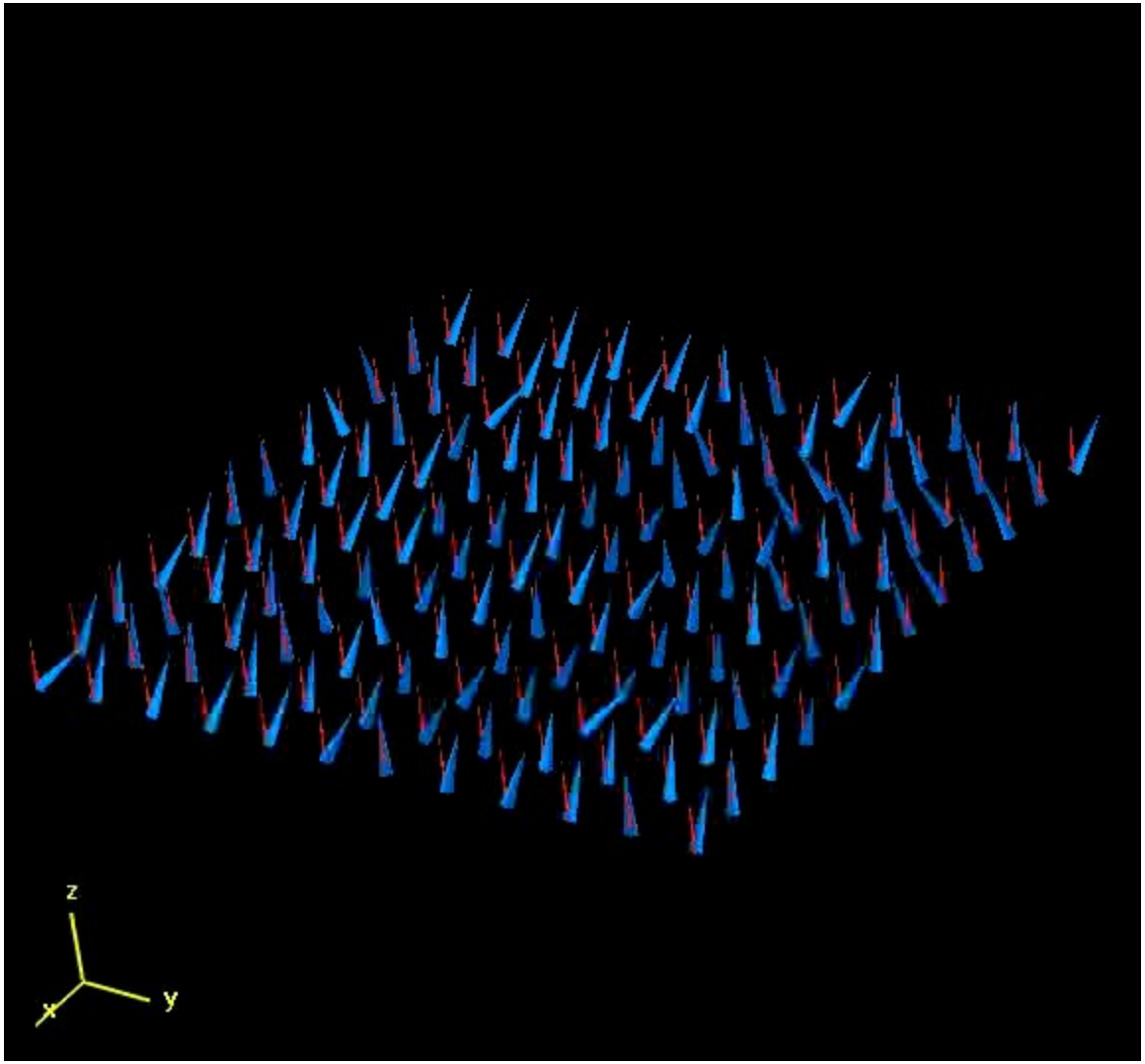
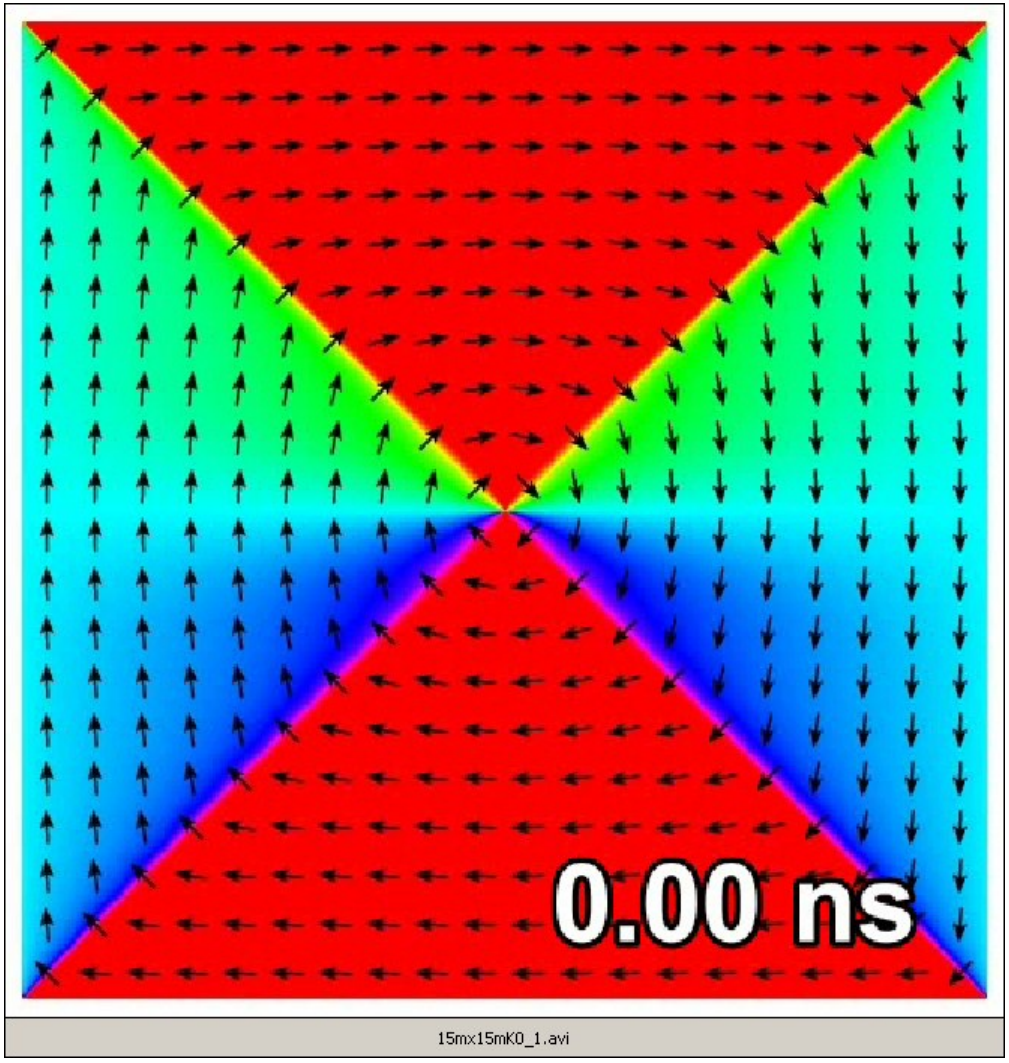
Spin Waves



