BL20B2 Medical and Imaging I

The bending-magnet beamline is allocated to medical applications and various imaging techniques in the energy range of 5 ~ 113 keV. The main optics is a fixed-exit double crystal monochromator. The X-ray beam produced by the bending magnet passes out of the experimental hall surrounding the storage ring and enters the biomedical imaging center. The experiments are performed in the experimental hall and the biomedical imaging center for alternative operations.

Area of research

The medical research mainly involves micro-radiography, micro-tomography and refraction-contrast imaging on biological specimens and small animals.
Imaging techniques involve the evaluation and development of various kinds of optical elements for novel imaging techniques.

Keywords

Scientific field

Preclinical radiographic imaging, Preserved tissue specimen imaging, Materials science, Earth science, X-ray optics, Ultra-small-angle scattering, X-ray fluorescence analysis of large materials

Equipment

High resolution X-ray detector, High precision diffractometer, Micro-angiography, Micro-tomography, Topography, Small-field micro-radiography, Large-field scanned projection radiography plain-wave wide-beam radiography multi-crystal diffraction topography

Source and optics

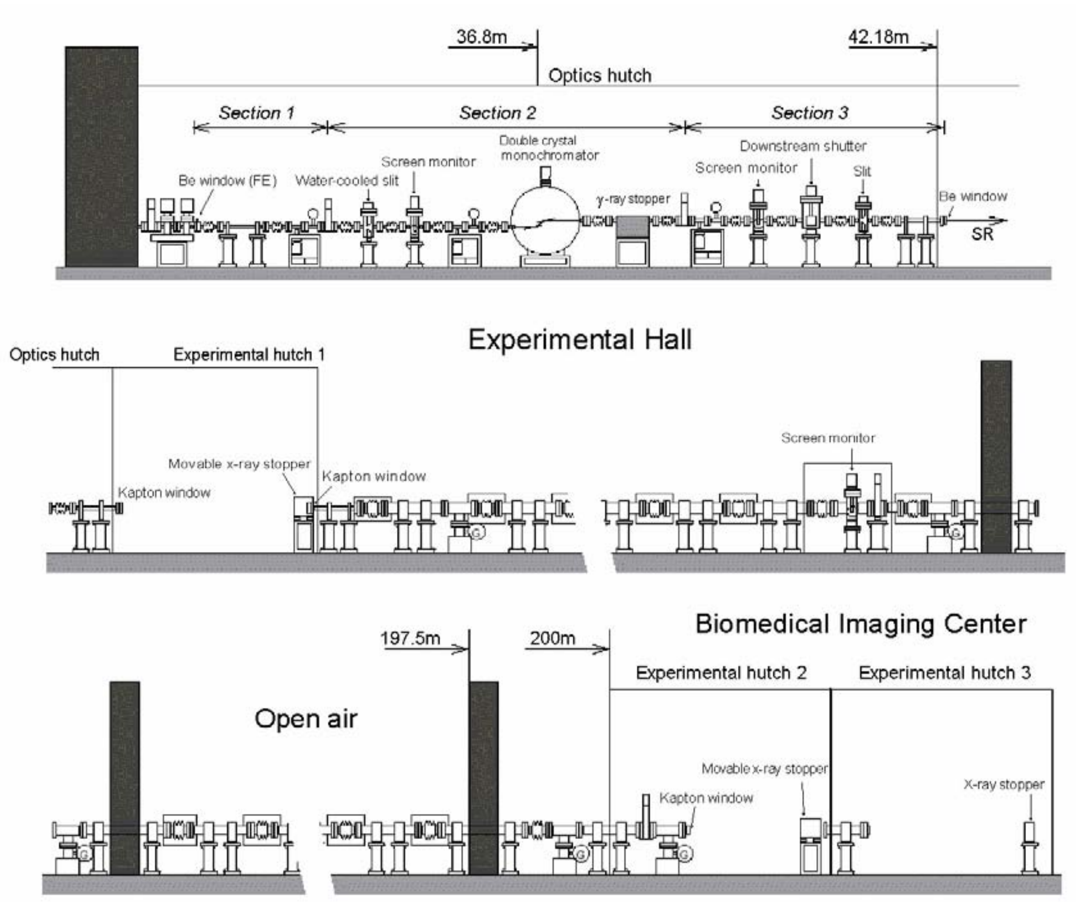


Fig.1. Transport channel of beamline

X-rays at sample

Critical energy	28.9 keV
Beam divergence	1.5 mrad (Horizontal)
