Chapter 3 Analysis Commands

The **Analysis** commands relate to analyzing the surface behavior of materials on images captured in Realtime mode. These commands are known as image processing or analysis commands. The commands contain views, options and configurations for analysis, modification, and storage of the collected data. The analysis may be automated (i.e., in autoprograms) or completed manually. In general, the analysis commands provide methods for quantifying the surface properties of samples.

Please refer to the following analysis commands available in **Analyze** menu of the NanoScope software:

- **Image:** Section 3.1
- **3D Surface Plot:** Section 3.2
- **Zoom:** Section 3.3
- **Depth:** Section 3.4
- **Power Spectral Density:** Section 3.5
- **Roughness:** Section 3.6
- **Section:** Section 3.7
- **XY Drift:** Section 3.8
- **Multiple Channel Analysis:** Section 3.9
- **AutoProgram:** Section 3.10

3.1 Image

The term **Image** refers to the data captured in Realtime mode. The current image processing capabilities include data analysis, modification, presentation and storage of the images. The source of the image includes:

- Data captured in Realtime scanning mode
- New image files created using modification or analysis commands

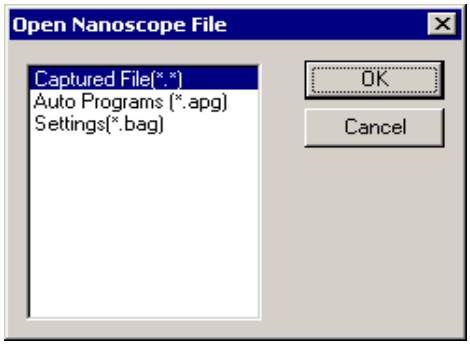
For general information on the interface and basic functions in image processing, see **Using the Image Interface:** Section 3.1.1.

3.1.1 Using the Image Interface

To process an image, you must open an image file. This can be done by:

- Clicking **File > Open**. When the **Open NanoScope File** dialog box opens (see Figure 3.1a), select **Captured File (*.*)** and click the **Ok** button.

Figure 3.1a Open NanoScope File Dialog Box



- Double-click an image in the **Browse** dialog box. The new image appears in the client window (see Figure 3.1b).

Figure 3.1b Image for Processing

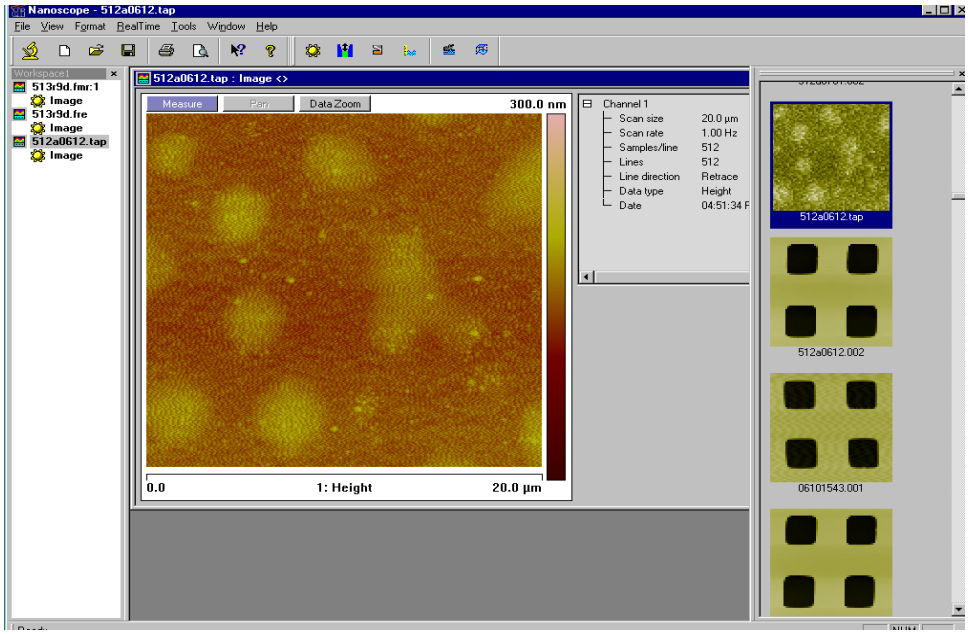
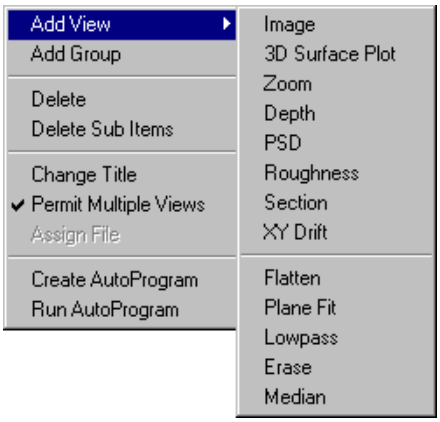


Image Processing Add View Commands

The Offline **Add View** menu for image processing differs from the Realtime **Add View** commands. The commands include measurement, analysis and modification commands (see Figure 3.1c).

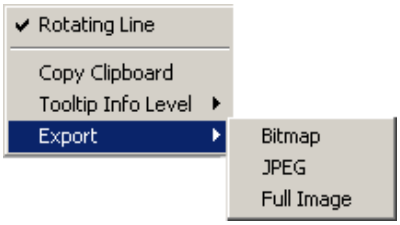
Figure 3.1c Image Processing Functions Menu



Right-Clicking on the Image

By right-clicking on the image, you will get a menu (see Figure 3.1d) that allows you to perform the following tasks:

Figure 3.1d Image Click



- **Rotating Line**—Left-click, hold, and drag out a line. Release the mouse button to end the line.
- **Box** (for some analyses)—Left-click, hold, and drag out a box and release the mouse button.

  Note: Left-clicking in the center of the box allows you to translate. Left-clicking on edges allows you to change the box size.
- **Copy Clipboard**—Copies the image to the Microsoft clipboard.
- **Tooltip Info Level**:
  - Basic
  - Medium
  - Advanced
  - None
- **Export**—Exports the image as a bitmap or JPEG (WYSIWYG), or Full Image (pixel by pixel data).

Image Buttons

Clicking the **Image** buttons above the captured image (see Figure 3.1e) performs the following functions:

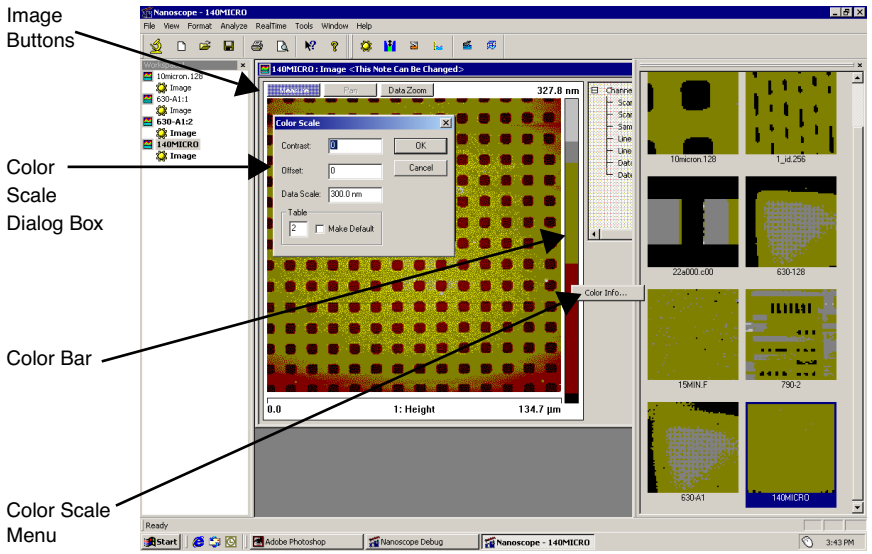
- **Data Zoom**—Left-click, hold, and drag out a box. Release the mouse button and the image will automatically zoom in to the area of the box.
- **Pan**—From a zoomed image, the user can pan around to other areas of the original image.
- **Measure**—Left-click, hold, and drag out a line. Length of line appears in a box near the line any time cursor is on the line.

Right-Clicking on the Color Bar

Right-clicking on the color bar along the right side of the image (see Figure 3.1e) will produce a **Color Scale** button. Clicking on this **Color Scale** button will open the **Color Scale** dialog box, where you can perform the following image adjustments:

- **Contrast**—Number (-10 to +10) designates contrast of colors in displayed image (e.g., 0 shows little change, while 10 shows highest contrast).
- **Offset**—Number (-128 to +128) designates offset of colors in displayed image (e.g., 120 shows illuminated background on image).
- **Data Scale**—Designates the vertical range of the image, corresponding to the full extent of the color table.
- **Table**—Designates the **Color Table** number.

Figure 3.1e Image Adjustment Controls



Using the Mouse Within a Captured Image

Left-Click anywhere in image window, drag line out, and release	Creates a line of X length, at X^{o} of angle in the image window
Place cursor on line	Displays length and angle values of line in the image window
Place cursor on line, click and hold left button, and drag	Allows you to drag the line anywhere in the image window
Click and hold on either end of line and drag	Changes length and/or the angle of the line
Right-Click	Clicking the right mouse button when the cursor is on the line accesses the Image Cursor menu (see Figure 3.1f) • **Delete**—deletes the line. • **Flip Direction**—switches the line end to end. • **Show Direction**—Adds small arrowhead to the line to indicate direction. • **Set Color**—Allows you to change the color of the line. • **Clear All**—Deletes all lines.

Figure 3.1f Image Cursor Menu

3.2 3D Surface Plot

The **3D Surface Plot View** 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.

You can view the **3D Surface Plot View** using *one* of the following methods:

- Right-click on the image name in the **Workspace** and select **Add View > 3D Surface Plot** from the popup menu.

  Or

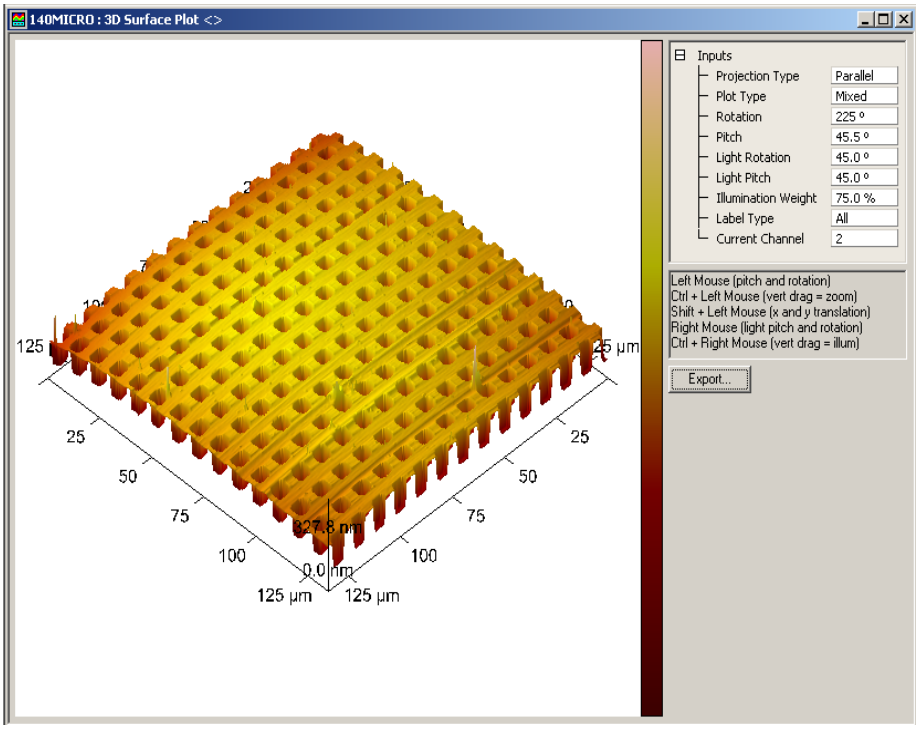
- Select **Analyze > 3D Surface Plot** from the menu bar.

  Or

- Click the **3D Surface Plot** icon in the upper toolbar. 

The **Surface Plot** panel appears and allows formatting of image data on the Display Monitor (see Figure 3.2a).

Figure 3.2a 3D Surface Plot Window



3.2.1 Parameters in the 3D Surface Plot Inputs

The **Projection Type**, **Plot Type**, and **Label Type 3D Surface Plot** parameters can be changed by clicking on the related window and selecting from the drop-down menus. The remaining parameters may be changed by typing the desired information in the related window or by use of the keyboard and mouse keys.

- To zoom in or out on the image, hold the control key down and slide the mouse up and down on the image while holding the left mouse button.
- To pan, hold the shift key down and move the mouse up, down, left, or right on the image while holding the left mouse button.
- Clicking and holding the right mouse button down while moving the mouse left and right changes the light rotation on the image. This is only available when plot type is set to mixed
- Clicking and holding the right button while moving the mouse up down changes the light pitch. This is only available when **Plot Type** is set to **Mixed**.

The function of the **Input** parameters are:

Projection Type — Select either **Parallel** or **Perspective**

- In parallel mode, the viewing volume does not change, which has the affect keeping objects the same size as they are projected. This is useful for maintaining the size and angle of objects between the front and back of the view.
- In perspective mode, objects appear to get smaller the further away they are from the eye. This is how the objects are perceived in the real world.

Plot Type — Select **Height**, **Wire**, or **Mixed**

- Height displays image with the height values encoded according to the color table.
- Wire displays image as a line representation of the scanned data.
- Mixed displays a combination of height and illumination encoding which is used on the displayed image.

Rotation — The **Rotation** parameter in the **Surface Plot Inputs** changes as the viewing angle in changed by rotating the displayed image about the Z axis relative to its captured orientation.

Pitch — The **Pitch** parameter in the **Surface Plot Inputs** changes as the viewing angle by manually changing the pitch of the Y axis in the three-dimensional Surface Plot image.