Spin Waves

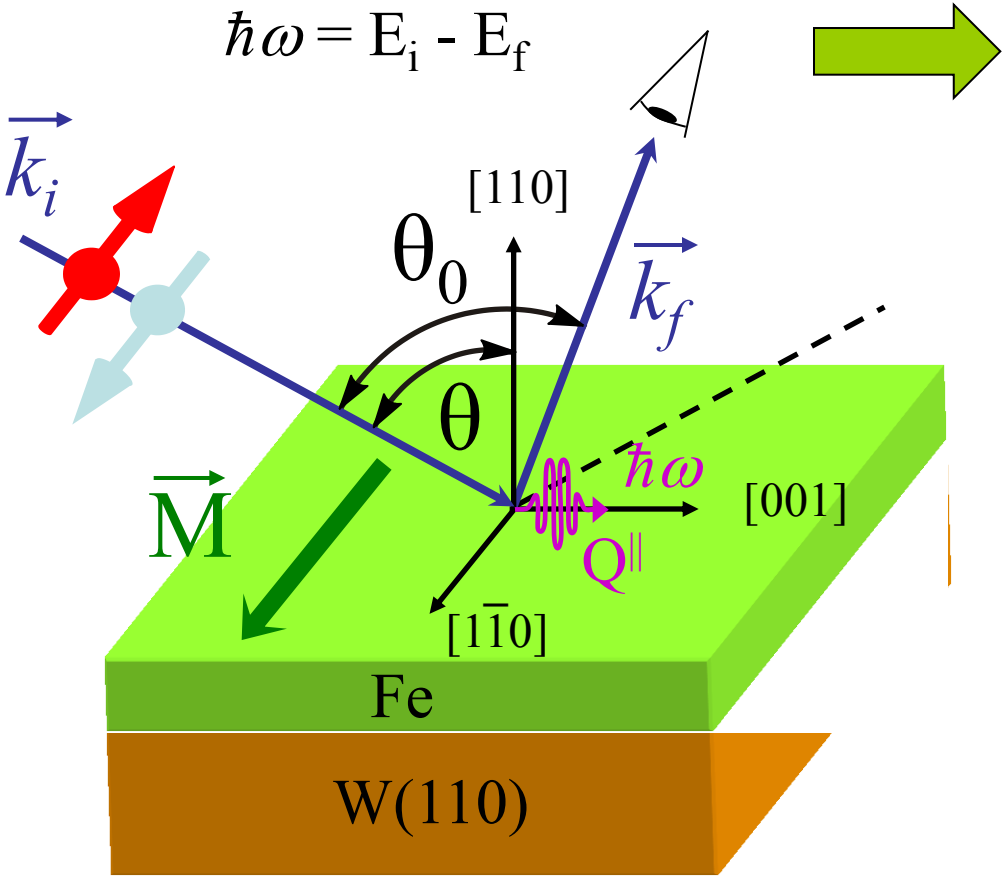


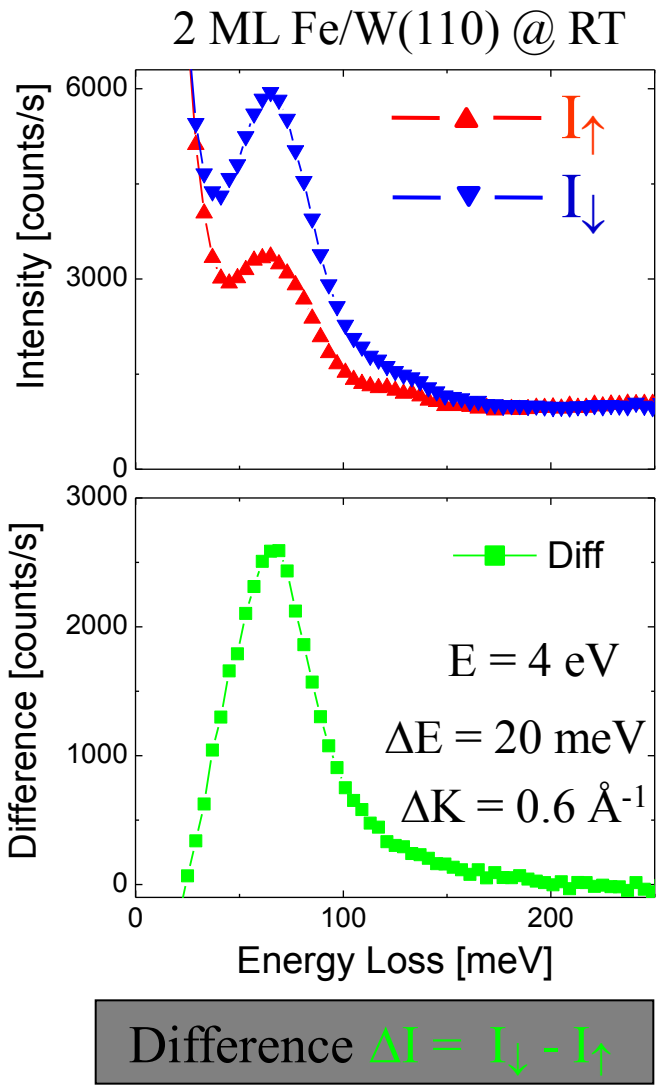
Spin Waves

Inelastic electron scattering – SPEELS

$$-Q^{\parallel} = \Delta K^{\parallel} = k^{\parallel}_f \sin(\theta_0 - \theta) - k^{\parallel}_i \sin(\theta)$$