	0.06 mrad (Vertical)
Energy range	Si 311 : 8.4 ~ 72.5 keV
	Si 111 : 5.0 ~ 37.5 keV
	Si 511 : 13.5 ~ 113.3 keV
Beam size 1	about 75 mm (H) × 5 mm (V) in the experimental hutch 1 located in the experimental hall (Si 311)
Beam size 2	about 300 mm (H) × 20 mm (V) in the hutches located in the biomedical imaging center (Si 311)

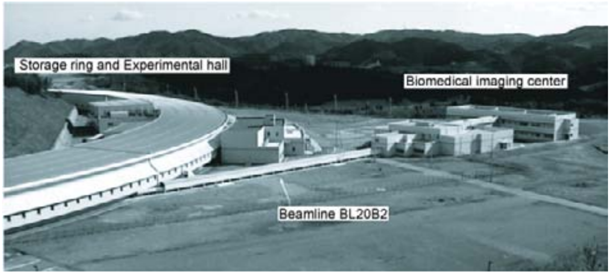


Fig.2. Overview of beamline

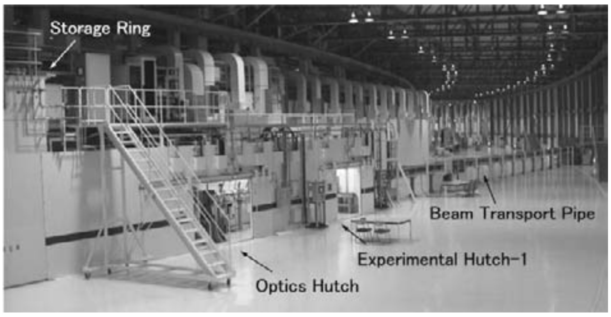


Fig.3. Beamline in the experimental hall

Experimental stations

Hutches

The beamline consists of an optics hutch and three experimental hutches (Fig.1). The double crystal monochromator is located in the optics hutch, which is attached to the shield wall (Fig.3).

The first experimental hutch (4 m long and 2.8 m wide) is located 42 meters from the source point in the experimental hall. Fig. 4 shows the second and third experimental hutches, which are located 200 and 206 meters from the source point, respectively, in the biomedical imaging center.

The second and third hutches are 3 meters wide and 6 and 9 meters long, respectively. In the third hutch, a large space is reserved for multipurpose use including refraction-contrast imaging with a long object-to-detector distance.

The monochromatized X-rays come out into the atmosphere in the first and second hutches by passing through Kapton windows. A 150-m long beam-transport vacuum pipe with a diameter of 40 cm joins the first experimental hutch to the second hutch.

