Strategies for 3D imaging and phase retrieval in mixed image and diffraction spaces.

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In the classic phase problem it is only possible to measure the intensity of the Fourier transform of a wave-function. If it is also possible to move an aperture or probe or support function over the original wave-function (or over the complex transmission function that would give rise to an exit wave-function), and then record all diffraction patterns as a function of that aperture position, then there is a direct (and extremely over-redundant) solution to the phase problem. This situation arises in scanning transmission electron microscopy (where a probe can be scanned over a specimen transmission function) and in a number of other microscopy applications. The advantages of solving for phase in this roundabout way is that it allows extension of the information limit of the microscope, thus improving obtainable resolution by many factors. This talk will describe the discrete (i.e. periodic) solution of the problem, sometimes called 'ptychography', and show how it can be extended to non-periodic objects. In the case of electron microscopy, the fact that the specimen is usually transparent (the magnitude of its transmission function is unity), leads to the presence of a semi-holographic solution for continuous objects. Although this reference is strictly not necessary for solution of the phase, the same approximation can be used to generate a perfect two-dimensional reconstruction of a projection of the specimen, thus leading to the possibility of 3D tomographic imaging at sub-atomic resolution. Improving the performance of electron microscopy this way is very promising, but still faces experimental difficulties associated with the quantity of data involved and the time taken to record it, during which the specimen can damage, drift or contaminate. However, a hybrid method, employing a combination of the transmitted reference wave and the phase reconstruction methods should be practical, given the advances in microscope stability, detector technology and computer speed.