Applications and methods of X-ray ptychographic nanotomography at the Swiss Light Source

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Imaging with high-energy X-ray photons, i.e. hard X-rays, offers the opportunity to study specimens of tens of microns with nanometer-scale resolution due to the combination of moderate penetration depth and small wavelength. Associated to this endeavor is the challenge to produce high-resolution imaging optics, which has very stringent manufacturing requirements. Alongside with the development of X-ray optics there has been for some time the push for lensless imaging techniques, such as coherent diffractive imaging (CDI). These techniques exploit the coherence of synchrotron X-ray beams to obtain images by replacing lenses with computational image reconstruction algorithms [1].

Among different techniques based on CDI, there has been an increasing interest in ptychography [2]. A typical ptychogram combines diffractive imaging and scanning microscopy: diffraction patterns are measured at different relative positions of the sample with respect to the incident X-ray beam, translation diversity in the measurements is ensured by the overlap between neighboring illuminated regions [3]. While ptychography has much more stringent demands on the sample stability and position accuracy compared to conventional CDI, the former is gaining traction in the community due to the added robustness of the reconstruction. This allows us to obtain reliable and routine measurements and reconstructions.

Combined with different sample orientations, ptychography can yield high-resolution 3D images [4], provided the data is acquired with sufficient scanning precision. At the cSAXS beamline, Swiss Light Source, we have developed two instruments for ptychographic tomography, they are based on differential interferometry between the sample and the X-ray optics that create a confined illumination onto the sample and they allow either measurements under cryogenic conditions or a flexible room-temperature environment, respectively. These instruments are currently used to obtain tomography currently demonstrated down to 15 nm 3D resolution [5]. More recent work has been focused on the development of a third end-station that uses the same interferometry concept but in a laminography configuration, which is better suited for extended flat samples.

Here I will give an overview of the state of the art of ptychographic tomography at the cSAXS beamline and present examples of applications of ptychographic nanotomography to biology and materials science, as well as early results on ptychographic laminography.

References