Nuclear resonance reflectivity investigation of the field induced magnetization reorientation in antiferromagnetic [Fe/Cr]n multilayers

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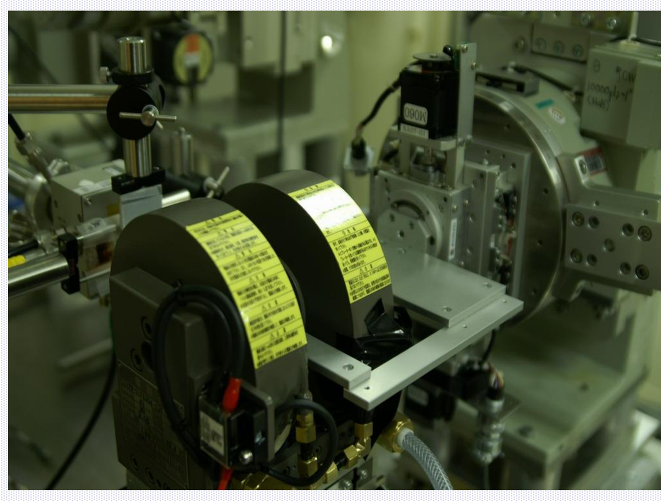
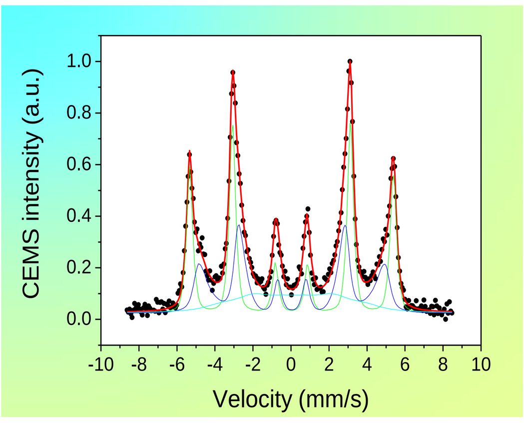
Extensive investigation of the magnetization reversal in the [^{57}Fe (3.0 nm)/Cr (1.2 nm)]$_{10}$ multilayer under the action of the applied magnetic field has been performed at the station BL09XU of SPring-8. Angular dependences of the nuclear resonance reflectivity (NRR) and the time spectra at the Bragg angles of different orders have been measured for different magnitudes of the gradually increased external field (0 – 1500 Oe) applied along (L-geometry) and perpendicularly (T-geometry) to the beam direction.

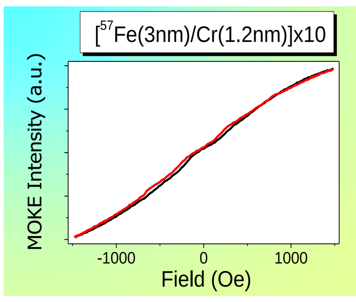


SAMPLES

Three samples
[^{57}Fe (2.0 nm)/Cr (1.2 nm)]x10,
[^{57}Fe(2.0 nm/Cr(1.2nm)]x20 and
[^{57}Fe (3.0 nm)/Cr (1.2 nm)]x10
have been grown in the Indore Center (India) by magnetron sputtering.



Moessbauer measurements (CEMS) give the broad line sextet, that indicates on the rather thick interfaces in the multilayer.

