Stimulated emission and absorption of photons in magnetic point contacts: toward metal-based spin-lasers

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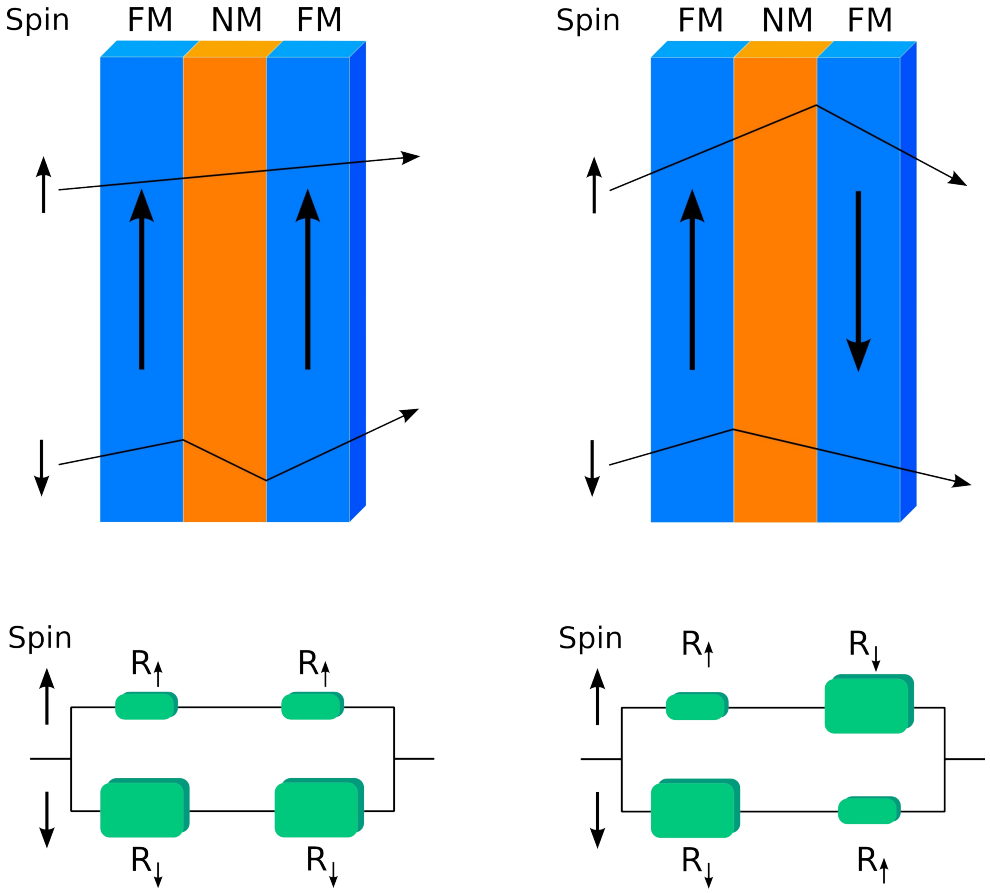
Literature discussion

