(Invited) Momentum-resolved STEM: Opportunities for dedicated contrast formation in electron microscopy of hard and soft matter

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Via the introduction of ultrafast camera hardware for the recording of large parts of the diffraction pattern at each scan position, STEM has been augmented drastically recently by the simultaneous availability of both real and momentum space resolution. Nowadays, dedicated contrast can hence be generated on the computer after the acquisition. For example, annular dark field imaging can be enhanced by the angular multi-range analysis [1] which allows for the mapping of specimen thickness and chemical composition from a single data set by exploiting the signal of virtual detectors with dedicated geometry. More importantly, momentum-resolved STEM offers data processing possibilities that are not available by analog established hardware. As an example, we will summarise our results on first moment imaging to measure electric fields at the atomic scale in 2D materials [2,3], and polarisation fields in piezoelectrics [4]. In addition, a conceptual comparison with other phase-retrieval methods such as electron holography and ptychography will be presented [5]. This will motivate a study on the dependence of, e.g., first moment results on the optical settings of the microscope, namely the defocus. It turns out that the foci for maximum contrast in first moment and annular dark field maps are very different, which we will demonstrate by experimental and simulated momentum-resolved STEM focal series of 1D metal nanostructures and 2D ferroelectrics. Moreover, first results of momentum-resolved STEM-based imaging of biological specimen, such as tabac mosaic viruses, will be shown and discussed as to dose efficiency and contrast enhancement compared to conventional imaging techniques. Finally, the necessity for dose efficiency and the huge data rates have lead to strong activities for in-situ data processing and visualisation. Besides the live imaging of STEM data obtained from virtual detectors, we demonstrate the possibilities of LiberTEM [6] combined with the Medipix detector for insitu ptychographic reconstruction.

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[3] Phys. Rev. B 98, 121408 (2018).
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[6] LiberTEM/LiberTEM 0.1.0. (2018); https://doi.org/10.5281/zenodo.1478763.