Crosscheck of Different Techniques for Two Dimensional Power Spectral Density Measurements of X-ray Optics

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Valeriy Yashchuk received his MS degree in experimental physics from St. Petersburg State University in 1979 and his PhD degree from St. Petersburg Nuclear Physics Institute, Russia in 1994. He is currently working at the Advanced Light Source, Lawrence Berkeley National Laboratory. He has authored more than 40 scientific articles in the fields of nonlinear optics, atomic physics, and laser spectroscopy. His current research interest is in the metrology of X-ray optics.

Abstract text:

The task of designing high performance X-ray optical systems requires the development of sophisticated X-ray scattering calculations based on rigorous information about the optics. One of the most insightful approaches to these calculations is based on the two-dimensional (2D) power spectral density (PSD) distribution of the surface height, allowing for the evaluation of three-dimensional distributions of X-rays scattered by the optics.

We are investigating the consistency of different instruments and methods for measuring 2D PSD distributions. The instruments are the Micromap-570 interferometric microscope (Micromap Corp, Tucson, AZ), the Digital Instruments 3100 atomic force microscope (AFM), and the X-ray scattering experimental facility (ALS beamline BL6.3.2) all available at Lawrence Berkeley National Laboratory.

The main conclusion from the crosscheck is that all three techniques provide essentially consistent results. At spatial frequencies from ~0.1 μm^{-1} to 50 μm^{-1}, the X-ray scattering measurements agree reasonably well with the AFM measurements. The frequency range available for the Micromap measurement is shifted to the lower frequencies, 0.001 μm^{-1} - 2 μm^{-1}; but still at the overlapped range, there was observed reasonable agreement between the PSD magnitudes measured with the different instruments. It is also shown that the measurements are complementary allowing for correction of the specific spatial

frequency dependent systematic errors of the instruments. For example, the AFM and the X-ray scattering measurements were used to correct the Micromap measurement error due to the modulation transfer function that is generally unknown. The correction procedure is discussed in detail.

The measurements were performed with a gold coated mirror with stainless steel substrate fabricated by InSync, Inc., Albuquerque, NM. The requirements for the mirror surface finish were specified in terms of the surface roughness to be less than 10 A RMS. Although the Micromap metrology has confirmed the required quality of the mirror, the measurements with AFM as well as the X-ray scattering experiment provide a roughness of about 20 A RMS. This discrepancy highlights the need for the evolution of mirror specifications to include the PSD, and not just the RMS roughness. Based on the crosscheck of the performance of the three methods, we present recommendations for the improvement of the specification process for X-ray optics.

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