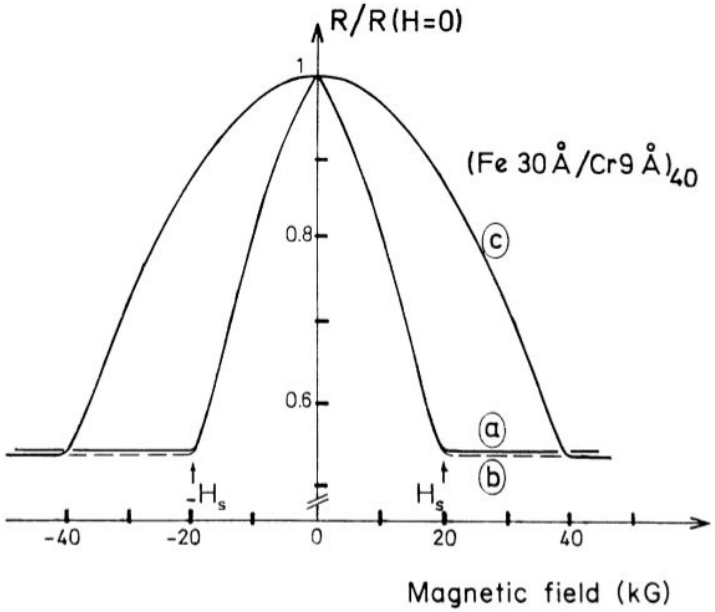
15 February 2011

Tim Verhagen

- Spin Transfer Torque
- Spin Lasing
- Experiment

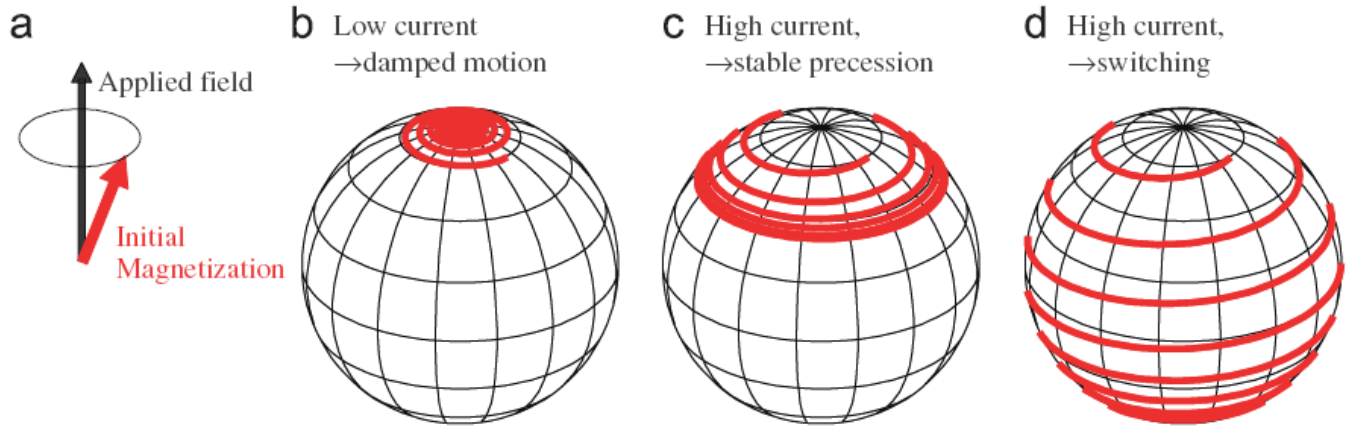
Giant Magnetic Resistance

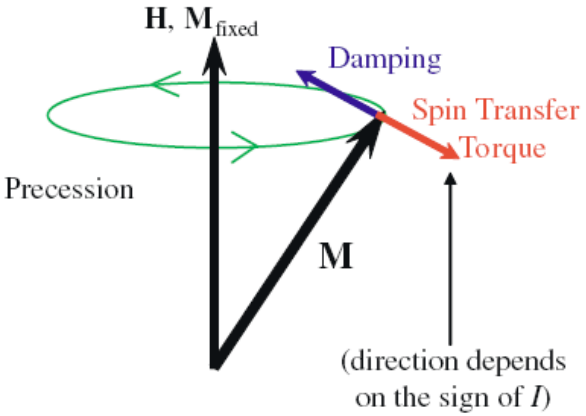




Baibich, Fert et al, PRL **21** 2472 (1988)

Spin Transfer Torque





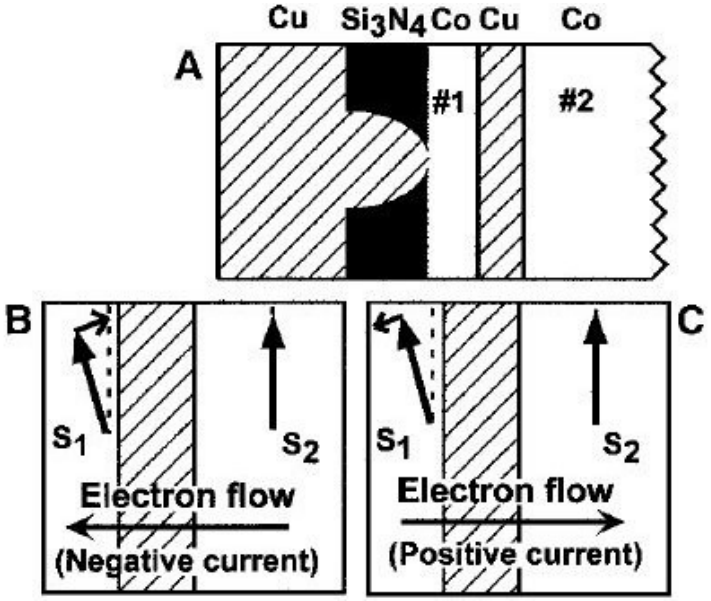
$$\tau \propto I\hat{s_1} \times (\hat{s_1} \times \hat{s_2})$$

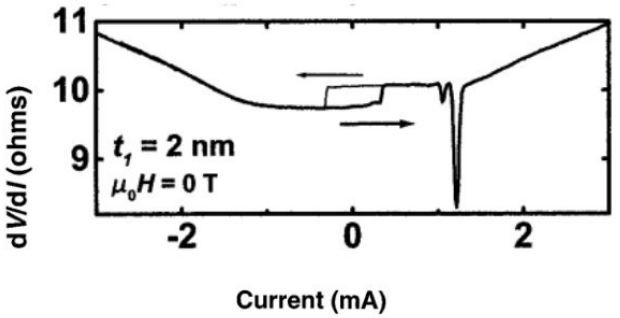
Dissipation

Generated torque

Slonczewski, JMMM **159** L1 (1996)
Berger, PRB **64** 9353 (1996)

