Phase Diversity in Ptychographic Reconstructions with a Programmable Phase Plate

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Phase Diversity in Ptychographic Reconstructions with a Programmable Phase Plate

Stephanie M. Ribet[1,2,3], Steven E. Zeltmann[4], Georgios Varnavides[3,5], Roberto dos Reis[1,2,6], Vinayak P. Dravid[1,2,6,*], and Colin Ophus[3,*]

[1]*Department of Materials Science and Engineering, Northwestern University, Evanston, IL, USA*
[2]*International Institute of Nanotechnology, Northwestern University, Evanston, IL, USA*
[3]*National Center for Electron Microscopy, Molecular Foundry, Lawrence Berkeley National Lab, Berkeley, CA, USA*
[4]*Department of Materials Science and Engineering, University of California, Berkeley, CA, USA*
[5]*Miller Institute for Basic Research in Science, University of California, Berkeley, CA, USA*
[6]*The NUANCE Center, Northwestern University, Evanston, IL, USA*

*Corresponding authors: v-dravid@northwestern.edu, clophus@lbl.gov

Programmable electrostatic phase plates are a promising platform for direct control over the electron beam [1]. They can be used for spherical aberration correction and the creation of unusual probe profiles, such as vortex beams. The phase plate, inserted in the probe forming aperture of the STEM, is composed of many smaller apertures each of which can impart a phase shift on the electron beam. Each aperture has a two terminal device which can be tuned independently and impart a linear ramping or constant phase shift on the electron probe.

Ptychography reconstructions are a dose-efficient phase imaging approach that can be used for high-resolution characterization, including super-resolution imaging [2,3]. Both the specimen transfer function and the complex wave function of the electron beam can be simultaneously updated using iterative algorithms. This allows for imaging using defocused probe configurations, where fewer probe positions are needed to cover an area. A defocused probe is beneficial, as it can help with dose fractionation and improve the transfer of information at low spatial frequencies [2,3,4].

Incorporating phase diversity into the incident beam has been suggested for improved ptychographic reconstructions [4,5]. A programmable phase plate could be used for adding diversity to the probe and dynamic phase during the scan. Here we will share our design for a programmable phase plate (Fig. 1) and illustrate the benefits of phase diversity for ptychographic reconstructions. Using tetracutinase (Fig. 2A) [6] as a model system, we explore how adding phase can be used in defocused probe ptychographic reconstructions. In these *ab*TEM [7] simulations at 300kV the probe was defocused to about 10 nm in diameter with a 1 nm step size, and Poisson noise was added to simulate 500 e^{-}/A^{2}.

The simulations with an ideal probe with a 2.5 mrad and 10 mrad convergence angle (Fig. 2B-C respectively) show the impact of probe size on the reconstruction. With a smaller convergence angle, the image appears low pass filtered, while the larger convergence angle reconstruction captures the high spatial frequency information. Compared to the images in Fig. 2B-C, the reconstruction with a diverse probe (Fig. 2D) shows a wider range of frequencies and more robustness to the vacuum region systematic errors. These simulations suggest that incorporating phase diversity into an incident probe can help improve defocused ptychography experiments [8].

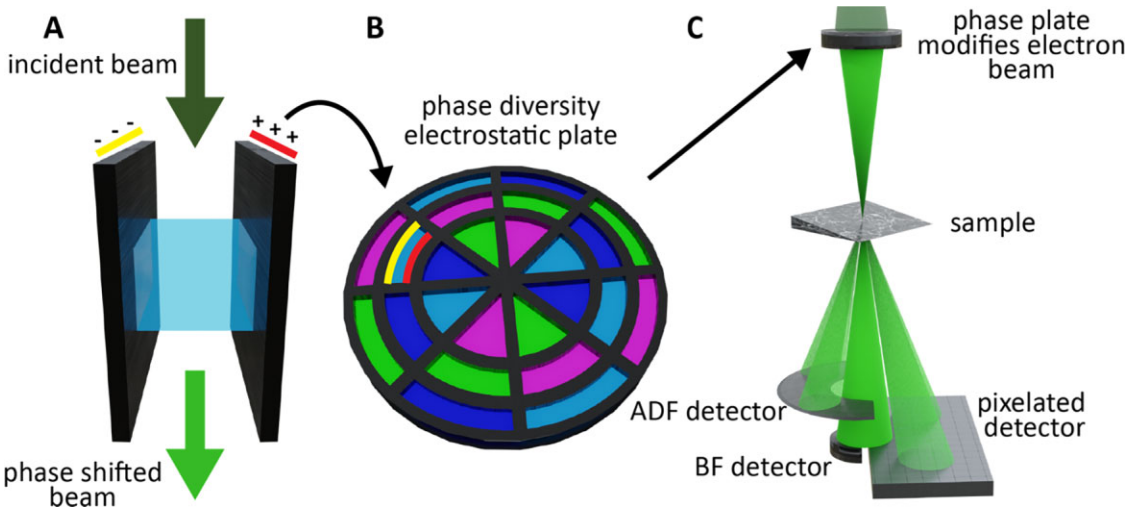

Fig. 1. (A) An electron beam is phase shifted when passed through an electrostatic potential. (B) A series of two-terminal devices can be arranged into a larger phase plate, where the potential in each aperture is tuned independently. Red and yellow lines in (A) and (B) denote terminals. (C) The device is inserted in the probe forming aperture of the STEM.

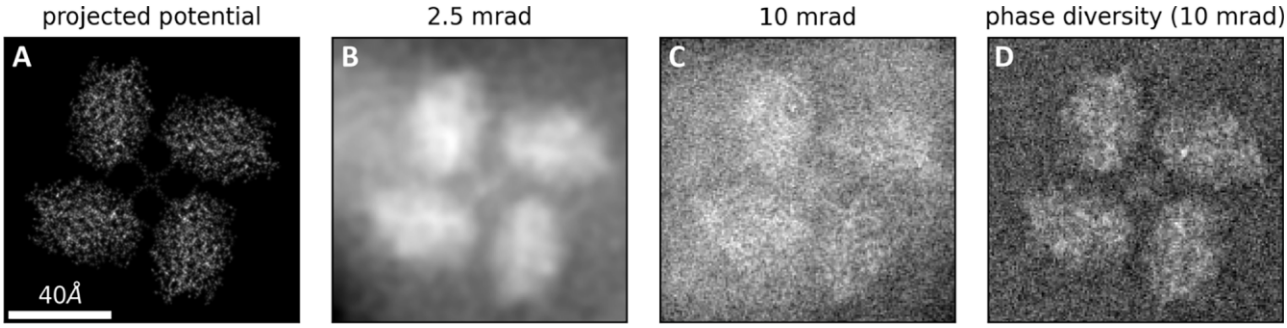

Fig. 2. A) Projected potential of tetracutinase and defocused ptychography reconstructions with (B) 2.5 and (C) 10 mrad defocused probes. (D) A phase plate adds diversity to the probe, and reconstructions capture a wider range of spatial frequencies.

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