Electron mirror in MEMS technology for phase manipulation of the wave function

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Electron wave front manipulation requires the electron to pass an electrostatic potential or physical structure. Examples in electron optics include the application of (contrast) phase plates[1], grating-like structures[2] and aberration correction[3]. Usually, such manipulation requires transmission through a material, resulting in undesired side-effects including inelastic scattering and charging. We propose the use of a reflection mode of operation to circumvent these effects.

Reflection of electrons is realized by an axial potential that is higher than the beam energy. When an electrically conducting plate is used, it is possible in principle to manipulate the equipotential at the turning point of the electron beam (Figure 1). For instance, a grating structure is expected to diffract an electron beam, finding application in quantum electron microscopy[4].

Here, we will show how micro-electrical mechanical system (MEMS) and nanofabrication technology allow for (sub)-millimetre designs of electron optical (mirror/phase-engineering) setups. This approach requires sub-micron alignment accuracy both for individual electrode aperture roundness and intra-electrode axial alignment. This precision is achieved by using an in-house designed hexapod aligner (Figure 2)[5]. Patterning of the mirror to enable phase engineering of the beam is performed with focused ion beam for small area and interference lithography (figure 3) for large area patterns.

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[1] E. Majorovits et al. Ultram. 107 p. 213-226 (2007)
[2] J. Verbeeck, H. Tian and P. Schattschneider. Nature Letters 467 p. 301-304 (2010)
[3] R.H. van Aken, C.W. Hagen, J.E. Barth and P. Kruit. Ultram. 93 p. 321-330 (2002)
[4] P. Kruit et al. Ultramicroscopy 164 p. 31-45 (2016)
[5] A.C. Zonnevylle. PhD thesis at Delft University of Technology, ch. 5 (2017)

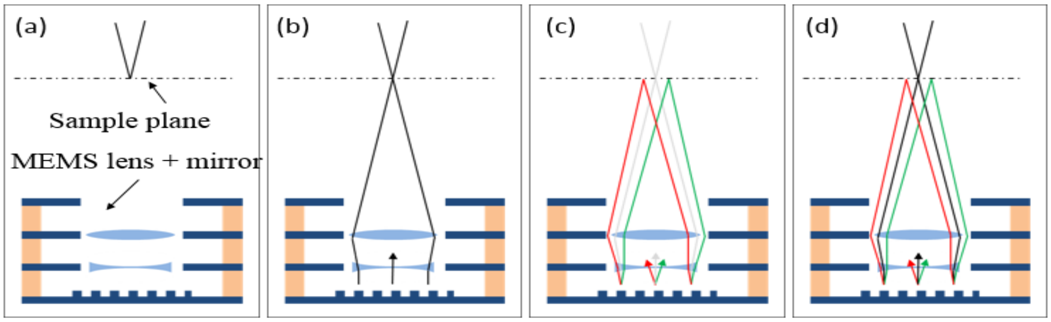

Figure 1: Proof of principle experimental setup. The primary beam passes a sample plane and is collimated on the patterned mirror[a,b]. Pattern effects are studied by focusing the collimated beam back to the sample plane[c,d].

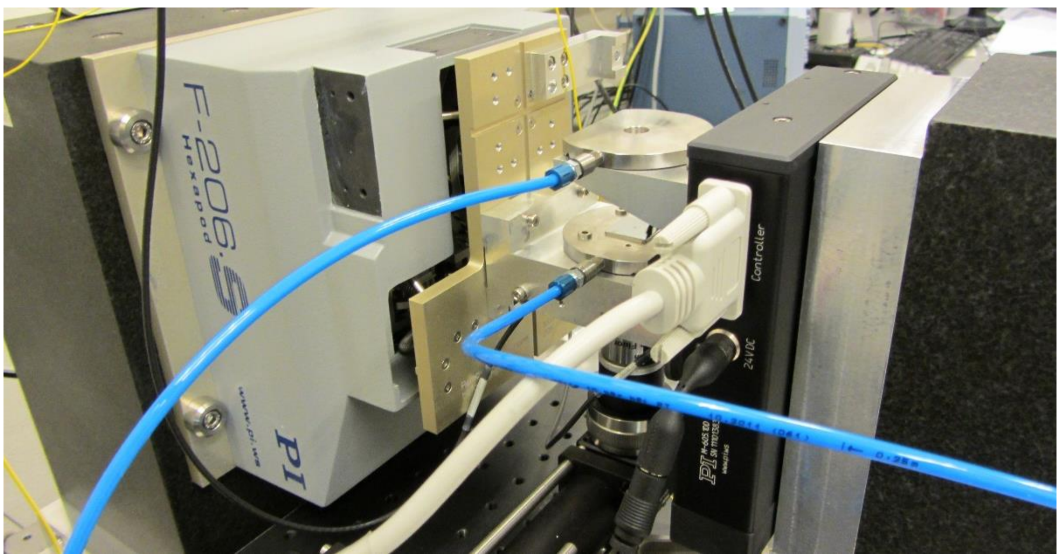

Figure 2: The hexapod (6D) aligner. Alignment accuracy for stacked elements up to 500 nm is achieved.

Figure 3: Cross-section of a large-area diffraction grating fabricated through optical interference lithography (Lloyd's mirror) followed by reactive ion etching. Scale bar is 1 µm. Inset: 25 mm diameter Si diffraction grating.