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Transforming a Thermionic Transmission Electron Microscope into an Electron Interferometer

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Here we demonstrate the implementation of path-separated electron interferometry in older transmission electron microscopes (TEMs) with thermionic electron sources. Conventional electron holography utilizes wavefront-dividing electrostatic wire beamsplitters, which require a coherence width greater than the diameter of the electrostatic wire [1]. These coherence width values typically can only be achieved in a TEM with a highly-coherent field emission gun [2]. Consequently, much work has been devoted to further develop electron sources with a higher degree of spatial coherence [1].

While improving the electron source is possible, we suggest another, more cost-effective approach. Here, by combining electron microscopy and interferometry, we demonstrate electron interferometric experiments within a low coherence TEM. We use an amplitude-dividing nanofabricated electron diffraction grating beamsplitter, which requires electrons to be coherent over the pitch of the grating, typically 0.1 µm. These gratings should therefore enable us to perform electron interferometry with a lower-coherence thermionic electron source.

We placed a 20 µm diameter, 200 nm pitch diffraction grating into the condenser aperture of a FEI Tecnai G2 Spirit TEM, which formed multiple spatially separated diffraction probe beams in the specimen plane, as shown in Figure 1. The projection lens system and objective lens were then used to interfere the diffracted orders, giving rise to a path-separated electron interferometer similar to an optical Mach-Zehnder interferometer [3]. We then measured the spatial coherence width of the beam by overlapping the diffraction orders and acquiring an interference fringe pattern at different overlap focus values while maintaining spatial probe separation in the specimen plane. We adjusted the overlap between the paths until the interference fringes were no longer visible. We incrementally defocused the diffraction orders and acquired a series of forty images. We computed the fringe visibility for each pattern and fit the maximal points of fringe visibility to a Gaussian. We report a spatial coherence of 1.81 ± 0.04 µm as demonstrated in Figure 2.

Our results clearly indicate that the diffracted orders interfere with one another to create an image of interference fringes. Furthermore, we have demonstrated that one can conduct a spatial coherence measurement at the plane of the grating assuming there is no post-specimen decoherence. Future work will aim to impart a phase to one of the diffracted orders by allowing a phase specimen interaction with only a single diffraction order and allow all other orders to pass through vacuum. This phase will be measured by measuring the fringe shift, before the specimen interaction and after. This work shows potential to enable science using electron interferometry within cheaper, widely available commercial TEMs.

References:
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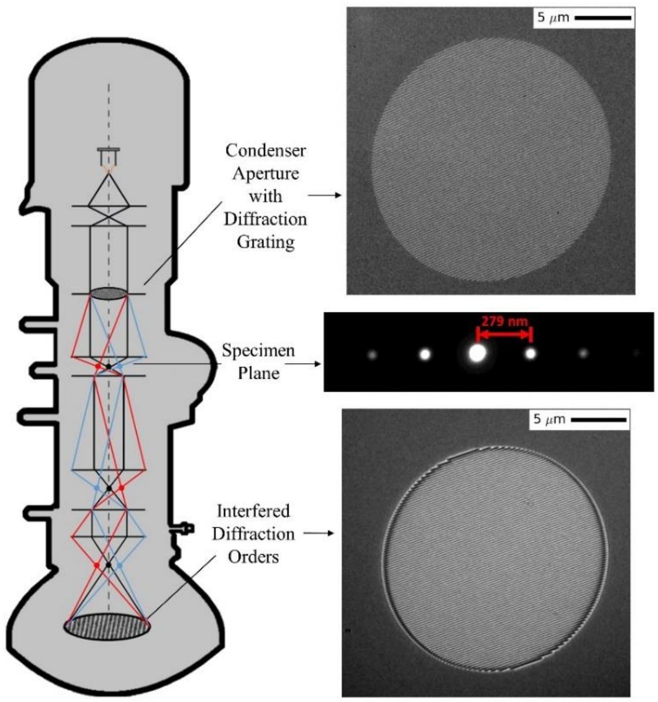

Figure 1. Experimental setup. The diffraction grating is placed in the condenser aperture of the TEM. Diffraction probes are visible in the specimen plane and are interfered in the image plane to produce interference fringes.

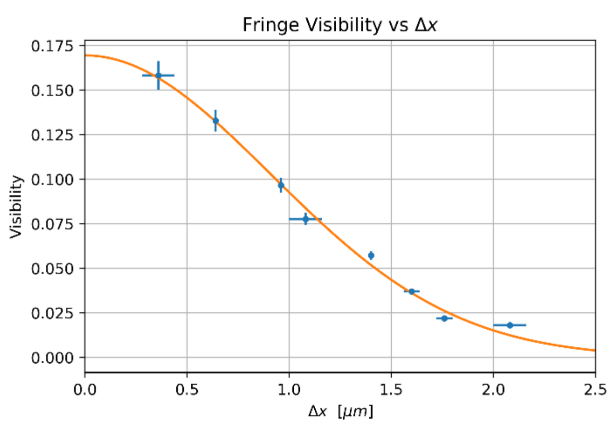

Figure 2. Fringe visibility over a 2.5 μm range of diffraction probe separation. The data has been fit to a Gaussian curve in order to measure the coherence width of the electron source in this TEM. We find that the coherence width is 1.81 ± 0.04 μm.