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Towards Automation of the Transmission Electron Microscope

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The Transmission Electron Microscope is a powerful tool investigating samples at the nano-Ångström scale. Despite its increasing popularity due to its unmatched spatial resolution, operation of the microscope is time-consuming and tedious. At times, even trivial tasks may require hours of manual operation. Automation has thus become attractive in the field, as it would lower the threshold and workload for advanced material investigations. Scanning TEM (STEM) differential phase contrast (DPC) is a technique utilizing movement of the centre beam to determine electric and magnetic domains. For a magnetic sample with domain formation, the beam will be deflected in different directions depending on the in-plane magnetic alignment in the sample, see graphic. This slight change can be measured using e.g. a pixelated detector. Nanomagnets with dimensions 225-75 nm are shown to have interesting monodomain properties, being currently widely studied for reservoir computing [1,2].

Problems arise when using the TEM as the magnetic field is typically too big for domain-formation. For this reason, the objective lens must be turned off, reducing the spatial resolution. With the objective lens turned off (so-called Low-Mag), the magnetic field can be estimated to be of the order of tens of millitesla. This is sufficiently low for ASI-samples to show hysteretic behaviour, and in-situ studies of the dynamics can be performed by either tilting the sample, increasing the magnetic field from the objective lens or rotating the sample.

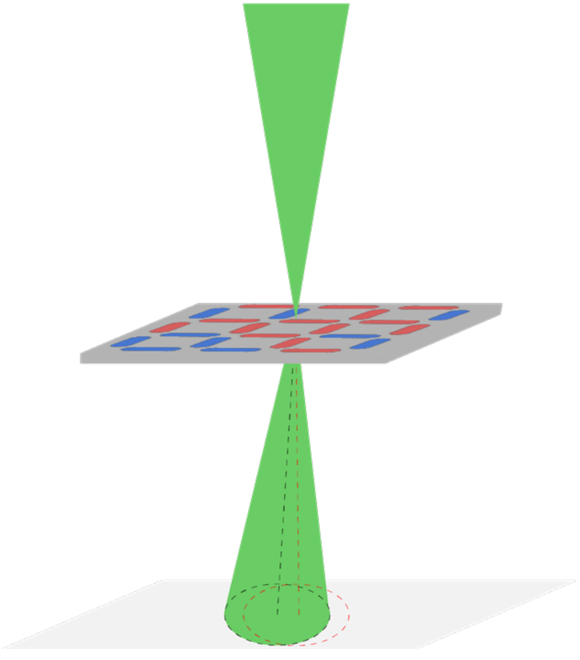
Once the TEM is aligned, the STEM-DPC technique is rather trivial, that is: acquire data, then change the magnetic field, repeat. This experiment is typically referred to as “continuous-tilt STEM-DPC” and can take hours to complete. The task however, is trivial and using human operating time is both inefficient and prone to human errors. This procedure is easy to automate, and allows other in-situ experiments such as varying the temperature over critical regions.

ASI structures will be prepared from TEM samples with 20-50 nm Si windows with top layers of permalloy and aluminium using FIB, creating nano-magnets with mono-domain behaviour. Continuous-tilt STEM-DPC will then be performed with either a MerlinEM direct electron detector or a conventional ADF detector followed by procedural post-processing. This experiment will be a proof-of-concept, and the choice of detector will depend on access to the Merlin detector.

The project aims to gain complete control of both the microscope and the detector- and scanning systems and build a python-library allowing experienced microscopists to automate their own experiments. Creating possibility for feedback-controlled automatic decision-making will also be done. Even further, programmable input-output devices for in-situ experiments will allow scripted exploration of the parameter space of all TEM samples using custom in-situ chips.

Further, given control of the scanning system, random and quasi-random sequences for data-acquisition will be implemented, reducing the necessary acquisition time for sufficient statistic. This procedure will also in particular benefit samples prone to beam damage.

Graphic:



Keywords:

TEM, Automation, in-situ

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