter output is as follows:

$$\text{Lowpass pixel value} \quad a_0' = \left(\sum_{\frac{-N}{2}}^{\frac{N}{2}} a_i f_i \right)$$

Highpass pixel value
$$a_0' = a_0 - \left(\sum_{\frac{-N}{2}}^{\frac{N}{2}} a_i f_i \right)$$

The actual impact of filtering on an image is best demonstrated by reviewing examples of images before and after filtering. In the following example, both **Lowpass** and **Highpass** Gaussian filter capabilities are demonstrated.

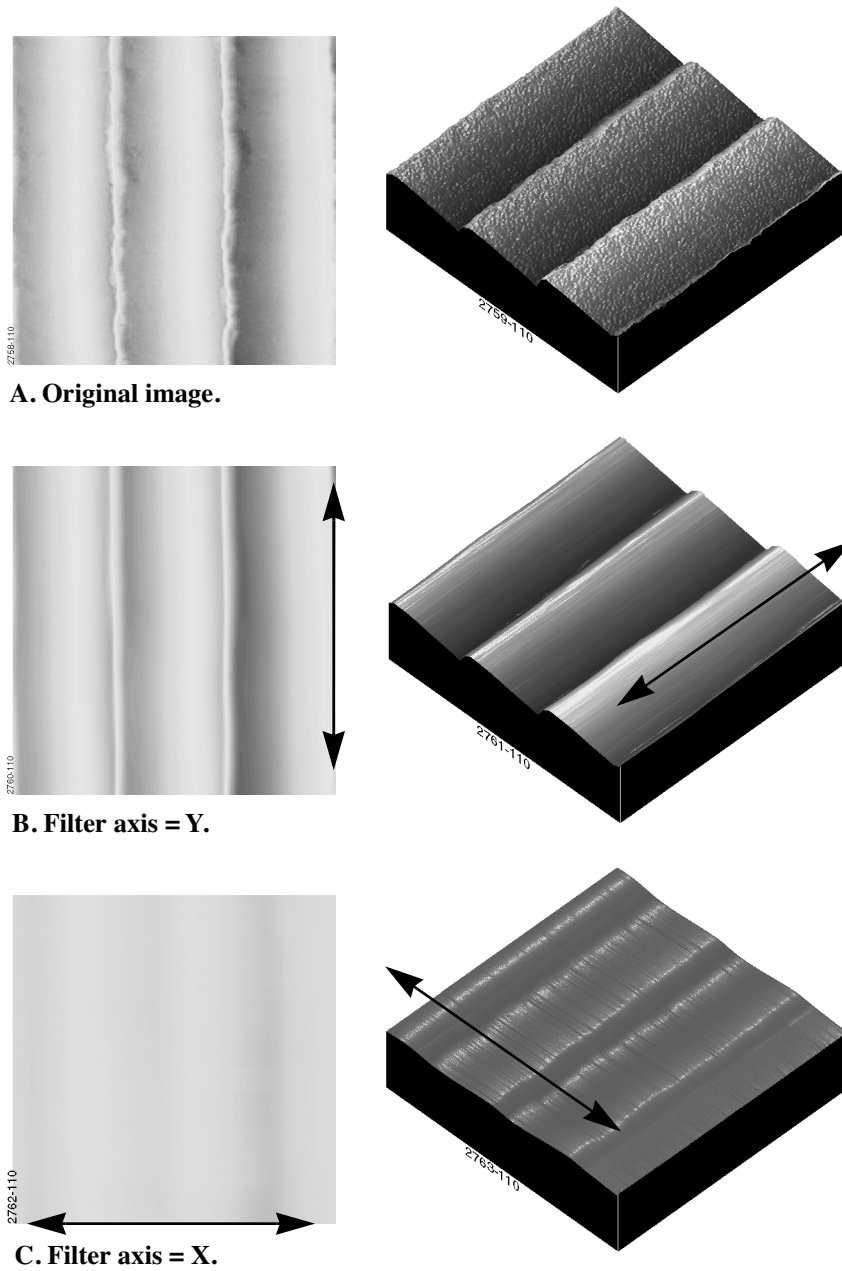
15.10.4 Lowpass-type Single Axis Gaussian Filtering

During **Lowpass** filtering, the **Single Axis Gaussian Filter** has a unique ability to average features oriented orthogonally to the scan frame. For example, the **Gaussian** filter can average features running parallel to an image's Y scan axis while leaving features relatively unchanged along the X axis, or vice versa. This is a similar capability to the **Modify / Spectrum 2D** function; however, it is more unidirectional (i.e., strictly operating along the X or Y axis). One such example is provided in the three views of a diffraction grating in [Figure 15.10e](#).

The "**grating**" image **Scan size** is 1.872 microns. Applying a **Single Axis Gaussian Filter** with **Filter size** of **500 nm** and a **Filter cutoff** of **250 nm** along the Y Filter axis results in view B. Notice that rulings running parallel to the Y axis are smoothed along their length by the filter, while features oriented orthogonal to the Y axis remain relatively unchanged. This results in an idealized (averaged) profile of the X axis. In this instance, the **Filter cutoff** is large with respect to the **Filter size**, giving rise to a significant impact upon the image. (Decreasing the **Filter cutoff** value reduces this impact.)

In view C, the **Filter size** and **Filter cutoff** values are unchanged; however, the **Filter axis** has been rotated 90° to the X axis. The filter's impact upon the image here is very dramatic, destroying the ruling features in the image by averaging across their profile. The result is an almost flat surface.

Figure 15.10e Views of Diffraction Grating



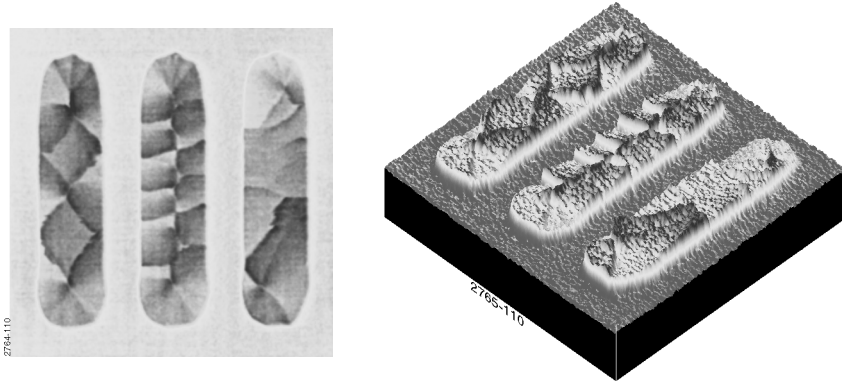
15.10.5 Highpass-type Single Axis Gaussian Filtering

Applications for Highpass filtering are limited to detecting smaller features. Generally, higher frequency (shorter wavelength) features are enhanced, while sacrificing lower frequency (longer wavelength) features and height data.

One example of applying a Gaussian **Highpass** filter is provided in [Figure 15.10f](#).

This 27.41-micron, MFM image reveals magnetic domains in a permalloy specimen. Although magnetic domains are visible on the original image, you may apply a **Gaussian** highpass filter to highlight boundaries between domains.

Figure 15.10f Magnetic Domains in a Permalloy Specimen



[Figure 15.10f](#) shows the magnetic force microscopy (MFM) image in its original form. This is an early MFM image of a permalloy specimen, and contains artifacts which are significantly reduced in phase analyzed images using the Extender™ Electronics Module. Magnetic force is represented in the image as height data. Suppose the microscopist wanted to highlight the magnetic boundaries without regard to magnetic force (height data). A **Gaussian** Highpass filter here would be appropriate.

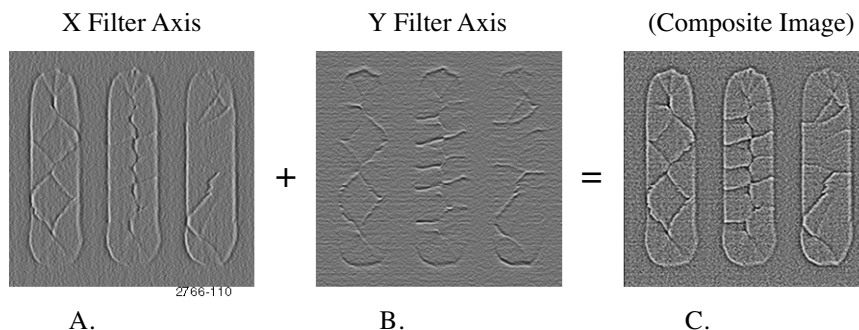
Procedures for the Gaussian Filter Command

1. Select a captured *.mfm image.
2. Load into the Gaussian filter by clicking on **Off-line / Modify / Gaussian**.
3. If the image is fairly large image (e.g., 27.41 microns), the **Filter size** may be set to **1.00 micron**; set the **Filter cutoff** to **250 nm**. (These values can be experimented with to observe how the filter's effects alter.)
4. Set the filter **Type** to **Highpass**.

Example Explanation. First, the image is filtered along the X-axis by setting the **Filter axis** to **X**. Clicking on **Execute** activates the Gaussian filter, and the result is shown on the display screen (See [Figure 15.10g](#), View A). Notice that features running parallel to the X-axis (e.g., the tips of each

oval area) are washed out, while features running perpendicular to the X-axis are enhanced. This image can be saved by clicking on **Save** and entering a file name.

Figure 15.10g Gaussian Highpass-Filtered Images



Next, reload the image and filter along the Y-axis by setting the **Filter axis** to **Y**. Clicking on **Execute** activates the Gaussian filter, and the result is shown on the display screen (See [Figure 15.10g](#), View B). Notice that features running parallel to the Y-axis (e.g., the sides of each oval area) are washed out, while features running perpendicular to the Y-axis are enhanced. Again, this image can be saved by clicking on **Save** and entering a file name.

To construct a composite image of the two Gaussian-filtered images, add them together. (This can be accomplished by subtracting an inverted image from another image.) A composite of the two filtered images is shown in [Figure 15.10g](#), View C. This shows the domain boundaries clearly; however, all Highpass filtered images have lost their height data, including the composite.

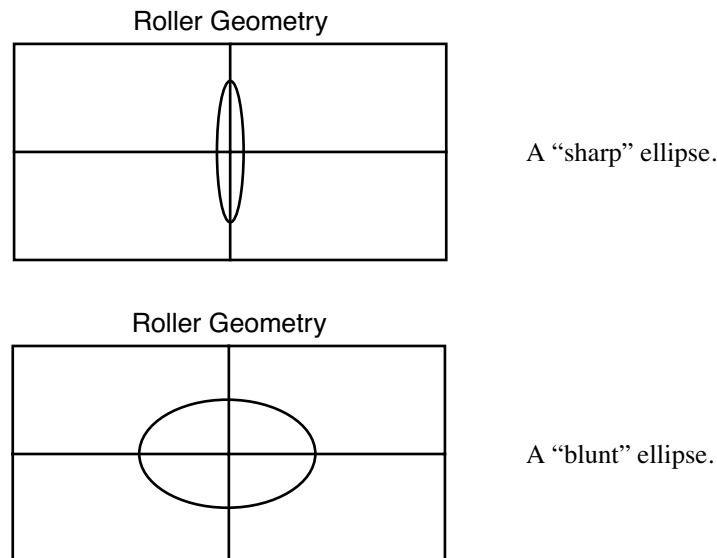
For more information regarding Highpass filtering, See [Section 15.12](#).

15.11 Geometric

The **Geometric** function is designed to perform unique Lowpass and Highpass filtering on image files. What makes the **Geometric** function unique is that it sections images, then analyzes the sectioned profiles either from above or below their surfaces.

In addition, the **Geometric** function also features a "roller" which allows filtering to be selectively applied. The roller—which can also be thought of as the tip of profilometer—is represented on the right side of the Display Monitor. By manipulating its shape with the mouse, its geometry may be changed from a sharp ellipse, through a circle, to a blunt ellipse.

Figure 15.11a Altering an Ellipse Geometry

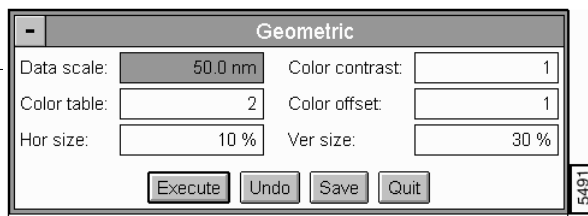


The **Geometric** command can perform Lowpass as well as Highpass filtering. The envelope of the data corresponds to the position of the center point of an ellipsoid as the ellipsoid scans over, or under, the sample surface. The envelope contains the low frequency components of the data. A Lowpass filter is performed by replacing the data with the envelope. When used as a Highpass filter, the data are replaced with the difference between data and the envelope. The size of the ellipsoid defines the cutoff frequency of the filter.

15.11.1 Geometric Panel

The **Geometric** panel is displayed allowing the display parameters to be adjusted to your preference.

Figure 15.11b Geometric Panel



Parameters and Buttons on the Geometric Panel

Execute—Applies the geometric filter based on the specified ellipse size.

Undo—Restores the original image.

Save—Allows the converted image to be saved to the disk.

Quit—Exits the operation.

Hor size

Defines the horizontal size of the elliptical roller used for finding the envelope as a percentage of the image size.

Data scale

Controls the vertical range used to display the top view image. The units of this item vary according to the type of image (e.g., nm, nA, etc.).

Color table

Selects the color table used to encode the Z information.

Ver size

Defines the vertical size of the elliptical roller used for finding the envelope as a percentage of the image size.

Color contrast

Controls the contrast in the image by compressing or expanding the Color Table.

Color offset

Changes the image color by shifting the range of the color table used to display the image.

15.11.2 Geometric Command Display Monitor

The menu bar, image, and status bar are shown on the Display Monitor. The mouse is used to define an arbitrary cross-section on the image as described below. At this point, the subtleties of the command operation become important.

After the position of the cross-section has been defined, **Section** subcommand displays the cross-section data in two windows. The window labeled "Roller Geometry" shows the relationship between the roller size and the section data. The window labeled *Section* shows the cross-section, the envelope, and the difference between the two.

On the **Section** plot, the red trace is the section data. The white trace represents the envelope created by the elliptical roller. The green trace is the data with the envelope removed (i.e., red trace minus white trace). Note that the green trace is the result of the Highpass filter on the section data and the white trace is the result of the Lowpass filter. The cursor in this window allows the data to be scrolled by the ellipse in the *Roller Geometry* window.

Geometric Display Menu Bar Commands

Envelope

Defines whether the elliptical roll runs over the top of the data or the bottom of the data to produce the Upper or Lower envelope, respectively. If Mean is selected, the average of the two envelopes is used.

Averaging

Defines the spacing between the data points that are compared to the roller. If 1 Pixel is selected, every data point in every line is compared. If 2 Pixels is selected, every other data point in every other line is compared.

Default

Value depends on the number of data points in the image. If default is selected, every data point is compared in 128 x 128 images; every other data point in every other line is compared in 256 x 256 images; and every fourth data point in every fourth line is compared in 512 x 512 images.

Filter

Defines whether a Low pass filter is performed by replacing the data with the envelope or High pass filter in which the data are replaced with the difference between data and the envelope.

Section

Draws the cross-section, envelope, and the difference between the two on the "Section" plot and draws the cross section on the "Roller Geometry" plot.

Execute

Filters and redisplay the image based on the current subcommand settings.

Clear

Removes the section from the image and the corresponding windows from the Display Monitor allowing a new cross-section to be defined.

Mouse Operation —Geometric

There are three main functions that the mouse performs in the **Geometric** command.

1. Define the cross section on the image.
 - The first click of the left mouse button when the cursor is on the image anchors a "rubber band" line.
 - The second click fixes the direction of the line, and draws a cross-sectional profile in the "Section" and "Roller Geometry" windows. The "Section" window also displays the line envelope and the filtered-line data.
2. Scroll the section in the "Roller Geometry" window.
 - The cursor in the Section window can be grabbed and released with the mouse.
 - As the cursor is moved, the section in the "Roller Geometry" window scrolls past the elliptical roller.
3. Change the size of the elliptical roller.
 - The size of the elliptical roller can be changed by clicking and dragging the elliptical cursor in the "Roller Geometry" window. As the roller size changes, the envelope is recalculated and the "Section" and the "Roller Geometry" windows are updated.

Note: The geometric filter can be used as a Highpass as well as a Lowpass filter. The cutoff frequency is essentially determined by the roller size. As the size increases, the cutoff frequency decreases.

Example for Using the Geometric Command

The **Geometric** command can be very helpful in removing saddle-type bowing from an image. A **Highpass** operation with relatively large ellipse works quite well.

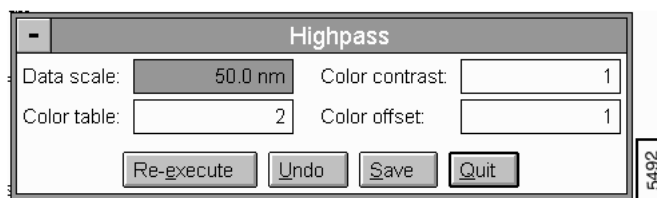
15.12 Highpass

The **Highpass** command replaces each data point in the image with the weighted difference between that data point and each of its eight neighbors. This operation is useful in highlighting edges or areas with rapidly changing height in images. Note that it does not make any sense to apply this filter more than once to an image.

15.12.1 Highpass Panel

The **Highpass** panel allows the display parameters to be adjusted to your preferences.

Figure 15.12a Highpass Panel



Parameters and Buttons on the Highpass Panel

Re-execute—Applies the **Highpass** filter to the data again.

Undo—Restores the image to its original form.

Save—Allows the converted image to be saved.

Quit—Exits the operation.

Data scale

Controls the vertical range of the image corresponding to the full extent of the color table. The units of this item vary according to the type of image (e.g., nm, nA, etc.).

Color table

Selects the color table used to encode the Z information.

Color contrast

Controls the contrast in the image by compressing or expanding the color table.

Color offset

Shifts the color table used to display the image.

15.12.2 Highpass Display Monitor

The **Highpass** filter is applied to the data as soon as the **Highpass** command is selected. (When the image is displayed after selecting the command, it has already been filtered once.)

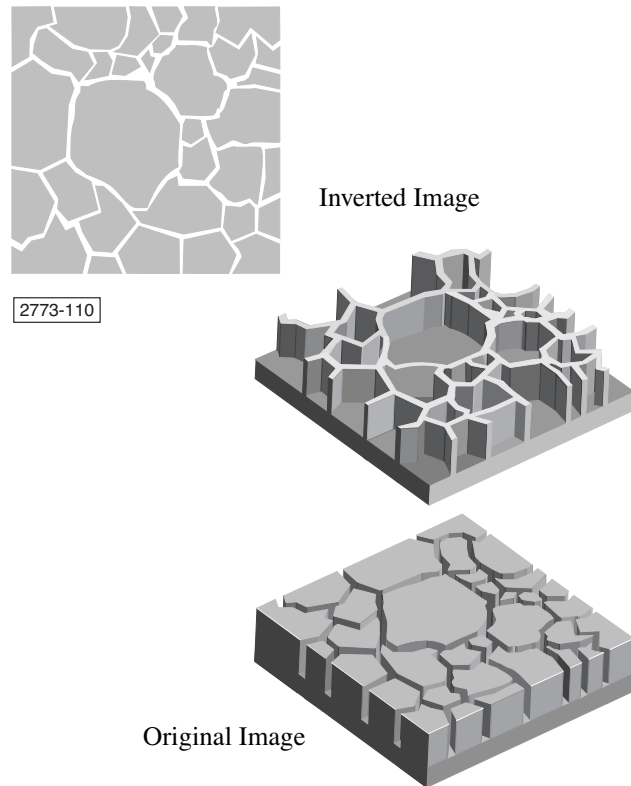
Example for Using the Highpass Command

The **Highpass** command can be used to bring out edges in images, since it essentially takes the derivative of the image, thus highlighting areas with rapidly changing surface height.

15.13 Invert

The **Invert** command *Inverts* image data along the Z-axis, effectively turning valleys into mounds and vice versa. The inverted image retains the symmetry and orientation of the original (it does not produce a reverse or "mirrored" image).

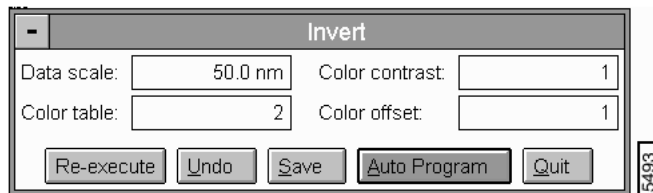
Figure 15.13a Invert Command Illustrated



15.13.1 Invert Panel

The **Invert** panel features a **Re-execute** button and allows display parameters to be adjusted.

Figure 15.13b Invert Panel



Parameters and Buttons on the Invert Panel

Re-execute—Runs the command again.

Undo—Restores the image to its original form.

Quit—Exits the operation.

Save—Allows the converted image to be saved to the disk.

Data scale

Controls the vertical range of the image corresponding to the full extent of the color table. The units of this item vary according to the type of image (e.g., nm, nA, etc.).

Color table

Selects the color table used to encode the Z information.

Color contrast

Controls the contrast in the image by compressing or expanding the Color Table.

Color offset

Shifts the color table used to display the image.

15.13.2 Invert Command Display Monitor

The original image is displayed in its inverted form when **Invert** is first selected. Use the **Re-execute** button to restore the image to its original form.

The **Invert** command can be used to add two images by subtracting an inverted version from an original. If image **A** is to be added to image **B**, invert image **B** first, then use the **Modify / Subtract Images** command to subtract image **B** from image **A**. (That is, $A + B \equiv A - (-B)$.)

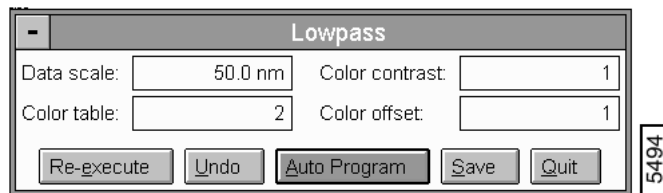
15.14 Lowpass

The **Lowpass** command replaces each data point in the image with the weighted average of the 3 x 3 cell of points surrounding and including the point. This command is faster than Fourier filtering, and it can be applied to the same image a number of times.

15.14.1 Lowpass Panel

The **Lowpass** panel allows display parameters to be adjusted to your preferences.

Figure 15.14a Lowpass Panel



Parameters and Buttons on the Lowpass Panel

Re-execute—Applies the Lowpass filter again.

Undo—Restores the image to its original form.

Auto Program—Allows the **Lowpass** command to be added to, or deleted from, the currently selected Auto Program file (See [Section 15.14.2](#)).

Save—Allows the converted image to be saved to the disk.

Quit—Exits the operation.

Data scale

Controls the vertical range of the image corresponding to the full extent of the color table. The units of this item vary according to the type of image (e.g., nm, nA, etc.).

Color table

Selects the color table used to encode the Z information.

Color contrast

Controls the contrast in the image by compressing or expanding the color table.

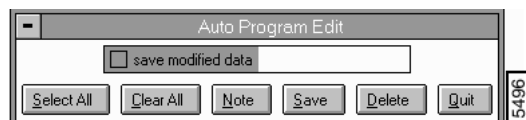
Color offset

Shifts the color table used to display the image.

15.14.2 Lowpass Auto Program Edit Panel

Accesses the **Auto Program Edit** panel and allows the **Lowpass** command to be added to, or deleted from, the currently selected Auto Program file.

Figure 15.14b Low Pass Auto Program Edit Panel



Buttons on the Lowpass Auto Program Edit Panel

Select All—Selects all the measurements simultaneously.

Clear All—Clears all the measurements simultaneously.

Note—Allows you to insert a command note in the Auto Program file.

Save—Saves selected measurements to the Auto Program file. If the **Lowpass** command is already in the current Auto Program file, it retains its position in the file.

Delete—Removes the **Lowpass** command from the Auto Program file.

Quit—Exits the **Auto Program Edit** mode without making changes to the Auto Program file.

Note: The **Auto Program File** command in the **Utility** menu must be used to select or create an Auto Program file.

Note: The **Auto** subcommand under the **Browse** command selects the files to be processed and executes the current Auto Program file.

15.14.3 Display Monitor

The Lowpass filter is applied to the data when the **Lowpass** command is selected from the **Modify** menu. The first time the data displays, it has already been filtered once.

See also: **Off-line / Modify** menu: **Median**, **Spectrum 2D**, and **Erase Scan Lines** commands.

15.14.4 Example

To remove high frequency noise from images, try several passes with the Lowpass filter. For images with a large number of features across the screen (more than 10 to 20), the Lowpass filter attenuates those features even on a single pass.

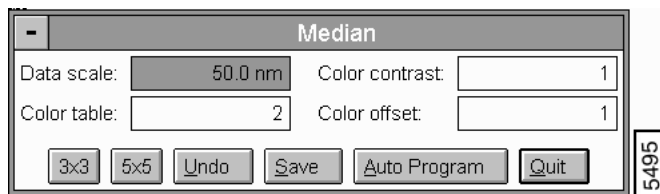
15.15 Median

The **Median** command replaces each data point in the image with the median value of either a 3 x 3 or 5 x 5 cell of surrounding points. The data point forms the center of the cell and is included in the calculation. The operation removes spot noise, and it can be applied repeatedly.

15.15.1 Median Panel

The **Median** panel is displayed allowing the display parameters to be adjusted to your preferences.

Figure 15.15a Median Panel



Parameters and Buttons on the Median Panel

3x3—Executes the operation for the 3 x 3 cell.

5x5—Executes the operation for the 5 x 5 cell.

Undo—Restores the image to its original form.

Save—Allows the converted image to be saved to the disk.

Auto Program—Allows the **Median** command to be added to, or deleted from, the currently selected Auto Program file (See [Section 15.15.2](#)).

Quit—Exits the operation.

Data scale

Controls the vertical range of the image corresponding to the full extent of the color table. The units of this item vary according to the type of image (e.g., nm, nA, etc.).

Color table

Selects the color table used to encode the Z information.

Color contrast

Controls the contrast in the image by increasing or decreasing the contrast of colors in the **Color Table**.

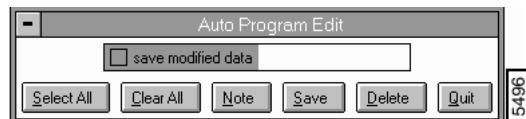
Color offset

Shifts the **Color Table** used to display the image.

15.15.2 Median Auto Program Edit Panel

Accesses the **Auto Program Edit** panel and allows the **Median** command to be added to, or deleted from, the currently selected Auto Program file.

Figure 15.15b Median Auto Program Edit Panel



Parameters and Buttons on the Median Auto Program Edit

Select All—Selects all the measurements simultaneously.

Clear All—Clears all the measurements simultaneously.

Note—Allows you to insert a command note in the Auto Program file.

Save—Saves selected measurements to the Auto Program file. If the **Median** command is already in the current Auto Program file, it retains its position in the file.

Delete—Removes the **Median** command from the Auto Program file.

Quit—Exits the **Auto Program Edit** mode without making changes to the Auto Program file.

15.15.3 Median Display Monitor

This operation is particularly useful in removing spot noise from images, but it can have a rather degrading effect on the image resolution. For optimal effect, this operation should be performed before the **Lowpass** operation if both are to be used.

See also: **Off-line / Modify** menu: **Lowpass**, **Spectrum 2D**, and **Erase Scan Lines** commands.

Example for Using the Median Command

This operation would be particularly useful on an image with randomly located sharp spike noise. The **Lowpass Filter** would require too many applications to remove the noise. A 3x3 or 5x5 **Median** operation would eliminate the spikes.

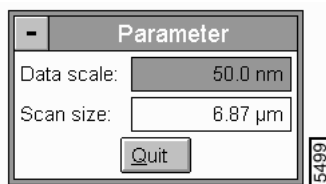
15.16 Parameter

The **Parameter** command allows the **Z range** and **Scan size** of a captured image to be rescaled based on new sensitivity information.

