INVITED PRESENTATION

SPring-8 as an IR-light source

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Abstract. SPring-8 at Harima in Japan is the third generation x-ray light source and a largest storage ring for synchrotron radiation (SR) in the world. The construction of infrared (IR) beamline, BL43IR, at SPring-8 has been completed in the fiscal year of 2000 for IR spectroscopic study and has been utilized by many scientists. The beamline covers a very wide wavelength region from 500 nm (20,000 cm^{-1}, 2.5eV) to 0.1mm (100cm^{-1}, 12.5 meV) and offers very high brilliant IR photon beam to the four experimental end stations. At BL43IR, a newly designed optical system including so-called "magic mirror" are adopted in order to extract of an intense IR light from SPring-8. The design of the optical system and the performance of SPring-8 as IR light sources are reported as well as the recently obtained results

Introduction

Up to now, synchrotron radiation (SR) has been recognized as a powerful light source because of its many excellent properties such as high brilliance, a small divergence angle of the light beam in the direction perpendicular to the plane of the ring, a continuous spectral distribution of the intensity over the entire energy range in addition to a well defined pulsed structure, and so on. These prominent characteristics of SR have been proved to be held also in the infrared (IR)-far infrared (FIR) wavelength regions by several groups at different places [1-8]. Particularly, infrared synchrotron (IRSR) is naturally a polarized light beam with a quite different polarization features compared to black body radiation sources, as its electric vector contains mainly the component parallel to the plane of the ring and a small perpendicular component out of the plane. So we can get an almost linear polarization in the plane close to the ψ=0 plane of the ring. Alternately, one can obtain an IRSR light beam with a circular polarization without any polarizer by extracting the radiation out of the plane of the ring. Such circularly polarized SR has been already performed in the measurement of a magnetic circular dichroism on magnetic materials in the X ray to VUV region. Kimura has developed such circular dichroism experiments in the infrared by IRSR [9].

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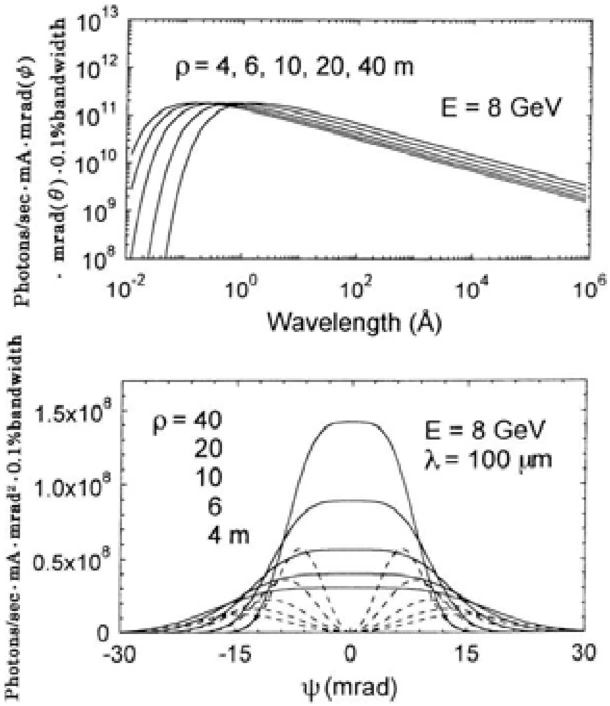


Figure 1. Computed spectral distribution curves of SR , (*a*) as a function of different bending radii , and (*b*) computed vertical angle distribution curves of photon numbers at 100 μm as a function of different bending radii with the same acceleration energy (E) of 8 GeV. Solid Curves correspond to a parallel component and dotted curves to a perpendicular one

Therefore, SR can make possible experiments, for example, on IR spectroscopy under extreme experimental conditions such as high magnetic field and high pressure as well as IR microscopic analysis on very small domains in synthetic specimens, *etc*.

SPring-8 at Harima in Japan can supply with higher brilliant IR photon beam to the experimental end stations than other small rings in the world. The utilization of the high brilliant IR photon beam is the aim of the construction of the BL43IR at SPring-8. The BL43IR was designed and constructed in FY1999 and dedicated for materials research from FY2000. Since the storage ring is largest in the world, a so-called magic mirror was newly designed and installed as a new concept of a collection mirror of the light emitted from the long emission arc length of the bending magnet [10]. In this paper, the design of the optical system and the recent experimental results are reported.

Why SPring-8 as IR light source?

Fig.1(a) shows computed spectral distribution curves as a function of different bending radii (ρ) with the same acceleration energy (E) of 8 GeV. Fig.1(b) shows the computed beam spread of the IRSR with the wavelength of 100 μm emitted into an angle (ψ) perpendicular to the ring with a unit horizontal angle (θ=1 mrad) as function of ρ with E= 8 GeV. These two figures clearly show that the ring with a larger radius of the electron orbit can supply with more intense IR photon beam to the end station. The brilliance of the IRSR goes up roughly with the factor of $\rho^{1/2}$. SPring-8 possesses the largest radius of the electron beam orbit of 39.8 meters among the storage ring facilities in the world and this is the reason why we are concentrated on SPring-8.

