Infrared spectromicroscopy and magneto-optical imaging stations at SPring-8

Infrared spectromicroscopy and magneto-optical imaging stations at SPring-8

S. Kimura[a,b], T. Nanba[a], T. Sada[a], M. Okuno[a], M. Matsunami[a], K. Shinoda[c], H. Kimura[d], T. Moriwaki[d], M. Yamagata[d], Y. Kondo[e], Y. Yoshimatsu[e], T. Takahashi[f], K. Fukui[g], T. Kawamoto[h], T. Ishikawa[i]

[a] *Graduate School of Science and Technology, Kobe University, 1-1 Rokkodai, Nada-ku, Kobe 657-8501, Japan*
[b] *PRESTO, Japan Science and Technology Corporation, Japan*
[c] *Department of Geosciences, Osaka City University, Osaka 558-8585, Japan*
[d] *SPring-8/JASRI, Mikazuki, Hyogo 679-5198, Japan*
[e] *Department of Applied Physics, Tohoku University, Sendai 980-8579, Japan*
[f] *Research Reactor Institute, Kyoto University, Osaka 590-0494, Japan*
[g] *Institute for Molecular Science, Okazaki 444-8585, Japan*
[h] *Institute for Geothermal Sciences, Kyoto University, Beppu 874-0903, Japan*
[i] *SPring-8, RIKEN Mikazuki, Hyogo 679-5148, Japan*

Abstract

At the BL43IR of SPring-8, infrared microanalysis on various kinds of solid specimens under multiple environments with a spatial resolution smaller than 10 μm in diameter is planned in the infrared region. In order to perform such analysis, two different stations, a multipurpose spectromicroscopy apparatus and a magneto-optical imaging one have been constructed. Measurements on the spatial two-dimensional cross-section of the infrared beam at the spectromicroscopy station have proven that the stations have a good prospective feature in the performance.

Keywords: Infrared synchrotron radiation; Spectromicroscopy; Magneto-optical imaging; SPring-8

1. Introduction

According to the development of brilliant infrared synchrotron radiation (IRSR) from electron storage rings, increasing attention has been paid to its application in the field of infrared spectromicroscopy. The brightness advantage of the IRSR in the infrared spectromicroscopy has been proven, for example, at NSLS [1] and ALS [2].

The beamline BL43IR at SPring-8 is a beamline exclusively dedicated to the infrared spectroscopy. The beamline consists of four different kinds of experimental stations arranged in the downstream of a Fourier transform spectrometer, Bruker 120HR/X, which covers a very wide wavelength regions from 500 nm (20,000 cm^{-1}, 2.5 eV) to 100 μm (100 cm^{-1}, 12.5 meV) by choosing suitable beam splitter and optical elements [3]. Four experimental stations of an infrared spectromicroscopy, a magneto-optical imaging, a surface science [4], and a two-color experiment with a synchronized laser [5] were constructed. Among them, the spectromicroscopy and the magneto-optical imaging stations have been installed to perform an infrared micro-analysis on various kinds of solid specimens with a spatial resolution smaller than 10 μm in diameter in the whole infrared region down to 500 cm^{-1} under various kinds of material environments such as temperatures, pressures, and magnetic fields.

Such experiments require particularly a low emittance and a beam stability of the IR beam. They can be performed by utilizing the IRSR from SPring-8. SPring-8 supplies a more collimated and brilliant IR photon beam than those from small storage rings and conventional IR light sources. The reasons are the largest radius of the electron orbit up to 39.3 m and the stable electron beam. We present here the details of the optical systems of these two experimental stations, an infrared microspectroscopy and a magneto-optical imaging station.