15.16.1 Parameter Panel

The **Parameter** panel allows the **Z range** and **Scan size** to be adjusted to change the dimensions of a stored image.

Figure 15.16a Parameter Panel



Parameters and Button on the Parameter Panel

Quit—Performs and exits the operation.

Data Scale—Allows Z distance to be entered.

Scan Size—Allows scan size to be entered.

Hints for Optimizing the Parameter Command

- The numbers and units shown in the panel when the command is first called are the values used to collect the data.
- The operation of this command is different than changing the **Z range** in the **Off-line / View** panels. Changing the **Z range** in the panels changes the range of the color bar used to display the Z data; this command changes the numerical values of the **Z range** and the **Scan size**.
- An image captured with incorrect piezo sensitivities can be corrected with this command.
- The correction does not show until the image is redisplayed.
- For offline profiler data files, an added feature allows you to change the data scale, in terms of length, by entering a new **Scan size**.



15.17 Plane Fit Auto

The Plane Fit Auto command calculates a single polynomial of a selectable order for an image and subtracts it from the image. The plane fit operation can be applied to either the X , Y or XY direction.

15.17.1 Fitted Polynomials

Refer to [Table 15.17a](#) to view the inherent software polynomials that calculate the best plane fit for the images in the Plane Fit Auto function.

Table 15.17a Plane Fit Auto Equations

Order	Variable	Polynomial Equation
0	X	$z = a$
	Y	$z = a$
	XY	$z = a$
1	X	$z = a + bx$
	Y	$z = a + by$
	XY	$z = a + bx + cy + dxy$
2	X	$z = a + bx + ex^2$
	Y	$z = a + cy + fy^2$
	XY	$z = a + bx + cy + dxy + ex^2 + fy^2 + gxy^2 + hx^2y + ix^2y^2$
3	X	$z = a + bx + ex^2 + jx^3$
	Y	$z = a + cy + fy^2 + ky^3$
	XY	$z = a + bx + cy + dxy + ex^2 + fy^2 + gxy^2 + hx^2y + ix^2y^2 + jx^3 + ky^3 + lxy^3 + mx^2y^3 + nx^3y^3 + ox^3y + px^3y^2$

Box cursors in the software functions, allow specific points to be used in the calculation of the polynomial. The calculation uses the average value of the columns in the box to determine the polynomial for X and the average across rows when Y is selected. One point is used for each column, or row, in every box. The command fits a polynomial of the selected order to the points and subtracts this same polynomial from each line in the image.

For further details on the Plane Fit Auto command, refer to the following sections:

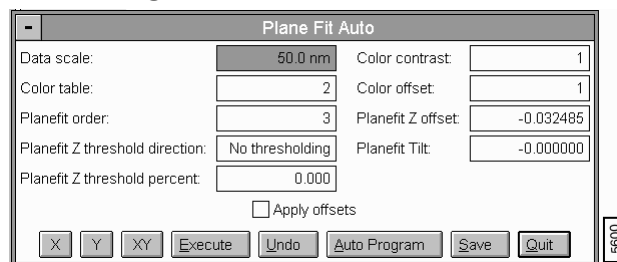
- [Plane Fit Auto Panel Section 15.17.2](#)

- **Planefit Auto Auto Program Edit Panel** [Section 15.17.3](#)
- **Plane Fit Display Monitor** [Section 15.17.4](#)
- **Procedure for Using Plane Fit Auto** [Section 15.17.5](#)

15.17.2 Plane Fit Auto Panel

The **Plane Fit Auto** panel allows the display parameters and the Planefit order to be adjusted to your preferences.

Figure 15.17a Plane Fit Auto Panel



Parameters and Buttons on the Plane Fit Auto Panel

X—Applies the plane fit operation along the X axis.

Y—Applies the plane fit operation along the Y axis.

XY—Applies the plane fit operation along the X and Y axis

Undo—Restores the image to its original form.

Auto Program—Accesses the **Auto Program Edit** panel allowing the **Plane Fit Auto** command to be added to, or deleted from, the currently selected Auto Program file (See [Section 15.17.3](#)).

Save—Allows the converted image to be saved to the disk.

Quit—Exits the operation.

Planefit order

Selects the order of the plane calculated and subtracted from the image.

Planefit Z offset

If **Apply offsets** is activated, the image is offset by the absolute value of **Planefit Z offset** in the negative direction.

Planefit Tilt

If **Apply offsets** is activated, the image is offset by the absolute value of **Planefit Tilt** in the negative direction.

Color offset

Shifts the color table used to display the image.

Data scale

Controls the vertical range of the image corresponding to the full extent of the color table. The units of this item vary according to the type of image (e.g., nm, nA, etc.).

Color table

Selects the color table used to encode the Z information.

Color contrast

Controls the contrast in the image by compressing or expanding the Color table.

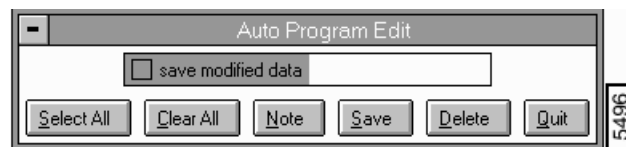
Apply offsets

When box is checked, the **Planefit Auto** offsets are applied.

15.17.3 Planefit Auto Auto Program Edit Panel

Accesses the **Auto Program Edit** panel allowing the **Plane Fit Auto** command to be added to, or deleted from, the currently selected Auto Program file.

Figure 15.17b Plane Fit Auto Program Edit Panel



Parameters and Buttons on the Plane Fit Auto Program Edit

Select All—Selects all the measurements simultaneously.

Clear All—Clears all the measurements simultaneously.

Note—Allows you to insert a command note in the Auto Program file.

Save—Saves selected measurements to the Auto Program file. If the **Plane Fit Auto** command is already in the current Auto Program file, it retains its position in the file.

Modify Menu
Plane Fit Auto

Delete—Removes the **Plane Fit Auto** command from the Auto Program file.

Quit—Exits the Auto Program Edit mode without making changes to the Auto Program file.

Note: The Auto Program File command in the **Utility** menu must be used to select or create an Auto Program file.

The **Auto** subcommand under the **Browse** command selects the files to be processed and executes the current Auto Program file.

15.17.4Plane Fit Display Monitor

The standard top view of the image plus the menu and status bars are shown on the Display Monitor.

Plane Fit Menu Bar Commands

Mode

Selects the orientation of the plane fit.

- **X**—Selects the horizontal direction for the polynomial curve-fit.
- **Y**—Selects the vertical direction for the polynomial curve-fit.

Mouse Operations—X and Y subcommands.

- **1st click**—fixes the corner of the box cursor. It "rubber bands" out as the cursor is moved.
- **2nd click**—fixes the position of the box cursor.
- **Subsequent clicks**—Clicks inside of an existing box picks up the box so it can be repositioned. Clicks outside of the box allow additional boxes to be drawn.

Cursor

Allows the mouse to be used to draw box cursors.

- **Delete**—Allows the mouse to remove individual box cursors.
- **Clear**—Removes all of the cursors from the image.

Mouse Operations —Delete subcommand

- Clicking on a box removes it.

Execute—Initiates the plane fit operation.

Undo—Restores the image to its original form.

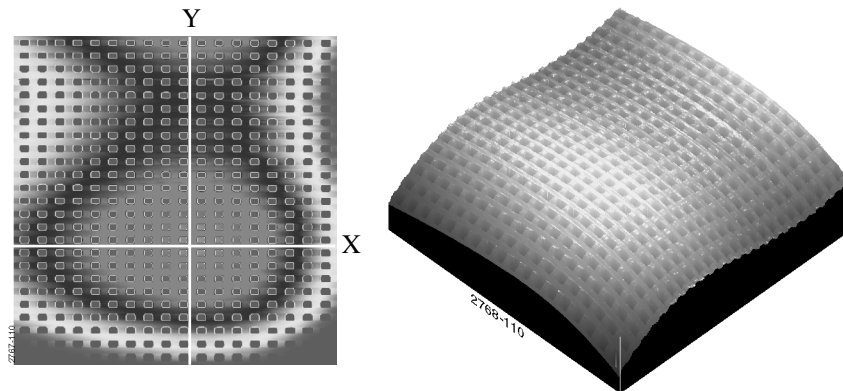
See also: **Off-line / Modify** menu: **Flatten**, **Geometric**, and **Plane Fit Manual** commands.

15.17.5 Procedure for Using Plane Fit Auto

Use **Plane Fit (Auto or Manual)** to correct the image distortion as follows:

1. Load and study a captured image before modifying it by clicking on **View / Surface Plot** (or use the **Surface Plot** icon). Notice any the strong saddle appearances as shown in [Figure 15.17c](#).

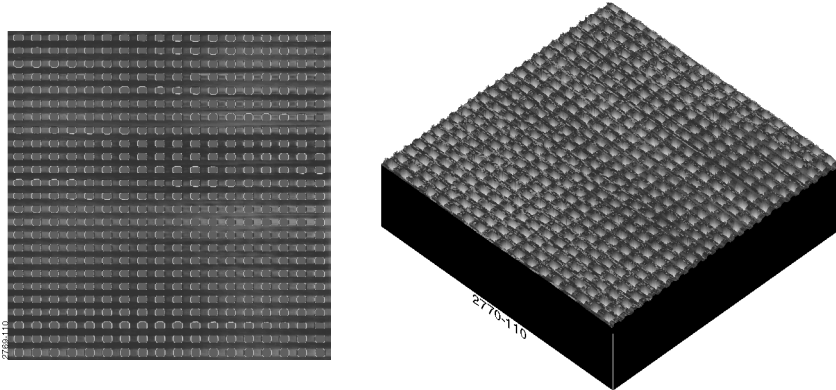
Figure 15.17c Saddle Image



2. Click on the **Modify / Plane Fit Manual** command (**Plane Fit Auto** is similar). The Plane Fit Manual panel appears on the Control Monitor; the top view image of the file is shown on the Display Monitor. For this image, the **Plane Fit order** value should be set to **3**.
3. Next, select the **X** cursor option on the display screen menu bar, then click on the image. A movable, white X-axis line cursor is displayed. Position the X line cursor to intersect the center of the bulge, between rows of pits. Click on the **Execute** button to plane fit the image along its X axis. The image is now corrected along the X axis, but not along the Y axis.
4. Repeat the process for the Y axis: select the **Y** cursor option on the display screen menu bar, then click on the image. A movable, white Y-axis line cursor is displayed. Position the Y line cursor between rows of pits. Click on the **Execute** button to plane fit the image along its Y

axis. The image is now fully *plane fit* along both X and Y axes, and appears as shown in Figure 15.17d.

Figure 15.17d Plane Fit Image



5. Notice that the image's distortion is removed almost entirely, reflecting a flat, planar profile. Checking a section of the pits' depth before and after **Plane Fit** reveals that the pit depth is relatively unchanged before and after, even near the most severely rolled-off edges.

Now, experiment with this image to explore the range of **Plane Fit** capabilities. Try the following:

- Change the **Planefit order** value to see its effects. Notice that there is a vast difference between a value of **1**, **2** or **3**.
- Try plane fitting in one axis (e.g., X), but not the other. This generally keeps whatever errors are presently oriented along the unused axis. For example, the image can be straightened along its Y axis, while leaving the X axis strongly bowed.
- Try using a different **Planefit order** for the X and Y axis. (For example, a setting of **3** for X, but a setting of **1** for Y.) This is similar to using one axis, but not the other.
- Compare the effect of **Plane Fit** with **Flatten**. Notice that each command has a significantly different impact upon this image; although, the difference is less noticeable for some other types of images.

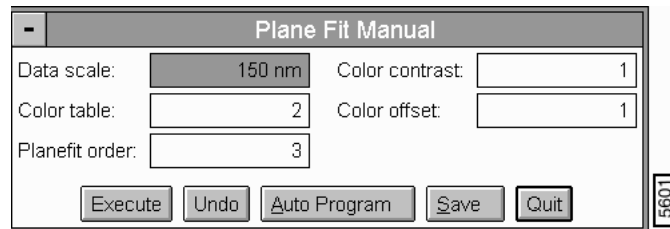
15.18 Plane Fit Manual

The **Plane Fit Manual** command allows either a vertical or horizontal line placed anywhere on the image to specify the data used for calculating the best-fit polynomial. Furthermore, sections of the line can be eliminated from the calculation and the order (first, second, or third) of the polynomial can be specified.

15.18.1 Plane Fit Manual Panel

The **Plane Fit Manual** panel allows display parameters to be adjusted to your preferences.

Figure 15.18a Plane Fit Manual Panel



Parameters and Buttons on the Plane Fit Manual Panel

Execute—Initiates the command.

Undo—Restores the image to its original form.

Auto Program—Accesses the **Auto Program Edit** panel and places the **Plane Fit Manual** functions on the Auto Program file ([Section 15.18.2](#)).

Save—Allows the converted image to be saved to the disk.

Quit—Exits the operation.

Planefit order

Specifies the order of the polynomial used to fit the cross section of the image. First, second, and third-order polynomials can be selected.

Data scale

Controls the vertical range of the image corresponding to the full extent of the color table. The units of this item vary according to the type of image (e.g., nm, nA, etc.).

Color table

Selects the color table used to encode the Z information.

Color contrast

Controls the contrast in the image by compressing or expanding the Color Table.

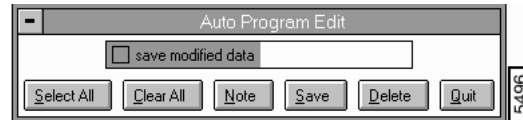
Color offset

Shifts the color table used to display the image.

15.18.2 Plane Fit Manual Auto Program Edit Panel

Accesses the **Auto Program Edit** panel allowing the **Plane Fit Manual** command to be added to, or deleted from, the currently selected Auto Program file.

Figure 15.18b Plane Fit Manual Auto Program Edit



Parameters and Buttons on the Plane Fit Manual Auto Program Edit

Select All—Selects all the measurements simultaneously.

Clear All—Clears all the measurements simultaneously.

Note—Allows you to insert a command note in the Auto Program file.

Save—Saves selected measurements to the Auto Program file. If the **Plane Fit Manual** command is already in the current Auto Program file, it retains its position in the file.

Delete—Removes the **Plane Fit Manual** command from the Auto Program file.

Quit—Exits the **Auto Program Edit** mode without making changes to the Auto Program file.

Note: The **Auto Program File** command in the **Utility** menu must be used to select or create an Auto Program file.

Note: The **Auto** subcommand under the **Browse** command selects the files to be processed and executes the current Auto Program file.

15.18.3 Plane Fit Manual Display Monitor

The standard top view of the image plus the menu and status bars are shown on the Display Monitor.

Plane Fit Manual Display Menu Bar

X

Selects the horizontal direction for the polynomial curve-fit and places a horizontal line to be positioned by the mouse on the image.

Y

Selects the vertical direction for the polynomial curve-fit and places a vertical line to be positioned by the mouse on the image.

Move

Allows the mouse to be used to reposition the horizontal or vertical reference line.

Draw

Allows the mouse to be used to add segments to previously erased portions of either the horizontal or vertical reference line.

Erase

Allows the mouse to be used to delete segments from either the horizontal or vertical reference line.

Clear

Removes the line from the image.

Execute

Initiates the plane fit operation.

Undo

Restores the image to its original form.

Mouse Operations—X, Y, Mover, Draw, Erase

X—Places a horizontal line on the image. The line position is tied to the mouse; therefore, the line can be positioned by moving the mouse up and down.

- 1st click—drops the line.

Y—Places a vertical line on the image. The line position is tied to the mouse; therefore, the line can be positioned by moving the mouse left and right.

- 1st click—drops the line.

Move:

- 1st click—picks up the line and ties the line position to the mouse movement.
- 2nd click—drops the line.

Draw—Places the cursor in the desired position

- 1st click—begins drawing along the reference line. Moving the mouse adds a new line segment where a portion of the reference line was previously deleted.

- 2nd click—ends the new line segment.

Erase—Places the cursor in the desired position

- 1st click—begins erasing the previously drawn line. Moving the mouse deletes a segment of the line.
- 2nd click—ends the erase process.

Hints for Optimizing the Mouse Operations

- The status bar reports the line orientation, X for horizontal or Y for vertical, and the line manipulation mode, **Move**, **Erase**, or **Draw**.
- After a **Clear** or **Undo** operation, a new line can be placed on the image in the orientation indicated in the status bar by clicking the left mouse button on the image.
- The **Move**, **Draw**, and **Erase** operations can be initiated by clicking the left button of the mouse in the image whenever the respective mode is highlighted in the status bar.

See also: **Off-line / Modify** menu: **Plane Fit Auto**, **Geometric**, **Flatten** commands.

15.19 Resize

The **Resize** command converts images collected with one number of data points, the **Number of samples** parameter, to another number of data points. Images captured in the 512 x 512 or 256 x 256 format can be reduced to smaller formats. Images captured in the smaller 128 x 128 or 256 x 256 formats can be expanded through interpolation to larger formats.

15.19.1 Resize Panel

The Resize panel is displayed allowing the display parameters to be adjusted to your preferences.

Figure 15.19a Resize Panel



Parameters and Buttons on the Resize Panel

Execute—Initiates the command.

Undo—Restores the image to its original form.

Quit—Exits the operation.

Save—Allows the converted image to be saved to the disk.

New size

Specifies the size of the image after the conversion operation.

Data scale

Controls the vertical range of the image corresponding to the full extent of the color table. The units of this item vary according to the type of image (e.g., nm, nA).

Color table

Selects the color table used to encode the Z information.

Color contrast

Controls the contrast in the image by compressing or expanding the Color Table.

Color offset

Shifts the color table used to display the image.

15.19.2 Resize Display Monitor

Images can be stored in smaller sizes to reduce the disk space required to store the image. Resizing to a larger format does *not* increase image resolution. The added pixels are interpolated from the original data.

Example for Using the Resize Command

The **Resize** command can be handy for seeing how 512 x 512 images would appear if stored in 256 x 256 format. Use this to see if there is any perceptible loss of image quality.

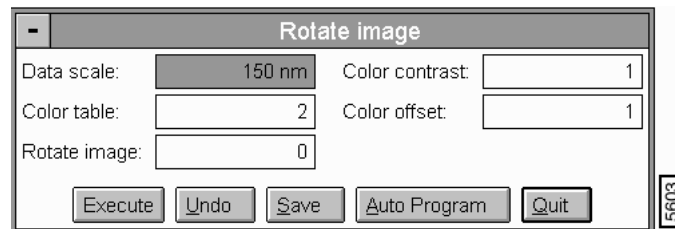
15.20 Rotate

Rotate serves to rotate an image in ninety degree increments. Occasionally, a scan is captured that would be easier to analyze if it were oriented a different way (a scan of a penny, for example). Rotate allows you to re-orient the scan. Note that the relative data remains unchanged, only the orientation of the data is altered.

15.20.1 Rotate Image Panel

The **Rotate** panel allows display parameters to be adjusted to your preferences.

Figure 15.20a Rotate Image Panel



Parameters and Buttons on the Rotate Image Panel

Data scale

Controls the vertical range of the image corresponding to the full extent of the color table. The units of this item vary according to the type of image (e.g., nm, nA, etc.).

Color table

Selects the color table used to encode the Z information.

Color contrast

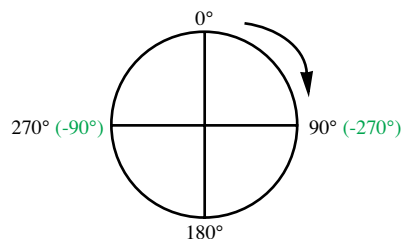
Controls the contrast in the image by compressing or expanding the Color Table.

Color offset

Shifts the color table used to display the image.

Rotate image

Rotates the image in 90° increments, in either the positive or negative direction.



Execute—Initiates the Rotate image operation.

Undo—Restores the image to its original form.

Save—Allows the converted image to be saved to the disk.

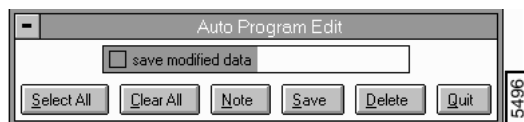
Auto Program—Places the **Auto Program Edit** panel on the Control Monitor allowing the Rotate command to be added to, or deleted from, the currently selected Auto Program file (See [Section 15.20.2](#)).

Quit—Exits the **Rotate Image** command.

15.20.2 Rotate Image Auto Program Edit Panel

Places the **Auto Program Edit** panel on the Control Monitor allowing the Rotate command to be added to, or deleted from, the currently selected Auto Program file.

Figure 15.20b Rotate Image Auto Program Edit



Buttons on the Rotate Image Auto Program Edit

Select All—Selects all the measurements simultaneously.

Clear All—Clears all the measurements simultaneously.

Note—Allows you to insert a command note in the Auto Program file.

Save—Saves selected measurements to the Auto Program file. If the **Rotate** command is already in the current Auto Program file, it retains its position in the file.

Delete—Removes the **Rotate** command from the Auto Program file.

Quit—Exits the Auto Program Edit mode without making changes to the Auto Program file.

15.21 Spectrum 2D

The **Spectrum 2D** (two-dimensional) function transforms images into a 2D fast Fourier transform (FFT) plot, then allows you to selectively pass or remove specific frequencies from the image. After selected frequencies are passed or removed, the image is reconstructed, yielding an improved version. The **Spectrum 2D** function is extremely useful in removing electrical and acoustic noise from images, and may also be used to isolate certain surface features (e.g., lathe lines on turned surfaces, load marks on ground or polished surfaces, etc.)

Noise is removable using the **Spectrum 2D** function generally consists of two types: 1) high frequency electrical noise (most visible at atomic resolution); 2) lower-frequency acoustic noise from floor vibrations, air blowers, etc. The 2D spectral display is scaled according to the scan size of the original image

15.21.1 Spectrum 2D Procedures

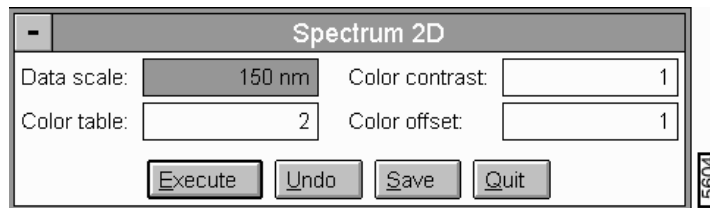
Before beginning, it is advisable to make a backup copy of the original image file. The **Spectrum 2D** function is capable of making major changes to the image which, if saved, can destroy the original data.

The **Spectrum 2D** command allows filtering of images in the frequency domain through the 2-dimensional fast Fourier transform (FFT). The 2-D FFT (power spectrum) of the image is calculated and displayed. Rectangular boxes representing either frequencies to pass (multiply by 1.0), passband, or frequencies to stop (multiply by 0.0), stopband, are selected. Finally, the inverse transform is performed on the filtered transform data to reconstruct a new filtered image.

15.21.2 Spectrum 2D Pane

The **Spectrum 2D** panel allows display parameters to be adjusted to your preferences.

Figure 15.21a Spectrum 2D Panel



Parameters and Buttons on the Spectrum 2D Panel

Execute—Initiates the two-dimensional FFT calculation.

Undo—Restores the image to its original form.

Save—Allows the converted image to be saved to the disk.

Quit—Exits the operation.

Data scale

Controls the vertical range of the image corresponding to the full extent of the color table. The units of this item vary according to the type of image (e.g., nm, nA, etc.).

Color table

Selects the color table used to encode the Z information.

Color contrast

Controls the contrast in the image by compressing or expanding the Color Table.

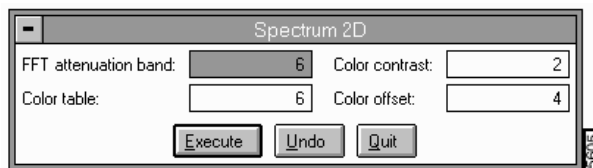
Color offset

Shifts the color table used to display the image.

15.21.3 Two-Dimensional FFT

When the two-dimensional FFT (2D FFT) is calculated and shown on the Display Monitor, a new panel is displayed on the Control Monitor (See [Figure 15.21b](#)). It allows the filtering process to continue by performing the inverse FFT after the desired passbands and stopbands have been selected.

Figure 15.21b Two-Dimensional FFT Spectrum 2D Panel



Parameters and Buttons on the 2D FFT Spectrum 2D Panel

Execute—Initiates the inverse FFT calculation.

Undo—Restores the image to its original form.

Quit—Exits the operation.

FFT attenuation band

Controls the pixel width of the attenuation band used to ramp the passband boxes to zero and the stopband boxes to one. This enables the effect of stopbands and passbands to be either gently "feathered" into the image spectral data (by using larger values, e.g., 16), or directly applied (by using smaller values, e.g., 0).

Range or Settings:

- 0, 2, 4, 6, 8, 10, 12, 14, 16

If **FFT attenuation band** values are set smaller than the stopband's box size in pixels, the stopband **DOES NOT WORK**. Stopbands that are to be applied directly to very small spectral "hot spots" should have their **FFT attenuation band** values set at **0**.

Color table

Selects the color table used to encode the Z information.

Color contrast

Controls the contrast in the image by compressing or expanding the color table.

Color offset

Shifts the color table used to display the image.

15.21.4 Spectrum 2D Display Monitor

In addition to the menu and status bars, the power spectrum, a color bar which reflects the amplitude of the power spectrum, and a measurement chart are shown on the Display Monitor. The subcommands available in the menu bar of the Display Monitor allow you to select different areas of the power spectrum. The status bar indicates which options are currently selected. The measurement chart contains data from the power spectrum.

Spectrum 2D Display Menu Bar Commands

Cursor

Controls the mode of the cursor and mouse in the Display Monitor.

Range or Settings:

- **Stopband**—Puts the mouse in the stopband mode. This allows placement of stopband boxes which set the frequency data within the boxes to zero. The data outside of the boxes is passed. Stopbands appear on the top view image as "X-ed rectangles.
- **Passband**—Puts the mouse in the passband mode. This allows placement of passband boxes which set the frequency data outside the boxes to zero. Data inside the boxes is passed.

Mode

Controls the Mode of the Stopband and Passband boxes.

- **Add**—Allows stopband or passband boxes to be placed on the image of the power spectrum.
- **Delete**—Allows stopband or passband boxes to be removed from the image of the power spectrum.
- **Clear**—Removes all of the stopband or passband boxes from the image of the power spectrum.

Mouse operations—Add mode

- 1st click—Fixes the position of a corner of the box and allows the mouse to drag out the desired shape of the box. A mirror image of the box is also drawn due to the symmetry of the calculation.
- 2nd click—Fixes the position of the opposite corners of the boxes.

Mouse Operation—Delete mode

- Each click erases from the power spectrum display any passband or stopband boxes that enclose the location where the click occurred. The complimentary box in the opposite quadrant is also removed.

Mouse Operations—Any mode

- Clicking the right mouse button completes the current operation and moves the cursor to the **Execute** subcommand in the menu bar.
- While the FFT transform is displayed, moving the cursor within the image and briefly stopping displays the period, angle, amplitude, and spectral density at the cursor position.

Execute

Initiates the calculation of the power spectrum, FFT, from the original image and the calculation of the image, inverse FFT, from the modified power spectrum.

Undo

Restores the image to its original form.

Zoom

Provides three levels of magnification for the power spectrum

Range and Settings:

- **1 : 1**— shows all of the available spectral frequencies
- **2 : 1**— zooms the display 2:1, showing the lowest one-half of X and Y spectral frequencies.
- **4 : 1**— zooms the display 4:1, showing the lowest one-quarter of X and Y spectral frequencies.

