New Infrared and Terahertz Beam Line BL6B at UVSOR

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Abstract. We have designed a new infrared beam line BL6B at UVSOR for infrared and terahertz spectroscopies including microspectroscopy with high brilliance and high flux. The beam line will be replaced in the spring of 2004 from the infrared beam line, BL6A1, at UVSOR. The beam line has a large acceptance angle of 215(H) × 80(V) $mrad^2$ and a so-called "magic mirror" is adopted to get the perfect focusing of the bending magnet radiation. The optics and expected performance (focus size, photon flux and brilliance) are reported.

INTRODUCTION

The infrared synchrotron radiation (IR-SR) becomes popular now because many IR beam lines have been constructed in the world. The IR beam line that was firstly dedicated to users in 1985 is the BL6A1 at the synchrotron radiation facility, UVSOR, Institute for Molecular Science. [1] The beam line has made an important contribution to the development of the IR-SR science.

In 2002-2003, UVSOR is upgraded to a high brilliance light source with the low electron beam emittance of 27 nm-rad and with three long and two short straight sections for insertion devices. [2, 3] The first mirror for BL6A1 locates on the extended line of a short straight section. Since a new beam line using an undulator at the short straight section is planned to be constructed, the first mirror has to move to the down stream position of the bending magnet B6 to avoid an interference with the new beam line. Then the IR beam line including the bending magnet chamber is reconstructed to a new one with a large acceptance angle and the name is changed to BL6B (the last B means a bending magnet beam line). The main purpose of the beam line is a multipurpose use including an IR and THz spectromicroscopy for development of new materials in the IR and THz regions. The THz microspectroscopy will be started at the beam line. In this paper, the optics design and the expected performance are reported.

OPTICS DESIGN

The design concepts are the followings.

(1) Higher photon flux and higher brilliance than those of the previous beamline, BL6A1.
(2) The place of the end station does not move because of the keeping of the experimental area. [4]

To achieve (1), the first collecting mirror (M0) is set in the bending magnet chamber as shown in the left figure of Figure 1. We adopted a perfectly focusing mirror for bending magnet radiation, so-called "magic mirror" as M0. [5] The magic mirror has been successfully installed in the IR beam line BL43IR at SPring-8. [6] The acceptance angle of BL6B becomes 215(H) × 80(V) $mrad^2$ that is about four times larger than BL6A1 (80(H) × 60(V) $mrad^2$). Since the photon flux is roughly proportional to the acceptance angle in the long wave length region, the photon

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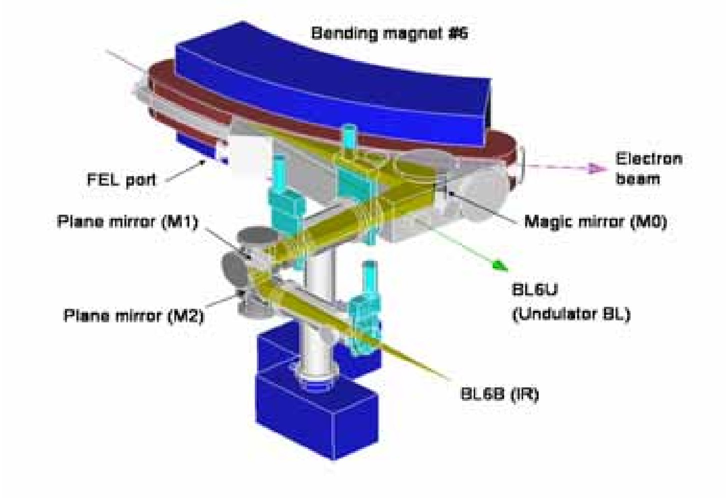

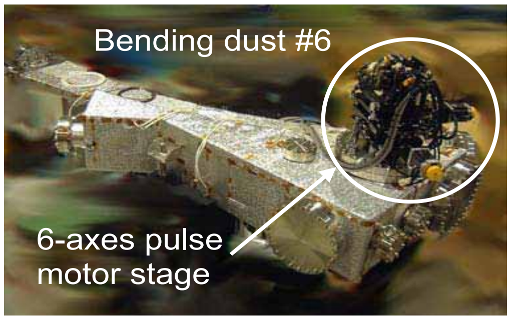

FIGURE 1. The design of optics and front end of the new infrared and terahertz beamline BL6B at UVSOR (left) and the picture of the bending magnet chamber with six-axes pulse-motor stage (right). The first focusing mirror so-called "magic mirror" is set in the bending magnet chamber.

flux of BL6B becomes four times higher than that of the previous beam line. Since the vertical length of the first mirror becomes 100 mm for the vertical acceptance angle of 80 mrad, a large chamber of 250-mm thickness outside of the bending magnet is adopted as shown in the right picture of Fig. 1. Then the distance from the emission point to M0 becomes 1,390 (upstream) - 760 (downstream) mm (1000 mm at the center of M0).

