

PtychoSTEM: an open source platform to perform electron ptychography

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The development of fast pixelated detectors (FPD) in the scanning transmission electron microscope (STEM) enables the recording of a full convergent beam electron diffraction (CBED) pattern for each probe position on the scan. The resulting 4D-dataset (two spatial dimensions and two reciprocal space dimensions) contains all the scattering information from the STEM experiment.

With this type of information, electron ptychography can be performed. This technique solves the phase problem in electron microscopy using interference between diffracted and undiffracted beams making phase imaging possible. Using this technique, phase contrast imaging at atomic resolution can be performed allowing imaging of both light and heavy atom columns, especially in combination with other STEM techniques [1, 2]. Moreover, due to the underlying working principle of ptychography, aberration-free phase imaging of materials is possible [2]. Several fields of materials and life sciences can benefit from the advantages that electron ptychography can offer.

In this work, we present an open source platform to perform electron ptychography from 4D datasets obtained in the STEM: ptychoSTEM. This Matlab-based tool is available to use for the microscopy community under a GNU General Public Licence (GPL) [3] and can be accessed via: <https://gitlab.com/ptychoSTEM/ptychoSTEM>. It includes a graphical user interface (GUI), as shown in Figure 1a. Using this GUI, the user can prepare the ptychography reconstruction settings and load the 4D dataset. Once the data is loaded, the Single Side Band reconstruction algorithm is used to retrieve a phase image [1]. This is a non-iterative method for focused probe electron ptychography, which allows for atomic resolution phase imaging. If the probe aberrations are known, the user can choose the option to correct the 4D dataset for probe aberrations and improve the phase image reconstruction. Moreover, the tool allows to setup synthetic digital detectors to create images with specific detector geometries, such as annular bright field or annular dark field detectors among others. An example result of a phase reconstruction and the corresponding synthetic detector imaging is shown in Figure 1b for a STO [100] simulation. This tool is intended to serve the microscopy community to perform electron ptychography in a simple and easy-to-use manner, enabling scientists to benefit from the opportunities that this novel technique can provide. As an open source project, we also encourage interested users to participate and contribute to its development [4].

[1] T. J. Pennycook, A. R. Lupini, H. Yang, M. F. Murfitt, L. Jones, P. D. Nellist, *Ultramicroscopy* vol. 151 pp. 160 - 167, 2015.

[2] H. Yang *et al.*, *Nat. Commun.*, vol. 7, pp. 12532, 2016.

[3] <https://www.gnu.org/licenses>

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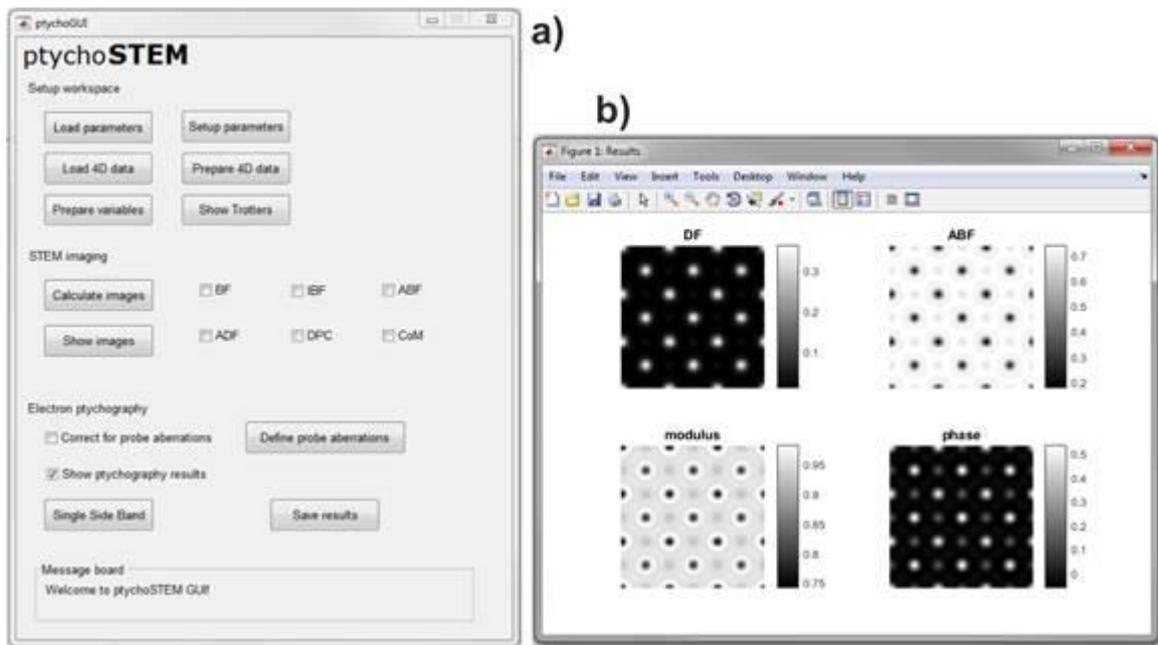


Figure 1. a) Main graphical user interface of PtychoSTEM. b) Example result of reconstruction, in which a STO [100] simulation was used. A comparison between ADF, ABF and Ptychography is presented.