Electron wave front modulation in (S)TEM with patterned mirrors

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We propose a technique that could enable the arbitrary shaping of the electron wave front inside a modified (scanning) transmission electron microscope ((S)TEM). The ability to arbitrarily sculpt the electron wave front in microscopy would enable many new techniques, such as low-dose imaging and structural hypothesis testing. Also, it could enable beam mode conversion of for instance a plane wave into a vortex beam that carries orbital angular momentum (OAM).

The recent developments in the field of electron beam shaping focus mainly on transmission based techniques. Instead, we suggest an illumination scheme, in which one or two electron mirror(s) terminate the end(s) of an optical axis that is positioned parallel to that of the microscope axis (figure 1). A benefit of using mirrors is the inherent property that the electron beam never reaches the mirror electrode surface, and hence we avoid typical drawbacks such as phase plate charging that is seen in equivalent transmission based approaches to beam shaping. By applying a voltage or topogaphic pattern onto the mirror the nearby electric field becomes spatially modulated, which could in turn modulate the phase, and there with the wave front, of the reflected electron.

The combination of parallel axes and miniature optics results in small deflection angles up to 50 mrad only, which reduces sensitivity to deflection aberrations [1]. The electron beam can be cycled repeatedly between the two axes and the sample plane by making use of temporally gated electron deflectors (Figure 1a), which would enable imaging modalities such as multi pass or quantum electron microscopy. Alternatively, pre- or post-specimen beam shaping could be realized under a continues beam regime in the configuration that is shown in Figure 1b.

We are currently constructing a prototype setup based on the double mirror design as shown in Figure 1c. The use of parallel axes leads to the close vicinity of the microscope and mirror optical axes, and we suggest to use miniature liner tubes that optically shield these from each other (Figure 2a). The use of lithographically fabricated electrodes enables the close proximity of the axes (figure 2b), and the deflection paths are realized by making use of an EBE beam separator [2].

References.

[1] Dohi and Kruit, Ultram. 189, 2018, pp. 1-23.
[2] Krielaart et al, Journal of applied physics 127, 2020, 234904.

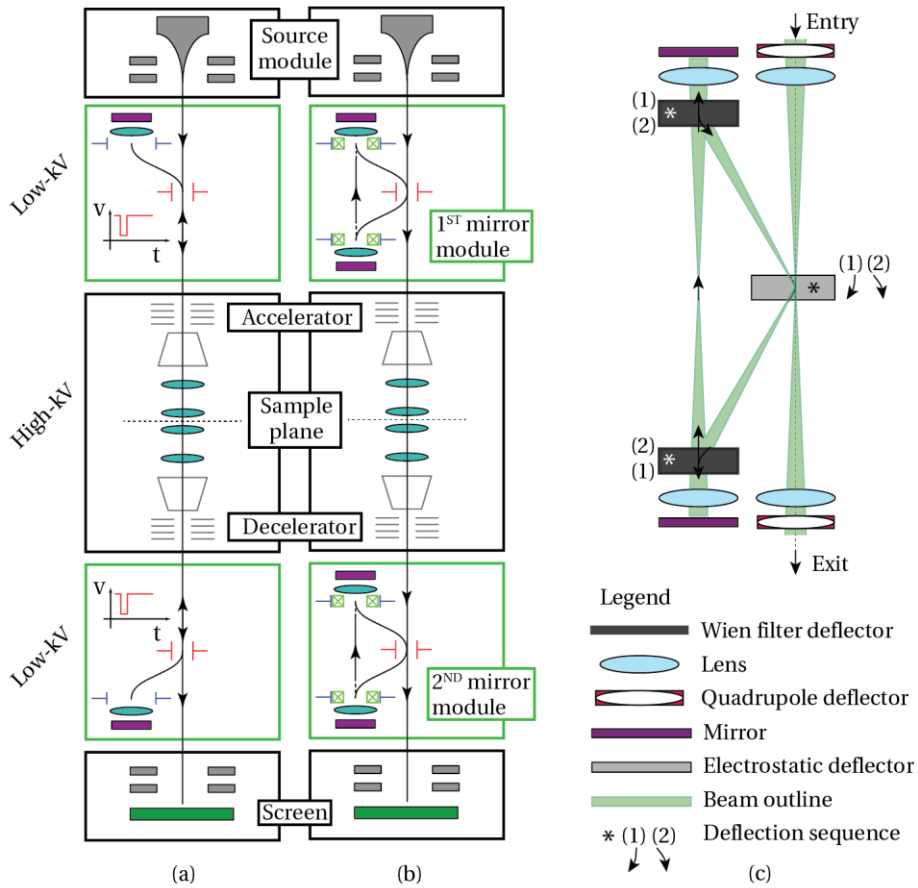

Figure 1. Integration of a single and double mirror module as an extension module for the column of a TEM. Shown implementations enable (a) multi pass and quantum electron microscopy, and (b) pre- and post-specimen wave front shaping. (c) The optical path and components of our prototype mirror module.

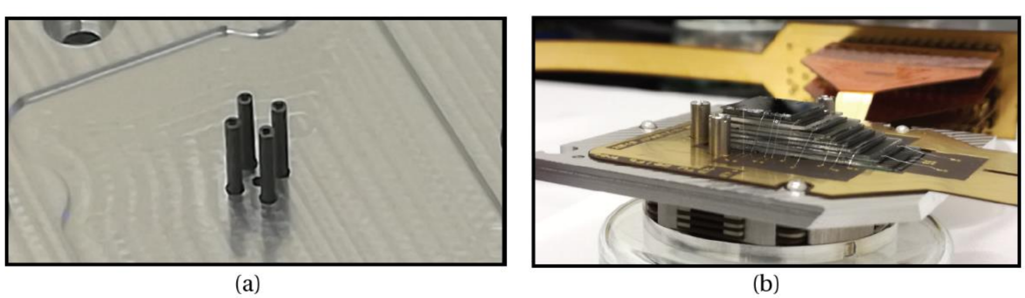

Figure 2. Photographs of a partially assembled MEMS mirror and lens stack. (a) Miniature liner tubes provide an optical separation between the microscope axis and the mirror axis. (b) MEMS unit consisting of miniature liner tubes, the electron mirror, focusing lenses, and a quadrupole deflector. The Wien filter type EBE beam separator is visible below the base plate that supports the MEMS elements.