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## Imaging Magnetism at the Nanoscale with Dichroic Spectro-ptychography

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Understanding and visualizing magnetic configurations at the nanoscale is essential for elucidating the mechanisms governing material functionality and optimizing advanced technologies, from energy-efficient devices to next-generation spintronic architectures. One promising technique that provides high spatial resolution imaging of magnetic configurations is dichroic ptychography, a coherent diffractive imaging technique that reconstructs the polarization-dependent complex transmission function of an object. When combined with spectroscopic measurements, this approach yields quantitative complex dichroic spectra with domain selectivity. In this talk, I will discuss three different approaches to magnetic imaging with X-ray ptychography. First, when combining it with X-ray magnetic circular dichroism to probe ferromagnetic order, we have found that access to the phase dichroism enables the study of samples an order of magnitude thicker than is possible with soft X-ray absorption-based techniques [1], offering access to a wider range of magnetic samples. Second, this phase contrast also provides an advantage when combined with linear dichroism, enabling higher signal-to-noise imaging of compensated magnetic configurations [2]. Beyond simple ferro- or antiferromagnetic order, there is a growing interest in orbitronics, which has emerged as a potential new field in magnetism, motivating efforts to disentangle spin and orbital contributions in magnetic systems [3]. To this end, we have combined dichroic ptychography with vortex beams carrying orbital angular momentum (OAM), and observe indications of coupling between the beam's OAM and the sample's ferromagnetic configuration. With these three approaches, we establish X-ray dichroic ptychography as a flexible, quantitative, and high-resolution approach to measure magnetic materials at the nanoscale.

[1] Neethirajan, J. et al. *Phys. Rev. X*, 14 (2024).

[2] Raboni-Ferreira, M. et al. *arXiv e-prints*, 2502.08617 (2025).

[3] Fukami, S. et al. *Nat. Phys.*, 1-7 (2025).

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