Light Rotation	The **Light Rotation** parameter in the **Surface Plot Inputs** rotates the light source in the horizontal plane (along the Z axis). This is only available when the **Plot Type** is set to **Mixed**.
Light Pitch	The **Light Pitch** parameter in the **Surface Plot Inputs** changes the viewing angle by selecting the pitch of the Y axis in the three-dimensional Surface Plot image. This is only available when the **Plot Type** is set to **Mixed**.
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**.
Label Type	The **Label Type** parameter in the **Surface Plot Inputs** selects whether labels, axes, and the view/illumination controller are displayed with the image.
Current Channel	Displays the current channel of multichannel scan displays.

The **Export** button allows the operator to export the image in the window to either JPEG or bitmap format. The graphic will be stored in the Capture folder.

3.3 Zoom

Use the **Zoom** function to extract an image from a large Version 6 image for Version 5 analysis. NanoScope Version 5 software features a number of **Analysis** functions currently not available in Version 6 software. Zoom will produce the largest Version 5 image size possible within the bounded region (128 x 128, 256 x 256 or 512 x 512).

Note: 512 x 512 is the most common image size, and will be used as the example throughout the rest of this section.

Note: The image produced by this analysis is Version 5 compatible, however, if the image is later processed by a Version 6 analysis, the image may no longer be Version 5 compatible.

3.3.1 Zoom Procedure

Use the Zoom analysis to isolate a 512 x 512 portion of a high resolution image.

1. Open a large Version 6 image (larger than 512 x 512).
2. You can view the **Zoom View** using *one* of the following methods:
   - Right-click on the image name in the **Workspace** and select **Add View > Zoom** from the popup menu.

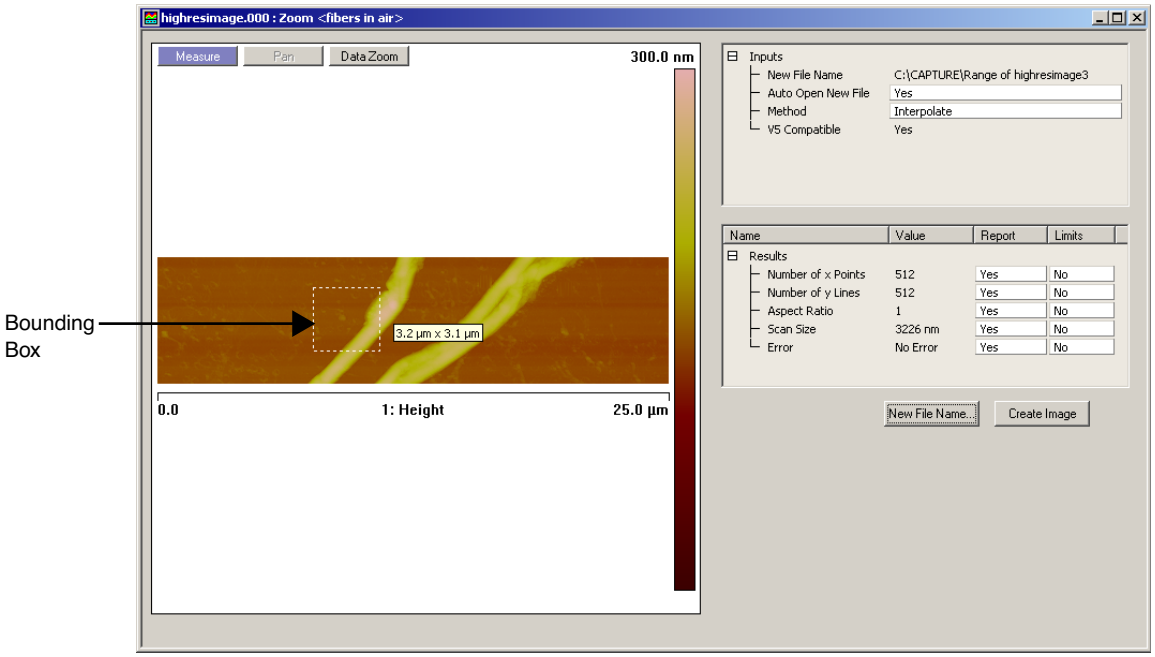
     Or

   - Select **Analyze > Zoom** from the menu bar.

     Or

   - Click the **Zoom** icon in the upper toolbar. 
3. The selected image opens in the **Zoom** dialog box (see Figure 3.3a).

Figure 3.3a Initial Zoom Dialog Box



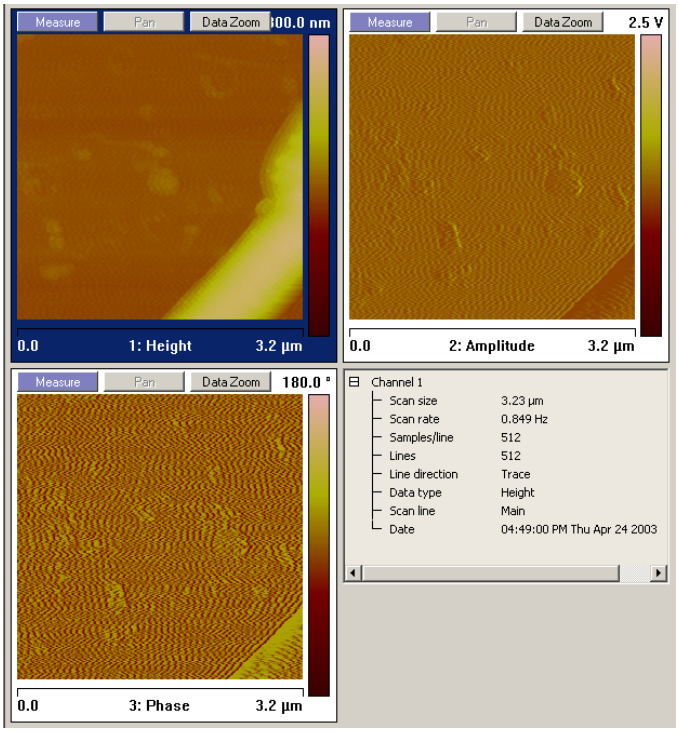
4. A bounding box appears in the image (see Figure 3.3a). Place the cursor inside the box, and while holding the mouse button, move the box to the location of interest. The box is restricted to the largest possible Version 5-compatible image size (usually 512 x 512).

5. Once the box is in place, select the **New File Name** button. Select a location and name for the new image.

6. Select the **Create Image** button.

    a. If the **Auto Open New File** parameter under **Inputs** is set to **Yes**, the image opens in the default image view (see Figure 3.3b).

Figure 3.3b New Zoom Image Dialog Box



b. If the **Auto Open New File** parameter under **Inputs** is set to **No**, The new image will be saved in the designated directory but will not automatically display.

7. Use this new image for Version 5 analysis.

3.3.2 Zoom Interface

Input Parameters

New File Name — Displays the path of the extracted image file.

Auto Open New File — Settings:

- If **Yes** is selected, after selecting the **Create Image** button the newly extracted image open.
- If **No** is selected, the new file will be created and saved in the designated directory, but will not automatically display.

Method — Settings:

- **Interpolate**—Data points will be interpolated to create new image.
- **Replicate**—Data points will be used as is to create a new image.

V5 Compatible — The image created using the Zoom function is compatible with Nano-Scope Version 5 software.

Results Parameters

Number of x Points — Number of x points in the new image.

Number of y Points — Number of y points in the new image.

Aspect Ratio — Aspect ratio of the new image.

Scan Size — Scan size of the new image. 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**.

Error — Possible errors:

- **No Error**—(Default)
- **Not Enough X Points**—Original image has less than 512 points/line.
- **Invalid Aspect Ratio**—Zoomed image results in an aspect ratio greater than 256:1.
- **File Write**—A disk error occurred.
- **Unknown**—An unknown error has occurred.

Zoom Buttons

New File Name — Browse for the location to save the new image.

Create Image — A Version 5 compatible image is created from the portion of the high resolution image that is contained in the bounding box.

3.4 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 similar sample sites (e.g., when analyzing etch depths on large numbers of identical silicon wafers).

Refer to the following sections on **Depth** analysis:

- **Depth Theory:** Section 3.4.1
- **Depth Procedures:** Section 3.4.2
- **Depth Interface:** Section 3.4.3

3.4.1 Depth Theory

The **Depth** command accumulates depth data within a specified area, applies a Gaussian low-pass filter to the data to remove noise, then obtains depth comparisons between two dominant features. Although this method of depth analysis does not substitute for direct, cross-sectioning of the sample, it affords a means for comparing feature depth between two similar sites in a consistent, statistical manner.

The display screen includes a top view image and a histogram; depth data is displayed in the results window and in the histogram. The mouse is used to resize and position the box cursor over the area to be analyzed. The histogram displays a Gaussian-filtered version of the data and is distributed proportional to its occurrence within the defined bounding box.

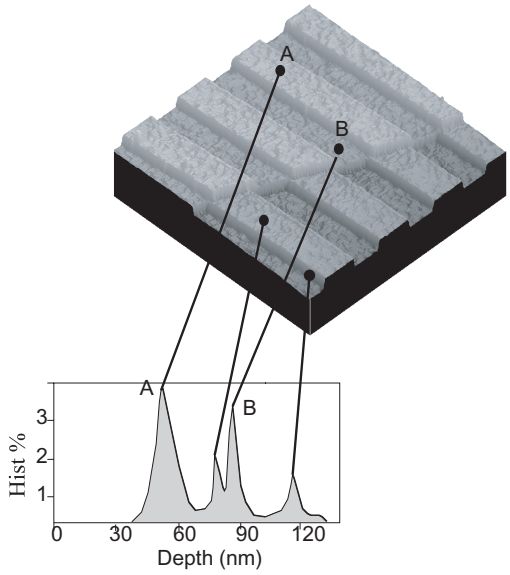
Histogram

Raw Data

Figure 3.4a displays a histogram (bottom graph) from raw depth data. Data points A and B are the two most dominant features, and therefore would be compared in Depth analysis. Depending upon the range and size of depth data, the curve may appear jagged in profile, with noticeable levels of noise. Data spikes are blue and correspond to specific depths of features on the sample surface.

Note: Color of cursor, data, and grid may change if user has changed the settings. Right-click on the graph and go to **Color** if you want to change the default settings.

Figure 3.4a Depth Histogram



Correlation Curve

The **Correlation Curve** also displays for depth data. It is a filtered version of the **Raw Data Histogram** and is located on the **Raw Data Histogram** represented by a red line. Filtering is done using the **Histogram filter cutoff** parameter in the **Input** parameters box.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 Curve** portion of the histogram presents a lowpass, Gaussian-filtered version of the raw data. 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.

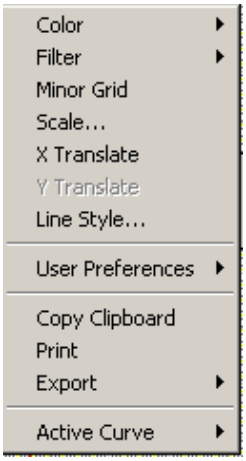
When using the **Depth View** for analysis, each peak on the filtered histogram is measured from its statistical centroid (i.e., its statistical center of mass).

Using the Grid Display

Measurement cursors for histogram are automatically positioned based on the numerical values selected in the **Input** fields. Right-clicking on the grid will bring up the **Grid Parameters** menu (see Figure 3.4b) and allow you to make the following changes:

Color	Allows operator to change the color of the: • Curve (data) • Text • Background • Grid • Minor Grid • Markers
Filter	Typically used for a Profiler Scan. • Type—Select None, Mean (default), Maximum, or Minimum • Points—Select 4k, 8k (default), 16k, or 32k
Minor Grid	Places a minor grid in the background of the **Vision** window.
Scale	Allows user to auto scale, set a curve mean, or set their own data range
Line Style	For each curve, the operator can choose a connect, fill down, or point line.
User Preferences	Restore—Reverts to initial software settings Save—Saves all changes operator has made during this session. This becomes the new default settings.
Copy Clipboard	Copies the grid image to the Microsoft Clipboard
Print	Prints out the current screen view to a printer
Export	Exports data in bitmap, JPEG or XZ data format
Active Curve	Determines which curve you are analyzing

Figure 3.4b Grid Parameters Menu



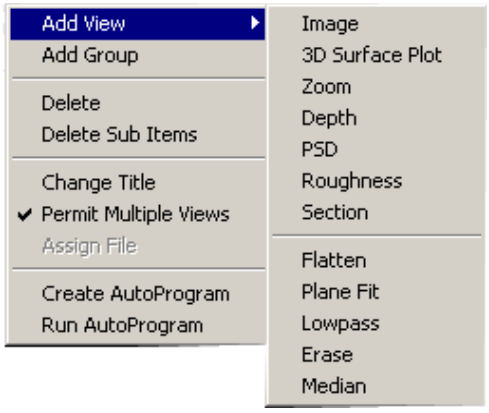
3.4.2 Depth Procedures

1. If no workspace is present, open a new workspace (**File > New Workspace**).

2. Open the image you wish to analyze (**File > Open > Captured Data File**) or double click on the browse view image.

3. In the workspace, position the cursor on the file name and right-click to access a functions pop-up menu.

Figure 3.4c Functions Menu



4. In the pop-up menu, select **Add View > Plane Fit**.

5. You can view the **Depth View** using *one* of the following methods:

   - Right-click on the image name in the **Workspace** and select **Add View > Depth** from the popup menu.

     Or

   - Select **Analyze > Depth** from the menu bar.

     Or

   - Click the **Depth** icon in the upper toolbar. 

6. Using the mouse, left-click and drag a box on the area of the image to analyze.
   The Histogram displays the depth correlation on this specified area.

   Note: If no box is drawn, by default, the entire image is selected.

