Bent Crystal Monochromators for High Energy Synchrotron Radiation (II)

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1. Requirements

We have made some calculations and designed two kinds of monochromators for use of high energy synchrotron radiation which are 100-150 keV and 300 keV, respectively[1]. For Compton scattering experiments in the beam line BL08W, it is required that energy resolutions, $\delta E/E$, and beam spot size are less than 10^{-3} and 0.5x0.5 mm^2 for 100-150 keV monochromator and about 5 x 10^{-3} and 3(v)x1(h) mm^2 for 300 keV monochromator, respectively[2]. Here we describe mechanical design of two monochromators mainly.

2. Crystal bender

The bender design we proposed is based on a 4-point bending system operated either end of the crystal or the crystal holder by two stepper motors each in a sinebar configuration for both kinds of monochromators. Multi-point benber more than 4-point will be better to get ideal curvature. But here deviation from ideal curvature when 4-point bender is used is small because of large curvature of radius. A 4-point bender system is considered to be enough for the purpose of the experiments in this beam line. As shown in Fig. 1, the crystal bending is achieved through the rotation of two columns A which are connected to other columns B vertically. Small linear motion of B gives the rotation of A and the crystal is bent. We call this mechanism “torsion bender”. We can control both columns independently. This bender has some advantages. First we can give the bending force through linear motion of column B and it is easy to realize. Second the bender is not affected by the temperature change in the columns. Small change in the incident angle gives big change in the refection energy because the incidence angle is very small in these monochromators. If the columns of the bender are connected to the crystal holder vertically, small temperature raise of the columns give significant effect on the change in the incident angle. It is noted that scattered x-rays heat up the bender components. But in our system the temperature change in the columns A does not affect the incident angle of the crystal. Third the torsion of column A is a good decelator that means direct force dose not transfer to the crystal.

3. 100-150 keV monochromator

For the 100-150 keV monochromator a symmetric Johann-type Si 400 crystal will be mounted on the cylindrical water-cooled Cu holder through liquid In-Ga layer. The monochromator will set at the distance of 41.2 m from the source. The holder will be bent with the crystal by the torsion bender mentioned above as to get q/p=1/3 focus. The incident power for the crystal is calculated to be about 800 W. The crystal was cooled indirectly through the Cu holder through which precise water-cooled channels are bored, and the holder will be nickel plated. This monochromator includes some stages and goniometers. They are summarized in Table I with the range and resolution. Access to the chamber and above system is via the side flange through which the main Bragg rotation is introduced into the chamber. This side flange can be manually withdrawn horizontally along a rail system for ease of assembly and maintenance. Bragg rotation is performed outside vacuum chamber and coupled to the mounting flange through hollow bore rotary shaft. The vacuum vessel will be mounted on a translation stage which can be manually moved up and down via a linked jacking system. Just above the crystal, a water-cooled Cu plate will be placed for the protection of the radiation from the crystal surface. The pipes for water cooling circuit will be introduced to the vacuum chamber through the central bore of the main Bragg angle rotation shaft as usual. Due to the space problem, the 300 keV beam from the 300 keV monochrmator passes through inside the chamber.

4. 300 keV monochromator

For the 300 keV monochromator an asymmetric Johann-type Si 771 reflection will be employed with asymmetrical angle of about 1 degree. The Si 771 crystal surface will be cut from a Si ingot crystal grown in the [001] direction. The crystal size is about 800x60x30 mm^3 and it can be changed to a thin crystal to utilize the transmitted beam at the 100-150 keV monochromator position in future. Essentially the crystal bending mechanism is similar to the 100-150 keV monochromator except the reflecting face is vertical as opposed to horizontal. Movements are summarized in Table I. The monochromator will be set at the distance of 38.7 m from the source. The crystal will be bent to focus vertically-diverged beam.

For the 300 keV monochromator the incident power after the filters is about 470 W. Within the vacuum vessel the system consists of the Bragg rotation, the crystal up and down actuation, and horizontal translation. The whole system is on the thick base plate which acts as a kinematic mount within the vessel. All motions are decoupled from the vacuum vessel. For the protection from the direct beam irradiation to the crystal two apertures including Pb and water-cooled Cu are set before and after the crystal.

5. Radiation problem

Radiation from the crystal and crystal holder is due mainly to Compton scattering which gives a power of about 100 W continuously. For 300 keV monochromator the primary crystal shield consists of a water-cooled rectangular Cu tube aligned around the crystal and crystal holder parallel to the beam axis. As the secondary shield a water-cooled Cu skin of 5 mm thickness is adjusted inside the vacuum vessel. Third shield is 20 mm thick lead which covered outside of the vacuum vessel. This local lead shield makes the white beam hutch lead shield thinner. As for the 100-150 keV monochromator the primary shield is a water-cooled Cu plate just above the crystal to protect from the scattered x-rays. The other shields are similar to those of the 300 keV monochromator. Any cable material suspect to radiation damage will be suitably used inside the vacuum chamber.

References

[1] H. Yamaoka et al. SPring-8 Annual Report 1995, p.195.
[2] Y. Sakurai et al. Rev. Sci. Instrum. & Methods **66**, 1774 (1995).

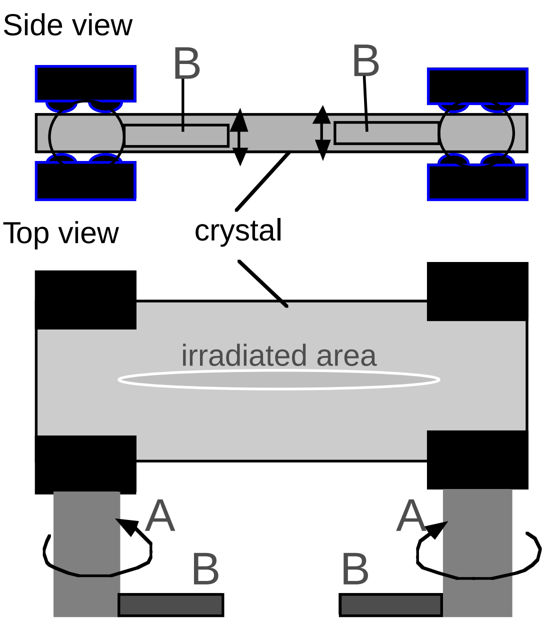

Fig. 1 Concept of SPring-8 BL08 monochromator bender.

Table I Each monochromator movements.

monochromator	100-150 keV monochromator		300 keV monochromator	
function	range	resolution	range	resolution
horizontal translation	±5 mm	0.005 mm/step	-10~50 mm	0.01 mm/step
in plane rotation	±3°	3.6”/step		
up and down vertical translation	10~-50 m	0.0001 mm/step		
Bragg rotation	-3~7 °	0.04”/step	-1~6 °	0.5”/step
base stage up and down (manually)	±30 mm		±20 mm	0.001 mm/step