Coherent imaging: applications and optics requirements

Cloetens P., Guigay J.P., Hignette O., Ludwig W.*, Mokso R., Schlenker M.[1]
ESRF, B.P. 220, 38043 Grenoble Cedex, France
*GEMPPM INSA Lyon
[1]Lab. Louis Néel CNRS Grenoble

The small source size, typically less than 150 µm at ESRF, results, especially on a long beam-line such as ID19 (source-specimen distance 145 m), in considerable spatial coherence (typical transverse coherence length 100 µm) of the X-ray beam. One can also consider that each point of the incident beam is characterised by an average propagation direction and an angular spread around this direction. This angular spread is in the ideal case given by the angular source size and can be smaller than 0.2 µrad (0.04 arcsec). The partial coherence of the beam is a crucial property for several applications such as coherent imaging, extreme focusing and photon correlation spectroscopy.

Along with images from inhomogeneities in absorption, it is possible to obtain phase images from the local variations in refractive index and/or thickness of the specimen, through simple propagation, i.e. Fresnel diffraction. The instrumental requirements of *coherent imaging* are simple, amounting essentially to a monochromator and a detector system. The propagation technique can be used either in a qualitative way, mainly useful for edge detection, or in a quantitative way, involving numerical retrieval of the phase from images recorded at different distances. The phase maps obtained for many orientations of the sample (several hundreds) then provide the input for tomographic reconstruction. This combined technique maps the 3D distribution of the variations in electron density and is called holotomography.

While the resolution is at present determined by the detector system, it is of interest to obtain magnified images, either by magnifying X-ray optics or in a projection geometry by *focusing* the beam upstream of the sample. With a Kirkpatrick-Baez mirror scheme a focal spot with a size smaller than 100 nm in both directions was obtained. Such a point source is used in a single setup for full-field projection microscopy and fluorescence mapping.

Under partially coherent illumination, unusual demand is put on the quality of all elements (windows, filters, mirrors, monochromators, …) in the beam-line, as any inhomogeneity leads to a perturbation of the original wavefront and spurious images. Propagation imaging of a periodic object leads to self-imaging at well-defined distances with respect to the grating. This phenomenon (Talbot effect) can be used to characterise in a robust way the coherence properties of the wavefront at the exit of an optical element. While silicon based optics became 'coherence compatible' during the last years thanks to interaction between fabrication and characterisation methods, a similar approach can be considered for diamond.