High Flux (BL40XU)

1. Introduction

High flux beamline, which is numbered BL40XU, was built in SPring-8 during the summer of 1999. The most important feature of BL40XU is that a very high X-ray flux can be used in various experiments. Crystal monochromators have a band-pass of the order of 10^{-4}, which is unnecessarily narrow in many experiments. On the other hand, the fundamental undulator radiation has an energy peak-width of 2% and thus, using the whole fundamental radiation peak, the flux is more than 100 times higher than that obtained with a crystal monochromator. With this concept in mind, we decided to use the fundamental undulator radiation as a quasi-monochromatic X-ray beam in the basic design of BL40XU, so that the use of the crystal monochromator was eliminated. BL40XU was commissioned from October 1999 to March 2000. Then, in April 2000, the beamline was open for users, and experiments were conducted using this apparatus until June 2000.

2. Outline of the Beamline

The X-ray source of BL40XU is a helical undulator, with a period length of 36mm and a period number of 125. Helical undulators were originally used to generate the circularly polarized X-rays. One of the specific features of this type of undulator is that the energy of the fundamental radiation is concentrated in the core of the radiation axis. On the other hand, most of the higher harmonics are emitted off-axis. So, by extracting the central part of the radiation, the fundamental radiation with a narrow peak-energy-width, which is treated as a quasi-monochromatic X-ray, can be used without loss of its flux. In fact, even when only the central 15 μrad (horizontal)×5 μrad (vertical) radiation is used, the energy peak-width is about 2% and the flux is calculated as high as 1.5×10^{15} photons/sec. The undulator gap can be varied so that the fundamental radiation is altered between 8 and 17 keV.

Among the front end components, the most important is the XY slit which is located at a point 33m from the light source, because the higher harmonics are almost completely cut off by these slits. Simultaneously, the elimination of higher harmonics helps to reduce the heat load on the optics. In order to use the quasi-monochromatic X-ray, the front end slits are used with an aperture of less than 15 μrad (horizontal)×5 μrad (vertical) in most experiments. However, the aperture was designed so that it could be opened up to 50×50 μrad for experiments which require quasi-white radiation.

Figure 1 shows the schematic view of the beamline. The optics of this beamline consists of two mirrors that are made of silicon and coated with rhodium, and two water-cooled slits. The upper stream mirror is for horizontal focusing and is 700 mm long. The other is for vertical focusing and is 400 mm long. Both mirrors are plane and water-cooled. By bending these two mirrors, an X-ray is focused horizontally and vertically. The glancing angle of the horizontally focusing mirror is set to 3 mrad and the second mirror to 4 mrad to eliminate higher harmonics. The horizontal mirror is placed first because the beam is larger in width than height: at a fixed glancing angle, the footprint of the beam is larger on a horizontally focusing mirror, thereby giving lower heat density. The mirrors are located in a position about 4:1 between the undulator source and the focus of the beam. Thus the beam size at the focus is about 1/4 of the source.

The experimental hutch is about 6 m (long)×4 m (width)×3 m (height) large. Users can freely arrange and set up a detector and other experimental apparatuses in the experimental hutch to suit their experiments. For small-angle scattering experiments, a 2 m-long vacuum pipe can be used. There are, moreover, two kinds of shutters in the experimental hutch. One is driven by a galvanometer-like motor and opens and closes within 1.5 msec after a trigger pulse. The other is a rotating-aperture type shutter. By synchronizing the two shutters, pulsed X-rays with different pulse widths can be generated. The shortest pulse width is 6 μsec. As a detector, a fast CCD

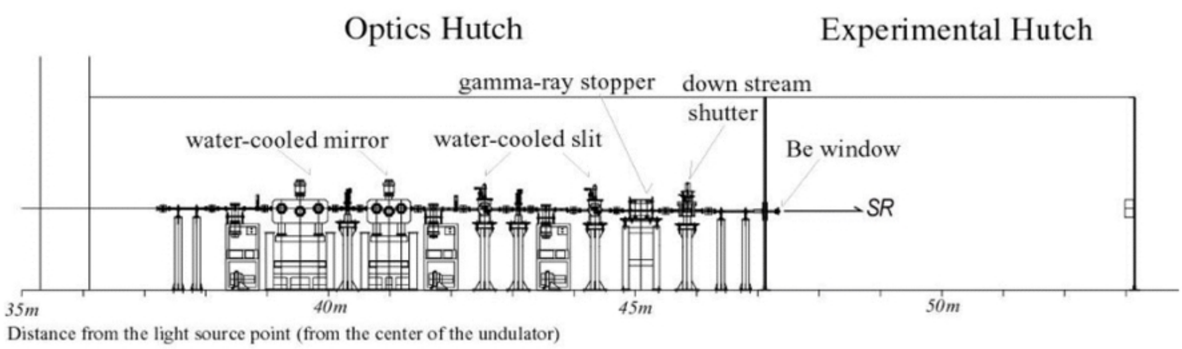
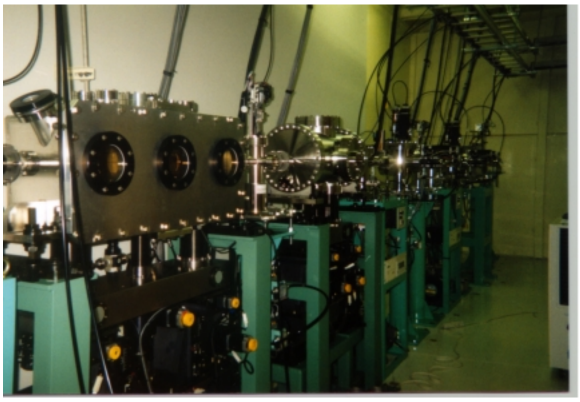
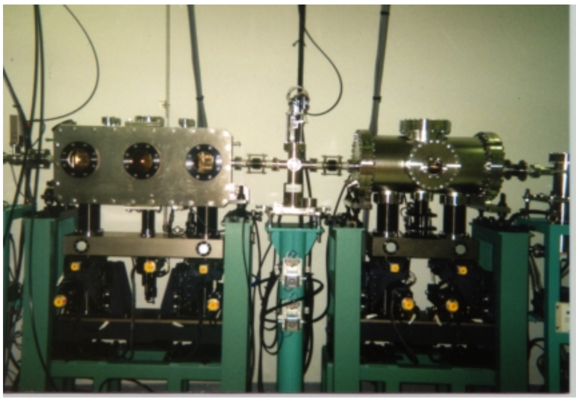


