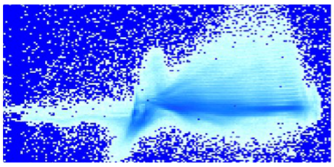

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High-throughput hard X-ray projection imaging with a sub-5 nm resolution

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Knowledge of the structure of materials and biological samples at nanometer scales and over large volumes is essential to understand the mechanics behind their function. Coherent x-ray imaging is being developed to address this need. Far-field diffraction methods suffer from noise sensitivity and high dynamic range requirement of detector. Recently, with the rapid development of x-ray focusing elements, projection imaging provides an alternative solution with unique advantages over these limitations. Here, with our own manufactured multilayer Laue lenses, we demonstrated such a projection imaging modality at Petra III P11 beamline of DESY. An object placed just out of the focus forms a magnified hologram or projection image of the sample on a pixel-array detector. Magnifications of 30,000 or more can be obtained, meaning a 75 µm detector pixel maps to an image pixel of 2.5 nm. On the other hand, at an illumination numerical aperture of 0.014, a defocus distance of 100 um would give a field of view of 2.8 um, in single shot. This mode is particularly fast and efficient for phase-contrast imaging over a large field of view that can be easily "zoomed". Signals contained in the holograms are boosted thousands of times with an improved signal-to-noise ratio, which makes it robust and easier to retrieve the object information from the measurements. For robust phase retrieval of the holograms, we stepped the sample relative to the probe, which was the method of near-field ptychography. A 4 nm half-period resolution imaging of hierarchical nanoporous gold has been achieved at the energy of 17.4 keV. Furthermore, a systematical numerical study was carried out to quantitatively illustrate the advantages of projection imaging modality over far-field diffraction method in terms of noise robustness and dose efficiency.

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