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Infrared beamline BL43IR at SPring-8: design and commissioning

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Abstract

The beamline BL43IR at SPring-8 has been constructed as a beamline exclusively dedicated to the infrared spectroscopy. The beamline was designed to make use of infrared synchrotron radiation emitted from a bending magnet of 39.3 m bending radius with the acceptance angle of $36.5(H) \times 12.6(V)\,\mathrm{mrad}^2$ and to cover a very wide wavelength range from 500 nm (20,000 cm^{-1}, 2.5 eV) to 100 μm (100 cm^{-1}, 12.5 meV). A Fourier transform interferometer and four experimental stations were installed to utilize the infrared synchrotron radiation at SPring-8.

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1. Introduction

After beginning of the application of infrared synchrotron radiation (IRSR) at UVSOR to solid state spectroscopy, the brilliance advantage of the

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IRSR has been proved at several storage rings: SRC, Daresbury and BESSY (For example, see Ref. [1]). To date, many storage ring facilities set up beamlines to deliver IRSR. All of them except SPring-8 are installed at small storage rings with a large aperture port.

In the case of the IRSR from a bending magnetic field, an ideal storage ring would be one equipped with the conditions of a large bending radius (for low divergence), a large stored current, a large aperture port (for high flux), and a low ring energy (for low heat load). In general, the third generation ring for X-ray has a low emittance of the IR beam. A high brilliant infrared photon beam can be supplied to experimental stations if the problems on heat load and focusing of the beam emitted from a large emission length in the bending magnet are resolved.

SPring-8 has the largest radius of 39.3 m of a bending magnet [2]. The low divergence of the IR beam from the bending magnet is advantageous to obtain an IR photon beam with a higher brilliance. The sharper IR beam is suitable for spectro-microscopy and as well as high resolution experiments. For focusing of the beam, we installed a so-called "magic mirror" which is described precisely in a separate paper [3]. In this paper, we report the design of the whole beamline, BL43IR, for infrared spectroscopy.

2. Front end

Fig. 1 shows a schematic view of the front end of BL43IR. The first plane mirror M0 was located in the crotch chamber at 2.66 m from the center of source. Its acceptance angles are 36.5 mrad (H) and 12.6 mrad (V). The ring chamber at the bending magnet section was reconstructed to obtain the SR beam of the large vertical angle (Fig. 2). The mirror has a narrow slit of 2 mm width in the orbital plane. Most of the SR power goes through the slit to downstream absorbers. Consequently, the power from intense SR to the mirror is drastically reduced from 5.7 kW to 3 W. The mirror substrate was made from oxygen-free copper. Additionally, indirect water-cooling was adapted to avoid the radiation from the downstream absorbers. Then, the flux loss in the IR region due to the narrow slit was limited to less than 6%. Furthermore, a movable upstream absorber was also placed in front of the M0 mirror in order to protect the mirror in the case of unusual operations.

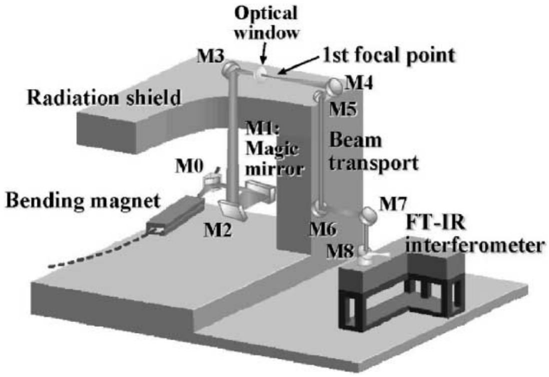

Fig. 1. Schematic view of the front end of BL43IR.

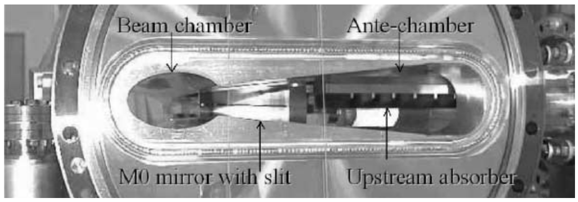

Fig. 2. Photograph of the ring chamber flange at BL43IR.

The horizontal acceptance angle of 36.5 mrad together with a bending radius of 39.3 m gives an emission length of 1.44 m. For such a long arc source, it is difficult to get good focal conditions by using conventional spherical or elliptical mirrors. We employed a magic mirror that is designed for focusing the light emitted from a long arc. The magic mirror M1 was located at 4.4 m from the source, and reflects the photon beam to the first focal point above the ceiling of the radiation shield (see Fig. 1). The observed beam sizes (σ) of the focal point at 11.3 m from the source were 0.63 mm (V) and 0.37 mm (H). At this point, the beam profile is rotated by 90° as the result of the geometrical mirror configuration.

