(Plenary talk) Ptychography - an old name for a modern revolution in imaging

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With advent of high-efficiency detectors that can collect '4D STEM' data, ptychography is slowly making inroads into electron microscopy. From a wider historical perspective, progress has been extraordinarily slow. Walter Hoppe proposed a first version of ptychography – an obscure solution to the crystallographic phase problem – more than fifty years ago [1-2]. The name was (perhaps regrettably) carried over into a generalised computational imaging strategy. In fact, the 'ptycho' element of Hoppe's insight is perhaps more relevant to the so-called 'oversampling' concept in coherent diffractive imaging, itself a serious misnomer. The real strength of the modern notion of ptychography [3] is the combination of diffraction and, most crucially, translational diversity: the movement of a constant wavefield (in the case of STEM, a focussed probe) with respect to the specimen.

The renaissance in ptychography has gained traction because of the increase in the size and power of computers, and the vastly improved quality of detectors. Although the concept of inverting '4D data' into continuous images was first investigated 30 years ago, it was the development of iterative search to the ptychographic inversion problem that led to a key hard X-ray experiment in 2007 at the Swiss Light Source.

This experiment showed that the numerical aperture of a microscope lens could be overcome by many factors – in fact, resolution is ptychography is only limited by the scattering strength of the object (in other words, the radiation wavelength) and it can be implemented without any lenses at all. Further innovations followed quickly, including ptychography's ability to measure image phase very accurately, calibrate any optics involved in the experiment, and to 'unwind' (reverse calculate) multiple scattering effects.

Ptychography is applicable at all wavelengths, and is now making inroads into microscopy that uses EUV, visible light, Terahertz, electron radiation.

This talk will first present an elementary introduction to ptychography for those who may not be familiar with its potential powers and applications. It will briefly review progress over all wavelengths. The author will also present recent results relating to how ptychography can handle partial coherence in the electron microscope and how modal engineering can increase useable flux for sources with relatively low coherence.

[1] Hoppe, W.. **A 25** (1969) p. 495.
[2] Hegerl, R. and W. Hoppe, Berichte Der Bunsen-Gesellschaft Fur Physikalische Chemie, **74** (1970) p. 1148-&.
[3] Rodenburg, J. and A. Maiden, *Ptychography*, in *Springer Handbook of Microscopy*, P.W. Hawkes and J.C.H. Spence, Editors. 2019, Springer International Publishing: Cham. p. 2-2.