2. IRSR spectromicroscopy station

The IRSR spectromicroscopy station performs microanalysis of various specimens as small as 10 μm in diameter with the use of SR, which is highly collimated and brighter than conventional IR light sources. The optical arrangement of the IR microscope is schematically shown in Fig. 1. Parallel light from the interferometer is reflected up (down) for reflection (transmission) measurement by switching a plane mirror, and is focused at the pinhole by a parabolic mirror. The lower pinhole is located at the focal point of the lower Schwartzschild mirror and used for optical adjustment. The upper pinhole is also located at the focal point of the upper Schwartzschild mirror, and selects the area which is measured. The lower Schwartzschild mirror can be vertically moved

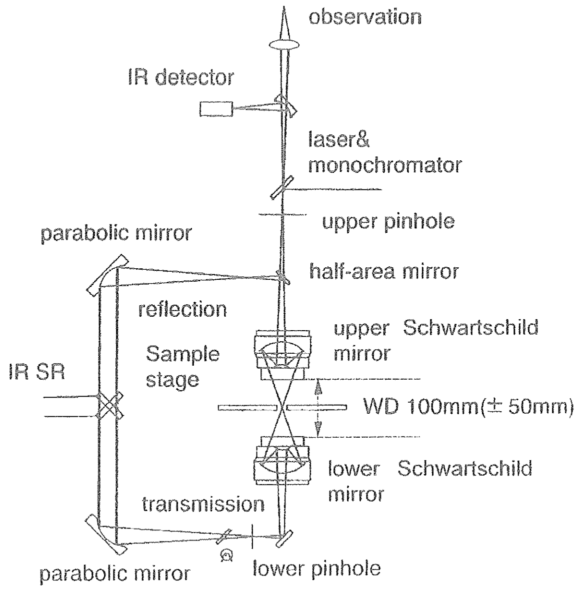

Fig. 1. Schematic diagram of the optical path in the IR spectromicroscopy station.

allowing IRSR to be focused on a specimen in various conditions such as in a diamond anvil cell (DAC). After adjusting all mirrors in the IR microscope against IRSR, micro-beam with full-width at half-maximum (FWHM) of 10 μm diameter was measured at the sample stage of the IR microscope by a two-dimensional scanning of 2-μm pinhole by 1-μm step as shown in Fig. 2.

For reflection measurements, a half-area mirror, set above the upper Schwartzschild mirror, is used to reflect the IRSR down. The reflected IRSR by a sample passes through the half-cut mirror and goes to the detector. Although the light efficiency in such an optical arrangement is usually 0.5, the IRSR microscope improves the light efficiency by installing an x–y stage at the entrance of incident light. The x–y stage can shift the incident IRSR horizontally towards the half-area mirror. The half-area mirror reflects the whole IRSR down. As the result, the reflection spectra show almost the same intensity as transmission spectra.

The advantages of the IRSR microscope are: (1) wide wave number region (100–20,000 cm^{-1}), (2) transmission and reflection measurements with high photon flux, (3) long working distance

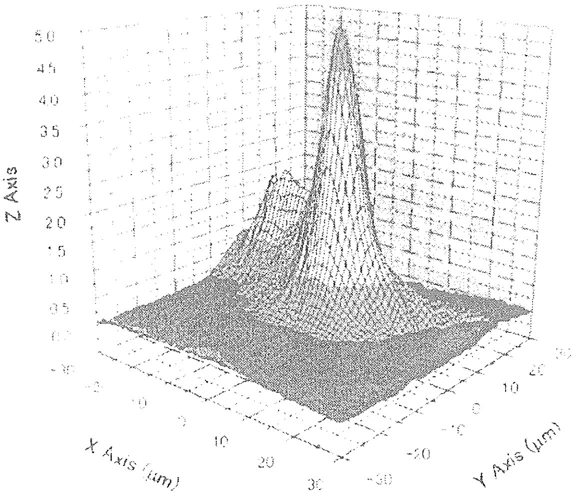

Fig. 2. Beam profile at the focal point of the IR microscope integrated in the wave number region of 1000–9000 cm^{-1} through a 2-μm pinhole on the sample stage with no other aperture in the IR microscope. The x- and y-axes are in μm-scale.

