# Phase retrieval with deep learning network and automatic differentiation*

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## Abstract

In this work, we demonstrate how machine learning and its related optimization tools can be used to replace conventional phase retrieval methods in X-ray transmission ptychography, X-ray Bragg ptychography, and Lorentz TEM.

X-ray transmission ptychography has become a well-established technique for high resolution imaging and phase retrieval. We present PtychoNN, a novel approach to solve the ptychography problem based on deep convolutional neural networks. Once trained, PtychoNN is capable of generating high quality reconstructions up to hundreds of times faster compared to conventional iterative methods, essential for implementing on-the-fly phase retrieval. Moreover, by surpassing the numerical constraints of iterative methods, the sampling condition can also be significantly relaxed.

The counterpart of transmission ptychography in diffraction condition is known as Bragg ptychography. The technique itself is less mature, as limited by the more complex diffraction geometry and data quality. Here we describe the forward propagation in Bragg ptychography using the Takagi-Taupin Equations (TTE). We show that, when combined with Automatic Differentiation (AD), TTE can be used as a general formalism for 3D phase retrieval, applicable to both Bragg ptychography and Bragg Coherent Diffraction Imaging. Compared to conventional Fourier Transform based methods, our approach accounts for additionally refraction, absorption, interference, dynamical effects, and is applicable to any kind of weakly strained material system.

* Title and Abstract of an Invited Presentation at the Workshop: AI/ML for Particle Accelerator, X-Ray Beamlines and Electron Microscopy at Argonne National Laboratory, November 1-3, 2021.