Electron wave front manipulation using patterned electrostatic mirrors

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Electron phase manipulation finds various application in electron optics. In transmission electron microscopy, phase plates are used for contrast enhancement. Other examples of phase manipulation include aberration correction, the generation of electron vortex beams and realizing new imaging modes. For instance, phase manipulation may enable the coherent electron beam splitting that is necessary in quantum electron microscopy [1].

Most forms of phase manipulation are achieved by some form of transmission mode imaging. The electron-matter interactions however result in undesired side effects such as inelastic scattering of the beam or charging of the phase plate. If instead a reflective mode of operation is used, these problems may be circumvented. We suggest the use of patterned electrostatic mirrors to create phase patterns.

Consider for example a flat plate that is patterned with a grating-like structure (figure 1, left). When an electrostatic potential is applied, the nearby equipotential lines are modulated in space. A potential slightly below the incident electron beam energy decelerates and reflects the electron. When the incident electron wave is spread out over the mirror pattern, the path length differences result in a phase modulation in the reflected wave. When focused back towards a sample plane, it is expected that this phase modulation results in a diffraction pattern.

To demonstrate the diffractive nature of the described patterned mirror, we are fabricating a setup using micro electromechanical system (MEMS) technology. This setup is placed in the sample chamber of a conventional scanning electron microscope (SEM). In the setup (figure 1, right), the beam is deflected towards a secondary axis by using electro(magneto)static deflectors. The beam is then reflected between two electrostatic mirrors facing each other. The first mirror performs aberration correction and the second mirror performs the phase manipulation. Next, the electron beam is deflected back to the primary axis. The effect of phase modulation is observed on a scintillator screen that is illuminated by the out coupled beam.

In a first experiment, we use a single patterned mirror. In these experiments, we aim to observe effects of diffraction in the reflected beam. We already observe the simultaneous imaging of the top and bottom of a sample (figure 2).

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[1] P. Kruit et al, Designs for a quantum electron microscope. Ultramicroscopy 164 p. 31-45 (2016).

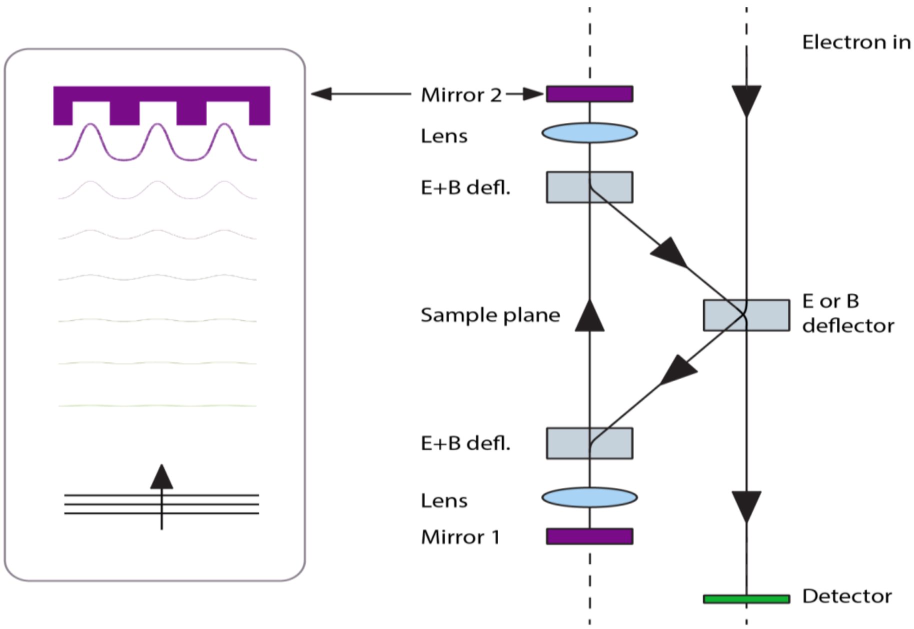

Figure 1. (left) Modulation of the mirror potential as a result of a grating-like pattern. The incident plane electron wave experiences path length differences upon reflection. This modulates the phase and is expected to result in diffraction spots when imaged towards a sample plane. (right) Schematic of the mirror setup placed inside the sample chamber of an SEM.

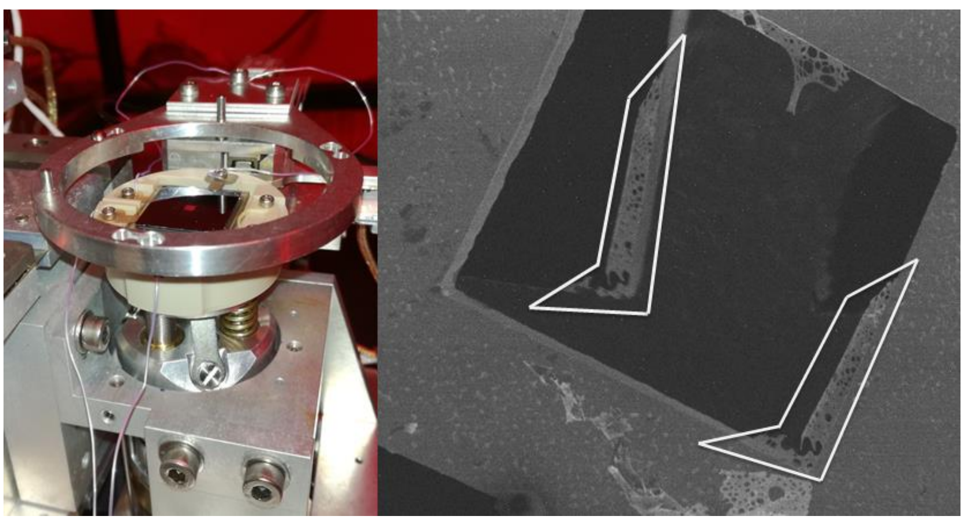

Figure 2. (left) The lens and mirror MEMS stack positioned on a translation and tilt stage for alignment. The sample holder is removed in this picture. (right) Micrograph of primary and mirror image in the same plane. The white shape indicates top and bottom of the same position on a sample. Full width 100 micrometer.