X-ray at-wavelength metrology of multi-layered surfaces

Sebastien Berujon[1), Pierre Piault [1), Eric Ziegler[1)

European Synchrotron Radiation Facility, CS 40220, 38043 Grenoble cedex 9, France

Multilayer-coated mirrors are widely used as optical elements to handle the X-ray beam produced by sources such as synchrotrons, notably for spectroscopy and imaging applications. Their assets are a wide and tuneable spectral bandwidth transmission, an optical behaviour free from chromatic aberration, a high reflectivity efficiency and the possibility to use them at incidence angles larger than for mirrors operating at the total reflection angle, thus increasing the optical aperture and lowering the diffraction limit. On the other hand, their performances are limited by the surface shape errors and roughness.

While well-known methods such as reflectivity and diffuse scattering permit to assess statistical characteristics of the multi-layered material along the growth direction [1], the full topological description of the surface is only accessible at the cost of greater experimental efforts [2]. For X-ray imaging applications using coherent light such metrology information is of significant importance since the height errors in the mirror deposition process are responsible for unwanted large intensity modulation of the X-ray beam through an interference process.

The challenge in characterizing these defects lies in the fact that such error amplitudes can be as small as the light wavelength, i.e. in the order of a few nanometers for spatial periods in the millimeter range and above.

This presentation will introduce the methods available for measuring and analysing small spatial frequency aberrations in a beam upon reflection on a multilayer-coated mirror surface. The interest in measuring the wavefront of the X-ray reflected beam is to infer the surface optical defects and to map out the layer deposition errors.
Theoretical and experimental implementation of these characterization methods using hard X-ray light produced by a synchrotron source will be given, especially the ones based on interferometry and speckle.

This metrology will eventually permit to better understand the origin of the wavefront intensity modulation generated by multilayer mirrors and enable the development of multilayer manufacturing process strategies capable of minimizing surface defects and preserve a highly uniform X-ray wavefront.

[1] Kozhevnikov I. V., Peverini L., Ziegler E., “Development of a self-consistent free-form approach for studying the three-dimensional morphology of a thin film”, *Physical Review B*, **85**, p. 125439, (2012).
[2] Berujon S., Wang H., Alcock S., Sawhney K., “At-wavelength metrology of hard X-ray mirror using near field speckle”, *Optics Express*, **22**, pp. 6438-46, (2014).