Hints for Optimizing the Spectrum 2D Command

- It is possible to negate the effect of a small stopband box or passband box by using a large value for the **FFT attenuation parameter**.
- If any passband boxes exist on the display, then data outside the passband boxes is deleted. Thus, it is superfluous to have a stopband box completely outside the confines of a passband box.
- Due to the symmetry of the transformed data about the line $f_x = -f_y$, all stopband and passband boxes drawn actually produce two boxes on the display.

See also: **Off-line/Modify** menu: **Lowpass** and **Highpass** commands.

15.21.5 Example 1 – Simplifying an Image

Regarding data contained within an image, *more* data is not always better. Sometimes it is desirable to *eliminate* components of an image to better isolate and accentuate another component of direct interest. The following example demonstrates how to utilize the Spectrum 2D function to simplify an image for analysis. The image utilized here is of lathed plastic used in the manufacture of contact lenses.

1. Load an image from the SPM/IMAGES DIRECTORY (or in the IMAGES folder on your installed system). Examine the image using the **Offline / Surface Plot** function.

Supposing you want to make a general, cross-sectional inspection of the sample's lathe lines, it may prove helpful to remove spikes and smaller, jagged features on the surface. Notice the surface topology may be analyzed in terms of two dominant influences: 1) lathe lines running parallel to the image's Y-axis; 2) a contiguous, jagged aspect to each lathe line (i.e., the lines themselves are not smooth streaks, but present a jagged profile along their length). Since the parallel lathe lines occur at longer wavelengths than the short-wavelength, jagged bumps and spikes, it is possible to separate these components using 2D spectral analysis.

2. With the image selected, click on **Offline / Modify / Spectrum 2D**. The **Spectrum 2D** panel appears on the Control Monitor; the image appears on the Display Monitor. Click on the **Execute** button.

The 2D spectrum of the image appears on the Display Monitor as a clustering of data having a narrow, horizontal band. This horizontal band reveals the prominence of the parallel lathe lines, and the fact that they are distributed uniformly along the X-axis of the image.

As the cursor is moved through the 2D plot, the **X period**, **Y period** and **R period** values are displayed in a box to the right of the plot. Moving the cursor through the data cluster reveals that shorter wavelengths lie around the periphery of the plot, while longer wavelengths lie near the plot's center. Notice that the plot is bandwidth limited at its exact center; that is, nothing larger than the scan size of the image may be plotted here. The centermost point of the plot (best viewed by using the **Zoom / 4:1** function on the Display Monitor) is labeled "DC." This reference to "direct current" is another way of saying that the longest wavelengths, when considered in terms of alternating current, approach infinite periods such as observed in a fixed (DC) waveform.

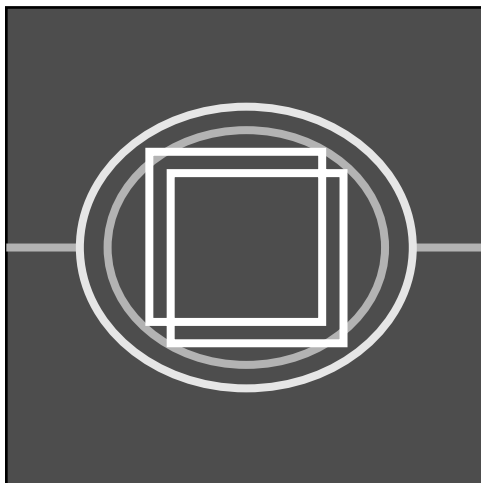
Note: The term "wavelength" as used throughout applies to actual surface features, NOT the color of light used to represent those features.

The trick to using 2D spectral filtering lies in first identifying wavelength components of interest to you. This requires some interpretive ability on your part and is perfected with practice. When the sought-after component is identified, all that remains is to remove everything else.

One use of 2D spectral modification is in removing high frequency components, commonly referred to as "noise." (Whether the component is referred to as "noise," or simply as "high frequency features" of an image is analogous to whether or not to call unwanted plants "weeds.") High frequency components are rendered on images as finely spaced, jagged lines, spikes and fuzz.

Assuming you want to remove high frequency noise, they would seek to eliminate outer portions of the plot. This is easily done with the

Spectrum 2D function by enclosing the central cluster of the plot within a passband drawn on the Display Monitor.



The objective here is to pass (allow) the central, longer wavelength portions of the plot, while stopping (disallowing) the shorter wavelength components located around the periphery of the plot. The **X period** and **Y period** of the enclosed area are displayed to the right as the boxes are drawn.

3. Click on **Cursor / Passband**, then draw a passband box around the central portion of the 2D spectral plot. Click on **Execute** to reconstruct the image with the high frequency components removed. To obtain the best view of the image, quit the **2D Spectrum** panel, then click on the **View / Surface Plot** function (or **Surface Plot** icon button). Changes to the image are most obvious when viewing from an elevated angle.

When the image is reconstructed with its high frequency components removed, the most obvious change is smoother, more contiguous image features. Jagged lines and spikes are reduced, accentuating the longer wavelength features.

Note: Filtering may also be accomplished by utilizing the **Offline / Modify / Lowpass** filter, although *without* selective wavelength controls.

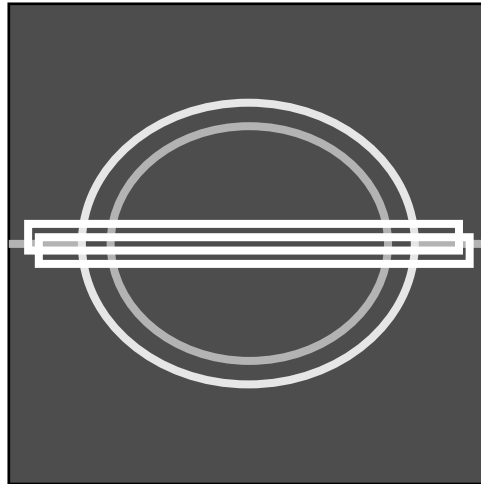
15.21.6 Example 2—Highlighting Features Using 2D Spectrum Modification

Another use of the Spectrum 2D function is in highlighting certain surface features by filtering out unwanted wavelengths. Continuing with the example of the lathed plastic, it is possible to isolate and accentuate lathe lines. (This might prove useful to an analyst intending to examine how cutting tool geometry imparts features to the surface of the plastic.) Conversely, it may also be used to isolate and accentuate smaller surface features inherent within lathe lines, while reducing the separation between lines.

1. Reload the image file used in [Section 15.21.5](#); but *do not* save the previously filtered version of the image. When the image is reloaded, select the **Modify / Spectrum 2D** function, then click on the **Execute** button. As before, the 2D spectrum of the image is plotted. To isolate

the lathe lines, draw a thin, horizontal passband box across the center of the plot (See [Figure 15.21c](#)).

Figure 15.21c Horizontal Passband Box Illustration



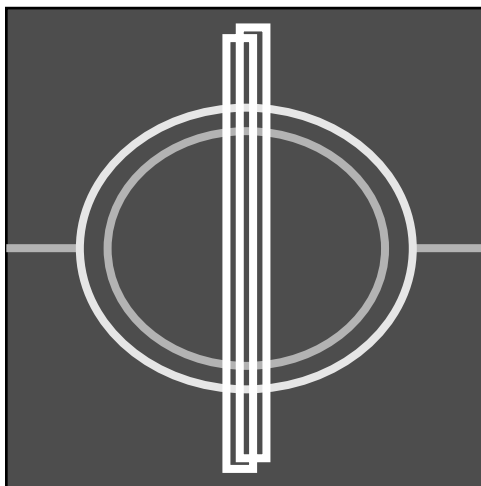
The intent is to pass most wavelengths inherent in the horizontally distributed lathe lines, while stopping those wavelengths inherent in the vertically distributed features of each line (i.e., the jagged contour running along each individual line). After the passband box is drawn, click on the **Execute** button to reconstruct the image. Quit the **Spectrum 2D** panel, then use the **View / Surface Plot** function to look closer at the reconstituted image.

The change in the image quickly becomes evident; lathe lines stand out more dramatically and have been smoothed along their length. By analyzing a section across the lathe lines (**Offline / Analyze / Section**), a cleaner profile of lathe lines in the plastic is obtained.

The vertically distributed features of the lathe lines may be similarly examined by filtering out the horizontal components. By drawing a passband box vertically, it is possible to isolate and accentuate the features running along each individual lathe line. (See [Figure 15.21d](#))

Note: This type of analysis might prove helpful in a study of how tool chatter affects the surface, without regard to tool geometry.

Figure 15.21d Vertical Passband Box Illustration



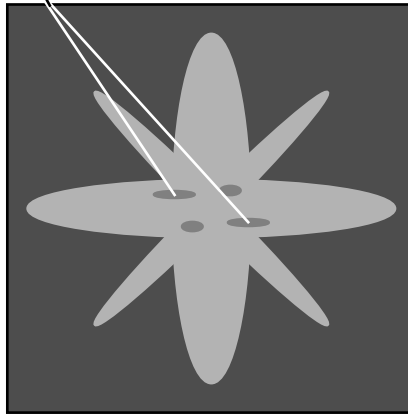
15.21.7 Example 3—Removing External Noise

In Example 1 above (See [Section 15.21.5](#)), high frequency surface noise was removed by drawing a passband around the center spectral plot of the image. This type of noise tends to be evenly distributed across the surface and is inherent to the surface itself. Another type of noise is externally introduced, either due to electrical noise (especially during extremely high resolution, atomic scans), or due to acoustic noise introduced from air blowers, loud sounds, etc. Distinguishing one type of noise from another requires some experience. Here are a few guidelines.

- Steady acoustic noise (such as from a constant pitch sound or moving air) and steady electronic noise, introduce *diagonal bands* to the image. These bands run parallel and are produced when the noise is introduced in sync with the scan. If the bands change their angle of orientation when the **Scan size** or **Scan rate** is altered, they are probably from this source. This type of noise can be easily removed from the image by using the **Spectrum 2D** function.
- Sporadic noise (such as from sudden, loud noises and/or powerful EMF spikes) introduce *isolated “noise lines”* which run partially or completely across the image. These may arise sporadically and without pattern. This type of noise *cannot* be removed from the image using the **Spectrum 2D** function; however, another function (**Modify / Erase Scan Lines**) easily removes this type of noise.
- To remove the diagonal bands characteristic of steady acoustic and electronic noise using the **Spectrum 2D** function, do the following:
 1. Load the image, then click on the **Modify / Spectrum 2D** function. Click on the **Execute** button to obtain the image’s 2D spectral plot. If the image is of a more or less isotropic surface, search the spectral plot for bright “hot spots”—small islands of high spectral concentration—near its center.

Figure 15.21e Spectrum 2D Hot Spots

Spectral "Hot Spots"



Note: Click on the **Zoom / 4:1** function to obtain a closer view of the "hot spots."

Depending upon the distribution and orientation of the noise bands, the hot spots should be distributed at the same angle in the spectral plot as they are on the image. There may also exist other spectral hot spots which are actually part of the surface features; however, these are usually distributed at some other orientation. If the surface is anisotropic and includes some type of banding features naturally, isolating the noise bands proves more difficult, especially if they run parallel to the noise bands.

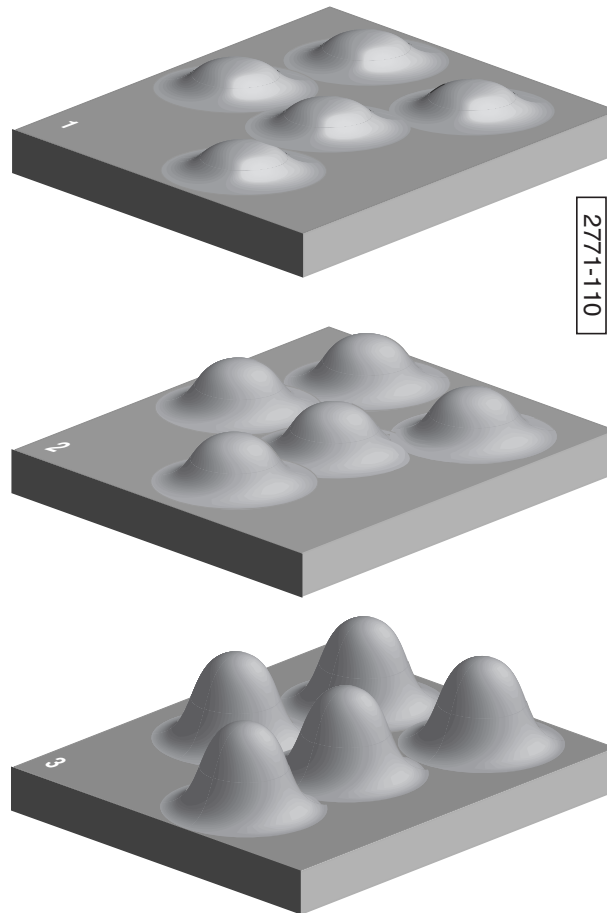
2. Verify that the **FFT attenuation band** value is set to **0**. When the hot spots are located, draw a stopband box around them, then click on the **Execute** button to reconstruct the image. The image should now appear without the noise bands. If noise bands are still present, click on the **Undo** option and try again by stopbanding different hot spots.

15.22 Subtract Images

The **Subtract Images** command enables data from one image to be subtracted from another. This proves most useful when comparing two or more images from a surface to determine changes over time, or to compare completely different images. The **Subtract Images** command cannot be directly applied to images having different pixel sizes (**Number of samples** value). For example, a 256 x 256 pixel image cannot be directly subtracted from a 512 x 512 image. Images may be resized, however, using the **Modify / Resize** command, then subtracted.

[Figure 15.22a](#) diagrams an image subtraction and its effects. Surface **2**, when subtracted from surface **3**, yields surface **1** ("**3**" - "**2**" = "**1**"). Conversely, surface **1** plus surface **2** yields surface **3** ("**1**" + "**2**" = "**3**").

Figure 15.22a Effects of Image Subtraction

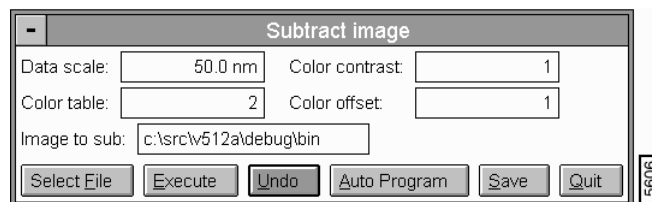


2771-110

15.22.1 Subtract Images Panel

Access the **Subtract Images** panel by clicking on the **Modify / Subtract Images** command. The command assumes that one of the two images (the minuend) is already selected when choosing this command. The panel requests a file to subtract (the subtrahend). Enter the file to subtract in the **Image to sub** field, then clicks on **Execute**. The result is shown on the Display Monitor.

Figure 15.22b Subtract Image Panel



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Parameters and Buttons on the Subtract Image Panel

Select File—Presents a panel for rapid selection of the file to be subtracted (subtrahend). To select a file, highlight the file name with the mouse, then click on Ok.

Execute—Subtracts the selected file from the currently loaded file. The resulting image is displayed.

Undo—Undoes the Subtract Images command. The originally loaded file (minuend) is restored to the Display Monitor.

Auto Program—Accesses the **Auto Program Edit** panel on the Control Monitor, allowing the **Subtract Images** command to be added to, or deleted from, the currently selected Auto Program file.

Save—Saves the subtracted image to the disk.

Quit—Exits the Subtract Images panel.

Data scale

Controls the vertical range of the image corresponding to the full extent of the color table. The units of this item vary according to the type of image (e.g., nm, nA, etc.).

Color table

Selects the color table used to encode the Z information.

Color contrast

Controls the contrast in the image by compressing or expanding the Color Table.

Color offset

Shifts the color table used to display the image.

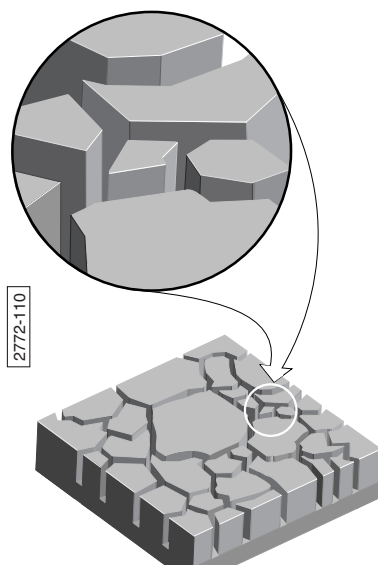
Image to sub

The disk drive, directory and file being subtracted (subtrahend) away from the currently loaded file. Enter this filename, automatically, by using the **Select File** field .

15.23 Zoom

The **Zoom** command expands selected areas of a captured image to fill the display screen. Selected features of captured images can be magnified using the **Zoom** command; however, they do not gain increased resolution beyond the original image. Image data is interpolated when magnifying to a larger size.

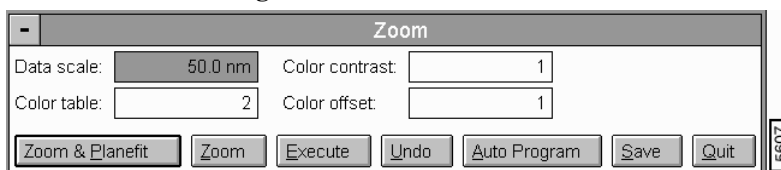
Figure 15.23a Zoom Command Illustrated



15.23.1 Zoom Panel

The Zoom panel controls the operation of the **Zoom** command (See [Figure 15.23b](#)).

Figure 15.23b Zoom Panel



Parameters and Buttons on the Zoom Panel

Zoom & Plane Fit—Expands the region defined by the Zoom box to the size of the regular top view display and includes a plane fit operation as described under the Plane Fit Auto command.

Zoom Only—Expands the region defined by the Zoom box to the size of the regular top view display.

Execute—Performs the selected zoom operation.

Undo—Restores the image to its original form.

Auto Program—Allows the **Zoom** command to be added to, or deleted from, the currently selected Auto Program file (See [Section 15.23.2](#)).

Modify Menu—Allows the converted image to be saved to the disk.

Zoom

Quit—Exits the operation.

Data scale

Controls the vertical range of the image corresponding to the full extent of the color table. The units of this item vary according to the type of image (e.g., nm, nA, etc.).

Color table

Selects the color table used to encode the Z information.

Color contrast

Controls the contrast in the image by compressing or expanding the Color Table.

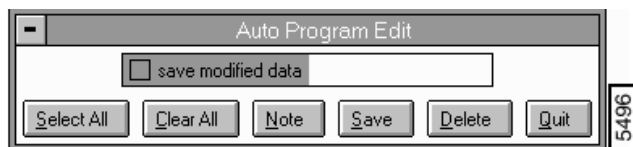
Color offset

Shifts the color table used to display the image.

15.23.2 Zoom Auto Program Edit Panel

The **Auto Program Edit** panel allows the **Zoom** command to be added to, or deleted from, the currently selected Auto Program file. The Auto Program File command in the **Utility** menu must be used to select, or create, an Auto Program file. The **Auto** subcommand under the **Browse** command (**File/Browse**) selects the files to be processed and executes the current Auto Program file.

Figure 15.23c Zoom Auto Program Edit Panel



Buttons on the Zoom Auto Program Edit Panel

Select All—Selects all the measurements simultaneously.

Clear All—Clears all the measurements simultaneously.

Note—Allows you to insert a command note in the Auto Program file.

Save—Saves selected measurements to the Auto Program file. If the **Zoom** command is already in the current Auto Program file, it retains its position in the file.

Delete—Removes the **Zoom** command from the Auto Program file.

Quit—Exits the **Auto Program Edit** mode without making changes to the Auto Program file.

15.23.3 Zoom Display Monitor

The standard top view of the selected image, the **Zoom** menu and status bars appear on the Display Monitor.

Zoom Display Menu Bar Commands

Zoom & Plane Fit

This selection followed by **Execute** expands the region defined by the **Zoom** box to the size of the regular top view display and includes a plane fit operation as described under the **Plane Fit Auto** command.

Zoom Only

This selection followed by **Execute** expands the region defined by the **Zoom** box to the size of the regular top view display.

Clear

Removes the **Zoom** box from the image.

Execute

Begins the selected operation.

Undo

Restores the image to its original form.

Mouse Operations

- 1st click, left button. Clicking within the image places the cursor box on the image.

Modify Menu
Zoom

- Successive clicks of the left button, toggles the **Zoom** box between *expansion* mode (where movement of the mouse causes expansion/contraction of the box) and *translation* mode (where movement of the mouse causes translation of the box).
- Click of the right button, Freezes the **Zoom** box and transfers the cursor to the menu bar allowing the desired subcommand to be initiated with a click of either mouse button.

See also: **Zoom** operations in the **Real-time / Image Mode**.

Chapter 16 Utility Menu

The **Utility** menu includes basic commands to **Print**, **Export**, **Import**, alter the image for saving, and access the **Auto Program** and **Auto Result** files.

This chapter includes the following **Utility** commands:

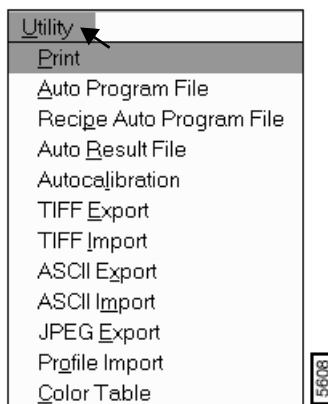
- **Overview** [Section 16.1](#)
- **Print** [Section 16.2](#)
- **Auto Program File** [Section 16.3](#)
- **Recipe Auto Program File** [Section 16.4](#)
- **Auto Result File** [Section 16.5](#)
- **Autocalibration** [Section 16.6](#)
- **TIFF Export** [Section 16.7](#)
- **TIFF Import** [Section 16.8](#)
- **ASCII Export** [Section 16.9](#)
- **ASCII Import** [Section 16.10](#)
- **JPEG Export** [Section 16.11](#)
- **Color Table** [Section 16.13](#)

16.1 Overview

16.1.1 Utility Menu

Select **Off-line/Utility** to access the **Utility** menu (See [Figure 16.1a](#)).

Figure 16.1a Utility Menu

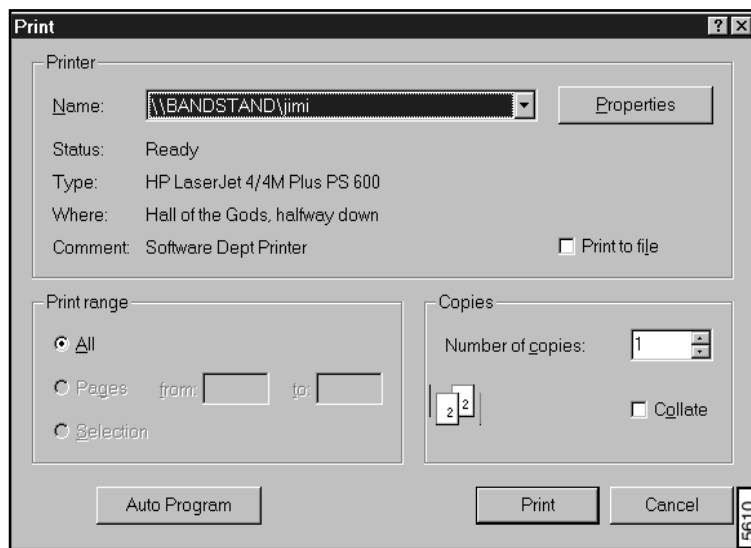


16.2 Print

The **Print** command outputs the Display Monitor screen data to the printer based on the selected options in the Print panel.

Computers running NanoScope software under Windows NT™ use the NT print panels and drivers. You can specify the NT printer, set the number of copies, and set the collation (if available). For more information on the NT print panels, consult the appropriate Windows NT documentation. Select the **Print** command to open the **Print** panel (See Figure 16.2a).

Figure 16.2a Print Panel



The **Print** panel shown on the Control Monitor allows you to select various printer options.

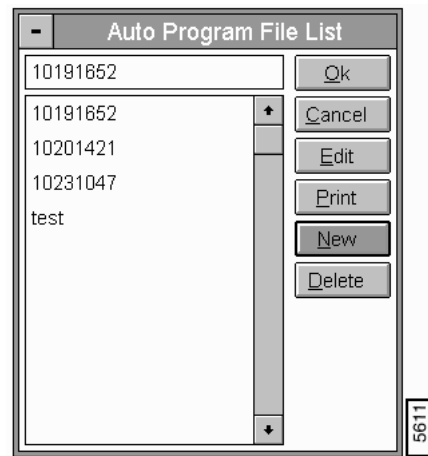
16.3 Auto Program File

The **Auto Program File** command contains several subcommands for creating and manipulating Auto Program files. Auto Program files are programmed from the individual commands. As the command is selected it can be inserted into the file. Auto Program files are run with the **Auto** subcommand in the **Browse** command. Up to 32 images can be processed with the **Top View, Section, Bearing, Roughness, Zoom, Lowpass, Flatten Auto, Planefit Auto, and Print** commands. Each command can be used once per file. The order of the commands depends on the order in which they are selected and edited into the auto program file.

The Auto Program file creates an output file that can be viewed and printed from the **Auto Result File** command.

The **Auto Program File** panel allows you to select an auto program file or create a new one. Buttons allow for reviewing and printing auto program files (See [Figure 16.3a](#)).

Figure 16.3a Auto Program File List Panel



Parameters and Buttons on the Auto Program File List

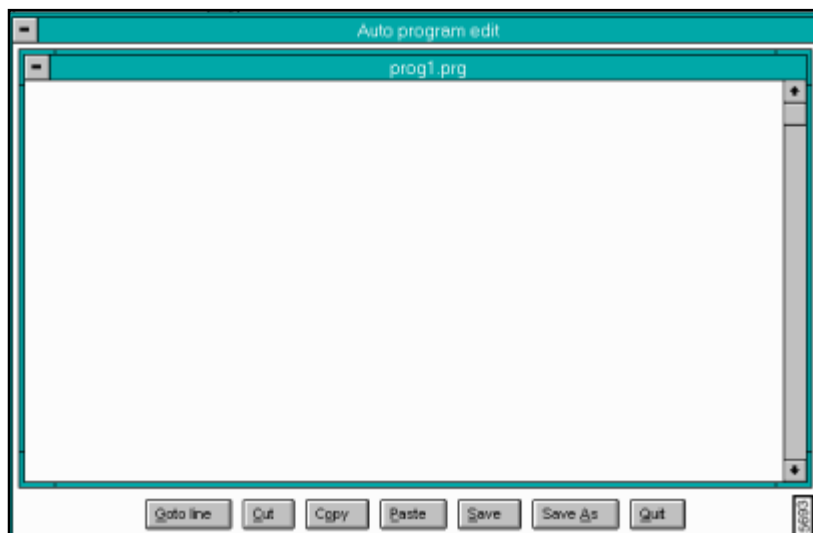
- **File name and List**—Lists the selected auto program file. The Up and Down arrow keys and the Page Up and Page Down keys help move through the list.

Ok—Exits the Auto Program command.

Cancel—Exits the Auto Program File List panel without executing the file.

Edit—Accesses the selected file name in the SPM/PAR Directory. The panel opens the list of parameters to view a specified line, cut, copy, paste, save changes and create a new file (i.e., Save As) (See [Figure 16.3b](#)).

Figure 16.3b Auto Program Edit Panel



Print—Prints the auto program file to a selectable printer and port.

New—Creates a new auto program file.

Delete—Removes the currently selected file from the list.

Procedures for Running the Auto Program File

General procedures for creating and running an **Auto Program** file are as follows:

1. Create the file in the **Auto Program File** command.
2. Select auto programs in the **Auto Program** panel and enter them into the **Auto Program** file from each **Off-line/Menu/Command**.
3. Select the image files, and run the **Auto Program** file from the **Browse** command.

Note: The program files are automatically stored in the C:\AUTO\PROGRAM directory with a .PRG extension.

Note: The result files are automatically stored in the C:\AUTO\RESULT directory with a .RES extension.

