Stabilization of Double-Crystal Monochromator at BL41XU

In SPring-8, double-crystal monochromator mechanisms were developed standards for facilitating the rapid construction of beamlines thirteen years ago. The basic design of the mechanisms has remained unchanged. At present, the mechanisms are used at 27 undulator and bending magnet beamlines. In the ten-year user operation, users' requests for X-ray beams are becoming severer as research studies with SPring-8 are pioneering new fields of science and technology. For example, at beamline BL41XU for structural biology research, the typical sizes of crystalline protein specimens are being reduced down to tens of microns, and users consequently require to obtain highly brilliant X-rays focused into the specimen sizes as stably as possible. However, the micro-focused beam has not been stable enough to reduce the intensity by 26% per hour and to fluctuate it by 13%, as shown in Fig. 1. Such reduction and fluctuation were most likely caused by the instability of the mechanism. Moreover, the synchrotron radiation deteriorated the performance of water-cooled crystals, and damaged the O-rings for the water seal and motor cables in the mechanisms with time. We solved the above problems at BL41XU.

Intensity reduction — Intensity reduction was induced when the diffraction net planes of the two crystals were not held in parallel. We measured temperature at about forty points in the monochromator, such as the coolant water, crystal holder and fine stepper stages. As a result, the angular shift between the net planes was nearly proportional to the temperature changes of the tilt stages for crystal adjustment. The temperatures of the tilt stages were controlled by two means: (a) elimination of heat sources and (b) efficient cooling of the stages. The former was carried out (a-i) by turning off the hold currents of the motors of fine stepper stages and (a-ii) by adding shield parts to block X-ray and electron radiations to the mechanism (Fig. 2). The latter was performed (b-i) by an indirect water cooling of the tilt stages and (b-ii) by changing the temperature of the cooling water from 20.0 to 25.5 °C (the room temperature). Consequently, the temperature difference between the first crystal and the tilt stages decreased from 9.5 to 0.5 °C, and that between the second crystal and the tilt stages from 5.4 to 0.3 °C. The control of stage temperature resulted in the stabilization of microbeam intensity (reduction rate 1% per hour), as shown in Fig. 1.

Intensity fluctuation — The black lines in Figs. 3(a) and 3(b) show the intensity fluctuation and its power spectrum of the monochromatic beam filtered with a narrow slit. Turning off the instruments around the monochromator, such as vacuum pumps and the chiller, one by one, we divided the vibration sources into four types: (A) the chiller to supply the coolant water into the crystal (< 5 Hz), (B) the water paths inside the vacuum chamber (50~100 Hz), (C) scroll vacuum pumps (179, 207 Hz) and (D) something undefined (117 Hz). As shown in Fig. 2, we put new accumulators to control water pressure for the vibration source (A), used the polyurethane inner tubes to smooth the water flow for (B), and put rubber cushions under the scroll vacuum pumps for (C). The intensity fluctuation after the above improvements (red lines in Fig. 3) decreases to the same level as the

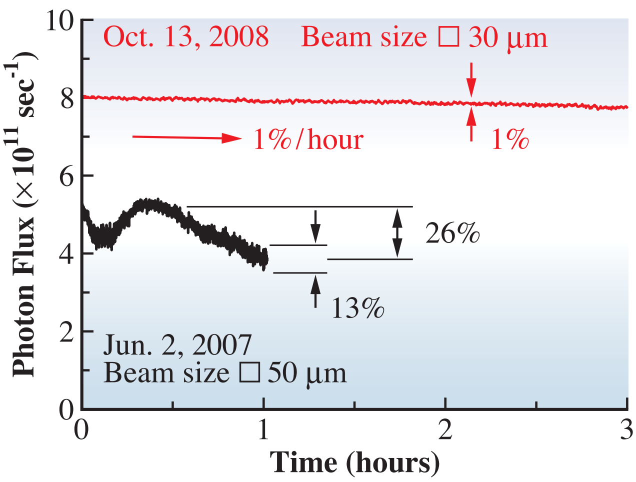

Fig. 1. Changes in microbeam intensity at the experimental station with time. The black and red lines show the beam intensities before and after the stabilization, respectively. The increase in beam intensity was caused by the improvement in crystal performance.

