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ESRF

# Experiment Report Form

**The double page inside this form is to be filled in by all users or groups of users who have had access to beam time for measurements at the ESRF**.

Once completed, the report should be submitted electronically to the User Office using the **Electronic Report Submission Application:**

*http://193.49.43.2:8080/smis/servlet/UserUtils?start*

***Reports supporting requests for additional beam time***

Reports can now be submitted independently of new proposals – it is necessary simply to indicate the number of the report(s) supporting a new proposal on the proposal form.

The Review Committees reserve the right to reject new proposals from groups who have not reported on the use of beam time allocated previously.

***Reports on experiments relating to long term projects***

Proposers awarded beam time for a long term project are required to submit an interim report at the end of each year, irrespective of the number of shifts of beam time they have used.

***Published papers***

All users must give proper credit to ESRF staff members and proper mention to ESRF facilities which were essential for the results described in any ensuing publication. Further, they are obliged to send to the Joint ESRF/ ILL library the complete reference and the abstract of all papers appearing in print, and resulting from the use of the ESRF.

Should you wish to make more general comments on the experiment, please note them on the User Evaluation Form, and send both the Report and the Evaluation Form to the User Office.

## Deadlines for submission of Experimental Reports

- 1st March for experiments carried out up until June of the previous year;
- 1st September for experiments carried out up until January of the same year.

## Instructions for preparing your Report

- fill in a separate form for each project or series of measurements.
- type your report, in English.
- include the reference number of the proposal to which the report refers.
- make sure that the text, tables and figures fit into the space available.
- if your work is published or is in press, you may prefer to paste in the abstract, and add full reference details. If the abstract is in a language other than English, please include an English translation.

| ESRF | **Experiment title:** Magnetic Imaging of the Canted Phase in Co/Pt Multilayers by X-ray Holography | **Experiment number**: HE 2365 |
|---|---|---|
| **Beamline**: ID 8 | **Date of experiment**: from: 10.7.2007 to: 21.07.2007 | **Date of report**: 27.8.2007 |
| **Shifts:** 18 | **Local contact(s)**: C. Tieg | *Received at ESRF:* |


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## Report:

We performed a coherent x-ray holography experiment for imaging magnetic domain structures with nanometer spatial resolution. We have used the resonant X-ray magnetic circular dichroism effect to image magnetic domains in Co/Pt multilayer films of different thicknesses. The films were deposited on silicon nitride membranes and the multilayers develop a domain structure with magnetic moments predominantly aligned perpendicular to the sample surface. The holography arrangement was similar to the one reported in [1]. A mask of Au/Pd (thickness 500-800nm) was deposited on the membrane. The mask is opaque for soft x-rays and contains a sample hole of 1.5 μm diameter where the x-ray beam falls onto the magnetic layer. In a distance of 2-3 microns from the sample hole up to 5 smaller holes of diameter 40-100 nm diameter were drilled in the structure producing the reference wave necessary for holography. A magnet allowed us to apply an external magnetic field of max. 500 mT in the direction of the x-ray beam. A partially coherent x-ray beam was produced by using pinholes of different diameters (5-50 microns) yielding intensities between 3.3 $10^7$ ph/s and 2.1 $10^9$ ph/s. The scattered radiation was detected by a CCD camera positioned 67 cm

downstream of the sample with the transmitted beam blocked by a beamstop of diameter 1mm. A pin diode allowed us to position the sample in the beam. X-ray holograms were recorded at the Co L3 edge (777.5 eV) with both left and right circularly polarized light. A helicity difference image provides a pure magnetic speckle image as it suppresses all non magnetic scattering contributions. This difference image serves as basis for the magnetic image reconstruction.

Figure 1 shows a typical magnetic hologram obtained from a Co/Pt multilayer containing 8 layers of Co/Pt and 5 reference holes of diameter 40 nm. Typical exposure times varied between 20 and 400 seconds. A Fourier transform of the hologram yields the spatial autocorrelation of the whole object, including the cross correlation between the object and the reference holes, which directly provides the spatial arrangement of the magnetic domains in the sample. Figure 2 shows the obtained Fourier transformed hologram. The center of the inverted hologram is dominated by the intensity autocorrelation function of the object while the magnetic images appear around the center. In addition we observe a spherically modulated density which is due to missing data in the forward direction caused by the beamstop. Each reference hole produces two sample images. In order to improve statistics we used 5 reference holes leading to 10 visible images. The domains with magnetic moments pointing up and down are clearly visible as black and white areas. Figure 3 displays a line profile through a domain pattern indicating the spatial resolution to be around 30 nm. A more detailed analysis aiming for the determination of magnetic moments and canting angles is under way.

