FIXED HEIGHT EXIT BENDER OF SYNCHROTRON X-RAY ABOVE 40 keV

Sagittal focusing is an efficient method for focusing synchrotron X-rays. Usually, the second crystal of a double-crystal monochromator is bent into a cylindrical shape, ideally without introducing any deformation of the crystal in the scattering plane. Accordingly, both energy and momentum resolutions are kept as high as those achieved by flat-flat double-crystal monochromators. The radius of the bend that will provide optimal focussing is a function of the Bragg angle; as the Bragg angle becomes smaller, so does the radius. Various bending mechanisms for sagittal focusing have been developed. However, most applications have been restricted to relatively low energy X-rays due to the difficulty of generating an ideal bend with small radius. In addition, simultaneous achievement of optimal focus and fixed-exit height despite changing output energy is preferable for most applications, and requires an even more complex bending mechanism.

Although the rhombohedral or double triangle ribbed crystals bent with a cam driver mechanism fulfill the fixed-exit condition, they are apt to introduce non-uniform bend due to cramping at the crystal center. We developed a new sagittal focus bender [1] that is compatible with the SPring-8 standard monochromator [2,3] for bending-magnet beamlines. In principle, the bender uses a conventional four-point bending mechanism, but the rollers for four-point bending are attached to rotation arms, making the central position of the crystal fixed regardless of the bending radius. This procedure is based on a simple geometrical theorem illustrated in Fig. 1(a). Two circles, A and B, are always across at the right angles to the circles C and D, the centers, O_C and O_D, of which lie on the

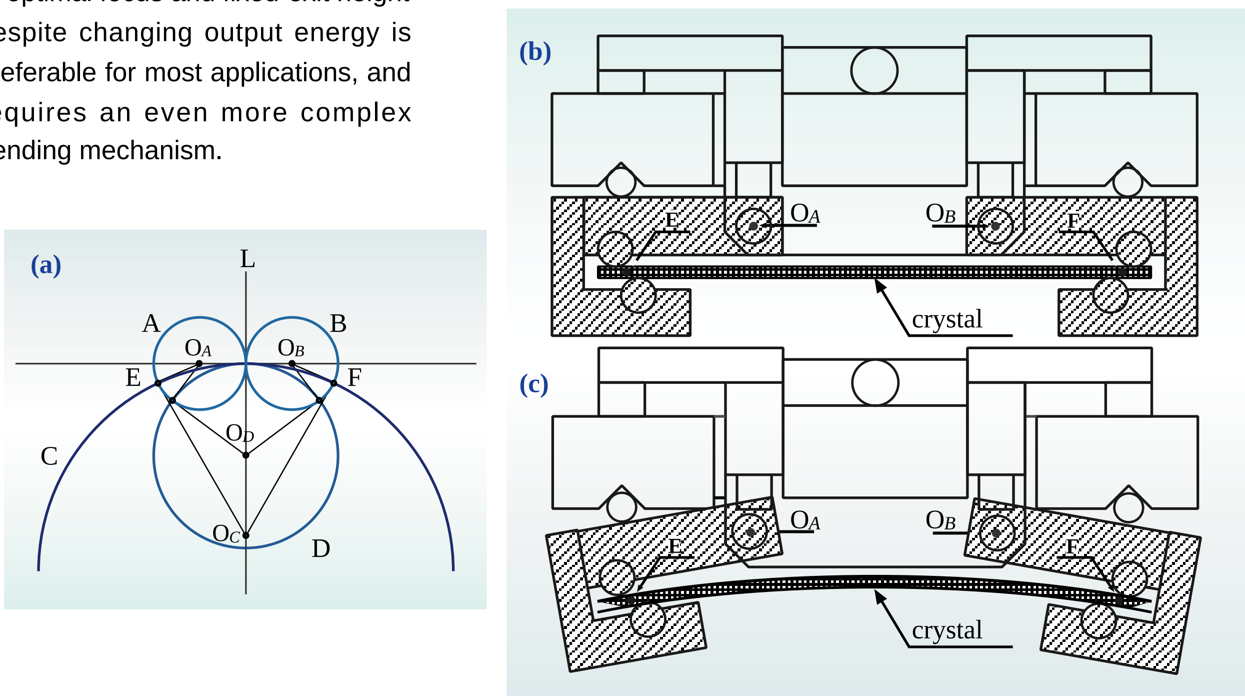

Fig. 1. **(a)** Geometrical basis of the fixed exit bender. Actual bending mechanism **(b)** when the crystal is flattened and **(c)** when the crystal is bent.

