Medical and Imaging I (BL20B2)

1. Introduction

BL20B2 is the first medium length beamline at SPring-8. The full length of the beamline is 215 meters from the X-ray source to the end station. The bending magnet beamline BL20B2 has been designed to support medical applications and various imaging techniques in the energy range 5 to 100 keV [1-3]. The main optics is the standard SPring-8 bending magnet system that contains a fixed-exit double crystal monochromator.

A satellite laboratory, biomedical imaging center, has already been built for BL20B2 and two other beamlines are scheduled in the future. The X-ray beam produced by the bending magnet passes out of experimental hall surrounding the SPring-8 storage ring and enters biomedical imaging center 197 meters from the X-ray source. Experiments will be performed in experimental hall and biomedical imaging center for alternative operations.

The medical research mainly involves microangiography, microtomography, phase-contrast imaging and refraction-contrast imaging. Research on imaging techniques involves novel optics and R&D on imaging techniques in the hard X-ray region.

The construction of BL20B2 will be completed in June 1999, and BL20B2 will be operational for users at the end of September 1999 after an advanced commissioning.

2. Beamline Design

The 215 m full length beamline from the X-ray source to the end station has been designed to provide a 200 mm wide and 15 mm high fan-shaped beam at the end station in biomedical imaging center. A large field of irradiation will be obtained for two-dimensional imaging by using an asymmetrically reflecting crystal for beam expansion in the vertical direction. Figure 1 shows the facilities around BL20B2. Biomedical imaging center is the satellite laboratory located about 100 meters from experimental hall building.

The beamline has been designed to have an optics hutch and three experimental hutches. The fixed-exit double crystal monochromator is located in the optics hutch and it is attached to the shield wall shown in Fig. 2. The first experimental hutch (4 m long and 2.8 m wide) is located in the experimental hall, 42 meters from the source point. Figure 3 shows the second and third experimental hutches, which are located 200 and 206 meters from the source point, respectively, in the satellite building, biomedical imaging center. The second and third hutches are 3 meters wide and 6 and 9 meters long, respectively. The 9 m long third hutch has been designed for refraction-contrast imaging using a long object-to-detector distance.

The monochromator is an adjustable inclined double crystal type that handles a wide energy range with a single pair of Si[311] crystals. The monochromator will cover the energy range 5 to 100 keV at the first order of diffraction by changing the net plane between Si[111], Si[311] and Si[511] and by realigning the monochromator to fix the exit beam position. The first and second crystals are an indirect water cooled flat type.

The monochromatized X-ray comes out from a vacuum tube into the atmosphere in the first hutch by passing through a beryllium window. A 150 m long beam transport pipe with a diameter of 40 cm joins the first experimental hutch to the second hutch. The ends of the tube are beryllium windows, which maintain a vacuum in the pipe.

3. Experimental Hutch

Each experimental hutch consists of a very flexible experimental table with long working distance xy 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.

Multi-axis high precision diffractometers are placed on the xy translation stages. These diffractometers consist of the following components: a ω-2θ goniometer (full circle), a precision θ table, tables with the rotation axis in a horizontal and a vertical direction for two-dimensional adjustment, xz high resolution tables and a 4-jaw slit.

These instruments will be used to evaluate and develop various kinds of optical elements for novel imaging techniques in the hard X-ray region. The high precision stages will also be used for three-dimensional microtomography with 12 - 24 μm spatial resolution.

In the 9 m long third hutch, a large space is left for multipurpose use. Medical imaging experiments including animal studies will mainly be performed in this hutch. This hutch will also be used for the imaging of large material objects.

4. Imaging Detector

Two-dimensional imaging detectors will be used for imaging. The detectors are a fluorescent screen lens coupling system. X-rays passing through the object are transformed into a visible image by the fluorescent screen; the screen is made from 10 and 20 μm thick gadolinium oxysulfide (Gd_2O_2S:Tb) phosphor layers. Images on the screen are read by a cooled CCD camera with a high numerical aperture lens (approximately

f/0.7 aperture).