We also recorded speckle patterns with an external applied magnetic field. Figure 4 shows a series of domain patterns as obtained by x-ray holography with different values of the external magnetic field directed along the beam and values ranging from 89 mT to 28 mT. The sample has first been saturated at 250 mT where all magnetic moments are aligned parallel to the field leading to a vanishing magnetic contrast in the hologram – the corresponding image is completely black. The external field has then been lowered and the sample is on the way back to the zero remanence. The corresponding change of the domain pattern and reappearance of the white domains is clearly visible.

In summary, we have demonstrated the feasibility of magnetic x-ray holography at beamline ID8. The method provides real space magnetic images with a spatial resolution of 30 nm. Further progress will be directed towards higher spatial resolution by covering a larger q-space.

[1] S. Eisebitt et al., Nature 432, 885 (2004)

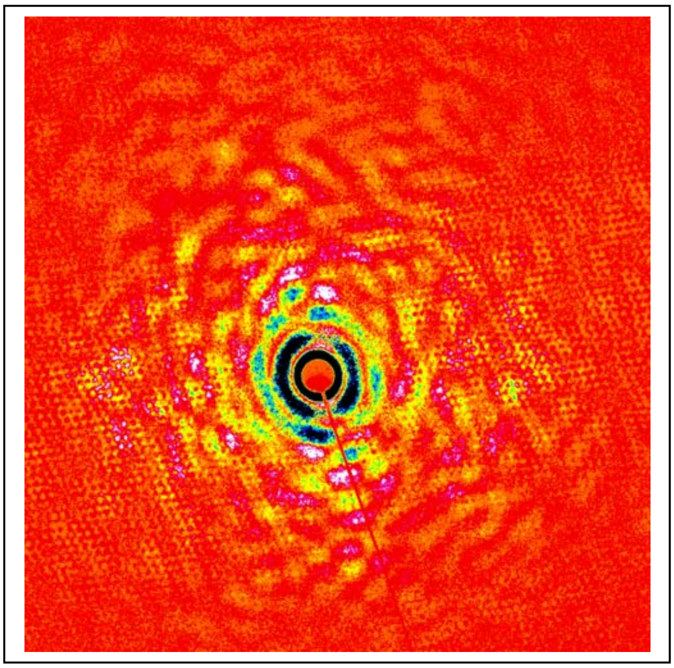

Figure 1: Magnetic hologram as obtained by the difference data from both x-ray helicities. The speckles arise from the magnetic domain structure of the Co/Pt film. The transmitted beam is blocked by a beamstop. Measured at the Co L3 edge.

