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IT-2-O-2157 An alternative normalization method for quantitative STEM

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Techniques such as annular bright-field (ABF) or high-angle annular dark-field (HAADF) scanning transmission electron microscopy (STEM) have become widely used in quantitative studies because of the possibility to directly compare experimental and simulated images when the experimental data is expressed in units of 'fraction of incident probe' [1]. This is achieved by subtracting by the amplifier's 'black-level' normalizing the experimental image by the mean sensitivity of the annular detector. Since the detector response is spatially inhomogeneous [2], a 'detector sensitivity' profile needs to be included in image simulations in order to account for these irregularities. Unfortunately, the quantification procedure now becomes both experiment and instrument specific, with new simulations needing to be carried out for the specific response of each instrument's detector. This not only impedes the comparison between different instruments but can also be computationally very time consuming.

In this work, we propose an alternative method for normalizing experimental data in order to compare these with simulations that consider a homogenous detector response. To achieve this, we determine the electron flux distribution reaching the detector by means of a camera length series, which is then used to determine the corresponding weighting of the detector response. Figure 1a) shows the detector scan and b) its corresponding active area. The electron flux reaching the active area of the detector is shown in Figure 1 c), which was determined using a camera length series (Figure 2). Next, after normalizing this flux profile to unity, it is multiplied pixel-wise with the experimental detector map, Figure 1d), in which the detector response inhomogeneity is clearly observed. By integrating Figure 1d), we obtain an overall 'flux-weighted detector sensitivity' value, which can be used for the experimental data normalization. To validate the proposed methodology, we simulated a [100] oriented Pt crystal using the StemSim software under the frozen lattice approach [3]. The simulations considered homogeneous and inhomogeneous detector sensitivities for 60 – 190 mrad detector acceptance angles. Figure 3 shows that the total intensity for a simulation considering inhomogeneous detector sensitivity followed by electron flux weighting (analogous to experimental conditions) is in perfect agreement with simulations performed with homogeneous detector sensitivity (the ideal case).

[1] J. M. Lebeau and S. Stemmer, Ultramicroscopy 108 (2008), p.1653-8
[2] K. MacArthur, L. Jones, and P. Nellist, Journal of Physics: Conference Series (2013)
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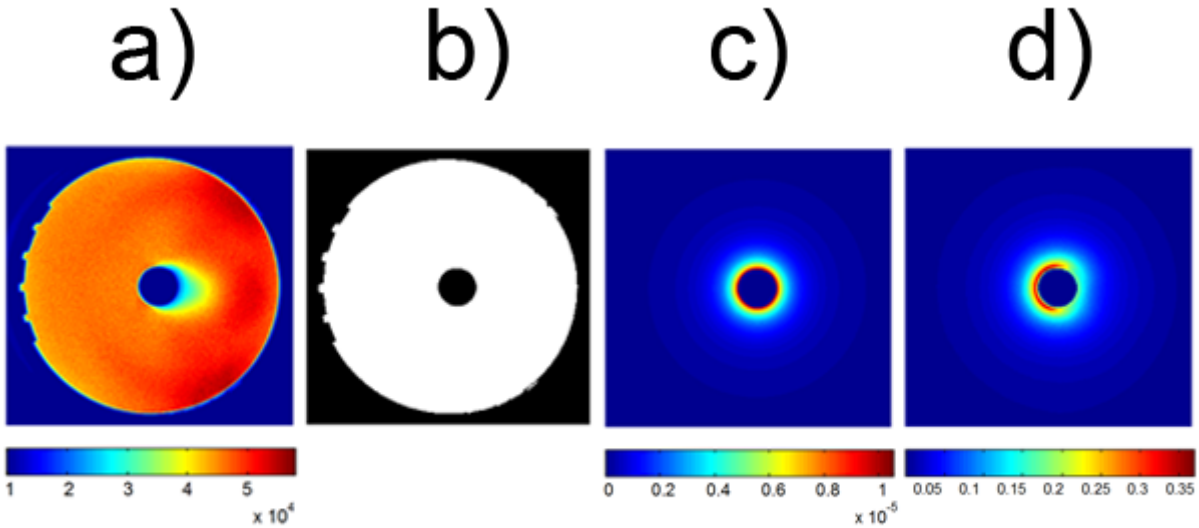

Fig. 1: Proposed flux-weighted normalization steps: a) experimental detector map, b) detector active area, c) determined flux pattern using camera length series, and d) flux-weighted sensitivity resulting from product of plots a) and c).

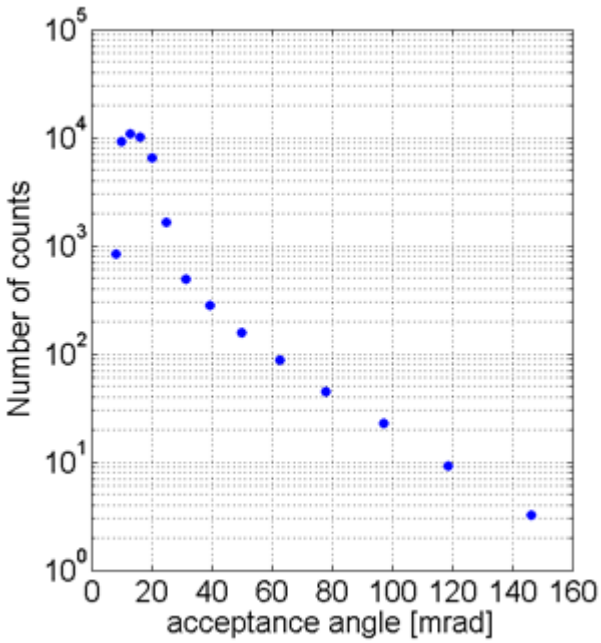

Fig. 2: Measured electron flux distribution from simulated camera length series. Using this plot, Figure 1c) is computed for the detector active area.

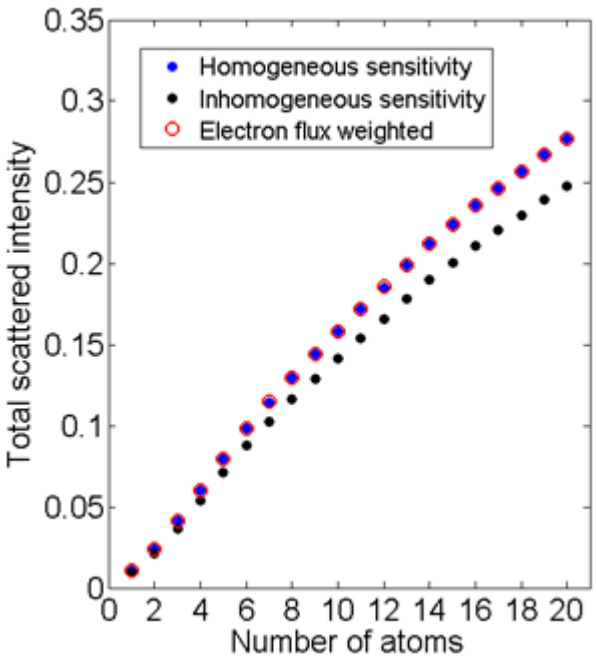

Fig. 3: Total scattered intensity for homogeneous (blue) and inhomogeneous (black) detector sensitivity. Red circles correspond to the total scattered intensity of inhomogeneous detector sensitivity after electron flux weighted normalization.