Hard X-ray holographic projection microscopy using multilayer Laue lenses for hierarchical 3D imaging

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Presentation type: Oral **Presentation time:** 12:15-12:30

We introduce nanoimaging capabilities based on multilayer Laue lenses [1] (MLLs) coupled to high-Z single-photon counting detection systems for holographic projection microscopy [2]. This approach enables high sensitivity, fast measurement, outstanding zooming capabilities, and spatial resolutions ≲50 nm. Operating at hard X-ray energies of 30 keV allows penetration of macroscopic specimens while maintaining sufficient contrast for small features close to the resolution limit.

Optimized image quality is achieved through detailed studies of MLL aberrations and their impact on propagation-based phase contrast imaging. In particular, the influence of optical distortions of different MLL geometries, namely flat and wedged designs, is investigated. This analysis enables the selection of optimal multilayer structures and ensures precise alignment conditions for high-quality imaging [2].

The presented development aims to provide nanoscale three-dimensional imaging with zoom functionality at the novel HiKA (Hierarchical Imaging Karlsruhe) end station located at the P23 beamline of the PETRA III storage ring at DESY. The HiKA station is a synchrotron-based X-ray imaging platform dedicated to hierarchical full-field imaging, integrating zoom capabilities from macro- to nanoscale resolution for computed tomography and computed laminography within a single experimental station. The combination of MLL-based cone beam and parallel beam imaging facilitates imaging with fields of view of a few centimetres down to a few tens of micrometres.

This combined approach enables non-destructive zoom imaging of extended specimens and devices by addressing the trade-off between sample size and local high-resolution imaging through optimization across the full imaging pipeline. Key components include highly sensitive detection using high-Z single-photon counting detectors, dedicated tomographic measurement geometries such as computed laminography [3], phase-contrast imaging [4], hierarchical guidance for identification and selection of regions of interest [5], and correlative imaging techniques using visible light.

The instrument is designed to support applications across materials science, engineering, and life sciences, enabling the investigation of complex hierarchical structures and processes over multiple length scales.

References

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