SPring-8 BL40XU Review Committee Report on High Flux (BL40XU)

Report for Director General of Japan Synchrotron Radiation Research Institute

Y. Inoko (Osaka University), Chair
A. Iida (KEK)
M. Kataoka (NAIST)
M. Koch (EMBL)
T. Hashimoto (Kyoto University)

Japan Synchrotron Radiation Research Institute (JASRI)

December 2005

1. Introduction

A committee meeting was held on December 8–9, 2005, on the SPring-8 campus. The committee members received the books of “Beamline Report BL40XU (High Flux)” and “SPring-8 Overview 2005” and then submitted the individual reports to the SPring-8 side prior to the meeting. Four domestic members attended the review committee meeting. After guidance on the beamline review and an overview of the SPring-8 facility, the members visited the beamline for inspection. After this, the members received an overview of the beamline facilities and detailed explanations of research outputs and future plans by the beamline responsible, and then had an open forum. This report was put together on the basis of the discussion among the domestic members and the report from Prof. Koch.

2. Technical Achievements in Beamline and Experimental Apparatuses.

BL40XU (High Flux) is a beamline that provides x-rays with ultrahigh flux, taking advantage of the spatial energy distribution of emitted x-rays from a helical undulator. Currently, quasi-monochromatic x-rays with a flux of 10^{15} photons/s in a 2% band width are available in the energy range between 8 keV and 15 keV. For the past five years, BL40XU has been used as a multipurpose beamline for a variety of advanced research studies, and key technical developments have been successfully accomplished. BL40XU is ranked first among beamlines of the same kind in the third-generation synchrotron radiation facilities, because of its top-level performance brought about by the unique design of the beamline and the highest degree of photon flux. Taking advantage of these characteristics, the beamline is used for many kinds of experiments such as x-ray diffraction and scattering, spectroscopy, and imaging in various research fields. Versatility for multiple purposes is one of the characteristics of the beamline.

(1) Optics: The beamline optics is made up of only a set of independent x-ray mirrors for vertical and horizontal focusings (KB arrangement), reflecting the design concept of BL40XU. There is no noticeable demerit in the beamline under this condition. In the future, however, improving the mirrors may become necessary since its better performance is requested by users who use a zone plate. Multipurpose usability is realized in the beamline by equipping it with a set of slits for cutting x-ray beams into various shapes, a fast rotating shutter for time-resolved measurements, and pin-holes for producing x-ray microbeams.
(2) Experimental Apparatus: The beamline is designed for both time-resolved measurements with a high timing resolution using high-flux x-rays and x-ray diffraction using microbeams. The

experimental stations are equipped with an x-ray image intensifier CCD detector for these experiments. The time-resolved experiments require an x-ray detector with a high timing resolution. The 3-CCD camera equipped with a prism is a unique x-ray detector for realizing a high timing resolution.

3. Research Activities

Notable research has been performed in BL40XU using high-flux x-rays. Although the number of published papers has been steadily increasing after the construction phase was over, it is not so many. Regarding the outputs, more accurate evaluation may need another two or three years.

(1) Time-resolved experiments: X-ray diffraction of a purple membrane with a timing resolution of 6 sec has been realized by a synchronous excitation of the sample by a Nd-YAG laser with pulsed x-ray beams, which are selected by the rotating and galvanometer shutters. For other experiments, such as x-ray diffraction of myofilaments in muscle, a timing resolution of semi-msec (0.5msec) has been achieved using the 3-CCD camera or one with a reduced pixel size. A challenging experiment, such as real-time observation of the heart in a living animal using x-ray diffraction, has been carried out in the beamline.

(2) Microbeam diffraction: Scattering and diffraction experiments probing a microarea have been realized using the attained x-ray microbeams. This has encouraged new challenging research, particularly on biological samples. The scattering and diffraction experiments probing a microarea of the hair and skin are highly evaluated in terms of industrial application.