perpendicular bisector L of the centers of circle A and B. This shows that the crystal, which corresponds to either circle C or D in Fig. 1, is bent cylindrically without changing the height of the middle point of its arc, when pure torque is applied at the cross points E and F. The actual bending mechanism when the crystal is flattened is shown in Fig. 1(b). The crystal was cramped with four cylindrical rollers of the cradle (gray region in Figs. 1(b) and 1(c)). The bending is performed without changing the position of the crystal center by rotating the cradle around O_A and O_C, as shown in Fig. 1(c).

Since the SPring-8 standard monochromator is designed to keep the exit-beam height constant, even with in changing energy, combination of the bending mechanism with the monochromator also preserves exit-beam height constancy with an optimized bending radius for each energy.

We used a row of grouped crystals joined by thin hinges of a Si (3 1 1) plate with a rectangular shape of 90 mm (along the beam) × 100 mm (across the beam) × 2 mm (thickness), as shown in Fig. 2, in order to avoid anticlastic bending that would degrades the total throughput. The focusing test was carried out at **BL14B1**, which is a bending magnet beamline dedicated to JAERI and equipped with a SPring-8 standard double-crystal monochromator. The fixed-exit bender was mounted on the second crystal stage of the monochromator as shown in Fig. 3. A pair of (3 1 1) Si crystals were used both for the first and second crystals. For the first crystal, an indirectly cooled flat plate was used instead of the standard direct fin-cooled crystal.

Figure 4 shows the observed beam profiles at 40 keV with different bending radii, R. The horizontal beam size was 65 mm at the screen position for the unbent crystal. The beam reflected from the slot parts of the crystal appeared like the teeth of a comb. We can quantify the number of slots reflecting the X-ray beam by counting the sharp lines. From the image, all slots were found to reflect the X-ray beam even when the bending radius was 4 m. The gain of the photon density was measured by horizontal slit scans, and was found to be 12 times larger than the flattened crystal, when the bending radius of 4 m was used (Fig. 4).

Dynamic sagittal focusing testes were performed

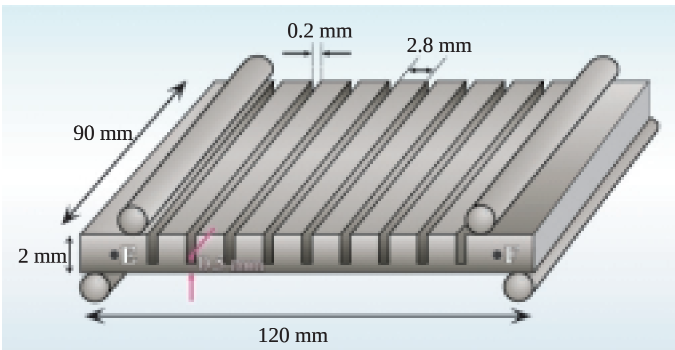

Fig. 2. Schematic diagram for a series of crystal slabs joined by thin hinges, cut parallel to the bending rods.

between 40 keV (*R* = 4 m) and 60 keV (*R* = 2 m). The beam height at the sample position was measured after optimizing of the bending radius and the parallel alignment the first and second crystals. The deviation of the beam height in the above energy range was within ±0.15 mm. Preliminary setup was carried out with flat-flat double crystals before installing the bender. The deviation of beam height with flat-flat double crystals was 0.1 mm in the 40 keV to 60 keV range. The practical deviation of beam height with the bender was somewhat larger than expected. When bending is performed, the fixed points are not on the surface of the bent crystal, but only in the center of the crystal. Because of the thickness and polygonal nature of the bent crystal, the practical beam height was changed slight in the 40 keV to 60 keV range. However, the beam deviation should be negligible in most experiments.

This sagittal focus bender is designed for an inclined double crystal monochromator. The properties of sagittal focusing of inclined geometry with a Si (111) reflection were tested. In Fig. 5 we compare a near-edge spectrum of a Cu foil registered in a dynamically focusing mode with that of a normal flat crystal. Because the two spectra are identical, we conclude that energy resolution is not affected by sagittal focusing, nor is any distortions introduced.

