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Tunable electron vortex beam generator

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An electron vortex beam (EVB) possesses one or more phase singularities at the center of its helical wavefront and is an eigenstate of the component of orbital angular momentum (OAM) along its propagation direction with eigenvalue $\ell\hbar$, making it an ideal probe for measuring the electronic and magnetic properties of materials. The ability to form EVBs in a transmission electron microscope (TEM) has been demonstrated using a helical phase plate [1], computer generated holograms [2, 3] and a magnetic monopole [4]. By taking advantage of their magnetic moment and angular momentum, EVBs have been applied to magnetic and shape dichroism measurements, chiral crystal structure characterization and nanoparticle manipulation. However, all of the methods that have been proposed to generate EVBs are limited by a constant value of OAM, which restrict their applications.
Here, we present a new concept for a helical phase plate for creating EVBs that is based on the electrostatic counterpart of the Aharonov-Bohm effect. We show both theoretically and experimentally that the phase plate is able to generate EVBs with any desirable value of OAM as a tunable and rapidly switchable device.
The proposed device creates an electrostatic monopole field, which can be realized using two narrow metallic parallel wires, to which an external voltage source is used to apply a potential difference. The device has been fabricated using a combined procedure involving electron beam lithography and focused ion beam milling. Details of its fabrication, performance in the TEM and possible applications will be discussed.

References:
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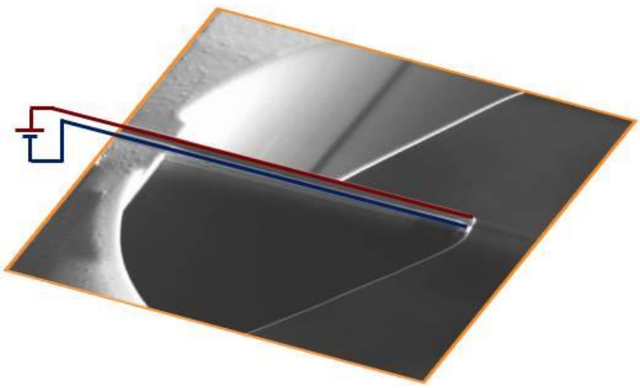

Figure 1. Secondary electron image of the tunable EVB generator. Two metallic nanorods that have a voltage applied between them are indicated by red and blue lines. The nanorods were patterned lithographically on a silicon-silicon nitride MEMS chip, in order to create an electrostatic monopole at their ends. The entire device is grounded to the microscope, while the wires are connected to an external voltage source. The use of a silicon nitride substrate prevents a short circuit between the metal lines.

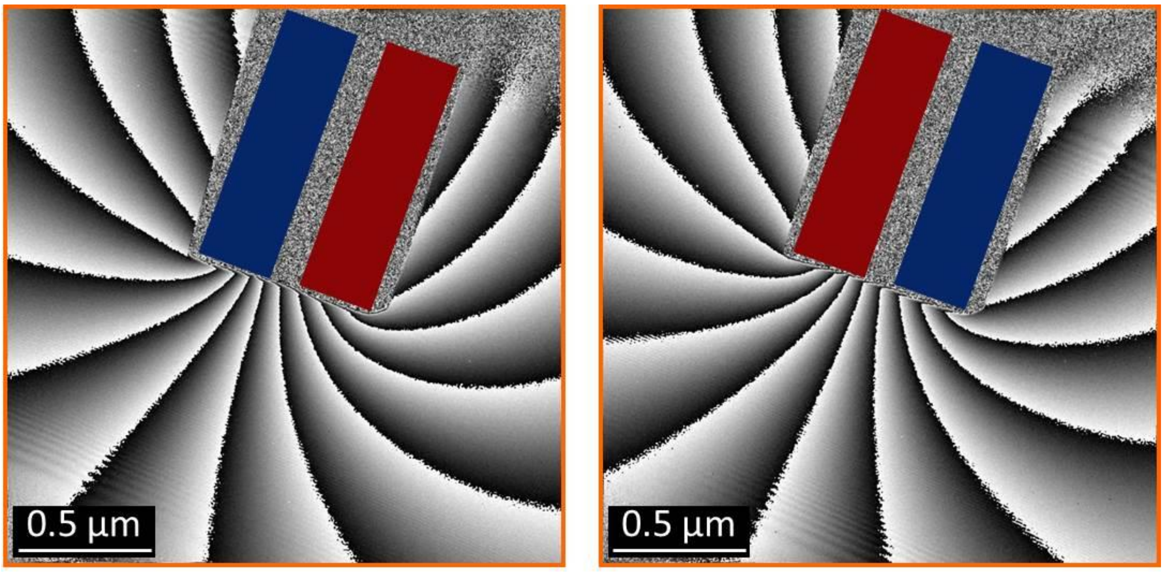

Figure 2. Reconstructed phase images (1× amplification) of the vacuum region around the end of the phase plate recorded using off-axis electron holography for voltages of -5 V (left) and +5 V (right) applied to the device.