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Sorting the orbital angular momentum of a wavefront in a spectrum – towards quantum electron microscopy

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Quantum complementarity states that particles exhibit wave-like properties such as diffraction and interference upon propagation. Electron waves that are defined by helical wavefronts are referred to as twisted electrons and have additional mechanical and magnetic properties that are associated with spin-to-orbit coupling.
Here, we introduce an electron-optical setup that can be used to measure the OAM content of an electron by using a transformation of an OAM-carrying azimuthal phase variation into transverse phase gradients that can be spatially resolved and separated using a lensing element, thereby creating an OAM spectrometer.
We will present different experimental ray paths in an electron microscope, which can be used to measure OAM components that are introduced to the wave function of an incident electron as it passes through an object (Fig. 1).
We will show experimental results illustrating the acquisition of OAM spectra (Fig. 2) in an electron microscope using holographic apertures (Fig. 1). We will also discuss the use of structured electrostatic fields to shape electron waves.
Our design is, in principle, able to transform the phase information carried by a single transmitted electron into intensity information in an OAM spectrum. We will discuss possible applications of this approach to the study of magnetic and electronic properties in materials. We will also consider the properties of more complex beams, which can be obtained by the superposition of vortex beams of different order.
Finally, we will assess the need for more unconventional electron-optical configurations, in the context of maximizing the information that can be recorded by single electron.

References:
[1] V. Grillo et al., arXiv:1609.09129 [quant-ph] (2016).

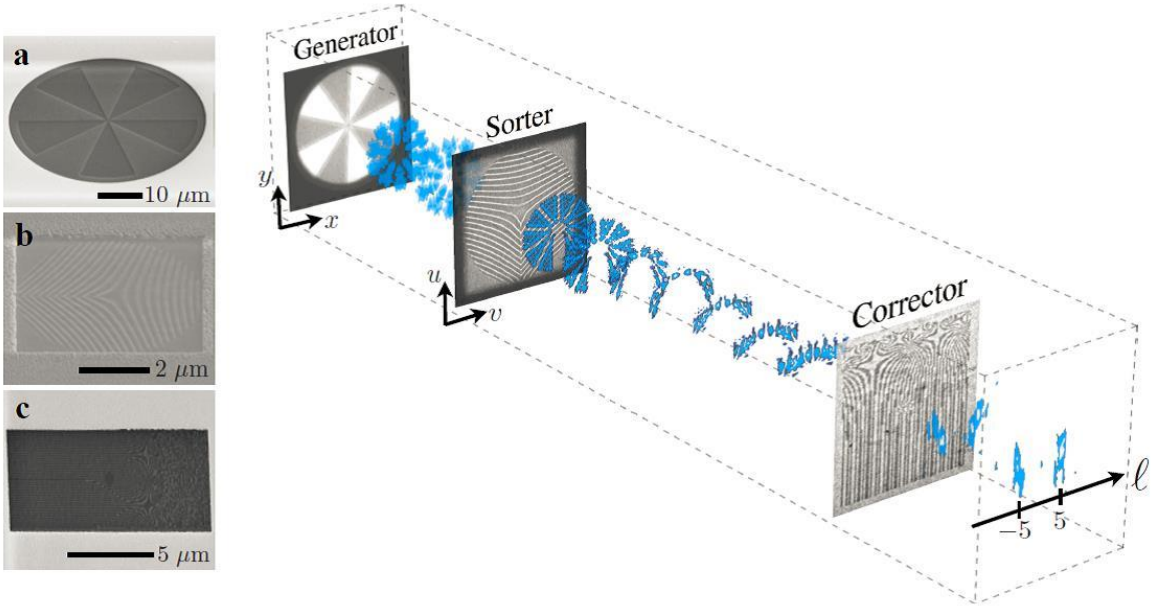

Figure 1. TEM images and schematic diagram of phase holograms and an electron beams transverse intensity profile recorded at different planes in the sorting apparatus.

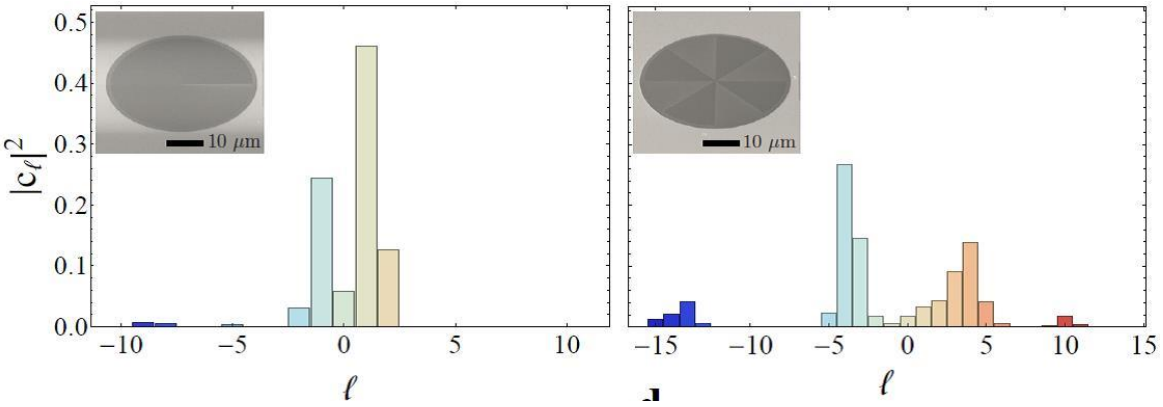

Figure 2. Experimentally recorded OAM spectra of different electron beams obtained from the sorters output for beams consisting of electrons defined by OAM values of +1,-1 produced using a spiral phase plate (left) and using a superposition of ±4 OAM states , produced using a phase mask (right).