To protect the storage ring against a vacuum trouble, a long beam pipe between the plane mirrors M2 and M3 was designed to have a

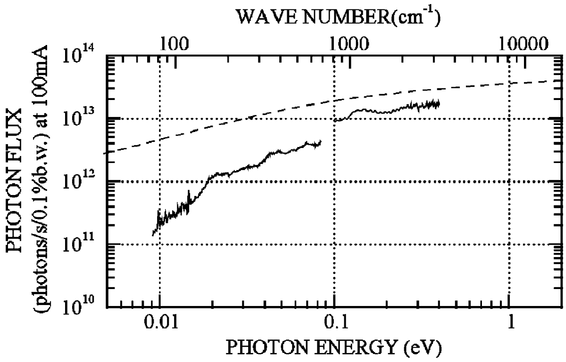

Fig. 3. Calculated (dashed line) and measured (solid line) photon flux spectra of BL43IR.

function of an acoustic delay line and a fast closing valve was installed after M0 mirror. A pair of wedged diamond windows and a BaF_2 window on a conflat flange are used to separate the UHV section of the storage ring from the low vacuum section of the beam transport line. These two kinds of windows are easily exchangeable without breaking the vacuum and changing the beam path.

The SR beam is transported to the FT-IR interferometer located at 20 m from the source by parabolic mirrors (M4, M8) and plane mirrors (M5, M6, M7).

3. Interferometer and experimental stations

A Fourier transform IR interferometer, Bruker IFS 120HR/X, was employed. It covers a wide wave number region from 100 to 20,000 cm^{-1} by choosing suitable beam splitters and optical elements. Its maximum wave number resolution is 0.0063 cm^{-1}. We measured the photon flux and compared it with an in-house globar source. In Fig. 3, the solid curves show the observed photon flux spectra, and the broken curve is the theoretical photon flux of SR source. The gradual decrease in the observed curve towards longer wavelengths from the theoretical curve seems to be due to the diffraction by finite size optical components.

The interferometer has two exporting beam ports. At both ports, beam condenser systems are connected, which consist of a pair of parabolic mirrors. The system reduces the beam size to 1/5.6, and re-corrects the beam to the parallel. The beam sizes transported to the experimental stations are 20 mm (H) and 10 mm (V).

To utilize the characteristics of IRSR of SPring-8, we constructed four experimental stations (see Fig. 4): (1) spectromicroscopy of solid and biological materials under extreme conditions [4], (2) spectroscopy of adsorbed materials on surfaces [5], (3) absorption and reflection spectroscopy (two

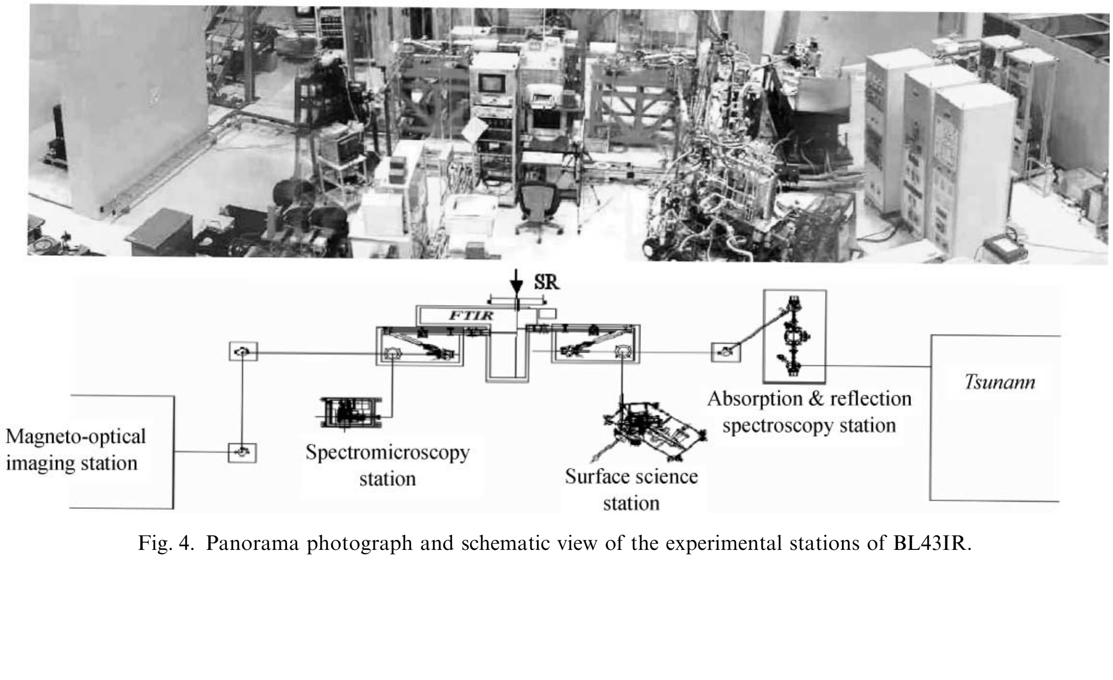

Fig. 4. Panorama photograph and schematic view of the experimental stations of BL43IR.

color experiment) with synchronized laser [6], (4) magneto-optical imaging spectroscopy under high magnetic fields [4].

4. Summary

We constructed an IR beamline at SPring-8 with a new concept of collection mirror optics and to do scientific programs under extreme conditions. The magic mirror designed was proved to work very well to get a well-focused small image. The beam profile observed in the IR region can provide us with a new opportunity to perform various kinds of experiments which are difficult to carry out with small SR facilities.

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