| | **Experiment title:** Magnetic tomography of a new type of domain walls | **Experiment number**: HC-5027 |
|---|---|---|
| **Beamline**: ID32 | **Date of experiment**: from: 21.02.2023 to: 27.02.2023 | **Date of report**: 05.03.2023 |
| **Shifts:** 18 | **Local contact(s)**: Flora Yakhou | *Received at ESRF:* |


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

*Guillaume Beutier (SIMaP)

*Alexis Wartelle (Institut Jean Lamour / ESRF)

*Marisel Di Pietro Martinez (Max-Planck-Institute for Chemical Physics of Solids)

*Gerrit van der Laan (Diamond Light Source)

* Katie Lewis (University of Exeter)

Feodor Ogrin (University of Exeter)

Nicolas Rougemaille (Institut Néel)


**Report:**

The purpose of the experiment was to determine the magnetic structure in Landau domain walls [1], a type of magnetic domain walls that has been predicted by microsimulations and observed in permalloy stips by MFM. Our recently-developed 3D Fourier-transform holography (FTH) method [2] was an ideal technique to check in details the magnetic texture predicted by the simulations.

However, due to the difficulty to prepare long permalloy stripes with a domain wall exactly in the holographic aperture, we modified the sample design and studied finite-size samples of elongated shape, which fit entirely in the holographic aperture. Their magnetic structure at equilibrium is very similar to the Landau domain wall [3], as shown in Figure 1 and Figure 2.