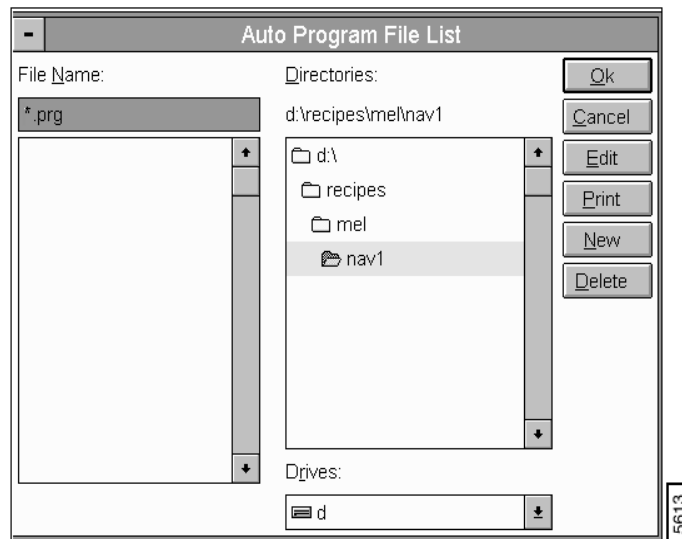
See also: Off-line/**View** menu: **Top View** command. Off-line/**Analyze** menu: **Section, Bearing,** and **Roughness** commands. Off-line/**Modify** menu: **Zoom, Lowpass, Flatten Auto** and **Planefit Auto** commands. Off-line/**Utility** menu: **Print** and **Auto Result File** commands.

16.4 Recipe Auto Program File

The **Recipe Auto Program File** command displays, prints, and deletes output files created in **Automation Recipe Programming**. For complete details on recipe programming, see the *Automation Supplement* manual, V. 5.13.

Select the **Recipe Auto Program File** command to access the **Auto Program File List**. When accessing this panel after creating a recipe, the recipe file being configured should appear in the **File Name** field as *.prg (i.e. your selected filename with the extension *prg*) (See [Figure 16.4a](#)).

Figure 16.4a Recipe Auto Program File List

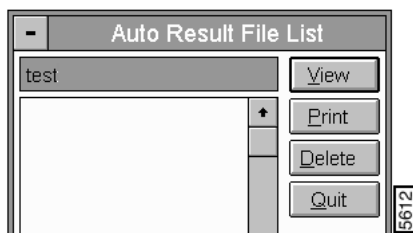


16.5 Auto Result File

The **Auto Result File** command displays, prints, and deletes the output files created by previously run auto program files.

The **Auto Result File** panel on the Control Monitor allows you to select an output file and review the contents, print the file, or delete the file (See [Figure 16.5a](#)).

Figure 16.5a Auto Result File List



Buttons on the Auto Result File List Panel

- **View**—Lists the selected auto result file.
- **Print**—Prints the auto result file to a selectable printer and port.
- **Delete**—Removes the currently selected file from the list.
- **Ok**—Exits the **Auto Result File** command.

16.6 Autocalibration

Because of the nonlinear electrical response of piezo materials, the electrical signals applied to SPM scanners must be carefully calibrated to ensure accuracy. Use the **Autocalibration** command to calibrate microscope scanners. It is based upon carefully measuring images of calibration standards captured with the **Capture Calibration** command in the **Real-time/Capture** menu. Sensitivities of the piezo to applied voltages and the derating of piezo sensitivity at low voltages are determined. The calibration of coupling parameters that maintain accuracy with rotated scans and account for changes in scan rate are also determined. This command automatically changes the parameter values stored in the parameter file (e.g. AFMJ.PAR) in the C:\EQUIP directory.

16.6.1 Autocalibration Control Monitor

The Autocalibration commands include:

- Calibrate individual parameters.

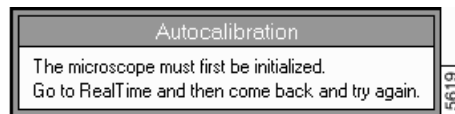
- Sequentially calibrate the sensitivities and deratings .
- Calibrate the couplings.
- Calculate all calibration parameters.

For details on the command options, see [Section 16.6.2](#).

16.6.2 The Autocalibration Panel

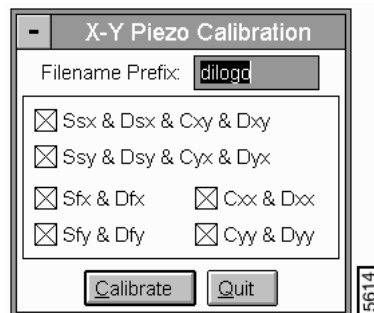
The user must initialize the microscope or a warning appears (See [Figure 16.6a](#)).

Figure 16.6a Autocalibration Warning



In the Off-line/**Modify** menu, select **Autocalibration** to access the **X-Y Piezo Calibration** panel (See [Figure 16.6b](#)).

Figure 16.6b X-Y Piezo Calibration Panel



Parameters and Buttons in the X-Y Piezo Calibration Panel

Filename Prefix

Defines the prefix of the name of the calibration images. The default name is the prefix of the currently selected file, but the name used to capture the images with the **Capture/Capture Calibration** command must be used.

Ssx & Dsx & Cxy & Dxy

Selects the proper images to calibrate the sensitivity of the piezo and derating of the piezo sensitivity in the X direction when the slow waveform is applied. The X Y coupling parameters are also calibrated with this selection.

Ssy & Dsy & Cyx & Dyx

Selects the proper images to calibrate the sensitivity of the piezo and derating of the piezo sensitivity in the Y direction when the slow waveform is applied. The X Y coupling parameters are also calibrated with this selection.

Sfx & Dfx

Selects the proper images to calibrate the sensitivity of the piezo and derating of the piezo sensitivity in the X direction when the fast waveform is applied.

Cxx & Dxx

Selects the proper images to calibrate the coupling between the slow X and fast X waveforms and the derating of the coupling between the slow X and fast X waveforms.

Sfy & Dfy

Selects the proper images to calibrate the sensitivity of the piezo and derating of the piezo sensitivity in the Y direction when the fast waveform is applied.

Cyy & Dyy

Selects the proper images to calibrate the coupling between the slow Y and fast Y waveforms and the derating of the coupling between the slow Y and fast Y waveforms.

CALIBRATE—Begins the calibration operation. The image for the selected calibration operation is shown on the Display Monitor, and a panel appears on the Control Monitor for each parameter being calibrated.

QUIT—Exits the **Autocalibrate** command and saves any changes made to the calibration parameters of the selected head or scanner.

Hints for Optimizing the Autocalibration Command

- After the horizontal or vertical line is drawn on the image between features of known spacing, a best guess of the distance based on the current value of the parameter displays in the panel. If the best guess is incorrect, enter a new value based on the known spacing of the features in the sample.

- The value of the parameter for the head or scanner updates automatically in the corresponding parameter file.
- When drawing lines, it is best to span as many features as possible. This has the effect of averaging values across the scan, thus improving accuracy.
- DO NOT draw lines between different portions of features (such as the top of one feature to the bottom of another, or the left side of one feature to the right side of another). It is easier to calculate distances between features based upon their even, regular spacing.
- Images are made using a DI-supplied calibration standard (e.g., 10-micron standard) with the **Capture Calibration** command. At least one-third of the captured images appear distorted (that is, elongated and/or angled) due to the unusual manner in which the image is scanned.

Note: Lines should be drawn on the image and distances entered without regard to this distortion. Do not “compensate” for any perceived angularity.

- The file name specified must match the file name used to capture the calibration images using the **Capture Calibration** command.
- For best results, the features on the calibration standard should be parallel to the scan directions.
- The **Autocalibrate** command automatically enters the new calibration parameters in the parameter file (e.g., afmj.par) for the scanner used to collect the calibration images. These numbers should be transferred to other parameter files that rely on the same scanner.

16.6.3 Autocalibration Display Monitor

For each parameter to be calibrated, a top view of the selected image appears on the Display Monitor. The direction “Draw a horizontal (or vertical) line” also appears. The following mouse operations should be used to draw a line between two features which are separated by a known distance.

Mouse Operations:

- 1st click, left button: Fixes one end of the reference line at the cursor position and extends from that position allowing either a horizontal or vertical line to be drawn.
- 2nd click, left button: Fixes the other end of the reference line at the current position.

Note: The images used to calibrate a particular head or scanner must have been captured with the head or scanner to be calibrated.

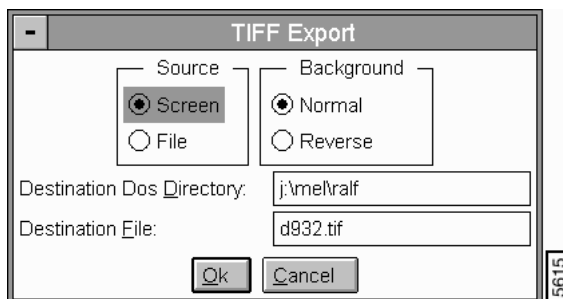
See also: **Real-time/Capture** menu: **Capture Calibration** command. **Real-time/Microscope** menu: **Select** and **Calibrate** commands.

16.7 TIFF Export

The **TIFF Export** command creates and stores a TIFF (Tagged Image File Format) file. A TIFF file is one of the industry-standard formats for stored image files. If a given file contains image-type data, then the file can be converted into a TIFF file. The file can then be integrated into documents with an application program capable of reading the TIFF format.

The following **TIFF Export** panel is displayed when the file selected is an image file.

Figure 16.7a Tiff Export Panel



Parameters and Buttons in the Tiff Export Panel

- **OK**—Executes the conversion operation.
- **CANCEL**—Exits the TIFF Export command.

Source

Selects the source of the file for the conversion.

Range & Settings:

- **Screen**—Results in a bit mapped version of the screen.
- **File**—Produces a top view of the image from the raw image data.

Background

Selects the color of the background in the converted file.

Range & Settings:

- **Normal**—Black.
- **Reverse**—White.

Destination DOS Directory

Specify the directory that the file is to be stored in.

Destination file

The name of the file to be created must be entered.

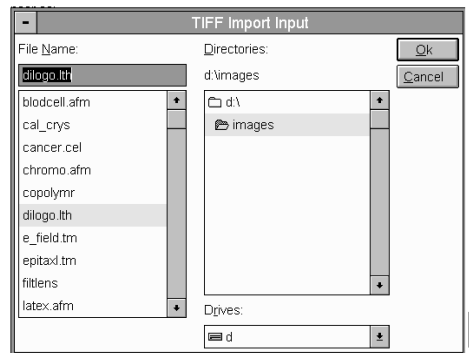
See also: Off-line/Utility menu: **Data Export**, **Print**, and **Printer File** commands.

16.8 TIFF Import

The **TIFF Import** command displays a TIFF (Tagged Image File Format) file list. The **Print** and **Printer File** commands can then be used to print or create a file for subsequent printing. To import the file, it must be in the TIFF 5.0 format, and it may not be compressed.

The **TIFF Import** panel specifies the TIFF file to display (See [Figure 16.8a](#)).

Figure 16.8a TIFF Import Panel



Parameters and Buttons on the Tiff Import Input Panel

- **OK**—Executes the conversion operation.
- **CANCEL**—Exits the TIFF Import command.

File Name—Specifies the source TIFF file to be displayed.

Directories—Directory containing the TIFF file to be displayed.

Hints for Optimizing the Tiff Import Command

- You can import TIFF versions of NanoScope screen or image files. You can import files from any other source as long as the files are uncompressed **and** in the TIFF 5.0 format.
- You can display NanoScope screen or image files that have been converted to TIFF format with the **TIFF Export** command and modified with desk-top publishing programs to be displayed within the NanoScope program. You can then print the modified files.
- Photostyler™ and Adobe Photoshop™ have been used to modify NanoScope TIFF files.
- Images that have been reduced in size are displayed at the center of the Display Monitor. The program does not display imported images that are larger than the screen.

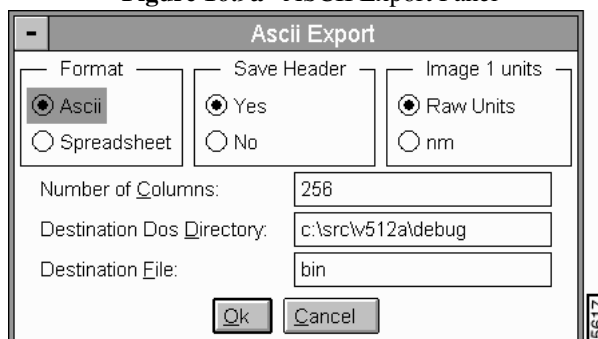
See also: Off-line/Utility menu: **TIFF Export**, **Print**, and **Printer File** commands.

16.9 ASCII Export

The **ASCII Export** command converts the selected binary file to an ASCII file in either Raw Units or nanometers.

In the Off-line/Utility menu, select **ASCII Export** to access the **Ascii Export** panel (See [Figure 16.9a](#)).

Figure 16.9a ASCII Export Panel



Parameters and Buttons on the ASCII Export Panel

Format

Determines how exported data will be separated. You should set this according to the requirements of third-party software accepting the data.

- **ASCII**—Each data value is separated with a space.
- **Spreadsheet**—Each data value is separated with a comma.

Save Header

Specifies whether the file header is retained or not.

- **Yes**—Retains the file header.
- **No**—Removes the file header. File consists only of raw data.

Number of Columns

Specifies the number of columns applied to the exported data.

Destination DOS Directory

Specifies the directory where the converted file is to be stored.

Destination File

Specifies the name of the destination ASCII file.

Note: The converted file contains the same ASCII header as the binary file.

Note: Specified **Destination DOS Directory** should be appended with a slash (for example, **B:**).

See also: Off-line/**Utility** menu: **ASCII Import** command.

16.10 ASCII Import

The **ASCII Import** command converts a previously converted ASCII file back to the binary format. The **ASCII Import** panel displays on the Control Monitor (See [Figure 16.10a](#)).

Figure 16.10a ASCII Import Panel



Source DOS directory

Specifies the name of the DOS directory containing the ASCII file to be imported.

Source File

Specifies the name of the ASCII file to be imported.

Destination DOS directory

The name of the DOS directory where the binary data file is to be stored.

Destination file

The name of the binary data file to be created.

Hints for Optimizing the ASCII Import Command

- The full menu bar is not available when an ASCII file (or any other non-NanoScope image file) is selected.
- Most of the commands in the Off-line menus are designed specifically for image data and do not operate on anything but image data.

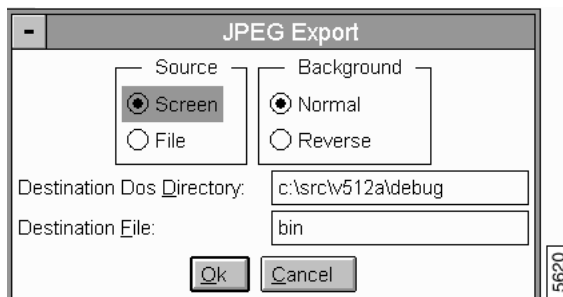
See also: Off-line/**Utility** menu: **ASCII Export** command.

16.11 JPEG Export

The **JPEG Export** utility command allows the storing of file images or screen shots as a jpeg compressed file. The compression reduces the TIFF (.tiff) or bitmap (.bmp) image file by 20 percent (a typical image file of 34 KB reduces to ~27 KB). View the JPEG images in your browser, save in any file or print.

In the **Utility** menu, access the **JPEG Export** panel (See [Figure 16.11a](#)).

Figure 16.11a JPEG Export Panel



Parameters and Buttons on the JPEG Export Panel

Source—Designates the image source or location of specified image.

- **Screen:** Choose this option when image is displayed on the screen.
- **File:** Choose this option if image is saved in a file.

Background—Designates background display of specified image.

- **Normal:** Choose this option for image to display as shown on screen or in file.
- **Reverse:** Choose this option for image to display reverse of image shown on the screen or in the file (i.e., For image displayed with black background, exported image displays with white background).

Destination DOS Directory—Designates destination to a DOS directory.

Destination File—Designates image destination to a file.

Ok—Executes the **JPEG Export** command.

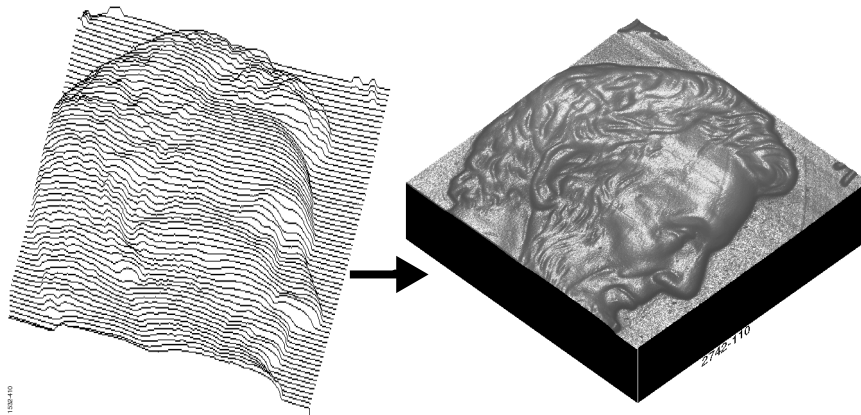
Cancel—Exits the **JPEG Export** command without saving.

16.12 Profile Import

The **Profile Import** command is for profiler-enabled systems (i.e. the Vx Profiler microscope). The Profiler microscopes are systems configured with a profilometer (scanning hardware) in addition to NanoScope SPMs. Although profilometers cannot reconfigure at the same magnitude as an SPM, they quickly and conveniently scan much larger areas. The profilometer files (here after referred to as *profiles*) include 128, 256 or 512 consecutive lines of data. When configuring the set of profiles, that data matches to essentially create the entire image file as one file. For complete details on profiling, see *Support Note 256, Profile Analysis* and *Support Note 299, 3D Profiling*.

The **Utility/Profile Import** command is designed to import profiles then convert them to NanoScope III files, as shown in [Figure 16.12a](#). The files may be viewed, modified and analyzed in exactly the same manner as a microscope image.

Figure 16.12a Profile Import Example

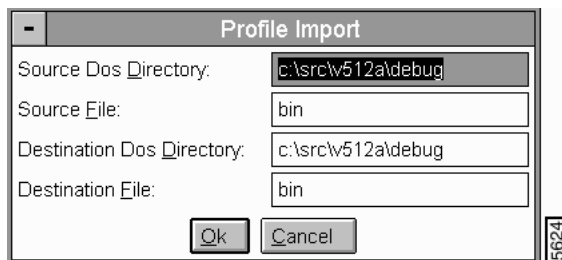


You should bear in mind that profile scans are usually conducted at much coarser raster spacings than SPM scans; therefore, much of the data must be interpolated to generate the more finely resolved NanoScope III file.

16.12.1 Profile Import Panel

Clicking on the **Utility/Profile Import** command accesses the **Profile Import** panel (See [Figure 16.12b](#)).

Figure 16.12b Profile Import Panel



Parameters and Buttons on the Profile Import Panel

- **Source DOS Directory**—The directory from which the profiles are imported.
- **Source File**—The name of the profilometry file to be converted. The file name entered should include the base name characters, plus the data files' extension (usually ".PIP").

- **Destination DOS Directory**—The Directory to which the converted file(s) are sent.
 - **Destination File**—New name to be assigned to the converted file.
- Note:** The program automatically sorts through all the profiles to construct the single NanoScope file.
- **Ok**—Button to accept configured parameters.
 - **Cancel**—Button to exit **Profile Import** panel without saving changes.

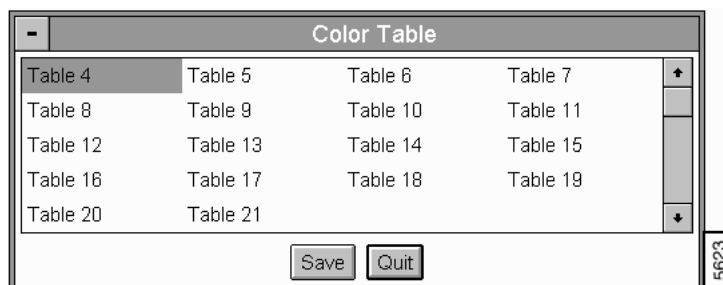
16.13 Color Table

The **Color Table** command allows the operator to modify existing color tables or to create new color tables. The red, green, blue, or gray intensities at a given Z position can be adjusted individually with this command.

16.13.1 The Color Table Panel

A list of the available color tables appears on the Control Monitor. The color composition of the listed color tables can be viewed and modified. A modified table can be saved or the modification can be ignored by quitting without saving. The desired color table can be selected with the mouse.

Figure 16.13a Color Table Panel



16.13.2 Color Table Display Monitor

In addition to the status and menu bars, a plot of the color intensity versus the length of the color bar (Z height), as well as a plot of the image, is shown on the Display Monitor. The intensities of the individual color components can be adjusted on the plot to create a color table that accentuates the important information in the image. The sum of the individual color intensities is displayed in a color bar across the bottom of the intensity plot. The image is also shown so the color table can be tailored to highlight features in a particular image.

Color Table Menu Bar Commands

Edit mode

- **Move**—Allows points placed on the plot to be rearranged.
- **Add**—Allows new points to be added to the plot.
- **Delete**—Allows points to be removed from the plot.

Color Select

Selects the color for the editing mode.

Range & Settings:

- **Red, Green, Blue, Gray**

Color Restore

Returns the selected curve to its original shape.

Range & Settings:

- **Red, Green, Blue**

Mouse Operations—All edit modes:

- Clicking the right button from the intensity plot moves the cursor to the menu bar.

Mouse Operations—Move mode:

- 1st click, left button—positioning the cursor on an existing point and clicking the left button picks up the point and tie its position to the mouse movement.
- 2nd click, left button—drops the point. The system automatically recalculates and draws the best curve-fit through the existing points.

Mouse Operations—Add mode:

- each click of the left button places a new point at the cursor position. The system calculates and draws the best curve-fit through the points as each point is placed.

Mouse Operations—Delete mode:

- Positioning the cursor over an existing point and clicking the left button removes the point from the plot.
- The system automatically recalculates and draws the best curve-fit through the existing points.

Hints for Optimizing the Color Table Command

- The sum of the individual color intensities is shown in the color bar under the intensity plot. This is the same color bar that is displayed along side of the image in the **Real-time Image Mode** and the Off-line **View** modes.
- You cannot modify Color tables 0 through 3. They are not included in the list.
- The system calculates the best curve-fit through the points as they are placed and draws the curve through the points. It updates the color bar along the bottom of the plot and the color of the image as each change is made to the plot.
- Either mouse button can be used to select subcommands.
- After an item is selected from a pull-down menu, the cursor moves to the center of the intensity plot.

See also: Off-line/**View**: **Color table**, **Color offset**, and **Color contrast** items.

Procedures for the Color Table Command

Suppose you have an image with features that are not highlighted well by any of the existing color tables. The **Color table** command can be used to create a new color table while viewing the image. The new color table can be adjusted until the image highlights are improved.

Appendix A Tip Selection Guide

Refer to the following sections and tables in determining tip selection:

- **Deflection Mode Cantilevers:** [Section 1.1](#)
- **Cantilever Data Specifications:** [Section 1.2](#)

1.1 Deflection Mode Cantilevers

The following tables provide information to help guide your selection of cantilever tips. [Table 1.2a](#), [Table 1.2b](#), and [Table 1.2c](#) list deflection mode cantilevers for use with standard atomic force microscopes (AFM), MultiMode™ AFMs (MMAFM), lateral force microscopes (LFM), BioScope™ and Dimension™ Series SPMs.

1.2 Cantilever Data Specifications

[Table 1.2d](#) and [Table 1.2e](#) lists Cantilever specifications called, "Diving Board Data in Air". [Table 1.2f](#) and [Table 1.2g](#) lists Cantilever specifications called, "Diving Board Data in Water".

The Digital Instruments Web Site at <http://www.di.com/> maintains a NanoProbe™ Tip Guide on the Products page. Reference the NanoProbe Tip Guide for the latest information on cantilevers available from Digital Instruments.

Table 1.2a

Model Number	NP	SP-S	DNP	NDP-S	NP-STT
Description	Standard Silicon Nitride	Oxide Sharpened Silicon Nitride	Standard Silicon Nitride	Oxide Sharpened Silicon Nitride	Oxide Sharpened Silicon Nitride Oriented Twin Tip
Force or Spring Constant(s) - Typical	0.01-0.6 N/m	0.01-0.6 N/m	0.01-0.6 N/m	0.01-0.6 N/m	0.01-0.6 N/m
Resonant Frequency - Typical	5 - 50 KHz	5 - 50 KHz	5 - 50 KHz	5 - 50 KHz	5 - 50 KHz
Nominal Tip Radius of Curvature	20 - 40 nm	20 - 40 nm	20 - 40 nm	20 - 40 nm	20 - 40 nm
Nominal Tip Height	3 μ m	3 μ m	3 μ m	3 μ m	2nd tip height clearance \approx 100 nm (for single tip image)
Tip 1/2 Cone Angle	35°	35°	35°	35°	35°
Reflective Coating	Gold	Gold	Gold	Gold	Gold
Cantilever Length	120 or 200 μ m	120 or 200 μ m	120 or 200 μ m	120 or 200 μ m	120 or 200 μ m
Cantilever Width per Leg-Perpendicular	15 - 40 μ m	15 - 40 μ m	15 - 40 μ m	15 - 40 μ m	15 - 40 μ m
Cantilever Thickness	0.4 - 0.6 μ m	0.4 - 0.6 μ m	0.4 - 0.6 μ m	0.4 - 0.6 μ m	0.4 - 0.6 μ m
Cantilever Configuration	V-Frame	V-Frame	V-Frame	V-Frame	V-Frame
Used in Microscope Models	AFM, LFM, MMAFM	AFM, LFM, MMAFM	BioScope, Dimension	BioScope, Dimension	AFM, LFM, MMAFM, BioScope, Dimension

Table 1.2b

Model Number	AFTS	ESP(W)	FESP(W)	TESP(W)	MESP(W)
Description	Experimental Fluid Taping Sampler	Contact Etched Silicon	Fore Modulation Etched Silicon	TappingMode Etched Silicon	Magnetic Resonant Etched Silicon
Force or Spring Constant(s)	0.004 - 0.125 N/m (soft)	0.02 - 0.1 N/m	1 - 5 N/m	20 - 100 N/m	1 - 5 N/m
Resonant Frequency	Various (includes 90 Lever types)	6 - 20 Khz	6 - 100 KHz	200 - 400 KHz	60 - 100 KHz
Nominal Tip Radius of Curvature	5 - 40 nm	5 - 20 nm	5 - 10 nm	5 - 10 nm	25 - 50 nm
Nominal Tip Height	3 μm	10 - 15 μm	10 - 15 μm	10 - 15 μm	10 - 15 μm
Tip 1/2 Cone Angle	35°	18° side, 25° front, 10° back	18° side, 25° front, 10° back	18° side, 25° front, 10° back	18° side, 25° front, 10° back
Reflective Coating	Gold	Aluminum	Uncoated	Uncoated	Gold
Cantilever Length	Various (includes 90 lever types, 35 - 195 μm)	450 μm	225 μm	125 μm	225 μm
Cantilever Width per Leg-Perpendicular	3 - 20 μm	30 - 40 μm	30 μm	30 - 40 μm	30 μm
Cantilever Thickness	0.4 - 0.6 μm	1 - 3 μm	2 - 3 μm	3.5 - 5.0 μm	2 - 3 μm
Cantilever Configuration	Various (V-Frame, Single Beam, Torsional)	Single Beam	Single Beam	Single Beam	Single Beam
Used in Microscope Models	AFM, LFM, MMAFM, BioScope, Dimension	AFM, LFM, MMAFM, BioScope, Dimension	MMAFM, Dimension	MMAFM, BioScope, Dimension	MMAFM, Dimension

Table 1.2c

Model Number	MESP-LM(W)	MESP-LC(W)	FIBLADE	FISPIKE
Description	Low Moment Magnetic Force Etched Silicon	Low Coercivity Magnetic Force Etched Silicon	TappyMode™ Etched Silicon FIB Blade	TappingMode™ Etched Silicon FIB Spike
Force or Spring Constant(s)	1 - 5 N/m	1 - 5 N/m	20 - 100 N/m	20 - 100 N/m
Resonant Frequency	60 - 100 KHz	60 - 100 KHz	200 - 400 KHz	200 - 400 KHz
Nominal Tip Radius of Curvature	20 - 40 nm	20 - 40 nm	75 - 100 nm	75 - 100 nm
Nominal Tip Height	10 - 15 μm	10 - 15 μm	Tip 10 - 15 μm , End Blade 1.5 - 2 μm	Tip 10 - 15 μm , End Spike 1.5 - 2 μm
Tip 1/2 Cone Angle	18° side, 25° front, 10° back	18° front to back (asymmetric)	3° side to side, 18° front to back (asymmetric)	3° on spike
Reflective Coating	Gold	Gold	Uncoated	Uncoated
Cantilever Length	225 μm	225 μm	125 μm	125 μm
Cantilever Width per Leg-Perpendicular	30 μm	30 μm	30 - 40 μm	30 - 40 μm
Cantilever Thickness	2 - 3 μm	2 - 3 μm	3.5 - 5 μm	3.5 - 5 μm
Cantilever Configuration	Single Beam	Single Beam	Single Beam	Single Beam
Used in Microscope Models	MMAFM, Dimension	MMAFM, Dimension	MMAFM, BioScope Dimension	MMAFM, BioScope, Dimension

Refer to the following key in reading [Table 1.2d](#), [Table 1.2e](#), and [Table 1.2f](#):

All data is in MKS units:

Length, RMS, FitRMS - (m)

ResFreq, ResFreqError - (Hz)

NoiseAtRes - (mHz^{1/2})

ThermalK - (N/m)

Sens - (V/m)

Table 1.2d Diving Board Data in Air

Width (μm)	Nominal Length (μm)	Length	Air RMS	AirFit RMS	AirRes Freq	AirFreq Error
12	18	2.260e-05	8.28e-12	3.36e-11	643671	46
16	25	2.950e-05	2.64e-11	5.33e-11	379264	46
20	34	3.910e-05	5.50e-11	6.93e-11	233771	39
20	46	5.140e-05	8.76e-11	9.83e-11	143835	40
20	57	6.270e-05	1.34e-10	1.32e-10	98994	43
20	72	7.780e-05	1.60e-10	1.59e-10	64759	18
20	98	1.047e-04	2.44e-10	2.32e-10	37821	21
20	124	1.306e-04	3.56e-04	3.26e-10	24466	30
20	156	1.645e-04	5.10e-10	4.49e-10	15984	18
20	194	2.030e-04	6.96e-10	6.03e-10	10472	28

Table 1.2e Diving Board Data in Air continued...

