Atomic-Sized Electron Probes with Selectable Orbital Angular Momentum

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The electron beam of a scanning transmission electron microscope (STEM) is an ideal probe to sample many nano- and atomic-scale features, but to access topological and chiral effects, such as valley polarization or magnetic/optical dichroism, the beam needs to possess a measurable value of angular momentum. An electron vortex beam is created by passing the regular probe through a holographic mask with a fork dislocation. The resulting interference through the mask produces a diffraction pattern where each spot is a vortex beam with a different discrete value of orbital angular momentum (OAM). The different vortex beams are now sensitive to phenomena that are inaccessible to standard STEM operation such as the detection of Zeeman interactions in the materials at the nanoscale, and atomic-resolution spin-obit coupling and ordering. However, without the ability to select individual vortex beams from this diffraction pattern the OAM induced effects cancel out when attempting to measure them in a technique like electron energy loss spectroscopy (EELS).

In this talk, we will show the recent progress towards achieving selectable-OAM vortex beams utilizing a monochromator inside a Nion aberration-corrected high-energy resolution monochromated EELS STEM (HERMES). Instead of the standard monochromator function, where the beam is dispersed by energy and a slit is used to select a narrow band of energies, we replace the monochromator entrance aperture with a holographic grating and set up the monochromator in a non-energy dispersive mode. In this mode, the OAM diffraction pattern is projected onto the slit plane instead of the beam energy-spread, and the monochromator slit can be used to select an individual vortex beam instead of a narrow band of energies. The monochromator then reforms the beam to an atomic-sized probe to allow for atomic-resolution measurements with an electron probe possessing a selectable value of OAM.

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