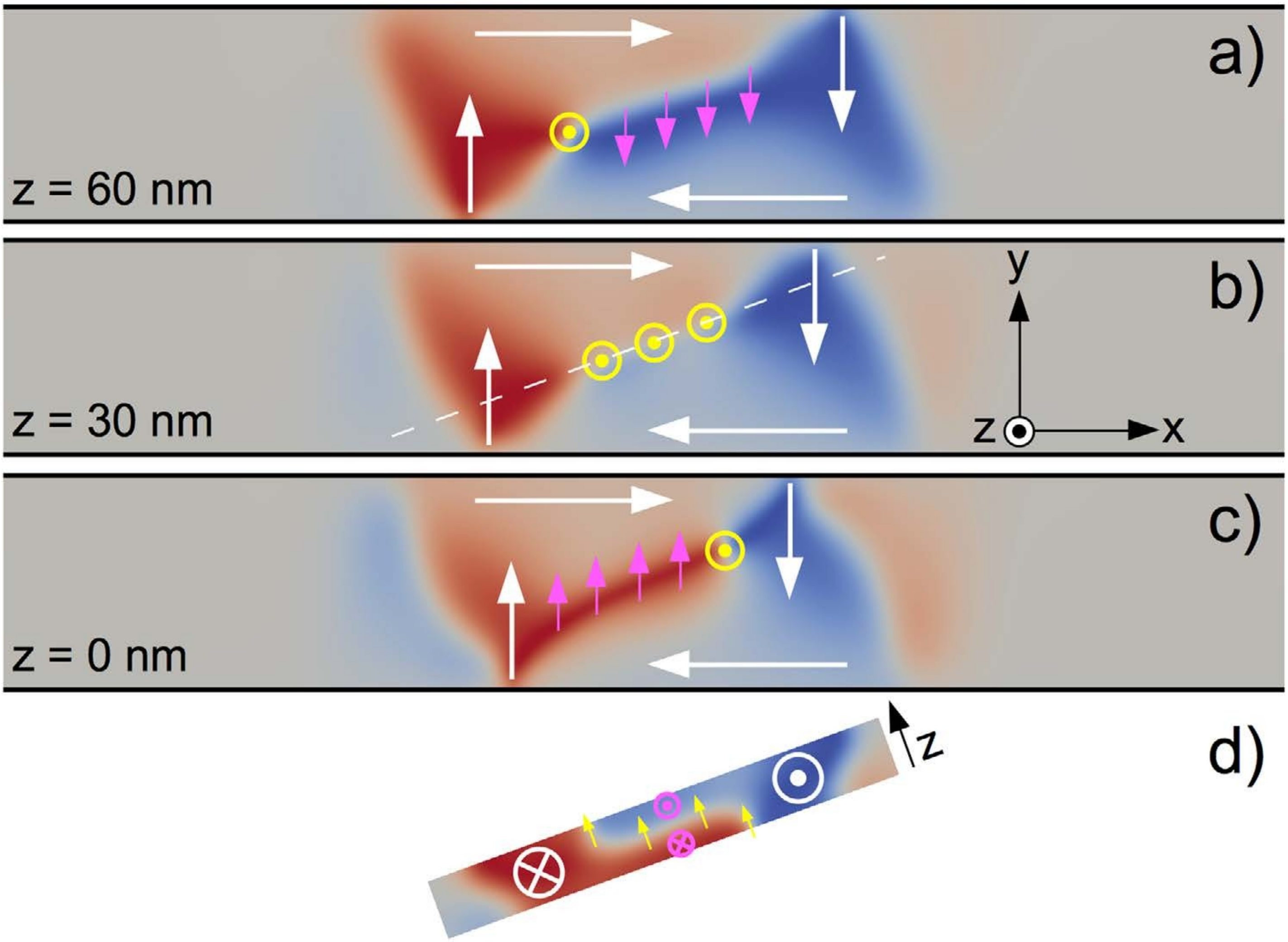


*Figure 1: Micromagnetic configuration of a Landau domain wall in a 200 nm wide, 60 nm thick permalloy strip. (a–c) XY cross section views of a Landau DW at different heights [(a) z = 60 nm, (b) z = 30 nm, (c) z = 0 nm] illustrating the 3 internal degrees of freedom the (clockwise) chirality (white arrows), the polarity of the Bloch wall (yellow arrows) and the direction of the Néel caps (magenta arrows) for the bottom (z = 0 nm) and top (z = 60 nm) surfaces. (d) Cross section view along the dashed white line shown in (b). In all images, X, Y and Z stand for the length, width and thickness of the strip, respectively. The red/ blue color code gives the amplitude of the magnetisation component along Y. Taken from [1].*

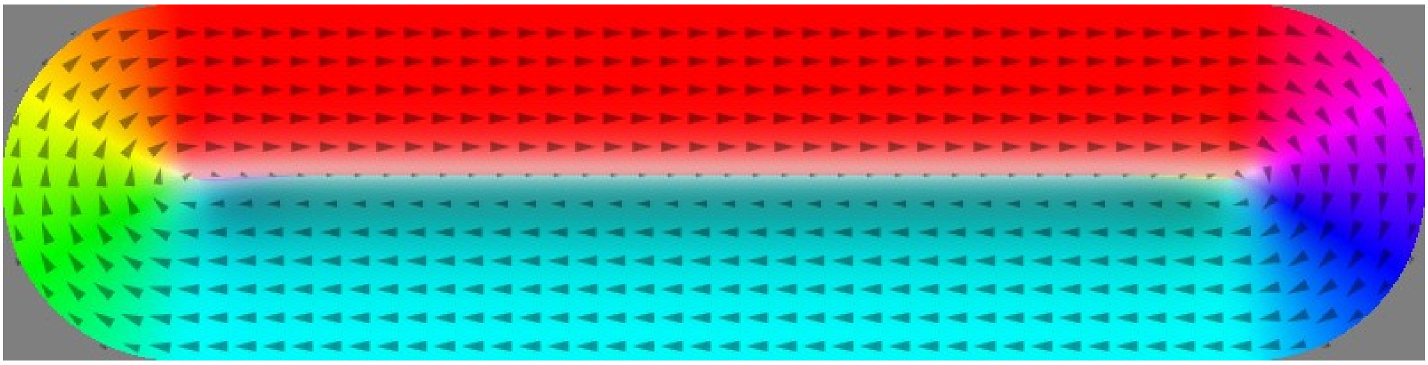

*Figure 2: Micromagnetic configuration in a 5 µm x 1 µm 240 nm thick permalloy bar. Similarly to the Landau domain wall in continuous strips, the core starts on one hand of the bar and emerges on the other end.*

