Differential Phase Contrast Imaging with a Universal Detector

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Differential phase contrast (DPC) imaging is a technique wherein the inherent electric and magnetic fields within materials deflect the electron beam during diffraction causing a measurable shift in the Ronchigram. Recently, the technique has been implemented in a scanning transmission electron microscope (STEM) to produce real-time atomic-resolution DPC images and to map magnetic grains and p-n junctions. While real-time DPC imaging requires specialized high-speed detectors, the technique can also produce high-resolution maps using direct electron detectors that can be straightforwardly incorporated into most standard microscopes.

The direct electron detector allows us to acquire images of the Ronchigram with short pixel dwell times (~1 ms per image), which allows for the standard STEM raster to produce a four-dimensional dataset of the captured Ronchigrams across the region of interest without damaging the sample or undergoing significant spatial drift. The 4D dataset acquisitions allow us to use the direct electron detector as a universal detector, where we can reconstruct bright field, annular bright field, or annular dark field images by masking different regions of the Ronchigram in each pixel. Furthermore, we can use the center-of-mass method and treat the direct electron detector as a pixelated detector to produce DPC images and measure the fields directly.

In this talk, we employ a Hamamatsu ORCA cMOS direct electron electron detector installed on a Nion aberration-corrected UltraSTEM 100 to produce atomic-resolution DPC images. The spatial-resolution of the technique is tested by measuring the position of light elements in distorted pervoskites, as well as examining the ability to detect rotations and coordinations in different classes of materials, and observing the electric field at atomically-sharp interfaces.

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