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LCLS soft x-ray imager mirrors and their performance

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Soft X-ray imager mirrors have been designed, calibrated and fabricated at Lawerence Livermore National Laboratory and characterized at the Advanced Light Source for their performance between 200 and 1300 eV.

The mirrors are coated with a multilayer coating consisting of 70 bilayers of W/ SiC. The mirrors are to reflect at 22.5 deg from grazing angle at 1.50 nm wavelength and the width of the reflectivity peak should be at least 1.3%. Also, the mirrors should be non-reflective elsewhere. Our multilayer design was optimized to satisfy these requirements. The coating is very challenging since the individual layer thicknesses need to be less than 1 nm thick and reproducibility from layer to layer is crucial. To minimize the second harmonic peak we designed a multilayer with $\Gamma = 0.5$ (W and SiC layer thicknesses are the same). This way we end up with a mirror that has only the 1^{st} and 3^{rd} harmonic peak as shown in Figure 1. To suppress reflectivity outside the first peak we used our novel approach, an antireflective coating. Modeling predicted substantial reduction in reflectivity, especially for lower energies as shown in Figure 1.

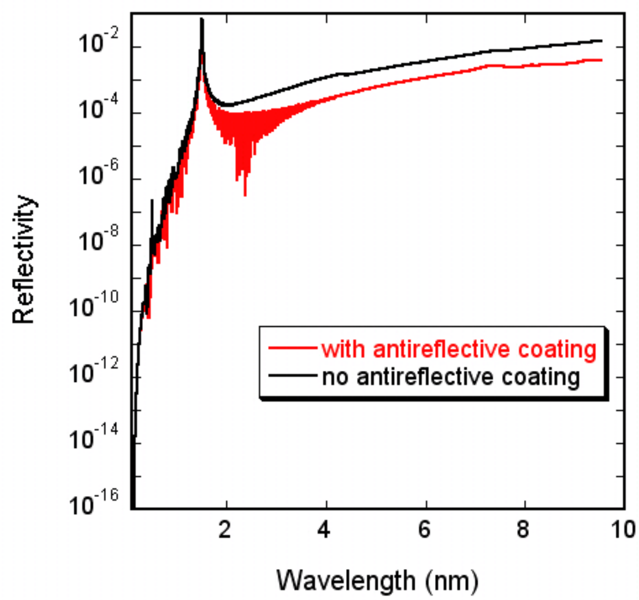

Figure 1: Modeled reflectivity shows complete suppression of the 2^{nd} order harmonic peak at 0.76 nm and a very weak 3^{rd} harmonic peak at 0.5 nm (10^{-7}) as an effect of the antireflective coating. The red curve is a mirror with antireflective coating and the black is the one without.

The experimental results of the soft x-ray imager mirror as measured at the ALS are shown in Figure 2 (log and linear scale). The energy range over which we measured the reflectivity is limited by the beamline hardware. This plot is a compilation of about six scans over different energy ranges using different gratings, filters and order sorter positions. The measured reflectivity of the peak at 1.505 nm is 4.3% with the peak width of 0.028 nm or 1.8%, satisfying the specs on the peak width.

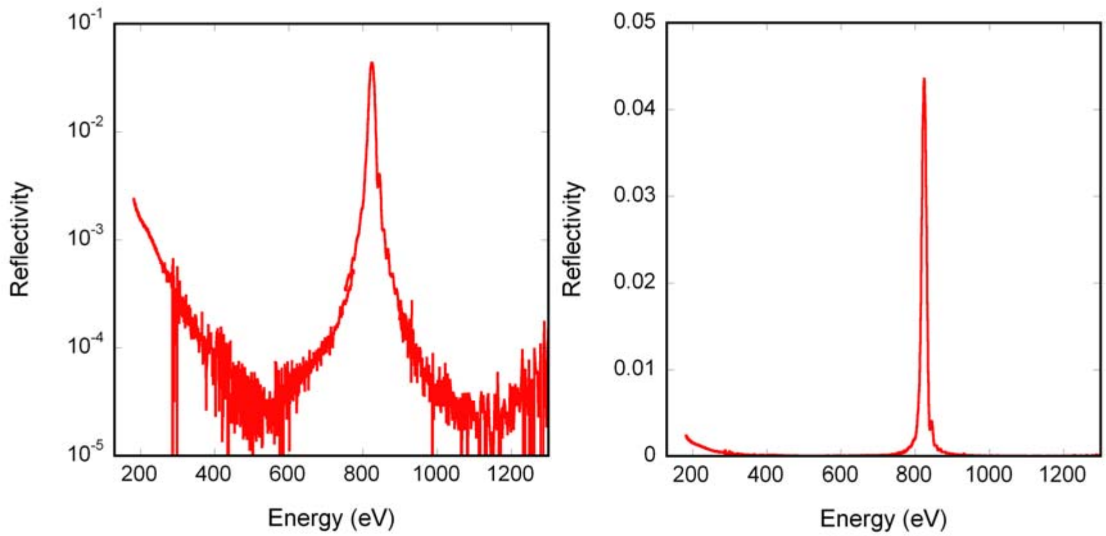

Figure 2: Measured reflectivity of the soft X-ray imager mirror for the LCLS between 200 and 1300 eV on a logarithmic (left) and linear (right) scale.