Width (μm)	Nominal Length (μm)	AirQ	AirQ-Error	AirNoise-as Res	Air-ThermalK	AirSens
12	18	138.6	3.48	4.87e-13	3.6122	3.032e+08
16	25	76.7	1.70	6.10e-13	1.4316	1.827e+08
20	34	57.9	1.28	8.71e-13	0.8476	2.927e+08
20	46	36.4	1.53	1.25e-12	0.4213	2.578e+08
20	57	27.7	1.33	1.77e-12	0.2321	1.889e-08
20	72	20.2	0.29	2.09e-12	0.1613	1.768e-08
20	98	12.5	0.21	3.24e-12	0.0754	1.523e-08

Width (μm)	Nominal Length (μm)	AirQ	AirQ-Error	AirNoise-as Res	Air- Thermalk	AirSens
20	124	9.3	0.23	4.96e-12	0.0383	1.196e-08
20	156	7.2	0.12	7.46e-12	0.0202	9.844e-07
20	194	4.5	0.17	9.95e-12	0.0112	7.193e-07

Table 1.2f Diving Board Data in Water

Nominal Length	Length	Water-RMS	WaterFit RMS	WaterRes Freq	Water Freq Error	Water Q
18	2.260e-05	3.42e-11	4.29e-11	261823	245	3.5
25	2.950e-05	4.81e-11	4.94e-11	141771	191	3.2
34	3.910e-05	6.31e-11	6.62e-11	77155	151	2.6
46	5.140e-05	9.94e-11	9.73e-11	43730	179	2.2
57	6.270e-05	1.42e-10	1.25e-10	29199	133	1.7
72	7.780e-05	1.78e-10	1.70e-10	18252	114	1.5
98	1.047e-04	2.65e-10	2.52e-10	10207	118	1.0
124	1.306e-04	3.62e-10	3.23e-10	6214	170	0.8
156	1.645e-04	4.98e-10	4.62e-10	3660	145	0.6
194	2.030e-04	6.99e-10	5.88e-10	1961	273	0.5

Table 1.2g Diving Board Data in Water continued...

Nominal Length	Length	WaterQ Error	Water Noise at Res	Water- Thermal k	Water Sens
18	2.260e-05	0.022	1.27e-13	2.2075	1.290e+08
25	2.950e-05	0.028	1.86e-13	1.6651	2.190e+08
34	3.910e-05	0.028	3.09e-13	0.9296	3.663e+08
46	5.140e-05	0.035	5.51e-13	0.4300	3.162e+08
57	6.270e-05	0.028	7.66e-13	0.2598	2.739e+08
72	7.780e-05	0.028	1.21e-12	0.1410	1.952e+08
98	1.047e-04	0.025	1.98e-12	0.0640	1.642e+08

Nominal Length	Length	WaterQ Error	Water Noise at Res	Water- Thermal k	Water Sens
124	1.306e-04	0.034	2.89e-12	0.0391	1.401e+08
156	1.645e-04	0.036	4.71e-12	0.0191	1.092e+08
194	2.030e-04	0.085	7.72e-12	0.0118	1.001e+08

Appendix B File Formats

This appendix details file format information for NanoScope software Version 5.12. Customers often upgrade to newer software, therefore, this appendix also includes compatibility and conversion information for earlier software versions (i.e., 4.3 - 5.12).

Note: For details on earlier file format information, refer to *Support Note 330 File Formats*, which includes versions 3.0 - 5.12.

This appendix includes the following information:

- **Overview:** [Section B.1 on Page 547](#)
- **File Compatibility:** [Section B.2 on Page 548](#)
- **Data File Organization:** [Section B.3 on Page 549](#)
- **Converting Data:** [Section B.4 on Page 553](#)
- **Converting Raw Data [Versions 4.3 - 5.12]:** [Section B.5 on Page 555](#)
- **General Format for a CIAO Parameter Objects:** [Section B.6 on Page 558](#)



WARNING: Before attempting data extraction on files, **always** make backup copies of the originals. If files become damaged due to loss of data, they may be irrecoverable.



AVERTISSEMENT: Toujours effectuer une copie des fichiers originaux avant d'en extraire des données. Si la perte de données endommageait des fichiers, ceux-ci pourraient être irrécupérables.



WARNUNG: Machen Sie bitte immer Backup-Files Ihrer Originaldaten, ehe Sie versuchen, Datenfiles selbst zu bearbeiten. Wenn Files durch Datenverlust beschädigt werden, könnten die Daten unwiederbringlich verloren sein.

B.1 Overview

File formats in the NanoScope software are of concern to users for at least two reasons:

- **Compatibility**—Processing older files using newer NanoScope software

- **Converting file data**—Exporting data into third-party applications such as spreadsheets and statistical packages to evaluate data in unique ways.

The ability to extract data from files is for the purpose of applying third-party software packages and analyze data in other formats. This may include displaying data in spreadsheets (e.g., Excel), statistical packages and expert systems. Typically, you extract data from the image files, then filter the data according to the requirements of their software. This section discusses how data files are organized to assist in extracting the file data.

B.2 File Compatibility

Digital Instruments, Veeco Metrology Group updates file formatting to ensure cross-compatibility of files between different versions of the NanoScope software. There are some exceptions. For example, version 3.0 electrochemical files are not compatible with version 4.23 or 5.12. [Table 2.2a](#) summarizes file compatibility by file type and NanoScope software version.

Note: Versions 3.0 and 4.1 software versions were written using DOS commands.

Table 2.2a File Compatibility

File Type	3.0 - 4.1 Versions of Software	4.3 - 5.12 Versions of Software
All data files	Files captured in this software may be open in the same or newer versions of software only.	Files captured in this software may be open in this or newer versions of software only.
Electrochemical (EC) Data	Not compatible with other versions.	Not compatible with other versions.

Almost all software can open earlier versions of software. Conversely, image files captured and saved on an earlier version of software should run on any later version of software. However, once the files are open and re-saved on a newer version, they are no longer usable in older versions of software. For this reason, use [Table 2.2a](#) as a guide to make backup copies of the files **before** saving them into the newer software version.



WARNING: IMPORTANT! To analyze old files using newer software versions and then to return the files to the older software version, make backup copies of the files with the old software **BEFORE** loading them into the newer software.



AVERTISSEMENT: IMPORTANT! Les Utilisateurs désirant analyser d'anciens fichiers en utilisant une nouvelle version de logiciel, et désirant également les retraiter par la suite dans l'ancienne version, doivent effectuer des copies (backup) de leurs fichiers **AVANT** de les charger dans la nouvelle version.



WARNUNG: WICHTIG! Anwender, die alte Datenfiles mit neuerer Software analysieren und später die Files wieder mit der alten Software einlesen wollen, sollten Backup-Kopien ihrer Files mit der alten Softwareversion machen, **EHE** sie diese mit der neuen Software laden.

B.3 Data File Organization

Images which are captured by the user are immediately stored in the NanoScope's capture directory as binary files. Depending upon the **Number of samples** taken per scan line (128, 256 or 512), files will vary in size from about 41K to 532K per image. Multiple images may be two or three times larger. Regardless of size, all files include: 1) a "header," containing various parameter settings used during the capture of the original image, a Ctrl-Z character to signal the end of the header, and "padding," comprised of random data; and, 2) data, stored two bytes (2^{16}) per pixel (2's complement).

File organization includes the following:

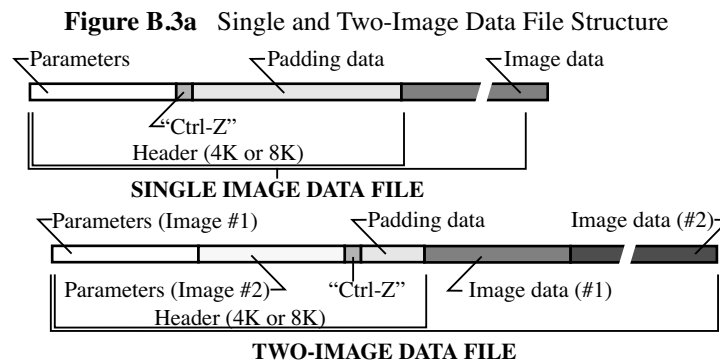
- **Header Files:** [Section B.3.1 on Page 549](#)
- **Parameters:** [Section B.3.2 on Page 551](#)
- **Control-Z (Ctrl-Z) Character:** [Section B.3.3 on Page 552](#)
- **Padding:** [Section B.3.4 on Page 552](#)
- **Raw Data:** [Section B.3.5 on Page 552](#)

B.3.1 Header Files

The first portion of every image file contains a **header** file. The header file tells the software about the data which follows. The header file size depends upon the number of parameters used at the time that data is captured. Also, depending upon the type of file saved and the version of NanoScope software used when saving the file, the header may contain more than 2,000 parameters.

Each header is divided into separate lists (beginning with the characters *). Users typically, manipulate only a few of the parameters for each application. See the [Parameters](#) section for a few of the most important parameters and characters.

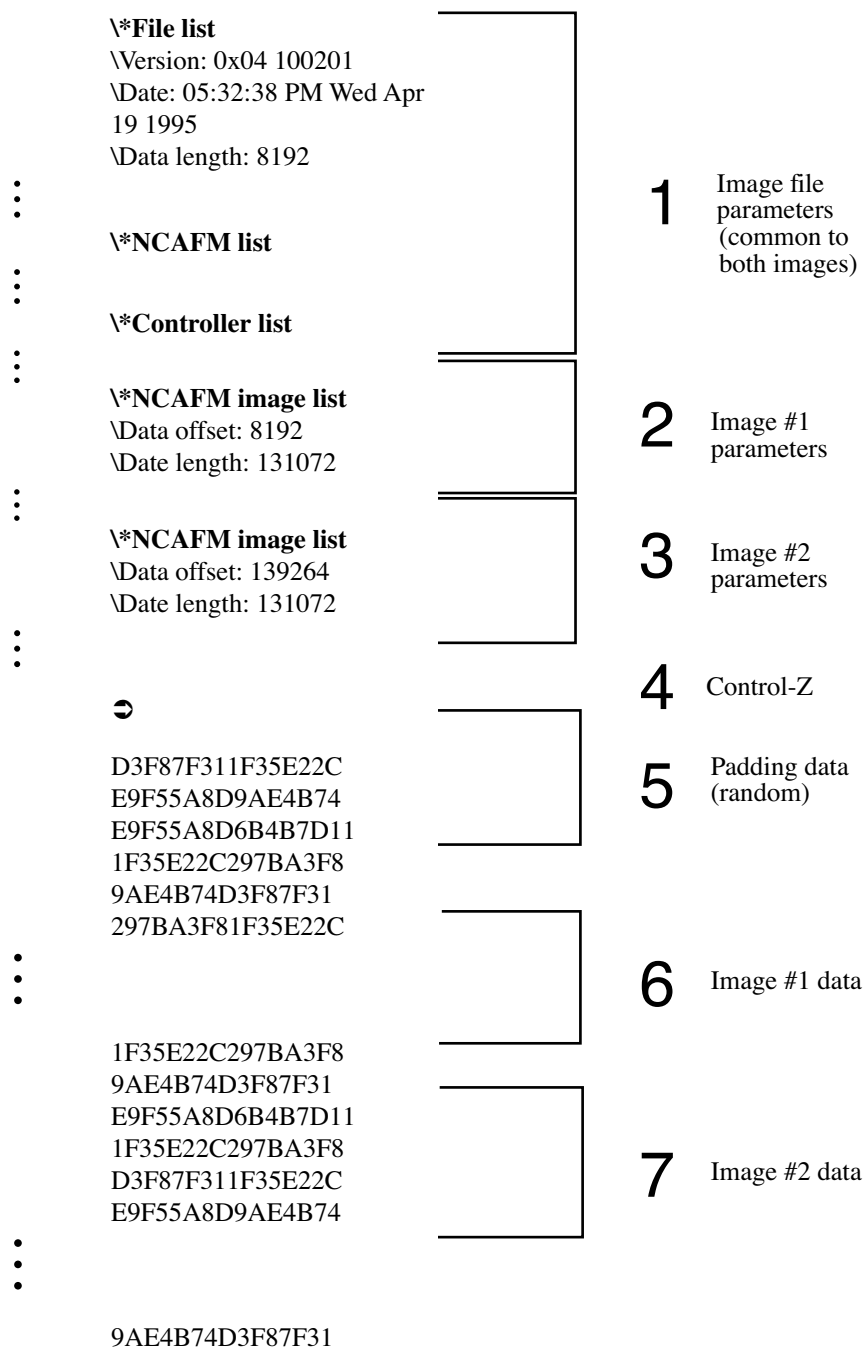
The header is also crucial to interpreting the data. The header information provides crucial parameter and setting information for converting ASCII file data. The end of the header file reveals where the actual data begins. [Figure B.3a](#) shows the size and relationship of data file formats commonly found in software versions prior to version 5.12.



Two-Image Files

Files with two or more images contain separate parameter lists and image data. [Figure B.3b](#) illustrates data organization of a two-image files.

Figure B.3b Example of a Two-image Header File



Analysis of the Two-Image Header File

- **Section 1** includes parameters common to both images (only a few are shown here). The parameters are included within various lists beginning with *. The type of image and the NanoScope software version also affect the lists and parameters. For example, the **\Data**

length parameter in the ***File list** of this section is generally either 4K, 8K or (rarely) 12K and includes the entire header.

- **Section 2** contains parameters which are specific to image #1. In this example, only two are shown; however, there may be dozens. The **\Data offset** parameter is very important because it indicates the Nth byte where data for image #1 begins (here, it is 8192). The **\Data length** parameter indicates the length of data for image #1 in bytes (here, it is 131072). By adding the **\Data offset** and **\Data length** together, the data offset for image #2 is found.
- **Section 3** contains parameters which are specific to image #2. The **\Data offset** parameter here indicates that data for image #2 begins at byte 139264 and is 131072 bytes in length.
- **Section 4** is a Ctrl-Z character which denotes the end of parameter lists.
- **Section 5** contains random padding data. This is added to the header to make it a predetermined length (specified in the first **\Data length** parameter at the start of the header) and is used to read the file into NanoScope software. Image files containing multiple images will have less padding than files containing only one image.
- **Section 6** contains image data specific to image #1. In this example, it begins at byte 8192 and is 131072 bytes in length. Depending upon whether the image was captured at 128, 256 or 512 samples per scan line, the length of data will vary.
- **Section 7** contains image data specific to image #2. In this example, it begins at byte 139264 and is 131072 bytes in length. The last data value in this section of the file denotes the end of the file.

B.3.2 Parameters

*** File List**—Denotes the beginning of several parameter lists. For example, ***Image list**, ***Microscope list**, etc. Each image in the file has its own image list (e.g., ***AFM image list**).

\Version—Describes the version of software currently in use.

\Data length—Length of header, Ctrl-Z character and padding in bytes.

\Samples/line—Number of pixels per scan line. This is the same as the **Number of samples** value on the **Real-time / Scan Controls** panel.

\Scan size—Height and width of the square scan area in nanometers.

\Z atten—Z-axis attenuation value. The total Z-axis range of data may be calculated from this number as follows:

$$\text{Total Z-axis range} = \frac{\text{Z atten value}}{65,536} \cdot 440$$

The Z attenuation value is divided by 65,536 (steps of resolution for Z scanner crystal), then multiplied times the Z-axis scanner crystal's voltage range (± 220 Volts) to yield the total Z-axis range of data.

\Data offset—Nth byte in the image file where raw data commences. This value is typically 8000 for version 2.3 and later NanoScope software.

\Data length—Length of raw data stream in bytes. Divide this value by 2 to obtain the total number of pixels in the image.

\Z scale—Factor used to convert data to indicated units. E.g., for **\Z scale: 20000 nm**,

$$\text{data (nm)} = \frac{\text{pixel value}}{65,536} \cdot 20000$$

\Z sensitivity—Z-axis scanner sensitivity in nanometers per volt. To obtain the maximum Z-axis scanner travel, multiply this value by 440.

\Z scale magnify—Multiplier applied to Z-axis height data to render a NanoScope image on the display screen. For example, a value of 1.0 would render data on the display screen at the same scale as actual features. This value is generally of no use outside the NanoScope software environment.

B.3.3 Control-Z (Ctrl-Z) Character

A Ctrl-Z (ASCII value 26) character is used to show the end of the parameter lists and the beginning of padding. Users wishing to organize their data for spreadsheets may search for this character to locate the end of the parameter lists.

B.3.4 Padding

After the Ctrl-Z character, a quantity of random data—“padding”—is inserted into the file to make the header a fixed length specified in the first **\Data length** parameter at the start of the header. (Before version 2.3 NanoScope software, the header length was typically 4K.) Padding contains no information, and exists only to accommodate various lengths of parameter lists for different image files.

B.3.5 Raw Data

Comprising the bulk of every image file is the raw data of the image itself. At the time of **Capture**, image data is stored 16-bits per pixel in the capture directory on the computer’s hard drive. (Data is stored in 2’s complement, LSB). The 16 bits accorded each pixel allows a 32K Z-axis resolution. Whenever image files are exported using the **Utility / ASCII Export** command, data is presented in a converted form.

B.4 Converting Data

Refer to the following sections for preparing file data:

- **Preparing Data for Spreadsheets (Summary):** [Section B.4.1 on Page 553](#)
- **Preparing Data for Image Processing (Summary):** [Section B.4.2 on Page 553](#)
- **Converting Data Files into ASCII:** [Section B.4.3 on Page 553](#)

B.4.1 Preparing Data for Spreadsheets (Summary)

You may load data files into third-party, spreadsheet software (e.g., Excel, Igor Pro, Mathematica, etc.). To convert data in to a spreadsheet program, complete the following:

1. Convert the data into ASCII format—for example, by using the **Off-line / Utility / ASCII Export** command. (**NOTE:** This may increase the size of the file substantially.)
2. Load the file into a suitable editor where it may be prepared for third-party applications.
3. Locate and note important header parameters.
4. Locate the start of raw data, then separate raw data from the remainder of the file.
5. Load raw data into the third-party software program, then condition data according to important header parameters and requirements of third-party software application(s).
6. Analyze or modify conditioned data as required.

B.4.2 Preparing Data for Image Processing (Summary)

You may convert data files into third-party, image processing software (e.g., Photoshop, CorelDraw). To convert the data into image processing software, complete the following:

1. Convert the data into TIFF format—for example, by using the **Off-line / Utility / TIFF Export** command. TIFF screen files include everything shown on the Display Monitor, along with the actual image.
2. Load the TIFF file directly into the third-party, image processing software.
3. Process the image file. This may include cropping the image from the rest of the display screen, filtering the image, adjusting contrast, brightness, color, etc.

B.4.3 Converting Data Files into ASCII

When NanoScope image files are captured and stored, they are in 2-byte, binary (LSB—least significant bit) form. Although some programs import raw, binary files, most users find they must convert the files into ASCII form first to use them. The converted file allows users to read the header information directly and works with many third-party programs requiring ASCII formatting. (Some users prefer to download the

File Formats

Converting Data

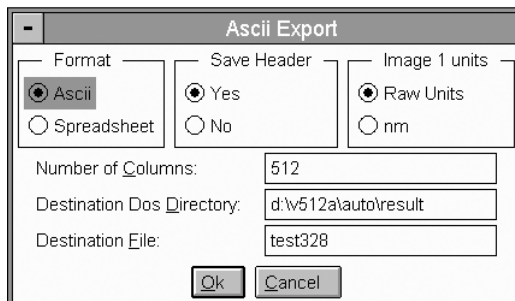
original, raw binary files into their third-party program, while using their ASCII version of the file as a guide map.)

Note: Depending upon the software version used during capture of the image data, the actual file format and file size varies. Headers may include more than 2000 parameters, followed by Ctrl-Z, data padding, and raw data (i.e., for NanoScope software prior to 5.x).

Convert captured data in to ASCII format by using the **Offline > Utility** menu command To convert files, complete the following:

1. Make a backup copy of the file to be converted and save it to a safeguarded archive.
2. Select the file to be converted from the **Offline** file list by clicking on it in the file menu box.
3. Click on the **Utility > ASCII Export** command. The **ASCII Export** dialog box displays.

Figure B.4a ASCII Export Dialog Box



4. Set options on the **ASCII Export** dialog box according to the type of conversion required.
5. In the **Format** options, select ASCII to save the data in plain text.
 - a. See also, [Section B.4.1](#) for converting data to a spreadsheet.
6. In the **Save Header** options, select **Yes** to display the header file information.

Note: In order to convert the ASCII data from binary (LSB) data to useful values (Phase, Frequency, Current, etc.), you must save the information in the header.

7. In the **Image Units** options, select **Raw Units** for displaying binary data numeric form.
 - a. For data to be converted to nanometers, select the nm option.
8. Select a **Number of Columns** for displaying the data (e.g., **512** displays all data in one column, **8** displays data in 8 columns).

Note: Data displays in rows from left to right. Total data points correspond to the number of data points per line selected in your parameter settings (i.e, 128, 256 or 512 data points per line) and the number of lines per scan (i.e., 128, 256 or 512 lines).

9. The **Destination DOS Directory** is the output directory to archive the ASCII file (e.g, SimpleText, NotePad).
10. Name the Destination File for retrieval and include a file extension (e.g., test.doc).

B.5 Converting Raw Data [Versions 4.3 - 5.12]

Before bringing raw data into a third-party application, the user can first convert the data.

Note: In Version 5.12, the **Utility** menu includes **Export** commands (i.e., **ASCII Export**, **JPEG Export**, **TIFF Export**) to convert the raw data in to nanometers and pixel data.

Usually, this means simply multiplying all values by a constant to convert them into common measuring units. Once converted, the data becomes more meaningful to analyze.

By using parameters in the header, it is possible to convert and analyze data for various purposes. Users need only understand how parameters are related to extract the maximum amount of information from their files. In the raw data information, each numeric value is relative horizontally and vertically.

B.5.1 Control Input and Output (CAIO)

As of the release of Version 4.3, the NanoScope uses a format to simplify the interaction between the software and the microscope electronics. The new format, or Z scales, use a new format called **CIAO** (Control Input and Output). This comes from the complete redesign of the internal code of the software that makes it easier for Digital Instruments to describe to the software the microscope electronics capabilities.

B.5.2 Calculating Height Data Values

In order to calculate height data, it must be converted from LSB form by using the Z scale value. Recall that raw data recorded from each scan is scaled to the maximum resolution of the Z-axis scanner crystal ($\pm 32,768$). Whether features are related in terms of “height” or “depth” is irrelevant. What matters most is that features be accurately represented in meaningful units.

To convert raw data into metric units, use the following relation:

$$Z \text{ height} = \frac{(\text{data point value})(Z \text{ scale})(\text{Sens. Z scan})}{2^{16}}$$

Note: The **Z scale** value in a parameter list includes the value and the units (for example, **Z scale: 1.57541 μm**). In this example, the units of measure are in microns (μm).

Calculating X and Y Pixel Width from Raw Data

To obtain the X axis pixel width, use the following relation:

$$X = \frac{\text{Scan size}}{(\text{Samples/line}) - 1}$$

To obtain the Y axis pixel width, use the following relation:

$$Y = \frac{\text{Scan size}}{(\text{Number of Lines}) - 1}$$

B.5.3 Calculating Raw Data Values

This section details equations to calculate values for **analysis** (e.g., height data, phase, etc.).

Note: Only one set of values may be found for each Z scale. That is, the Zscale units are different for each type of image (Hz for Frequency, or nA for Current), and the Zscale for a Height image (for example) may not be used to find values for Phase.

For software version 4.2x, the equations for converting the LSB data points into various values are as follows:

Height

$$\text{Height} = \frac{\text{data point}}{65536} \times Z \text{ scale height value}$$

Phase:

$$\text{Phase} = \left(\frac{\text{Data point}}{65536} \right) \times \left[Z \text{ scale phase} \times \left(\frac{180^\circ}{65536} \right) \right]$$

Frequency

$$\text{Frequency} = \left(\frac{\text{Data point}}{65536} \right) \times \left[Z \text{ scale freq} \times \left(\frac{25e^6}{2^{32}} \right) \right]$$

Potential

$$\text{Potential} = \left(\frac{\text{Data point}}{65536} \right) \times \left[Z \text{ scale pot} \times \left(\frac{2 \cdot \text{In } 2 \text{ max}}{65536} \right) \right]$$

Current (nA)

$$\text{Current} = \left(\frac{\text{Data point}}{65536} \right) \times \left[Z \text{ scale amplitude} \times \left(\frac{2 \cdot \text{In } 1 \text{ max}}{65536} \right) \times \text{In sensitivity} \right]$$

Amplitude (nm)

$$\text{Amplitude} = \left(\frac{\text{Data point}}{65536} \right) \times \left[Z \text{ scale amplitude} \times \left(\frac{2 \cdot \text{In } 1 \text{ max}}{65536} \right) \times \left(\frac{\text{In sensitivity}}{\text{Detect sens}} \right) \right]$$

For LFM Aux data, the torsional deflection of the cantilever in volts (or whatever else, depending, on the definition of the input sensitivity) can be calculated by applying the following formula to each point in the data file:

$$\text{Deflection} = \left(\frac{\text{Data point}}{65536} \right) \times \left[Z \text{ scale Aux A} \times \left(\frac{2 \cdot \text{In } 2 \text{ max}}{65536} \right) \times \text{In sensitivity Aux A} \right]$$

In this formula, the parameter **Aux A** and **In sensitivity aux A** can be substituted with the corresponding parameters for **Aux B**, **Aux C**, and **Aux D**. In order to get the **In sensitivity aux (A,B,C,D)** parameters to appear in the header, you must select **Microscope / Calibrate / Detector**, highlight the parameter, and then press enter.