Performance of BL43IR as an IR light source

The BL optics from bending magnet to interferometer is schematically drawn in Fig.2. The BL

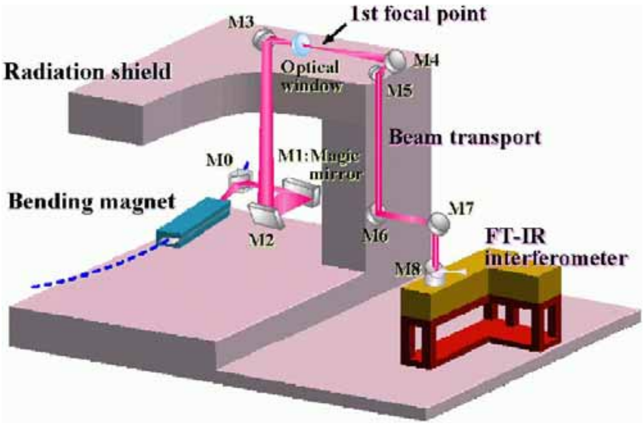


Figure 2. Schematic drawing of optical system of infrared beamline, BL43IR, of SPring-8. M1 represents a magic mirror. W indicates optical window which separates ultrahigh-vacuum of upstream and low-vacuum of downstream

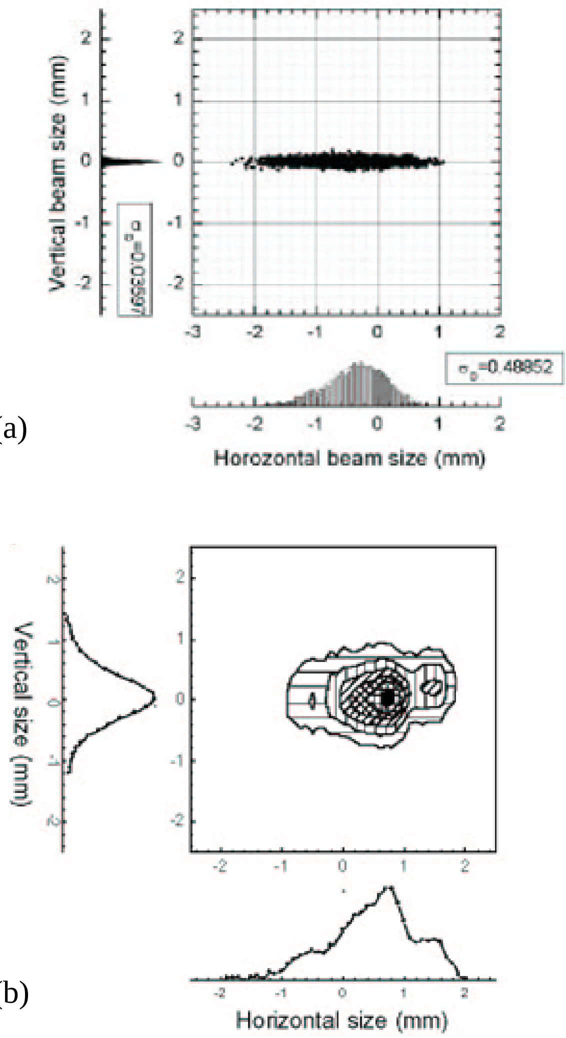
was designed to use IR synchrotron radiation (IRSR) from a bending magnet with the acceptance angle of 36.5(horizontal) $\times$ 12.5(vertical) mrad^2. Since the radius of the electron beam orbit is 39.3 m at the bending magnet and the horizontal acceptance angle is extremely large, the emission length amounts to 1.43 m. To focus the light from the long emission length, we employed a perfect focusing mirror to the circular orbit, so-called ”magic mirror” initially proposed by Lopez-Delgado and Szwarc [11]. However, they gave only the formation on emission plane. Then we expanded the formation also to the vertical direction by assuming a spherical curve. Such a magic mirror was installed as M1 mirror in the figure.

The result of the ray trace at the focusing point is shown in Fig.3 (a). In order to investigate the performance of the newly designed magic mirror, the two-dimensional cross-sectional size of IRSR was measured at the focusing point. The IRSR between 1,000-9,000 cm^{-1} was detected by a HgCdTe detector by moving the detector stage against the incident photon beam. Fig.3 (b) shows the observed spot size, where “horizontal” means the component parallel to the ring. The root-mean-square spread of the Gaussian line shape ($\sigma_{x,y}$) fitted to the horizontal and vertical components are respectively 0.63 and 0.37 mm. The horizontal size is in good agreement with the calculation of the ray trace, while the vertical one is an order of magnitude larger than the calculation. The reason of discrepancy is considered to be the lack of surface accuracy of the magic mirror. The time structure at the focusing point was also observed and was recognized to be almost equal to the longitudinal electron bunch length ($\sigma \sim$ 100 psec). The spectral intensity distribution curve in 20,000 -100 cm^{-1} region was also measured and the almost half of the theoretically expected photon flux was found to be observed at the sample position in the interferometer besides the FIR region where the diffraction loss in intensity occurs [10].

