Lorentz Transmission Electron Microscopy

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Lorentz microscopy has been used extensively for the past 40 years to study magnetic domain structure and magnetization reversal mechanisms in magnetic thin films and elements. It uses a transmission electron microscope to penetrate a thin sample where its magnetization can cause deflection of the electrons creating a magnetic contribution to the signal captured on camera/detector. Normal operation of every modern TEM instrument includes an objective lens, which immerses the sample space with very high magnetic field (approx. 2T) which does not allow for observation of remanence magnetization states. For this reason, the objective lens is typically turned off during the magnetic imaging sacrificing a lot of spatial resolution. On the other hand, the objective lens can be slightly excited to introduce controlled magnetic field influencing the sample.

In the introductory part of the session we will discuss the working principle of the TEM microscope and its alignments needed for the Lorentz microscopy using Fresnel (defocused) imaging on camera and Differencial Phase Contrast (DPC) imaging on a STEM detector.

In the experimental part we will examine a sample consisting of patterned NiFe layer on a 30nm SiN membrane showing several typical domain structures (Landau patterns, vortices, multidomains) using:

1. Fresnel imaging mode on camera
2. DPC using STEM mode imaging of a segmented detector
3. Simulation of Fresnel mode images using micromagnetic simulations and their comparison to images captured on the microscope

Recommended reading:

[1] H. Hopster, H. P. Oepen, Magnetic Microscopy of Nanostructures. *NanoScience and Technology*, *Springer* (2005). doi:10.1007/b137837

[2] Zweck, J. & Uhlig, T. Lorentz Microscopy of Thin-film Systems. Handbook of Magnetism and Advanced Magnetic Materials (2007).

[3] Petford-Long, A. & Chapman, J. Lorentz Microscopy. Magnetic Microscopy of Nanostructures NanoScience and Technology 67–86 (2005).