High Resolution Holographic Imaging

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Multilayer Laue lenses (MLLs) are diffractive X-ray optics that are fabricated by multilayer deposition. This method can produce structures with nanometer periods and large aspect ratios, overcoming limitations of diffractive optics made lithographically. Over the last several years we optimised the fabrication of hard X-ray MLLs of high numerical aperture (NA) with a few nanometer spatial resolution [1], with a goal to reach 1 nm resolution. This progress was enabled by an understanding of the materials properties of the lenses and at-wavelength optical metrology to characterise their performance.

Such high-resolution optics can be used to image complex internal structures of many materials, either artificially prepared or found in nature, which are of great interest both from a fundamental point of view as well as for applications. We have been exploring various imaging modalities. In particular, we find projection holography a particularly robust and low dose high resolution method, which is suitable for all kind of x-ray sources including x-ray free electron lasers. This robust phase-contrast imaging method is to focus a coherent X-ray beam to produce a diffraction-limited spot that diverges onto a downstream detector. A magnified hologram is then produced of an object placed just beyond that focus. Holograms of arbitrarily-large fields of view can be recorded using a new approach we developed called ptychographic X-ray speckle tracking (PXST) [2,3]. The method can stitch together holograms with high accuracy, preserving the inherent high resolution set by the focal spot size (from which the beam diverges). In doing so, residual wavefront distortions of the lens are corrected for, providing a sensitive non-interferometric wavefront metrology.

[1] S. Bajt *et al.*, Light Sci. Appl. **7**, 17162 (2018).
[2] A. Morgan *et al.*, J. Appl. Cryst. **53**, 760 (2020).
[3] A. Morgan et al., J. Appl. Cryst. **5**3, 927 (2020).