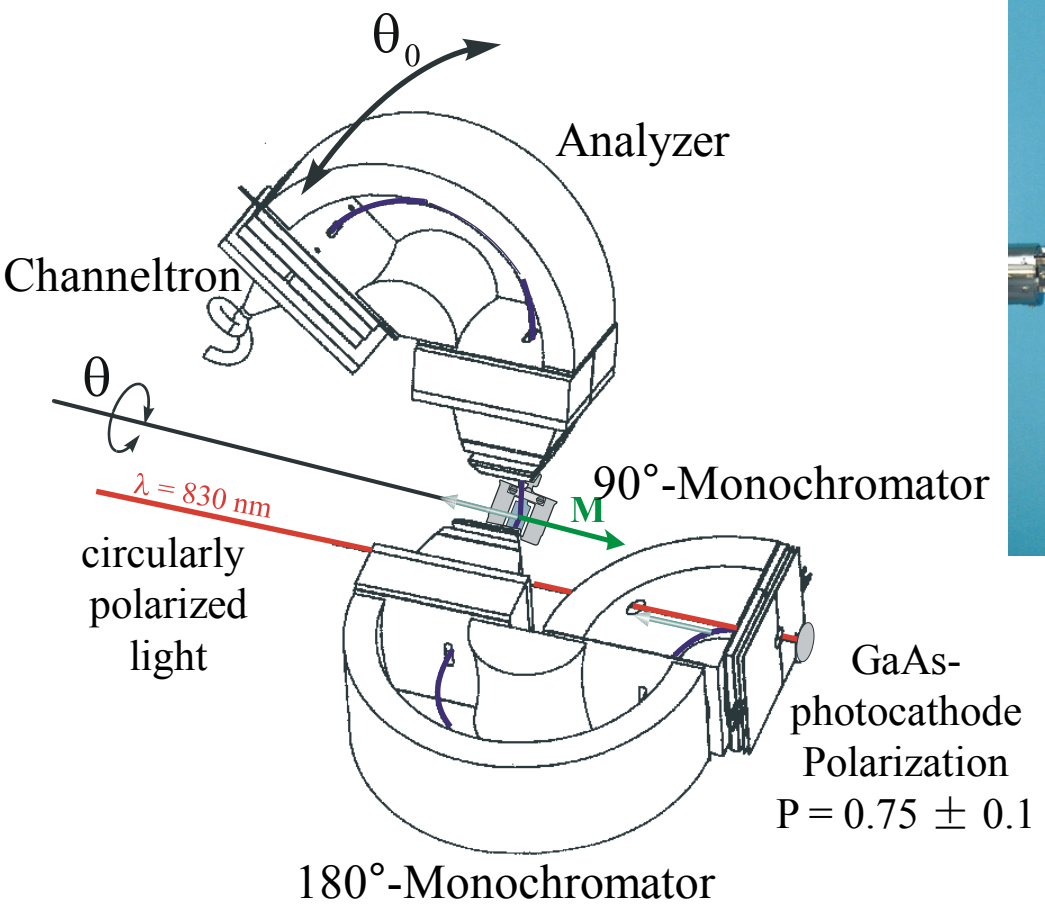
$$\hbar\omega = E_i - E_f$$

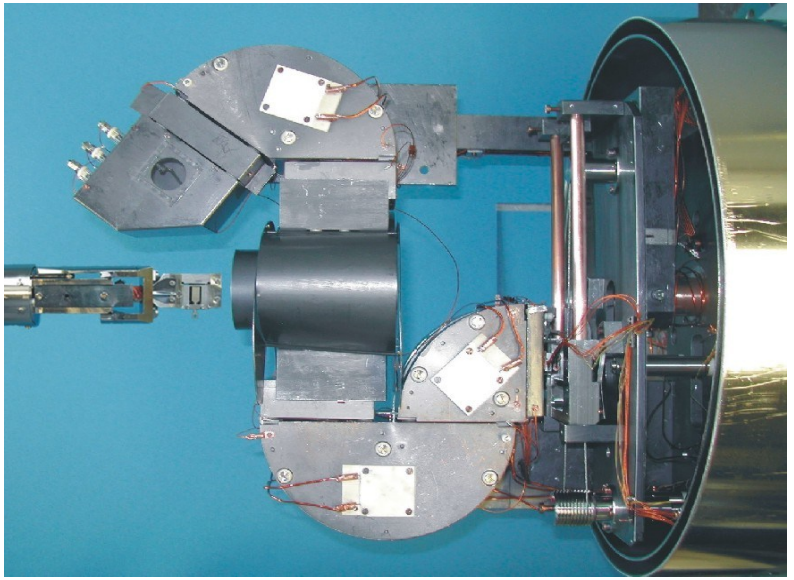


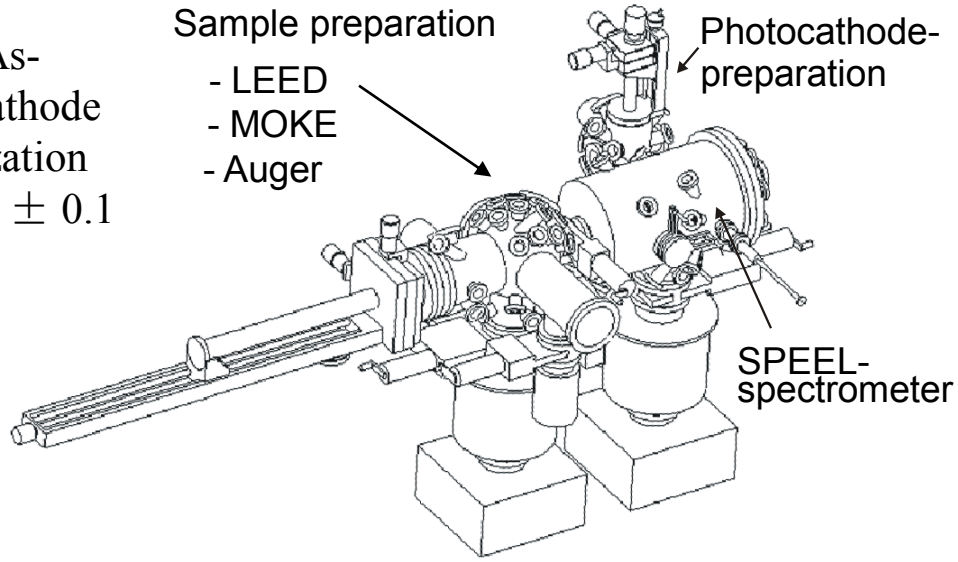


Difference $\Delta I = I_\downarrow - I_\uparrow$

The SPEEL – Spectrometer



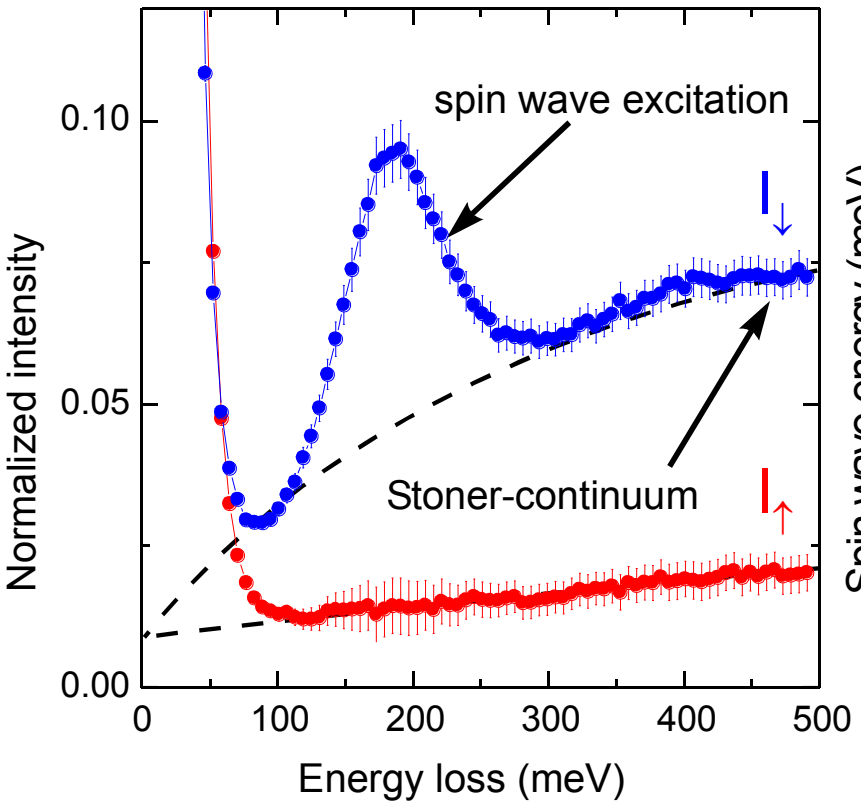


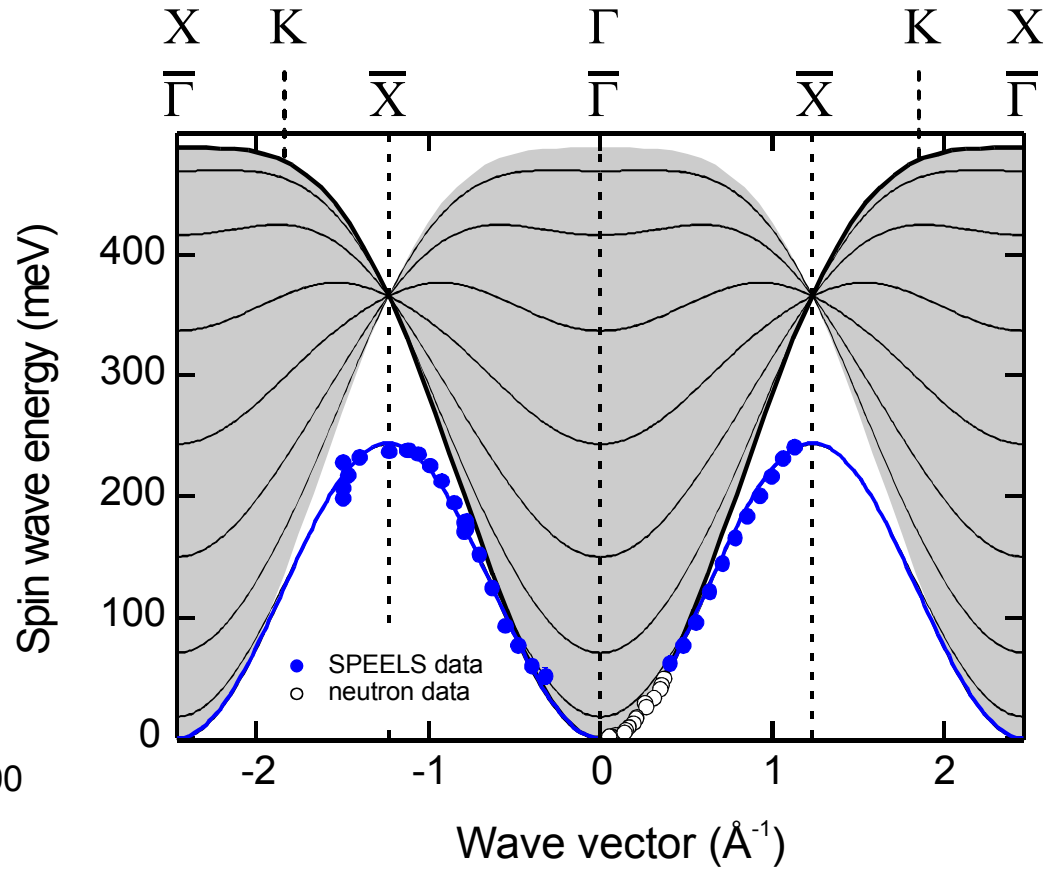


H. Ibach, D. Bruchmann, R. Vollmer, M. Etzkorn, P. S. Anil Kumar and J. Kirschner, Rev. Sci. Instrum., 74 (2003) 4089.

