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Methods and Applications for Sculpted Electrons

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The phase and amplitude of electron matter waves can be sculpted and measured using methods that are analogous to light optics. Such sculpted electrons can be used to probe materials and fields in new ways. Here I will discuss some techniques for preparing and measuring the spatial phase of free electrons. Nanofabricated holographic devices to coherently manipulate the structure and phase of electrons in conventional electron microscopes. For example, such devices can be used to remove aberrations from the beam, imprint phase vortices and associated quantized orbital angular momentum onto the wavefunction of individual free electrons[1], [2], or used to coherently divide each electron wave into multiple paths in order to implement interferometry in an electron microscope[3], [4], [5]. I will review examples of how these prepared electrons can be applied to new forms of electron microscopy techniques, such as probing nanoscale optical excitations and quantum measurements.

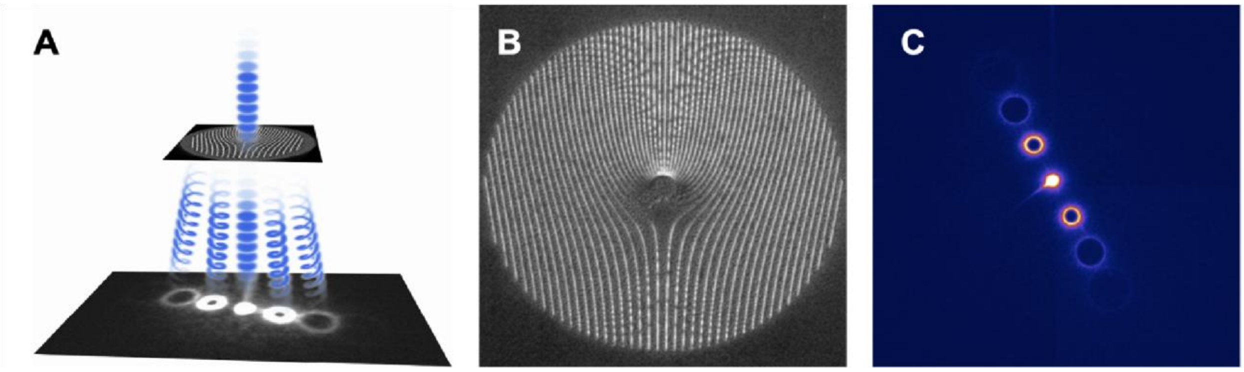
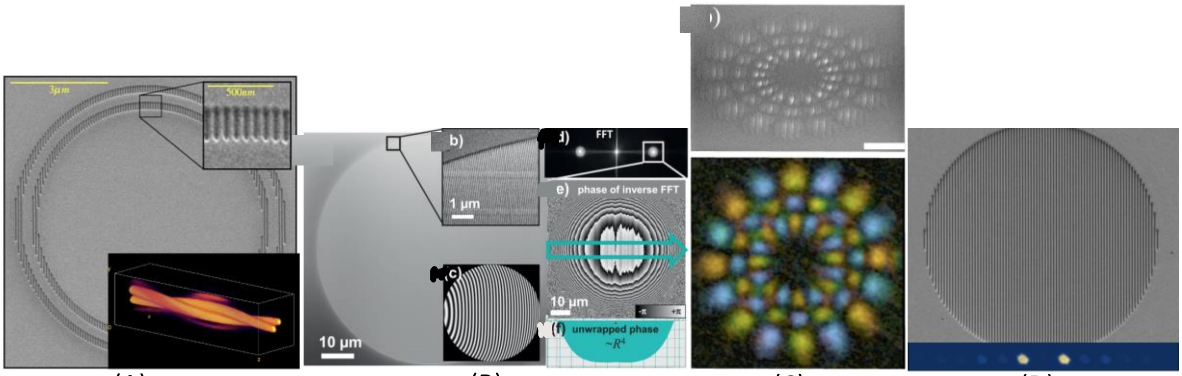


Figure 1: Generation of vortex beam in the electron microscope. A) TEM scattering through a spiral phase plate. B) Silicon nitride spiral phase plate used in the TEM. C) Orbital angular momentum (OAM) eigenstates, Lz, in vortex beams; Lz starting with the top most as $-2\hbar$, $-1\hbar$, 0, $1\hbar$, and $2\hbar$.



(A) (B) (C) (D)

Figure 2: Holographic gratings for creating (A) coiling electron beam[6], (B) spherical aberration correction[7], (C) arbitrary superpositions of Laguerre-Gauss spatial modes[8], (D) amplitude-dividing beamsplitter[9].

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