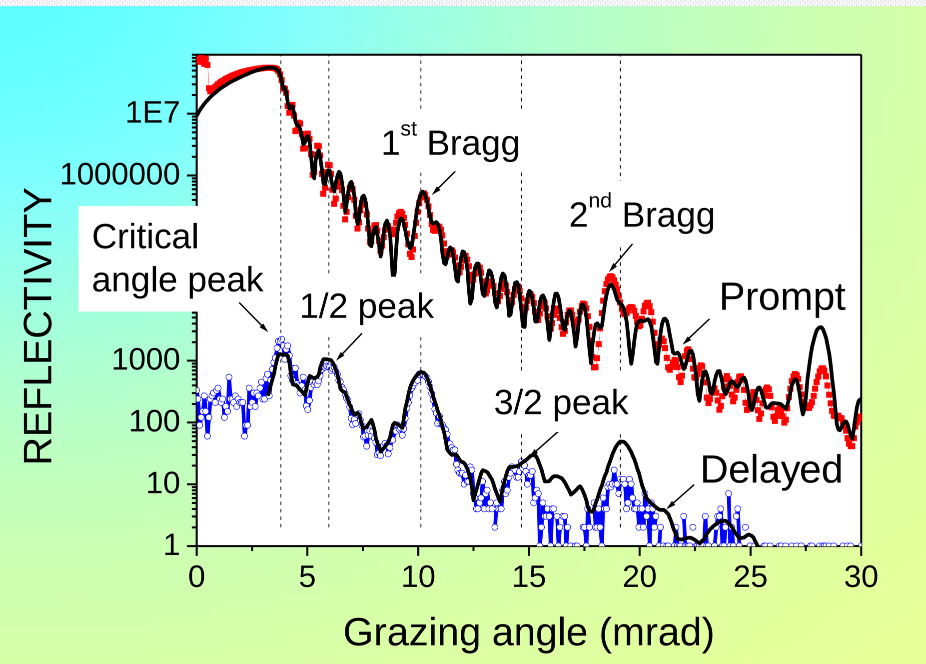


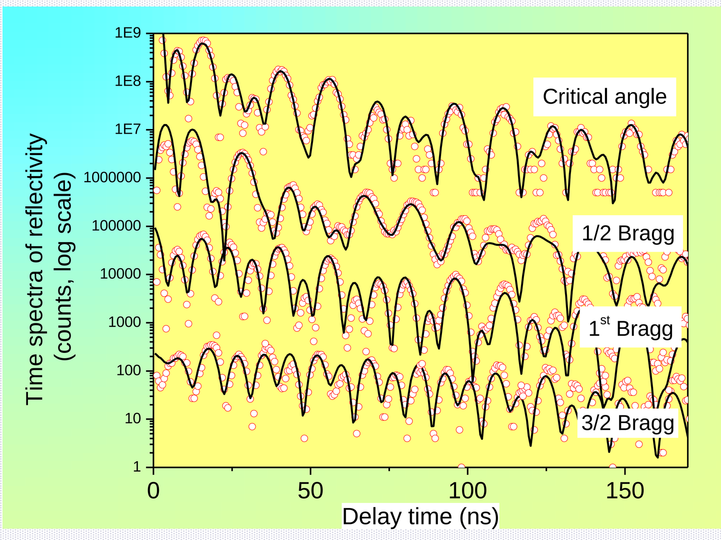
MOKE measurements confirm the AF interlayer coupling in the samples, but reveal the multi-domain structure of the film.

Experimatal results obtained at SPring-8

[Si/SiO$_2$](substrate)/Cr(10nm)/[^{57}Fe(3nm)/Cr(1.2nm)]x10/Cr(2.8nm)

