The Advanced Photon Source

Nested K-B Mirrors for Nanofocused X-rays

Kirkpatrick-Baez (K-B) mirror systems are utilized to focus synchrotron x-ray beams down to spot sizes of microns in order to study materials, chemical, and biological samples. But traditional K-B mirror systems lack the precision necessary to focus intense synchrotron beams down to nanometer dimensions. Moreover, elliptical mirrors for aberration-free focus are very costly to produce. But a new nested (as opposed to the usual sequential arrangement), or Montel K-B mirror system solves these problems by incorporating two innovations into the fabrication process. This new mirror system will provide a more efficient and less expensive way to fabricate precise nested K-B mirrors. In addition, these newly designed mirrors can be used — for the first time — for ultra-precise micro- and nanofocusing of intense synchrotron x-ray beams.

Researchers from the Argonne and Oak Ridge national laboratories developed the new mirrors in order to overcome the shortcomings of existing K-B systems. Those using benders to bend flat trapezoid silicon mirrors to elliptical reflecting surfaces have stability problems and are bulky, hard to adjust, and difficult to focus in the nanometer range. Those made by computer-controlled surfacing are very expensive to manufacture, each costing around $100,000 and involving many fabrication steps.

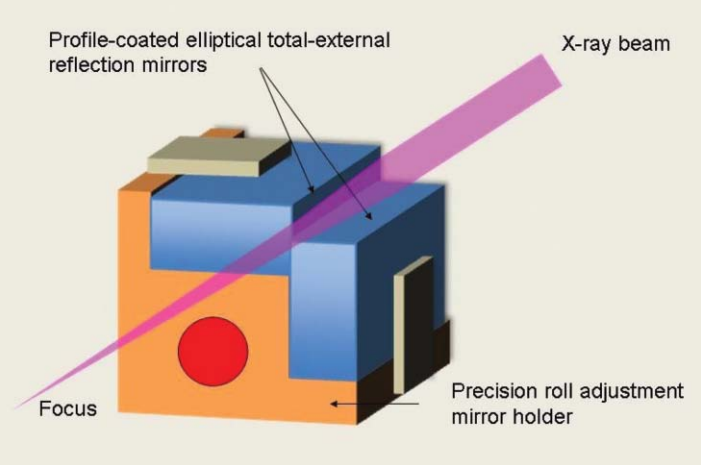

Fig. 1. A prototype Montel K-B mirror design. Two profile-coated elliptical total-external reflection mirrors are seen, along with the precision roll adjustment mirror holder. The x-ray beam is seen coming in from the top-right, with the focus at the bottom-left. From C. Liu et al., Appl. Surf. Sci. **258**, 2182 (2012).

The new design (Fig. 1) is compact and easy to use, with no need for benders. The system, which features highly precise, profile-coated elliptical reflecting surfaces that are able to efficiently focus hard x-rays to less than 100 nm, can be employed in many applications where x-ray nanobeams are required.

The main challenge overcome involved eliminating the imperfections at the edges where the two perpendicular elliptical mirrors come together. The problem was solved by developing a profile coating technique that converts inexpensive, flat silicon substrates into precise elliptical mirrors. The technique uses a contoured aperture mask in a magnetron sputtering system that coats a predetermined profile onto mirror substrates. During the development, gold and platinum were found to be suitable coating substances. Taking only a few hours per coating run, a primary coat and a follow-up corrective coat were determined to be all that was needed to produce precise elliptical K-B mirrors. Multiple mirrors can be coated during each run. A focal spot as small as 70 nm was achieved using the profile coating method when applied to a flat silicon substrate.

Another problem solved was the way the mirror systems were produced and aligned. Instead of cutting the mirrors at 45° to their surface and assembling them via an alignment that required 2 degrees of freedom on each end; the mirrors were polished at 90° to their surface. The polished surface was pushed against the other mirror's surface so that only 1 degree of freedom was needed. The mirror edges were made in two ways: the side of the mirror was polished and the two mirrors together were coated to produce identical elliptical mirrors; and a wider mirror was coated first, then cut into two mirrors, and the side of one was polished.

The nested K-B mirrors were tested at the XSD 34-ID beamline of the Advanced Photon Source, revealing a point focus of around 100 nm, which was considered excellent. A larger incident divergence was able to be focused because of the new nested arrangement of mirrors. This improvement led to an increased demagnification factor and potentially smaller focusing when compared to a sequential K-B system.

This beamline test also proved that nested Montel K-B mirrors can be fabricated successfully for synchrotron beamlines, and that the profile coating technique is capable of producing high-quality Montel K-B mirrors using flat silicon substrates.

Because of this successful first-ever test of a synchrotron hard x-ray nested K-B mirror system, the developers are confident that scientific research will benefit from the new Montel optics.

— William A. Atkins

See: Chian Liu*, G.E. Ice, W. Liu, L. Assoufid, J. Qian, B. Shi, R. Khachatryan, M. Wieczorek, P. Zschack, and J.Z. Tischler, "Fabrication of nested elliptical KB mirrors using profile coating for synchrotron radiation X-ray focusing," Appl. Surf. Sci. **258**, 2182 (2012).

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Call for APS General-User Proposals

The Advanced Photon Source is open to experimenters who can benefit from the facility's high-brightness hard x-ray beams.

General-user proposals for beam time during Run 2013-3 are due by Friday, July 12, 2013.

Information on access to beam time at the APS is at http://www.aps.anl.gov/Users/apply_for_beamtime.html or contact Dr. Dennis Mills, DMM@aps.anl.gov, 630/252-5680.

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