Experimental proof STT



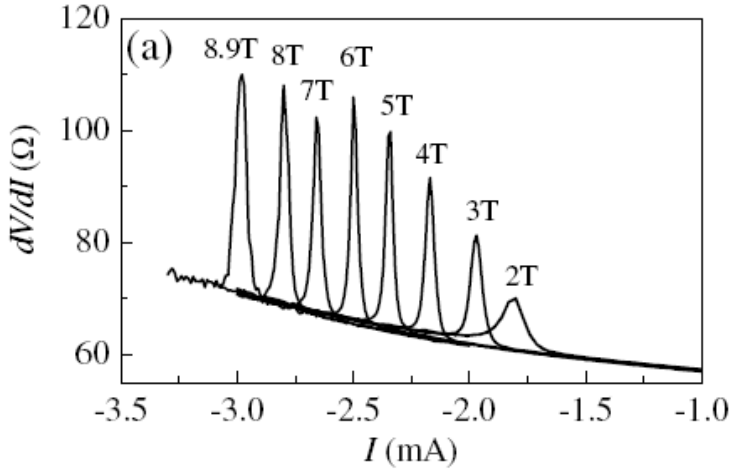


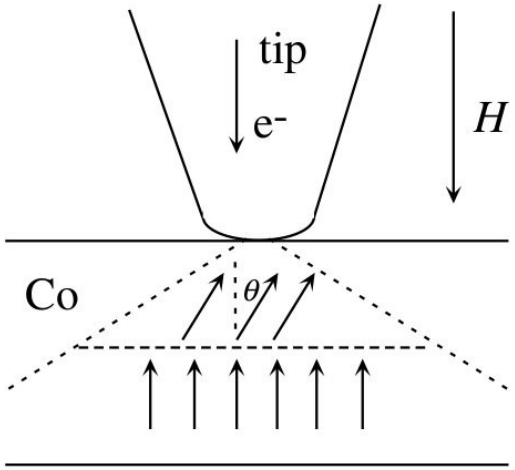
Damping increase with decreasing film thickness

Birth of spin pumping!
To be discussed next time, see RMP 77 1375

Myers et al, Science **285** 867 (1999)

Excitations magnetic layer





Co|Ag

Ji, Chien and Stiles, prl 90, 106601 (2003)

- Spin Transfer Torque
- Spin Lasing
- Experiment

Spin flip laser

Semiconductor (laser diode)

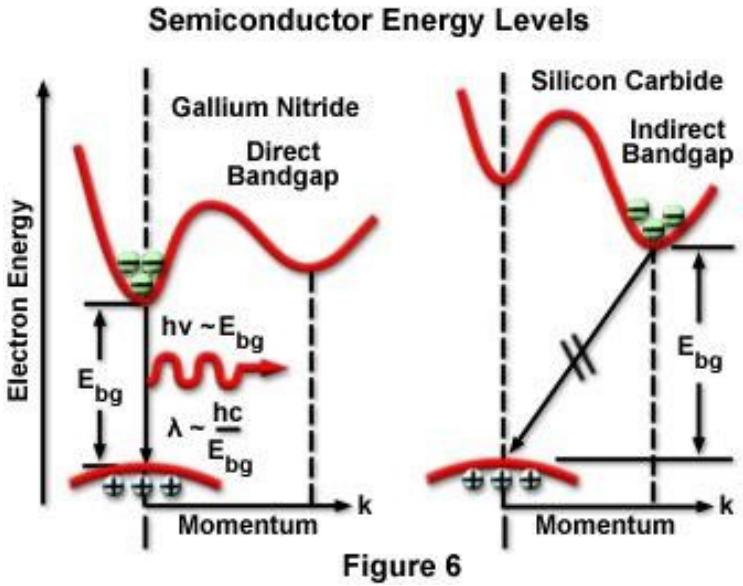


Figure 6

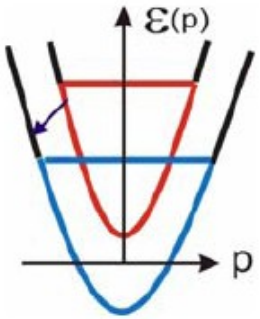
$\Delta k = 0$

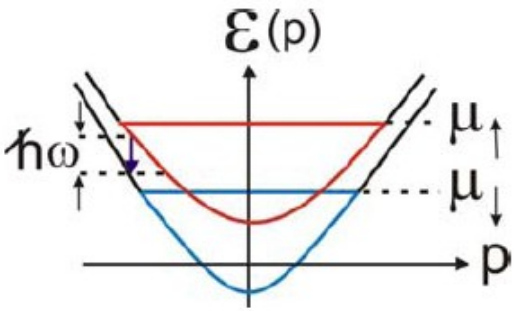
photon

$\Delta k \neq 0$

phonon

Magnetic (spin flip laser)





