Hyperfine Interact
DOI 10.1007/s10751-011-0532-0

Upgrade of the nuclear resonant scattering beamline, BL09XU in SPring-8

Yoshitaka Yoda · Yasuhiko Imai · Hisao Kobayashi · Syunji Goto · Kunikazu Takeshita · Makoto Seto

Abstract An Upgrade of the nuclear resonant scattering beamline, BL09XU in SPring-8 has been conducted. A liquid nitrogen cooled high-heat load monochromator was installed and a 2nd experimental hutch was constructed. The instruments installed in the hutch allow for a variety of sample conditions. Newly developed high-resolution monochromators with better stability including the back scattering geometry monochromator have opened up the easy access to more isotopes and more precise measurements.

Keywords Nuclear resonant scattering · Synchrotron radiation · Mössbauer effect · X-ray beamline · High-resolution monochromator

1 Introduction

Nuclear resonant scattering (NRS) beamlines were constructed in the 3rd generation SR facilities after the first observation of NRS at DESY [1] and the first observation of the nuclear resonant inelastic scattering at TRISTAN-AR [2]. In SPring-8 the

Y. Yoda (✉) · Y. Imai · S. Goto · K. Takeshita
Japan Synchrotron Radiation Research Institute/SPring-8, Sayo-cho, Sayo-gun, Hyogo 679-5198, Japan
e-mail: yoda@spring8.or.jp

H. Kobayashi
Graduate School of Material Science, University of Hyogo, Kamigori-cho, Ako-gun, Hyogo 678-1297, Japan

M. Seto
Research Reactor Institute, Kyoto University, Kumatori-cho, Sennan-gun, Osaka 590-0494, Japan

Y. Yoda · Y. Imai · H. Kobayashi · M. Seto
CREST, Japan Science and Technology Agency, Saitama 332-0012, Japan

Published online: 13 January 2012

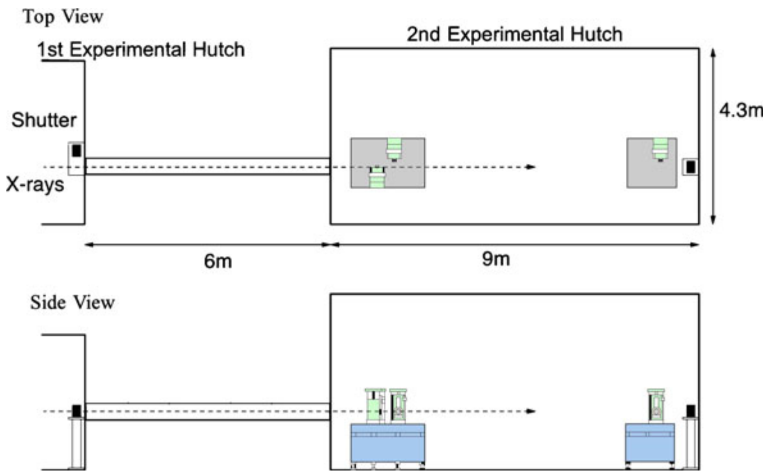

Fig. 1 Schematic view of the 2nd Experimental hutch at BL09XU, SPring-8. The goniometers are mounted on the two optical tables in the 2nd hutch. The first table is mainly used for the sample mounting and the second one is mainly used for the back scattering HRMs

nuclear resonant scattering beamline, BL09XU [3] was constructed in 1997 with one optics hutch for the high heat-load monochromator and one experimental hutch for the high- resolution monochromator (HRM) and the sample. We report the upgrade of BL09XU, which has been done after 2006.

2 2nd experimental hutch

The 2nd experimental hutch is designed to fulfill the following requirements. (1) The HRM and the sample should be separated for the energy stability of the HRM which requires the temperature stability. (2) The sample space for the big devices such as a super-conducting magnet, a laser heating device and an ultra-high vacuum chamber is needed. (3) The HRM for X-rays above 30 keV should be arranged using cryo-cooled back-scattering geometry because we have many attractive Mössbauer isotopes above 30 keV. (4) The space for the focusing optics is needed for the very small samples because the beam size is ~1.0 mm × 0.6 mm in FWHM at the sample position without focusing. (5) It is better to keep the HRMs for different isotopes on the tables in the 1st experimental hutch to save time for changing the isotopes and improve the stability.