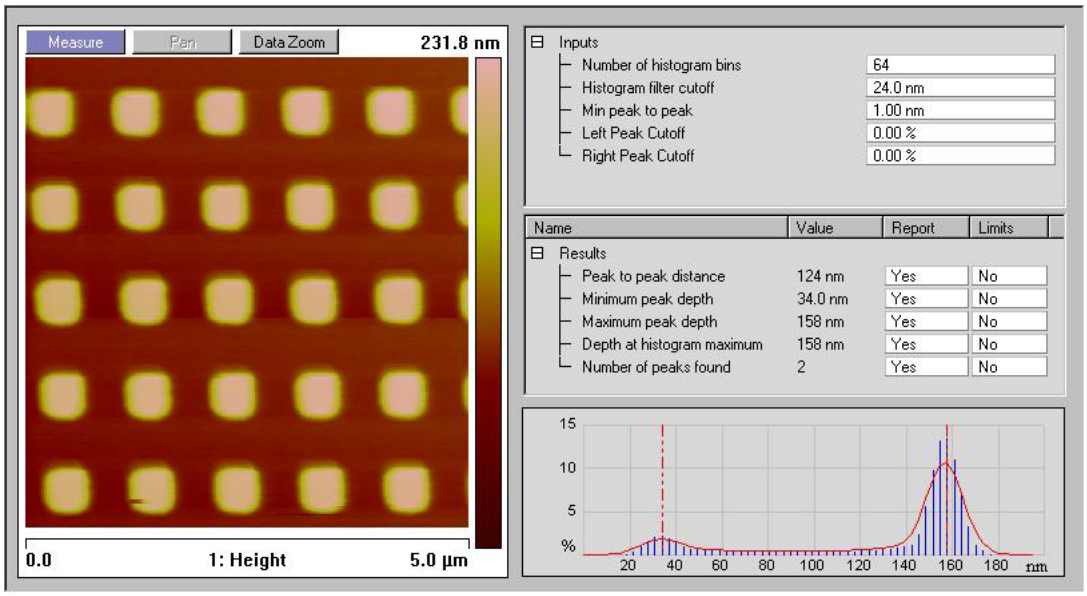
7. Adjust the **Minimum Peak to Peak** to exclude non relevant depths.

8. Adjust the **Histogram Filter Cutoff** parameter to filter noise in the histogram as desired.

9. Note the results.

Note: To save or print the data, run the analysis in an **Auto Program** (see Section 3.9).

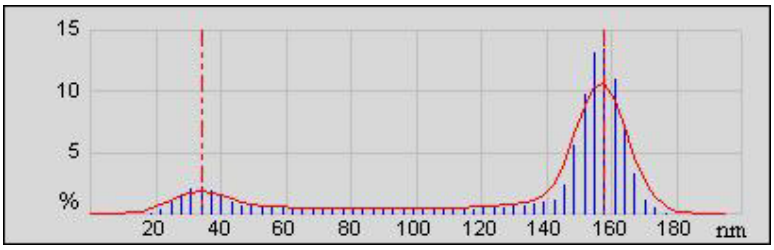
Figure 3.4d Depth Interface



3.4.3 Depth Interface

The **Depth** interface includes a captured image, **Input** parameters, **Results** parameters and a correlation histogram (see Figure 3.4e).

Figure 3.4e Depth Histogram



Depth Input Parameters

The depth input parameters below define the slider cursor placement for determining the exact depth of a feature.

Number of Histogram Bins	The number of data points, ranging from 4 to 512, which result from the filtering calculation.
Histogram Filter Cutoff	Lowpass filter which smooths out the data by removing wavelength components below the cutoff. Use to reduce noise in the Correlation histogram.
Min Peak To Peak	Sets the minimum distance between the maximum peak and the second peak marked by a cursor. The second peak is the next largest peak to meet this distance criteria.
Lowest Peak	The left (smaller in depth value) of the two peaks chosen by the cursors. Value used to define how much of the left 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 percent of the peak is included in the calculation of the centroid.
Highest Peak	The right (larger in depth value) of the two peaks marked by the cursors. Value used to define how much of the right 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 percent of the peak is included in the calculation of the centroid.

Results Parameters:

Peak to Peak Distance	Depth between the two data peak centroids as selected using the line cursors.
Minimum Peak Depth	The depth at which the smaller of the two peaks occurs.
Maximum Peak Depth	The depth at which the larger of the two peaks occurs.
Depth at Histogram Max	Depth at the maximum peak on the histogram.
Number of Peaks Found	Total number of peaks included within the data histogram.

3.5 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 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 3.5.1
- **PSD and Surface Features:** Section 3.5.2
- **PSD and Flatness:** Section 3.5.3
- **Performing a Spectral Density Analysis:** Section 3.5.4
- **Changing Parameters of the Spectrum Plot:** Section 3.5.5

3.5.1 NanoScope PSD Measurements

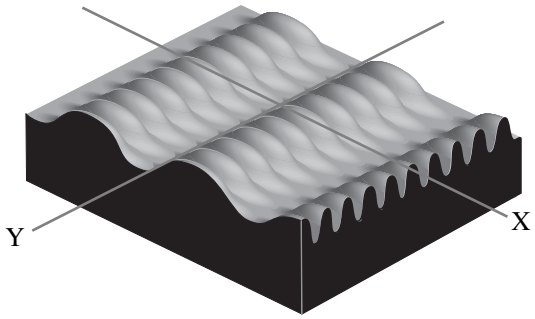
The **Power Spectral Density** function computes the following information for the image:

- **Total power spectrum—**Power is roughness amplitude squared, so power is in units of length squared for a topographic image. 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.

3.5.2 PSD and Surface Features

Consider the image in Figure 3.5a.

Figure 3.5a Waveform Surfaces



2D Spectrum

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_o is approximated by:

$$PSD(f) = \frac{2d_o}{N}\left|\sum_{n=1}^{N} e^{\frac{i\,2\pi}{N}(n-1)(m-1)} z(n)\right|^2 \qquad \text{for } f = \frac{m-1}{Nd_o}$$

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:

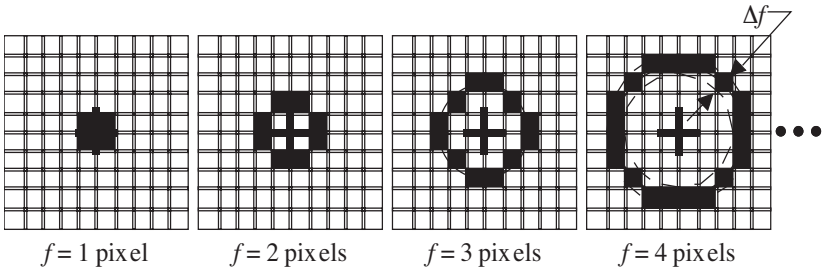
$$\text{1D PSD} = \frac{P}{\Delta f}$$

$$\text{1D isotropic PSD} = \frac{P}{2\pi f}$$

$$\text{2D isotropic PSD} = \frac{P}{2\pi f(\Delta f)}$$

The terms used in the denominators above are derived by progressively sampling data from the image's two-dimensional FFT center (see Figure 3.5b).

Figure 3.5b 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 or Nyquist frequency) of the PSD plot. The lower bandwidth limit is defined at 1/L.

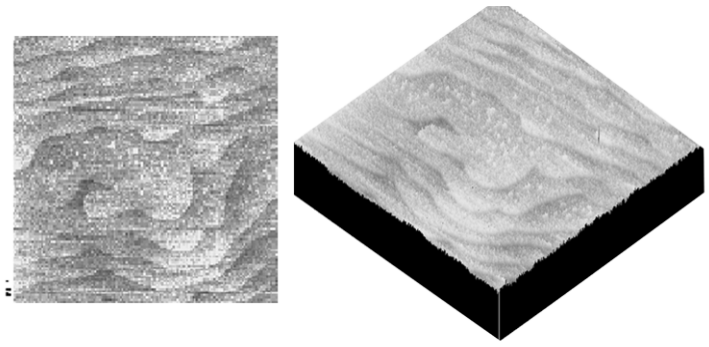
3.5.3 PSD and Flatness

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.

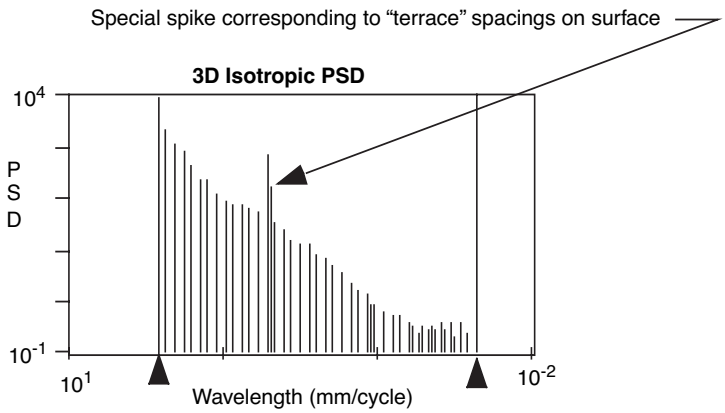
Consider the image of epitaxial gallium arsenide in Figure 3.5c.

Figure 3.5c 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 3.5d.

Figure 3.5d 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.

3.5.4 Performing a Spectral Density Analysis

To use the **PSD Analysis** function, perform the following procedures:

1. Select **View > Browse** from the menu bar, then open the image you wish to analyze by double-clicking it.

2. You can view the **PSD Analysis View** using *one* of the following methods:

   - Right-click on the image name in the **Workspace** and select **Add View > PSD** from the popup menu.

     Or

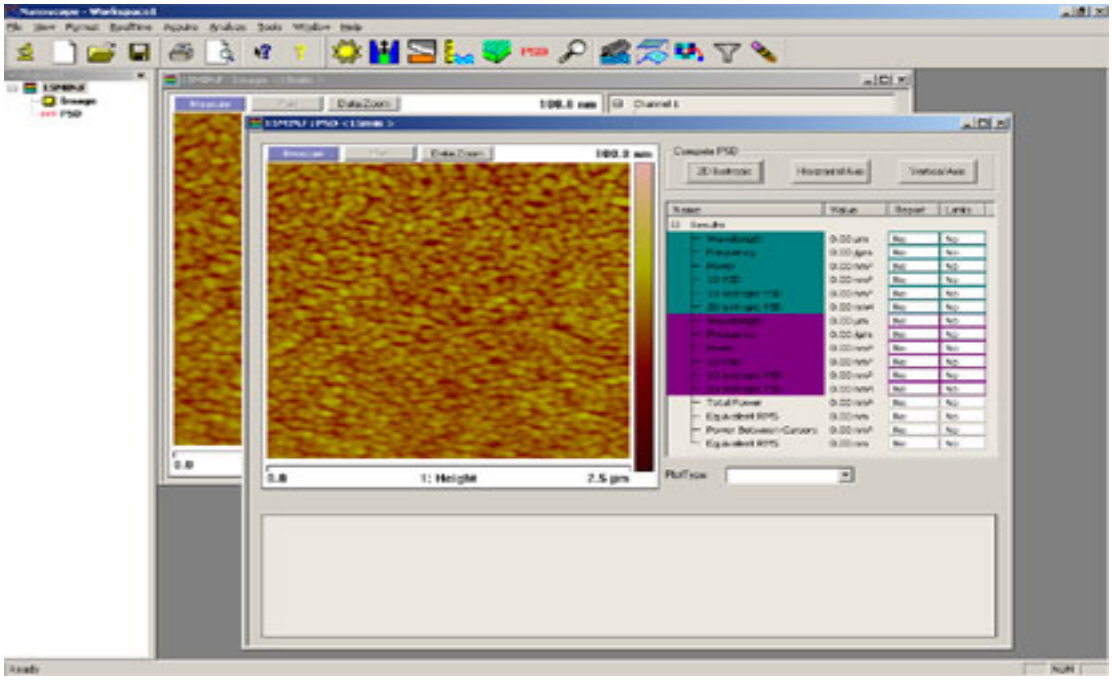
   - Select **Analyze > PSD** from the menu bar.

     Or

   - Click the **PSD** icon in the upper toolbar. 

The **PSD** window opens to allow spectral density plotting on the Display Monitor (see Figure 3.5e).

Figure 3.5e PSD Analysis



Compute PSD Buttons

Once the **PSD analysis** window is opened, select the type of spectral density analysis you wish to perform by clicking the appropriate button above the **Results** window.

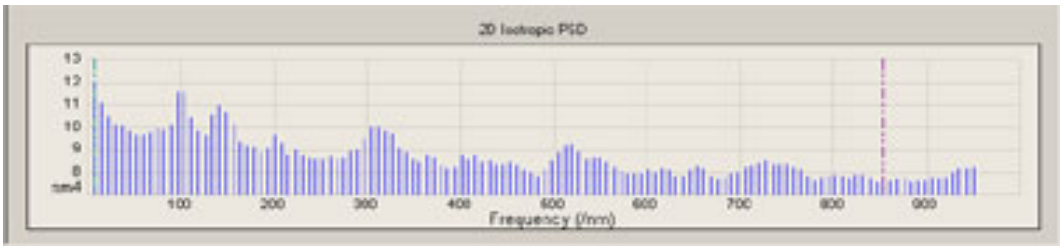
2D Isotropic—Executes a two-dimensional **Power Spectral Density** analysis.

Horizontal Axis—Executes a one-dimensional **Power Spectral Density** analysis along the X-axis.

Vertical Axis—Executes a one-dimensional **Power Spectral Density** analysis along the Y-axis.

The calculation begins as soon as the button is selected. The **PSD** and a table of values from the graph are shown in the **Results** window. Completion of the analysis will also result in a topographical histogram in the spectrum plot window (see Figure 3.5f).

