Multilayer gratings in tender X-ray monochromators

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Classical metal coated gratings have decreasing performances with higher energies. Typically the efficiency becomes very low over 2 keV, moreover, the grazing incidence and deviation angles must be kept very small thus limiting the tunability. Blazed gratings may improve the situation but profiles with clean blaze angles of 1° or smaller are difficult and expensive to produce.

Multilayer (ML) coatings offer the significant advantage of providing good reflectivity at much larger grazing incidence angle than simple metal coating at the same photon energy. However the incidence angle must be matched to the photon energy and multilayer period through the Bragg law. This chromaticity might be a problem for mirrors, but for gratings it simply adds a constraint on the deviation angle, while the grating law constrains the asymmetry factor (C factor) between the sines of incidence and exit grazing angles. The deviation angle variation however implies that a Plane Grating Monochromator is used, and that a matched ML coated plane mirror is opposed to the grating in order to achieve a fixed exit direction.

Optimizing the diffraction efficiency is a complex trade-off between several effects. ML reflectivity increases with the number of participating layers, hence smaller periods, but the interface roughness and a small inter-diffusion of coating material prevent the realization of very small periods below a few nanometers. Our gratings have a lamellar profile before coating. There is thus an optimal grove depth for a given ML period and vice versa. Grating manufacturers cannot guarantee the achieved groove depth to much better than a nanometer. The actual depth must be measured with a properly calibrated AFM. Then, electromagnetic dynamic diffraction codes are used to optimize the efficiency according to models of the coating structure. The result is validated with at wavelength diffraction efficiency and rocking curve measurements. Then a similar optimization is done on the associated mirror in order that the two rocking curves are matched.

At Soleil, several beamlines are equipped with multilayer grating monochromators. We will illustrate the fabrication and optimization processes and the achieved results on the example of the CrB4C grating and mirror pair which is presently used in the Sirius beamline monochromator in the 1-4.5 keV range.