BL39XU
X-ray Absorption and Emission Spectroscopy

1. Introduction

BL39XU is a hard X-ray beamline mainly dedicated to the study of magnetic materials and strongly correlated electron systems. Techniques include X-ray absorption spectroscopy (XAS), X-ray magnetic circular dichroism (XMCD), and X-ray emission spectroscopy (XES). Recently, developments in these methods have been gradually progressing toward upgrading the beamlines in anticipation of SPring-8-II. The upgrade of BL39XU was implemented in July 2023, and commissioning has been underway since January 2024. The operation for users is scheduled to begin in July 2024.

The beamline layout after the upgrade is shown in Fig. 1. The main features of the upgrade are as follows: (1) replacement of higher-harmonics cut mirror (HCM), (2) installation of a double X-ray phase retarder (DXPR) to realize variable polarization, (3) building a new experimental hutch (EH) for the XES, and (4) installation of focusing mirrors in each EH. After the upgrade, XAS/XMCD under multiple extreme conditions, XES/HREFD-XAS, and nanoprobe XAS/XMCD will be performed in three EHs (EH1, EH2, and EH3, respectively).

2. Beamline Optics Installed in Optics Hutch

In this upgrade, the beamline optics except for the monochromator have been almost completely renewed. An HCM is installed downstream of the monochromator to remove high-order reflections from the monochromator. By adopting triple reflection, the specifications not only increase the higher-harmonic X-ray rejection but also maintain the optical axis from the monochromator. The adjustment of the focusing optics installed at the

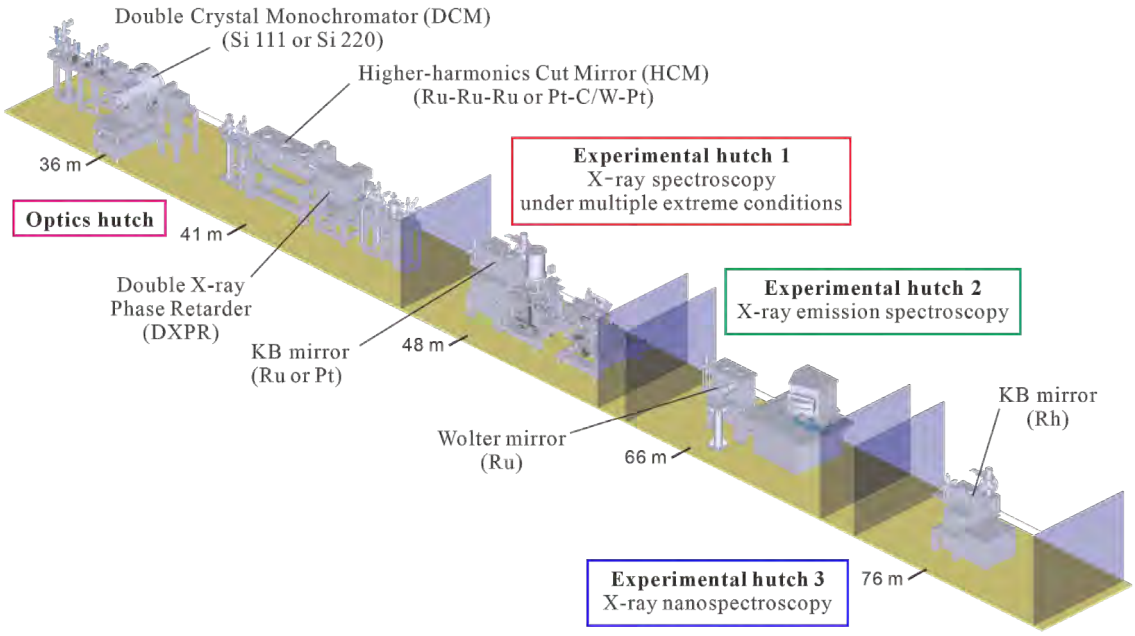

Fig. 1. Beamline layout of BL39XU after the upgrade.

Table 1. Specifications of the focusing mirror installed at each experimental hutch: EH1, EH2, and EH3.

	EH1	EH2	EH3
Focusing optics	KB	Wolter	KB
Mirror aperture V × H (mm)	0.93 × 1.08	2.0 × 1.1	0.76 × 1.2
Focal size V × H (μm)	1 × 10	1 × 15	0.1 × 0.1
Energy range (keV)	4.92 ~ 30	4.92 ~ 20	4.92 ~ 16
Photon flux (photons/s)	1×10^{13}	1.5×10^{13}	$\sim 10^{11}$
Work distance (mm)	750	1,300	100
Coating material	Ru or Pt	Ru	Rh

experimental station is simplified because the X-ray axis does not change upon changing the glancing angle of the HCM.

A DXPR system is installed downstream of the HCM to control X-ray polarization. Before the upgrade, X-ray polarization was controlled by only one single-crystal diamond and was mainly limited to the use of circular polarization and horizontal and vertical linear polarizations. The upgrade comprised the installation of a two-stage phase retarder and the introduction of a rotation axis centered on the X-ray axis in the second-stage phase retarder, which not only improves the vertical linear polarization but also allows the rotation of the oscillating plane of the linear polarization.

On the upstream side, the Be window was removed and replaced with a differential exhaust in anticipation of possible expansion into the tender X-ray region below 5 keV.