SPEELS – fundamental example

8 ML Co on Cu(001)





$E = 6.7$ eV

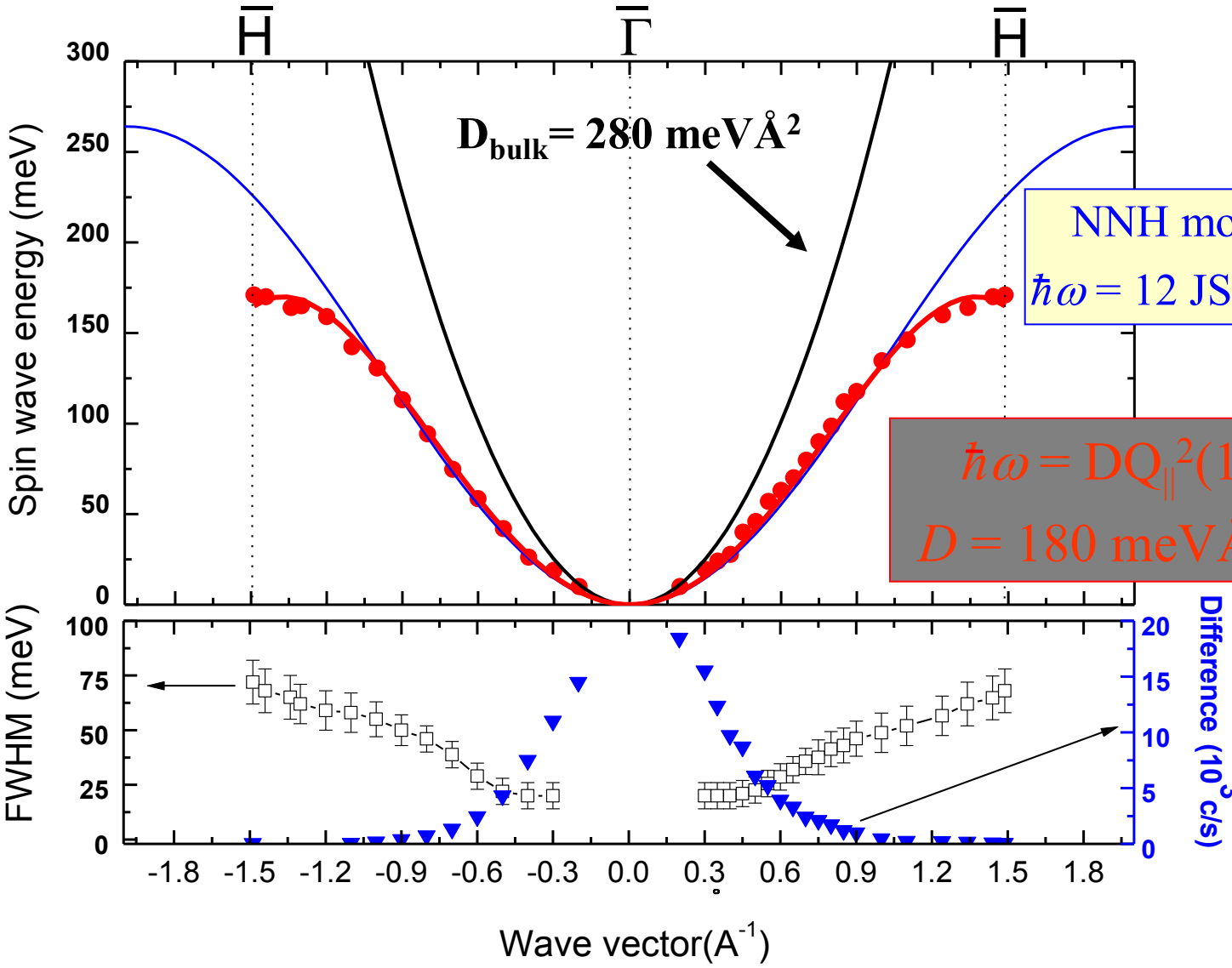
$\Delta E = 40$ meV

$\Delta K = 0.87$ Å^{-1}

R. Vollmer (†), M. Etzkorn, P. S. Anil Kumar, H. Ibach, J. Kirschner, Phys. Rev. Lett. **91**, 147201 (2003).

neutron data: R. N. Sinclair and B. N. Brockhouse, Phys. Rev. **120**, 1638 (1960).

