# Magnetic Spin Structure in Multilayers Probed via Cross-Sectional Nuclear Resonant Scattering.


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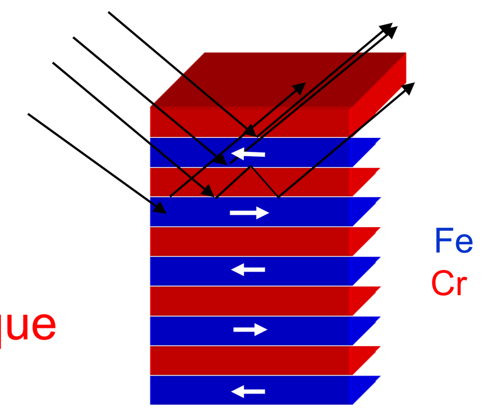
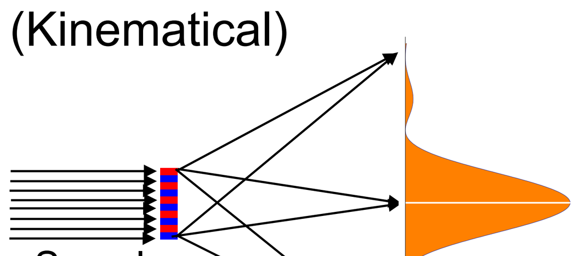
## Motivation

**Reflectivity**
Multiple scattering
(Dynamical)
Established technique




- Antiferromagnetic arrangement of magnetization between Fe-layers
- The light scatters many times from different layers
- Provide the magnetic structure of the whole system

**Diffraction**
Single scattering (Kinematical)
New approach!

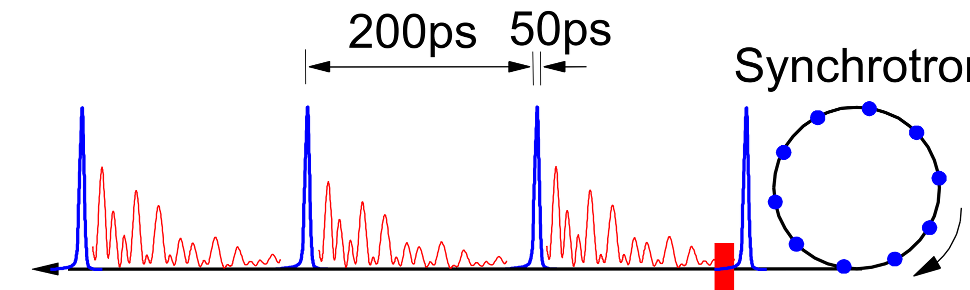


Sample:
cross-sectionally
Illumination / transmission

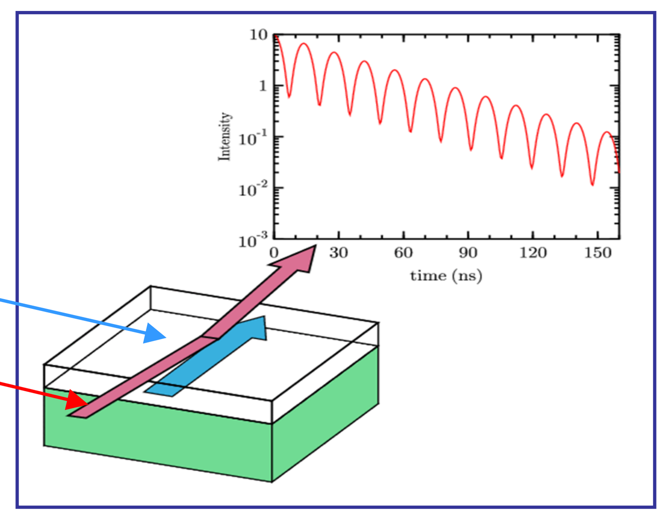
- Antiferromagnetic arrangement of magnetization between Fe-layers
- The light scatters only once from individual layers. Transmission though cross-sectionally Illumination in a thin sample.
- Can provide the magnetic structure of each individual layer