$\Delta k \neq 0$

magnon

↓

High frequency oscillators

$\Delta k = 0$

photon

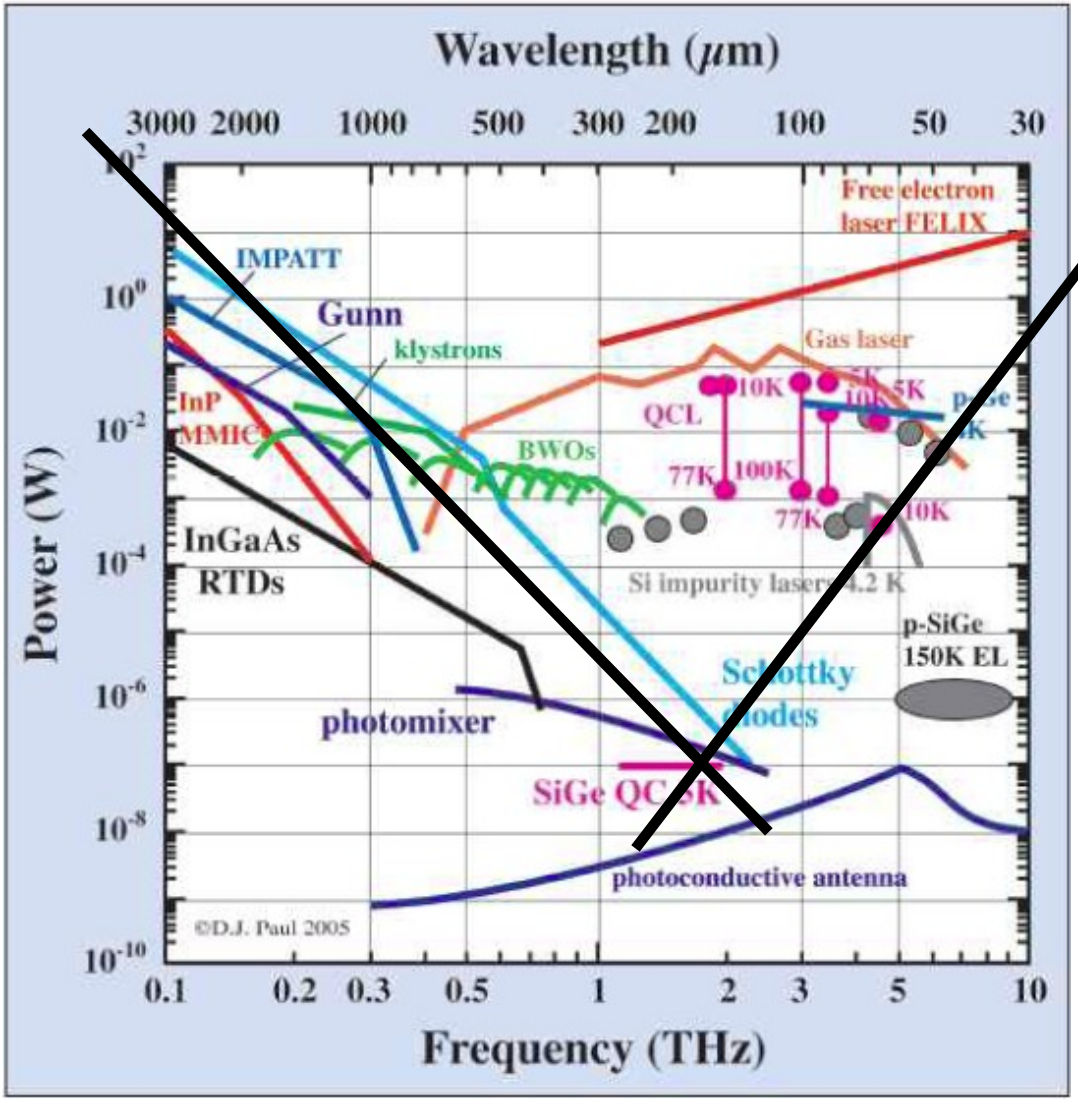
↓

High frequency lasers

Why magnetic lasers?

