tibaDESC: Precise Measurement of Diffraction Pattern Distortions for Quantitative STEM

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The shape and sensitivity distribution of the detector used for the acquisition of STEM micrographs is of the utmost importance for the accuracy of quantitative evaluation. This is especially the case for HAADF-STEM, which is frequently used for thickness measurement and chemical composition determination using Z-contrast. The roundness and uniformity of different detectors and the influence of exact centering has consequently been a central item in numerous publications. Here, the detector sensitivity is commonly characterised by scanning the focused electron probe over the detector without a specimen working in imaging mode to get a so-called detector scan. While this allows for a precise measurement of the shape and sensitivity of the physical detector, using the imaging mode for this detector scan completely neglects any effects that will occur exclusively in diffraction mode, in which the actual STEM acquisitions are done.

However, looking at a diffraction pattern in a microscope with an image aberration corrector quickly reveals that the diffraction pattern is indeed strongly distorted with a symmetry corresponding to the corrector architecture and also is limited by a visible cutoff at higher spatial frequencies. The distortion field responsible for the deformation can strongly change the shape of the effective detector sensitivity experienced by the scattered electrons: Electrons leaving the specimen under a certain angle may be deflected into a completely different area of the detector than expected without the distortions or may not even reach the detection plane at all due to the cutoff. Therefore even a perfectly round and uniform detector can result in an unfavourable anisotropic sensitivity.

To take all these effects of the diffraction pattern into account, an alternative detector scan procedure called tibaDESC that is operated in diffraction mode is presented [Ultramicroscopy **161**, 146 (2016)]. It allows direct determination of the effective sensitivity of the detector, which includes both the cutoff and all occurring distortions. This "tilt-based" detector scan method is automated.

The effective detector sensitivity of a Fischione HAADF detector in an image corrected FEI Titan 80-300 microscope was characterised with the tilt-bases detector scan for various camera lengths and clear and significant differences to the conventionally determined sensitivities were found. The results are shown in Fig.1: The effective sensitivity is not nearly as round as the almost perfectly annular form of the physical detector, which partially results in large deviations in the radial sensitivity curves. The quantitative influence of these deviations on the results of thickness and composition measurements was investigated.

In a further study, the tilt-based detector scan method was combined with an aperture in front of the detector plane to measure not only the effective sensitivity but also the radial position where specific scattering angles are detected in the detection plane. From this the radial distortion field can be extracted.

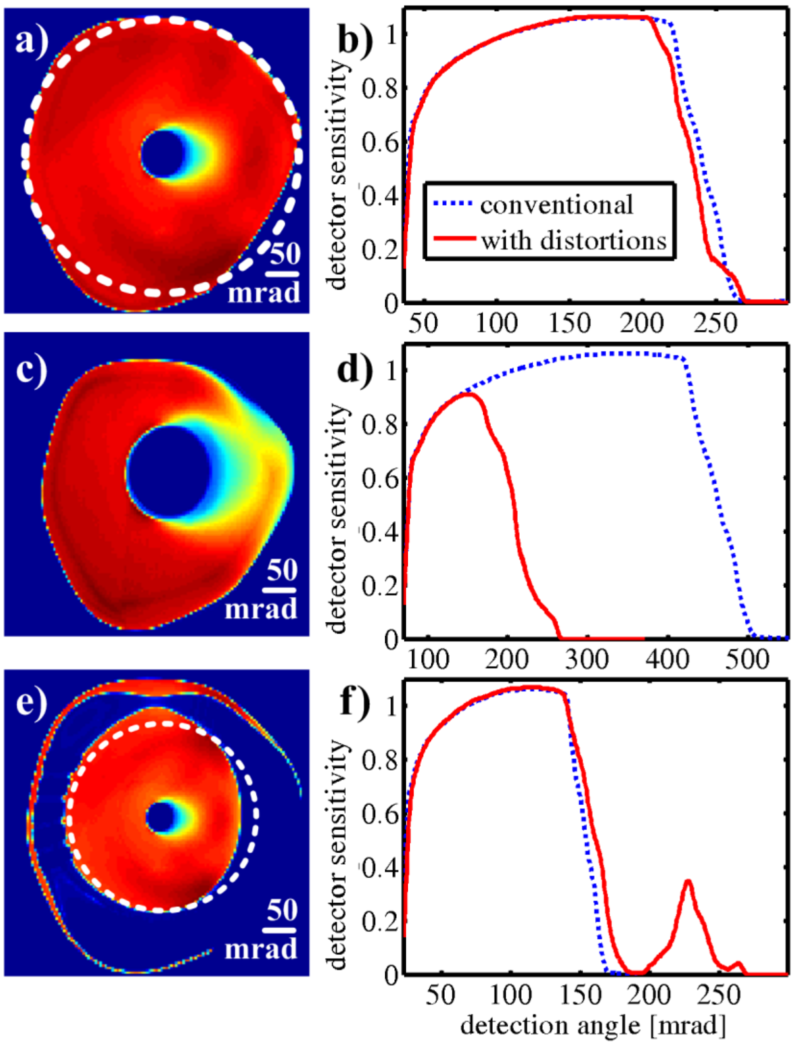

Fig 1: Left: Tilt based detector scans for different camera lengths ((a)196 mm; (c)102 mm; (e)301 mm). The dotted circle shows the expected outer border from the conventional method. The right column shows the resulting radial sensitivities in comparison with conventional curves.