At higher energy SR rings, the avoidance of the heat load to the first mirror is one of the serious problems. [7] However, since the acceleration energy of UVSOR is 0.75 GeV, the radiation power from SR is less than 1.5 W/mm^2 even on the orbital plane as shown in Figure 2. Then the orbital plane of M0 is masked by a copper rod (7 mm in diameter) with water cooling for avoiding the change of the mirror curvature by the heat load. Due to the copper rod, the total heat load to the M0 is expected to be less than 10 W but the photon flux and the brilliance do not change so much. The collecting mirror is controlled by six-axes pulse-motor stage (x, y, z, θ_x, θ_y, θ_z) from the upper flange as shown in the right picture of Fig. 1.

The collected IR-SR is horizontally led to the outside of the bending magnet chamber as shown in the left of Fig. 1 because of the design concept (2). The IR-SR crosses the undulator radiation of BL6U and is guided to the first focal point and to two Fourier-transform interferometers (FTIR) by two plane mirrors (M1, M2). Due to the two

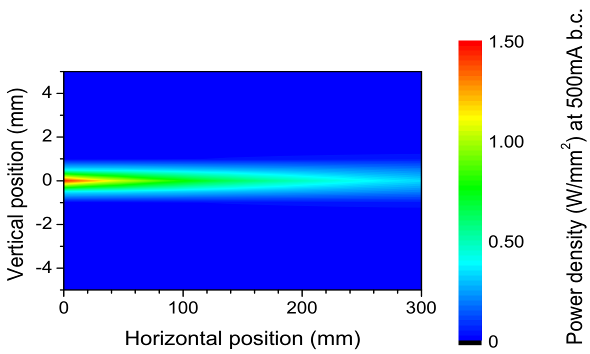

FIGURE 2. Calculated power density on the collecting mirror (magic mirror) from the bending magnet radiation at the beam current of 500 mA without the masking of a copper rod on the electron orbital plane. The left side is near the electron orbit in the storage ring.

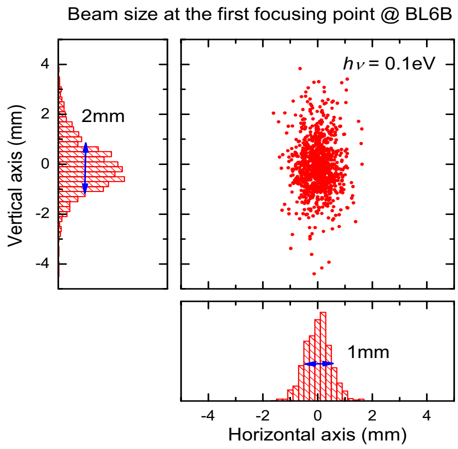

FIGURE 3. Ray trace result at the first focal point at the photon energy of 0.1 eV (~ 800 cm^{-1}).

plane mirrors, the polarization direction of the IR-SR changes from horizontal to vertical because the efficiency of the FTIR for the vertical polarization is better than that for the horizontal one. After the first focal point, the IRSR is guided to the same optics of the previous beam line. [4]

BEAM SIZE AT THE FIRST FOCAL POINT

The IR-SR is focused at the distance of 2641.7 mm from the center of M0. The beam size at the first focal point evaluated by a ray trace is shown in Figure 3. The beam size at $h\nu$ = 0.1 eV (~ 800 cm^{-1}) was calculated to be 2.0(V) × 1.0(H) mm^2 that is much smaller than that of the previous BL6A1 (about 5(H) × 3(V) mm^2). In the case of the previous beam line, a spherical mirror was employed as the focusing one. Therefore the longitudinal emission length of 176 mm that corresponds to the horizontal acceptance angle of 80 mrad makes the larger beam size at the focal point. On the other hand, a magic mirror is employed at BL6B. The mirror eliminates the length of the light source (473 mm) by the principal property. Therefore, the small beam size at the focal point is achievable.

