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A Multiwavelength Monochromator for the X3A1 Fixed-Angle Station at the National Synchrotron Light Source

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A new revolving monochromator intercepting 2 mrad of the radiation fan at the State University of New York (SUNY) X3 beamline at the National Synchrotron Light Source (NSLS) is described. The design allows for easy interchange between four different monochromator crystals. The photons are reflected in the horizontal plane to provide a monochromatic beam at a fixed-angle diffraction station. The triangular crystals can be bent for horizontal focusing.

Keywords: monochromators; sideways beamlines; triangular-shaped crystals; fixed-angle stations.

1. Introduction

To optimize usage of synchrotron sources, the fan of synchrotron radiation at each beamline port may further be divided into segments that can be used independently. Each such branch can be equipped with different optical elements in order to match specific experimental requirements. In many cases a vertical diffraction plane is used to take advantage of the low divergence in the vertical plane and the horizontal polarization of the synchrotron beam. Although the vertically diffracting optical elements intercept large portions of the horizontal fan, mechanical constraints often leave several milliradians of radiation unutilized. Such a segment can be intercepted by a fixed-angle single-crystal monochromator, diffracting in the horizontal plane, and providing an intense X-ray beam for applications where a wide energy scan is not required, or for wavelength-dispersive experiments (Wittry & Li, 1993; Finkelstein & Sutton, 1994).

Triangular-shaped silicon or germanium crystals have been used as effective focusing monochromators for fixed-wavelength applications (Lemonnier, Fourme, Rousseaux & Kahn, 1978; Greenhough, Helliwell & Rule, 1983). We have used such a monochromator during the past decade for the fixed-angle SUNY X3A1 diffraction station at the National Synchrotron Light Source. It uses 2 mrad of radiation left between the *A* and *B* branches of the beamline (Phillips, 1989). Though the station has proved useful for numerous experiments at the wavelength λ = 0.6575 Å, the absence of a multiwavelength capability has been a disadvantage.

We report on the mechanical design of a new revolving monochromator. A different monochromator crystal is selected by simple rotation of the crystal holder, thus providing a multiwavelength capability.

2. Monochromator design

The new design (Fig. 1) incorporates four interchangeable crystals mounted on the surface of a rotary crystal holder (Fig. 2), and allows for selection of a number of different wavelengths and energy bandwidths. The crystal holder, mounted on a large goniometer head (not shown in Fig. 2), allows fine adjustment of the angular and positional parameters of the crystals. The monochromator crystals can be shifted in the horizontal plane by ± 5 mm (with a resolution of 1 μm) in the direction normal to the crystal surface (shown as adjustment *T* in Fig. 1). No adjustment in the vertical plane is necessary once the monochromator assembly has been installed and clamped to the monochromator tank. The fine adjustment of the Bragg angle has a range of 10° with resolution of 1 arcsec. The coarse positioning is determined by the beamline geometry (θ = 6° at X3A1) and preset manually during the initial alignment of the assembly.

Angular variation of the vertical tilt of the crystal with a range of ± 2° and resolution of 4.5 arcsec is used to adjust the vertical position of the monochromatic beam at the sample, as well as for maximization of the beam intensity (angle χ in Fig. 1).

Multiwavelength capability is achieved by using four 0.5 mm thick triangular crystals with different *d* spacing of the reflecting planes (Table 1). A particular crystal is moved into the reflecting position by rotating the crystal holder around its horizontal axis (angle λ in Fig. 1). The maximum heat load on the crystals at the X3 bending-magnet line is estimated at 32 W, sufficient to cause a distortion in the angular and energy distribution of the reflected beam. To minimize heating effects, spiral channels for cooling water circulation (4 in Fig. 2) have been machined close to the surface of a copper cylinder on which the crystals

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are mounted. An InGa eutectic is used for transfer of heat from the crystal to the substrate (3 in Fig. 2), which is made out of molybdenum to prevent inter-diffusion of an InGa alloy into the water-cooled copper body (Hulbert, 1992). The temperature of the cooling water increased by only 3° during continuous operation of the monochromator, which has now been used in the collection of several crystallographic data sets.

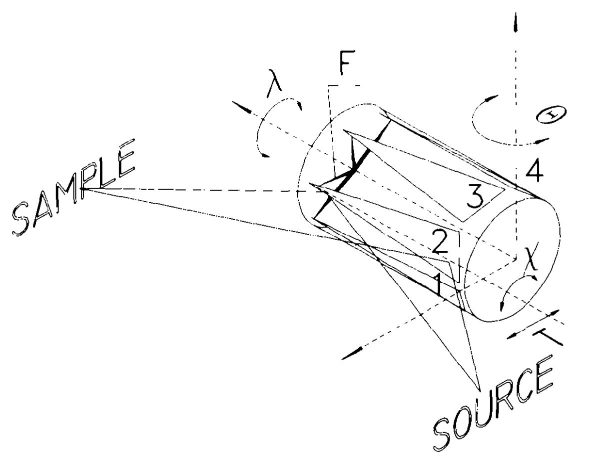

Figure 1
The revolving monochromator assembly, located inside a vacuum chamber alongside the double-crystal monochromator (not shown in the figure).

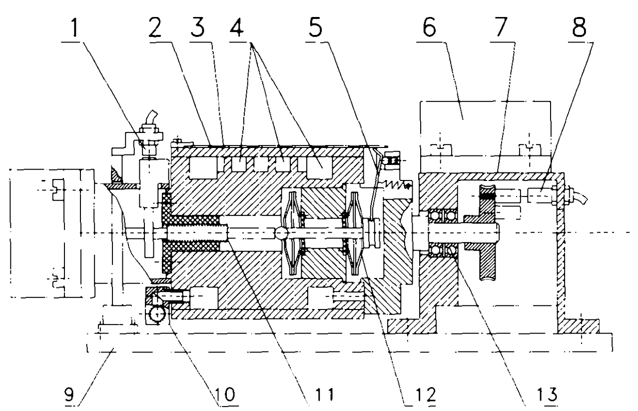

Figure 2
The rotary crystal holder. 1, limit switch; 2, crystal; 3, molybdenum substrate; 4, water channels; 5, actuator; 6, stepping motor; 7, gear reducer box; 8, position sensor; 9, base plate; 10, water outlet; 11, lead screw; 12, flat spring; 13, ball bearing.

Table 1
Characteristics of the monochromator crystals used.

Crystal	2*d* spacing (Å)	Wavelength (Å)	Energy (keV)	Darwin width (arcsec)
Si (111)	6.271	0.656	18.9	7.4
Ge (111)	6.533	0.683	18.1	16.3
Si (220)	3.840	0.401	30.9	5.5
Quartz (1010)	8.52	0.891	13.9	7.5

The crystals are clamped to the substrate. A flat actuator (5 in Fig. 2) can bend the triangular crystals to conform to the focusing conditions of a Rowland circle of 7.3 m radius. One step (0.72°) of a motor shaft rotation, converted into linear translation of the lead screw (11 in Fig. 2) and actuator (5 in Fig. 2), corresponds to a 0.3 µm shift of the tip of the crystal (shown as adjustment *F* in Fig. 1). The maximum shift of the crystal apex is restricted to 1200 µm by the limit switches (TL-X1R5C2-GE, OMRON) (1 in Fig. 2). Proximity switches (8 in Fig. 2) of a similar type are used as sensors for coarse positioning of the selected crystal in the reflecting position.

The design is customized for the conditions at X3A1, but not limited to the configuration described. The number of selectable crystals can be increased to eight after rearrangement of water-cooling outlets (10 in Fig. 2), and the range of reflecting angles can be increased when space is not limited.

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