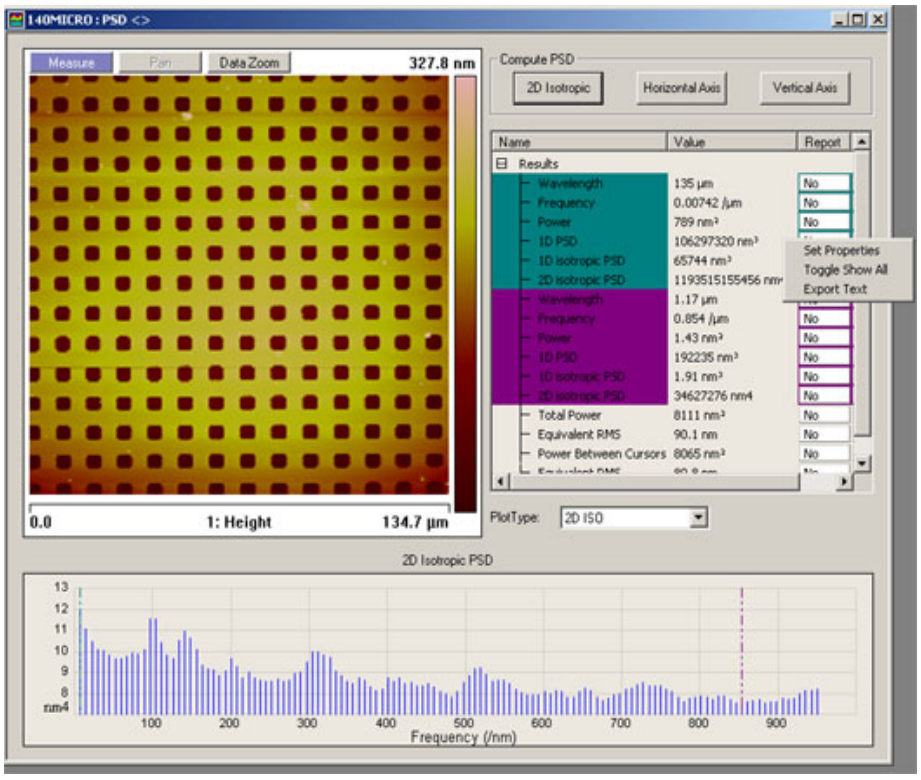
Figure 3.5f Power Spectral Density Histogram



Results Display

The **Results** window displays the **Name** and **Value** of the procedures performed during a **PSD** analysis. The teal shaded area in the display window corresponds to the area designated by the teal cursor on the **Power Spectral Density** histogram, and the purple shaded area corresponds to the purple cursor. The operator can select to have a report generated for each **Result** displayed by toggling the **Report** window between **Yes** and **No**. Right-clicking in the **Results** window will open a popup menu (see Figure 3.5g) that allows you to set the result properties, select the parameters that will be displayed, and export the results data to the clipboard as a text file.

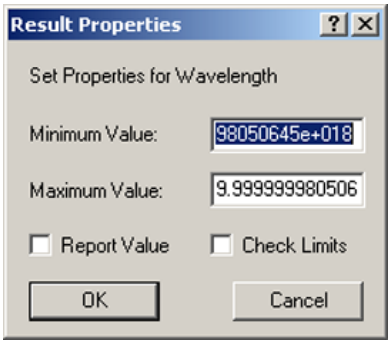
Figure 3.5g Power Spectral Density Display



Set Properties

The operator can select the wavelength properties for each **Results** window parameter by selecting **Set Properties** from the **Results** popup menu, which opens the **Result Properties** window (see Figure 3.5h), and entering the a **Minimum Value** and a **Maximum Value**. Checking the **Report Value** check box will change the **Report** window from **No** to **Yes** for that particular parameter. When **PSD** is being used as part of an **AutoProgram** (see **AutoProgram:** Section 3.10), Checking the **Check Limits** box will cause the analysis to fail if the results are not within designated limits.

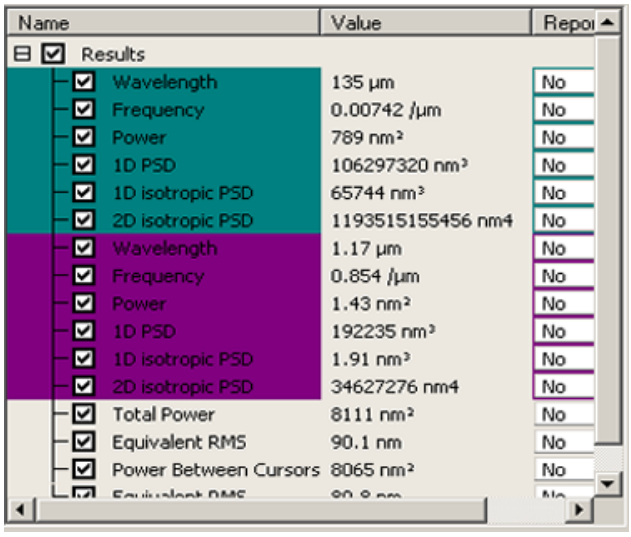
Figure 3.5h Result Properties Window



Select Displayed Parameters

The operator can select which **Results** will or will not be displayed in the **Results** window by Right-clicking in the **Results** window, selecting **Toggle Show All** from the popup menu, and checking or unchecking the appropriate boxes (see Figure 3.5i).

Figure 3.5i Select Show All On/Off Check Boxes



Export Text

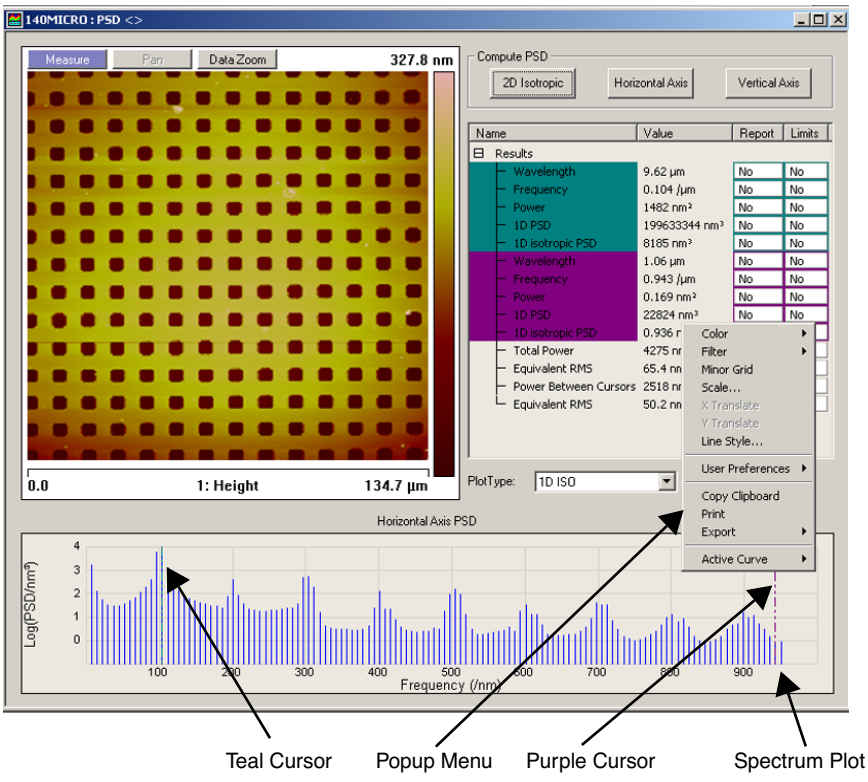
Selecting **Export Text** from the popup menu will copy the text from the **Results** window, in tab-delimited text format, to the Windows clipboard. You may then paste it into a text or word processing program.

3.5.5 Changing Parameters of the Spectrum Plot

The **Spectrum Plot** window displays results of the **PSD** analysis (see Figure 3.5j). The window has two cursors whose color corresponds to the shaded areas in the **Results** window. You can move either of these cursors within the **Spectrum Plot** window by placing the cross hair cursor directly over the cursor, clicking and holding the left mouse button, and dragging the mouse to the left or right. You can also move both cursors simultaneously by left-clicking the mouse with the cross hair cursor anywhere between the two cursors and dragging to the left or right.

To change the parameters of the **Spectrum Plot**, right-click in the **Spectrum Plot** window at the bottom of the display and choose from the popup menu.

Figure 3.5j Spectrum Plot Parameter Menu



Spectrum Plot Popup Menu Items

Color—Changes the colors of the curves, text, background, grid lines, minor grid lines (if selected), and the marker pairs (see Figure 3.5k).

Filter—Selects Filter type and points (see Figure 3.5l).

Minor Grid—Shows/hides minor grid lines

Figure 3.5k Color Menu Items

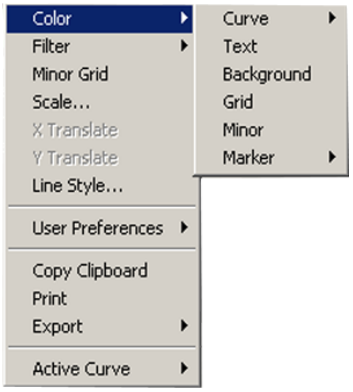
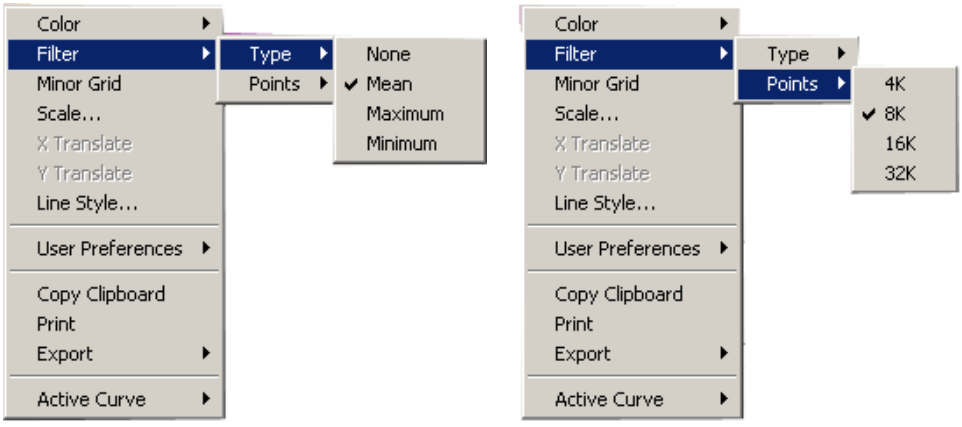


Figure 3.5l Filter Menu Items



Scale—Sets the vertical axis range, the center of the range, or allow the software to autoscale (see Figure 3.5m).

Line Style—Changes the line style of the Spectrum Plot graphical display (see Figure 3.5n).

User Preferences—You can either save all changes made to the graphical display, or restore previously saved settings (see Figure 3.5o). **Save** will result in all graphical displays maintaining any design changes made to this display.

Copy Clipboard—Copies the graphical display only to the Windows clipboard, allowing it to be pasted into any compatible Windows program.

Print—Prints the graphical display only to a printer.

Export—Saves the graphical display as a JPEG graphic, a Bitmap graphic, or as an XZ Data file text, which can be read in a database program (i.e. Excel).

Active Curve—Changes the curve displayed when more than one curve has been plotted. (Does not occur in PSD).

Figure 3.5m Scale Settings Dialog Box

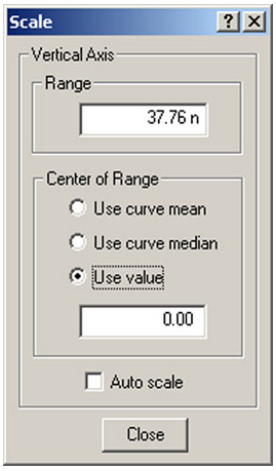


Figure 3.5n Line Style Display

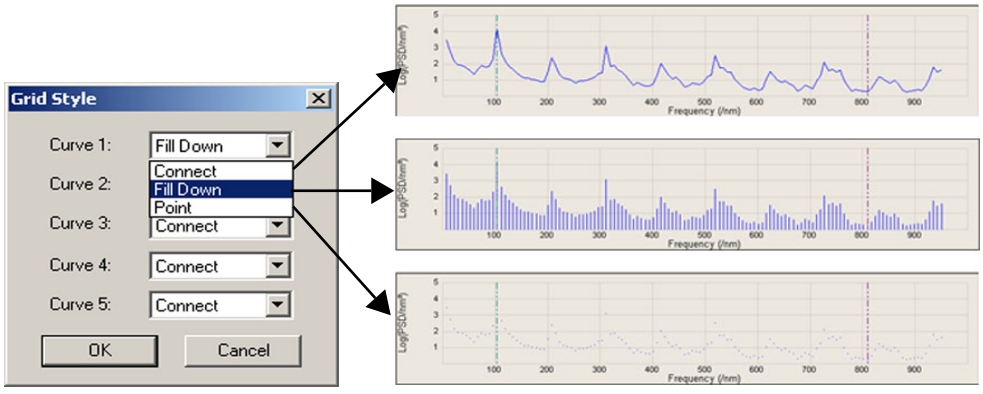
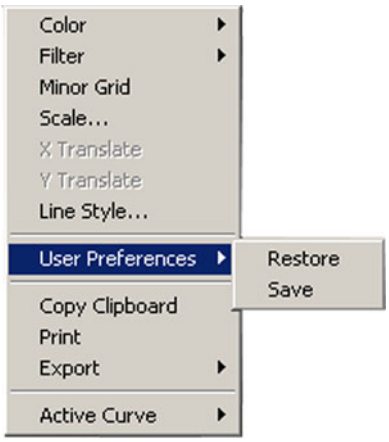


Figure 3.5o User Preferences Menu



3.6 Roughness

The **Roughness** command generates a variety of statistics on surfaces, including classical roughness values, and peak and zero crossing data. “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 data can be augmented with *stopbands*, (excluding features) to isolate desired analysis.

Refer to the following sections on **Roughness**:

- **Roughness Theory:** Section 3.6.1
- **Roughness Procedures:** Section 3.6.2
- **Roughness Interface:** Section 3.6.3

Most industrial standards for roughness measurement call for planefitting data *before* calculating values. Planefitting applies a temporary, first-order planefit before calculating statistics. On many surfaces, especially those which are tilted, this yields different values from those seen in raw (unplanefitted) 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 on large scanners), apply a second- or third-order **Flatten** and **Planefit** to the image *before* using **Roughness** analysis.
- Isolate your analysis to specific areas of the image. This may be accomplished by using the box cursor in **Roughness** to analyze only select portions of the image.

3.6.1 Roughness Theory

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 **Offline planefit** from a **Channel** panel, or via the **Analyze > Plane Fit** function.

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.