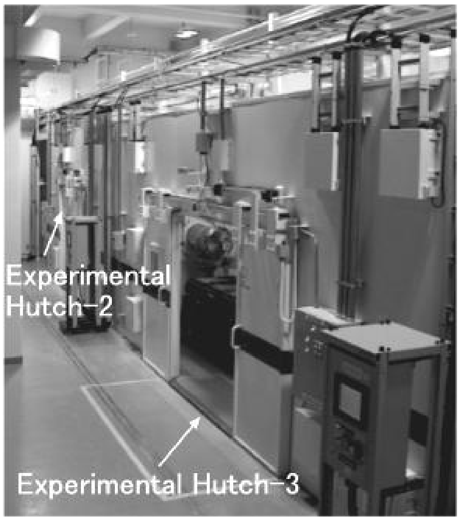


Fig.4. Experimental hutches in the biomedical imaging center

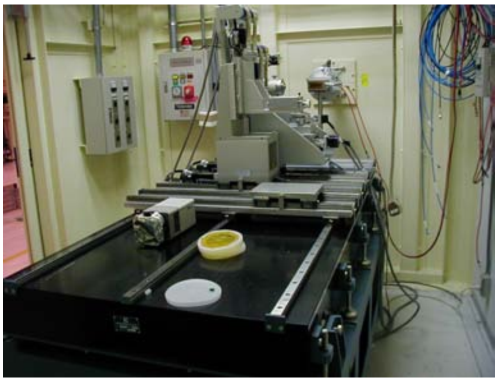


Fig.5. Experimental hutch 1

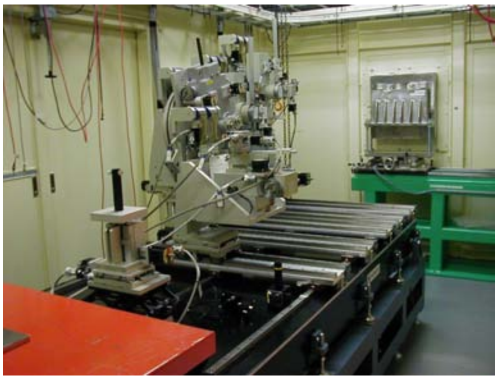


Fig.6. Experimental hutch 2

Table Property of cooled CCD cameras

	C4880-10-14A (HAMAMATSU PHOTONICS)	C4742-95HR (HAMAMATSU PHOTONICS)
pixel size	12 µm	5.9 µm
CCD format	1000 (H) × 1018 (V)	4000 (H) × 2624 (V)
dynamic range	14 bits	12 bits
readout time	4 sec/frame	0.6 sec/frame

Fig.7. Experimental hutch 3

Experimental tables

Each experimental hutch consists of a very flexible experimental table with long working distance X-Y translation stages. The experimental table housed in the first experimental hutch is 2 m long and 1 m wide. The tables in the second and third hutches are 2.4 m long and 1.2 m wide. Multiple-axis high precision diffractometers are placed on the X-Y translation stages.

These instruments are used to evaluate and develop various kinds of optical elements for novel imaging techniques.

Image detectors

High-spatial-resolution 2-dimensional image detectors are prepared for radiographic imaging. The detectors are a fluorescent-screen lens-coupling system (Fig.8). X-rays passing through the object are transformed into a visible image by the fluorescent screen. Images on the screen are read by a cooled CCD camera with a high numerical aperture lens.

The CCDs consist of respectively (Table). The equivalent pixel sizes projected onto the screen area are 5.83 µm when C4880-10-14A is combined with coupling lenses (beam monitor AA40), which have the magnification factor of 2. The equivalent pixel size is 5.87 µm when C4742-95HR is combined with a lens (beam monitor AA60), which has the magnification factor of 1.

The high-spatial resolution CCD image detectors take images of biological specimens by using techniques of micro-tomography and refraction-contrast imaging. Digitized images with 14 or 12 bits resolution are captured and stored into a personal computer. These detectors are also used for novel imaging techniques using various kinds of optical elements.

A real-time digital micro-imaging system is under development for micro-angiography so that small blood vessels with diameters of less than 10 µm can be accurately diagnosed for circulatory disorders and early stage malignant tumors in animal studies. For the large field imaging, flat panel sensor (C7942, Hamamatsu Photonics K.K.) and imaging plate reader (R-AXIS-DS3, Rigaku) are prepared at Biomedical imaging center.