Electronics

$$P \propto \frac{1}{\nu^4}$$



Optics

$$k_b T < h\nu$$

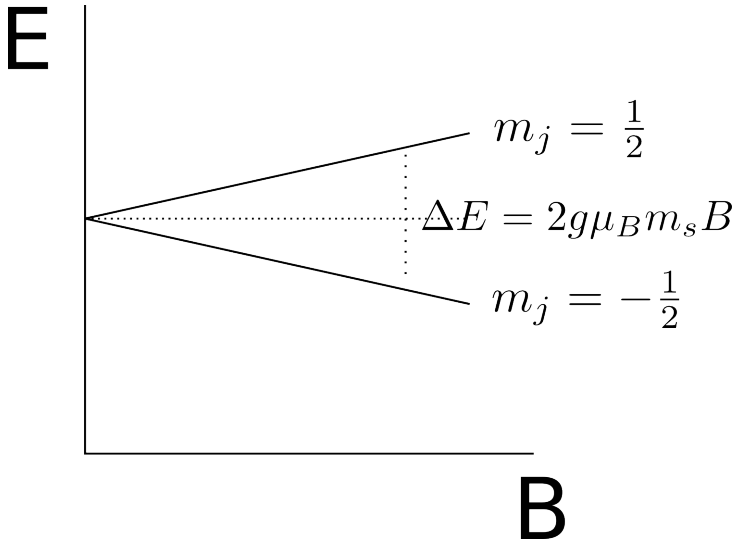
1 THz = 4meV

1 THz = 48K

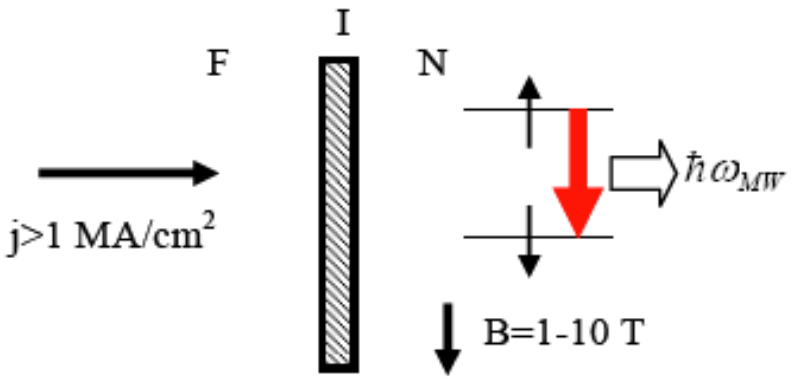
1 THz = 33cm-1

1 THz = 0.3mm

Zeeman split transition



Zeeman effect



$$h\nu = 2g\mu_B m_s B$$

$$\nu = 0.014gB\left[\frac{THz}{T}\right]$$

Devices, Majority F

If coercive field of F is (much) bigger than applied field

$SmCo_5, AlNiCo, Nd_2Fe_{14}B$

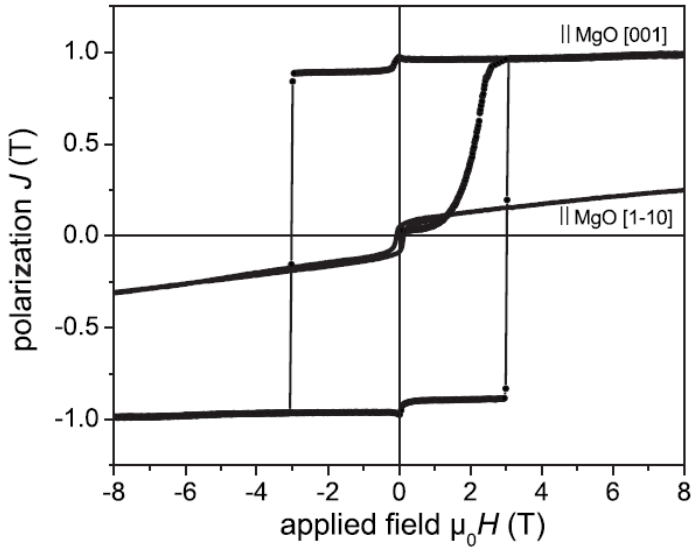


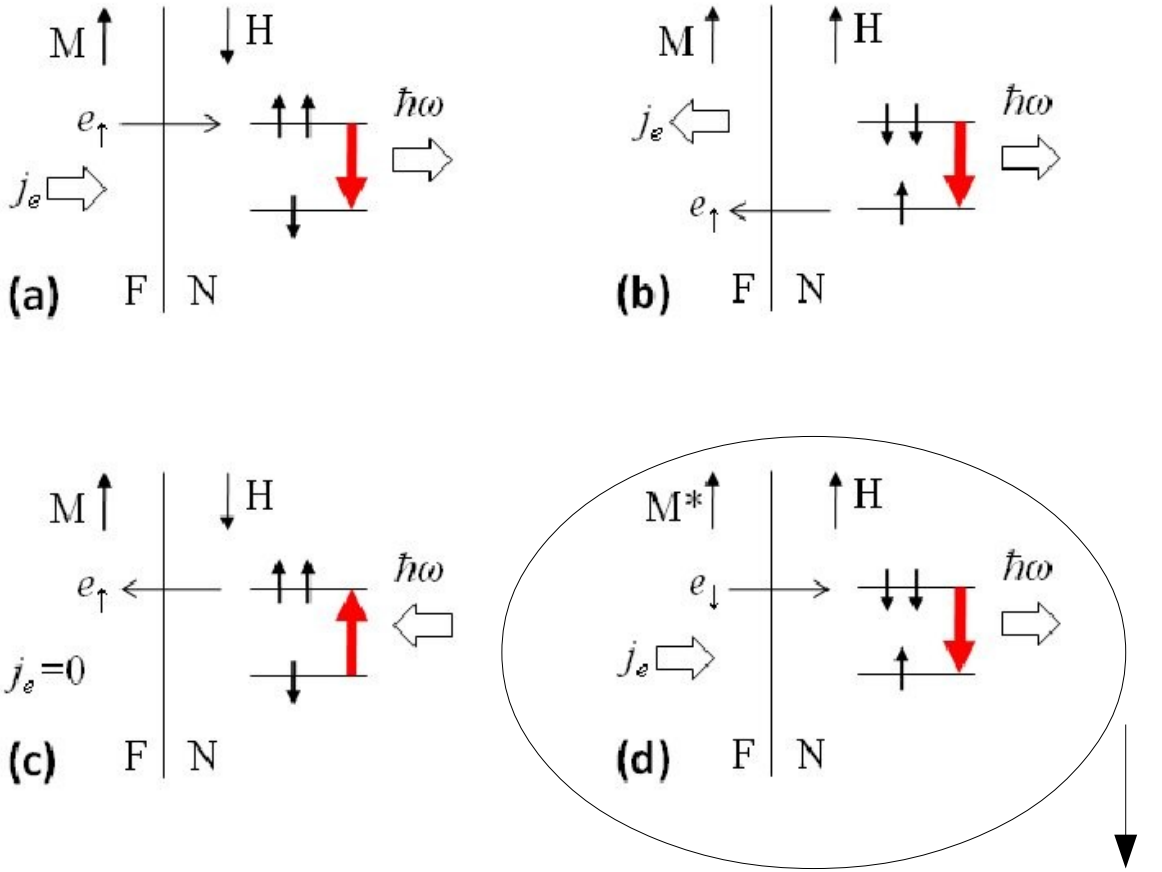