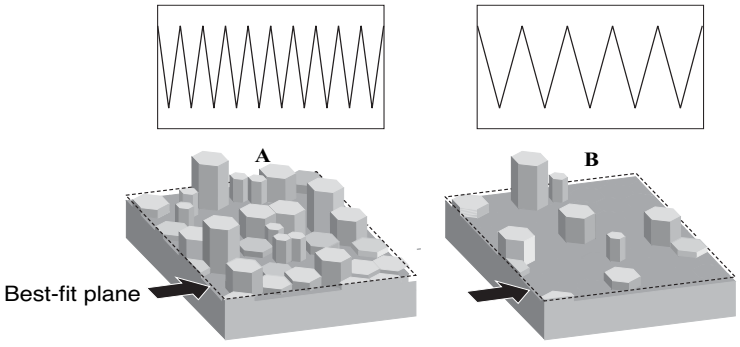
The relationship between the zero plane and the data also changes according to the setting of the **Offline planefit** parameter. If the **Offline planefit** parameter is set to **None** the offset is not removed from the data and it is very possible that the zero plane does not intersect the data. The 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 3.6a 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.

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 other statistical parameters such as Power Spectral Density.

Figure 3.6a Basic Roughness Measurements



3.6.2 Roughness Procedures

Example of Using Roughness Analysis

For general **Roughness Analysis**, complete the following procedures:

1. Select an image file from the file browsing window at the right of the main window. Double click the thumbnail image to select and open the image.

2. You can view the **Roughness View** using *one* of the following methods:

   - Right-click on the image name in the **Workspace** and select **Add View > Roughness** from the popup menu.

     Or

   - Select **Analyze > Roughness** from the menu bar.

     Or

   - Click the **Roughness** icon in the upper toolbar. 

3. The **Roughness View** appears showing results for the entire image.

4. To perform **Roughness** measurements within an area, left-click and move the mouse to draw a measurement box. Click on the **Execute** button to calculate the **Roughness** inside the box.

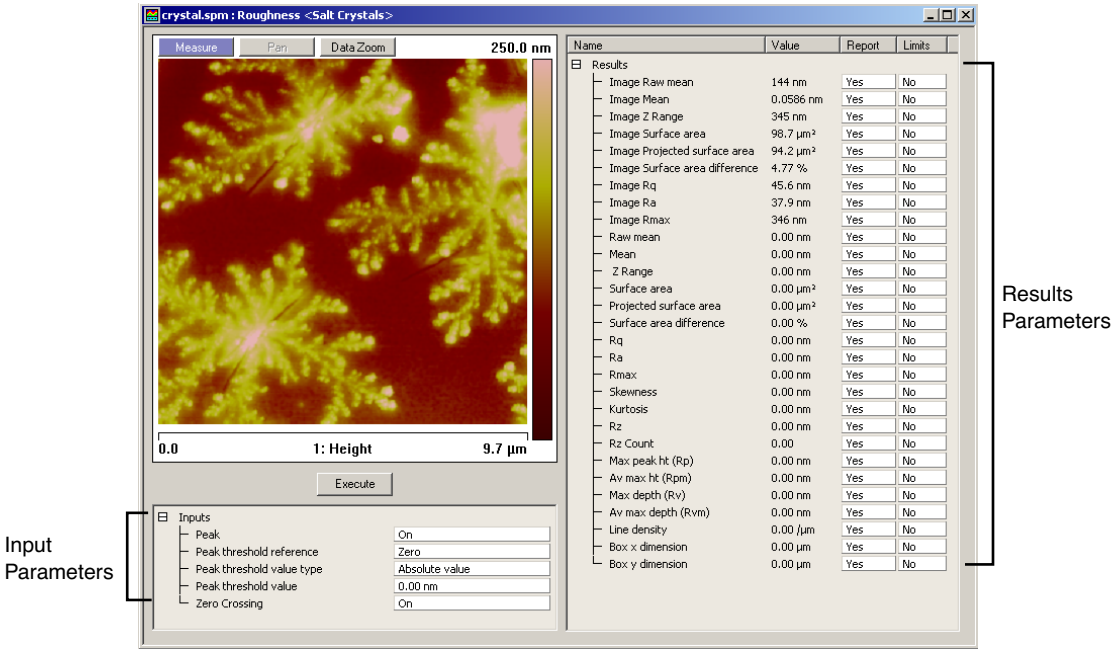
5. To exclude an area, right-click in the image to access a pop-up menu and select **Stop band**. Using the mouse, draw a box around the area to be excluded by the stop band command. Click on the **Execute** button to calculate the **Roughness** outside the box.

3.6.3 Roughness Interface

The **Roughness View** shows the image along with **Input** parameters and a **Results** window.

Note: Some parameters are reported only when certain subroutines are turned on.

Figure 3.6b Roughness Display



Input Parameters

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** parameters, 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 mean (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.

Range or Settings—When **Peak** is turned **On**, the following subcommands are activated (see Figure 3.6c):

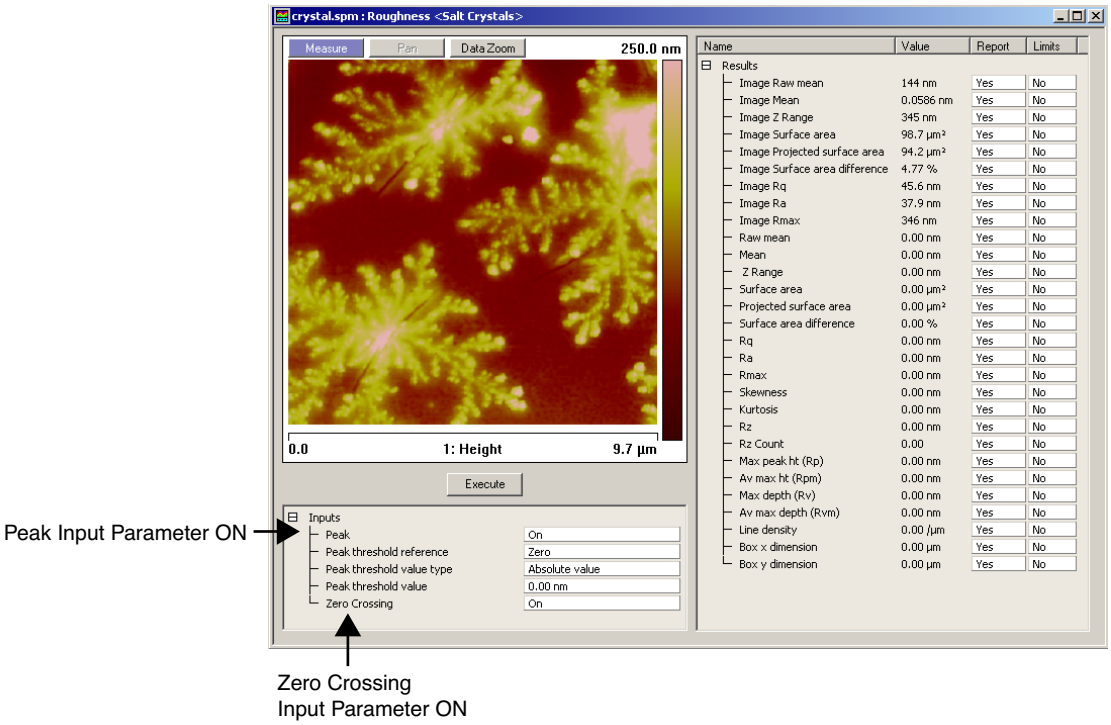
Peak Threshold Reference	The **Reference** buttons select whether the threshold is defined relative to the **Zero** (lowest) value, or the tallest **Peak** in the selected region.
Peak Threshold Value Type	The **Value Type** determines whether the threshold is defined as an absolute distance from the reference point in nanometers (**Absolute value**) or a percentage of the root-mean-square (**Rms %**) of the Z values.
Peak Threshold Value	The **Value** is an absolute distance from the reference point in nanometers (Absolute value) or a percentage of the root-mean-square (Rms %) of the Z values.

When **Peak** is turned **On**, the following statistical parameters are turned on. All **Peak** parameters are calculated from the thresholds you define with the **Peak** subcommands.

- **Rz**
- **Rz count**
- **Max peak ht (Rp)**
- **Av. Max ht (Rpm)**
- **Max depth (Rv)**
- **Av. max depth (Rvm)**

When **Peak** is turned **Off**, statistics are not calculated.

Figure 3.6c Input On Parameters



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 or Settings—When **Zero crossing** is turned **On** and you click the **Execute** button, the number of zero crossings along the X and Y center lines of the box cursor is determined (see Figure 3.6c). 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**.

When **Zero crossing** is turned **Off**, the zero crossing determination is not performed.

Results Parameters

Statistics used by the Roughness routine are defined in this section. The terms are listed *alphabetical*ly. Most are derived from ASME B46.12 ("Surface Texture: Surface Roughness, Waviness and Lay") available from the American Society of Mechanical Engineers, which should be consulted.

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.
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.
Image Mean	Mean value of data contained within the image.
Image Projected surface area	Area of the image rectangle (X x Y).
Image R_a	Arithmetic average of the absolute values of the surface height deviations measured from the mean plane. $$R_a = \frac{1}{N}\sum_{j=1}^{N}\left|Z_j\right|$$
Image Raw mean	Mean value of image data without application of plane fitting.
Image R_{max}	Maximum vertical distance between the highest and lowest data points in the image following the planefit.
Image R_q	Root mean square average of height deviations taken from the mean image data plane, expressed as: $$\sqrt{\frac{\sum Z_i^2}{N}}$$
Image Surface area	The three-dimensional area of the entire image. This value is the sum of the area of all of the triangles formed by three adjacent data points.
Image Surface Area Difference	Difference between the image's three-dimensional **Surface area** and two-dimensional projected surface area.
Image Z range	Maximum vertical distance between the highest and lowest data points in the image prior to the planefit.

Kurtosis

This is a non-dimensional quantity used to evaluate the shape of data about a central mean. It is calculated as

$$\text{Kurtosis} = \frac{1}{R_q^4}\frac{1}{N}\sum_{j=1}^{N} Z_j^4$$

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:

$$R_a = \frac{1}{N}\sum_{j=1}^{N} |Z_j|$$

Projected Surface Area

Area of the selected data.

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.

Rz Count

Number of Surface peaks taller than the threshold.

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).
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.
Z Range	Peak-to-valley difference in height values within the analyzed region.

3.7 Section

The **Section** command displays a top view image, upon which a single reference line may be drawn. The cross-sectional profiles and fast Fourier transform (FFT) of the data along the reference line is shown in separate windows. Roughness measurements are made of the surface along the reference line you define.

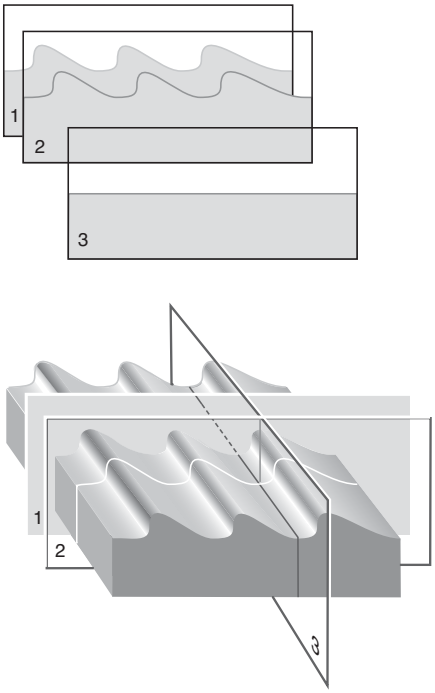
Section is probably the most commonly used **Analyze** command; it is also one of the easiest commands to use. To obtain consistently accurate results, ensure your image data is corrected for tilt, noise, etc. *before* analyzing with **Section**.

- **Sectioning of Surfaces: Overview:** Section 3.7.1
- **Section Procedures:** Section 3.7.2
- **Section Interface:** Section 3.7.3

3.7.1 Sectioning of Surfaces: Overview

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.

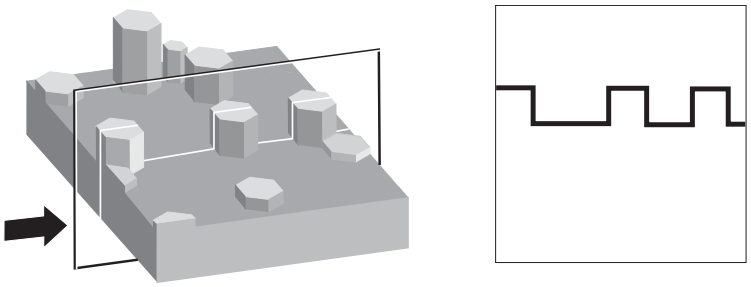
Figure 3.7a Section Analysis Orientation



In Figure 3.7a, 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 in the **Section** grid (see Figure 3.7b).

Figure 3.7b 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:

- 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.

Features are discussed below. Refer to **Roughness:** Section 3.6 for additional information regarding roughness calculations.

Using the Grid Display

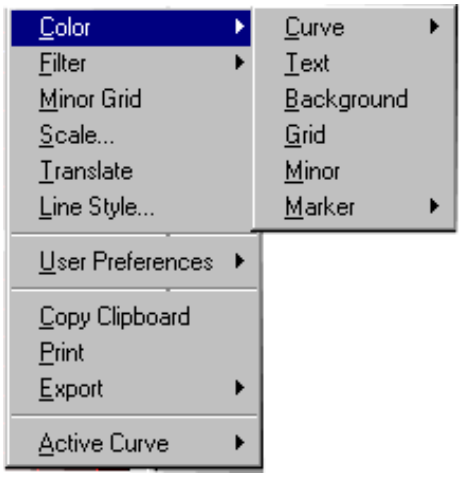
Measurement cursors for histogram and cross section views in depth and section are provided to the left and right of the **Grid Display**. You can bring the cursors into the grid by placing the mouse cursor onto the measurement cursors, clicking and holding the left mouse button, and dragging them onto the grid. When you place the mouse cursor onto a measurement cursor, the cursor will change to a horizontal or vertical double-arrow cursor ↔ , which indicates you can grab and drag this cursor.

