Phase Retrieval with the Ptychographical Iterative Engine: Analysis of Success for STEM given Incorrect Initial Parameters

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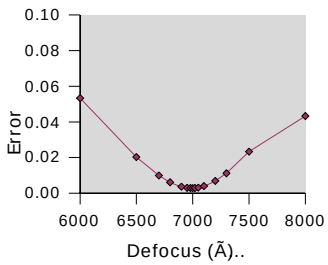
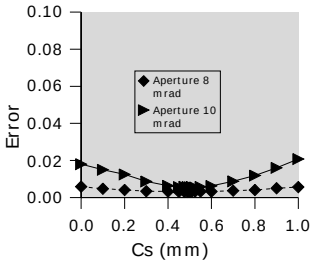
The Ptychographical Iterative Engine (PIE) algorithm [1] is a phase retrieval algorithm that uses measured wavefunctions, created with a probe which is assumed to interact multiplicatively with the specimen. It solves a problem previously thought to be intractable: that of iterative phase retrieval in STEM [3], and is applicable to many other situations. The algorithm combines useful properties of iterative methods, such as numerical stability and insensitivity to noise, with the ability to image at high resolution through the use of diffraction data.

The PIE algorithm may be used in many forms of microscopy, and is currently specifically being applied to STEM. To be effective in experimental practise, it must be tolerant of problems that arise in experiments, such as inaccurate characterisation of the imaging system, or incoherence effects. This paper studies the behaviour of the algorithm in such situations.

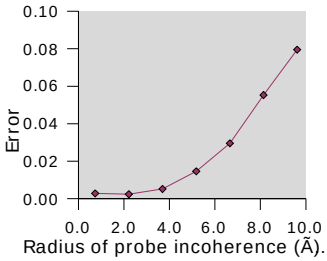
Figures 1(a) and (b) demonstrate the effect on PIE phase retrieval in STEM when a probe parameter is inaccurately known. In general, the PIE algorithm is tolerant of incorrect characterisations of the probe parameters, suggesting that this will not cause problems in experimental practise. Very poor characterisation of these parameters has a detrimental but well behaved effect on the algorithm. Therefore, iterating the algorithm over small variations in the assumed parameters may be used to test and improve the accuracy of the probe characterisation, increasing the success of that and future experiments using the same probe.



(a) Error with varying defocus
Correct defocus was 7000Å



(b) Error with varying C_s
Correct C_s was 0.5mm



(c) Error with increasing probe incoherence

Figure 1: Error results of iterative algorithm (after 400 iterations) when varying known probe parameters away from the correct value, and for varying probe incoherence.

Figure 1(c) shows the behaviour of the algorithm as the probe incoherence is increased. The phase retrieval accuracy decreases with increasing incoherence. However the algorithm is tolerant of much greater incoherence than would be present in a normal experiment. These results suggest that the PIE algorithm is a very good candidate for experimental success.

References

[1] - H. M. L. Faulkner and J. M. Rodenburg., Appl. Phys. Lett., 85 (20), 4795, (2004).
[2] - J. C. H Spence, U. Weierstall and M. Howells. Phil. Trans. R. Soc. Lond. 360, 875, (2002).