2025 Conference on Lasers and Electro-Optics Europe & European Quantum Electronics Conference (CLEO/Europe-EQEC) | 979-8-3315-1252-1/25/$31.00 ©2025 IEEE | DOI: 10.1109/CLEO/EUROPE-EQEC65582.2025.11109582

# High-speed computational imaging with path-corrected fly-scan ptychography

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Ptychography is a computational imaging technique that enables the reconstruction of the amplitude and phase of an object and an illumination field using a series of recorded diffraction patterns [1]. Compared to conventional imaging techniques, ptychographic measurements offer more comprehensive information about the reconstructed object without requiring high-quality lenses, while also accommodating correction of experimental imperfections such as distance inaccuracies, angular misalignments, and other experimental errors. However, as ptychography is not a single-shot measurement technique, it is time-consuming, with a significant part of the measurement time attributed to the scanning process. Such mechanical scanning is inherently slow due to the acceleration limitations of the sample stage and the time required for stabilization [2].

In this study, we propose a fly-scan ptychographic lensless imaging approach to accelerate the measurement process, wherein the object moves continuously along an arbitrary scanning trajectory rather than in discrete steps during the acquisition of diffraction patterns. This continuous motion eliminates the overhead associated with the movement and settling of the sample positioning system, thereby significantly reducing the time wasted when data is not being collected. However, the continuous motion of the sample during an exposure causes averaging of rapidly varying fine features in the diffraction patterns, resulting in a loss of contrast in our captured images. Consequently, performing a conventional ptychographic reconstruction on this washed-out dataset yields inferior results when compared to step-scan measurement. To maintain a high resolution we need to adapt our forward model to account for this decoherence in our measurement.

The continuous object movement in the experiment is described by decomposing the reconstructed object into identical modes, which are then shifted along the initial fly-scan path [3]. This approach, combined with automatic differentiation (AD), not only facilitates fly-scan reconstruction but also enables precise correction and reconstruction of the fly-scan trajectory, significantly enhancing reconstruction quality without relying on expensive and complex high-speed sample tracking systems. Without the need for high-precision sample positioning and tracking, we can perform a fly-scan measurement in a conventional ptychographic measurement setup. With this reconstruction algorithm, we increase the measurement speed by several times and up to an order of magnitude for strongly diffracting samples (only limited by the camera framerate), while still being able to achieve diffraction-limited image reconstructions of the object. Our AD-based reconstruction algorithm provides a way to correct for deviations in the scan path, allowing us to maintain diffraction-limited resolution even when the fly-scan trajectory is not precisely known.

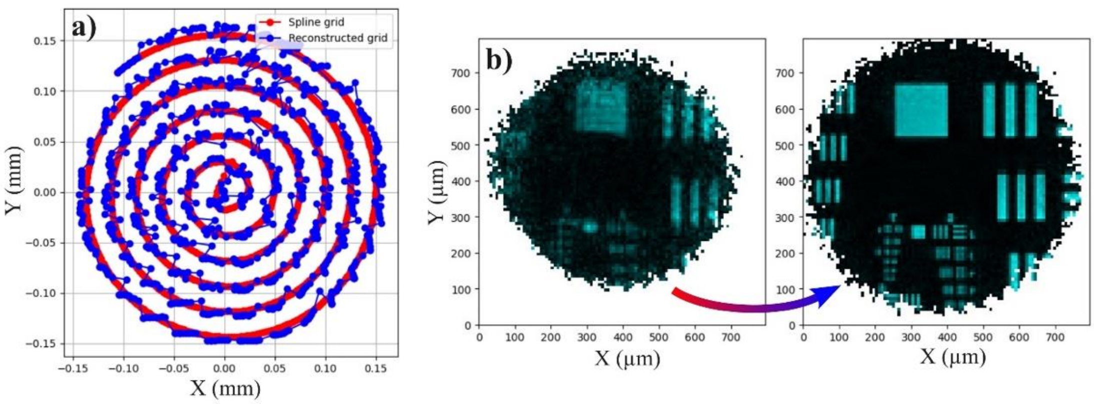


**Fig. 1** Experimental fly-scan ptychography results: a) Initial spline-approximated scangrid and reconstructed experimental scangrid achieved by fly-scan object mode decomposition algorithm; b) Object reconstructions when using a spline-approximated scangrid (left), and when using a reconstructed scangrid achieved by fly-scan object mode decomposition algorithm (right).

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