No external field

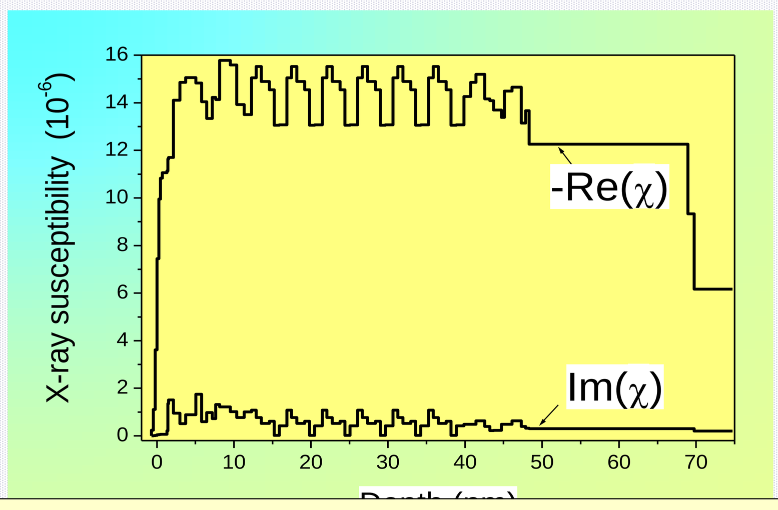




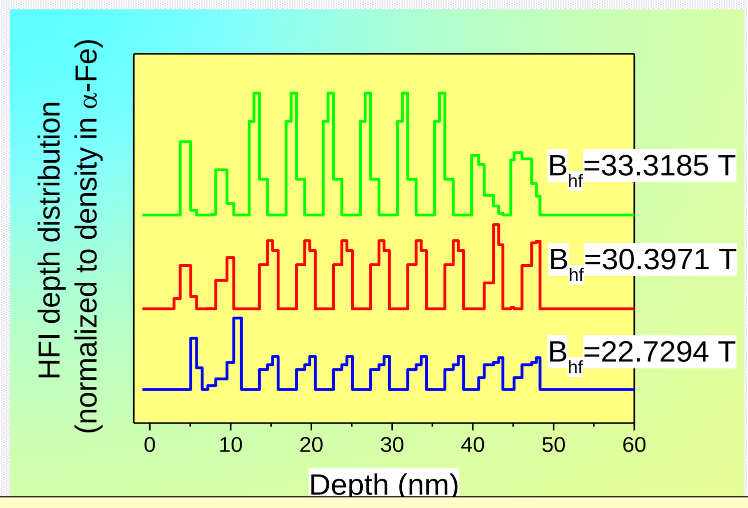
The investigated samples show the pronounced superstructure maxima (1/2 and 3/2) on the delayed reflectivity curves. That confirms the doubling of the magnetic period.

Fit results: depth distributions

Electronic density



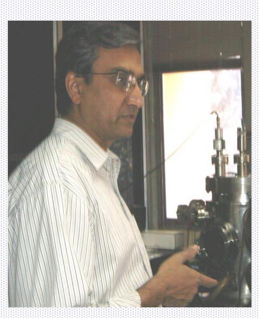
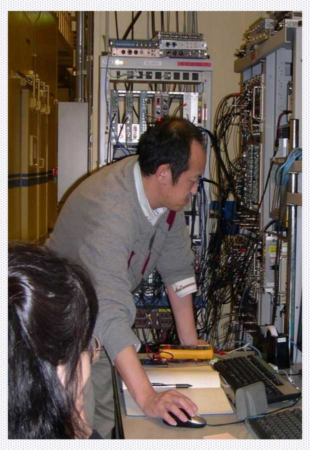
Hyperfine fields

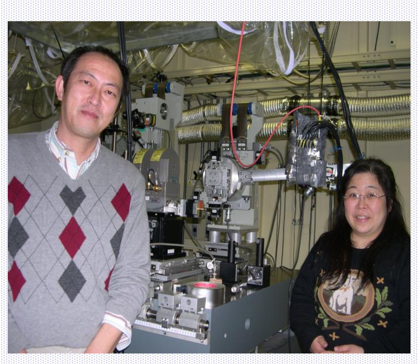


The fit of the prompt reflectivity curve gives us the electron density profile. It is not simple and we see that not only top Cr layer but also the surface [Fe/Cr] bilayer at the interface with Cr buffer layer are somehow distracted. The electron density of Fe and Cr layers differs from the table values due to some intermixture. The larger than the table values of Im(χ) in the interfaces can be explained by the roughness initiating the diminution of the specular reflection.
The fit of the delayed reflectivity curve should be done simultaneously with the fit of the time spectra of reflectivity which were measured at 5 angles: at the critical angle, at ½, 1st, 3/2 and 2nd orders Bragg peaks. We have got that the highest hyperfine field of 33.1 T is attributed to the nuclei situated preferably near the top interface. That means that the Fe-on-Cr interface is more diffused than the Cr-on Fe interface in our sample.