## Magnetic Sensitivity of Nuclear Resonant Scattering (NRS)

$^{57}Fe$
Resonance energy:
$E_0$=14.47 keV
Lifetime: $\tau_0$=141 ns



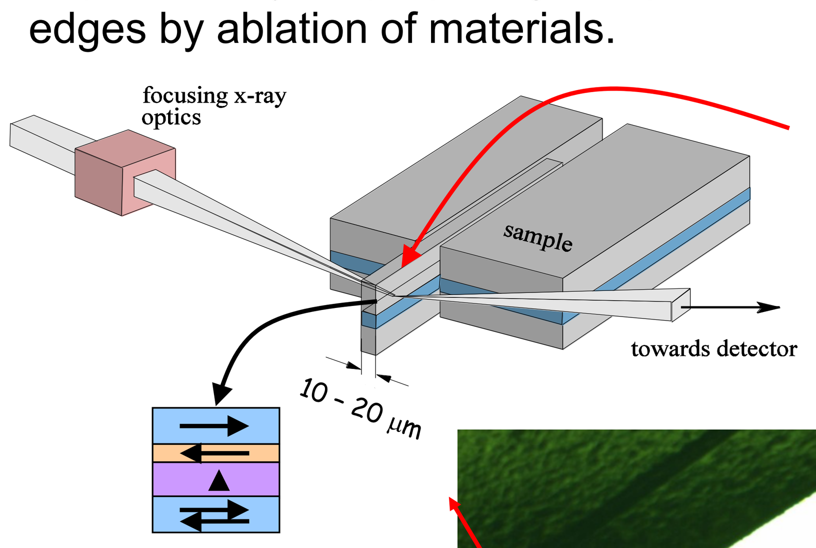

Beat pattern depends on strength and orientation of the Magnetic hyperfine field relative to the Photon wavevector and on its polarization



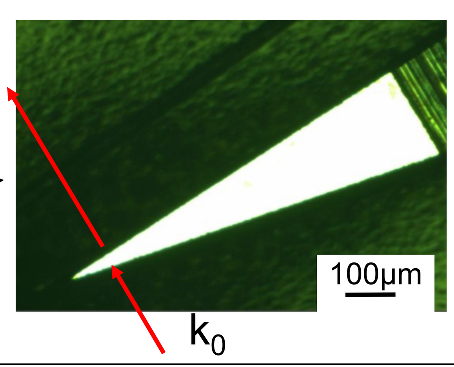
**NRS:**
- isotope sensitive
- sensitive to magnetic structure
- sensitive to magnetization dynamics

## Nuclear resonant scattering from magnetic layer systems using x-ray nanobeams

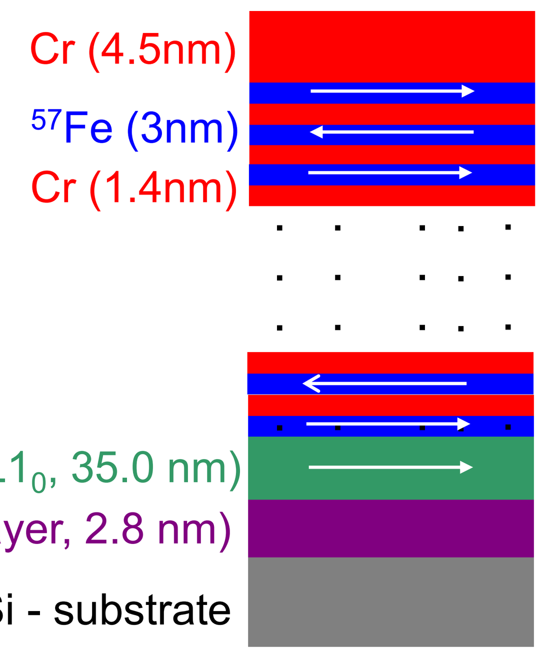
**Focused ion beam (FIB)**, is a technique used particularly for preparing sharp edges by ablation of materials.




