# A programmable phase patterning device for electron beams

S. A. Koppell, A. J. Bowman, Y. Israel, M. A. Kasevich
*Department of Applied Physics, Stanford University*
*382 Via Pueblo Mall, Stanford, California, 94305*
skoppell@stanford.edu

In contrast to the fantastic diversity and modularity of the tools of light optics, electron optical elements are significantly constrained. A programmable phase patterning device could simulate light optics which are difficult to implement for electrons and open up exciting possibilities like inexpensive, high order geometric aberration correction, efficient phase imaging, adaptive and compressive imaging, exotic beam shaping (e.g. bessel and vortex beams), and beam splitters for quantum electron microscopy[1].

As a step towards this goal, a 2x2 array of 1 micron Einzel lenses was recently demonstrated by Verbeeck et al[2]. As noted in their work, it will be difficult to scale this design beyond a few tens of pixels while maintaining the ability to address each pixel independently and while keeping charging and decoherence effects small.

We have designed an electron phase modulating device consisting of several thin films deposited on a silicon nitride membrane. The total thickness of the device is less than 50nm, making it nearly transparent to high energy electrons. It can also be used as a reflective element to control wavefronts produced by an electron mirror. Each micron-sized pixel on the device can be addressed in parallel to rapidly (<1ms) program a phase shift between 0 and $2\pi$. Our proof of concept device has hundreds of programmable pixels, and can straightforwardly be scaled to hundreds of thousands of pixels. This talk will describe the physical mechanism and progress in characterizing the device. We will also present simulations of the device performance for applications like aberration correction and phase imaging.

[1] P Kruit et al, *Designs for a quantum electron microscope*, Ultramicroscopy, 164:3145, 2016.

[2] Verbeeck et al, *Demonstration of a 2×2 programmable phase plate for electrons*, Ultramicroscopy, 190.10.1016, 2018