Samples were thus prepared by growing a 300 nm thick layer of permalloy by magnetron sputtering at ~400°C on a SiN membrane. The back side of the latter had previous been covered with a thick Au-Ti multilayer designed to be opaque to soft X-rays. 4 devices were etched in the permalloy layer, and FTH masks milled by FIB in the Au-Ti multilayer in front of the permalloy samples. One of them is shown in Figure 3.

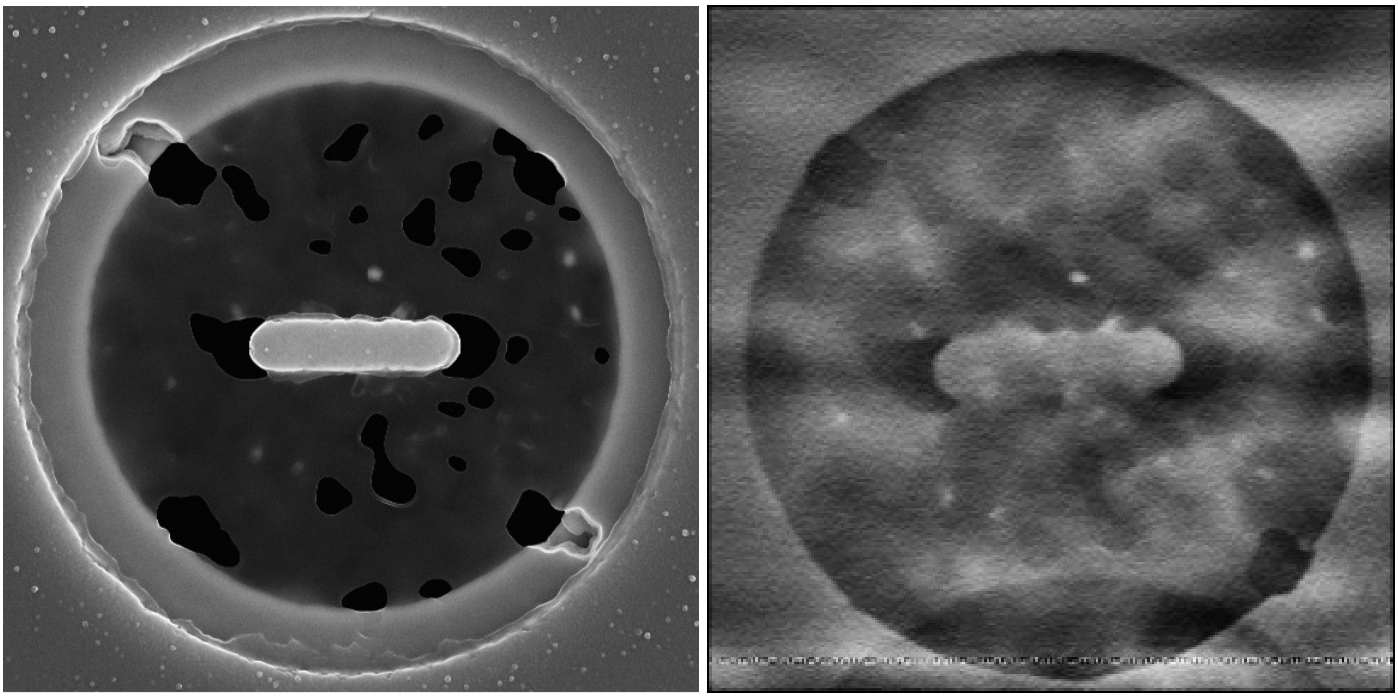

*Figure 3: Left: SEM view of device "D", a 4 µm x 1 µm permalloy bar. The circular aperture in the Au/Ti mask on the back side of the membrane is visible. Right: FTH view of the charge part of devide "D".*

The sample was mounted on the sample stage of the FTH chamber of ID32. The X-ray beam was tuned to the Fe L3 edge and filtered for coherence by a set of pinholes upstream the samples. The coherent scattering patterns were recorded on the Dhyana95 sCMOS camera, which had previously been sent back to the manufacturer to solve the condensation issue. The reconditionned camera worked better than during previous experiments, but it was not perfect. Stains started to appear after 4 days of beamtime. A bake-out *in situ* was necessary before continuing with the last 2 days. Moreover, some burns were visible on the chip.

