BL40XU　High Flux

The basic design concept of BL40XU is to use the fundamental peak of undulator radiation as a quasi-monochromatic x-ray beam. This eliminates the use of a crystal monochromator which has a band-pass of the order of 10^{-4}, unnecessarily narrow in some experiments. The fundamental undulator radiation has an energy peak-width of 2% and thus the flux is 100 times higher than that obtained with a crystal monochromator.

Area of research

Time-resolved diffraction and scattering experiments
X-ray speckle
X-ray fluorescence trace analysis

Keywords

Scientific field

High flux, Structural biology, Small-angle X-ray scattering/diffraction, Time-resolved experiments, X-ray fluorescence analysis

Equipment

X-ray shutters, Fast CCD camera, X-ray image intensifier, YAG laser, Vacuum path for small angle X-ray scattering

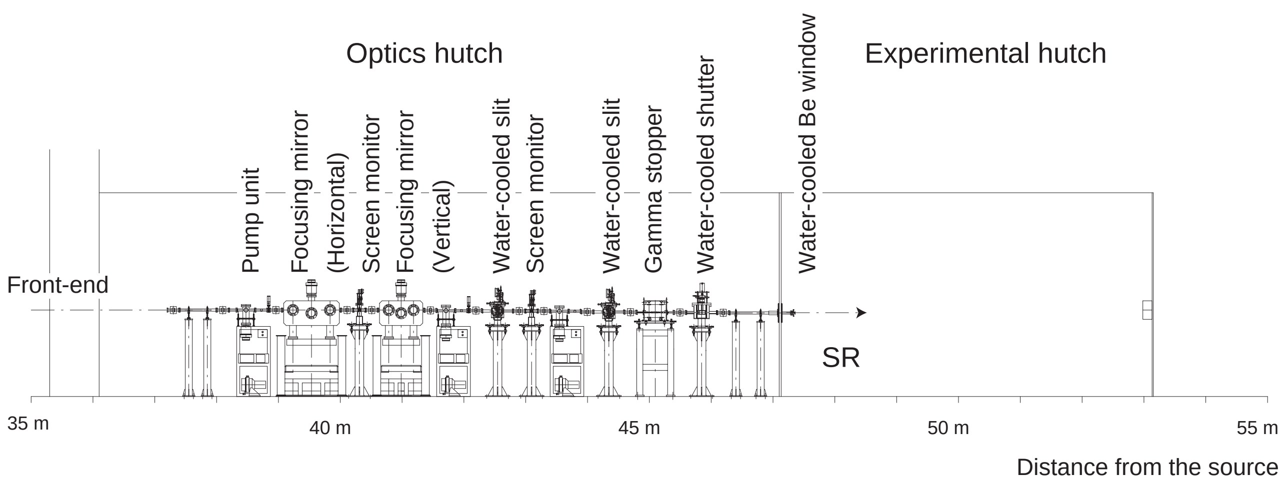
Source and optics

Light source

The X-ray source of BL40XU is a helical undulator, whose period length is 36 mm and the number of period is 125. Helical undulators were originally used to generate 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. 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 narrow peak-energy-width, which is treated as a quasi-monochromatic X-ray, can be used without loss of its flux. The undulator gap can be varied so that the fundamental radiation is altered between 8 and 17 keV.　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, it was designed that the aperture can be opened up to 50 × 50 μrad^2 for experiments which require quasi-white radiation.

X-rays at sample

The focusing optics consists of horizontally and vertically focusing mirrors that are made of silicon and coated with rhodium. Both mirrors are water-cooled. The glancing angle of the first (horizontally focusing) mirror is set to 3 mrad and the second mirror to 4 mrad to eliminate higher harmonics.



