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Type: Oral

Magnetic REXS and absorption imaging at different lengthscales

Thursday, 9 October 2025 09:00 (35 minutes)

Magnetic REXS (RMXS) has been used for many years as a complementary tool to neutron scattering for the determination of magnetic structures. Although limited in many cases by the small size of the Ewald sphere, RMXS has two great advantages over neutron scattering: firstly, an exquisite control of the incident and scattered polarisation, analogous to neutron spherical polarimetry (NSP) but without the requirement of zero magnetic field on the sample; and, secondly, beam spots in the range of tens of micrometers, enabling one to isolate and study individual domains in multi-domain samples and to image them as a function of parameters such as temperature, magnetic and electric fields. These approaches were successfully applied to the field of multiferroics^{1,2}, where one encounters particularly rich phase diagrams that are highly suitable for RMXS imaging at these length scales. In these studies, limited attention was often paid to the underlying spectroscopy: a common approach was to maximise the magnetic resonance signal and assume that this arose principally from a E1-F(1) term with spherical symmetry.

Later, a growth of interest for real-space topological structures such as skyrmions prompted a significant evolution of this approach. The highly disordered nature^{3,4-6} or sometimes the complete absence of a magnetic lattice or propagation vector drove the requirements for much higher resolution in real space, down to a few nanometres. Moreover, individual topological structures are much larger than the structural unit cell, which means that most of the magnetic scattering occurs at small angle even with soft X-rays. A natural connection can then be made, via the optical theorem and the Kramers–Kronig relation, between RMXS and related scattering techniques and X-ray absorption spectroscopy (XAS) and imaging. In particular, the well-developed spectroscopic framework developed in the context of XAS is increasingly being employed for RMXS and RMX imaging, very often in conjunction with real-space reconstruction of RMX images via holography⁷ and ptychography.

The current worldwide trend in synchrotron radiation source upgrades is heralding a true revolution in the way we think about magnetic scattering. Dichroic small-angle RMXS imaging in 2D (ptychography) and 3D (laminography) will become routine, thanks to powerful real-time image reconstruction techniques. Two challenges can be envisaged in the near future: to design suitable sample environments (especially difficult with soft X-rays) and to exploit the full spectroscopic and tensorial framework beyond the ‘pretty pictures’.

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Session Classification: Talks Thursday Morning