Towards an application of quasi non-diffractive electron Bessel beams in scanning transmission electron microscopy

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Shaping the electron beam opens up novel imaging modes in electron microscopy. Besides electron vortex beams, which meanwhile are generated in an excellent quality [1], quasi non-diffractive Bessel beams (BBs) are promising for numerous applications, e.g., tomography [2]. We present analysis and application of single BBs with high quality generated by direct phase masks (PMs). The PMs consist of nanostructured thin films surrounded by an obstructing Pt aperture and are fabricated using lithography and customized focused ion beam milling. The resulting PMs are analyzed in the low-magnification mode of a FEI Titan and are implemented as C2 aperture for application purposes.

Figure 1a shows an experimental image of a BB generated in the object plane. The BB exhibits a full width at half maximum (FWHM) of 0.5 nm which is surrounded by concentric rings of weaker intensity. In theory, the non-diffractive property manifests itself in a constant beam profile upon propagation. However, due to the limited lateral size of the generating PM, the profile is not constant in the experiment. The quasi non-diffractive property is measured by tracing the intensity of the central maximum I_{CM} of the BB in dependence of the propagation distance behind the PM (Figure 1b). I_{CM} oscillates around a linear increase before it drops once the maximum propagation distance is reached. The observation is in agreement with theory and previously published results [2,3]. A suitable profile of the BB is selected for imaging by adjustment of the condenser lens system. Conventional scanning transmission electron microscopy (STEM) imaging however is not beneficial with the BB depicted in Figure 1a. The relative intensity in the central maximum represents only a small fraction of the total BB intensity which leads to a weak signal-to-noise ratio. An application in the novel imaging (i)STEM mode [4] however allows the preservation of the quasi non-diffractive property while exploiting the total BB intensity. Figure 1c shows an iSTEM image acquired with the BB depicted in Figure 1a which clearly reveals the layer system (Pt/aC/Pt) of the test specimen. Nevertheless, a low signal-to-noise ratio is still an issue as the PM (diameter 10 m) still blocks a large amount of electrons compared to the conventional STEM aperture (50 m).

We demonstrated the successful generation of a BB with sub-nm size using a direct PM. The same BB was applied on a test specimen in the iSTEM mode. PM fabrication and design will be further optimized to improve the application of BBs in (i)STEM.

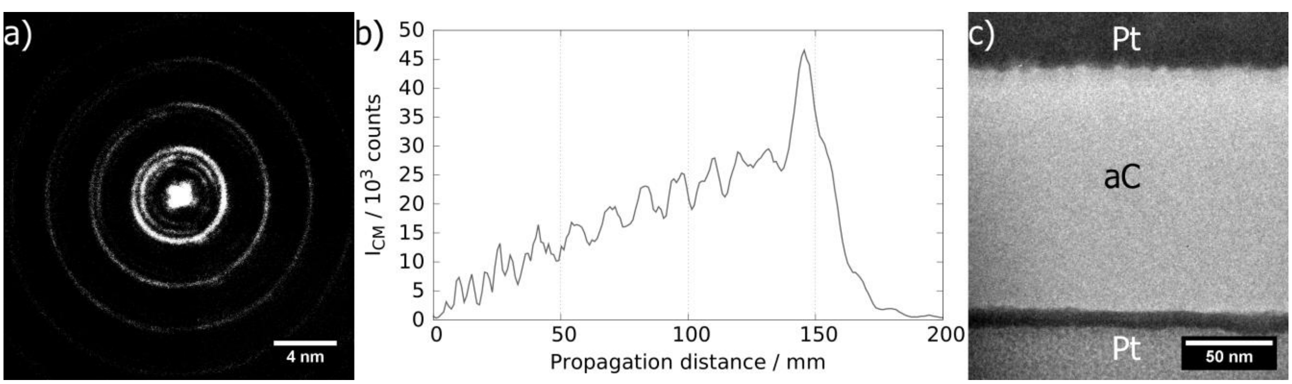

Figure 1: (a) Experimentally generated BB exhibiting a central maximum with a FWHM of 0.5 nm observed in the object plane. (b) I_{CM} in dependence of the propagated distance after transmission through the PM. (c) iSTEM image acquired with the BB depicted in (a).

References:

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