Numerical modelling of reflective multilayer based X-ray optics

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Artificially stratified films deposited on a mirror surface are envisaged as optical elements capable to either propagate a perfect wavefront from the source to the sample without degradation or to correct for wavefront imperfections.

Current multilayer-coated mirrors have shown to degrade the beam coherence and distort the reflected wavefront, although significant efforts were made to minimise them [1-3]. The propagation of phase distortions may result in the presence of undesired intensity variations in the recorded images as stripe-line modulations perpendicular to the diffraction plane. The most likely interpretation of these modulations is based on the explanation already given for silicon mirrors, i.e. imputing the wave distortion to the height deviation from a perfect surface [4-6]. However, this problem may get rapidly complicated if one tries to consider the role of every layer in the coating.

To address these issues the following project was initiated:

Firstly, images of W/B_4C multilayers were characterised at the ESRF instrumentation beamline BM05. The reflected monochromatic beam was recorded at various distances to detect a possible dependence of the stripes on the figure errors of the multilayer. Further experiments were performed to gain an insight into the way X-ray propagation in a multilayer in order to build an effective model for the reflection of a multilayer with imperfections. For instance, the speckle metrology technique [7] is used to recover the beam wavefront. The multilayer is also flipped from the vertical to the horizontal position to investigate the role of the diffracted beam coherence length on the image pattern.

Secondly, we started developing a numerical model capable of simulating the wave reflected by a multilayer. For a comprehensive simulation of the layered medium, topographies of the multilayer coating and/or substrate surfaces as recorded by Fizeau interferometry are needed. The model should provide height deviation maps as well as X-ray profiles propagating in the multilayer. Our first approach consists in modifying a model based on the Takagi-Taupin equations developed originally for a perfect flat or elliptical multilayer to simulate X-ray propagation in layered media perturbed by figure errors. In this case, these height deviations are implemented as suitable offsets of the susceptibility of the layered medium.

The ultimate goal of this work (in progress) is to explore and eventually propose ways to improve the quality of multilayer mirrors for forthcoming applications in present and future X-ray source facilities.

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