FIG. 2. Magnetic hysteresis of a $SmCo_5$ film measured along the easy magnetization axis (||MgO[001]) and along the in-plane hard axis (||MgO[1−10]).

- Pulsed laser Deposition
- Seed layer Cr
- Capping layer Cu

PRB 77 104443

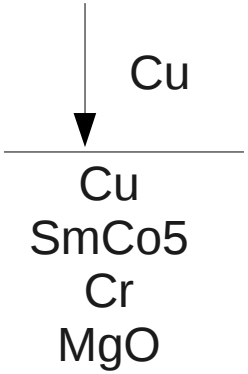
How to build?

This paper:



FeCr -> see New J Phys 13 023007 (2011)

- Spin Transfer Torque
- Spin Lasing
- Experiment

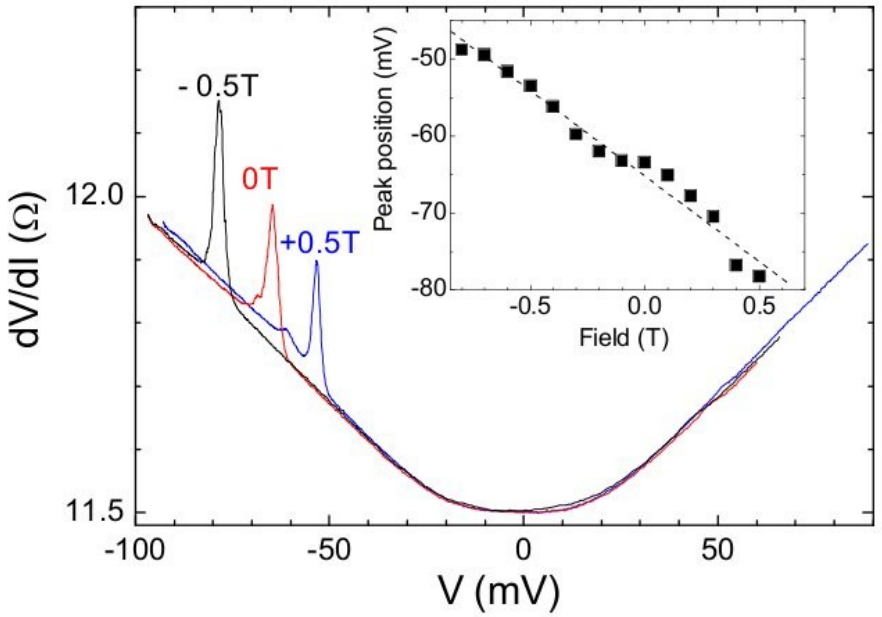


Spin Transfer Torque

- linair dependance -> STT

- spin polarized current!