Spin wave dispersion for the 2 ML Fe/W(110) film



NNH model for 2 ML Fe

$\hbar\omega = 12\ JS\ [1 - \cos(Q_{||}a_0/2)]$

$\hbar\omega = DQ_{||}^2(1 - \beta Q_{||}^2)$

$D = 180$ meVÅ² $\beta = 0.256$

E = 4 eV

ΔE = 20 meV

For $Q_{||} > 1.1$ Å^{-1}

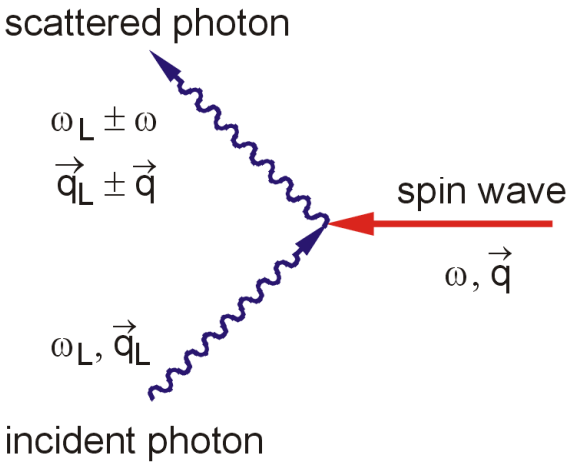
E = 6.25 eV

ΔE = 25 meV

W. X. Tang, Y. Zhang, I. Tudosa, J. Prokop, M. Etzkorn, J. Kirschner, Phys. Rev. Lett. **99**, 087202 (2007).

Brillouin light scattering (BLS) process

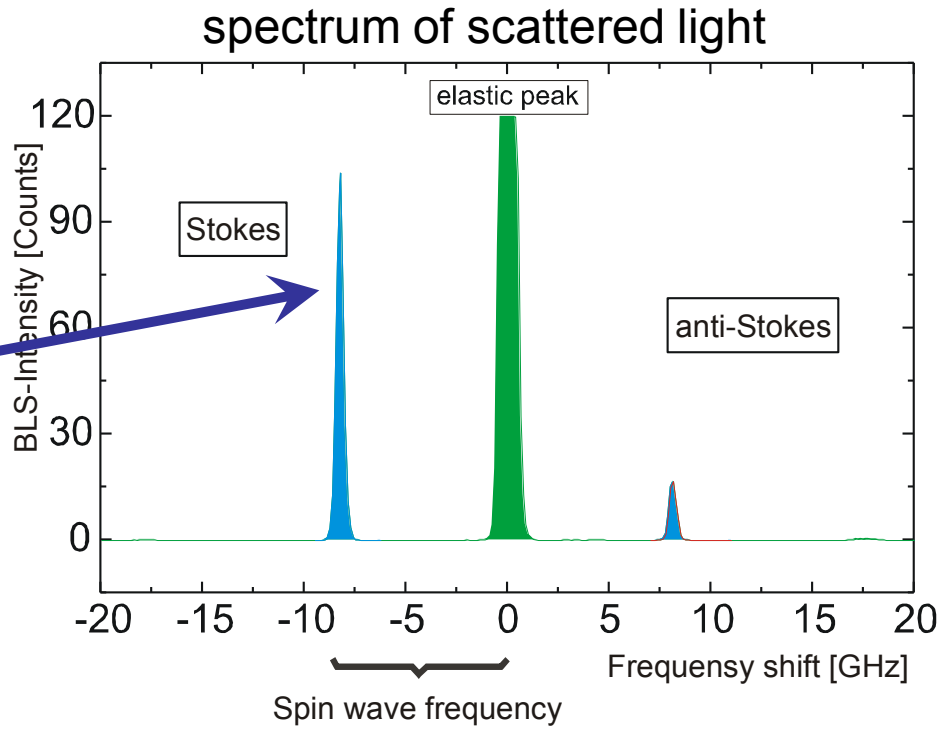
= inelastic scattering of photons from spin waves