Fig. 1. The schematic view of the beamline.



(a)



(b)

Fig. 2. Photographs of the beamline.
a) The view from the upper stream
b) Two mirror chambers

camera with a framing rate of 290 per sec (640×480 pixels, 10 bits) is installed with an X-ray image intensifier which has a short-decay phosphor. By reducing the size of the frame, a framing rate up to 5000 per sec is achievable. A YAG laser is also installed in the hutch for experiments that require a quick trigger of events.

3. Present Status of BL40XU

On October 22, 1999, the first light was introduced into the experimental hutch through the transport channel. Since then, the test operation of the beamline was carried out. By tuning the front end XY slit and the two mirrors, the X-ray beam size can be altered to suit different experiments. In the case of most experiments, it is expected that the front end XY slits are used with an aperture of 15 µrad (horizontal)×5 µrad (vertical). The X-ray focus size was observed to be as small as 250 µm (horizontal)×40 µm (vertical) (FWHM) by bending optimally the two focusing mirrors. Considering the actual size of the light source (horizontal 600 ~ 1000 µm, vertical 10 ~ 20 µm), it is thought that the surface unevenness of the mirror is affecting the vertical beam size. The flux is roughly estimated to be 1×10^{15} photons/sec. Using this value, the flux density is calculated to be 1×10^{17}

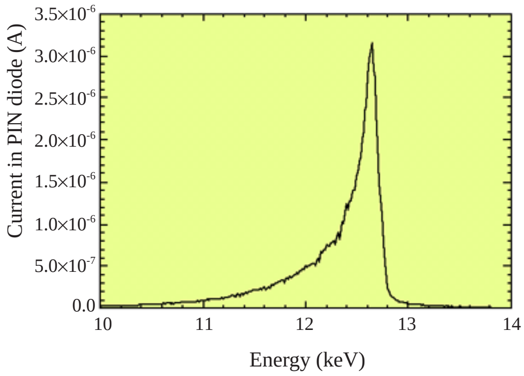


Fig. 3. The representative energy spectrum.
The peak of the fundamental energy was 12.4 keV and the aperture of the front end XY slit was 15 µrad (horizontal)×5 µrad (vertical).

photons/sec/mm^2. Figure 3 shows a representative energy spectrum observed at the sample position. It was measured with Silicon (111) crystal. The peak of the fundamental energy was set to 12.4 keV and the aperture of the front end XY slit was 15 µrad (horizontal)×5 µrad (vertical). The energy spectrum showed a sharp peak and its peak width was about 1.8 % (FWHM). The higher harmonics were not observed. This peak width of the fundamental energy did not change when the peak of the fundamental energy was

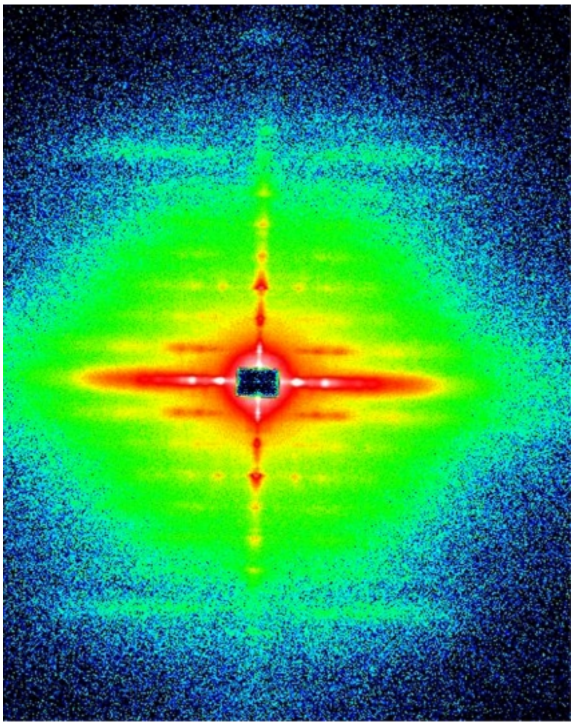


Fig. 4 The first diffraction image
An X-ray diffraction from frog skeletal muscle recorded on an imaging plate. Exposure time was 1.4 ms.

altered between 8 keV and 15 keV (data not shown).

Figure 4 shows the first diffraction image measured at BL40XU. It is the diffraction from frog skeletal muscle recorded on an imaging plate. The exposure time was 1.4 msec and the energy was 12.4 keV. Despite the very short exposure time, the diffraction is very clear. Until June 2000, some experiments, especially some requiring high flux, such as time-resolved diffraction and scattering experiments, X-ray speckle measurement, X-ray fluorescence trace analyses and time-resolved protein crystallography were carried out.

For the future, we expect that new research with a new concept and which makes the best use of a high X-ray flux will be attempted and developed at BL40XU.