- What is the history of SmCo5?



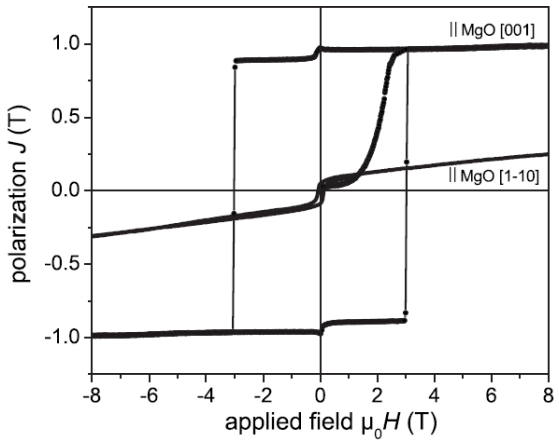
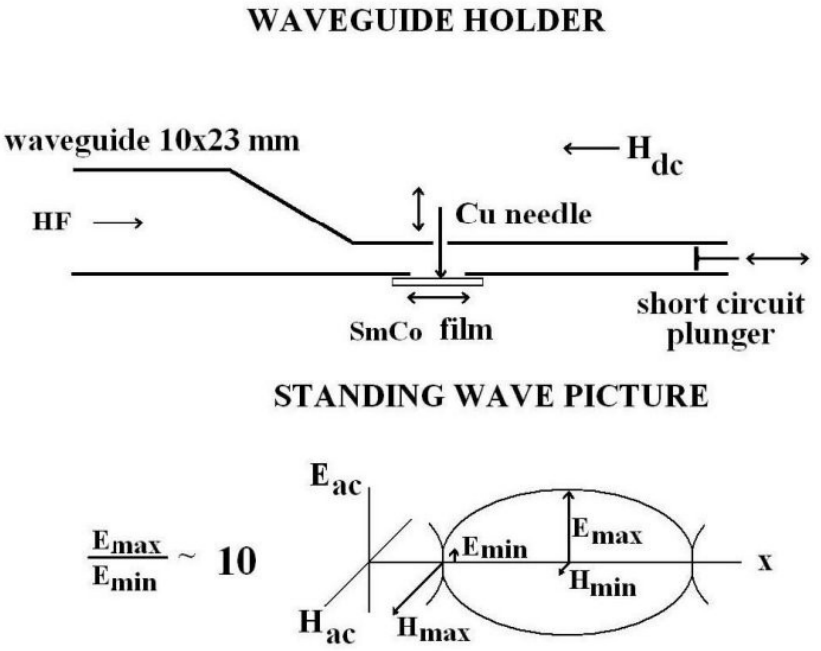


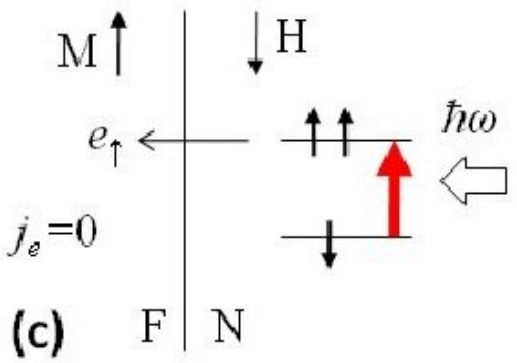
FIG. 2. Magnetic hysteresis of a $SmCo_5$ film measured along the easy magnetization axis (||MgO[001]) and along the in-plane hard axis (||MgO[1−10]).

