

Domain dynamics in magnetic materials by ultrafast coherent X-ray diffraction

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Abstract

I will introduce the use of coherent X-ray scattering methods and describe their applications to imaging domain structures in crystalline materials. One method is resonant Bragg ptychography, which we used to image domains in $\text{La}_{2-x}\text{Sr}_x\text{NiO}_4$. Here we used soft X-rays at the Ni L_3 absorption edge. The images show a slow time dependence, previously seen by X-ray Photon Correlation Spectroscopy (XPCS), which turns out to be domain “breathing” by fluctuation of the domain-wall positions [1]. Secondly, using Bragg Coherent Diffraction Imaging (BCDI), we investigated how the long-range antiferromagnetic (AFM) state of Sr_2IrO_4 organizes itself in space and time following its electronic demagnetization driven by an ultrafast laser. This method allows us to see crystalline domains and domain walls in micron-sized samples. We showed by ultrafast pump-probe resonant coherent X-ray imaging that domains shrink and regrow in the same location every time. Ultrafast magnetic BCDI experiments were performed at the MID instrument of the European X-ray Free Electron Laser (XFEL) facility [2]. The 106 magnetic reflection of a high-quality single crystal sample of Sr_2IrO_4 was aligned at 100 K and 11.215 keV, just below the Ir L_3 absorption edge, using XFEL self-seeding. Real space images, obtained by inversion of the BCDI diffraction patterns, revealed an array of antiphase domains, a few microns in size, which shrank and grew again in response to a 50 fs laser pulse of 15 mJ/cm^2 .

[1] Longlong Wu, Yao Shen, Andi M. Barbour, Wei Wang, Dharmalingam Prabhakaran, Andrew T. Boothroyd, Claudio Mazzoli, John M. Tranquada, Mark P. M. Dean and Ian K. Robinson, *Physical Review Letters* 127 275301 (2021)

[2] I. K. Robinson, D. Yang, R. Harder, D. Sheyfer, L. Wu, J. Griffiths, E. Bozin, M. Dean, J. Liu, H. Zhao, G. Cao, A. Rodriguez-Fernandez, R. Shayduk and A. Madsen, submitted to *Physical Review Letters* (2026)

Ian Robinson is a professor at the London Centre for Nanotechnology. He uses X-ray diffraction to study the structure of materials. His research is currently focussed on the development of coherent X-ray diffraction methods for imaging the structure of nanoparticles and domain structures in larger crystals. The X-ray coherence leads to interference effects in the diffraction patterns which can be inverted, using phase retrieval methods, to 3D images. His research makes extensive use of synchrotron radiation facilities and Free-Electron Lasers. Historically, the earliest beamlines were used to discover Crystal Truncation Rods, opening the field of surface structure determination, for which Robinson was awarded the Surface Structure Prize in 2011, the Gregori Aminoff Prize in 2015 and the Arthur H. Compton Prize in 2025.



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