Right-clicking on the grid will bring up the **Grid Parameters** menu (see Figure 3.4b) and allow you to make the following changes:

Color	Allows operator to change the color of the • Curve (data) • Text • Background • Grid • Minor • Marker

Filter	Typically used for a Profiler Scan. • Type—Select None, Mean (default), Maximum, or Minimum • Points—Select 4k, 8k (default), 16k, or 32k
Minor Grid	Places a minor grid in the background of the Vision Window.
Scale	Allows user to auto scale, set a curve mean, or set their own data range
Line Style	For each curve, the operator can choose a connect, fill down, or point line.
User Preferences	**Restore**—Reverts to initial software settings **Save**—Saves all changes operator has made during this session. This becomes the new default settings.
Copy Clipboard	Copies the grid image to the Microsoft Clipboard
Print	Prints out the current screen view to a printer
Export	Exports data in bitmap, JPEG or XZ data format
Active Curve	Determines which curve you are analyzing

Figure 3.7c Grid Parameters Menu



3.7.2 Section Procedures

1. Select an image file from the file browsing window at the right of the main window. Double click the thumbnail image to select and open the image.

2. You can view the **Section View** using *one* of the following methods:

   - Right-click on the image name in the **Workspace** and select **Add View > Section** from the popup menu.

     Or

   - Select **Analyze > Section** from the menu bar.

     Or

   - Click the **Section** icon in the upper toolbar. 

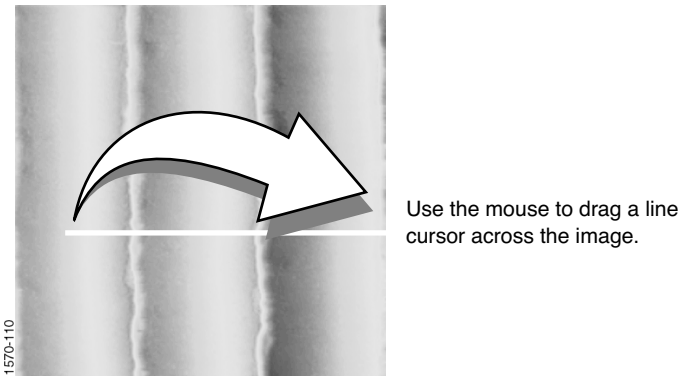
3. Before doing a section analysis, ensure that the image is properly oriented by removing any tilt or bow. This is especially important if a high level of precision is to be employed in measuring the blaze angle.

4. To remove any tilt which might be present, select **Analyze > Plane Fit**. Set the **Planefit Order** parameter in the panel to **1st**, then click 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.

5. In Section Analysis, to make a single-line section of the image, use the mouse to draw a line through the image, as in Figure 3.7d, and note the results.

6. Move the grid cursors along the section to make measurements.

Figure 3.7d Mouse Drawing Line



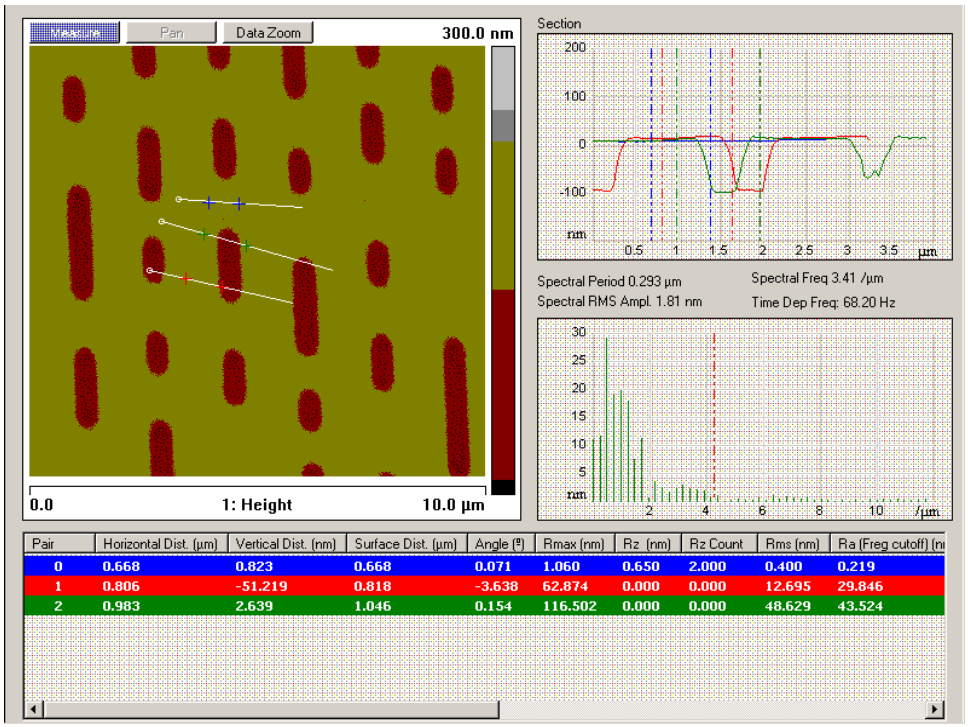
3.7.3 Section Interface

When a line is drawn on the image, the cross-sectional profile is displayed in the upper right window, and the FFT spectrum along the line is displayed directly below it (see Figure 3.7e).

Note: To prevent undersampling, 1024 points along the selected line are used in the FFT calculation. The extra points are generated by interpolation.

The markers may be positioned in the profile and FFT spectrum. The results window at the bottom of the display lists roughness information based on the position of the presently selected reference markers. Each marker pair is color coordinated with the data in the results window.

Figure 3.7e Section View



Grid Markers:

A pair of markers in the section grid and a single marker in the spectrum grid will automatically be drawn. Place the mouse cursor on the desired marker and left-click to move.

Marker pair 0 Default display color is blue. Slide the markers into the grid from the left or right side by clicking and holding the left mouse button. Data between the two markers will be displayed in the results window at the bottom of the display screen in blue.

Marker pair 1	Default display color is red. Slide the markers into the grid from the left or right side by clicking and holding the left mouse button. Data between the two markers will be displayed in the results window at the bottom of the display screen in red.
Marker pair 2	Default display color is green. Slide the markers into the grid from the left or right side by clicking and holding the left mouse button. Data between the two markers will be displayed in the results window at the bottom of the display screen in green.
Spectrum Marker	Displays the third slider cursor location along the spectral data (e.g., FFT Spectrum).

Results Parameters:

The standard deviation RMS (**R_q**), 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 **Results** parameter grid.

Results Parameters:

Length	Length of the roughness curve.
***RMS* (Standard Deviation)**	Standard deviation of the Z values between the reference markers, calculated as: $$RMS = \sigma = \sqrt{\frac{\sum (Z_i - Z_{ave})^2}{N}}$$ 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.
***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.
Freq. Cutoff (υm)	**Frequency Cutoff** measured in terms of a percentage of the root mean square.

Changing the cursor on the FFT changes l_C, the cutoff 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 cutoff affects the calculated roughness values.

- **RZ Count**—number of peaks used for rz computation
- **Radius**—radius of circle fitted to the data between the cursors
- **Radius Sigma**—mean square error of radius calculation
- **Surface Distance**—distance measured along the surface between the cursors
- **Horizontal Distance**—horizontal distance between the cursors
- **Vertical Distance**—vertical distance between the cursors
- **Angle**—angle of the imaginary line drawn from the first cursor intercept to the second cursor intercept
- **Spectral Period**—spectral period at the cursor position
- **Spectral Frequency**—spectral frequency at the cursor position
- **Spectral RMS Ampl.**—amplitude at the cursor position

Mouse Operations for a Line 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.
- Clicking on the center of the line and dragging moves the line on the image.
- Clicking on either end of the line rotates the line.

Mouse Operations for Box Cursor (Right-Click Selection):

- 1st click—Anchors the origin of a box and "rubber bands" out from the center of the selected position.
- As a reference, the cursor positions show up on the center line 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.
- Holding the **Shift** button down while clicking on the box and dragging in a circular direction rotates the box.

3.8 XY Drift

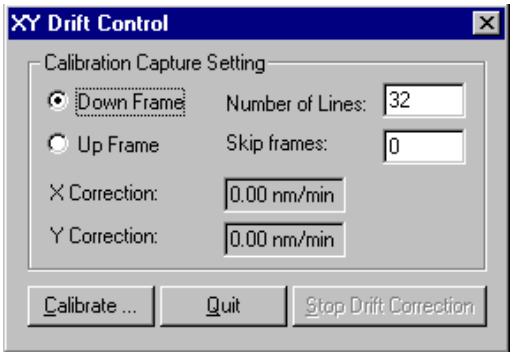
Due to temperature differences, thermal lateral drift can occur between two successive images while scanning. Using Offline **XY Drift** analysis, the software can calculate the lateral shift between two images. You can also manually enter the drift.

3.8.1 Realtime XY Drift

You can capture two images in Realtime mode for later **XY Drift** analysis in Offline mode.

1. You must be in Realtime mode and engaged (**Realtime > Engage**).
2. Select **Realtime > XY Drift**. The **XY Drift Control** dialog box displays (see Figure 3.8a).

Figure 3.8a XY Drift Control Dialog Box



3. Enter the appropriate capture calibration settings and select **Calibrate**. Two images are captured with the number of lines designated, then the Offline **XY Drift View** opens (see **Offline XY Drift Analysis:** Section 3.8.2).

   Note: Both images must have the same microscope configuration and scanner calibration settings currently in use.

Calibration Capture Settings

Down Frame	Captures lines from the top of the image to the bottom. 
Up Frame	Captures lines from the bottom of the image to the top. 
Number of Lines	Designates the number of lines to capture. This number must be less than or equal to the Lines parameter in the **Scan View > Scan** tab panel.
Skip Frames	Designates the number of frames to skip at the beginning of the scan.
X Correction	Reports the current X correction value.
Y Correction	Reports the current Y correction value.

XY Drift Control Dialog Box Buttons

Calibrate	Stops any current drift correction and captures 2 images. After capturing the images, the Offline **XY Drift View** automatically displays.
Quit	Closes the **XY Drift Control** dialog box.
Stop Drift Correction	Stops any current drift correction.

3.8.2 Offline XY Drift Analysis

Requirements

Two images from the same capture directory captured within 1 day of each other are required. The capture direction must be the same for both images (up or down), and the images must have the same microscope configuration and scanner calibration properties.

Procedure

To calculate XY Drift using the software:

1. Start with the earliest image and use *one* of the following methods to open the **XY Drift Analysis View** (see Figure 3.8b).

   - Right-click on the image name in the **Workspace** and select **Add View > XY Drift** from the popup menu.

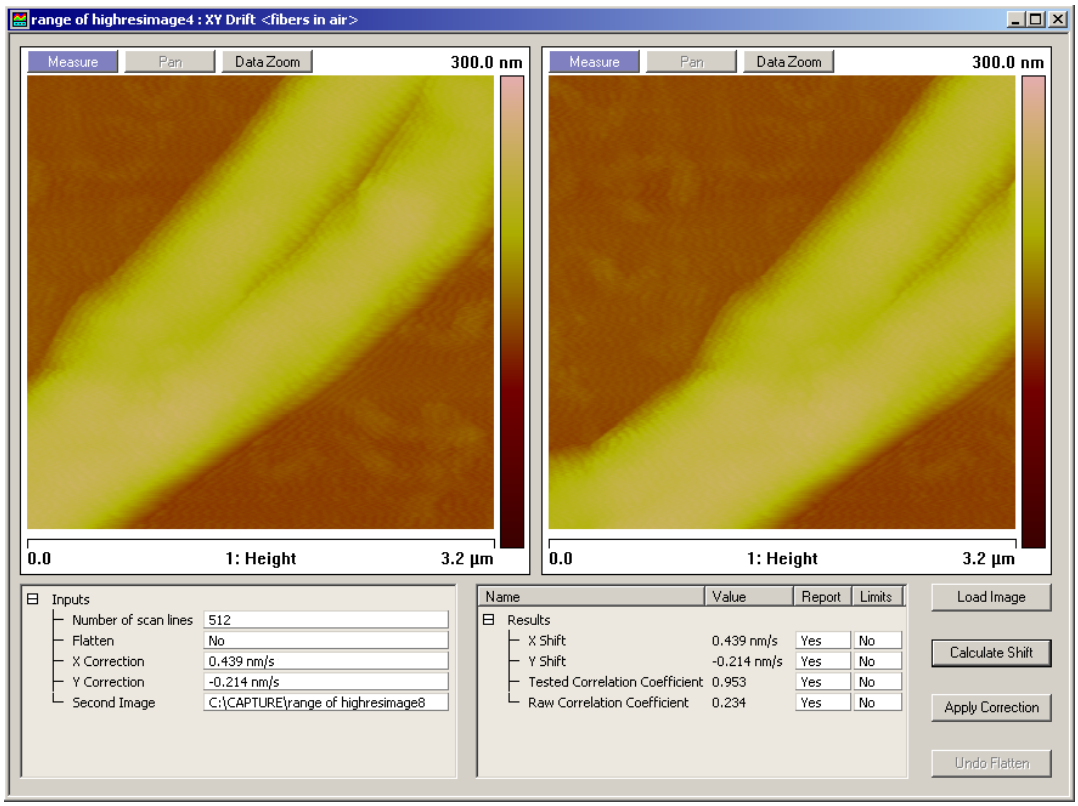
     Or

   - Select **Analyze > XY Drift** from the menu bar.

     Or

   - Click the **XY Drift** icon in the upper toolbar. 

Figure 3.8b XY Drift View



2. Use the **Load Image** button to browse for the subsequent image.

3. Click the **Calculate Shift** button. The software will calculate the shift of the second image relative to the first image.

4. The results display in the **Results** box.

    a. To apply the corrections in the **Inputs** box, click the **Apply Correction** button.

    Or

    b. You can also manually enter the correction values in the **Inputs** box. Click the **Apply Correction** button.

    Note: **Apply Correction** effects Realtime by applying a drift correction to the Realtime images. Do not use **Apply Correction** if this is not your intent.

Input Parameters

Statistics used by the **XY Drift** analysis are defined in this section.

Number of scan lines	Specifies the number of lines to calculate.
Flatten	Flattens both images before the shift is calculated. (Use the **Undo Flatten** button to reverse the flatten).
X Correction	Specifies the amount of correction to apply to the X-axis of the scanner.
Y Correction	Specifies the amount of correction to apply to the Y-axis of the scanner.
Second Image	Defines the location of the second image used in the analysis.

Results Parameters

Results of the **XY Drift** analysis are presented in this section.