Dynamical sagittal focusing in a wide energy range, from 8.5 keV to 150 keV, performed without exchanging monochromator crystals will become feasible by using the present bending mechanism in the inclined geometry.

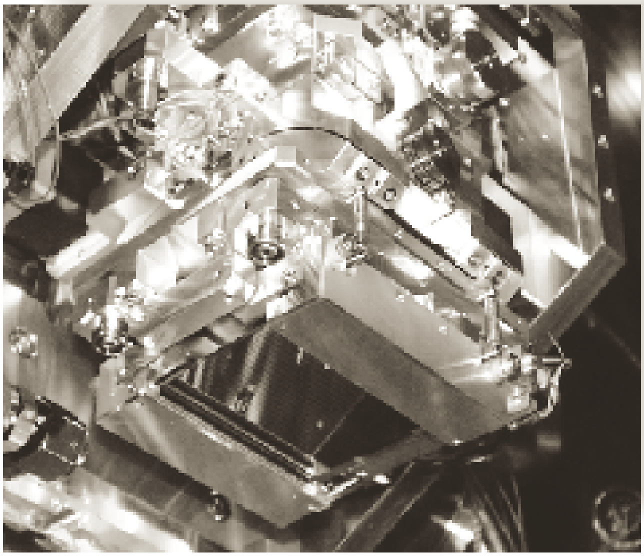

Fig. 3. Sagittal focus bender with a row of grouped crystals joined by thin hinges installed in standard monochromator as the second crystal.

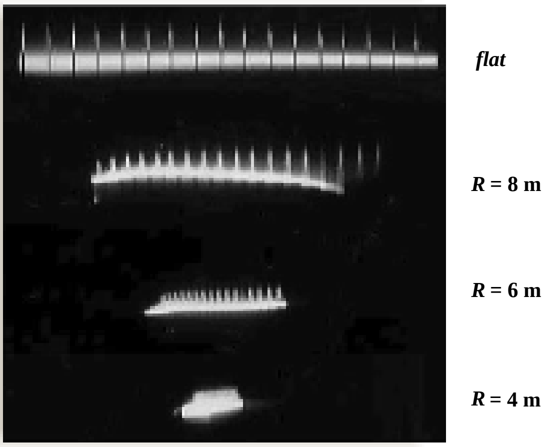

Fig. 4. Beam profiles using the sagittally focusing crystal monochromator at 40 keV. The period of the slotted crystal is 3 mm. The X-ray beam was more effectively focused at smaller bending radii R.

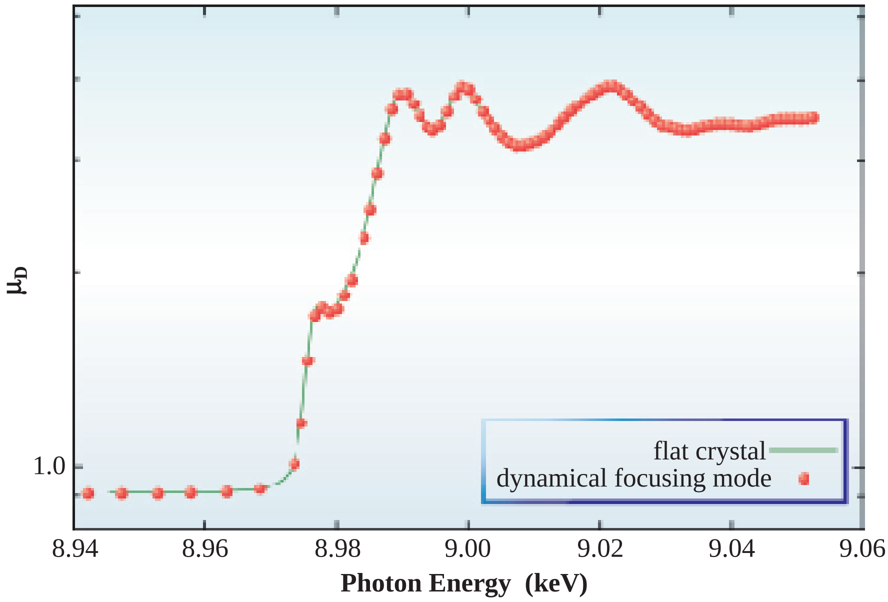

Fig. 5. Near-edge absorption spectra of Cu foil, registered in the dynamical focusing mode and in the flat crystal mode. Energy resolution is not affected, as all edge structures are reproduced without distortion.

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