SPring-8 BL39XU Evaluation Report

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1. Preface

This Evaluation Committee meeting was held on October 20 and 21, 2003 in SPring-8. Before the meeting, this Evaluation Committee received the following materials.

1) Beamline Report BL39XU (Magnetic Materials)

2) SPring-8 Overview.

Every committee member submitted a written comment to the chairman in advance. Four domestic committee members attended the meeting, and were first given an overview of SPring-8 by the staff. The four committee members then inspected the beamline, and were given detailed descriptions of the beamline by the person in charge. The four members participated in a question-and-answer session, and discussed with each other. Referring also to the written comments, the committee drafted the evaluation report.

In 1996, BL39XU was built, which is a beamline for developing two different research activities: X-ray fluorescence analysis and XMCD-XMD (X-ray magnetic circular dichroism, X-ray magnetic diffraction). In 1997, scientists commenced the use of the beamline in experiments. In 2000, the internal staff and with the cooperation of subgroup users attained the targeted specifications of the beamline. Both research activities of XMCD-XMD and X-ray fluorescence analysis were continued until the first half of 2002. In the second half of 2002, X-ray fluorescence analysis researchers moved to the newly built BL37XU. Since then, BL39XU has been operated exclusively for XMCD-XMD.

On the basis of the history of BL39XU, the Evaluation Committee evaluated both XMCD-XMD and X-ray fluorescence analysis activities in the past five years. In order to propose the future of BL39XU, the Committee held a discussion concentrating on XMCD-XMD. Thus, we present the following evaluation report.

2. Beamline apparatus technology

1) The X-ray phase retarder technology is used in hardware which is a distinctive device for XMCD experiments, and which is practically used only in this beamline in the world. Such hardware can produce all polarization states. In addition, such hardware enables ultrahigh-S/N measurement (10^5) by the combined use of high-speed polarization switching (100 Hz) and a locking amplifier.

2) In the XMCD sample environment, easy-to-use normal electro magnets produce a magnetic field of up to 2 T and a temperature range of 20 - 300 K. When introduced, superconducting magnets produce a sample environment of 1.7 - 300 K up to 10 T. In cooperation with users, the beamline staff enables experiments under a diamond anvil. Such sample environment variations are highly appreciated.

3) For XMD, scientists develop experiments by mainly combining the 90-degree magnetic Bragg scattering experiment with a retarder. Some users have introduced a device that produces a temperature range of 1.5 - 300 K, a magnetic field of up to 6 T, and a pressure of up to 20 GP. Such a device is being set up. It is difficult, however, to conduct a normal X-ray magnetic scattering (resonance, non-resonance) because this device is based on the two-axis diffractometer.

4) For X-ray fluorescence analysis, in early stages, the staff provided four important synchrotron radiation analyses: ultramicroanalysis, microbeam analysis, wavelength dispersion analysis, wavelength dispersive analysis, and total reflection analysis. Every analysis uses the high brilliance of the third-generation synchrotron radiation source. Other third-generation synchrotron radiation facilities in the world tend to be designed for microbeam technology. In contrast, this beamline is used and equipped for scientists who use analytic methods. Such equipment is highly appreciated. Scientists will attempt to develop new analytic methods in the newly built BL37XU.

3. Research results

1) XMCD

The high S/N obtained by polarization modulation enables the measurement of thin samples. XMCD research produced remarkable results: for example element-specific magnetization measurement (Gd/Fe multilayer film, for example) that would be difficult if magnetic field modulation were used, magnetic phase transition measurement (Mn_3ZnC) in high magnetic fields, magnetic state changes (Fe_4N) at high pressures, and magnetization distribution in Pt of a Pt/Co bilayer film. In contrast to soft X-ray MCD, XMCD produces a state in which no core electrons produce dipole transition to a shell orbital that directly produces magnetism, except for 5d transition metals like Pt. It is important to cooperate with theorists to understand the spectral profile. It is easy to continue measurement while varying the sample environments like high-pressure environments. The staff are taking positive steps to develop such research subjects. It can be understood that such measurement will be an important research field.

2) XMD

In this beamline, non resonance magnetic scattering experimental values are measured using the 90-degree scattering method, and using not magnetic field inversion but polarization inversion. Its feature is LS separation. The values are measured ($Ho_3Fe_5O_{12}$) at the compensation temperature that would make measurement impossible if the magnetic field inversion method is used. Scientists are conducting resonance magnetic scattering experiments; however, they have not yet been published.