X Shift	Specifies the amount of calculated shift along the X-axis of the second image relative to the first.
Y Shift	Specifies the amount of calculated shift along the Y-axis of the second image relative to the first.
Tested Correlation Coefficient	Reports the correlation coefficient after correcting for the detected shift. A perfect correlation is 1.0. If the tested correlation coefficient is too low, then the calculation is not valid and should not be applied. You may need features that have more distinct contrast.
Raw Correlation Coefficient	Reports the correlation coefficient between the two images prior to processing.

XY Drift Buttons

Load Image	Browse to open the second image in the right box.
Calculate Shift	Compares left image to right image, and reports the shift statistics in the **Results** box.
Apply Correction	Applies the correction in the **Inputs** box to the second image.
Undo Flatten	**Undo Flatten** restores the image to its original form.

3.9 Multiple Channel Analysis

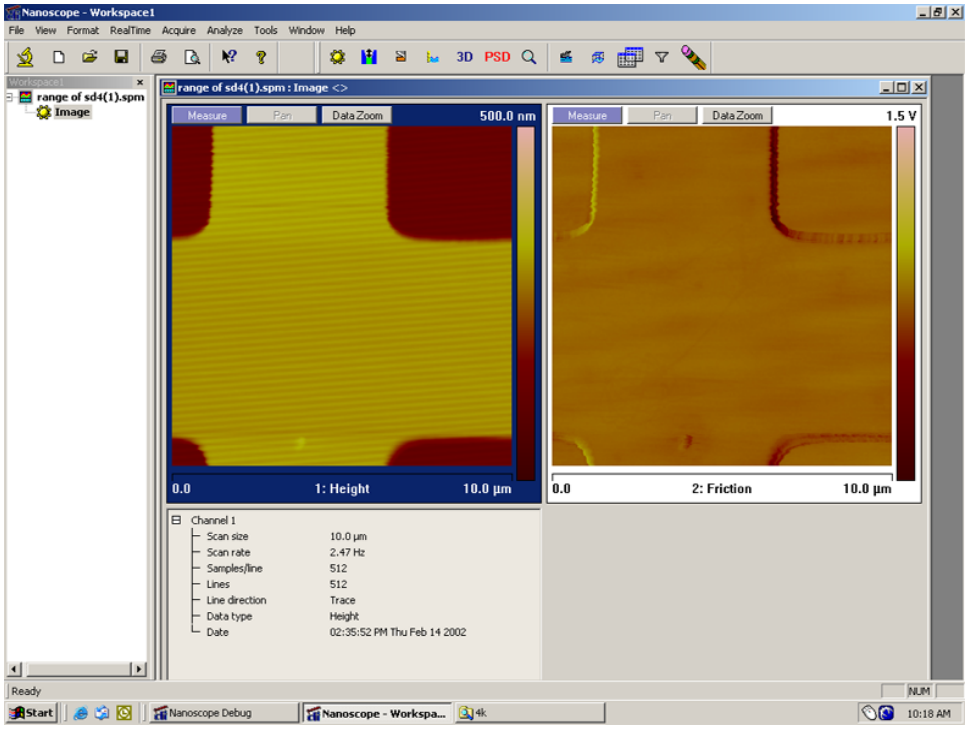
It is often necessary to analyze more than one channel of data from the same scan. This can be done by opening a captured dual-scan or triple-scan image Offline.

3.9.1 Dual-Scan Image

When you open a dual-scan image, the **Channel 1** and **Channel 2** images will appear side by side, with **Channel 1** on the left and **Channel 2** on the right, and the channel data will typically be shown below the left image. Click on the desired image to select the channel and the corresponding channel data will appear (see Figure 3.9a).

Note: The location of the Channel data may vary depending on window proportions.

Figure 3.9a Captured Dual-Scan Image

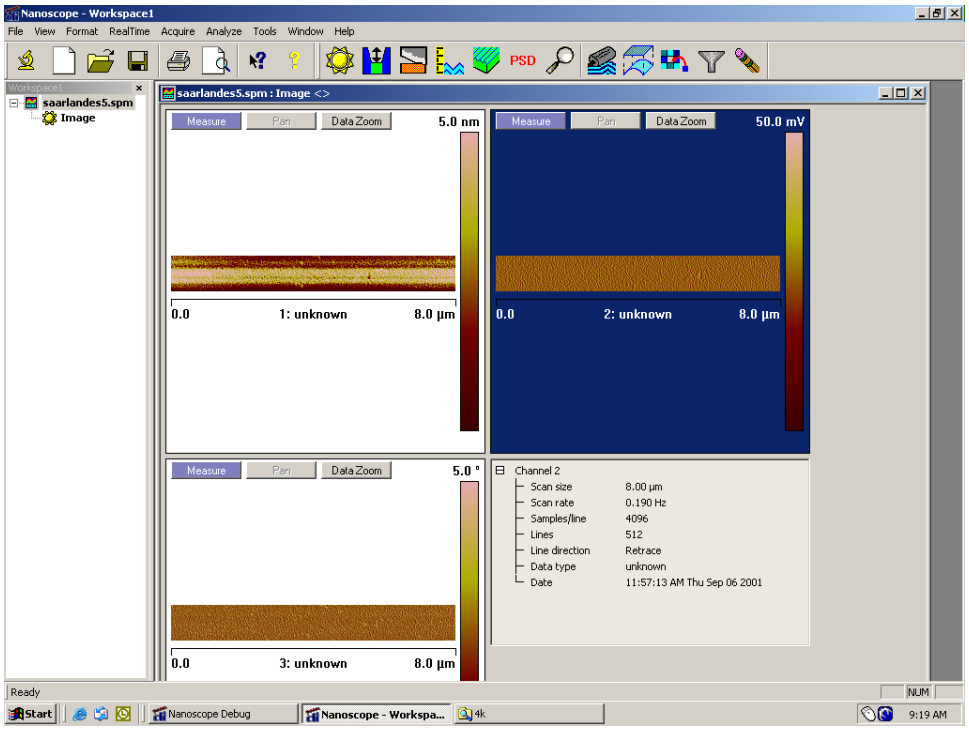


3.9.2 Triple-Scan Image

When you open a triple-scan image, the **Channel 1** and **Channel 2** images will typically appear side by side, with **Channel 1** on the left and **Channel 2** on the right, and the **Channel 3** image will typically appear below the **Channel 1** image. Channel data is now shown to the right of the **Channel 3** image. Click on the desired image to select the channel and the corresponding channel data will appear (see Figure 3.9b).

Note: The location of the Channel data may vary depending on window proportions.

Figure 3.9b Captured Triple-Scan Image



3.9.3 Analyzing Captured Multichannel Images

When performing any analysis of a multichannel scan, you may only analyze one channel at a time. Highlight the appropriate channel image by clicking on it, then select the desired **Analysis View** by any one of the following:

- Right-clicking on the image file name in the **Workspace**, selecting **Add View**, and clicking on the desired view.
- Selecting **Analyze** from the menu bar and clicking on the desired view.
- Clicking on the appropriate button in the button bar.

Once you select the desired channel, and the appropriate view, a new window will open with only the image of the selected channel and you may start your analysis in accordance with the instructions in Section 3.1 through Section 3.3. If the image display in the view is not the desired channel, you can right-click on the image, go to **Channel**, and select the appropriate channel from the pop-up menu.

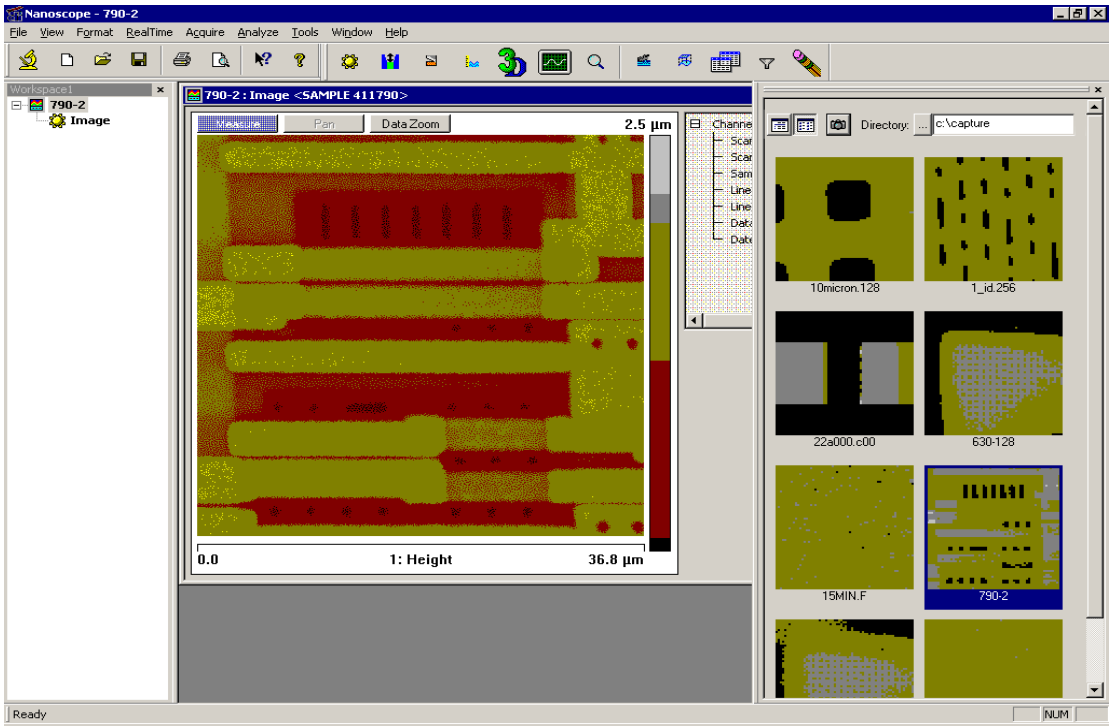
You can also print multichannel images simultaneously. All channels must be open in the same view, then select **File > Print**.

3.10 AutoProgram

An AutoProgram is a sequence of operations that may be applied automatically to at least one previously captured image. Typically, an AutoProgram is created to rapidly analyze a large number of images taken under similar conditions. Any image **Modify** or **Analyze** command may be included in an AutoProgram. Do the following to create an AutoProgram:

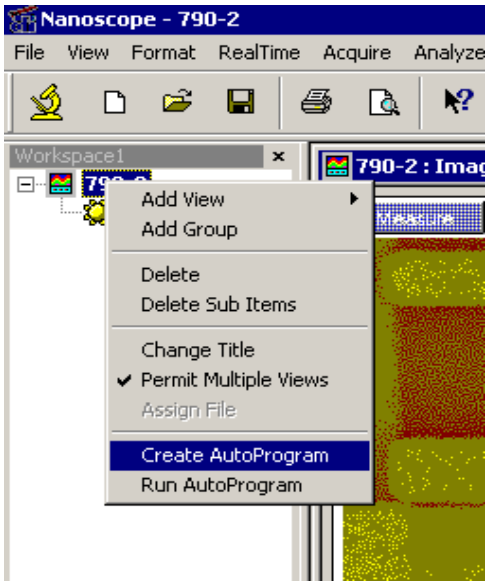
1. Select a directory, then an image file within it, from the file browsing window at the right of the **NanoScope** main window. Double-click its thumbnail to select and open the image. The image file name and the **Offline** icon, as well as a **sunburst** icon and the word "**Image**" are added to the **Workspace**, and the image opens in the viewing window (see Figure 3.10a).

Figure 3.10a Open Image



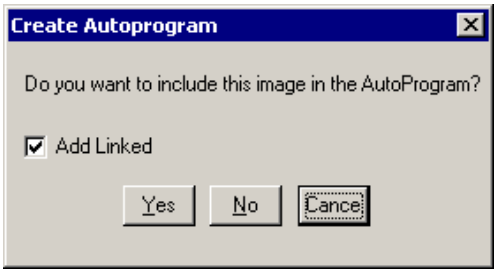
2. In the **Workspace**, right-click on the image file name or its **Offline** icon and select **Create AutoProgram** (see Figure 3.10b).

Figure 3.10b Create AutoProgram



3. You are asked if you want to include the selected image to define the AutoProgram among the images processed by the AutoProgram (see Figure 3.10c). (Typically: "Yes.") The **Add Linked** box should also be checked. When linking, any changes made to the currently active view will then alter any linked views.

Figure 3.10c Include Selected Image Box



4. In the **AutoProgram Results View** (see Figure 3.10d):

   a. Right-click on **Autoprogram**, under the image file name or icon appearing on the line under **Run Group**.

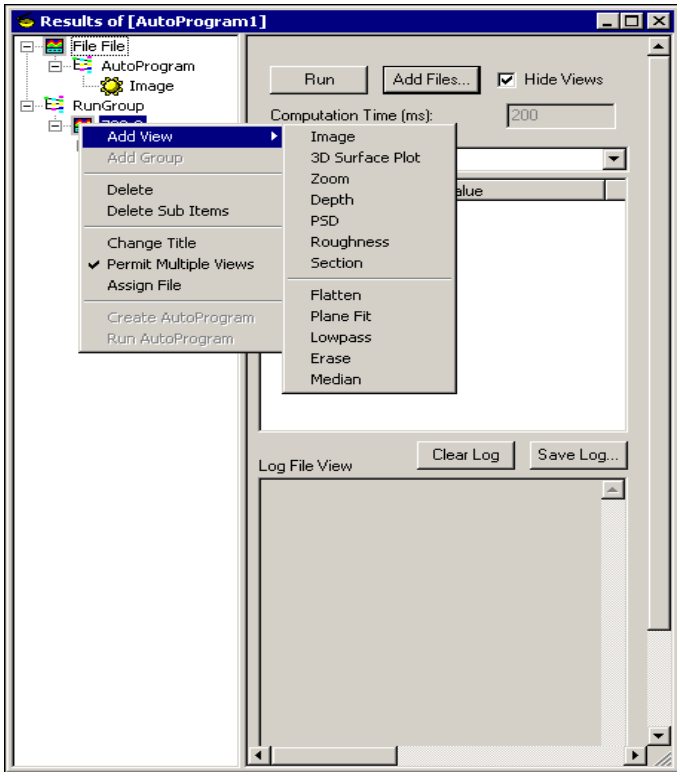
   b. Click **Add View**.

   c. Click the view of an **Analyze** or **Modify** command to be performed first by the AutoProgram.

d. Repeat for additional views (in Figure 3.10a, **Flatten**, **Depth** then **Roughness** operations will be performed).