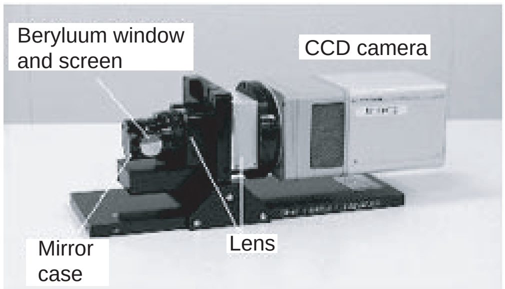


Fig.8. High resolution image detector

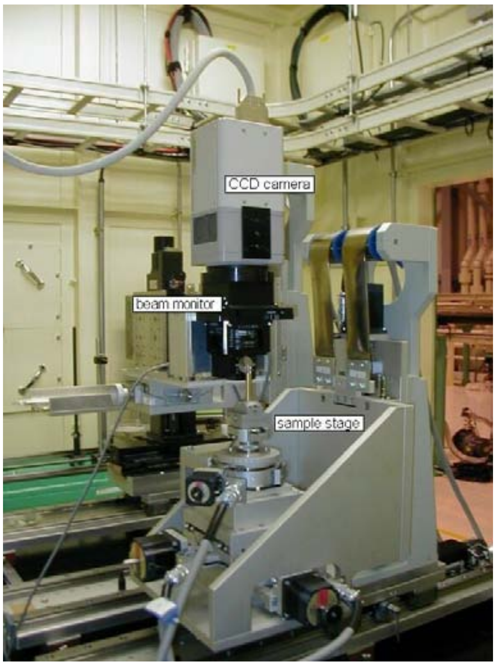
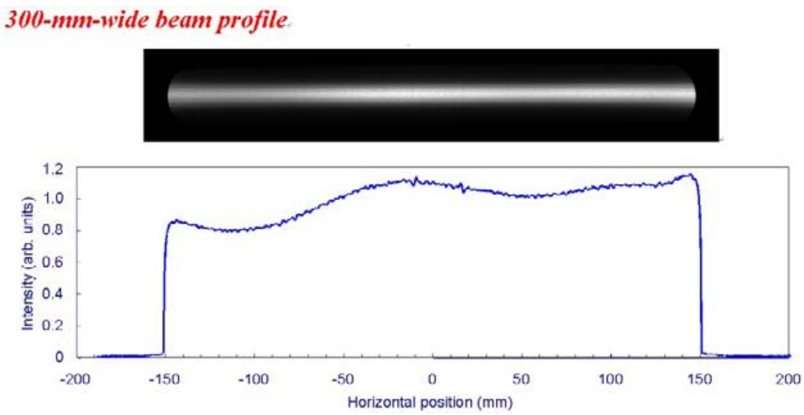


Fig.9. High resolution X-ray tomographic system using high resolution 2-dimensional detector in experimental hutch 1



Experimental results

(i) 300mm wide beam image and profile

Fig.10. A 300-mm-wide direct beam image recorded by Imaging Plate at 201 m from the source point (upper) and intensity distribution in the horizontal direction for 15 keV photons from Si 311 reflection (lower). Non-uniformity of ± 20% was observed due to deformation of monochromator crystal.

(ii) Topograph of 300mm diameter silicon crystal

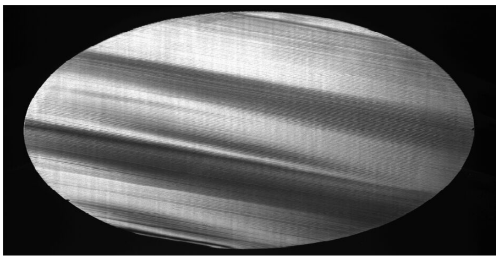


Fig.11. At experimental hutch 2

Sample : 300 mm diameter silicon crystal
Photon energy : 21 keV
511 asymmetric reflection with glancing angle of 0.6 deg.
Detector : imaging plate (pixel size 100 µm × 100 µm)

(iii) Refraction enhanced image

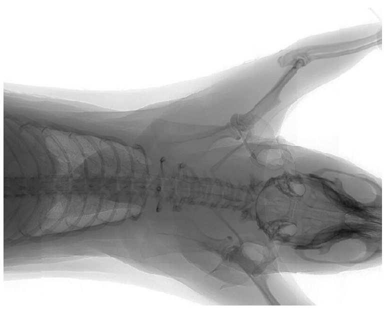


Fig.12. Refraction image of hairless rat imaged with beam monitor AA60 coupled with C4880-31-24A at experimental hutch 3 (The equivalent pixel size is 24 µm).

(iv) Micro-tomography

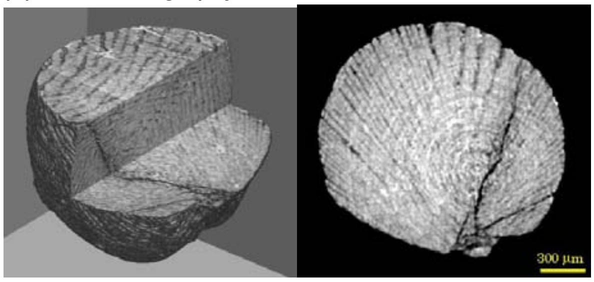


Fig.13. Imaged with computed micro-tomography system at experimental hutch 1

Right: High resolution tomographic image of radial pyroxene chondrule removed from the Bjurbole chondrite (L4). Pyroxene (bright gray), mesostasis (dark gray), Fe-Ni alloy or Fe sulfide (white), and crack (black) are seen.
Left: Three-dimensional image of radial pyroxene chondrule.

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