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Free Electron Beams with Helical Wavefronts and Quantized Angular Momentum[1]

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Electron vortex beams, composed of helical electron wavefunctions that carry quantized orbital angular momentum (OAM), are analogous to optical vortices in beams of light. Electrons in the beam possess quantized amounts of orbital angular momentum (OAM) and have an associated magnetic moment. To produce such states, we use nanofabricated diffraction holograms to coherently imprint a phase vortex onto free electron matter waves in a transmission electron microscope (TEM). We also use this approach to place free electrons in coherent superpositions of orbital states, and we apply this to observe the Gouy phase for matter waves and to measure the orbital magnetic moment of the vortex state. Electron vortex beams can interact with surfaces and materials in unique ways. For example, electron vortex beams can transfer quantized OAM to an atom through inelastic scattering, inducing the same atomic and molecular transitions induced by circularly polarized light. Such OAM-dependent scattering provides a "dichroic" signal that can be measured in electron energy loss spectra from samples in a TEM. We will discuss our efforts toward using this to measure optical, electronic, and magnetic properties of samples with sub-nanometer resolution.

[1]Work done in collaboration with Tyler Harvey, Jordan Pierce, and Tyler Yahn, Department of Physics, University of Oregon; Peter Ercius and Martin Linck, National Center for Electron Microscopy, Lawrence Berkeley National Laboratory.