Note: Example specifications of the **Flatten**, **Depth** and **Roughness** commands for inclusion in an AutoProgram are described next. Similar actions apply to include other Offline **Analyze** and **Modify** commands in an AutoProgram.

Figure 3.10d Add Views to be Included in an AutoProgram



3.10.1 Example command: Flatten

To open the **Flatten View**:

1. Click the command name or icon that has been added to the **Run Group** Autoprogram.

2. Click in the image and drag open a box over features in the image that are to be excluded from the polynomial fit calculations (see Figure 3.10e). Typically, only featureless areas are used for flattening an image.

3. On the right of the **Flatten View**, set parameter values to apply for all images operated on by the AutoProgram.

4. Close the **Flatten View**.

3.10.2 Example command: Depth

To open the **Depth View**:

1. Click the command name or icon that has been added to the **Run Group** Autoprogram.
2. Click in the image and drag open a box over an area that contains a height step (see Figure 3.10g).
3. On the right of the **Depth View**, set parameter values that will apply for all images operated on by the AutoProgram.
4. Close the **Depth View**.

Figure 3.10e Specify a Flatten Operation

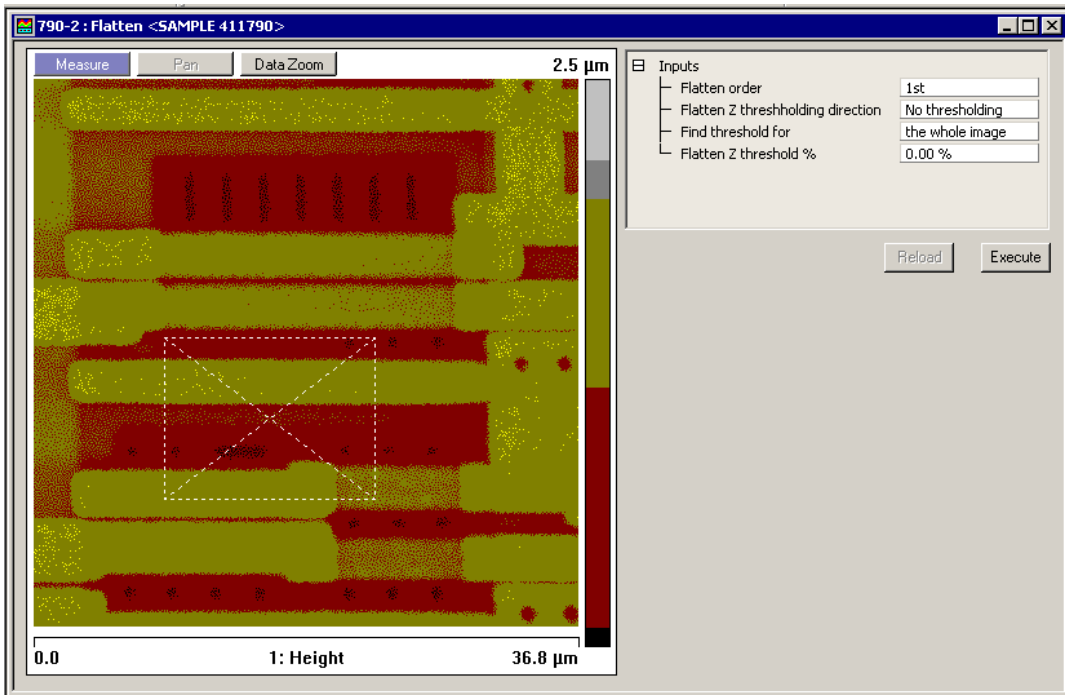
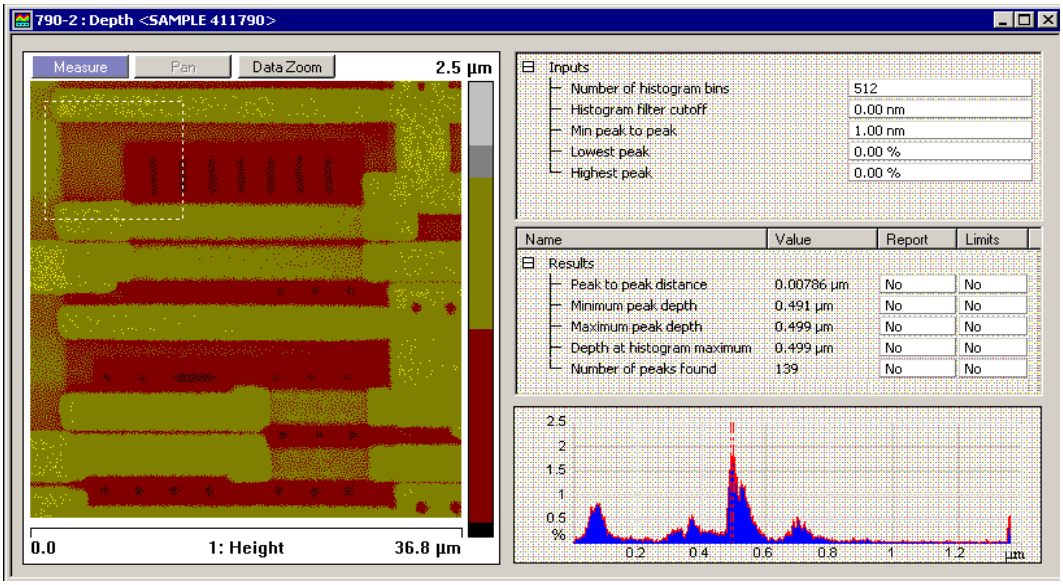


Figure 3.10f Specify a Depth Measurement

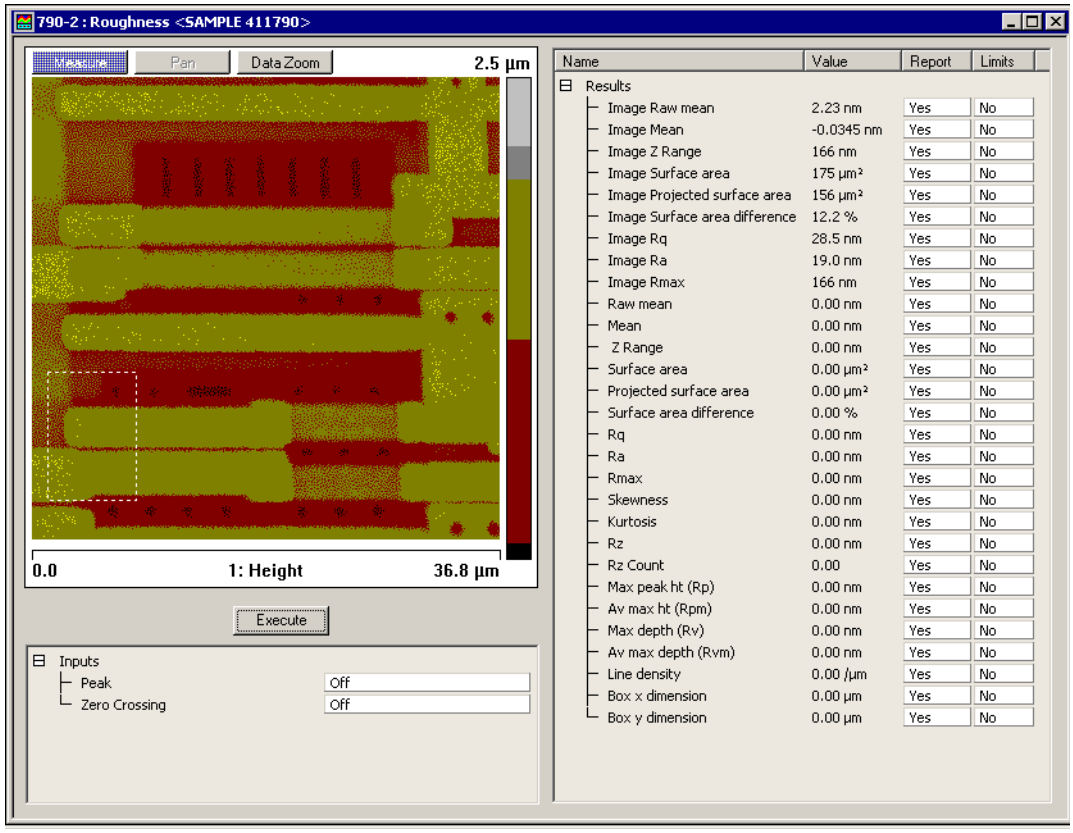


3.10.3 Example command: Roughness

To open the **Roughness View**:

1. Click the command name or icon that has been added to the **Run Group** Autoprogram.
2. Click in the image and drag open a box over an area where you would like the sample surface condition analyzed (see Figure 3.10g).
3. On the upper right of the **Roughness View**, set parameter values that will apply for all images operated on by the AutoProgram.
4. On the lower right of the **Roughness View**, select what measurements to report.
5. Close the **Roughness View**.

Figure 3.10g Specify a Roughness Measurement for Inclusion in an AutoProgram



3.10.4 Running AutoProgram

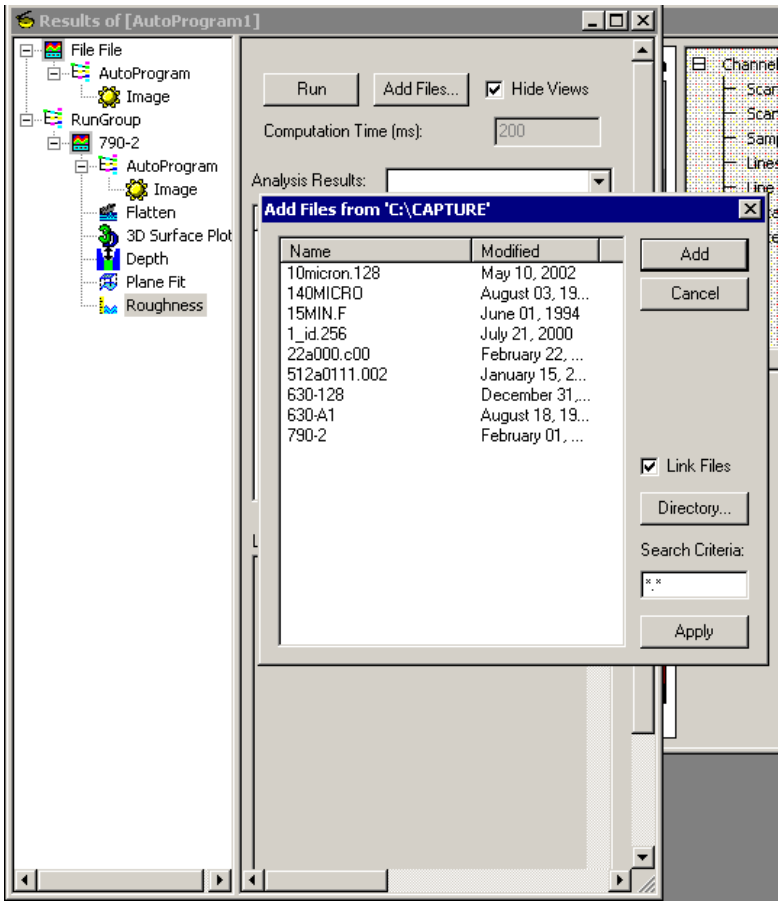
Once all commands are included in the AutoProgram list and their action specified, you are ready to run AutoProgram.

1. Click the **Add Files** button in the **AutoProgram Results View** (see Figure 3.10h). The **Add Files** dialog box appears.

2. In the **Add Files** dialog box, select the **Link Files** box to have the same **AutoProgram** instructions apply to each file. Select files of interest and click **Add** to have the selected files included when the **AutoProgram** is run. Hold down the **Shift** key to select a consecutive group of files or the **Control** key to select more than one individual file.

3. In the **AutoProgram Results View**, check the **Hide View** box if you don't want the images displayed, as they are automatically analyzed by the **AutoProgram**. If you want to see the images processed during **AutoProgram** execution, leave **Hide View** unchecked. Increasing the value in **Computation Time** allows more time to view operations during Autoprogram execution.

Figure 3.10h Add Files Dialog Box

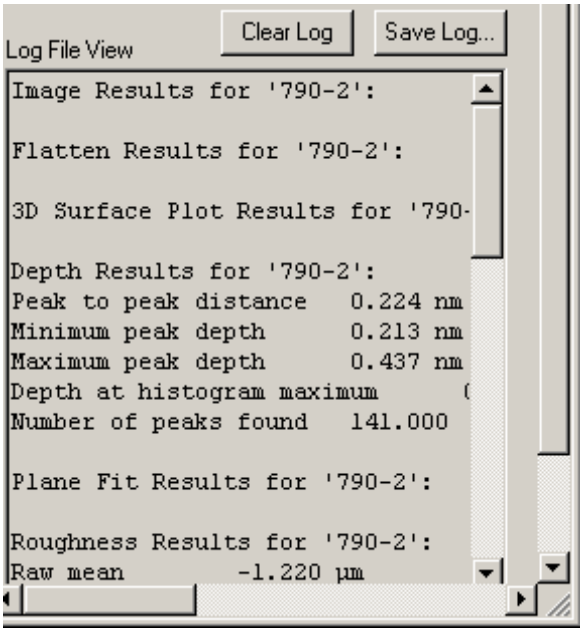


4. Click the **Run** button in the **AutoProgram Results View** to start the **AutoProgram**.

   Note: The **RUN** button toggles to display **Stop** while the AutoProgram is running. Click it if you need to stop the process before it is completed. Clicking the **Run** button again restarts the **AutoProgram** at the first image.

5. Upon completion, the data appears in the **Log File View** property sheet (see Figure 3.10i).

Figure 3.10i Log File View Property Sheet



6. If you close the **Autoprogram Results View** without saving the Autoprogram, you will be prompted to save the Autoprogram as an .apg file.

7. To save the log file, select the **Save Log** button in the **Log File View**.

8. You can print the Autoprogram results and also save the results as tab delimited text.