Ex situ tuning of bendable x-ray mirrors for optimal beamline performance

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Presentation preference: Oral Presentation

Abstract text:

We extend analytical and numerical methods recently developed at the Advanced Light Source (ALS) optical metrology laboratory (OML) for optimal tuning and calibration of bendable x-ray optics based on ex situ measurements with surface slope profilers [Opt. Eng. 48(8), 083601 (2009); Proc. SPIE 8141, 8141-19 (2011)]. We minimize the rms variation of residual slope deviations from ideal surface figure. Previously, our adjustment assumed the deviations were weighted equally across the optic. In this work, we analyze the case when the mirror length is significant with respect to the imaging conjugate. This corresponds, for example, to high de-magnification by bendable Kirkpatrick Baez mirror pairs, used near the ends of synchrotron and free electron laser beamlines for micro- and nano-focusing that often results in a very short mirror to image distance, of the same order of magnitude as the mirror's length. In this case, contribution to focal distortion of residual errors of mirror surface figure (appearing due to mechanical alignment tolerances, sagittal shaping errors, and the limited number of adjustable parameters inherent in a two-couple bender) strongly depends on position across the optic. Specifically, the downstream deviations from exact shape should be weighted less because the rays have a shorter path to travel to the image. Here, we derive an analytical expression for the weighting function and present a mathematical background for the bending adjustment procedure for optimization of mirror's beamline performance. The efficacy of the optimization is demonstrated for a short-focus mirror used for diffraction limited focusing at ALS beamline 5.3.1.

Keywords: bendable mirrors, x-rays, x-ray optics, synchrotron radiation, synchrotron beamline, Kirkpatrick-Baez

Abstract submitted to SPIE Optics and Photonics 2012, Conference OP320: Advances in Computational Methods for X-Ray Optics IV, San Diego, August 12-16, 2012

100 word version

We extend methods developed at the ALS for tuning of bendable optics, minimizing the slope with respect to ideal figure. Previous adjustments assumed the deviations were weighted equally. If the mirror length is significant with respect to the imaging conjugate as in high de-magnification by bendable Kirkpatrick Baez mirror pairs focal errors depend on position across the optic. Downstream deviations from exact shape are weighted less because the rays have a shorter path. We derive the weighting function and adjustment method for a mirror, demonstrated by a short-focus mirror used for diffraction limited focusing at ALS beamline 5.3.1.

Principle author's biography:

Wayne R. McKinney received his BA, MA, and PhD in Physics from The Johns Hopkins University, finishing in 1974 with a thesis in ultraviolet astronomy. He then completed a post-doctoral appointment in molecular biology supported by a National Cancer Institute Fellowship at the Biology Department of Brookhaven National Laboratory in 1977. Remaining at Brookhaven from 1977 to 1979 in the Instrumentation Division he designed optical systems for the National Synchrotron Light Source. From 1979 to 1987 he joined the research staff of the Richardson Grating Lab in Rochester New York, becoming Manager of Diffraction Grating R&D in 1981. From 1987 to 1989 he was a staff scientist in the Center for X-Ray Optics at Lawrence Berkeley National Laboratory working on water cooled optical components and monochromator designs for the Advanced Light Source. This work won local and national Tech Transfer Awards, and led to Fellow status in the OSA. He now works directly for the Advanced Light Source where he designed and built the first infrared beamlines. Currently his responsibilities are in optical metrology, particularly the specification of x-ray optics by calculation of scattering, and optimization of the adjustment of adaptive x-ray mirrors.

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This work was supported by the Director, Office of Science, Office of Basic Energy Sciences, of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

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