In-Line High-Resolution Monochromator for 21.6 keV X-rays

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We constructed a dual-purpose, high-resolution x-ray monochromator that can be used both for nuclear resonant scattering from the 21.542 keV nuclear resonance in ^{151}Euand also for nonresonant inelastic x-ray scattering when used in combination with a near-backscattering silicon (18 6 0) diced spherical analyzer that operates at 21.657 keV. We present the monochromator design along with its performance measured at the 21.542 keV nuclear resonance in ^{151}Eu.

The design of the high-resolution monochromator begins with the choice of diffracting crystals and is based on the fact that asymmetrically cut crystals can be used to collimate x-rays. From this fact, it was suggested that one could use an asymmetrically cut low-order crystal reflection, which has both a large angular acceptance as well as a collimating effect on the x-rays, followed by a high-order crystal reflection to achieve efficient monochromatization [1]. For the low-order crystal reflection, we use silicon (4 4 0) with an asymmetry angle of 16.0°, and for the high-order crystal reflection, we use a symmetrically cut silicon (15 11 3) [2]. In practice, these crystal reflections can be arranged with channel-cut crystals in a (+,+,−,−) scattering geometry to redirect the transmitted x-ray beam into the forward direction. The two channel-cut crystals are "nested" in a manner shown in figure 1.

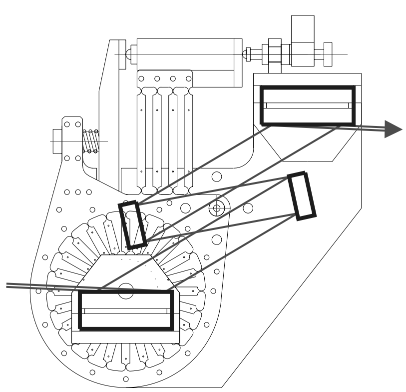

FIG. 1. Design of the high-resolution monochromator using silicon +(4 4 0), +(15 11 3), −(15 11 3), −(4 4 0) crystal reflections.

A difficulty arises as one attempts to apply this nested geometry to energies above 20 keV where the Darwin widths of high-order reflections become precariously small. Effects, such as crystal strain, thermally induced deformations, and crystal quality over large volumes, can preclude the realization of an efficient high-resolution monochromator. To overcome these potential pitfalls, we constructed what would normally be the "outer channel-cut" as two separate crystals mounted on a rigid metal plate using a piezo-driven multiple-flexure design that allows one to compensate for small angular misalignments between the crystallographic planes [3]. The piezo-driven weak-link mechanism was constructed using an overconstrained flexure design to obtain high stiffness, which is paramount for angular stability. A diagram of the crystal arrangement with the piezo-driven weak-link mechanism is shown in figure 1.

We measured the resolution and efficiency of the high-resolution monochromator at the 3-ID undulator beamline of the Advanced Photon Source. The energy-resolution function is measured by energy scanning the monochromator through the 21.542 keV nuclear resonance of ^{151}Eu while monitoring the delayed x-ray flux. The result of this measurement gives a transmitted energy bandwidth of 1.0 meV and is shown in figure 2.

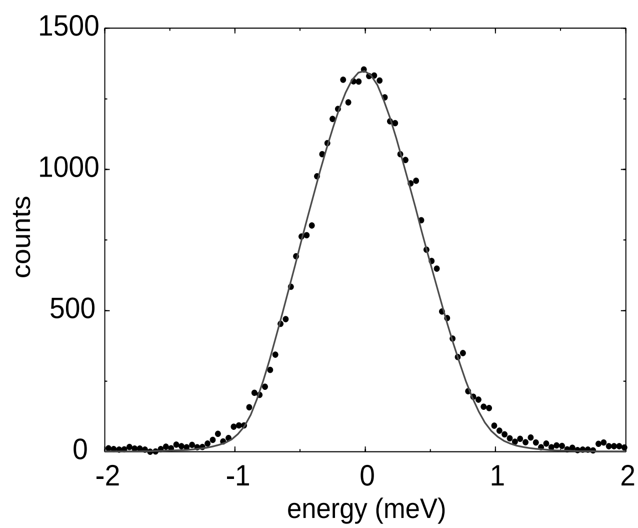

FIG. 2. Energy resolution function of the monochromator as measured by nuclear resonant scattering from ^{151}Eu. The energy width is 1.0 meV FWHM.

The transmitted flux is $\approx 4\times10^8$ ph/s at 100 mA storage ring current, which represents approximately 20 % of the incident spectral flux.

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[1] T. Ishikawa, Y. Yoda, K. Izumi, C.K. Suzuki, X.W. Zhang, M.Ando, and S. Kikuta, Rev. Sci. Instrum. **63** 1015 (1992).
[2] T.S. Toellner, Ph.D. Dissertation, Northwestern University, June, 1996.
[3] D. Shu, T.S. Toellner, and E.E. Alp, to be published in the proceedings of Synchrotron Radiation Instrumentation Conference, SSRL, 1999.