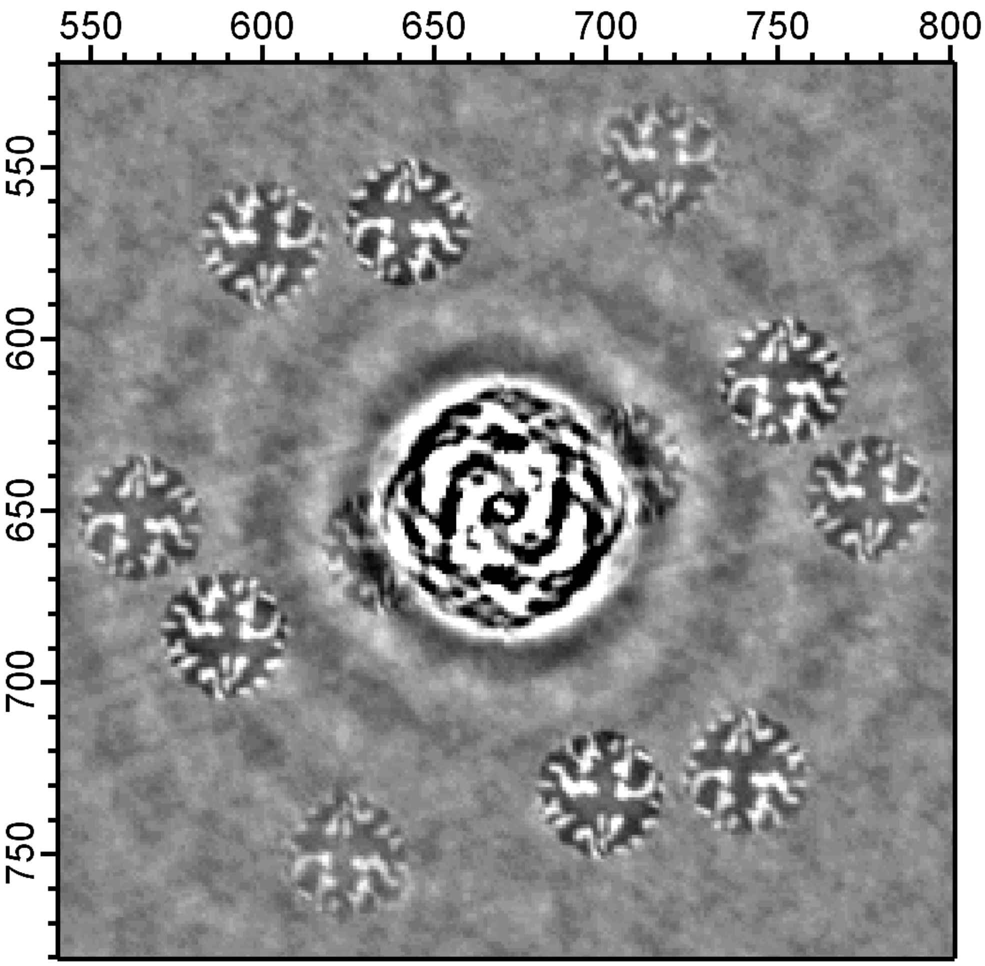


Figure 2: Inverted hologram of a Co/Pt multilayer showing the autocorrelation of the object in the center and the images (diameter 1.5 microns) of the object as produced by the 5 reference holes. The magnetic domain pattern is clearly visible.

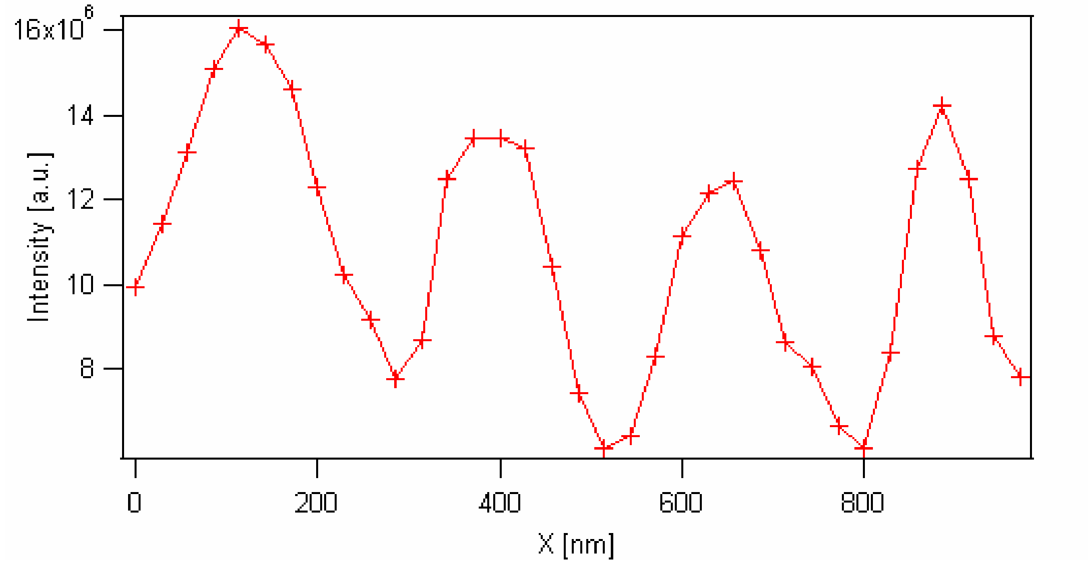


Figure 3: Line profile through the holographic image. The spatial resolution is approximately 30 nm.

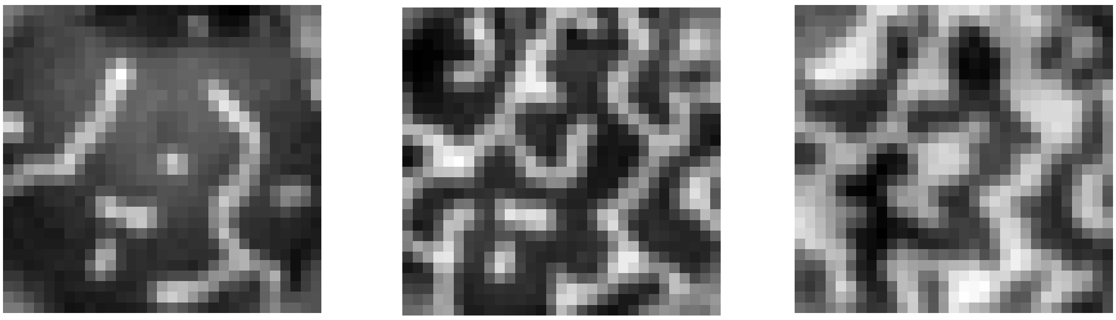

Figure 4: Domain pattern of a Co/Pt multilayer as a function of external magnetic field. The sample was first saturated and is on the way back to the zero field. From left to right: 89 mT, 54 mT and 28mT, respectively. The appearance of “white” domains from a saturated black image is visible.