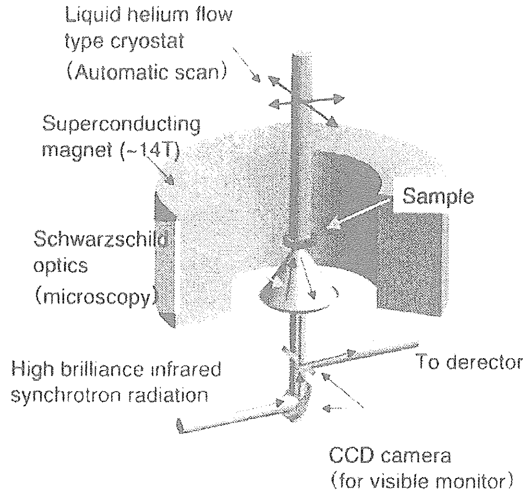

Fig. 3. Schematic diagram of the magneto-optical imaging station. The station consists of a liquid-helium-free superconducting magnet (maximum magnetic field is 14 T), reflection IR microscope and a liquid-helium-flow sample cryostat with an automatic scan manipulator.

(100 mm (± 50 mm)) between Schwartzschild mirrors (× 8, NA = 0.5), (4) in situ measurement of ruby fluorescence for DAC study, (5) all optical paths are possible to be purged with N_2 gas, (6) also usable as a polarizing microscope and equipped with CCD camera to observe and take optical images. With the advantage of a long working distance, such instruments can be installed with a (1) x–y mapping stage (maximum working length 100 mm, minimum working step 1 μm), (2) flow-type cryostat (Oxford microstat-He, Temp. 4.2–400 K), (3) high temperature DAC (~1000 K, ~30 GPa), (4) low temperature DAC (10–400 K, ~20 GPa).

3. Magneto-optical imaging station

The IR magneto-optical imaging station has been constructed for magneto-optical microspectroscopy of solids. The main purpose of this station is to investigate magneto-optical properties of materials near the Fermi level, especially for small samples, for instance organic superconductors, and also to investigate electronic structure of magnetic domains. The experimental methods are magnetic circular and linear dichroism measurements using circularly (off-axis) and linearly (on-axis) polarized IRSR. An infrared magneto-optical experiment using IRSR has been done at UVSOR [6]. The magnetic field and the beam size on sample of the station at SPring-8 exceed those at UVSOR. The station is equipped with a liquid-helium-free superconducting magnet, a reflection microscope and a liquid-helium flow-type cryostat for samples as shown in Fig. 3. The superconducting magnet has a room temperature bore with an 80-mm diameter and a maximum of 14-T magnetic field. The microscope is a reflection-type microscope with a Schwartzschild mirror (× 16, NA = 0.3). The temperature of the sample can be cooled down to 2.3 K by the cryostat.

4. Summary

At SPring-8, two infrared spectromicroscopy stations (multi-purpose spectromicroscopy and magneto-optical imaging) have been constructed and dedicated for materials science under various environments such as different temperatures, pressures, and magnetic fields. These stations will provide us with new experimental fields of condensed matters, earth sciences, polymer chemistry, biology and so on.

References

[1] G.P. Williams, Rev. Sci. Instrum. 63 (1992) 1535.
[2] T. Warwick et al., Synchrotron Radiat. News. 11 (4) (1998) 5.
[3] H. Kimura et al., Nucl. Instr. and Meth. A 467–468 (2001), these proceedings.
[4] M. Sakurai et al., Nucl. Instr. and Meth. A 467–468 (2001), these proceedings.
[5] H. Okamura et al., Nucl. Instr. and Meth. A 467–468 (2001), these proceedings.
[6] S. Kimura, Jpn. J. Appl. Phys. 38 (Suppl. 38-1) (1999) 392.