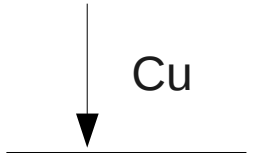
Setup

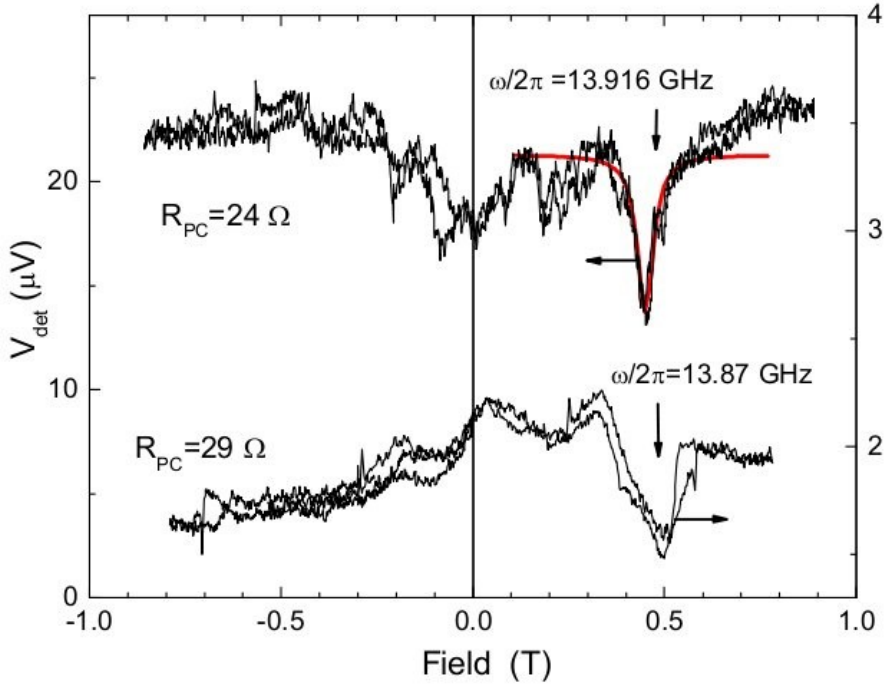


Modulate microwave power

Photon generation without bias

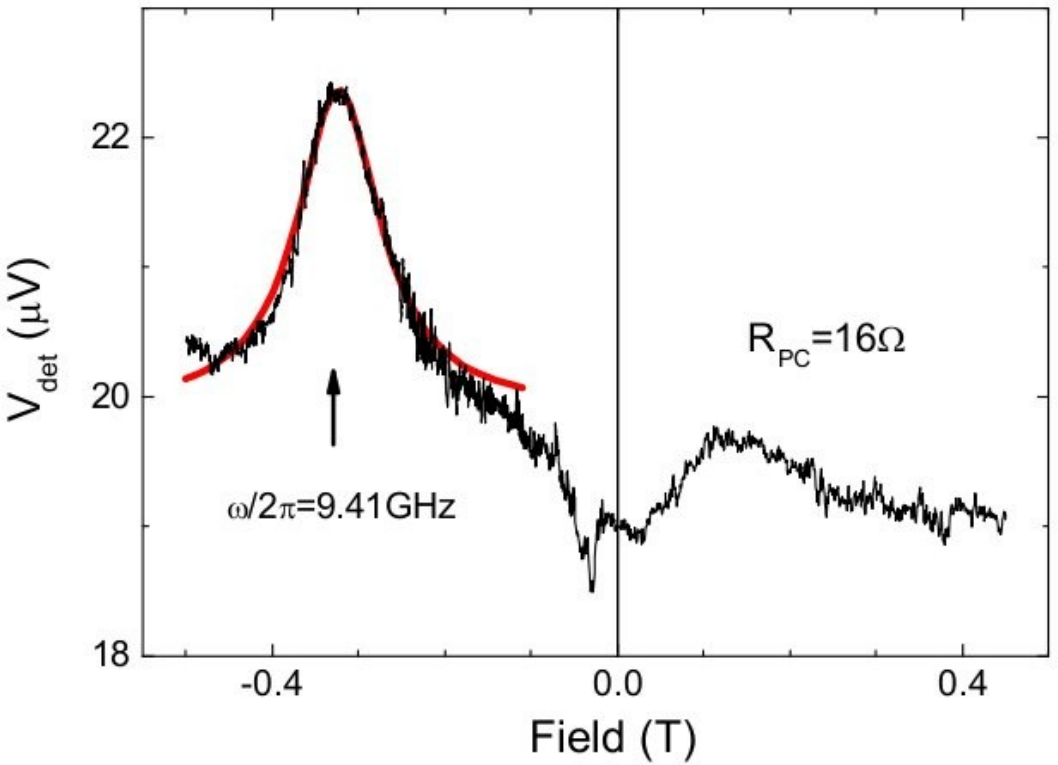


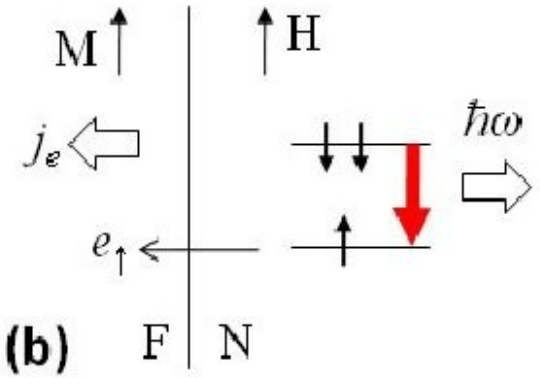




Photon generation with bias

Bias: -20mV





- no STT
- @ resonance, diameter pc increase -> dissipating power

Some numbers

- Spin relaxation time 100-500 ps
- 1% pc works (STT 5-10%)

Outlook

Nice physics, but is this all the data?