3) X-ray fluorescence analysis

From the statistics of the number of subjects, beam time, and the number of papers published, it is judged that work related to X-ray fluorescence analysis made up approximately half of research activities using this beamline. Of the 50 papers regarding this beamline that have been published in journals, approximately 25 papers were related to synchrotron X-ray fluorescence analysis. As many as half of the 25 papers included the development of devices as the main purposes, probably because in the past five years, development and set-up work of devices were the main research activities in synchrotron X-ray fluorescence analysis using this beamline. Remarkable results were the microbeam analyzer and wavelength dispersive analyzer. Presumably 10 papers or so describe the use of this beamline mainly for practical analysis in biomedical fields. In such fields, only regular groups have used this beamline so far. Some listed subjects are analyses in different fields that have been published in journals. Scientists have recently proposed such subjects. It is anticipated that such analyses will show results. The newly built BL37XU will also be used in future developments.

4) Others

Research results other than those mentioned above include those of X-ray fluorescence holography, total reflection polarization XAFS of monomolecular films performed using a retarder, and electron state measurement based on X-ray emission spectroscopy. The publication of 50 papers every five years is no less than expected. Considering the allocated machine time, however, we mention that the publication of

XMCD and XMD is inferior. As this beamline is used exclusively for magnetic research, it will be necessary to discuss suitable measures for increasing the number of publications.

4. Operation and support for users

1) The number of allocated shifts is substantially proportional to the percentage of applications in each research subject field. Although the two different fields (XMCD-XMD and X-ray fluorescence analysis) coexist in this beamline, the staff allocate shifts for operation so as not to cause a significant imbalance.

2) Even in the second half of 2002, an adoption rate of approximately 50% continued although the coexistence of the two research activities was eliminated. This fact shows that scientists are active in researching the XMCD-XMD field. An adoption rate of 50% provides evidence of a desirable competition. To produce a high level of research, we regard such an adoption rate as acceptable.

3) At present, two beamline scientists are engaged in the construction this beamline. With very high experimental technology, the two staff members have contributed to the construction of remarkable beamline technology for five years. We can expect that scientists will use the unique device technology to develop excellent research. Presumably, operation will be more effective if a person or organization in the field materials science serves as an advice.

4) For future developments, this beamline lacked internal staff who specialized in X-ray

fluorescence analysis. Nevertheless, sufficient device development and application research were attained, probably because user groups contributed greatly to such attainment.

5. Future developments of science and technology

The evaluation materials include the following proposals.

1. extension of measurement environment (ultra-low temperature, ultra-high pressure, high magnetic field, high temperature)
2. development of XMCD microscopes
3. introduction of military diffractometers for XMD.

The plan to develop magnetic research both in basic science and industrial applications by the above-mentioned three proposals, basically, seems acceptable. Considering the given manpower and experimental hatch size at present, however, we doubt that scientists can advance the development of the above-mentioned three devices and their research. Although any one of the three items is to be used for important applications and to be themes of future developments, the given staff cannot possibly manage to set up an XMD multiaxis diffractometer, for example. The Evaluation Committee recognizes that the XMCD equipment alone does not provide sufficient research environment because the XMCD scientists research only ferromagnets. Thus, we can understand the significance of adding antiferromagnet to the research subjects by introducing the multiaxis diffractometer.

6. Recommendations

1) For future developments, BL39XU should be used exclusively for XMCD-based research. Sufficient research environment should be provided for XMCD-based research. As described above, regarding research policy, a group of advisors should be organized. Concrete examples of research subjects include: I) magnetic thin-film interface magnetism, II) magnetic states of ultrafine particles, and III) disappearance and emergence of magnetism in special environments like high-pressure.

2) It is very important to add antiferromagnet to research subjects by introducing a six-axis diffractometer for XMD. Personnels should be provided before introduction. The staff should discuss the use of BL39XU and other possible beamlines for developing such research.

3) The development of XMCD microscopes is important for future developments in the applications of magnetic recording materials, for example, magnetic dots. Because XMCD applications facilitate observation in a high magnetic field and do not require ultra-high vacuum, we recommend that the staff should develop such a theme.

4) We refer to the Beamline Report that has a publication list which includes a large number of research subjects, that have not yet been published although they used the machine time. It is necessary to assist them in publication, and to inspect the conditions under which they were not attain published.

5) As recommended above, XMCD microscopes should be promoted. As basic

beamline elements, the double-crystal monochromator tends to be degraded in performance by pin-post cooling. Such degradation is very likely to influence microbeam experiments. The staff should make a plan to change the monochromator into a high-load device as soon as possible. To regard the high-pressure experiment as an important experiment item, the staff should discuss the introduction of a two-dimensional condenser system in to the beamline.

7. Summary

We recommend that BL39XU be retained and used for future developments. Because this beamline has X-ray polarization modulation technology that is distinctive in the world, XMCD-XMD equipment facilitates measurement of experimental data with a high S/N. Using such technology mainly, research activities have been developed. This beamline should be equipped so as to facilitate the measurement extreme conditions in the future. As described in the previous section, regarding research policy, a group of advisors should be organized for future developments.

Using the BL39XU beamline, scientists have already developed major devices for synchrotron X-ray fluorescence analysis. It is highly appreciated that scientists are carrying out research using such devices. We hope that such devices will be used in the newly built BL37XU for future developments.