The other important specification was overall low reflectivity (except for 1st harmonic). We demonstrated this with the antireflective coating that is applied on these mirrors. The application of the antireflective coating also reduces the reflectivity of the 1st harmonic peak from 8.23% to 4.30%, which is in agreement with our modeling results. As shown in Figure 3 the antireflective coating substantially suppresses reflectivity in the energy range between 200 and 800 eV.

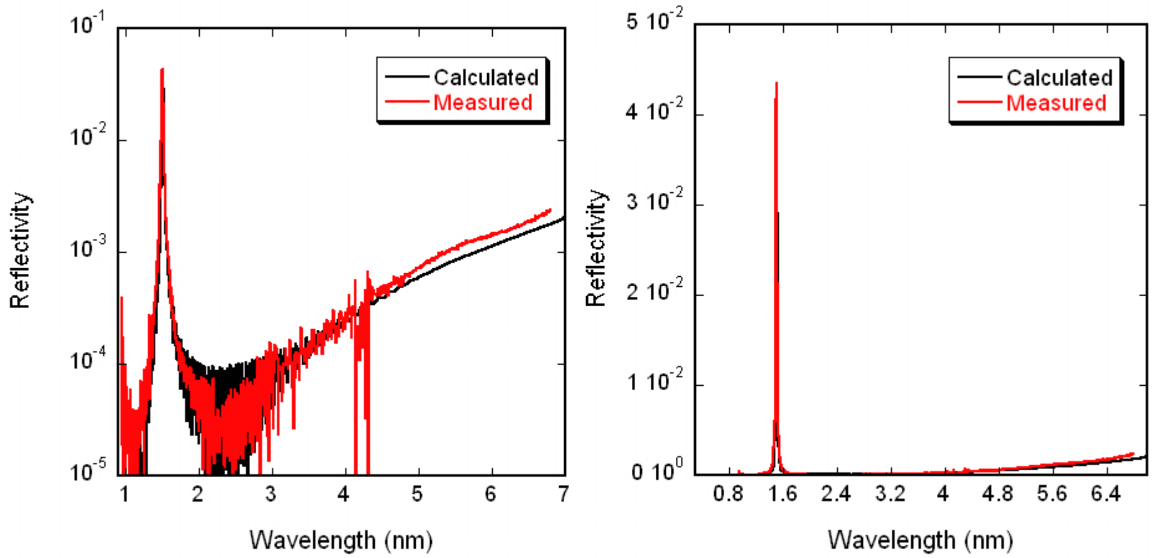

Figure 3: Measured (red) and calculated (black) reflectivity of soft x-ray imager mirror for the LCLS on a logarithmic (left) and liner (right) scale.

Considering the excellent agreement between modeled and measured data we then take a step further and extrapolate the calculation (Figure 1) up to 10 keV (0.12 nm). It is clear that the 2nd order harmonic is suppressed while the 3rd harmonic has reflectivity of only 10^{-7}. Finally, we also calculate the rocking curve of the 1st harmonic (Figure 4), which is of importance if a two bounce mirror system will be necessary.

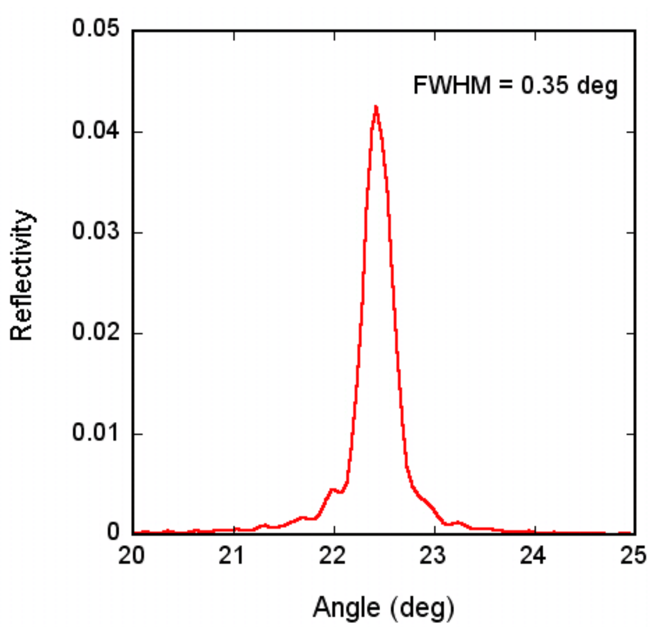

Figure 4: Calculated rocking curve for the 1st harmonic.

In summary, two 100 mm mirrors with >4% reflectivity at 1.50 nm and 1.8% FWHM for operation at 22.5 deg grazing angle were fabricated. Both mirrors are coated with antireflective coating that suppresses radiation outside the 1^{st} harmonic. Experimental and modeling results are in excellent agreement indicating that we understand the physics of this multilayer system very well.

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