$$\vec{q}_{SC} = \vec{q}_L \pm \vec{q}$$

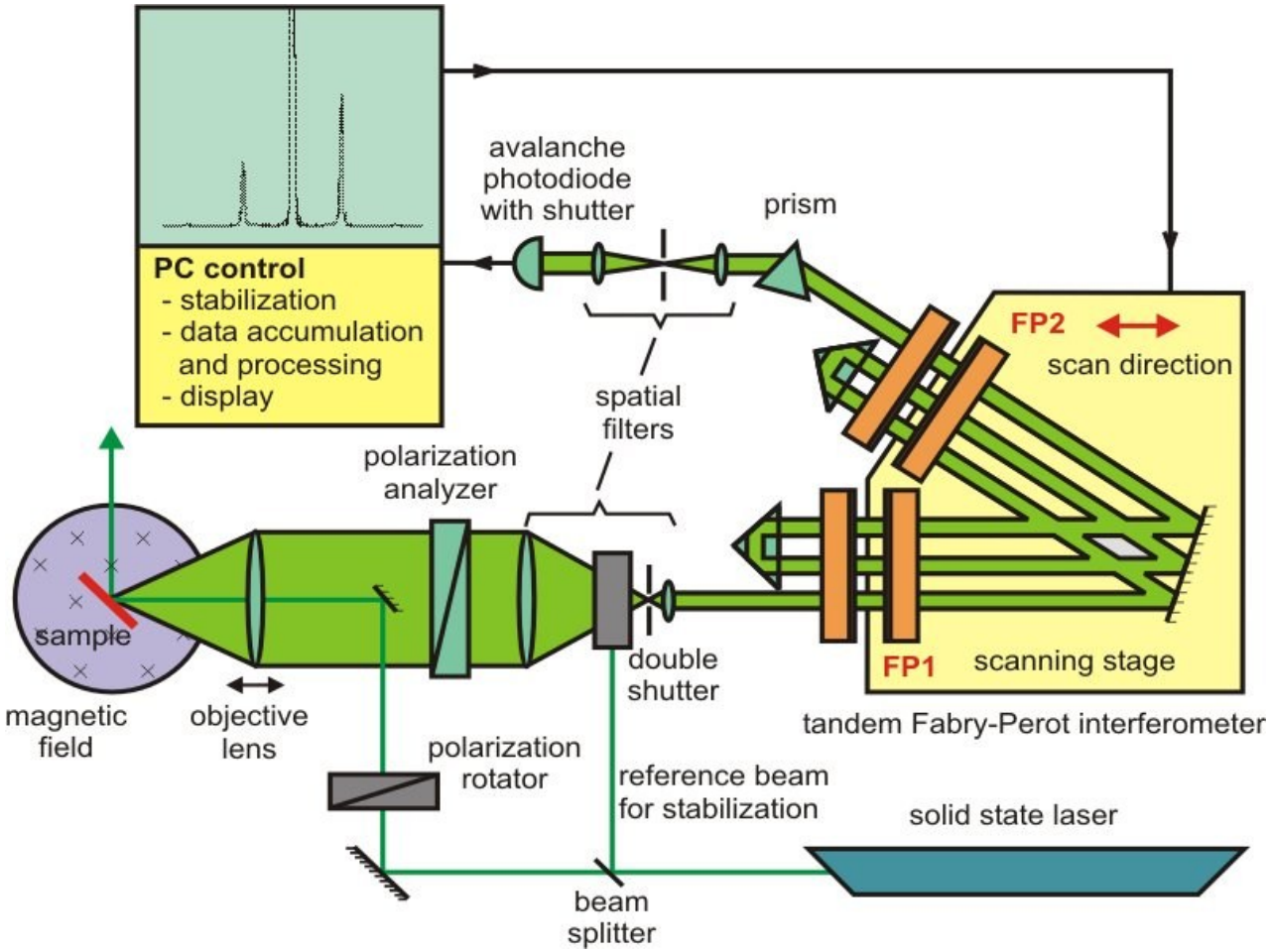
$$\omega_{sc} = \omega_L \pm \omega$$

proportional to the
spin wave intensity $|\varphi|^2$



Brillouin light scattering spectrometer

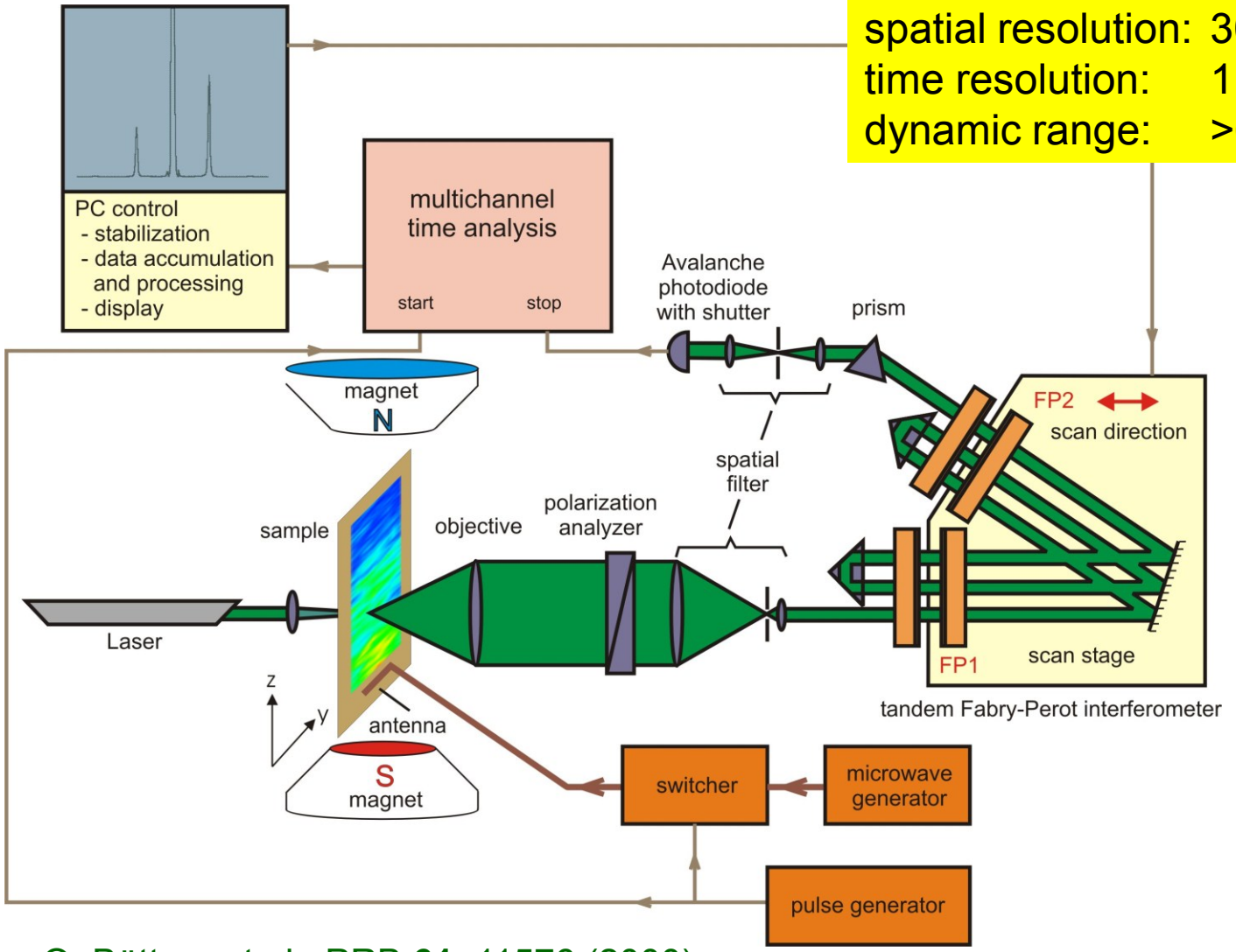
high-resolution interferometry with high contrast
for measurements of acoustic phonons and spin waves



