Challenges and solutions of diffraction signal numerical separation in multibeam ptychography.

Runqing Yang[1], Pablo Villanueva Perez[1], Maik Kahnt[2], Giovanni Fevola[3], Ken Vidar Falch[3], Mikhail Lyubomirskiy[2], Tang Li[3], Manfred Burghammer[4], Michael Sztucki[4]

[1] *Lund University, Sweden*
[2] *MAX IV Laboratory, Lund University, Sweden*
[3] *Deutsches Elektronen-Synchrotron DESY, Germany*
[4] *European Synchrotron Radiation Facility, France*

Presentation type: Oral **Presentation time:** 10:15-10:30

Ptychography has become a key technique for high-resolution coherent X-ray imaging[1], but as a scanning-based method, it is limited in acquisition speed and scalability for large-field and high-throughput measurements. Multibeam Ptychography (MBP) addresses these limitations by simultaneously illuminating multiple sample regions, enabling a scalable approach for high-throughput coherent X-ray imaging while maintaining quantitative phase sensitivity and high spatial resolution[2,3].

A central challenge in MBP is that increasing the number of beams also increases the mixing and superposition of the diffraction information, making reconstruction strongly dependent on information separability between beams[4,5]. As more diffraction information from different beams becomes superimposed, separating the contributions from individual beams during reconstruction becomes increasingly difficult, raising fundamental questions regarding the scalability, achievable throughput, and reconstruction quality of MBP.

This presentation addresses the issues causing challenges in numerical separation of diffraction signal from an increasing number of beams in MBP, particularly the role of probe design in improving information separability from different beams. Recent results demonstrate that stable MBP reconstruction requires probe sets that are not only individually suitable for ptychography but also sufficiently separable and uniform when used together under multi-beam conditions[6]. To evaluate these requirements, probe sets are assessed using three key criteria: separability, uniformity, and experimental feasibility. The presentation will further discuss MBP throughput scaling with the number of beams used. Particularly, the relationship between beam number, achievable throughput gain, and the number of diffraction measurements required to maintain stable reconstruction quality.

These observations suggest that the scalability of MBP depends not only on the number of beams but also on how effectively diffraction information from different beams can be separated during reconstruction. Achieving robust and scalable MBP, therefore, requires efficient numerical separation of the diffraction signal from different beams.

References

[1] Pfeiffer, Franz. "X-ray ptychography." Nature Photonics 12.1 (2018): 9-17.
[2] Bevis, Charles, et al. "Multiple beam ptychography for large field-of-view, high throughput, quantitative phase contrast imaging." Ultramicroscopy 184 (2018): 164-171.
[3] Li, Tang, et al. "X-Ray Multibeam Ptychography at up to 20 keV: Nano-Lithography Enhances X-Ray Nano-Imaging."Advanced Science11.30 (2024): 2310075.
[4] Lyubomirskiy, Mikhail, et al. "Multi-beam x-ray ptychography using coded probes for rapid non-destructive high resolution imaging of extended samples." Scientific Reports 12.1 (2022): 6203.
[5] Penagos Molina, Daniel S., et al. "Multiplexing information limits in multi-beam ptychography."Optics Express33.6 (2025): 12925-12938.[6] Yang, Runqing, et al. "Optimizing probes for multi-beam ptychography." Optics Express 34.7 (2026): 12463-12478.