B.5.4 Force Curve File Format Information

The following Force Curve File Format information is for force curves captured with software version 4.3 - 5.12.

When exporting the force curve in ASCII format, it is recommended that the file be exported twice, once with the header and once without. The one without the header should be exported in Spreadsheet format (this makes it comma delineated).

When you import the file without the header into MS Excel each value should come up as a separate entry. In your file, there should be 1024 values, the first 512 are the retract curve and the next are the extend curve. The scan size in Z is calculated by looking at the Scan size value in the **Force cal.** list in the header and the **Z sensitivity** in the Microscope list. You then do the following calculation.

In the header, find the line "`*Force cal. list`" and "`Scan Size`". The Scan Size is in 16-bit values. Convert to nm by:

$$\text{Size (nm)} = \frac{\text{Z Scan size} \cdot \text{Sens. Z scan}}{(\text{Number of Data points} - 1)}$$

In some cases it may be necessary to calculate the force to determine the vertical (Deflection) axis of a curve. The following calculation may be used, as long as the microscope is in **ContactMode** and **Input Atten** is set to **1x**.

$$\text{Value (nm)} = \text{data point (LSB)} \cdot \text{Sens. Defl.} \cdot \text{Z scale}$$

Note that the above equation only works when calculating force vs. separation. When calculating force vs. Z, *Z magnify force* must be removed from the calculation. When calculating deflection vs. Z, the spring constant must also be removed from the calculation.

When interested only in the deflection of the curve, the calculation below will suffice. Divide by the number of samples to get the Z step per data point. This value is also found in the "`*Force Image list`" near the header end.

Force Data Organization

In later versions, the data changes and is opposite from previous versions of software. For example, the first **n** samples of data includes the **Extend** curve from the closest approach to the farthest distance. The next **n** samples are the **Retract** curve data from the closest to farthest distance.

Converting the Force Data to Volts [4.3 - 5.12]

The actual data is again in 16-bit values for the input signal. Convert to volts by:

$$\text{Value (V)} = \frac{\text{Value (LSB)}}{32768} \cdot (\text{Full Volt Range})$$

The volt range is **20V** for **Contact Mode** when In Atten is 8X. Its 2.5 for 1X In Atten. If you are in **TappingMode** looking at deflection (normal mode using Nanoindentation), it's 5V (see the table below).

Microscope Mode	InAtten / Deflection	Volt Range
Contact mode	8X	10V
Contact mode	1X	1.25V
TappingMode	(normal mode)	5V

The Detector Sensitivity is under the "`\AFM list`", as "`\Detect Sens.`" in units of $\frac{\text{V of detector}}{\text{nm of Z}}$.

B.5.5 Force Volume File Format Information

The curve data should be right after the image height data. The curve data is the data collected at each Z point as in a normal single force curve file. If deflection, volts is given by:

$$\text{Deflection (V)} = \frac{\text{Data point (LSB)}}{32768(\text{LSB})} \cdot \frac{10(\text{V})}{\text{Input atten (1 or 8)}}$$

Using the value for deflection in volts (V), it is possible to calculate the deflection in nanometers (nm) using the equation:

$$\text{Defl (nm)} = \frac{\text{Deflection (V)}}{\text{Detector Sensitivity (V/nm)}}$$

The way force volume works, it gets tricky to figure which image pixel corresponds to which force curve data. The data and force curve are in the same order: bottom to top, left to right. There are three pixel numbers that are needed:

- Under "*[NC]AFM" image list, "\Samps/line" gives the number of image pixels/line, 128, 256 or 512
- Under "*Force" image list, "\Samps/line: n m", where n is the number of samples per Force line.
- Under "*Force cal." list is the "\force/line: n m" parameter, where n is the number of force curves / image line.

Consider a square block of pixels that represents one force curve. Including the data in the bottom left corner, a simple analysis allows the identification of which pixel corresponds to which curve. If the number of samples/force line is 128 and the number of force curves/image data is 32 and there are 256 pixels/image data, then there is a curve every 256/32 or 8 pixels. The next image data line with force curves is the 8th one from that line. Since there are 128 samples/force curve, they are 256 pixels or 512 bytes each. Thus, the first image pixel matches the first force curve, the 8th pixel matches the second force curve 512 bytes later, etc.

Even though there are 3 data displays during Force Volume (Image, Force plot and FV Image), the FV image is **NOT SAVED**. It is calculated during both the Real-time and Off-line display from the force curve data as described above.

B.6 General Format for a CIAO Parameter Objects

In the file header some parameters start with '@' instead of simply '\'. This is an indication to the software that the data that follows is intended for one of our new CIAO parameter objects. After the '@', you might see a number followed by a colon before the label. This number is what we call a "group number" and can generally be ignored.

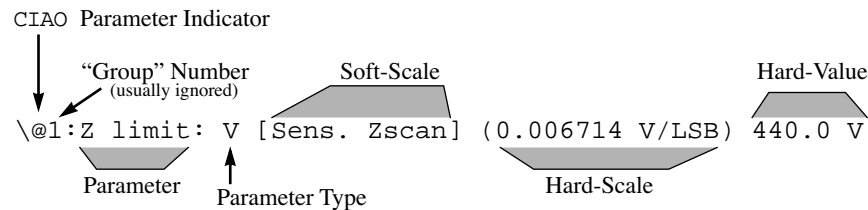
Further, after the label and its colon, you will see a single definition character of 'V', 'C', or 'S'.

- V means **Value** – a parameter that contains a double and a unit of measure, and some scaling definitions.
- C means **Scale** – a parameter that is simply a scaled version of another.
- S means **Select** – a parameter that describes some selection that has been made.

The **Value** (identified by the letter “V”) parameters have the following format.

[soft-scale] (hard-scale) hard-value

Example 1



LSB

Since the NanoScope is a digital device, all data is numeric. We call this number in its rawest form an **LSB** (i.e., scaling values on ADCs and DACs as Volts per Least-Significant-Bit). The LSB is the digital representation of volts or frequency.

Hard value

The hard value is the analog representation of a measurement. It is simply the value read on the parameter panel when you set the **Units**: to **Volts**. The hard-value is the value you would read with a voltmeter inside of the NanoScope electronics or inside the head. This value is always in volts with the exception of the Drive Frequency (which is in Hertz) and some STM parameters (which are in Amps).

Hard Scale

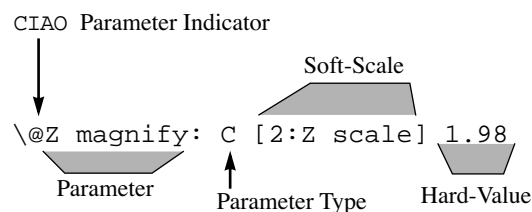
The hard scale is the conversion factor we use to convert LSBs into hard values. We use the prefix "hard-" in hard-scale and hard-value because these numbers are typically defined by the hardware itself and are not changeable by the user.

Note: Soft-scale and soft-value also exist for distinguishing units. A soft-value is what the user sees on the screen when the **Units**: are set to Metric. The soft-scale is what we use to convert a hard-value into a soft-value. Soft-scales are user defined, or are calibration numbers that the user divines. Soft-scales in the parameters are typically not written out – rather, another tag appears between the brackets, like `[Sens. Zscan]`. In that case, you look elsewhere in the plist for tag and use that parameter's hard-value for the soft-scale.

A value parameter might be missing a soft-scale or a hard-scale, but must **always** have a hard-value.

The **Scale** parameters (identified by the letter “C”) have the following format.

Example 2: [Soft-scale] hard-value

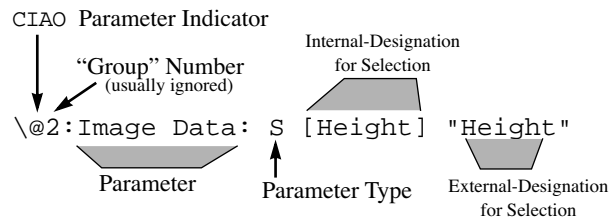


General Format for a CIAO Parameter Objects

- The hard-value is almost always a scalar value.
- The soft-scale always points to another parameter – this parameter is the target of the scaling action.
- Most often used for the Z magnify parm to allow user to change scaling of Z scale in Off-line without actually affecting the real data in the file.

The **Select** parameters (identified by the letter “S”) have the following format:

Example 3: [Internal-designation for selection] "external-designation for selection"



B.6.1 Procedures to find Z scale CIAO Parameter Objects

To find the Z scale conversion factors, refer to [Figure B.6a](#) to complete the following calculation:

1. Find the **soft scale** by searching for a tag in brackets. Note that the parameter “Sens . Zscan” appears in brackets in some of the value parameters and defines a specific **soft scale**.
2. Locate the `[Sens . Zscan in nm/V]` in the **Scanner List**.

Figure B.6a Sample Parameter List

```

\*File list
\Version: 0x04310000
\Data length: 20480
\*Equipment list
\Description: D5000
\Controller: IIIA
\Scanner file: xxxg.scn
\*Scanner list
\Scanner type: Dimension
\Serial number: xxxG
\Piezo size: G
\@Sens. Zscan: V 12.50 nm/V
\*Ciao scan list
\Scan size: 311.1 nm
\Samps/line: 256
\Lines: 256
\Scan rate: 61.0352
\@InterleaveList: S [InterleaveOffMode] "Disabled"
\@MicroscopeList: S [TMMMode] "Tapping"
\@2:SPMFeedbackList: S [SPMFb] "Amplitude"
\@3:SPMFeedbackList: S [SPMFb] "Amplitude"
\@Sens. Deflection: V 1.000
\@1:Z limit: V [Sens. Zscan] (0.006714 V/LSB) 440.0 V ← Soft scale, Sens. Zscan value
\*Ciao image list
\Data offset: 20480
\Data length: 131072
\Bytes/pixel: 2
\Samps/line: 256
\Number of lines: 256
\@2:Image Data: S [Height] "Height"
\@Z magnify: C [2:Z scale] 1.98
\@2:Z scale: V [Sens. Zscan] (0.006714 V/LSB) 202.2 V
\*File list end

```

The hard scale (e.g., 0.006714 V/LSB) is the scale at which the file was originally captured. However, to help minimize round off errors in the off-line processing, the software automatically scales the image data to the full range of the data word. While the hard value of the Z scale is updated, the hard scale is not. Therefore, this hard scale should be ignored.

Following are two formulas that explain the relationship between the hard scale, the hard-value, and the soft-scale:

$$\text{hard scale} = \frac{\text{hard value}}{2^{(8 \times (\text{bytes}) / (\text{pixel}))}}$$

$$\text{hard value} \cdot \text{soft-scale} = \text{soft-value}$$

Using these two formulas, it is possible to figure out all one might want to know about the data.

Converting Raw Data into Height

The raw data in the file is assigned 2-byte number. The numbers in the data file are called LSBs (and, for our purposes, assigned a unit of 'LSB'). In order to convert the raw data in the file, use the number from the file and multiply it by both the hard-scale and the soft-scale.

For example, using the above parameter list in Figure B.6a, the hard scale would be:

$$\frac{202.2 \text{ V}}{2^{(8 \cdot 2)}} = \frac{202.2 \text{ V}}{65536} = 0.003085 \frac{\text{V}}{\text{LSB}}$$

File Formats

General Format for a CIAO Parameter Objects

Now, if we had a value of 54 in the data file, the result would be:

$$(54\text{LSB}) \cdot \left(0.003085 \frac{\text{V}}{\text{LSB}}\right) \cdot \left(12.5 \frac{\text{nm}}{\text{V}}\right) = 2.08\text{nm}$$

Note: The same procedure may be used to calculate frequency, current, potential, amplitude data, etc., by using the appropriate Z scale. However, each data set requires a specific Z scale. For example, the Z scale for potential may not be used to calculate frequency.

What is the range of the data in the file?

The range of data in the file may be found by multiplying the hard-value by the soft-scale. Using the hard-value and soft-scale values from the example above:

$$202.2\text{V} \cdot 12.5 \frac{\text{nm}}{\text{V}} = 2.53\mu\text{m}$$

Data is expanded in the NanoScope file after capture to prevent round-off in the Off-line calculations. The expansion procedure changes the Z scale to correspond with the new scale of the expanded data. Yet, in Off-line, the software displays the data with the original Z scale I used to capture it.

How can I calculate the displayed Z scale for use in my own analysis programs?

Use Z magnify to discover the displayed Z scale. The modified Z scale is $2.53 \mu\text{m}$. Z magnify (from the [Sample Parameter List](#)) tells us there is a scale of 1.98 missing. So the data on the screen in the NanoScope off-line is displayed at 5.00 nm. This trick also works if the user changed the displayed Z scale in Off-line.

Force Curve File Format

To find the Z scan size and steps, refer to the [Sample Parameter List](#) and complete the following:

1. Under `*Ciao Force List` are the parameters that describe Z:
`\@Z scan start:` (last number is in volts)
`\@Z scan size:` (last number is also in volts)

You can convert using the `\@Sens. Zscan:` which shows the value and units (typically 12.5 nm/V) under the `*Scanner list` line.

2. Find the number of pixels/line of data is under the `*Ciao force image list` (usually last) as:
`\Samps/line:` nnn [where nnn is the number of pixels in each direction]

Also in the `*Ciao` section is the Data Type:

```
\@4: Image Data: S [data type] "data description"
```

Note: **Data type** is usually Deflection or Amplitude and can be "Deflection", "TM Deflect." or "Amplitude".

Glossary

Abstract

This glossary defines terms used in the semiconductor and general purpose microscopy industries, as well as terms specific to Digital Instruments, Veeco Metrology Group. Some of the terms in this glossary are specific to SEMATECH. This version also includes terminology from other industry organizations, namely ASME, SIA, EIA, IEEE, ASTM, and SEMI. Sources are indicated at the end of each definition.

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Quick Reference

[A-E](#) | [F-J](#) | [K-O](#) | [P-T](#) | [U-Z](#)

Term	Definition
A-E	
absolute pressure	In mass flow controllers, the pressure measured relative to zero pressure (perfect vacuum). [SEMI E28-92]
accuracy	In statistical process control, the compliance of the measured or observed value to the true value or accepted reference value. [EIA 557]
acetone	A colorless, volatile, and extremely flammable liquid used as a solvent and as a reagent. [SEMATECH]
acoustic isolation	The combination of a complete acoustic enclosure of the isolation platform and a multilayer foam design results in a complete acoustic isolation system which effectively dampens acoustic noise sources.
actuation cycle	The full operation of a valve, such as from a fully opened position to fully closed and back to fully opened. [SEMATECH]
adjusted decibel (dBa)	A unit used to express the relationship between the interfering effect of a noise frequency and a noise power level. [SEMATECH]
AFM	Atomic Force Microscope or atomic force microscopy .
air velocity (V_A)	In the thermal testing of semiconductor devices, the velocity of the cooling air at a specified location upstream from the device under test. Air velocity is measured in linear feet per minute. [SEMI G38-87]
aliasing	Electronic image error due to differences in resolution between surface features and the pixels used to represent them.
alignment	1: The accuracy of the relative position of an image on a reticle with reference to an existing image on a substrate. [SEMATECH] 2: a procedure in which a wafer is correctly positioned relative to a reticle. [SEMATECH] 3: the mechanical positioning of reference points on a wafer or flat panel display substrate (also called alignment marks or alignment targets) to the corresponding points on the reticle or reticles. The measure of alignment is the overlay at the positions on the wafer or substrate where the alignment marks are placed. [Adapted from SEMI P18-92 and D8-94]

Term	Definition
ambient pressure	In mass flow controllers, the absolute pressure of the medium surrounding the device. [SEMI E28-92]
ambient temperature	1: the temperature of the surrounding medium, such as air or liquid, that comes into contact with the device or apparatus. [SEMATECH] 2: the temperature of the specified, surrounding medium (such as air, nitrogen, or a liquid) that comes into contact with a semiconductor device being tested for thermal resistance. [SEMI G38-87]
American National Standards Institute (ANSI)	An organization that compiles and publishes computer industry standards. [SEMATECH]
analog	A signal in an electronic circuit that takes on a continuous range of values rather than only a few discrete values; a circuit or system that processes analog signals. [1994 National Technology Roadmap for Semiconductors]
angstrom (Å)	Unit of linear measure equal to one ten billionths of a meter (10^{-10} m). The preferred SI unit is nanometers. $10 \text{ Å} = 1 \text{ nm}$. [SEMATECH]
area contamination	Foreign matter on localized portions of a wafer or substrate surface. [SEMI M3-88]
artifact	1: A physical standard against which a parameter is measured; for example, a test wafer used for testing parametric drift in a machine. [SEMATECH] 2: a superficial or unessential attribute of a process or characteristic under examination; for example, a piece of lint on a lens that appears through a microscope to be a defect on a die. [SEMATECH] 3: in surface characterization, any contribution to an image from other than true surface morphology (e.g., contamination, vibration, electronic noise, and instrument imperfections). [SEMATECH]
aspect ratio	1: In etch, the depth-to-width ratio of an opening on a wafer. [SEMATECH] 2: in feature profile, the ratio of height to width of a feature. [SEMATECH]
atmosphere (atm.)	A unit of pressure equal to the pressure exerted by a vertical column of mercury 760 mm high, at a temperature of 0°C , and under standard gravity. One technical atmosphere equals 1 kg f/cm^2 (14.7 pounds per square inch). [ASTM D1356 REV A-73]

Term	Definition
atmospheric hood	An enclosure for use with the MultiMode Scanning Probe Microscope (SPM) which enables control of the imaging environment. It is strongly recommended for users who need to control humidity or require specific environmental atmospheres during operation.
atomic force microscopy (AFM)	A microscopy technique based on profilometry using an atomically sharp probe that provides three-dimensional highly magnified images. During AFM, the probe scans across a sample surface. The changes in force between the sample and the probe tip cause a deflection of the probe tip that is monitored and used to form the magnified image. [SEMATECH] The three primary AFM modes used at Digital Instruments, Veeco Metrology Group are: Contact Mode, Non-Contact Mode and Tapping Mode.
Auto Step Height	The process of collecting all relative height measurements along profile data between defined regions.
automated material handling system (AMHS)	Equipment that helps control the flow of material in a manufacturing facility; e.g., robots, computers, sensors, and protective carriers. [SEMATECH]
automatic valve	A valve with an actuation device that can be operated remotely, such as a pneumatically or electrically controlled valve. [SEMATECH]
bandwidth	The difference between the highest and lowest values in a range of two pattern characteristics, such as efficiency, frequency, or impedance. The bandwidth of significant frequencies (frequencies that conform to standards or that are required for reliable frequencies) within a spectrum is expressed in hertz. [SEMATECH]
bay	Of a cleanroom, a confined area that contains equipment used for one or more steps in a process. [SEMATECH]
BEEM	Ballistic Electron Emission Microscopy.
bellows valve	A packless valve that incorporates a statically sealed bellows to isolate the controlled medium from the atmosphere. [SEMI Chemicals/Gases, Vol. 1, 1990 (no longer in print)]
bias	Electrical potential applied to a tip or sample which causes electron flow to ensue from one to the other (scanning tunnel microscopy and electric force microscopy only).

Term	Definition
bidirectional	In the bar code marking of silicon wafers, refers to a bar code that can be read successfully in either scanning direction, right to left or left to right. [Adapted from SEMI T1-93]
boiling point (bp)	The temperature of a liquid at which the vapor pressure equals the prevailing atmospheric pressure. The normal boiling point is specified at one atmosphere. [SEMI Chemicals/Gases, Vol. 1, 1990 (no longer in print)]
boot	The process of starting or resetting a computer, from "pulling oneself up by the bootstraps"; the chicken and egg problem of a computer starting itself.
Bow	Bow, which increases with scan size, is the result of 2nd order or 3rd order curvatures from an ideal plane. Bow can be removed from a captured image by using Modify >Planefit Auto.
browser	Type of software that lets your computer read HTML documents and access related files and software on the Internet, intranets, or your local hard drive.
bug	An error in coding or logic that causes a program to work incorrectly (from the 50s when insects caused electrical shorts between vacuum tubes).
c-AFM-air	Contact atomic force microscopy in air.
c-AFM-fluid	Contact atomic force microscopy in fluid.
calibration	Measurement of known features to ensure accuracy of SPM images.
cantilever	Flexible portion of probe extending from the substrate and to which the tip is attached.
cantilever tune	Process of finding a cantilever's natural, resonant frequency by exciting the cantilever through a range of frequencies until maximum amplitude is obtained. The frequency at which maximum amplitude is obtained is the resonant frequency.
cassette	An open structure that holds one or more substrates. [SEMI E44-95]

Term	Definition
ceiling	In safety threshold limit values, the concentration that should not be exceeded during any part of the working exposure. [SEMI S2-93]
check valve	A flow-controlling device, installed in a tube or pipeline, that allows flow to occur in only one direction and positively prevents flow in the opposite direction. [SEMI International Standards 1990, Vol. 1, Glossary]
chemical-mechanical polishing (CMP)	A process for the removal of surface material from a wafer. The process uses chemical and mechanical actions to achieve a mirror-like surface for subsequent processing. [SEMI M1-94 and ASTM F1241]
child node	A name for any subordinate node under another node found in a workspace .
child view	Name representing view under a top view.
CITS	Current Imaging Tunneling Spectroscopy.
Classic Control	The name for the NanoScope Control display on the modal, dual display, version of software. The Classic Control displays menu bars, status bars, control panels and file lists.
Classic Control and Image	The name for the NanoScope Control and Image displays combined (See also Classic Control and Classic Image).
Classic Image	The name for the NanoScope Image display on the modal, dual display, version of software. The Classic Image displays imaging data, menu bars, data boxes and graphs.
Classic Interface	The name for the NanoScope software configured for two displays: control monitor (Classic Control) and image monitor (Classic Image).
cleanroom	A confined area in which the humidity, temperature, particulate matter, and contamination are precisely controlled within specified parameters. The class of the cleanroom defines the maximum number of particles of 0.5 mm size or larger that may exist in one cubic foot of air in the designated area. For example, a class 1 cleanroom allows one such particle of any kind to exist in one cubic foot of space; a class 10 area may contain no more than 10 such particles in one cubic foot of space. [SEMATECH]

Term	Definition
clearance	The minimum distance between the edges of sequentially applied images. [ASTM F127-84]
client window	Central window for viewing all real time graphical displays, image processing graphical displays, dockable windows and views.
Cognex	Third-party software used as the primary link in the NanoScope vision system.
compressed gas	A gas or mixture of gases in a closed container having an absolute pressure exceeding 40 psi at 70°F. [SEMATECH]
configuration	The definition of equipment and interfaces necessary for a given application. [SEMATECH]
contaminant	An unwanted substance present in the cleanroom or on the product. [SEMATECH]
controlled work area	A space within a building where hazardous production materials may be stored, handled, dispensed, or used. [SEMI F6-92]
coordinate system	A means to specify location by mapping each dimension of a space onto the real number line. A point in the space is identified by its coordinates, the locator numbers in each dimension.
crater	On the surface of a slice or wafer, an individually distinguishable bowl-shaped cavity. A crater is visible when viewed under diffused illumination. [SEMATECH]
creep	The drift of the piezo displacement after a DC offset voltage is applied to the piezo.
critical dimension (CD)	The width of a patterned line or the distance between two lines, monitored to maintain device performance consistency; that dimension of a specified geometry that must be within design tolerances. [ASTM F127-84]
critical pressure	The pressure at which a substance may exist as a gas in equilibrium with the liquid at the critical temperature. [SEMI Chemicals/Gases, Vol. 1, 1990 (no longer in print)]
critical temperature	The temperature above which gas cannot be liquefied by pressure alone. [SEMI Chemicals/Gases, Vol. 1, 1990 (no longer in print)]

Term	Definition
current	In scanning tunneling microscopy, tunnel current, expressed in nanoamperes (nA), that flows across the tip surface gap. [SEMATECH]
Cutoff	The act of isolating or separating values to obtain data (e.g., cutoff filter).
data	1: information, including programs, program instructions, and the information used or produced by a computer. [SEMATECH] 2: any representation to which meaning is or might be assigned (for example, characters). [SEMI E13-91]
data integration	1: the degree to which tools can share data through a framework. The degree of integration is dependent on the granularity of data that a framework supports. [SEMATECH] 2: The means by which design data is transferred between computer-aided design applications. [1994 National Technology Roadmap for Semiconductors]
datum point	In wafer transport systems, the left rear corner of wafer transport equipment; formed by the intersection of the planes that define the left side, back side, and wafer plane. [SEMI E8-92]
design pressure	Of a system or subsystem, the pressure at the most severe condition of coincident internal or external pressure and temperature expected during normal service. The maximum pressure expected in any portion of a system or subsystem is typically determined by the maximum adjustable setting of the last pressure regulator that supplies it, the supply pressure to the regulator, or the actuation pressure of any relief device incorporated. [SEMI F1-90]
diameter	Of a semiconductor wafer, the linear dimension across the surface of a circular wafer that contains the wafer center and excludes flats or other peripheral fiducial geometries. [ASTM F1241]
diaphragm valve	A packless valve that incorporates a statically sealed diaphragm with which to isolate the controlled medium from the atmosphere. [SEMI International Standards 1990, Vol. 1, Glossary]
dielectric	A nonconductive material; an insulator. Examples are silicon dioxide and silicon nitride. [SEMATECH] 2: a material applied to the surface of a ceramic or preformed plastic package to provide functions such as electrical insulation, passivation of underlying metalization, and limitations to solder flow. [SEMI G33-90]

Term	Definition
differential pressure	In mass flow controllers, the difference in absolute pressure between two points of measurement in a system. Note—As it applies to a mass flow controller, differential pressure is usually the measured difference in pressures between the gas inlet and outlet fittings of the mass flow controller. [SEMI E28-92]
diffusion	A high-temperature process in which desired chemicals (dopants) on a wafer are redistributed within the silicon to form a device component. [SEMATECH]
digital signal processor (DSP)	Computer processor used to control Scanning Probe Microscope feedback loop.
Dimension Series Microscopes	A series of scanning probe microscopes (i.e. 5000, 7000, 9000 and 9300) in which the stage moves under the probe. The Dimension 7000 - 9300 microscopes also include a robot for fully automated scanning.
drift	In scanning tunneling microscopy or atomic force microscopy, movement of the sample surface with respect to a microscope tip or cantilever due to a lack of thermal equilibrium. [SEMATECH]
drive amplitude	Amplitude of the signal used to oscillate a tip in TappingMode.
drive frequency	Frequency of the signal used to oscillate a tip in TappingMode.
DSP	Digital signal processor.
dump	Presentation of intermediate results just prior to an error that stops a software procedure from completing.
dynamic port	In automated material movement, a port with associated mechanisms capable of assisting with the physical movement of a transfer object or of interfering with the transfer of an object during the transfer. Such mechanisms may include doors, elevators, and robot arms. A transfer partner using a dynamic port for the transfer may be active or passive, as required. Note—The concepts of dynamic and static are associated with a port rather than equipment, as equipment may have both dynamic and static ports. [SEMI E32-94] Contrast with static port.
ECAFM	Atomic force microscopy (AFM) in fluid with provision to control the potential difference (voltage) between the tip and sample to study electrochemistry (EC).