Courtesy of J. Hamrle, TU Kaiserslautern

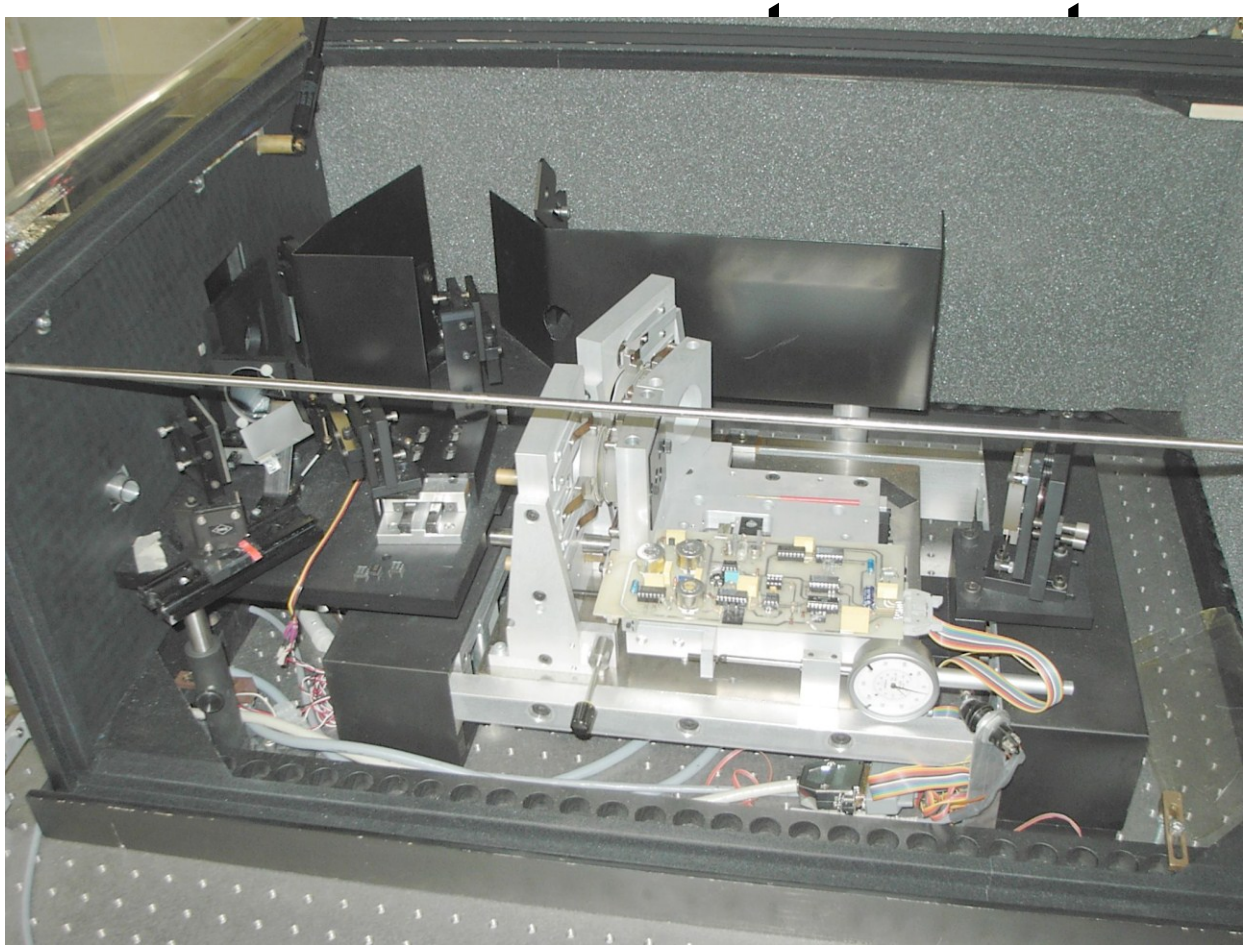
Space and time resolved BLS

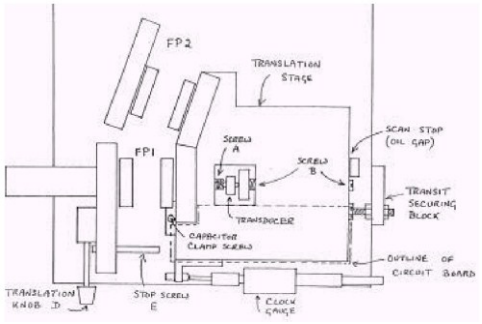
spatial resolution: 30 µm (300nm)
time resolution: 1.7 ns
dynamic range: >60 dB

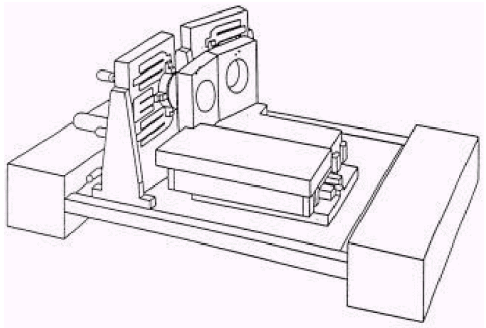


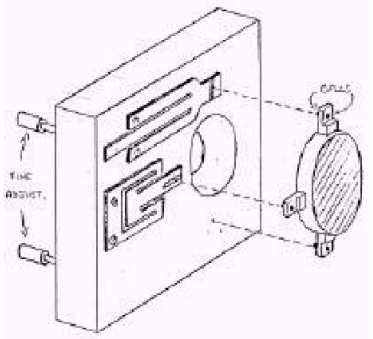
O. Büttner et al., PRB **61**, 11576 (2000)

Brillouin light scattering





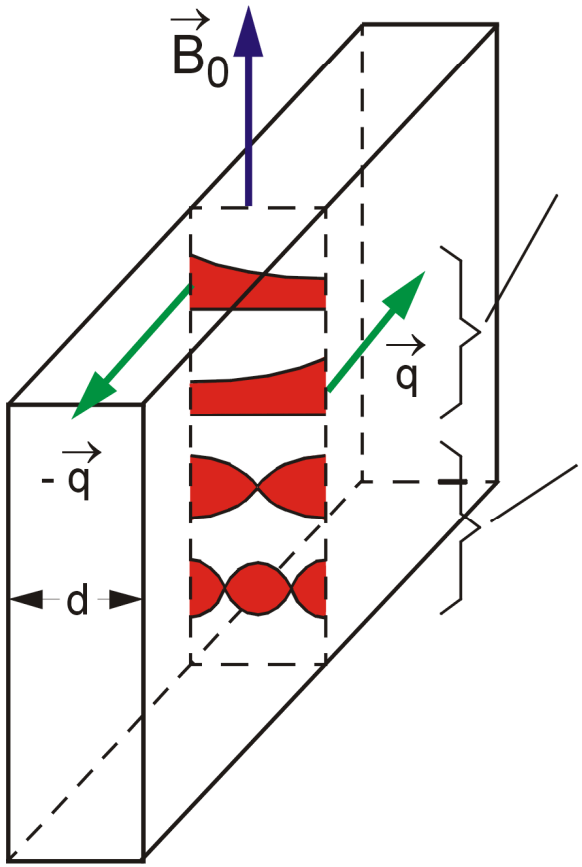




Tandem Fabry-Perot Interferometer

Sketches of mechanical stage and mirror mount for the FP1 rigid mirror are reproduced from John Sandercock's 1993 manual.

