SPring-8 BL43IR Review Committee Report
on
Infrared Materials Science
(BL43IR)

Report for Director General of
Japan Synchrotron Radiation Research Institute

Yasuo Nozue (Osaka University), Chair
Akira Yagishita (KEK)
G. L. Carr (Brookhaven National Laboratory)
Hiroshi Kondo (The University of Tokyo)
Susumu Komiyama (The University of Tokyo)

Japan Synchrotron Radiation Research Institute
(JASRI)

January 2006

1. Introduction

This review committee meeting was held on 13 and 14 January 2006, on the SPring-8 campus. The committee members received “Beamline Report BL43IR (Infrared Materials Science)” and “SPring-8 Overview 2005” in advance, and they then submitted individual reports to SPring-8 prior to the meeting. Four domestic members attended the meeting on these days. After the orientation for the beamline review and general explanation of SPring-8 by the facility staff, the committee visited the BL43IR beamline to inspect experimental apparatuses. After that, the committee received detailed explanations of the apparatuses, research output and future plans by the beamline responsible, and they had a session for questions and answers and for exchanging views. This review report has been compiled on the basis of the discussion among the domestic members and the individual report from Professor Carr.

2. Technical Status of Beamline and Experimental Apparatuses

* Evaluation

Four experimental stations for infrared microspectroscopy, infrared surface science, absorption and reflection spectroscopy, and magnetooptical spectroscopy have been constructed. The attainment of designed performances by the staff, in spite of the serious incident of the M0 mirror melting, is highly evaluated.

Notably, in realizing infrared beams with a spot size of approximately 10 μm in the infrared microspectroscopy station, the infrared microspectrometer has attained a high performance utilizing the merit of polarized synchrotron radiation. In addition, by employing a working distance of 100 mm and a long Schwarzschild mirror a wide applicability for measurements has been achieved, and new experiments such as spectroscopic measurement under high pressure using a diamond anvil cell at a high or low temperature, have become possible. In the magnetooptical station, spectroscopic measurement under multiple extreme conditions, including high magnetic field which is inaccessible to other experimental methods, has also become possible.

The excellent stability of the infrared synchrotron radiation due to the stable electron beams in the SPring-8 storage ring compensates the weak intensity of the available infrared synchrotron radiation, and achieves almost the same signal-to-noise ratio as those in other facilities in actually measured spectra. On the other hand, infrared microspectroscopy using a conventional thermal radiation source has been developing in recent years, and at present, synchrotron radiation is not necessarily superior to thermal radiation for experiments in which a high spatial resolution or a polarized beam is not essential. However, synchrotron radiation is superior to thermal radiation when using mid-infrared beams (wavelengths lower than ~5000 cm^{-1}) in microspectroscopic experiments which require a spatial resolution of ~ 10 μm and a polarized beam. Time domain spectroscopy (TDS) in the THz region has also been developing and is becoming a powerful experiment technique in the wavelength region lower than 500 cm^{-1}. Nevertheless, at present, synchrotron-radiation-based techniques are superior to TDS in the wavelength region higher than 500 cm^{-1}.

In the infrared surface science station, spectroscopic measurements of material surfaces have become possible with an incident angle of 87 degrees, and a high-resolution EELS apparatus is also available. However, synchrotron radiation is not necessarily completely advantageous over conventional thermal radiation.

In the absorption and reflection spectroscopy station, pump-and-probe infrared spectroscopy has become possible using a synchronous Ti-sapphire laser beam. However, the merit of using synchrotron radiation is not necessarily complete.

* Recommendation

In BL43IR, the experimental method that can make the best use of the high-brilliance infrared synchrotron radiation is microspectroscopy including magnetooptical microscopy. The committee recommends upgrading of the optics and detectors for better performance, in addition to maintaining and fully utilizing the current performance.

3. Research Activity

* Evaluation

Constant output has been produced from the infrared microspectroscopy station and further development is expected in the future. In particular, the mapping of the separated metal and insulator phases in the organic conductor by the infrared microscopic imaging and the discovery of the pressure-induced phase transition associated with proton displacement in the mineral crystal by the high-brilliance infrared microscopy are both outstanding. The chemical mapping of the polymer materials by infrared micro-spectroscopy is a good example of research that fully utilizes the high sensitivity of infrared to chemical bonding and demonstrates the usefulness of this technique in future research on soft materials such as polymers and biological specimens. Some research results from the magneto-optical spectroscopy station have been published, which indicate that infrared microspectroscopy is a powerful tool in materials science.

On the other hand, the research results from both the infrared surface science station and the absorption and reflection spectroscopy station are insufficient since the performances of these experimental setups are not necessarily superior to that of microscopic measurement using a conventional infrared source.

* Recommendation

The committee recommends that the research activities at the microspectroscopy and magnetooptical stations should be maintained and expanded since excellent results have been produced at these stations. We also recommend that the promotion of the use of these experimental stations should be carried out in a wide range of research fields.

4. Support System for Public Users

* Evaluation

In infrared microspectroscopy experiments, some skill is needed in handing specimens and adjusting infrared beams. Because these tasks are difficult to carry out routinely, an effective support system for users is expected of the in-house staff. Regarding this point, the in-house staff effort is highly commended by the committee as well as by the users. However, there seems to be a slight misunderstanding between the users and the in-house staff about the current performance of the apparatus for microspectroscopy. This is due to insufficient explanation of its performance, whereby the specifications are not clarified.

Many research proposals are from the fields of physics and chemistry, while few are from biology.

* Recommendation

Users should be well informed of not only the characteristics of the apparatuses but also the limitations of their applications, prior to submission of proposals. Manuals should be prepared as carefully as possible, in particular an easy-to-read manual is useful for routine measurement.

In order to recruit new users from a wider range of research fields, publication of the research projects as well as the performance of the apparatuses, including what one can and cannot do, is effective. At this time, a comparison with thermal radiation sources would be a good demonstration for potential users. It is worthwhile to seek new users from biology.

5. Instrumentation and Future Research Direction

* Evaluation

The characteristics of infrared synchrotron radiation and the advantage and disadvantage of using synchrotron radiation as a light source for spectroscopy, have both been clarified by R&D over the past five years, and some appropriate measures have been carried out against the discovered disadvantages. Additional efforts are necessary for improving the performance of the whole system, particularly the signal-to-noise ratio and the spatial resolution. It is a heavy workload for the current in-house staff to operate all four stations well, as initially planned. The committee agrees to the direction proposed by SPring-8 that they will proceed instrumentation and research mainly related to micro-spectroscopy.

The committee recognizes that the mapping system is well organized.

* Recommendation

In order to acquire spectra of higher quality, it is worthwhile to further improve the stability of signals and enhance the intensity of the light source. Regarding the development of infrared spectroscopy using a near field, the committee recommends close collaboration with outside experts since much new R&D is needed. However, SPring-8 should decide whether to begin developing this technique after sufficient survey. SPring-8 should also proceed with the development of the microspectroscopy station, with an appropriate grasp of the development of TDS, as described in “2. Technical Statuses of Beamline and Experimental Apparatuses.”

The committee recommends further upgrading of the mapping system.

6. Summary

At the beginning of the SPring-8 project, four stations were constructed to cover the wide range of research activities related to infrared spectroscopy. After five years of experience, it has become clear that microspectroscopy (including high magnetic field and high pressure) makes full use of infrared synchrotron radiation. Finally, the committee recommends that SPring-8 concentrates its budget and manpower on promoting research involving microspectroscopy, in the pursuit of its goal of becoming a user-friendly beamline for advanced research.