Theoretical and experimental study on detection precision and imaging quality of a PSD based non-pixelated COM detector for DPC

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The development of probe-corrected STEM allows the measurement of picometre scale potential variations using differential phase contrast microscopy (atomic DPC) [1-4]. In contrast to conventional DPC with an annular detector (cDPC), the potential gradient across the electron probe is no longer constant, resulting in a diffractive redistribution of intensity in the diffraction disk. Müller-Caspary and Krause showed that the intensity weighted centre of the diffraction disk, often called centre of mass (COM) can be related to the average lateral momentum the electron ensemble gains by interacting with the specimen and therefore to strength and direction of the deflecting fields [3].

To measure this COM we choose a duo-lateral-position sensitive diode (PSD), combining the fast detection speed and comparably low pricing of a cDPC detector with the ability of pixelated detectors to track the absolute position of the diffraction disk's COM. Additional advantages of a PSD are that, in contrast to cDPC, the measurement is independent on the beam current density and yields absolute positions of the diffractions disk's COM, which facilitates calibration massively. With our setup, we are able to measure beam deflections with an accuracy of ~0.5 rad [5] at an acquisition speed of 5-10 s per scanning point.

We will discuss the performance of the PSD in terms of its precision in beam shift detection and further compare the results to our cDPC setup. We present an analytical description and simulations on the achievable precision. The measurement parameters taken into account were the current density on the detector, the diffraction disk radius and beam broadening in the detector material (Fig. 1). Based on this we derive criteria for microscope settings enabling optimal conditions for DPC measurements with the new detector.

In addition, we present experimental results comparing the imaging capabilities of the PSD with the cDPC detector. Figure 2 shows the results obtained with the PSD and cDPC detector, both imaging the same magnetic cross-tie wall in a 35 nm thick cobalt film. Based on these measurements we calculate the SNR, which turns out to be about three times higher when measuring with the PSD. While for all practical purposes the results of the PSD measurements match (or slightly exceed) the imaging capabilities of the cDPC detector, one has to keep in mind that it additionally offers the advantage of tracking the position of the diffraction disk's COM. From these results we expect the detector to serve well in (sub-atomic) DPC field sensing, possibly replacing today's segmented or pixelated detectors.

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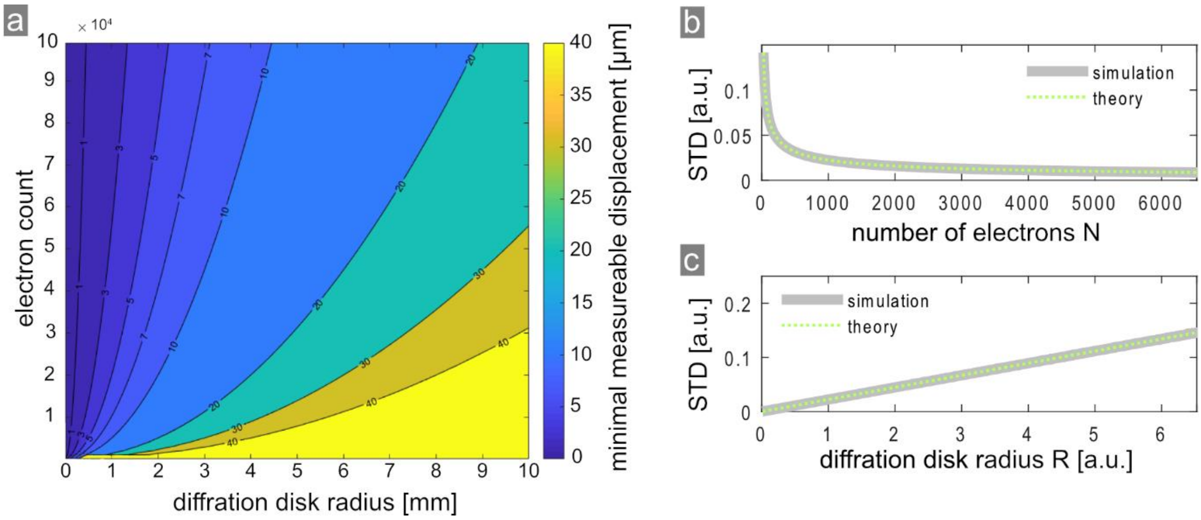

Fig. 1 Theoretical description of the minimal measureable beam displacement (**a**) and standard deviation STD (**b/c**) in dependence on electron count and diffraction disk radius.

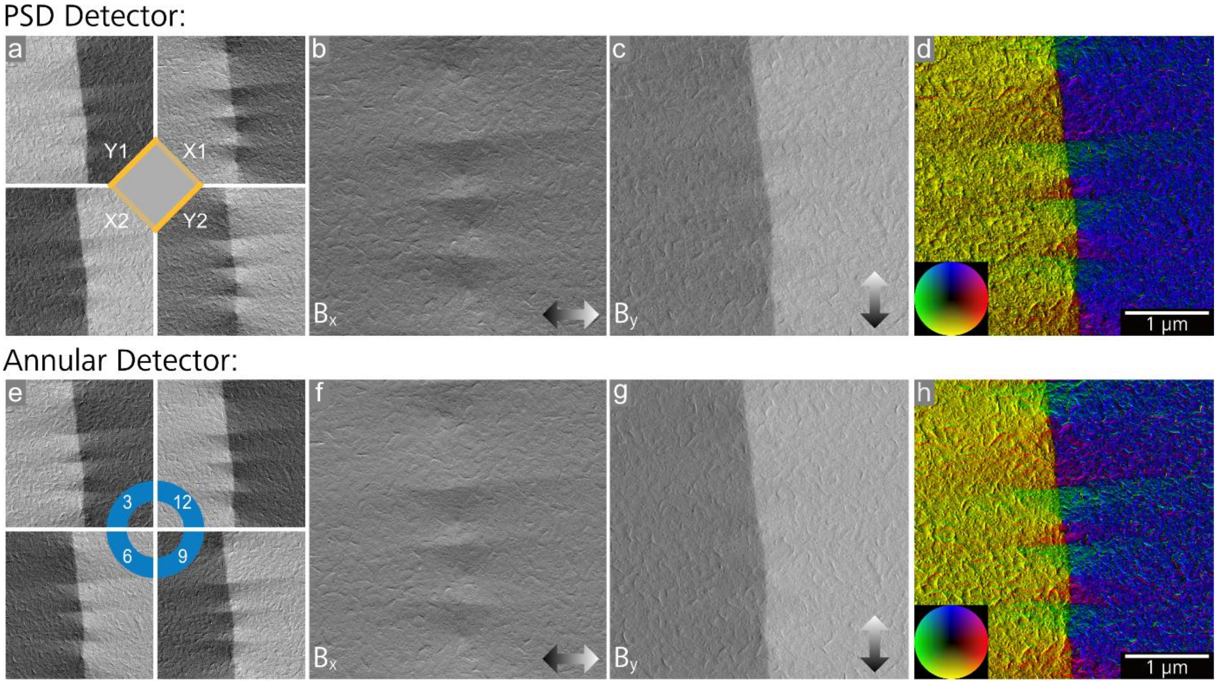

Fig. 2 Comparison between PSD and cDPC detector when imaging the magnetic induction of a cobalt cross-tie domain wall.