Report HE830: Imaging of Magnetic Domains in GdFe systems at ID21 (27.9.-3.10.2000)

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Aims of the experiment and scientific background

A detailed understanding of magnetic microstructures in ferromagnetic systems is nowadays an outstanding issue in magnetism both from a fundamental physics point of view and for technological applications. Thus a huge variety of various imaging techniques (e.g. Kerrmicr., Magnetic Force Micr., Lorentz TEM, SEMPA, PEEM, etc.) is currently available. It has been shown recently by the proposer that the combination of soft X-ray microscopy with Fresnel optics and X-ray magnetic cicular dichroism as an element-selective magnetic contrast mechanism allows for imaging magnetic domains on a nanometer length scale [1,2,3]. The major advantage of this technique in comparison e.g. with Photoelectron-Emissionmicroscopy (PEEM) is the possibility to record images in varying external fields to study the switching of the domains within complete hysteresis loops. As the penetration depth of soft X-rays is limited to less than 100nm the use of hard X-rays would allow for element-specific studies of the magnetic microstructure even for sample thicknesses in the micrometer range. The aim of the proposed experiment was to study the element specific properties of the microscopic domain structure in GdFe multilayers and nanostructures at the corresponding Gd L edges in varying external fields.

Results

As this was the first experiment on magnetic imaging on ID21 several commisioning tasks had to be handled.

a) Undulator/Ring

As the helical undulator (HU52) was operating for the first time for user experiments, the parameters of the required gaps to obtain circularly polarized light had to be determined. There is an asymmetric field distribution between x- and z-magnet arrays. Gap scans in x- and z-direction were performed and gave optimum values of x=9.6mm and z=13.5mm. The encoder of the undulator allowed only values up to ±12.46mm. A direct proof of the emission of circularly polarized light by detecting the X-MCD effect could not be obtained.
Beam instabilities that occurred during that period from time to time did not allow accurate spectroscopic scans, which even could not be removed by proper normalization procedure. This might be due to angular deviations of the beam.

b) Monochromator

The monochromator works up to the Gd L3 edge (>7.2keV), however the count rate drops drastically due to a Rh mirror. There is sufficient flux at the Fe K edge. The energy resolution of 10-4 is sufficient for X-MCD spectroscopy.
There is no monochromator stabilization and feedback system available. However this anticipates stable beam conditions. Studying systematic deviations in measured absorption spectra these could be traced back to the feedback system of the cooling systems for the monochromator. Several "glitches" at certain energies could also be observed.

c) Zone plates

The zone plates used for this experiment were not optimized for the energy range of 6-8keV. Either the thickness of the central stop in the zone plates used was not enough or the focal length was that large that the resolution is determined by the source size (approx. 2.2mum vert. and 9mum hor.).

d) Io Detector

Io detection was obtained by measuring the scattering on a Kapton foil with a diode. It turned out that this signal had a low SNR and thus could not be related to the transmitted signal.

e) Fluorescence detector

Recording the fluorescent yield at a EuIG sample allowed to take non-magnetic absorption profiles. However, no magnetic signal could be detected. This might be due that in remanence the net magnetization is 0.

There was no magnet system available to saturate the samples.

Conclusion

The aim of the experiment to image magnetic structures with hard X-rays was not reached at all.

Several attempts to detect spectroscopically X-MCD effects both at L edges in Gd and Eu and at the K edge in Fe failed. This was mainly due to the instabilities of the ring and the monochromator. It should be mentioned that measuring the X-MCD effect at the Fe K-edge is a standard procedure to estimate the degree of circular polarization e.g. at HASYLAB.

The microscope seems to be better suited at lower photon energies. The resolution (5-10mum) should be sufficient to see magnetic structures that could be detected in a Kerr microscope. In the Eu-garnet sample we could proof the existence of magnetic domains with a polarized version of the optical microscope at ID21 on-site.

Outlook

Despite the failure of this pilot experiment the use of ID21 to image element-specifically magnetic domains is still challenging. Currently there are other groups in Japan and USA that also work in that field [4,5]. However this requires an improvement of the experimental set-up, i.e. fully characterized undulator, stable monochromator, low SNR detection with e.g. ionisation chambers for I0 and I1.

According to the zone plates that are currently available at ID21, magnetic systems with absorption edges at lower photon energies (e.g. Pd L edges) seems to be more suited for the moment.

Once the first magnetic domains can be imaged at ID21 an outstanding challenge would be to incorporate also the tilting stage which would allow for a tomographic imaging of the magnetization.

References

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