Our program package for the data treatment is "REFTIM"
(http://www.esrf.eu/Instrumentation/software/data-analysis/OurSoftware/REFTIM)

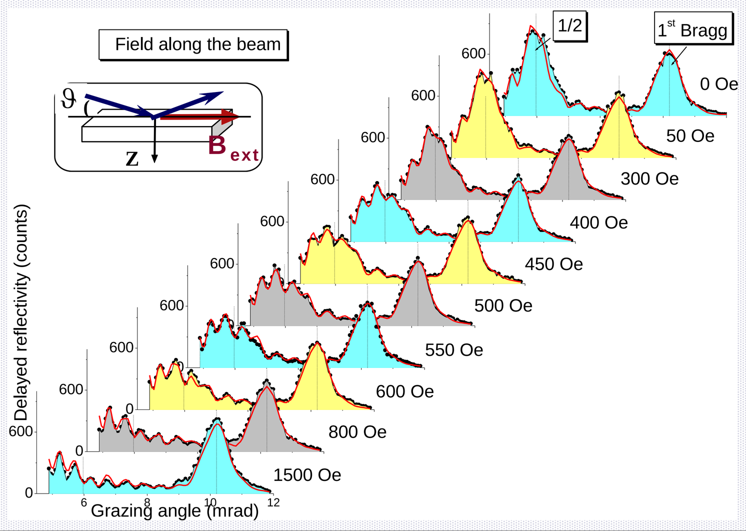
The results are published in http://arxiv.org/ftp/arxiv/papers/1507/1507.07074.pdf and accepted to PRB