The CCDs consist of 1,024 × 1,024 pixels with 12 and 24 μm pixel sizes. The equivalent pixel sizes projected onto the screen area are 12 and 24 μm when the demagnification factor of the coupling lens is 1:1. Since the 10 and 20 μm thick phosphor layers are less than the pixel sizes of 12 and 24 μm, limiting spatial resolutions are the same as the equivalent pixel sizes.

Image signals from the CCD are converted into a digital format by an analog-to-digital converter with 14 bit resolution in the camera. Digitized images are captured and stored into a personal computer.

The high spatial resolution CCD imagers will take images of biological specimens by using techniques of microtomography and refraction-contrast imaging. These imagers will also be used for research on various imaging techniques. In addition, a realtime high spatial resolution microangiography system is under development so that small blood vessels with diameters of less than 50 μm can be accurately diagnosed for circulatory disorders and early stage malignant tumors in animal studies.

References

[1] K. Umetani, *et al.*, "X-ray refraction-contrast imaging using synchrotron radiation at SPring-8" Proc. SPIE **3659** (1999) 560.

[2] K. Umetani, *et al.*, "Monochromatized X-ray medical imaging at SPring-8" Technical Report of the Institute of Electronics, Information and Communication Engineers EID **99-14** (1999) 77. (in Japanese)

[3] K. Umetani, *et al.*, "Construction of Medical and Imaging Application R&D BL20B2" SPring-8 Information **4** (3) (1999) 50. (in Japanese)

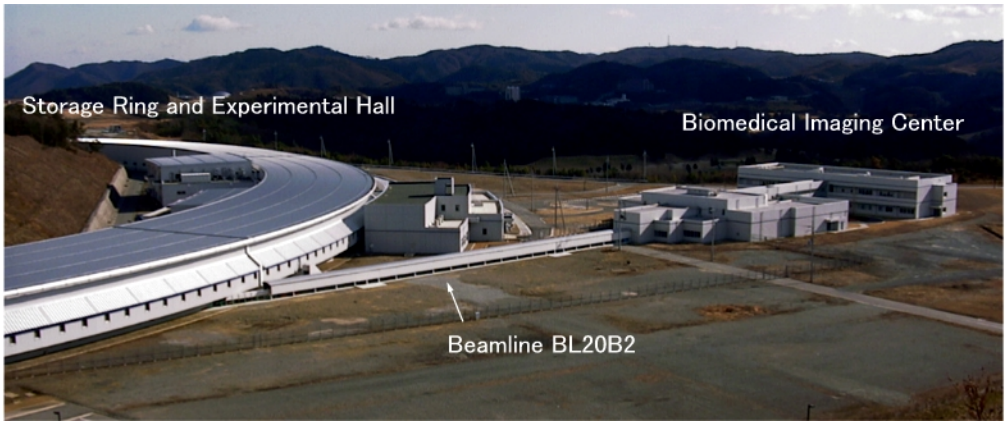

Fig. 1. A bird's eye view of beamline.

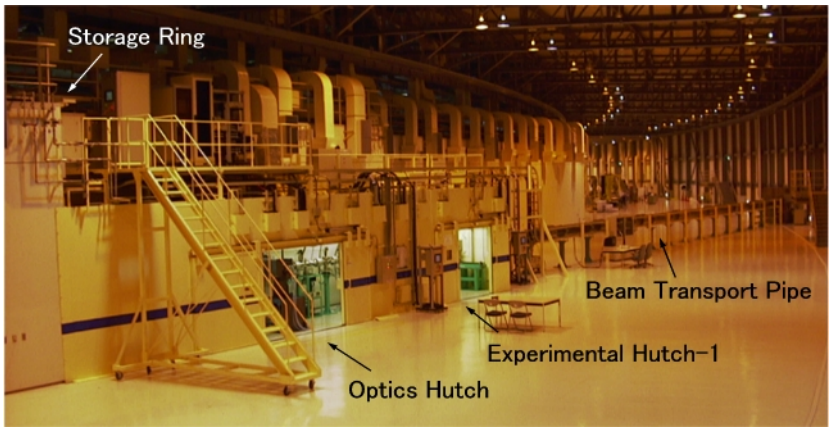

Fig. 2. Beamline in experimental hall.

Fig. 3. Beamline in biomedical Imaging center.