Compared to the previously existing set-up, we used 2 days to optimise a procedure to combine data with and without beamstop: special care was taken to reject harmonics, allowing to use a strong attuator (a 2.5 µm thick zinc film) for the measurement of the direct beam. This improved set-up to make quantitative measures, whereas approximations were needed without the direct beam measurements. For instance, the charge image now shows similar contrast to SEM (Figure 3).

First the 4 devices were imaged in normal incidence, to try to identify those with the most interesting magnetic textures. Two of them were particularly interesting. Device "C", a 5 µm x 1 µm bar, showed a diamond structure (Figure 4) already seen experimentally in epitaxial Fe islands [3] and predicted numerically for the permalloy strips in certain circonstances.- Device "D", on which we focused the rest of the measurement, displayed a contrast simoilar to the expected one for Landau doamin wall in normal incidence (Figure 5). Measurements at several tilt angles at 2 orthogonal azimuths were taken, but several issues with the camera (in particular the stains) prevented us from aquiring a full data set for tomography. However, some of the individual images are of excellent quality and my be used for comparison with numerical models.

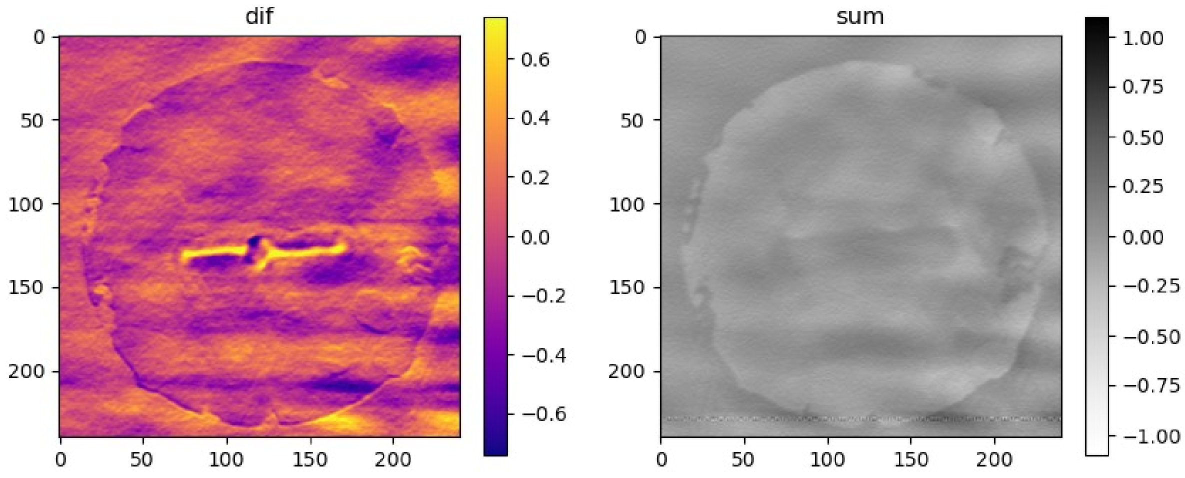


*Figure 4: Magnetic (left) and charge (right) images of device "C".*

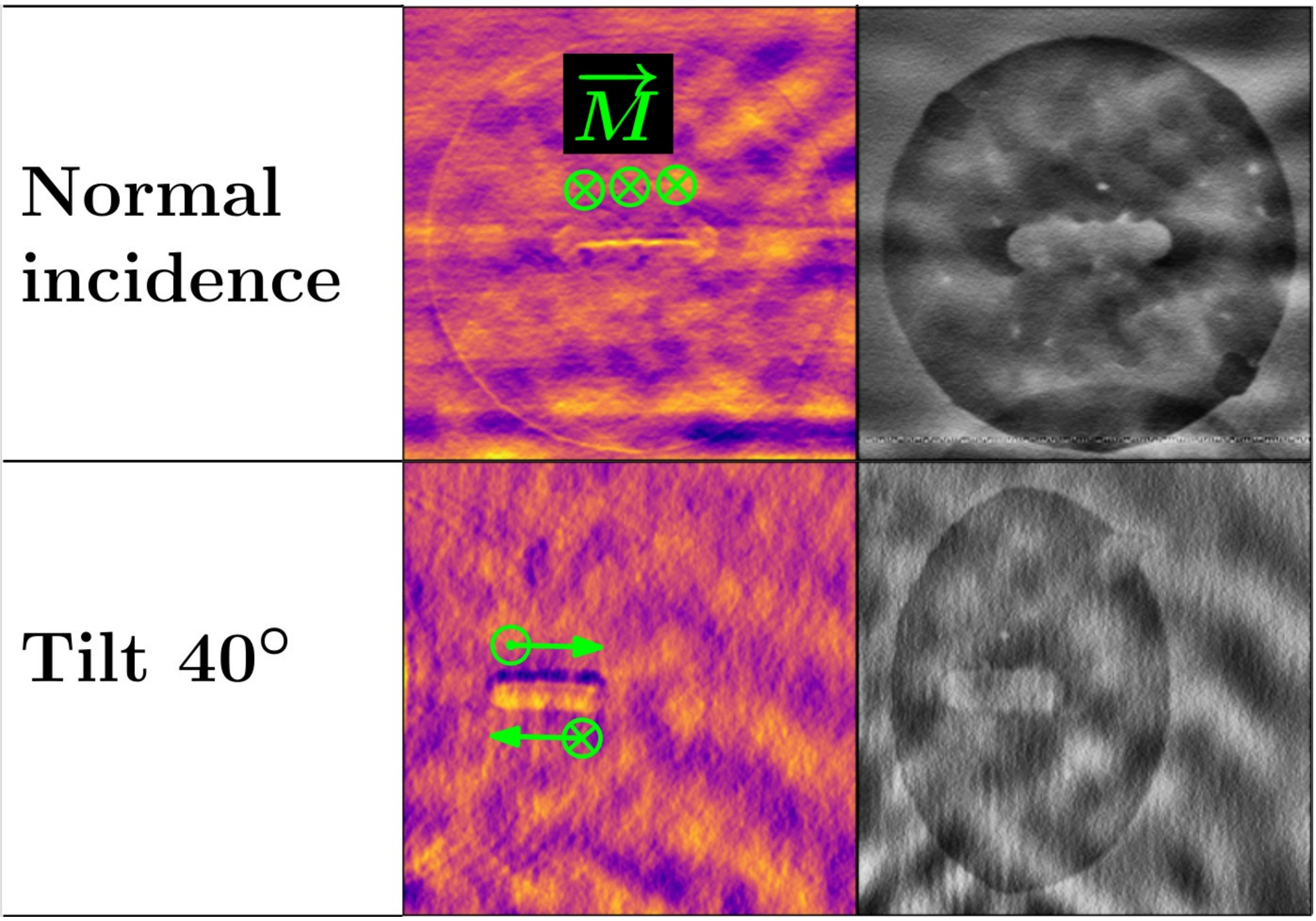

*Figure 5: Magnetic and charge images of device "D" in normal incidence and at 40° of tilt.*

## References


1. Nguyen *et al.*, *Scientific Reports* **5**:12417 (2015).
2. Di Pietro Martinez *et al*, Phys. Rev. B, accepted, arXiv:2212.10183 (2023)
3. Masseboeuf *et al*, Ultramicroscopy 115, 26–34 (2012).