Top view of the sample prepared by diamond saw cutting



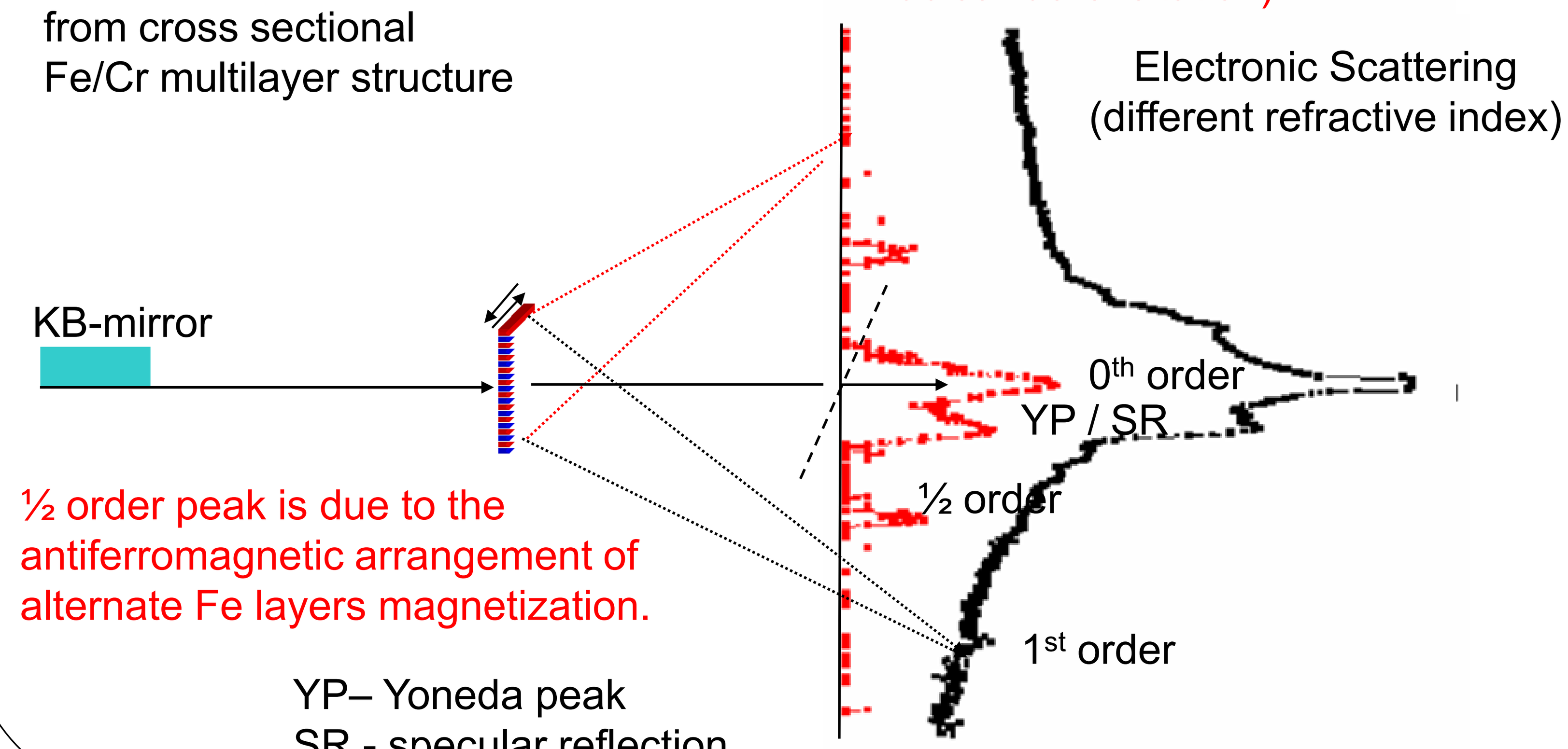

Future sample design via focused ion beam techniques (FIB)




$[Fe(3nm)/Cr(1.4nm)]_{30}/Fe_{55}Pt_{45}/Ta/Si$

## First Experimental results

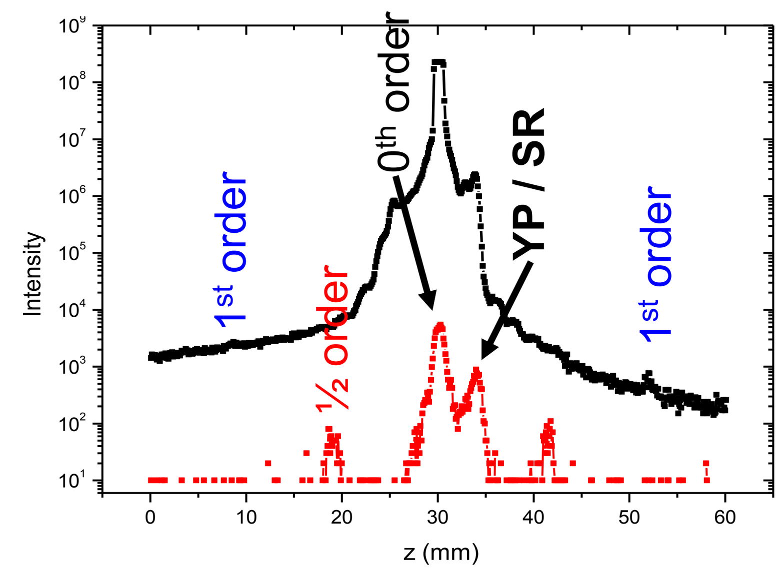
Experiment@ESRF ID 18,
Electronic and nuclear diffraction from cross sectional Fe/Cr multilayer structure