Term	Definition
ECLFM	Lateral force microscopy (LFM) in fluid with provision to control the potential difference (voltage) between the tip and sample to study electrochemistry (EC).
ECM	Electrochemical microscopy.
edge effect	Localized structure about the edge of a specimen. [ASTM F1241]
edge sensor	A sensor on automatic test equipment that determines the location of the edge of the wafer. [SEMATECH]
EFM	Electric force microscopy.
electric force microscopy	Electric field measurement at a fixed small distance from a surface. Surface topography is established first by atomic force microscopy (AFM).
electrochemical microscopy	Use of a scanning probe microscope in a fluid with control over tip and sample voltages.
electromagnetic compatibility (EMC)	The ability of electronic equipment to function properly with respect to environmental electromagnetic interference and electrostatic discharge. [SEMI E33-94]
electromagnetic interference (EMI)	Any electrical signal in the nonionizing (suboptical) portion of the electromagnetic spectrum with the potential to cause an undesired response in electronic equipment. [SEMI E33-94]
electrostatic chuck (ESC)	A mechanism for holding wafers using electrostatic attraction. [SEMATECH]
electrostatic discharge (ESD)	A sudden electric current flow, such as between a human body and a metal oxide semiconductor, with potential damage to the component. [SEMATECH] 2: the transfer of electrostatic charge between bodies at different electrostatic potentials. [SEMI E33-94]
emergency off (EMO)	Fail safe control switch or circuit that, when de-energized, will stop the operation of associated equipment and will shut off all potential hazards outside the main power enclosure. [SEMI E20-91]

Term	Definition
emergency off (EMO) circuit	In facilities and safety, a control circuit that, when deactivated, places the equipment into a safe shutdown condition and will restrict all hazardous potentials to the main power enclosure. This is a condition in which all hazardous voltage has been removed from the equipment, all hazardous production materials flow has been stopped, any radiation sources have been de-energized or totally contained, any capacitors have been grounded, all moving parts stopped, internal and external heat sources shut off, and the equipment presents minimum hazard to personnel or the facility. [Adapted from SEMI S2-93]
emergency off (EMO) interface	The location at which a process or cassette module EMO cable is connected into the cluster tool circuit. [SEMI E20-91]
enabled	Refers to one of the two major SECS communication states (enabled and disabled). The enabled state has two sub-states, communicating and not communicating. In the enabled state, the equipment will periodically attempt to establish communication with a host computer or uphold communications with the host. [SEMI E30-94]
enclosure	In mini environments, a physical barrier between the localized environment and its surroundings. [SEMI E44-95]
end effector	In cluster tools, a physical location attached to a transport resource, capable of holding a wafer during an end-to-end material transfer. [SEMATECH]
engagement	Process of bringing a probe tip and sample together in a controlled manner such that useful information about the surface is obtained without damaging either the tip or the sample.
environmental isolation	Separation from the ambient atmospheric environment. [SEMI E21-94]
equipment cycle	One complete operational sequence of processing, manufacturing, and testing steps. In single-unit processing systems, the number of cycles equals the number of units processed. In batch systems, the number of cycles equals the number of batches processed. [SEMI E10-92]
equipment downtime	The hours when the equipment is not in a condition or is not available to perform its intended function; does not include any portion of nonscheduled time. [SEMI E10-92]

Term	Definition
equipment failure	Any interruption or variance from the specifications of equipment operation that requires the replacement of a component (other than specified consumables) because of degradation or failure. Also includes assists that interrupt operation and require more than six minutes. [SEMI E10-92]
equipment uptime	The amount of time when the equipment is in a condition to perform its intended function, including productive, standby, and engineering time; does not include any portion of nonscheduled time.
ergonomics	The science that deals with adapting the work environment to the needs of the worker.
error	Difference between actual tip-sample force measured at the detector and the setpoint force.
etch	A category of lithographic processes that remove material from selected areas of a die. Examples are nitride etch and oxide etch. [SEMATECH] 2: in the manufacture of silicon wafers, a solution, a mixture of solutions, or a mixture of gases that attacks the surfaces of a film or substrate, removing material either selectively or nonselectively. [SEMI M1-94 and ASTM F1241]
excess flow valve (EFV)	A valve inserted in a supply line designed to shut off the flow positively in the event its predetermined flow is exceeded. [SEMI S2-93]
exposure	The process of subjecting a photosensitive material to light or other radiant energy. [SEMATECH] 2: the amount of light or other radiant energy received per unit area of sensitized material. [ASTM F127-84]
Extender Electronics Module	Offers phase and frequency detection capabilities for enhanced magnetic and electric force microscopy that eliminate artifacts and improve image quality. Also allows measurement of sample surface potential. It is recommended for all users performing magnetic or electric force measurements and for specialized applications requiring microscopic measurement of surface voltage.
F-J	
fab	The main manufacturing facility for processing semiconductor wafers. [SEMATECH]

Term	Definition
fail safe	A system so designed that a failure of any component in the system will stop the equipment and prevent unsafe operation of the equipment. [SEMI S2-93]
false engagement	Condition due to surface effects or insufficient setpoint (too low during contact AFM; too high during TappingMode) in which the feedback controller attempts imaging a sample that is not engaged with the tip.
false negative	A measurement that indicates the failure to count a particle that is present. [SEMATECH]
false positive	A measurement that indicates the presence of particles when no particles are present. [SEMATECH]
fast axis	In optics, of a doubly refracting crystal, the direction in which the velocity of light is a maximum. [ASTM F1241]
fast scanning	The ability to scan a sample at speeds up to 10 times faster than possible with conventional Atomic Force Microscope and Scanning Probe Microscope systems (available in TappingMode and Contact Mode). This translates to complete scans in seconds versus minutes while maintaining integrity and accuracy
feature	An area within a single continuous boundary (for example, an aggregate image) that has an optical-density value (gray-level range) that is distinct from the background area outside the feature; for example, the simplest element of a pattern such as a single line, space, or L-bar. [SEMI P19-92]
feature height	In scanning tunneling microscopy and atomic force microscopy, the height of features on a surface profile; the distance in the Z-direction of any point in a microscope's scan area, relative to the lowest point in the scan area, as derived from measurement fluctuations during raster. [SEMATECH]
feedback	In atomic force microscopy, a process by which the cantilever is moved in the Z-direction relative to the sample to maintain a constant force during scanning. 2: in scanning tunneling microscopy, a process by which the tip is moved in the Z-direction relative to the sample to maintain a constant current during scanning. [SEMATECH].
fiber optics	A technique for transmitting light through very fine, flexible glass rods by means of internal refraction. [SEMATECH]

Term	Definition
field	The printed pattern from a reticle. [SEMATECH]
field rotation	The rotation of a printed reticle pattern with respect to previously exposed fields. [SEMATECH]
flammable liquid	A liquid that has a flash point below 37.8°C (100°F) and a vapor pressure not exceeding 40 psi (absolute) at 37.8°C. [ASTM E772-87]
flange	In plastic and metal wafer carriers, the material on the exterior of a wafer carrier and perpendicular to the side walls. [SEMI E1-86]
flatness	1: for wafer surfaces, the deviation of the front surface, expressed in total indicator reading (TIR) or maximum focal plane deviation (FPD), relative to a specified reference plane when the back surface of the wafer is ideally flat, as when pulled down by a vacuum onto an ideally clean, flat chuck. [SEMI M1-94 and ASTM F1241] Contrast bow and warp. Also see global flatness, site flatness, total indicator reading, and focal plane deviation. 2: in a ceramic package or lead frame, the allowable deviation of a surface from a defined reference plane. The tolerance zone is defined by two parallel planes within which the surface must lie. [SEMI G61-94]
floating menu	Pop-menu appearing on top of a specific window for configuring window elements. Also known as properties menu .
flow coefficient (C_v)	The number of standard cubic meters of air per minute that can flow through a valve at a pressure drop of 1 psi. [SEMATECH]
flow rate	Measurement of the amount of fluid or gas that passes one point at a given time. [SEMATECH]
flow velocity (V)	In equipment exhaust systems, the average speed at which the effluent stream travels through the exhaust duct. It is measured in meters per second (m/s) or feet per minute (fpm). [SEMI S6-93]
flow volume (Q)	In equipment exhaust systems, the volumetric flow rate of the effluent stream passing a given location in the exhaust system per unit of time. It is measured in cubic meters per second (m ³ /s) or cubic feet per minute (cfm). [SEMI S6-93]
fluid cell	Accessory used for imaging materials in fluid, consisting of a specialized tipholder and o-ring.

Term	Definition
fluid cell	A container for electrochemically interesting fluids with provision for admitting a scanning probe microscope (SPM) probe and possibly allowing fluid to circulate.
flux	The number of particles flowing through a given area per unit time. [ASTM 1296-92]
FM	Frequency modulation.
focal plane	The plane perpendicular to the optical axis of an imaging system that contains the focal point of the imaging system. [SEMI M1-94]
focal plane deviation (FPD)	The distance parallel to the optical axis from a point on the wafer surface to the focal plane of the optical system. [SEMI M1-94 and ASTM F1241]
focal range	In the measurement of photolithographic instruments, the total distance of defocus in which, over the whole of the processed image field, the processed image is sufficiently resolved for practical use. [SEMI P25-94]
focal surface	In the measurement of photolithographic instruments, the surface determined by finding the focus for each point-like object in the optical image field, with the object fixed with respect to the lens. The focal surface is then the map of Z-axis displacements for the highest contrast at each point in the optical image field as a function of the (x, y) or (r, j) coordinates. [SEMI P25-94]
focussed ion beam	An imaging tool that can be used to deposit or etch materials on wafers. A focussed ion beam is often used in the etch mode to selectively cleave structures for failure analysis. It is also used in photomask repair for removing or adding material, as necessary, to make the photomask defect free. [SEMATECH]
footprint	The floorspace (in square feet) that a piece of equipment occupies. [SEMATECH] 2: on a semiconductor package, the pattern of the metallized pads, leads, or pins used to make contact between the internal metallization of the package and the connecting external circuitry. [SEMI G22-86]
force	For atomic force microscopy, interactions in the nanometer scale leading to movement of the cantilever relative to the sample surface. [SEMATECH]
force curves	Also referred to as <i>force plots</i> . The force acting vertically on a probe tip as a function of its distance above the sample.

Term	Definition
force modulation	Force modulation imaging is a scanning probe microscopy (SPM) technique that identifies and maps differences in surface stiffness or elasticity.
force volume	An array of force plots taken at different locations on a sample.
fork	In cluster tools, a two-prong transport module end effector designed to hold the wafer around its periphery. [SEMI E22-91]
functions menu	Pop-up menu found only in a workspace (permit multiple views, add new views, etc.).
FV	Force volume.
gas	A material that is shipped in compressed gas cylinders or acts as a gas upon release at normal temperatures and pressure, or is used or handled as a gas, whether or not in strict accordance with the definition of a compressed gas as set forth in Article 9 of the Uniform Fire Code. [SEMI S4-92]
gas temperature	In a mass flow controller, the actual temperature of the flowing gas at the primary flow standard. [SEMI E18-91]
gauge pressure	In mass flow controllers, the differential pressure measured relative to ambient pressure. For example, when the pressure within a system equals the prevailing ambient pressure, the gauge pressure equals zero. [SEMI E28-92]
Generic Equipment Model (GEM)	1: a generalized model that describes a recommended implementation of the SEMI Equipment Communications Standard II. [SEMATECH] 2: in communications and control of semiconductor manufacturing equipment, a reference model for any type of equipment. It contains functionality that can apply to most equipment, but does not address unique requirements of specific equipment. [SEMI E30-94]
gowning	A procedure that includes hand washing and the donning of gloves, head covering, masks, shoe covering, and other specialized garments before workers enter the cleanroom. [SEMATECH]
graphical user interface (GUI)	The area on the display monitor that includes all information displayed graphically. A graphical user interface is a combination of icons, scroll bars, windows, help systems, menus, views, dialog boxes and other services to make a program easier to use. [SEMATECH]

Term	Definition
groove	In a semiconductor wafer, a shallow scratch with rounded edges that is usually the remnant of a scratch not completely removed by polishing. [SEMI M1-94 and ASTM F1241]
hazard	A set of recognizable conditions with the potential for initiating an event that could result in death, injury, or illness to people, and/or facility/equipment damage. [SEMI S1-90]
hazardous materials	1: those chemicals or substances that are physical hazards or health hazards as defined and classified in National Fire Protection Association (NFPA) 704, whether the materials are in use or in waste conditions. [SEMI S2-93] 2: substances or mixtures having properties capable of producing adverse effects on the health or safety of a human. [SEMATECH]
help interface	A menu item for initializing the help files and Follow Along Help. The help is displayed or hidden using the View>Help command. The help interface allows you to view documentation related to using the NanoScope software.
HEPA	See high-efficiency particulate air (HEPA) filter.
hermetic seal	A coat applied in the final stage of thermal processing to seal the ceramic package and to protect the device from the external environment. [SEMATECH]
hertz (Hz)	A term applied to the number of repetitions of a periodic wave per second. [SEMATECH]
heterogeneous environment	An environment that contains a collection of platforms having both similar and significantly different parts. [SEMATECH]
HF MFM	High Frequency Magnetic Force Microscopy.
high pressure isolation (HPI) valve	A shutoff valve located on the high-pressure side of a gas piping system that, when closed, isolates the purged volume from the pressure regulator and other downstream components. [SEMI F13-93]
High Temperature Heater	Accessory for the MultiMode Scanning Probe Microscope that allows imaging at temperatures up to 250°C, which covers the melting range of most common polymers
high-efficiency particulate air (HEPA) filter	A replaceable extended media, dry-type filter in a rigid frame and having a minimum particle-collection efficiency of 99.97% on all particles larger than 0.3 mm. [SEMATECH]

Term	Definition
histogram	A graph obtained by dividing the range of the data set into equal intervals and plotting the number of data points in each interval. [EIA 557]
icon	A small image (e.g., displayed on a computer screen) representing something (e.g. an item on the computer that the user can access).
IFM	Interfacial force microscopy.
image	1: any single geometric form appearing in a layout as a part of a master drawing or layout (image, drafting) projected on a screen or viewed, usually at some magnification or reduction (image, optical) etched in the silicon dioxide layer on an oxidized silicon wafer (image, oxide) in a photomask or in the emulsion of a photographic film or plate (image, photographic) an exposed and developed coating on a substrate (image, photoresist) [ASTM F127-84 and SEMI P25-94] 2: in scanning tunneling microscopy, representation of surface topography obtained using the signal from the tip or surface during rastering and runder tunneling conditions. [SEMATECH] 3: in atomic force microscopy, representation of surface topography obtained by using the signal from the cantilever or surface during rastering in constant force conditions. [SEMATECH]
image display	Window of the realtime scan or captured image.
image processing	The process of analyzing, modifying or reconstructing real time data (e.g., AFM images or profiles).
input parameters	A grid of parameters in the image processing commands allowing for editing parameters settings.
inputs window	Window within image processing commands allowing for editing parameters settings.
insoluble	Not capable of being dissolved. [SEMATECH]
integral gain	Amount of correction applied in response to the average error between setpoint force and actual force measured by the detector.
integrated circuit (IC)	1: two or more interconnected circuit elements on a single die. [SEMATECH] 2: a fabrication technology that combines most of the components of a circuit on a single-crystal silicon wafer. [SEMI Materials, Vol. 3, Definitions for Semiconductor Materials]

Term	Definition
integrated mini-environment	A mini-environment that is an integral part of the tool. [SEMI E44-95]
integrated standard mechanical interface (SMIF)	A unit that includes a SMIF port and a mechanism for indexing the port door, and which is entirely incorporated within the tool. [SEMI E44-95]
interconnect	A highly conductive material, usually aluminum or polysilicon, that carries electrical signals to different parts of a die. [SEMAT-ECH] 2: the wiring between elements on a die, package, or board. [1994 National Technology Readmit for Semiconductors]
isolation valve	1: in cluster tools, a mechanical component used at an interface plane to permit environmental isolation between the transport module and an attached module. There is always one isolation valve under the control of the transport module. [SEMATECH] 2: in the pressure testing of fluorocarbon tube fittings, a valve used to separate high-temperature fluid from high-pressure fluid, or to separate the samples from each other. [SEMI F10-93]
K-O	
label	A piece of paper or other material affixed to a container or article, on which is printed information concerning the product or addresses. It may also be printed directly on the container. [ASTM D996-90]
laminar air flow	A flow of air uniformly parallel from ceiling to floor, or wall to wall in a room or workstation, moving with uniform velocity and a minimum of turbulence. [SEMATECH]
latent image	A condition produced and persisting in the image receptor by exposure to radiation that is able to be converted into a visible image by processing. [ASTM E586 REV A-90]
lateral force microscopy (LFM)	A scanning probe microscopy (SPM) technique that identifies and maps relative differences in surface frictional characteristics
leak	In the measurement of mass flow controller leak rates, a path or paths in a sealed system that will pass helium when a partial pressure differential exists. A partial pressure differential can exist for helium even though a total gas pressure differential may not exist. A leak may be a mechanical leak or a permeation leak, or it may have both mechanisms operating in parallel. [Adapted from SEMI E16-90]

Term	Definition
life cycle	The stages beginning with original requirements specifications and ending with the final retirement of a program, application, or tool. [SEMATECH]
lift access	In quartz and high temperature carriers, the clearance space in which an implement is inserted to pick up a wafer carrier. [SEMI E2-93]
lift access height	In quartz and high-temperature wafer carriers, the distance from the horizontal center line of the lift access opening to the bottom plane. [SEMI E2-93]
lift access opening	In quartz and high-temperature wafer carriers, the size of the opening provided for the insertion of an implement that picks up the wafer carrier. [SEMI E2-93]
LiftMode™	Two-part, proprietary method of imaging surfaces consisting of a surface scan to obtain height data, followed by a second scan to extract other information about the surface (such as magnetic force or elasticity) while the tip profiles the previous Z path at a constant height. The two images are subtracting from each other to yield an image uninfluenced by topography.
linearity	In the linearity of mass flow devices, the closeness to which a curve approximates a straight line. It is measured as a nonlinearity and expressed as a linearity. [SEMI E27-92]
lithography	A process in which a masked pattern is projected onto a photosensitive coating that covers a substrate. [SEMATECH] Also called photolithography.
load (verb)	To place a cassette on the cassette stage of the equipment. [SEMI E23-91]
load height	The distance from the bottom of the cassette or container to the floor on which the tool is installed. [SEMI E15-91]
look	1: (noun) An image displayed by the vision system which (potentially) includes a model or a scanning site. Registration of a single point (e.g., origin only) entails at least one look. Registration of two points (e.g., origin and deskew) entails at least two looks. 2: (verb) The process of detecting a model in an image and adjusting the relative positions of the sample and probe such that the model occupies the same area of the video image (i.e., same pixel coordinates) as when the user taught the model.

Term	Definition
LookAhead gain	Amount of correction applied in response to the error signal between setpoint force and actual force measured by the detector, based upon recorded information from the adjacent scan line.
low pressure isolation (LPI) valve	A shutoff valve located on the low pressure side of a gas system that, when closed, isolates the purged volume from the distribution piping and all other downstream components. [SEMI F13-93]
LTG	Light-modulated tunneling gap.
machine vision	The automatic acquisition of graphical information.
Magnetic Actuated Drive TappingMode	Option for the MultiMode Scanning Probe Microscope specifically designed for TappingMode in fluids. The option offers easy setup and operation, including AutoTune automatic cantilever tuning.
maintenance	The act of sustaining equipment in a condition to perform its intended function. [SEMI E10-92]
manual override	A mechanism incorporated into a remotely actuated valve that provides for manual closing and locking. [SEMI F4-90]
material data safety sheet (MSDS)	1: written or printed material concerning a hazardous material that is prepared in accordance with the provisions of 29 CFR 1910.1200. (See UFC "88" 9.115.) (Form OSHA 20) [SEMI S2-91] 2: the descriptive data provided on a data sheet recommended by the Occupational Safety and Health Administration (OSHA) to provide information regarding the hazards of materials to prevent and respond to emergency situations. [SEMATECH]
MDM	Magnetic dissipation microscopy
median surface	Of a semiconductor wafer, the locus of points in the wafer equidistant between the front and back surfaces. [ASTM F1241]
menu	A list of options visually presented on a terminal by a computer program to allow a user to select a course of action. [SEMATECH]
metrology	The science of measurement to ascertain dimensions, quantity, or capacity; the techniques and procedures for using sensors and measurement equipment to determine physical and electrical properties in wafer processing. [SEMATECH]
MFM	Magnetic force microscopy

Term	Definition
micro environment	Ambient conditions in a very small region. [SEMATECH]
micrometer (μm)	A metric unit of linear measure that equals 1/1,000,000 meter (10 - 6 m), or 10,000 angstroms. The diameter of a human hair is approximately 75 micrometers. [SEMATECH] Also called micron.
micron	See micrometer.
mini environment	A localized environment created by an enclosure to isolate the product from contamination and people.
MMAFM-ECAFM	Electrochemical atomic force microscopy (AFM) on MultiMode Atomic Force Microscope (AFM)
MMAFM-ECSTM	Electrochemical scanning tunneling microscopy on MultiMode Atomic Force Microscope (AFM).
model	A region within a displayed image that is favorable for pattern recognition due to subregions of high contrast.
module	1: a program unit that is discrete and identifiable with respect to compiling, combining with other units, and loading. For example, the unit may be the input to, or output from, an assembler, compiler, linkage editor, or executive routine. [SEMATECH] 2: a logically separable part of a program. [SEMATECH] 3: in modular equipment, an independently operable unit that is part of a tool or system. [SEMI E21-94] 4: in the calibration of mass flow devices, the number of moles per unit of time flowing in a closed channel. [SEMI E29-93]
monitor	A graphical display device for pointing to or selecting individual pixels within a monitor display.
MSDS	See material safety data sheet.
MSM	Magnetoresistance sensitivity mapping.
MultiMode	The most compact Digital Instruments Scanning Probe Microscope.
NanoScope™	Trademark name applied to Digital Instruments' scanning probe microscopy products.
nc-AFM	Non-contact atomic force microscopy.

Term	Definition
node	Corresponds to the names found in a workspace allowing to view captured images, microscope settings, or views (e.g., Realtime, Recipe, Setup).
normal operating differential pressure	In a mass flow controller, the range of differential pressure required by the device to meet its stated performance specifications. [SEMI E28-92]
normal operating temperature	In a mass flow controller, the temperature range within which the influence of ambient temperature on the performance is stated. [SEMI E18-91]
NSOM	Near-field scanning optical microscopy.
object-oriented	Describes a perspective that views the elements of a problem or solution by decomposition into objects and object relationships. [SEMATECH]
objective	Of a microscope, the primary magnifying system, consisting of a system (generally of lenses, less frequently of mirrors) forming a real, inverted, and magnified image of the object viewed. [ASTM E175-82]
operating temperature limits	In a mass flow controller, the temperature range within which operation is permitted, but performance is not specified beyond the normal operating temperature. If the instrument is operated outside these limits, damage may occur. [Adapted from SEMI E18-91]
operator	In communications and control of semiconductor manufacturing equipment, a human who operates the equipment to perform its intended function (for example, processing). The operator typically interacts with the equipment through the equipment-supplied operator console. [SEMI E30-94]
origin	Of a dot matrix, the physical center point of the dot in the cell common to the primary border row and secondary border column. [SEMI T2-93]
orthogonality	The measure of perpendicularity between the X- and Y-axis geometries printed on a substrate. [SEMATECH]
P-T	
parent node	A name for the highest level view found in a workspace corresponding to a captured image, microscope settings, group or view.

Term	Definition
parent view	Name representing top view.
particle	1: a minute quantity of solid or liquid matter. [SEMATECH] 2: in the manufacture of photolithographic pellicles, material that can be distinguished from the film, whether on the film surface or embedded in the film. [SEMI P5-94] 3: the replating step in which a catalytic material, often a palladium or gold compound, is absorbed on a surface to act as sites for initial stages of deposition. [ASTM B374-93]
particulate	Discrete particle of dirt or other material. [ASTM F1241] 2: discrete particle of material that can usually be removed by (nonetching) cleaning. [SEMI M10-89] 3: describes material in small, discrete pieces; anything that is not a fiber and has an aspect ratio of less than 3 to 1. Examples are dusts, fumes, smokes, mists, and fogs. [SEMATECH]
particulate contamination	On a semiconductor wafer, a particle or particles on the surface of the wafer. [ASTM F1241]
partition coefficient	The quotient of the solubility of a compound in octanol and its solubility in water. [SEMATECH]
pattern shift ratio	In silicon wafers, the lateral distance between the center point of the pattern on the surface of the substrate and the center point of the pattern on the surface of the epitaxial layer, divided by the epitaxial layer thickness. [SEMI M18-94]
pattern step height	In silicon wafers, the difference in vertical position of the diffused (buried layer) surface and the original substrate surface, after removal of oxide. [SEMI M18-94]
pattern surface	In flat panel display, that surface of a substrate that has, or will have, patterns applied. [SEMI D4-94]
patterning	The process of photolithography; formation of geometrical shapes by the use of photosensitive resists, masks, and etching techniques. [SEMATECH]
pedestal	A support pillar axially symmetric to the wafer transport position in a process or cassette module. [SEMI E22-91]

Term	Definition
permissible exposure limit (PEL)	1: a time-weighted average exposure limit (typically 8 hours) or a ceiling exposure limit for employees to any material listed in Occupational Safety and Health Administration (OSHA) Regulation 29 CFR, Air Contaminants. [SEMATECH] 2: the maximum permitted eight-hour time-weighted average concentration of an airborne contaminant. The maximum permitted time-weighted average exposures to be used are those published in 29 CFR 1910, Subpart Z. [SEMI S2-93]
phase imaging	Provides nanometer-scale information about surface structure often not revealed by other scanning probe microscopy (SPM) techniques by mapping the phase of the cantilever oscillation during the TappingMode scan.
photolithography	See lithography.
photomask	A structure comprising functional pattern images produced on a film, plastic, or glass-based material and accurately positioned so as to be useful for selective exposure of a photoresist coating. [ASTM F127-84]
photomask, negative	A photomask having an opaque background and transparent images. [ASTM F127-84]
photomask, positive	A photomask having transparent background and opaque images. [ASTM F127-84]
photomask, reverse polarity	A photomask that maintains the same geometric orientation of the array on its surface as that of a referenced photomask, but is of the opposite polarity, as a correct positive mask to a correct negative mask. A correct negative mask is a reverse polarity mask of a correct positive mask. [ASTM F127-84]
photomasking	An operation in which patterns or images are produced on a glass plate to create a mask. [SEMATECH] 2: the practice of photolithography. [SEMATECH] 3: the name of an area or a group that performs photolithography. [SEMATECH]
physical interlock	Mechanical connection through which interlock conditions are verified. [SEMATECH]
piezoelectric	A material property such that an applied voltage causes a change in object size and, inversely, expansion or contraction induces a voltage across the object.

Term	Definition
pin	In plastic and metal wafer carriers, part of a wafer carrier that enters the hole or slot of another wafer carrier for alignment when wafers are transferred. [SEMI E1-86]
pit	1: in a wafer surface, a depression in a wafer surface that has steeply sloped sides which meet the surface in a distinguishable manner, in contrast to the rounded sides of a dimple. [ASTM F1241] 2: in semiconductor packages, plastic or ceramic, or in the leadframes, a shallow depression or crater. The bottom of the depression must be visible in order for the term to apply. A pit is formed during the component manufacture. [SEMI G61-94] Contrast chip. 3: in flat panel display substrates, a small indentation on the glass substrate surface. [SEMI D9-94]
pitch	The distance between a point on an image and a point on the corresponding image in an adjacent functional pattern that lies in either a row or column on a photomask or reticle. [SEMATECH]
planarization	A process that smooths the contours of the wafer surface by minimizing the step heights. [SEMATECH] 2: minimizing the difference in depth of the test probe pin with respect to the bond pads of a die. [SEMATECH]
pod	A box having a standard mechanical interface (SMIF). [SEMI E44-95]
polar transmission	A method of transmitting teletypewriter signals when current flows in opposite directions. Direct current flowing in one direction identifies the marking signal, and an equal current flowing in the opposite direction identifies the spacing signal. [SEMATECH]
polarization	In optics, the term used to describe the orientation of the electric field vector in an electromagnetic wave. [ASTM F1241]
polarized light	In optics, light that exhibits different properties in different directions at right angles to the line of propagation. [ASTM F1241]
pop-up menu	A floating menu that appears when right-clicking on each window or screen. Configures the properties found on that screen or window (e.g., cursor type, color table in the image display).

