| ESRF | **Experiment title:** Antiferromagnetic domains in thin Ho and Dy films | **Experiment number**: HE-963 |
|---|---|---|
| **Beamline**: ID10A | **Date of experiment**: from: 27-June-01 to: 10-July-01 | **Date of report**: Feb 28, 2002 |
| **Shifts:** 36 | **Local contact(s)**: G. Grübel | *Received at ESRF:* |

**Names and affiliations of applicants** (* indicates experimentalists):

**Christian Schüßler-Langeheine*, Holger Ott*, Denis Vyalikh*, Daniel Wegner*, Eugen Weschke**

**Institut für Experimentalphysik**
**Freie Universität Berlin**
**Arnimallee 14**
**14195 Berlin**
**Germany**

## Report:

Intention of the experiment was to investigate helical antiferromagnetic domains in Ho- and Dy-metal films grown in situ in UHV on W(110). In the helical phase, the magnetic moments in each basal plane of the hcp-crystal structures are ferromagnetically ordered with each plane being rotated by a certain angle against the neighboring planes thus forming a helical structure along the crystallographic *c*-axis. This magnetic superstructure gives rise to additional reflexes of magnetic origin in the diffraction pattern. These reflexes are situated symmetrically around each charge-scattering Bragg peak offset by the magnetic modulation wave vector $\pm\tau$. For such a helical structure, two different magnetic domains with different helicities may exist. By magnetic x-ray scattering using circularly polarized light, a domain contrast can be achieved. One helicity domain gives rise to the $+\tau$ satellite, the other to the $-\tau$ satellite.

In 1997, the domain ratio of a Ho bulk single crystal has been investigated by Sutter *et al.* using this method and a value close to unity was found [1]. We tried to perform the corresponding experiment on thin epitaxial Ho and Dy films. These films can be grown on W(110) in UHV with high crystalline quality [2,3]. Earlier experiments at the ESRF showed, that these films have a bulk-like magnetic structure down to a thickness of at least 30 ML [4,5]. The scattering data also prove that the magnetic coherence perpendicular to the film surface is of the same extension as the whole film thickness. From this we conclude that domain walls along the helix-propagation direction, which are known to be about 10 layers thick [6], do not occur in thin films. From x-ray topography data of Ho one can further conclude that the lateral extension of magnetic domains can reach several square micrometers [7]. Therefore, we expected to achieve a strong domain asymmetry in the scattering volume and from that a strong contrast in the scattering data.

At ID10A, circularly polarized light is produced by means of an x-ray phase plate inserted into the beam [8]. For our experiment, a new goniometer for the phase plate was used which proved to work very accurately and reliably. The degree of polarization obtained with this setup is shown in Fig. 1. The polarization was measured using a graphite analyser crystal measuring the horizontal and vertical polarization component of the direct beam.

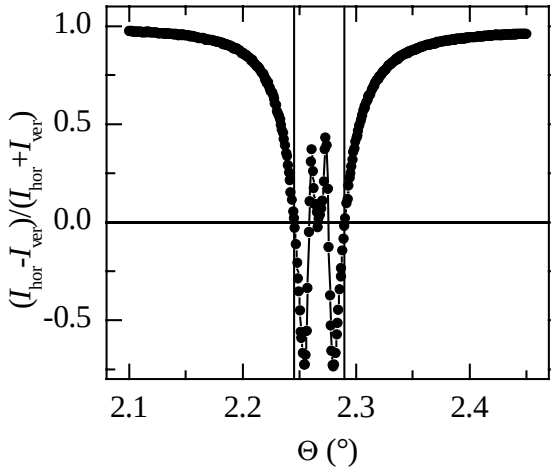


Fig. 1: Degree of linear polarization obtained with the phase plate versus plate angle. +1 corresponds to horizontal linear polarization, -1 to vertical polarization. Zero polarization in the centre of the pattern means un-polarized light, the two vertical lines mark the angles, where circular polarized light is transmitted.