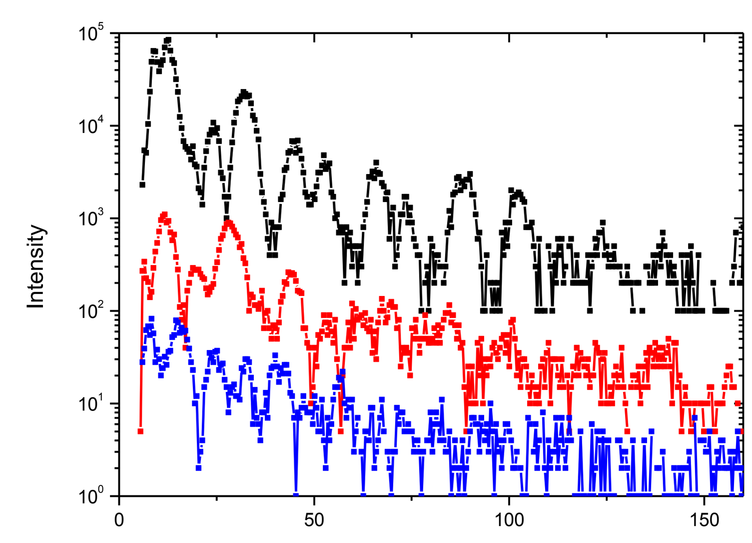



½ order peak is due to the antiferromagnetic arrangement of alternate Fe layers magnetization.

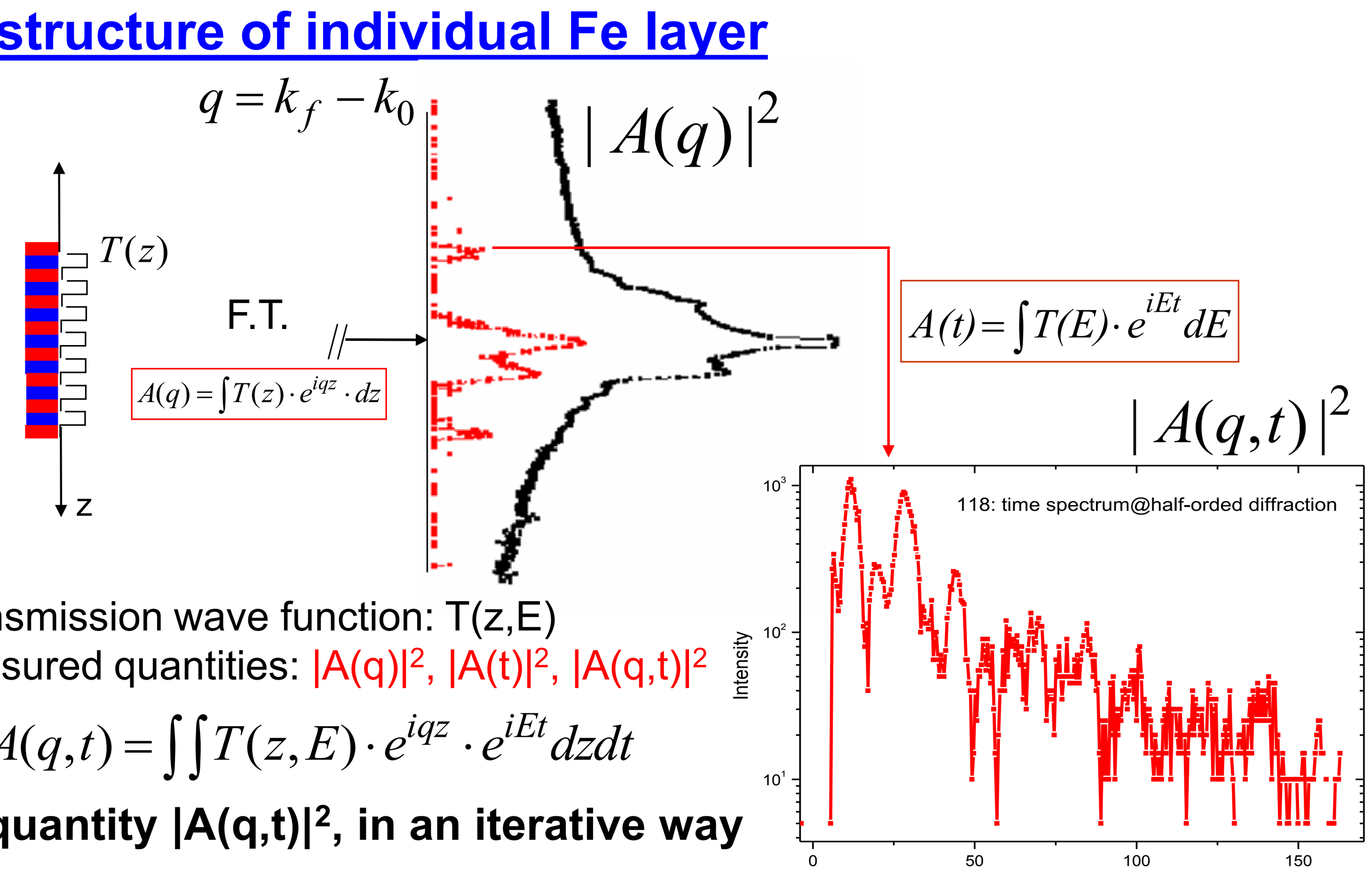
YP– Yoneda peak
SR - specular reflection