The beam size of BL6B is larger than that of BL43IR at SPring-8 in spite that the same "magic mirror" is commonly installed. The reason does not come from the different cross section of the electron beam but from the different emission angle. The magic mirror requires a minute horizontal emission angle from one point of the electron orbit. However, the emission angle actually depends on the acceleration energy and the electron orbital radius, *i.e.*, a high energy ring with a large bending radius such as SPring-8 is suitable for the magic mirror.

PHOTON FLUX AND BRILLIANCE

The calculated photon flux and brilliance are shown in Figure 4. The photon flux of BL6B is about four times higher than that of the previous beam line BL6A1 and one order higher than that of the IR beam line, BL43IR, at SPring-8. The main reason is the large acceptance angle. On the other hand, the brilliance becomes one order higher than that of BL6A1 as shown in the right figure of Fig. 4 because of the smaller focus size. However, the brilliance above $h\nu$ = 0.1 eV is still one order lower than that of SPring-8 BL43IR because the emission solid angle of SPring-8 is about one order smaller than that of UVSOR. However, considering the diffraction effect, the brilliance of BL6B is higher than that of SPring-8 BL43IR in the THz region below $h\nu$ = 0.01 eV (~ 80 cm^{-1}). Therefore experiments using the high brilliance in the THz region is suitable for BL6B rather than for BL43IR. Actually a good performance of the THz microscope at the previous BL6A1 has been obtained. [8] Note that the diffraction effect has been checked at SPring-8 BL43IR as shown in Fig. 4. The obtained brilliance spectrum is

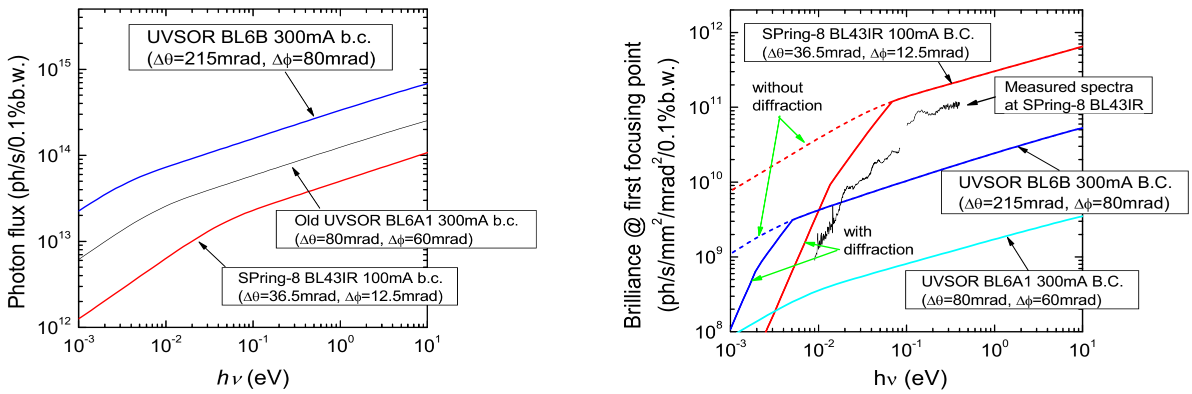

FIGURE 4. Calculated photon flux (left) and brilliance (right) spectra of BL6B compared to the previous BL6A1 of UVSOR and BL43IR of SPring-8 with each typical beam current. Measured brilliance spectrum at BL43IR is also plotted in the right figure.

qualitatively equal to the calculation. The difference of the obtained data from the calculation result is considered to due to the error of optical elements.

Considering to the THz microspectroscopy, the emittance of about 100 μm-rad is required if a typical IR microscope (NA = 0.3, the focal size is equal to the wave length) is adopted. In the case of BL6B, since the emittance at the first focal point is 38 μm-rad (H) × 146 μm-rad (V), the beam line is suitable for the THz microspectroscopy.

SUMMARY

We designed a new IR and THz beam line at UVSOR with large acceptance angle of 215 (H) × 80 (V) mrad^2 and calculated the beam size at the focal point, the photon flux and the brilliance. The beam line is dedicated not only for multipurpose use in the wide energy region from THz to visible but also for a THz microspectroscopy. The beam line will be opened in the spring of 2004.

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