Spin waves in a magnetic film



Dipolar Damon-Eshbach modes

$$\omega^2/\gamma^2 = [B_0(B_0 + J_s) + (J_s/2)^2 (1- e^{-2qd})]$$

Standing spin waves

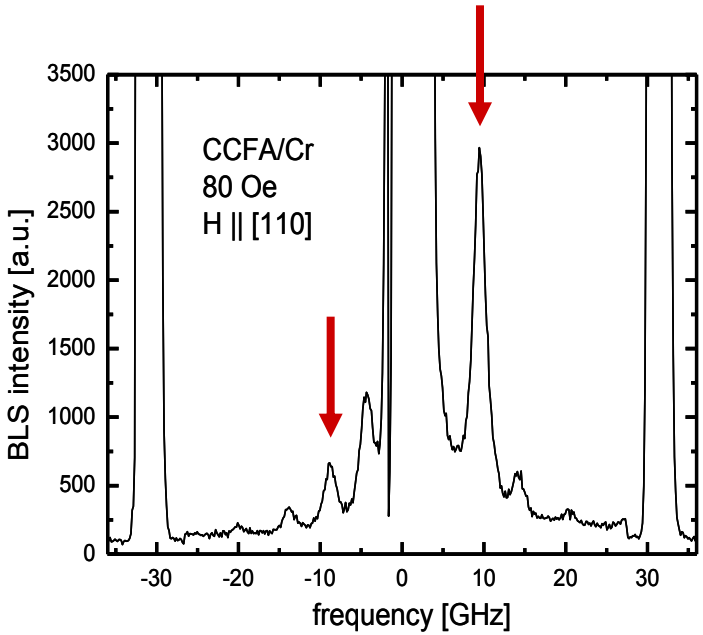
$$\frac{\omega}{\gamma} = \frac{2A}{M_s} \cdot q^2 = \frac{2A}{M_s} \left(\frac{n\pi}{d}\right)^2 \qquad n = 1,2,...$$

A: exchange constant

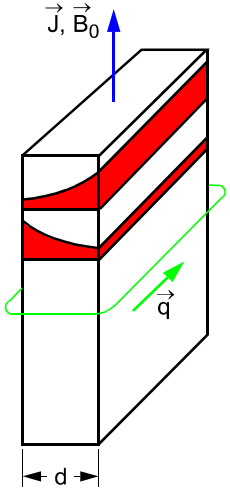
M_s: magnetization

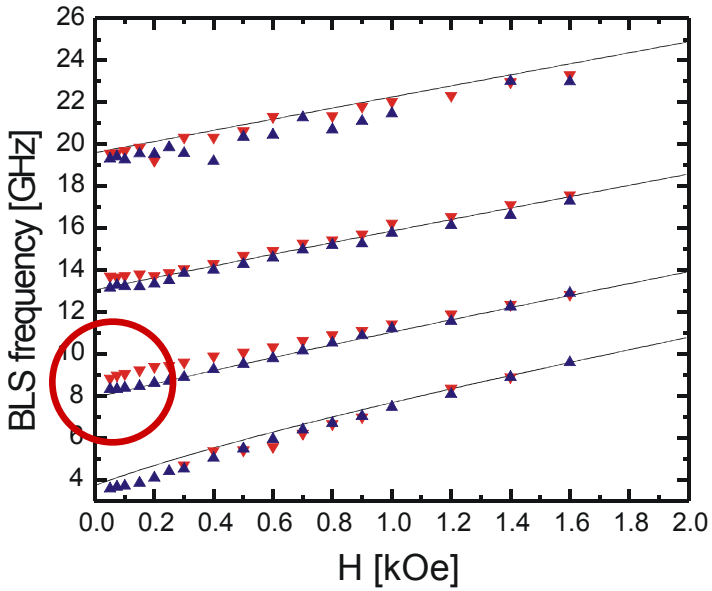
Heusler compound $Co_2Cr_{1-x}Fe_xAl$: Magnetic properties determined by BLS

Brillouin light scattering spectrum



Mesurement of perpendicular magnetization gradient



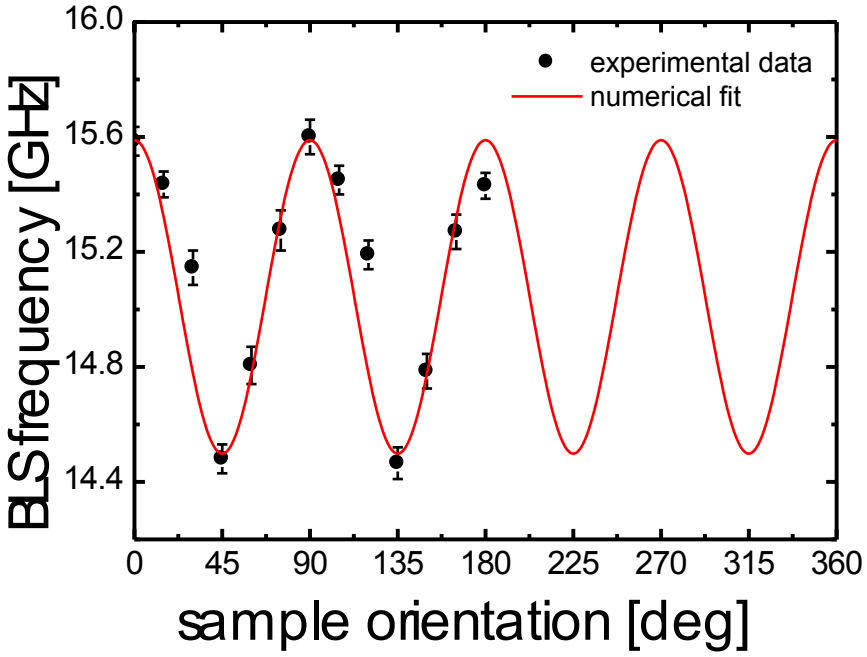


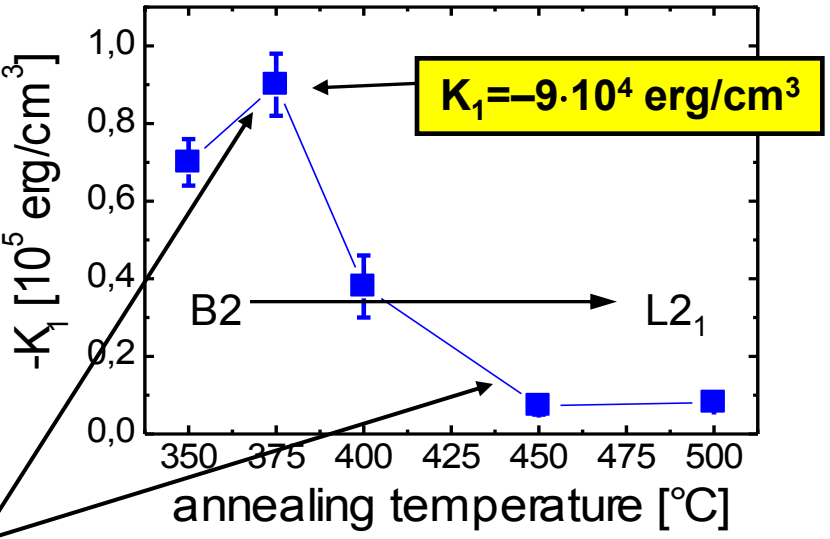
by fit to model found: A=0.48≯0.4 erg/cm^3 (for bcc Fe: A=2.0 erg/cm^3)

Courtesy of J. Hamrle, TU Kaiserslautern

Heusler compound Co_2MnSi: anisotropy and structural transition

Al(1.3nm)/Co_2MnSi(30nm)/Cr(40nm)/MgO(100):





volume anisotropy constant K drops down by a factor of 10

Courtesy of J. Hamrle, TU Kaiserslautern