Coherent Hard X-Ray Imaging

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Abstract

Radiography and tomography with hard X-rays are common techniques for medical and industrial imaging. Classically, absorption-contrast is used, hence local variations in the beam attenuation. The coherence of third generation synchrotron beams makes a trivial form of phase-contrast imaging possible. It is based on simple propagation and corresponds to the defocusing technique of electron microscopy. Phase imaging 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 with respect to the sample.

Coherent imaging puts stringent requirements on all optical elements in order to avoid spurious phase images or a coherence degradation along the X-ray path. Especially in reflection geometry, sub-nanometer height variations of the reflecting surface can be detected due to the small wavelength of the X-rays. Phase imaging is therefore a tool to characterise substrates for multilayer optics and the multilayered structure itself.

State-of-the-art multilayer optics can be used as broad bandpass monochromators with an acceptable degradation of the coherence and beam homogeneity. Three-dimensional (tomographic) imaging requires the acquisition of about thousand radiographs corresponding to different angular positions of the sample. To achieve micrometer spatial resolution within a reasonable acquisition time a very high incident photon flux is required. On the other hand, the monochromaticity required for absorption or phase-contrast imaging is most often less critical, a value of 10^{-2} being acceptable. Quantitative phase tomography was performed using a flat multilayer as only X-ray optical element.

Keywords: synchrotron radiation, monochromator, coherence, X-ray imaging

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