The hutch was constructed in the winter shutdown of 2006. It is 9 m long, 4.3 m wide and 4.3 m high. It is located 6 m downstream of the 1st experimental hutch as shown in Fig. 1. The temperature in the hutch is controlled within 0.1° by the air conditioner. Two optical tables are placed in the hutch. The Goniometers and sample stages can be arranged at any position on the tables by means of air pads. The first table is 1800 mm long and 1200 mm wide. It is mainly used for the sample mounting in the cryostat or in the diffraction geometry. The second table is 1200 mm long and 1200 mm wide. It is mainly used for the back scattering HRMs. The hutch is large enough to install the above mentioned big instruments. We also have enough space for the focusing optics. The two experimental hutches are connected by the vacuum pipe with a 248 mm inner diameter. The 20 mm wide Kapton windows on both side of the vacuum pipe has vertical acceptance of 250 mm from 1400 mm to 1650 mm. The beam height from the high-heat load monochromator is 1430 mm. This big acceptance makes the setting easier and ensures the flexible design of the HRMs in the future.

3 Sample environment

A super-conducting magnet and a laser heating system have been installed for the experiments under multiple extreme conditions. Both the magnet and the laser heating system are placed behind the 1st optical table in the 2nd experimental hutch and removable from the beam path when it is not in use.

The super-conducting magnet was designed based on the Oxford Instruments SM4000. A diamond anvil cell (DAC) can be loaded inside to allow for the high-pressure experiments combined with high magnetic fields and low temperature. The highest magnetic field is 8 T (horizontal) and the lowest temperature is 1.5 K. This magnet can be used for the nuclear forward scattering experiment.

The laser heating system with DAC was prepared for the high pressure experiments combined with high temperature. It is similar to the system installed at the high-pressure research beamline BL10XU, SPring-8 [4]. The sample in the DAC is heated by the YAG laser from the top and the bottom. The sample can reach temperatures higher than 1500 K. Two avalanche photo diode detectors can be set near the sample for the nuclear inelastic scattering experiment. This system can also be used for the nuclear forward scattering experiment.

4 X-ray optics

A liquid nitrogen cooled monochromator [5] was installed as a high-heat load beamline monochromator in the spring of 2006 in place of the water-cooled diamond monochromator, which was installed in 2004.

The cryo-cooled back-scattering monochromator was installed at the end of the 2nd experimental hutch. The liquid helium continuous flow optical cryostat, which is based on the Oxford Instruments Optistat CF-V, is mounted on the goniometer with 2 axes of θ and φ. The temperature is controlled by the Cryo-con 32B temperature controller. The sapphire crystal is used close to $\pi/2$ Bragg angle [6] and the silicon crystal is used at the high Bragg angle [7]. In case of the backscattering geometry, the sample is located in the 1st experimental hutch. The offset from the direct beam is made by the double crystal Si 111 reflections arranged at the first table in the 2nd experimental hutch.

The optical table, 1800 mm long, was installed in the 1st experimental hutch for the HRMs. The nested in-line type HRMs [8] have been developed for ^{151}Eu and ^{149}Sm and ^{119}Sn in place of the 3 bounce type HRMs [9] and used for the user experiments [10–12]. The 3-bounce type HRM for ^{57}Fe with the resolution of 0.8 meV [13] has been developed and used for the user experiments [14]. These HRMs are arranged in the 1st experimental hutch and the samples are usually installed in the new 2nd experimental hutch. Consequently the stability of the HRMs has improved and easier access to the different isotopes has been achieved.

5 Summary

The nuclear resonant scattering beamline, BL09XU in SPring-8 has successfully been upgraded. The installed instruments have been working well and allowed for the variety of sample conditions and wider selection of isotopes.

Acknowledgements The construction was supported by CREST project of JST headed by Seto and the hutch was dedicated to the CREST members until 2010. The development of the back scattering HRMs was carried out under the approval of JASRI (Proposal No. 2007B1581, 2008A1453, 2008B1429, 2009B2135).

References

1. Gerdau, E., et al.: Phys. Rev. Lett. **54**, 835 (1985)
2. Seto, M., et al.: Phys. Rev. Lett. **75**, 2216 (1995)
3. Yoda, Y., et al.: Nucl. Instrum. Methods A **467**, 715 (2001)
4. Ohishi, Y., et al.: High Press. Res. **28**, 163 (2008)
5. Mochizuki, T., et al.: Nucl. Instr. Methods A **467–468**, 647 (2001)
6. Imai, Y., et al.: Proc. SPIE **6705**, 670512 (2007)
7. Tsutsui, S., et al.: J. Phys. Soc Jpn. **76**, 065003 (2007)
8. Ishikawa, T.: Rev. Sci. Instrum. **63**, 1015 (1992)
9. Yoda, Y., et al.: AIP Conf. Proc. **879**, 926 (2007)
10. Saito, M., et al.: Appl. Phys. Express **2**, 026502 (2009)
11. Kamihara, Y., et al.: Phys. Rev. B **78**, 184512 (2008)
12. Suharyadi, E., et al.: J. Magn. Magn. Mater. **322**, 158 (2010)
13. Chumakov, A.I., et al.: Nucl. Instrum. Methods A **383**, 642 (1996)
14. Tinberg, E., et al.: J. Am. Chem. Soc. **132**, 18168 (2010)