## Novel model for determination of magnetic structure of individual Fe layer




Time spectra measured at different order of diffraction peaks are different.
This information may be used to determine the spin structure at individual Fe layers in magnetic/non-magnetic multilayer system.

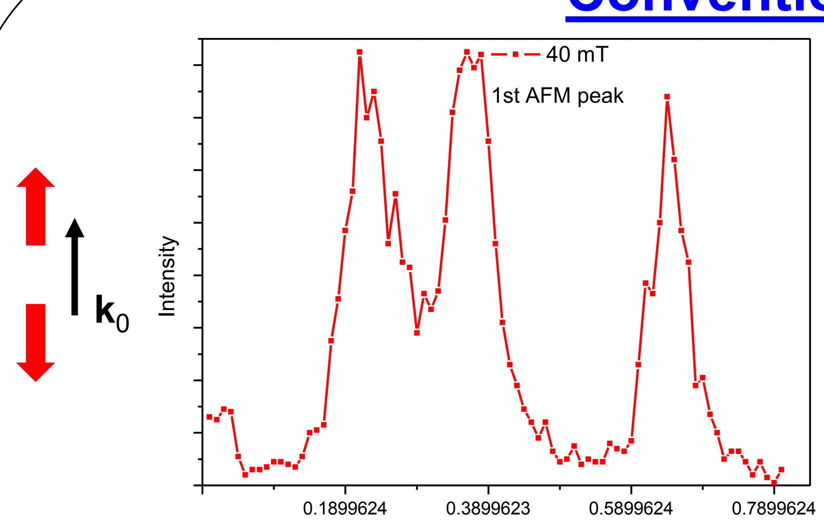



- Transmission wave function: T(z,E)
- Measured quantities: $|A(q)|^2$, $|A(t)|^2$, $|A(q,t)|^2$