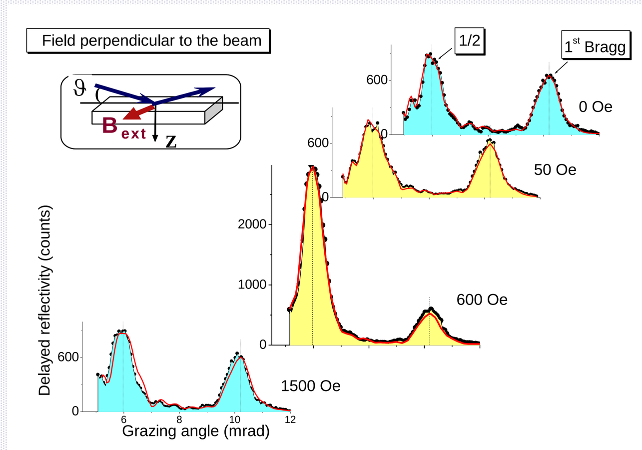



External field influence

Longitudinal geometry

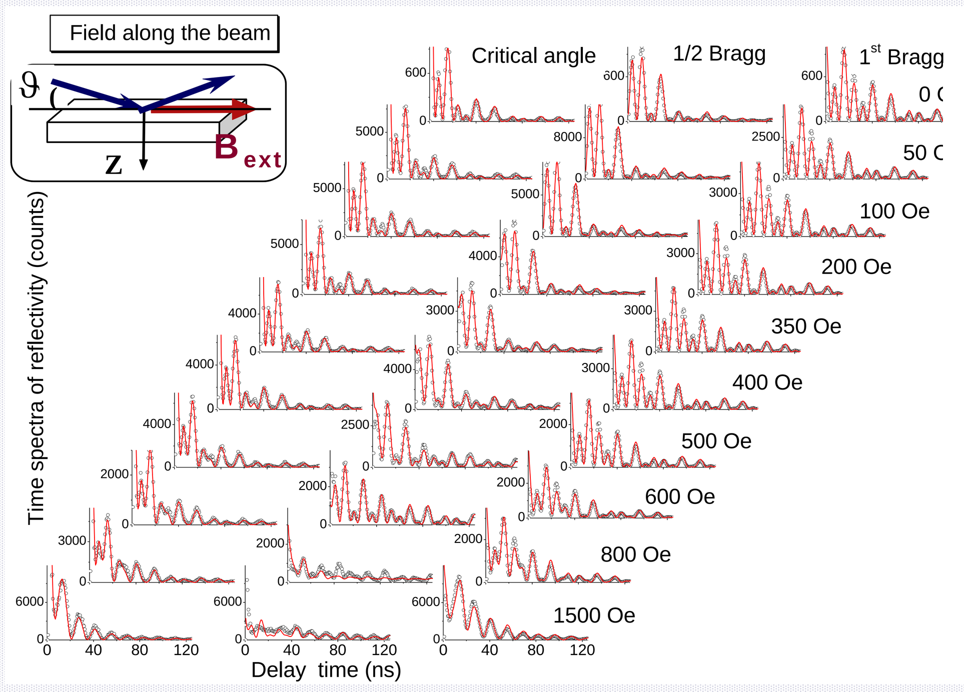


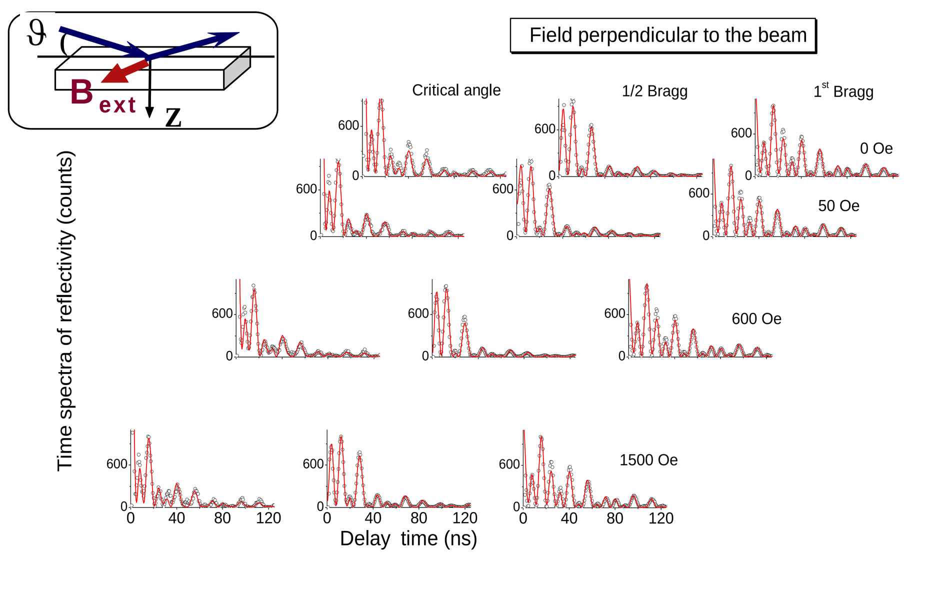
Transverse geometry



Delayed reflectivity curves as a function of the external field applied along the beam direction and perpendicular to it. The "magnetic" maximum (1/2 Bragg) essentially decreases in the longitudinal geometry at the medium field 600 Oe, but it increases at this value of the external field in transverse geometry.

