

*Integrated Differential Phase Contrast (iDPC) STEM*Ivan Lazić¹, Eric G. T. Bosch¹, Sorin Lazar¹¹Thermo Fisher Scientific (formerly FEI), Eindhoven, Netherlands
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In this talk we present Integrated Differential Phase Contrast (iDPC) STEM [1-3], an electron microscopy (EM) technique that directly images the electrostatic potential field produced by charged particles forming the sample. The electrostatic potential field of the sample has clear maxima at the atomic core positions. Therefore it represents an ideal sample map and is the ultimate goal for any EM imaging technique. For thin samples, the phase of the transmission function of the sample is directly proportional to the projected electrostatic potential field. The iDPC-STEM is therefore also a direct phase imaging technique.

For non-magnetic samples we know from basic electrostatics that the electric field of the sample (which is a conservative vector field) is the gradient (differential) of the electrostatic potential field of the sample (a scalar field). An electron passing the sample is influenced by this electric field. If the sample is thin, the electric field at the impact point deflects the electron proportionally to its in-plane component. This deflection can be measured by detecting the position of the electron at the detector in the far field. Measurement of the electron (beam) deflection is the subject of Differential Phase Contrast (DPC) techniques [4, 5]. In reality, the motion of the electron is described quantum mechanically with its electron wave function. By focusing the electron wave (the probe) we increase the probability that the electron passes at a certain position and is influenced by the electric field at that position. In the far field, at the detector plane, we obtain a corresponding convergent beam electron diffraction (CBED) pattern, a result of many electrons passing the sample. It was indicated [5] and strictly proven [2] that the mathematical expectation of the electron position in the detector plane, in other words, the center of mass (COM) of the CBED pattern preserves a linear relation to the local electric field at the position of the probe. By scanning the probe, the full COM vector field can be obtained as a linear measure of the electric vector field of the sample. An ideal DPC technique should therefore acquire the COM vector field. A straightforward way of performing this is to use a camera. By recording each CBED pattern COM components can be computed directly [2, 6]. Because this requires fast readouts and stable drift-free samples, in practice COM components are measured using detectors with only a few segments [2, 3]. These methods are fast and enable live imaging, as in (A)BF- and (HA)ADF-STEM.

By integrating the measured COM vector field we obtain the iCOM scalar field, a linear measurement of the electrostatic potential field of the sample [1-3]. iDPC-STEM is a practical method of obtaining iCOM. In this talk iDPC-STEM using a 4 quadrant segmented detector will be explained. Various experimental results and applications will be presented and compared to standard (S)TEM imaging results. It will be demonstrated that iDPC-STEM is capable of imaging light and heavy elements together, has full low frequency transfer and is a low dose technique.

[1] Lazić I. et al (2014) US Patent 9312098.

[2] Lazić I., Bosch E.G.T. and Lazar S. (2016) Ultramicroscopy 160, 265-280.

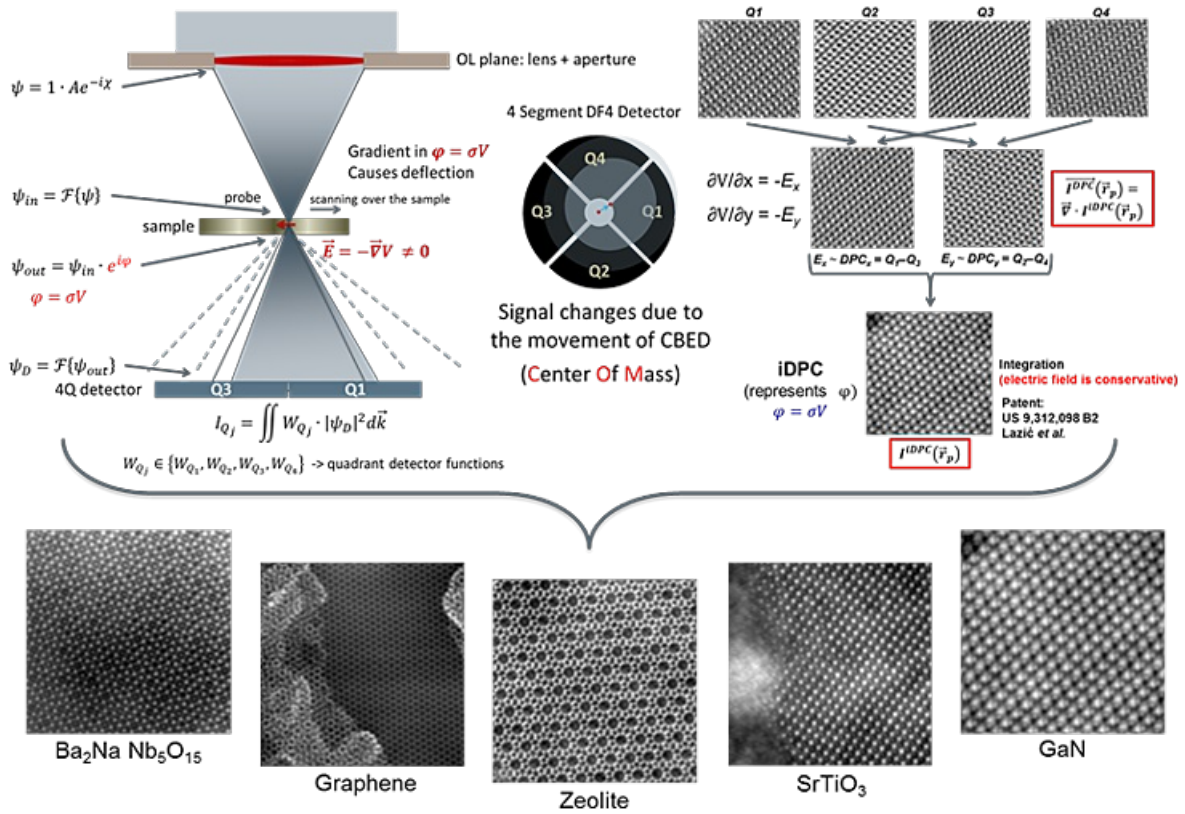
[3] Lazić I., Bosch E.G.T. (2017) Advances in Imaging and Electron Physics 199, in print.

[4] Dekkers N.H., de Lang H. (1977) Phillips Tech Rev. 37, 1-9.

[5] Waddell E.M., Chapman J.N. (1979) Optik 54, 83-96.

[6] Muller D.A. et al (2016) Microsc. Microanal. 22, 478-479.

iDPC-STEM using 4Q detector



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