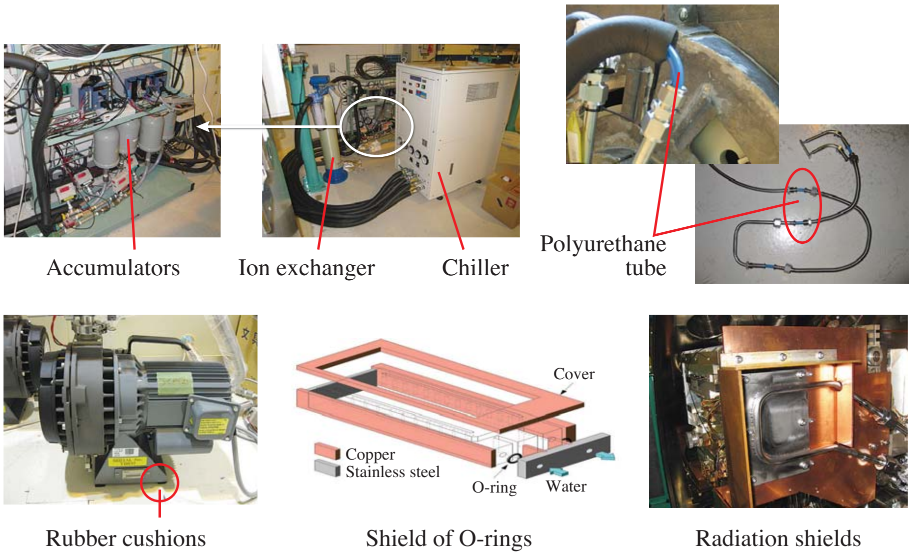

Fig. 2. Parts of the improvements for the stabilization of the monochromator.

instruments around the monochromator were turned off (blue lines in Fig. 3). The intensity fluctuation of the microbeam reduced from 13% to 1% accordingly as shown in Fig. 1.

Radiation damage — The deterioration in crystal performance was mainly caused by the jamming of copper compound in the water paths. Copper ions were dissolved from the crystal holders. We coated all the water paths inside the newly designed crystal holders with nickel. In addition, the coolant water was continuously refined with the ion exchanger shown in Fig. 2. The water paths inside and outside the crystal were changed to shield the O-rings from radiations (Fig. 2). The shield parts for X-ray and electron radiations played a role in the protection of the motor cables.

We are planning to stabilize other beamline monochromators on the basis of the above results.

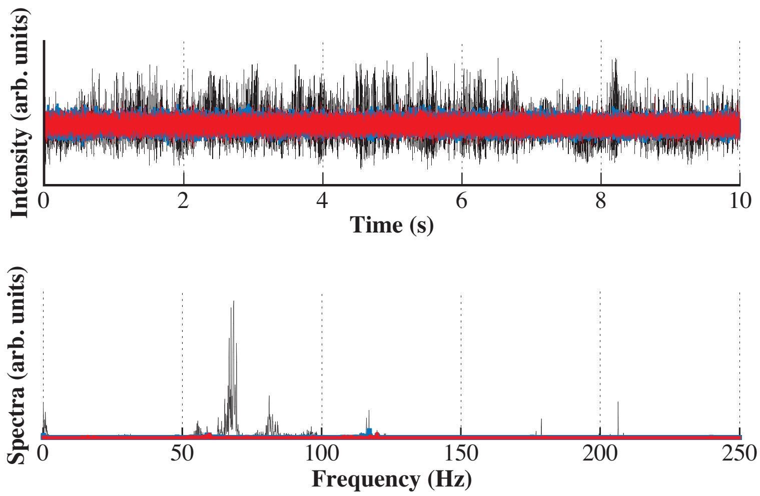

Fig. 3. **(a)** Monochromatic beam intensities filtered with a narrow slit and **(b)** their power spectra. The black and red lines show the data before and after the stabilization, respectively. The blue lines were measured when the instruments around the monochromator were turned off.

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