A Mechanism for the Simple Control of High-Resolution Optics

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1. Introduction

An x-ray high-resolution monochromator (HRM) using perfect crystal has been a key optical device for nuclear resonant scattering, x-ray inelastic scattering, and x-ray coherent applications. As an HRM configuration, the two nested channel-cut crystal (NCC) design in (+n, +m, -m, -n) arrangement [1] has been widely used. With the NCC design, good energy resolution and higher angular acceptance can be achieved in a compact crystal size. Since the exit beam from the optical devices is parallel to the incident beam, we can easily add some optics downstream to the NCC arrangement.

The NCC design needs two high-resolution rotation axes to control the Bragg angles of two channel-cut crystals which are closely placed. For this purpose, the following mechanical design has been conventionally used. Two high-precision goniometers on translation stages are placed opposite each other on an experimental table. Swivel and translation stages are additionally attached to the goniometers. With this mechanical design, however, the setting up and alignment of the optics is rather difficult and complicated, because the design has a greater degree of freedom than necessary. Further, this mechanical design occupies a larger space in the orthogonal direction to the light axis. A specially designed wider table is consequently required. These complicities and particularities may block the utilization of the NCC optical design for other applications.

In this report, we introduce a compact mechanism developed for the simple control of the NCC design. The test results will be described. A new crystal design in (+n, +m, -m, -n) arrangement will be also presented.

2. Mechanism

The developed mechanism is composed of a dual coaxial high-precision goniometer, which has θ_{in} and θ_{out} axes with 0.0025" resolution, and two crystal mounts connected to the rotation axes (Fig. 1). A channel-cut crystal A for the 1st and 4th reflections is attached to the outer crystal mount, and another crystal *B* for 2nd and 3rd reflections is fixed on the inner crystal mount. The movable part of the outer crystal mount is a stepper motor driven tilt stage (*T1*). The inner crystal mount is composed of a tilt stage (*T2*) and a manual z translation stage (*Z2*). The resolution of *T1* and *T2* stages is 0.09". The goniometer is placed on x-z stages (*X*, *Z* axes) with 1 mm resolution. The crystal *A* is aligned to the incidence beam with *X*, *Z*, qout and *T1* axes. The crystal *B* is tuned to the exit beam from crystal *A* with *Z2*, θ_{in} and *T2* axes. The whole mechanism can be placed on a small experimental table. The total cost for the mechanism is low.

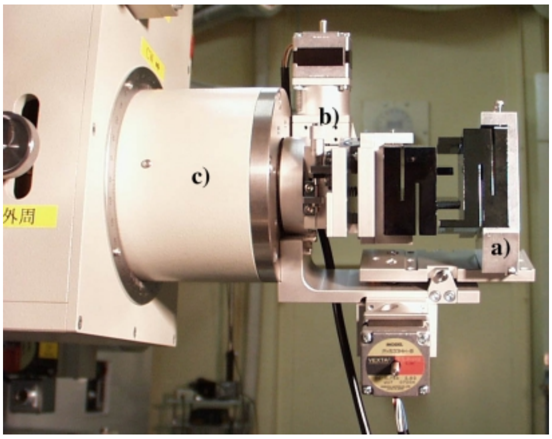

Fig. 1. The developed HRM system, viewed from the upstream side. a) outer crystal mount; b) inner crystal mount; c) dual co-axial goniometer.

3. Test Result

For the test experiment, two channel-cut crystals were made as shown in Fig. 2 (b). The crystal A gives a 422 reflection with an asymmetry factor of 1/15.7 for 14.41 keV X-rays, whereas the crystal *B* gives a 11 5 3 reflection with an asymmetry factor of 2.8 (Fig. 2). The design value of the energy resolution was calculated at 2.6 meV with an angular acceptance of 3.8 arcsec.

The test was carried out at BL29XU of SPring-8 [2]. The undulator gap was fixed at 20.1 mm, As a pre-monochromator crystal, a Si 111 pin-post crystal in inclined geometry was exploited. Using the pre-monochromator, the photon energy was selected at 14.41 keV, which corresponded to the fundamental radiation energy at the gap.