Fig.4 shows the drawing of the measured spatial two-dimensional intensity distribution at the focal position of the microscope with Schwartzshild mirrors (x8, NA=0.5) . The IR-beam with FWHM of almost 15 (x) and 10 μm(y) was observed.

Experimental

At BL43IR, four kinds of experimental end stations has been installed at the downward of the interferometer in order to cover interesting spectroscopic studies in the various kinds of fields from physics, chemistry, earth science to a life science and so on. They are the stations for (1) microscope [12], (2) absorption-reflection experiment [13], (3) surface science [14], and (4)



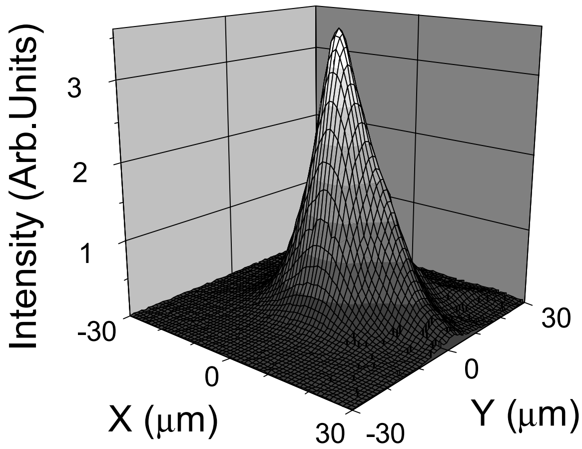


Figure 4. (top) Measurement of Integrated intensity profile of the microscope in the IR region between 1,000-9,000 cm^{-1} through 2μm pinhole on the sample position with no other aperture

Figure 3. (left) Ray trace result (a) and measured two-dimensional beam size (b) at the focusing point in Fig. 2

magneto-optical experiment with microscope. The IR photon beam can be guided to each end station by switching a mirror. In this session, we show, as a typical example, the experimental result which was obtained at the microscope station. Fig.5 shows the spectral change in the IR transmission spectra of (001) platelet single crystal of natural brucite using a diamond anvil cell (DAC) under the conditions at high temperature and high pressure. Brucite is a prototype of hydrous magnesium silicate minerals and the behavior of hydroxyls (OH-) under high pressure and high temperature is an interesting subject from stand point of earth science. The crystal structure is a type of CdI_2 one and simply shown chemically by (Mg $(OH)_2$). The observed main peak at 3700 cm^{-1} in the absorption spectrum is due to the stretching motion of the dipole moment of OH^- in a lower pressure phase. A new peak grows at 3650 cm $^{-1}$ with pressure in addition to the main peak in the lower pressure phase. This new peak is assigned to be the absorption due to the induced dipole moment in the high pressure phase by the partial rearrangement of the dipole $OH^-$by the transfer of proton of the original dipole to neighboring oxygen atoms [15]. These results suggest the existence of two kinds of dipole moments, original dipole and pressure-induced dipole one in the high-pressure phase.

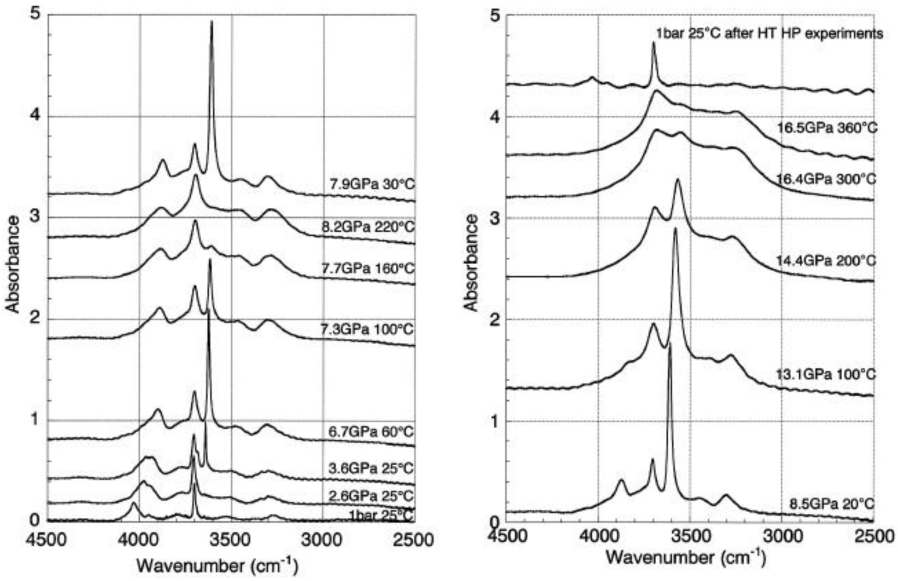


Figure 5. IR absorption spectra of (001) platelet single crystal of natural brucite $Mg(OH)_2$ from Zimbabwe up to 16.5 GPa and 360 $°C$

Conclusions

At SPring-8, the beamline (BL43IR) for the utilization of brilliant IRSR has been constructed and experiments at BL43IR has proved SPring-8 to be a very powerful and useful source as IR and FIR-light source. SPring-8 will provide us with new experimental fields.

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