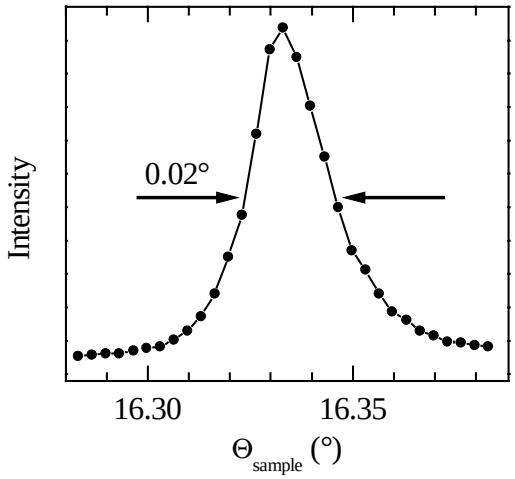


Fig. 2: Transversal scan through the (002) Bragg peak of a 55 ML film of Dy/W(110).

Even though the phase plate appeared to work well and films of high crystalline quality were grown (Fig. 2), only very weak magnetic scattering signals could be obtained. In order to rule out possible problems caused by sample contamination, we tested our setup using a MBE-grown Y/100 ML Ho/Y sample, which was characterized by neutron scattering and soft x-ray scattering before. From this sample, however, no stronger magnetic signal could be obtained, either.

Though the pressure during sample preparation was not as good as usual, the test with the MBE samples rather convinces us that the problems we faced are of different origin. In order to be sure, not to have *c*-axis domain walls in the film, we investigated rather thin samples. Possibly these films were too thin to give a sufficiently strong signal. We also struggled with a quite high background, which appeared to be related to the phase plate. Therefore, no reliable information about the helical domains could be obtained.

We are planning to repeat this experiment using magnetic scattering in the soft x-ray range, where the magnetic-scattering cross section is larger. Analysis of data obtained with soft x-rays, however, is much more difficult because the long wavelength allows to measure only one single magnetic satellite at (00τ), so that domain contrast can only be achieved by changing the light helicity and a quantitative analysis has to rely on the stability of the beamline upon polarization change.

[1] C. Sutter, G. Grübel, C. Vettier, F. de Bergevin, A. Stunnault, Doon Gibbs, C. Giles: PRB 55, 954 (1997).
[2] E. Weschke, C. Schüßler-Langeheine, R. Meier, G. Kaindl, C. Sutter, D. Abernathy, G. Grübel: PRL 79, 3954 (1997).
[3] E. Weschke, C. Schüßler-Langeheine, R. Meier, G. Kaindl, C. Sutter, G. Grübel in Festkörperprobleme/Advances in Physics, B. Kramer (Ed.), p. 541, Vieweg Braunschweig 1999.
[4] C. Schüßler-Langeheine, E. Weschke, Chandan Mazumdar, R. Meier, A. Yu. Grigoriev, G. Kaindl, C. Sutter, D. Abernathy, G. Grübel, M. Richter: PRL 84, 5624 (2000).
[5] C. Schüßler-Langeheine, E. Weschke, A. Yu. Grigoriev, H. Ott, R. Meier, D. V. Vyalikh, Chandan Mazumdar, C. Sutter, D. Abernathy, G. Grübel, and G. Kaindl: Journ. Electron. Spectrosc. Relat. Phenom., 114-116, 953 (2001).
[6] W. M. Fairbairn, S. Singh : J. Magn. Magn. Mater. 54-57, 867 (1986).
[7] S. B. Palmer, J. Baruchel, A. Drillat, C. Patterson, D. Fort: J. Magn. Magn. Mater. 54-57, 1626 (1986).
[8] C. Giles, C. Vettier, F. de Bergevin, C. Malgrange, G. Grübel, F. Grossi : Rev. Sci. Instrum. 66, 1518 (1995).