Term	Definition
port	1: a terminal of a semiconductor device or component at which information can be extracted or inserted. [SEMATECH] 2: in automated material movement, a point on the equipment at which a change of equipment ownership of a transfer object occurs, including any dedicated mechanisms that either prepare for, facilitate, or are capable of interfering with the transfer. [Adapted from SEMI E32-94]
position reference point	In cluster tools, a location defined in an attached module's local coordinate system, through which an end effector will pass during a wafer exchange sequence. [SEMATECH]
positive mask	See photomask, positive.
power dissipation (PH)	In the measurement of the thermal resistance of a semiconductor device, the heating power applied to the device to cause a junction to specified reference point (possibly case) temperature difference. PH is measured in watts. [SEMI G38-87]
practical resolution	The minimum linewidth that reproduces the mask (or drafting) dimensions faithfully. [SEMI P25-94]
precision	The measure of natural variation of repeated measurements. [EIA 557]
probe	Integrated mechanical device used to image surfaces, including a substrate, cantilever and tip.
probe	A cantilever, typically several hundred microns in length, with an atomically-sharp tip attached to the free end for use in scanning probe microscopy imaging.
probe damage	1: on a substrate, local damage caused by mechanical probing or measurement. Probe damage consists of pitted areas that have spacing equal to that of the probe array. [SEMI Materials, Vol. 3, Definitions for Semiconductor Materials and SEMI M10-89] 2: in gallium arsenide technology, any damage to the wafer surface caused by mechanical probing or measurement. [SEMI M10-89]
probe holder	A removable fixture where consumable scanning probe microscopy probes are mounted for use.
process control	The ability to maintain specifications of product and equipment during the manufacturing operations. [SEMATECH]

Term	Definition
process time	The length of time required to process one wafer or one batch (for sequential and batch tools, respectively) at a given workstation or through an entire process. [SEMATECH]
processed image	In the measurement of photolithographic instruments, any single geometric form that appears in the realized pattern or topographical variation of a material surface or material constitution, and that is obtained by a physical process of pattern transference from an optical image. [Adapted from SEMI P25-94]
properties menu	Pop-up menu appearing on each window or screen that configures the properties of elements found on that screen or window (e.g., cursor type, color table in the image display). Also known as floating menu .
proportional gain	Correction applied in response to the error signal between setpoint force and actual force measured by the detector, in direct proportion to the error.
protective clothing	Articles of apparel to prevent gases, vapors, liquids, and solids from contacting the skin and to prevent them from being inhaled or ingested. This clothing includes self-contained breathing apparatus. [SEMATECH]
PSTM	Photon scanning tunneling microscopy.
radio frequency (RF)	Electromagnetic energy with frequencies ranging from 3 kHz to 300 GHz. Microwaves are a portion of radio frequency extending from 300 MHz to 300 GHz. [SEMI S2-93]
ramp-down	The portion of a maintenance procedure required to prepare the equipment for hands-on work. It includes purging, cool-down, warm-up, etc. Ramp-down is included only in scheduled and unscheduled downtime. [SEMI E10-92]
ramp-up	The portion of a maintenance procedure required, after the hands-on work is completed, to return the equipment to a condition in which it can perform its intended function. It includes pumpdown, warm-up, stabilization periods, initialization routines, etc. It does not include equipment or process test time. Ramp-up is included only in scheduled and unscheduled downtime. [SEMI E10-92]
range	The region between the limits within which a quantity is measured, expressed by stating the lower and upper range values. [SEMI E27-92]

Term	Definition
rapid thermal processing (RTP)	A process in which a wafer is heated to a specified temperature for short periods of time.
raster	The movement or area defined by repetitively scanning (with a microscope) in the X-direction while moving stepwise in the Y-direction. [SEMATECH]
reach	The distance measured from the interface plane to the wafer centroid (center of mass) within a process module or a cassette module of a cluster tool. [SEMI E21-94]
reactivity	The tendency of a substance to undergo chemical reaction, either by itself or with other materials, and to release energy. [SEMATECH]
reactor	A sealed isolation chamber in which a reaction occurs. [SEMATECH]
reagent	In the semiconductor industry, a chemical that is suitable for use in the manufacture of semiconductors or in the performance of chemical tests. The purity of a reagent solution is higher than the purity of a standard solution. [SEMATECH]
realtime	Pertaining to a system designed to control a dynamic process within the timing constraints of the process. [SEMATECH]
recipe	The computer program, rules, specifications, operations, and procedures performed each time to produce a wafer that contains functional die. Examples are the setup recipe and the process recipe. [SEMATECH]
reference plane	In semiconductor technology, a plane defined by one of the following: three points at specified locations on the front surface of a wafer; the least squares fit to the front surface of a wafer using all points within the fixed quality area (FQA); the least squares fit to the front surface of a wafer using all points within a site; or an ideal back surface (equivalent to the ideally flat chuck surface that contacts the wafer). [SEMI M1-94]
refractive index	The ratio of the velocity of light in the first of two media to its velocity in the second as it passes from one into the other. The first medium is usually a vacuum. [SEMATECH]

Term	Definition
registration	1: the accuracy of the relative position of all functional patterns on any reticle with the corresponding patterns of any other reticle of a given device series when the reticles are properly superimposed. [ASTM F127-84] 2: a vector quantity defined at every point on the wafer. It is the difference, R, between the vector position, P1, of a substrate geometry and the vector position of the corresponding point, P0, in a reference grid. [SEMATECH] 3: in the overlay capabilities of wafer steppers, a vector quantity defined at every point on the wafer. It is the difference, R, between the vector position, P1, of a substrate geometry, and the vector position of the corresponding point, P0, in a reference grid. [SEMI P18-92]
regulator	A valve designed to reduce a high incoming pressure (for example, from a cylinder) to a lower outlet pressure by automatically opening to allow flow until a desired, preset pressure on the outlet side is reached and then automatically throttling closed to stop further pressure increase. [SEMI International Standards 1990, Vol. 1, Glossary]
relative humidity (RH)	The quantity of water vapor present in the atmosphere as a percentage of the quantity that would saturate at the existing temperature. [SEMATECH]
relative minimum	In optics, a minimum in the amount of light transmitted through a polarizer and analyzer combination that results when either the polarizing angle or the analyzing angle is varied (with the other angle fixed). [ASTM F1241]
reliability	Of equipment, the probability that the equipment will perform its intended function, within stated conditions, for a specified period of time. [SEMI E10-92]
relief valve	A pressure-relieving device, installed in a line or control component, designed and adjusted to release pressure that could damage other components in the system. [SEMI International Standards 1990, Vol. 1, Glossary]
residue	Any undesirable material that remains on a substrate after any process step. [ASTM F127-84 and SEMI P3-90]
resistivity (ρ)	1: of a semiconductor, the ratio of the potential gradient parallel with the current in the material to the current density. Units are Ωcm . [SEMI M4-88] 2: the resistance that a unit volume of semiconductor material offers to the passage of electricity when the electric current is perpendicular to two parallel faces. [SEMI M1-94] 3: the measure of difficulty with which charge carriers flow through a material. Resistivity is the reciprocal of conductivity. [ASTM F1241]

Term	Definition
resolution	The fineness of detail revealed by an optical device. Resolution is usually specified as the minimum distance by which two lines in the object must be separated before they can be revealed as separate lines in the image. [ASTM E7-90]
results data	A grid of measurements within the image processing commands displaying resulting data from the configured input parameters, cursor placement and histogram slider cursor placement.
results window	Window within the image processing commands displaying data from the configured inputs window settings and cursor placement.
reticle	A very flat glass plate that contains the patterns to be reproduced on a wafer; the image may be equal to or larger than the final projected image. Typical reticle substrate material is quartz, and typical magnifications are 10, 5, and 1 times final size. The reticle is used in a stepper. [SEMATECH]
RMS amplitude	Root mean square (RMS) signal measured at the detector (TappingMode only).
rotation	In dielectrically isolated (DI) wafers, the angle of deviation between the primary flat of the DI wafer and the X axis of the photolithography pattern. [SEMI M22-92]
roughness	1: the more narrowly spaced components of surface texture. [ASTM F1241] 2: in flat panel display substrates, the criterion for the smoothness of the sheet surface. [SEMI D9-94]
roughness average	In surface profilometry, the arithmetic average of the absolute values of the measure profile height deviations taken within the sampling length and measured from the graphical center line. [ASME B46.1-85]
safe	Free of conditions that can cause occupational illness, injury, or death to personnel, damage to or loss of equipment or property, or damage to the environment. [SEMI S2-93]
sample angle	In electron spectroscopy for chemical analysis, the angle of the surface with respect to a horizontal axis, which is defined as zero. [SEMATECH]
sample flow rate	In particle contribution testing, the volumetric flow rate drawn by the counter for particle detection. The counter may draw higher flow for other purposes (for example, sheath gas). [SEMATECH]

Term	Definition
sample tilt angle	In scanning electron microscopy, the angle that the sample plane makes with a line normal to the incoming electron beam. [SEMATECH]
sample volume flow	The actual amount of liquid being monitored in an optical particle counter, measured in units of liters or milliliters per minute. [SEMATECH]
sampling distance	The lateral distance between areas to be measured for characterizing a surface. [SEMATECH]
SAWM	Surface acoustic wave microscopy.
scan	In scanning tunneling microscopy, movement of the microscope tip relative to sample surface, continuously in one direction. Contrast raster. [SEMATECH] 2 v to move the microscope tip continuously in one direction. [SEMATECH]
scan area	In scanning tunneling microscopy, area defined by successive, side-by-side scan lengths. [SEMATECH]
scan direction	In scanning tunneling microscopy, the direction in which the tip or sample is continuously scanned, orthogonal to the Y-direction, in the sample plane. [SEMATECH]
scan length	In scanning tunneling microscopy, the distance from start to end of a single scan. [SEMATECH]
scan path	A linkage of registers in an integrated circuit with associated control mechanisms that enables the registers to be operated as a shift register in addition to their normal mode of operation. This permits the registers to be controlled and observed during test mode, greatly enhancing testability. [1994 National Technology Roadmap for Semiconductors]
scan rate	In scanning tunneling microscopy and atomic force microscopy, the speed at which the tip or cantilever moves relative to the surface. [SEMATECH]
scanning probe microscopy (SPM)	Generation of graphical portraits of the control signal needed to maintain a particular tip/sample interaction while scanning a sample surface with an atomically-sharp tip. The two primary forms of SPM are scanning tunneling microscopy (STM) and atomic force microscopy (AFM).

Term	Definition
scanning tunneling microscope (STM)	An instrument for producing surface images with atomic scale lateral resolution, in which a fine probe tip is raster scanned over the surface and the resulting tunneling current is monitored. [SEMATECH]
scheduled downtime	The total time during which equipment is not available to perform its intended function because of planned downtime events.
SCM	Scanning capacitance microscopy.
scope display	Window that toggles with the video display and shows a scope trace of the realtime scanning image.
score	The rank of a correlation between a saved model and an image. When the model and a portion of an image correlate perfectly, the score is 1000.
SEM	Scanning electron microscopy.
SEMI Equipment Communications Standard 1 (SECS-I)	A SEMI Equipment Communications Standard (SEMI E4) that addresses the mechanism for conveying information over an electrically controllable medium such as wire, fiber-optic cable, or electromagnetic transmission. [SEMATECH] 2: a standard that specifies a method for a message transfer protocol with electrical signal levels based on EIA RS232-C. [SEMI E30-94]
SEMI Equipment Communications Standard 2 (SECS-II)	A SEMI Equipment Communications Standard (SEMI E5) that addresses how information should be structured for conveyance; provides syntax and semantics. [SEMATECH] 2: a standard that specifies a group of messages and the respective syntax and semantics for those messages relating to semiconductor manufacturing equipment control. [SEMI E30-94]
semiconductor	An element that has an electrical resistivity in the range between conductors (such as aluminum) and insulators (such as silicon dioxide). Integrated circuits are typically fabricated in semiconductor materials such as silicon, germanium, or gallium arsenide. [SEMATECH]
Semiconductor Equipment and Materials International, Inc. (SEMI)	An international trade organization with membership from companies that supply equipment, materials, and services used in the semiconductor manufacturing industry. [SEMATECH]
sensitivity	Amount of movement produced by a scanner piezo for a given amount of voltage.

Term	Definition
server	A computer in a network that stores programs and files that other computers in the network can access.
servos	Electromechanical devices for effecting control based on feedback from a process.
setpoint	1: Operator-selected force threshold between tip and sample used as the feedback control loop's target. 2: In mass flow controller testing, the electrical input signal to the device that sets the desired value of the controlled flow. [SEMI E17-91]
sharpness	The visual impression of distinctness in a photographic reproduction, such as the edge of an image; the subjective effect of the physical property acutance. [ASTM F127-84]
shutdown	The time required to put the equipment in a safe condition when entering a nonscheduled state. It includes any procedures necessary to reach a safe condition. Shutdown is included only in non-scheduled time. [SEMI E10-92]
shutoff valve	A valve designed for and capable of positive closure to prevent flow within a piping system. Typical shutoff valves include, but are not limited to, manually-actuated, power-actuated, or spring-actuated fail-safe shutoff valves. Usually excluded are self-actuated valves, such as check valves, pressure regulators, flow controllers, and other devices that are not intended to provide positive shutoff for safety isolation. [SEMI F1-90]
SI	Abbreviation for the International System of Units (in its original French, le Système International d'Unités), which is a modernized metric system accepted as the standard by (among others) the American Society for Testing and Materials (ASTM), Semiconductor Equipment and Materials, International (SEMI), and the Institute of Electrical and Electronics Engineers (IEEE). [SEMAT-ECH]
Signal Access Module (SAM™)	An in-line hardware utility that lets you access or interrupt every signal going into and out of your NanoScope controller for experimentation and diagnostic evaluation.
silicon probes	Electrical probes on an integrated circuit testing system that have been etched monolithically from a silicon wafer using a variation of integrated circuit processing technology. [1994 National Technology Roadmap for Semiconductors]

Term	Definition
site	On the front surface of a wafer, a rectangular area, the sides of which are parallel and perpendicular to the primary flat or to the notch bisector and the center of which falls within the fixed quality area (FQA). [SEMI M1-94]
slot	The area in which a wafer is situated within a wafer carrier. [SEMATECH] 2: a two-sided support for a standard wafer carrier when the carrier is oriented with its axis in a vertical attitude. [SEMI E22-91] 3: in cluster tools, a wafer location within a cassette module associated with the function of wafer I/O. Wafers enter or leave the intratool environment through slots. Generally, a slot, through its slot group, corresponds to a carrier location within a wafer carrier. [SEMATECH]
SMIF	See integrated standard mechanical interface.
software interlock	Data exchange between two programs in order to verify that interlock conditions are met. [SEMATECH]
solvent	A substance capable of dissolving another substance, or substances, to form a solution. Examples are isopropyl alcohol, methyl alcohol, and xylene. [SEMATECH]
SPC	Statistical process control.
specification	A detailed, precise description of a tool, material, process, method, or procedure. [SEMATECH] 2: a detailed definition of the logic used by an application or a program. [SEMATECH]
spike	In an epitaxial wafer surface, a tall, thin dendrite or crystalline filament that often occurs at the center or recess. [ASTM F1241] 2: an extreme structure that has a large ratio of height-to-base width and no apparent relation to epitaxial film thickness. [SEMATECH]
spring constant	Ratio of resultant force to deflection for a given cantilever or spring.
standard	A method, rule, or description subscribed to by the consensus of the appropriate industry and under control of the issuing organization for document revision. [SEMATECH]

Term	Definition
standard coordinates	In the measurement of photolithographic instruments, a system of Cartesian coordinates with the Z axis along the optical axis of the system and with the X and Y axes in the flat plane perpendicular to the optical axis. The system user or vendor will specify the X and Y directions in this plane for any particular equipment studies. [SEMI P25-94]
standard deviation	A measure of the spread of the process output or the spread of a sampling statistic from the process. The true standard deviation (represented by the Greek letter sigma) is estimated by calculating the difference of each individual observation from the average of the observations, squaring the differences, finding the sum of the squares, dividing by one less than the number of observations, and finding the square root of the result. 2: a measure of the variation among the members of a statistical sample. [SEMATECH] 3: in the pressure testing of fluorocarbon tube fittings, a measure of the variation among the members of a statistical sample. [SEMI F8-92]
standard pressure	In the calibration of mass flow devices, the pressure, in pascals, specified as a reference for measurement and comparison. In the semiconductor industry, this pressure is defined as 101.32 kPa (760 torr). [SEMI E29-93]
standard temperature	1: defined as 21°C– 5°C (70°F–10°F). [SEMI F4-90] 2: in the calibration of mass flow devices, the temperature, in degrees Celsius, specified as a reference for measurement and comparison. In the semiconductor industry, this temperature is defined as 0.0°C. [SEMI E29-93]
standby state	One of the six equipment states or conditions; a period other than nonscheduled time, in which the equipment is not operated, although it is in a condition to perform its intended function, and the chemicals and facilities are available. [SEMI E10-92]
standby time	The total time (other than nonscheduled time) during which equipment is not operated, although it is in a condition to perform its intended function, and the chemicals and facilities are available. [SEMI E10-92] Also see standby state and nonscheduled time.
statistical process control	Area of software that reports statistical deviations from recipe program configurations.
step	A single action in the performance of an operation, procedure, or process. [SEMATECH] 2: the transitions from lower levels of a wafer pattern to upper layers; the topography of a patterned wafer. [SEMATECH]

Term	Definition
Step Height	The value of relative height measurements between two regions (steps) on sample surfaces.
step response time	In mass flow controller testing, the time between the set point step change and the moment the actual flow first enters the specified band. [SEMI E17-91]
stepper	Equipment used to transfer a reticle pattern onto a wafer. [SEMATECH]
SthM	Scanning thermal microscopy.
STM	Scanning tunneling microscopy.
stress test	Exposure of components to extreme mechanical, temperature, humidity, and biased conditions. [SEMATECH]
STS	Scanning tunneling spectroscopy.
submenu	Name for a drop-down menu resulting from hovering over a main menu item.
substrate	In the manufacture of semiconductors, a wafer that is the basis for subsequent processing operations in the fabrication of semiconductor devices or circuits. [ASTM F1241]
surf	To browse among Internet websites or TV channels.
surface	The boundary that separates an object from another object, substance, or space. [ASME B46.1-85] 2: in electron spectroscopy for chemical analysis (ESCA), that volume from which the photoelectrons can escape. [SEMATECH]
surface imaging	Multilayer resists on which the image to be transferred is focused onto a thin resist layer on the surface when developed. This thin layer serves as a mask to pattern a thick resist layer that is employed for forming the image on the wafer. [1994 National Technology Roadmap for Semiconductors]
surface profile	The contour of the surface in a plane perpendicular to the surface, unless some other angle is specified. [ASME B46.1-85]

Term	Definition
surface roughness	The finer irregularities of the surface texture, usually including those irregularities that result from the inherent action of the production process. Examples include traverse feed marks and other irregularities within the limits of the roughness sampling length. [ASME B46.1-85]
surface texture	The topographic deviations of a real surface from a reference surface. NOTE—Surface texture includes roughness, waviness, and lay. [ASTM F1241]
symmetrical valve	A valve bilaterally identical with respect to its center line and having similar flow and pressure characteristics in either direction. [SEMATECH]
TappingMode™	Proprietary mode of scanning probe microscopy exclusive to Digital Instruments which utilizes an oscillating probe to obtain nanometric images. Advantages include negligible surface impacts, high resolution and sensing of magnetic, electric and chemical forces.
teach	To program an automated system to perform a sequence of operations and give the sequence a name so it may be subsequently called to enact the sequence automatically.
temperature coefficient (K_t)	In regulator performance testing, the average rate of change of the regulator's set point per degree of temperature change, that is, Pa per 1°C. The temperature coefficient may be positive (set point increases with increasing temperature) or negative (set point decreases with increasing temperature) or both. [SEMATECH]
Thermal Accessory	This accessory provides controlled heat to the bottom of the sample from ambient temperature to 50°C. It can be used with any scanning technique (TappingMode™, contact mode, force measurements, etc.) and in liquid, ambient air, or controlled gaseous environments.
thermal deposition	A process in which chemical dopants are introduced onto a silicon wafer in a controlled atmosphere at temperatures typically greater than 950°C. [SEMATECH]
thermocouple (TC)	A pair of dissimilar metal wires; used for accurate measurement of temperature. [SEMATECH]

Term	Definition
thickness	Of an epitaxial layer, the distance from the surface of the wafer to the layer-substrate interface. [SEMI M2-94 and ASTM F1241] 2: of a semiconductor wafer, the distance through the wafer between corresponding points on the front and back surfaces. [ASTM F1241]
throughput	The number of wafers per hour through a machine, assuming 100% equipment uptime and a fully loaded machine. The number is adjusted downward for any detracting factors one wants to consider (for example, downtime, setup time, idle time, etc.)[SEMAT-ECH]
tilt	A small angle of offset from the normal horizontal or vertical surfaces of a cassette or container, designed to preferentially align or keep wafers in their normal places. [SEMI E15-91] 2: the loss of parallelism between the die pad and the Z-plane formed by the dambars of a semiconductor devices leadframe. [SEMI G2-87]
tip	In a scanning tunneling microscope probe, a sharpened, nonoxidized, or minimally oxidized conductive point at the end. [SEMATECH]
Tip Estimation	Refers to the approximation of current tip sharpness based on periodic checking of images generated by scanning with that tip.
tip holder	Removable appliance for mounting scanning probe microscope probes. On MultiMode Scanning Probe Microscopes, the tipholder is installed within the head of the microscope. On Dimension Series Scanning Probe Microscopes, the tipholder plugs onto the end of the scanner tube.
Tip Qualification	Software generates a tip status by comparing the estimated tip diameter and aspect ratio with user-selected threshold and limit values. The software will usually return one of the following tip statuses: good, worn, or bad.
tm-AFM-air	TappingMode atomic force microscopy in air.
tm-AFM-fluid	TappingMode atomic force microscopy in fluid.
tm-AFM-pi	TappingMode atomic force microscopy phase imaging.
toggle	To switch a transistor between “off” and “on” states. [SEMAT-ECH]

Term	Definition
tool	An instrument, machine, or device used to perform a task or to measure a characteristic or quality. [SEMATECH] 2: any piece of semiconductor fabrication or inspection equipment designed to process wafers delivered in cassettes or cassettes in containers intended for use with an automated material transport system. [SEMI E15-91]
toxic	Describes a chemical or material that has the ability to seriously injure biological tissue. Examples of toxic substances are phosphine, diborane, and arsine. [SEMATECH]
trackball	A ball mounted on a console and rotated to control the movement of a cursor or mechanical motion (e.g., probe height).
transfer envelope	In automated material movement, the three-dimensional space occupied during the transfer by the transfer object and all associated transfer mechanisms of both transfer partners. This defines the space in which transfer activity occurs, and in which the potential for physical interference with the transfer exists. [SEMI E32-94]
transfer job	In automated material movement, the set of atomic transfers constructed by the host to accomplish a cohesive material movement objective. [SEMI E32-94]
transfer object	In automated material movement, a physical object that is transferred to and from equipment, such as a product material, an empty carrier, or a carrier containing material to be processed. Tools, such as stepper reticles, and expendable materials also may be transfer objects. [SEMI E32-94]
transfer standard	In the calibration of mass flow devices, a device typically calibrated against a primary standard that can guarantee sufficient accuracy to, in turn, calibrate another device. [SEMI E29-93]
trench	A deeply etched area used to isolate one area from another or to form a storage capacitor on a silicon wafer. [SEMATECH]
U-Z	
UFM	Ultrasonic force microscopy.
unload	To remove a cassette from the cassette stage of the equipment. [SEMI E23-91]

Term	Definition
unscheduled downtime	The total time during which equipment is not in a condition to perform its intended function because of unplanned downtime events. [SEMI E10-92]
user	In communications and control of semiconductor manufacturing equipment, a human or humans who represent the factory and enforce the factory operation model. A user is considered to be responsible for many setup and configuration activities that cause the equipment to best conform to factory operations practices. [SEMI E30-94]
vacuum	An absence of air or other gas. [SEMATECH]
vacuum wand	A tool that uses suction on the back of an individual wafer to pick up the wafer. [SEMATECH]
vapor pressure	The pressure exerted when a solid or liquid is in equilibrium with its own vapor. Vapor pressure is a function of the substance and of the temperature. [SEMI Chemicals/Gases, Vol. 1, 1990 (no longer in print)]
vibration isolation	Provides the high damping needed for optimum isolation of high ground noise sources.
video display	Window that displays the surface or tip during realtime scanning (toggles with the scope display).
view	Name for a specific screen that appears in the client window for configuring the settings to run the microscope or image processing commands.
viscosity	Measurement of the flow properties of a material expressed as its resistance to flow. [SEMATECH]
Vx Series Microscopes	An Atomic Force Microscope combined with a stylus profiler for 2-dimensional scans (larger than the range of the Atomic Force Microscope's piezoelectric actuators). Also referred to as the Atomic Force Profiler (AFP).
wafer	In semiconductor technology, a thin slice with parallel faces cut from a semiconductor crystal. [ASTM F1241]
wafer carrier	1: any vessel or supporting structure used to contain or transfer wafers during processing. [SEMATECH] 2: a device for holding a wafer for various processing steps in semiconductor manufacturing. [SEMI E1-86]

Term	Definition
wafer environment	The atmosphere contained within a chamber in which the wafers are exposed. [SEMATECH]
wafer height	In quartz and high-temperature wafer carriers, the distance from the horizontal center line of a wafer to the bottom plane of the wafer carrier. [SEMI E2-86]
wafer tilt	In plastic and metal wafer carriers, the possible unparallel position of a wafer in relation to the crossbar end of a wafer carrier when the wafer carrier is resting on the crossbar end. [SEMI E1-86]
wafer transfer	The act of relocating wafers from one carrier into another. [SEMI E1-86]
waviness	The more widely spaced component of surface texture. NOTE- Waviness may be caused by such factors as machine or work piece deflections, vibration, and chatter. Roughness may be considered as superimposed on a wavy surface. [ASTM F1241]
working distance	In scanning electron microscopy, the distance between the bottom of the objective lens and the sample. [SEMATECH]
workspace	A hierarchical arrangement of nodes. Each node corresponds to a captured image, microscope settings, group or view. If a node corresponds to a view, clicking on the node displays a window that contains information about the most immediate parent node. A dockable window used for configuring a hierarchy of views.
X Series Microscopes	Similar to the Atomic Force Profiler with additional automated features.
X-direction	See scan direction.
Y-direction	In characterizing surface roughness, the direction over which successive scans are taken by a microscope, orthogonal to the scan direction, in the sample plane. [SEMATECH]
Z-direction	In characterizing surface roughness, the direction perpendicular to the sample plane, orthogonal to the X and Y directions. [SEMATECH] Also called feature height direction.
zero effect	In flat panel displays, the change in zero due to a change in ambient temperature from one normal operating temperature to a second normal operating temperature. All other conditions must be held within the limits of reference operating conditions. [SEMI E18-91]

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