Schematic view of beamline

The mirrors are located about 4:1 position between the undulator source and the focus of the beam. Thus the beam size at the focus is demagnified to about 1/4 of the source. By tuning the front end XY slits and the two mirrors, 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 two focusing mirrors optimally (Fig. 2). The flux, when the ring current was 100 mA, was estimated to be 7 × 10^{14} photons/sec at 8 keV, 9 × 10^{14} photons/sec at 10 keV, 1 × 10^{15} photons/sec at 12 keV and 6×10^{14} photons/sec at 15 keV, respectively (Table 1). These values were measured with an ion chamber at 1 mA of the ring current and calculated by extrapolation to 100 mA. Using these values, the flux density was calculated to be on the order of 10^{17} photons/sec/mm^2 . The energy spectrum showed a sharp peak and its peak width was about 1.8% (FWHM). The higher harmonics were not observed. The peak width of the fundamental energy was observed to be 1.8% at 10 keV, 1.7% at 12.4 keV and 2.0% at 15 keV, respectively (Fig.2).

Energy (keV)	Flux (photons/sec)
8	7×10^{14}
10	9×10^{14}
12	1×10^{15}
15	6×10^{14}

Table 1. Photon flux

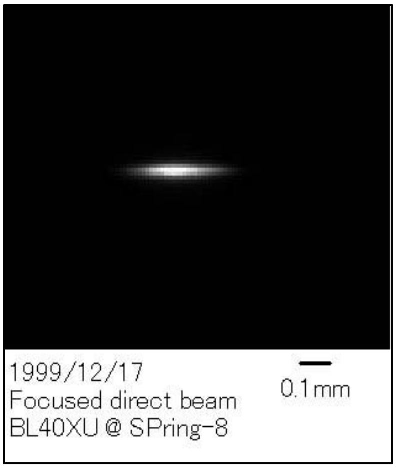


Fig.1. Focused direct beam

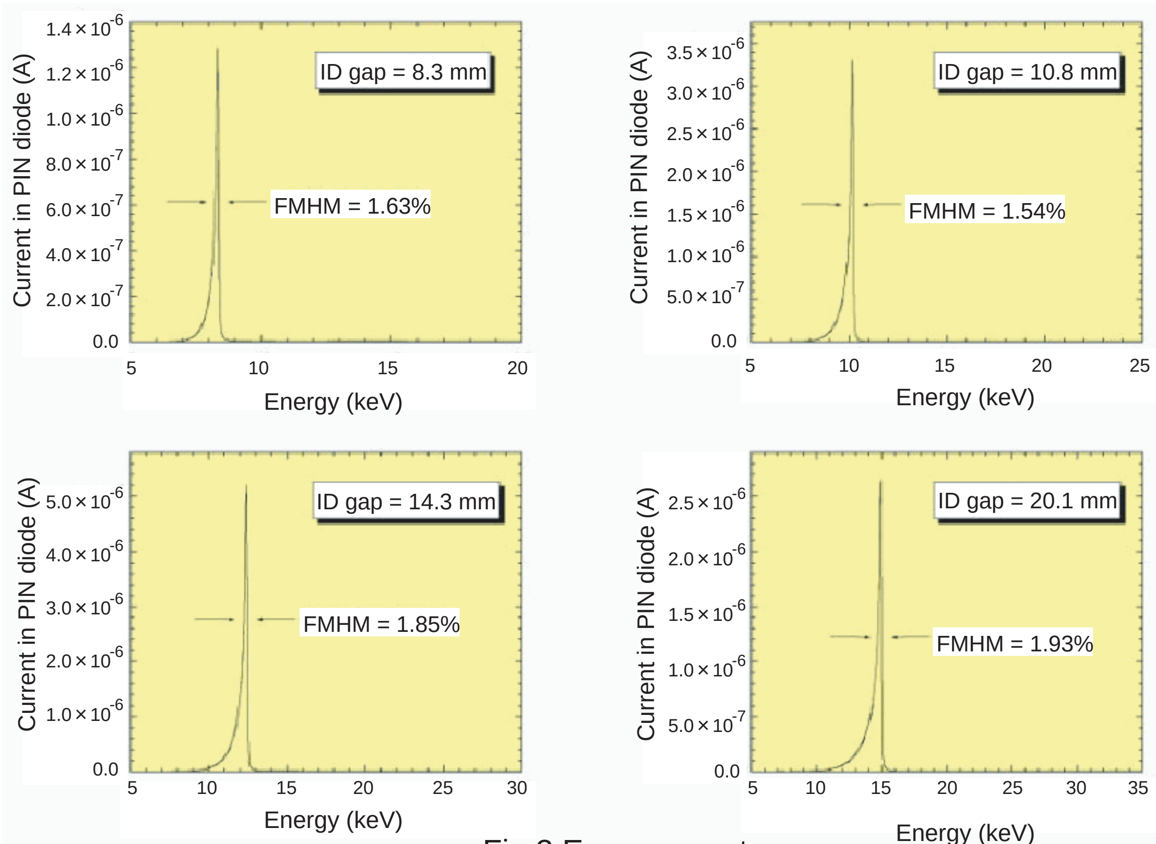


Fig.2 Energy spectrum

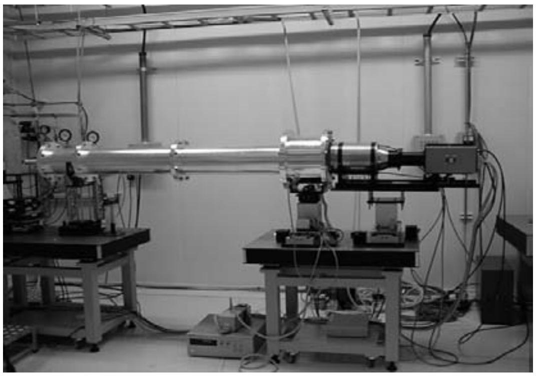


Fig.3. Vacuum path for small-angle X-ray scattering

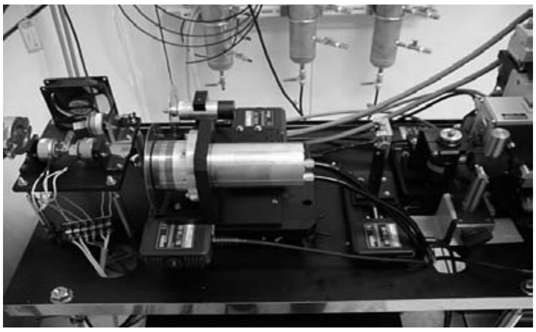


Fig.4. X-ray shutters

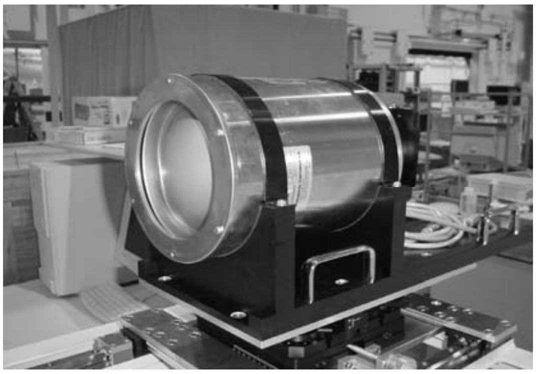


Fig.5. An X-ray image intensifier

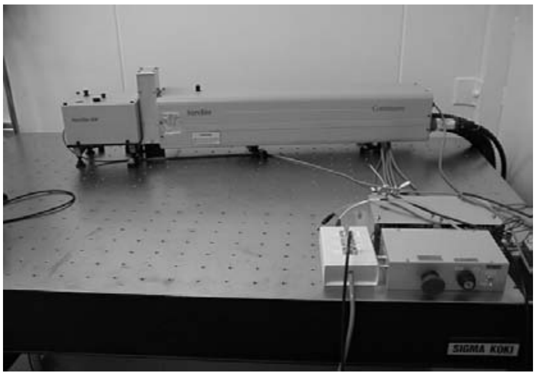


Fig.6. YAG laser

Experimental stations

The experimental hutch is about 6 m long × 4 m wide × 3 m high. 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 3 m-long vacuum pipe can be used (Fig.3). There are, moreover, two kinds of shutters in the experimental hutch (Fig.4). One is driven by a galvanometric motor operating 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 msec. As a detector, a fast CCD camera with a framing rate of 290 per sec (640 × 480 pixels, 10 bits) is installed with which has a short-decay phosphor. By reducing the size of the frame, a framing rate up to 5,000 per sec is achievable. A YAG laser is also installed in the hutch for experiments that requires quick trigger of events (Fig.6).

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