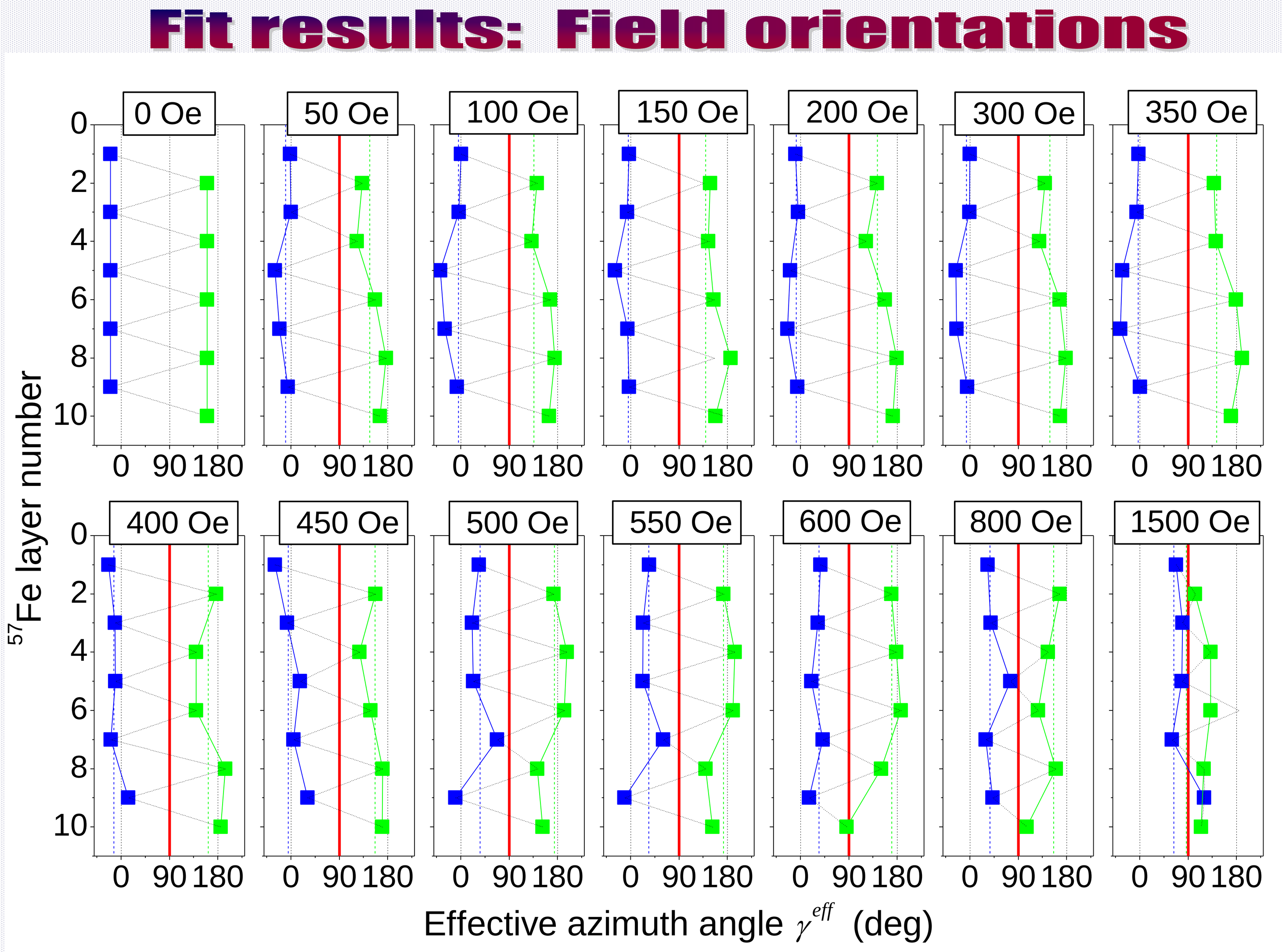
Time spectra are more sensitive to the influence of the external field





Time spectra of reflectivity as a function of the external field, measured at 3 grazing angles: at the critical one, at ½- and 1st-order Bragg maxima.

Fit results: Field orientations



The real meaning of the "effective azimuth angle" is discussed in the poster:
M.A. Andreeva "Transverse coherence of synchrotron beam and reflectivity data interpretation for magnetic multilayers"

Results

The obtained results gives a rather complicated picture of the layer-by-layer resolved reorientation of magnetization in ^{57}Fe layers under the applied field. The detailed analysis has shown that the collinear alignment in each magnetic sublattices and its cophasing rotation does not take place. We have seen that the reorientations even at the smallest applied field affected all layers but not just the top or bottom ones. The most specific magnetization state under the applied field is the twisted one, the bending details being the function of the applied field magnitude. The result should have some impact on the developing of the theory of the interlayer aniferromagnetic interaction. From our picture it is clear that in the theory we can not restrict ourselves by the interaction between just the adjacent magnetic layers, but should include the whole system simultaneously.

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