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Single-shot ptychography at free-electron laser

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Ptychography is a scanning coherent diffraction imaging technique capable of simultaneous imaging of extended samples and beam characterization with diffraction-limited resolution. It is well developed at synchrotrons, but its scanning nature prevents its use for single-shot imaging at wide applications on FEL facilities.

Single-shot ptychography can be performed by collecting the diffraction patterns of multiple overlapping beams in one shot, thus measuring the whole dataset at once and removing the need for scanning. A setup realizing this principle was proposed for visible light[1]; however, it cannot be straightforwardly applied to X-ray due to the use of refractive optics.

We solved this problem by using a single-shot ptychography setup based on a combination of X-ray focusing optics and beam-splitting grating and a corresponding forward model that facilitates single-shot imaging of extended samples at soft X-ray wavelengths [2]. The setup was tested during the proof of concept experiment at the free-electron laser FLASH at DESY and allowed us to obtain a reconstruction of a test sample and probe wavefield from the data measured with a single pulse of FLASH. However, the fidelity and resolution of the reconstruction were limited by the low performance of the diffraction grating and the inability of the forward model to fit the inter-beamlet interference.

Here, we present further progress in the single-shot ptychography at FELs. We used an improved experimental setup based on the Damman grating [3] with higher diffraction efficiency and diffraction order uniformity and an improved forward model. These improvements allowed us to perform single-shot ptychographical imaging and beam characterization during the beamtime at FLASH. This technique further improved and adapted for harder X-rays, will allow the high-resolution single-shot imaging of extended dynamical samples as well as the single-shot beam characterization at X-ray free-electron lasers.

[1] Sidorenko, Pavel, and Oren Cohen. "Single-shot ptychography." *Optica* 3.1 (2016): 9-14.

[2] Kharitonov, Konstantin, et al. "Single-shot ptychography at a soft X-ray free-electron laser." *Scientific Reports* 12.1 (2022): 14430.

[3] Krackhardt, U., and N. Streibl. "Design of Damman-gratings for array generation." *Optics communications* 74.1-2 (1989): 31-36.

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