(3) Spectroscopy: Ultrahigh sensitivity in x-ray fluorescence analysis has been achieved by applying a wavelength-dispersive x-ray (WDX) technique to both conventional and total x-ray reflection fluorescence (TXRF) analyses. A group from industry has also attained such high sensitivity, applying the WDX technique to the TXRF analysis. The high sensitivity and the application to chemical characterization of the WDX technique have been realized for the first time in the world, using high-flux x-rays in the beamline.

(4) Others: Basic research for Fresnel-lens based x-ray microscopy and imaging such as x-ray CT has been pursued, implying the high potential of the beamline.

4. User Support

(1) Support System: Four staff members are assigned to the BL40XU beamline for user support and their activity level is evaluated as high. We think that the staff is overloaded with their duties for user support since high skills and much experience are needed for users to exploit the high-flux x-rays. Other potential members from different research fields should join the staff to cover the extended

research fields, since currently three of the four staff members are scientists in structural biology. The staffing level is too low to carry out sufficient scientific work. Pursuit of user-friendly support is not necessarily sound at this moment since many R&D studies are needed on the sample environment in BL40XU.
(2) Adequateness of Proposal Selection and Beamtime Assignment: The committee understands that adequate competition works well in BL40XU since the success rate of ~ 80 % is in the standard level of the SPring-8 beamlines. The number of assigned shifts is approximately 80 % of requested ones on average. Time-resolved experiments occupy 50 % or more of the shifts, and we think that the reasons for the high occupation rate are that there were many R&D subjects for this type of experiment in the construction phase and consequently the intensive R&D has led to easy and effective experiments in time-resolved research.

5. Future R&D and Research Directions

(1) The present level of the beamline optics should be retained at least since the committee does not see any problems on it. We also expect further developments for advanced research in the future.
(2) Both high-timing-resolution measurement and x-ray microbeam diffraction will still be the two main uses in the future. We expect that these techniques will contribute to industrial applications as well as to basic scientific research. Regarding the WDX technique, developing new applications is a key goal in the future. On the other hand, both XIFS and dynamical single molecular observation use the features of the BL40XU beamline, namely high-timing-resolution measurement, quasi-monochromatic x-rays and the high-density flux of x-ray beams, and both techniques are appropriate for future research themes.
(3) The CREST project “X-ray Pinpoint Structural Measurement” is regarded as a highlighted research project. The committee expects that the project will produce many outputs from time-resolved, microbeam x-ray diffraction, taking full advantage of the characteristics of the beamline.

6. Summary

The performances of the beamline optics and public experimental apparatuses in BL40XU, as a high-flux beamline, are of a high level. The committee evaluates the research activity for the past five years highly since the experiments perfromed include advanced research subjects. However, since the potential of the high-flux x-rays in BL40XU has not been fully tapped yet, we recommend that the SPring-8 side implements the future plans proposed for further advanced research.

The beamtime for R&D and setups will increase, along with the implementation of the future plans, including the above-mentioned CREST project as a main plan. The real worth of BL40XU in the utilization phase will be judged in five years. In line with this, some new ideas are needed in beamline management (selection of proposals, assignment of shifts, user support system) to produce outputs steadily in the future.

RECOMMENDATIONS:

As mentioned above, the in-house staff for user supports is mainly from structural biology. BL40XU is in urgent need of technical staff dedicated to the beamline, in order to maintain the current high activities in diversified fields.

BL40XU has a capability that an unimaginable research proposal will come out using the characteristic of high flux x-rays in the future. For this, the advertising on possible research targets and samples aimed at researchers in various fields is essential. The committee requests the enlargement of user community through these efforts.

One of our concerns is a possible decrease in beamtine for general proposals down to ~ 35 %, caused by increasing proposals for priority research. We recommend that a sufficient beamtime is assigned to the research of general proposals since it includes an important R&D.

We expect that this team will develop a fast and high-resolution system in the future since they are capable of developing and utilizing x-ray detectors. A large impact on domestic x-ray users is expected.