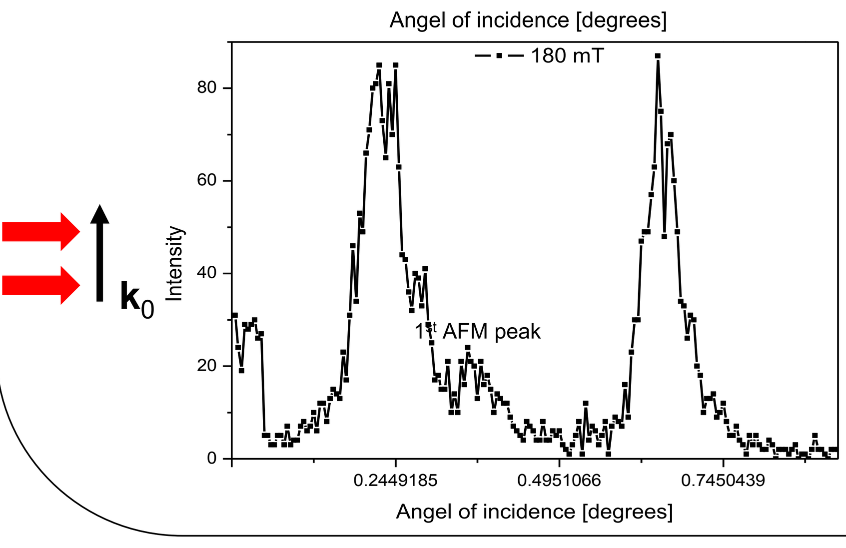
$$A(q,t) = \int\int T(z,E) \cdot e^{iqz} \cdot e^{iEt} dzdt$$

**Task:** Determination of T(z,E) by inversion of this equation with help of the measured quantity $|A(q,t)|^2$, in an iterative way

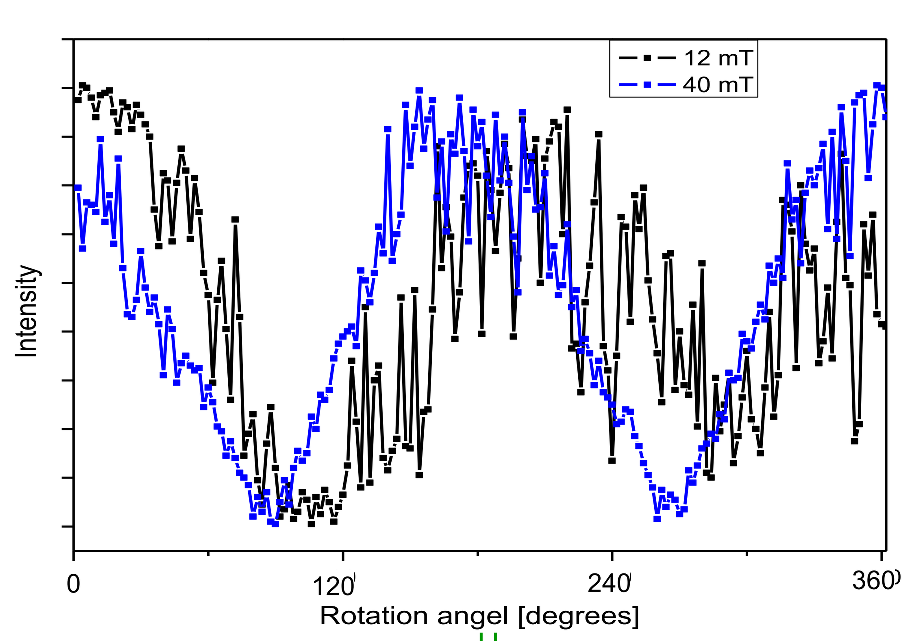
## Conventional way: Resonant grazing incidence Reflectometry



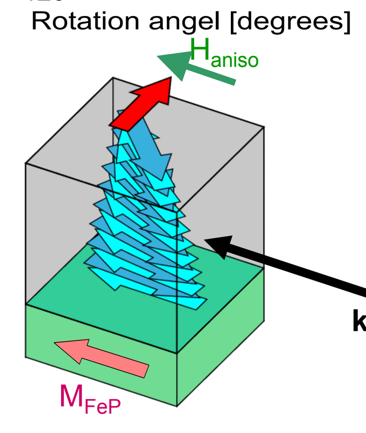

Reflectivity curve, measured at the easy axis of the sample at 40 mT external magnetic field (applied along hard axis).




Reflectivity curve, measured at the easy axis of the sample at 180 mT external magnetic field (applied along hard axis).




Rotating magnetic field scan at first AFM peak at different external magnetic field (12 mT and 40 mT).




Scattering geometry

## Outlook:

- Development of a new method to determine the magnetic structure and dynamics of deeply buried layers and interfaces:
- Combination of cross-sectional nuclear resonant diffraction, reflectometry and MOKE
- Magnetic structure of individual layers will be reconstructed from the time spectra measured at the diffraction peaks of different orders. First results look promising.
- Current induced magnetization reversal and spin-torque behaviour at different depths of the nanostructure will be studied.

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