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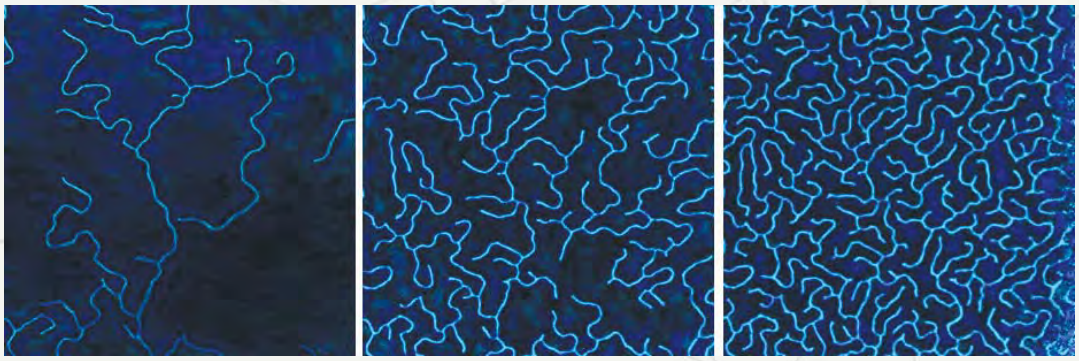
Seeing on the Nanoscale without Lenses



Evolution/nucleation and growth of nanoscale magnetic domains as a function of applied magnetic field.

While many experimental techniques exist for seeing the very small, such as x-ray and electron microscopy, each has its own limitations and constraints, whether from technological capabilities or simply the laws of nature. The development of new nanoscale imaging methods for the nanotechnology toolbox is therefore a matter of continuing and pressing importance. Researchers from the University of California, San Diego, and Argonne carrying out investigations at the APS have conceived and demonstrated a new approach to lensless imaging of magnetic structure at the nanoscale: x-ray coherent diffractive imaging (CDI). This work points toward greater insights about magnetic oxides at the nanoscale and the ways assembly of nanostructures can be controlled.

Working at the 2-ID-B beamline at the APS, the experimenters employed the principle of dichroism, in which a crystal structure absorbs light with one polarization while transmitting light of a different polarization. Their new CDI technique obtains a coherent x-ray scattering pattern from a sample, maps the Ewald sphere (the sphere of reflection), then inverts the pattern mathematically. In this way, images can be generated without the need for any reference wave or precision optics. The team used this lensless CDI technique to map ferrimagnetic domains in a multilayer Gd/Fe film and to partly follow domain structural evolution through its hysteresis loop.

The experimenters examined a Gd/Fe film beginning with the sample in a magnetically saturated state, in which the entire film is in a single magnetic domain, then reduced the applied field to observe the emergence of the ferromagnetic domain patterns. These began to appear at about 44 mT. As the applied magnetic field was decreased, classic stripe patterns arose, of a type found in many other systems such as diblock copolymers, liquid crystals, and Langmuir monolayers. The domain behavior is highly sensitive to the fluctuations of the applied magnetic field, which is not the case with other multilayer films such as cobalt/palladium.

Unlike other techniques, the spatial resolution of CDI is not dependent upon extreme nanoscale precision of optical equipment, but simply on a high-frequency signal-to-noise ratio in the coherent diffraction measurements, and on the stability and precision of the x-ray beam. Thus, because their "lens" was mathematical rather than physical, the team was able to obtain reconstructions of the evolution of magnetic configurations of the film with extremely high resolution. The technique is also not limited to only magnetic materials, but can be applied to any dichroic structure and can image samples of any size. It will become even more valuable as new-generation x-ray sources become available, featuring beams with greater brilliance and transverse coherence.

With this powerful yet technically uncomplicated technique, the researchers have opened a new window into understanding the structure and behavior of complex magnetic oxides at the smallest scales. *— Mark Wolverton*

See: Ashish Tripathi[1,2], Jyoti Mohanty[1], Sebastian H. Dietze[1], Oleg G. Shpyrko[1]*, Erik Shipton[1], Eric E. Fullerton[1], Sang Soo Kim[2], and Ian McNulty[2], "Dichroic coherent diffractive imaging," Proc. Nat. Acad. Sci. USA **108**(33), 13393 (August 16, 2011). DOI:10.1073/pnas.1104304108

Author affiliations: [1]University of California, San Diego, [2]Argonne National Laboratory

Correspondence: *oshpyrko@physics.ucsd.edu

Work at the University of California, San Diego, was supported by the U.S. Department of Energy Office of Science (DOE-SC) under Contract DE-SC0001805. E.S. and E.E.F. were partially supported by DOE Award DE-SC0003678. Use of the Advanced Photon Source at Argonne National Laboratory was supported by the U.S. DOE-SC under Contract No. DE-AC02-06CH11357.

Advanced Photon Source
Bldg. 401/Rm A4115
Argonne National Laboratory
9700 S. Cass Ave.
Argonne, IL 60439 USA