The alignment of HRM crystals was carried out as follows. Displacing the crystal *B* using the *Z2* stage, the 422 reflection from the lower blade of the crystal was searched by rotating the θ_{out} axis. Fine position tuning was carried out with the Z axis. After the diffracted intensity was maximized, the crystal *B* was moved back to the original position and the θ_{in} axis was rotated to find the 11 5 3 reflections. The tilt was

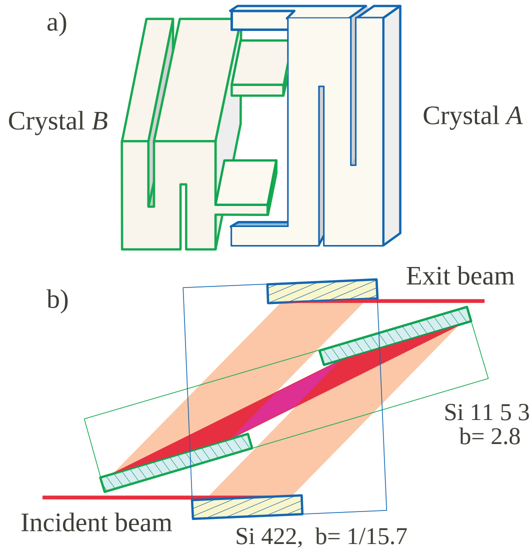

Fig. 2. Crystal design for NCC optics.

tuned to minimize the energy band width.

The energy resolution was measured by detecting ^{57}Fe nuclear resonant γ-rays using an avalanche photo diode (APD). Figure 3 shows a measured rocking curve of Si 11 5 3. The rocking curve width corresponds to an energy resolution of 2.6 meV in full width at half maximum (FWHM). The measured resolution agreed with the calculated value. Incident photon flux at 60 mA operation was measured at 9.2×10^{11} photons/s for 0.5×0.5 mm^2 area, whereas output intensity was 3.8×10^8 photons/s at that condition. Since the incident energy band width was measured at 2.5 eV (FWHM), the throughput of flux density per unit bandwidth was estimated at 40 %. The whole system was placed on an experimental hutch, where temperature was stabilized within ±0.1 °C with an air conditioner. At that condition, no drift of output intensity was observed.

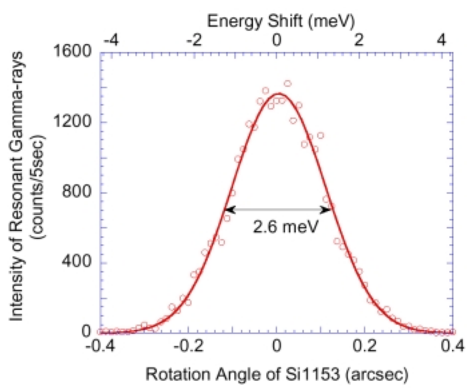

Fig. 3. Measured intensity of ^{57}Fe resonant γ-rays, as a function of rotation angle of Si 11 5 3 (circles). A solid line is a Gaussian fit.

4. New Crystal Design as HRM

We introduce a new crystal design as HRM in (+m, +n, -n, -m) arrangement, using a grooved flat crystal and a channel-cut crystal (Fig. 4). Here we call it an FCC design. A channel cut crystal in the NCC design was replaced by a grooved flat crystal in the FCC design, where the grooved part is used as a beam path. The merit to using the flat crystal is the feasibility of making a good surface finish for highly asymmetric reflection. A good surface finish tends to avoid stray scattering, which may cause to broaden the energy resolution, or to destroy the coherence of the wave field.

We show an example of FCC design for 14.41 keV X-rays, as shown in Fig. 4 (b). Si 620 reflections with an asymmetry factor of 1/19.4 are used for a flat crystal, whereas Si 10 6 4 reflections with an asymmetry factor of 6.9 are used for a channel-cut crystal. The energy resolution was calculated at 2.3 meV with 41 % efficiency.

We note that the mechanism developed for the NCC design can be easily applied to the FCC design.

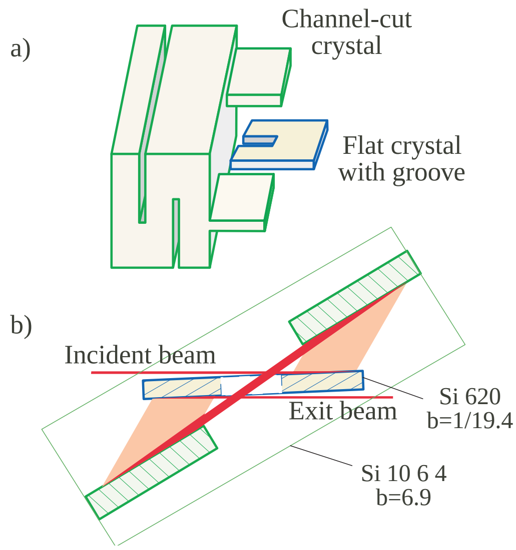

Fig. 4. Crystal design for FCC optics.

5. Concluding Remarks

The mechanism for the simple control of HRM, as well as the test experiment, were described. A new crystal design in (+m, +n, -n, -m) arrangement was also presented.

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References

[1] T. Ishikawa *et al.*, Rev. Sci. Instrum. **63** (1992) 1015.
[2] K. Tamasaku *et al.*, in this volume.