3. Experimental Station for X-ray Spectroscopy under Multiple Extreme Conditions (EH1)

EH1, located about 48 m away from the undulator source, is mainly used for XMCD measurements under multiple extreme conditions. In FY2023, new focusing optics [Kirkpatrick and Baez (KB) mirrors] for high-pressure experiments was installed. The specifications of the focusing mirrors are shown in Table 1. The coated material on the surface can be selected from Ru and Pt, and X-rays up to 30 keV with a focusing size of 10 μm in

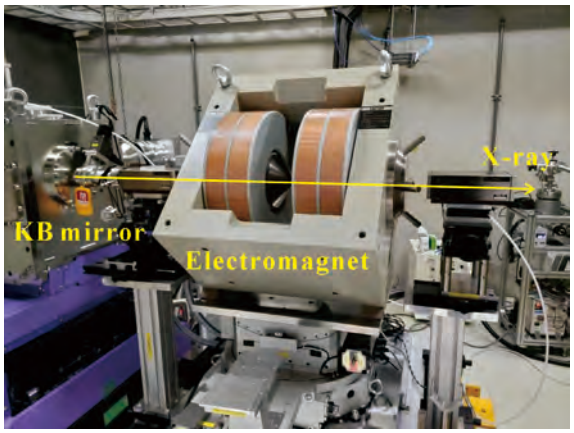

Fig. 2. Photograph of setup of the KB mirror and electromagnet for XMCD measurements under high pressure.

horizontal and 1 μm in vertical directions are available. After the upgrade to SPring-8-II is completed, the horizontal focusing size will be further reduced.

The relocation of experimental equipment was also considered with the beamline upgrade. In EH1, the experimental setup was organized mainly to realize X-ray spectroscopy in external field environments such as high magnetic field, high pressure, and low temperature. Therefore, EH1 is equipped with a superconducting magnet, a combination of an electromagnet with a cryostat, and other equipment. As an example, Fig. 2 shows a setup of the KB mirrors and electromagnet. This setup makes it possible to measure XMCD in a high magnetic field and under high pressure.

4. Experimental Station for X-ray Emission Spectroscopy (EH2)

EH2, located about 66 m away from the undulator source, was newly constructed for the XES and high-energy-resolution fluorescence detection (HERFD) XAS measurements as part of the upgrade. In addition, new focusing optics (Wolter mirror) [1] was installed for micro-area XES/HERFD-XAS measurements and their two-dimensional (2D) imaging. The specifications of the focusing mirror are shown in Table 1. The coated material on the surface is Ru, and X-rays up to 20 keV with a focusing size of 15 μm in horizontal and 1 μm in vertical directions are available. After the upgrade to SPring-8-II is completed, the horizontal focusing size will be further reduced, similar to the KB mirrors installed in EH1.

The XES spectrometer [2], which was installed in EH1 before the beamline upgrade, was relocated to this newly constructed EH2. Figure 3 shows the general setup of the XES spectrometer at room temperature. The XES spectrometer can be equipped with a pulse tube-type cryostat, enabling measurements at 3–300 K.

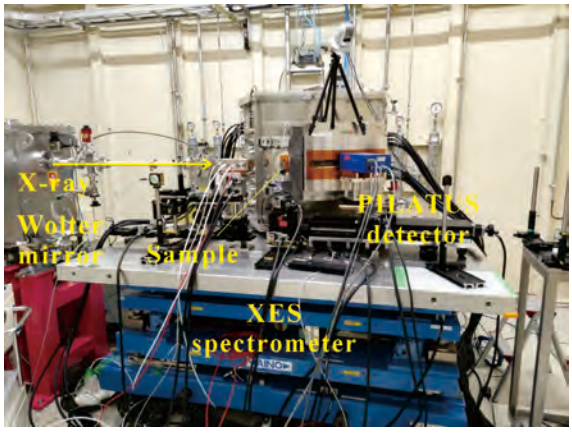

Fig. 3. Photograph of the Wolter mirror and the XES spectrometer installed in the new EH2.

5. Experimental Station for X-ray Nanospectroscopy (EH3)

EH3 (EH2 before the upgrade) is located about 76 m away from the undulator source and has been used for XAS/XMCD nanospectroscopy since FY2011 [3]. Basically, there was no change in the focusing optics or XAS/XMCD measurement instruments after the upgrade. KB mirror optics with the specifications shown in Table 1 can generate a focused X-ray beam with a typical spot

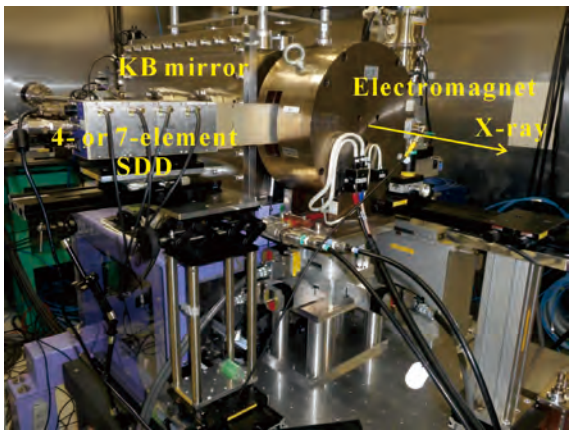

Fig. 4. Photograph of the KB mirror and the nano-XAS/XMCD spectrometer in EH3.

size of 100 nm × 100 nm in an energy range of 5–16 keV. After the upgrade to SPring-8-II is completed, the flux density will be further increased with the same focusing size because the virtual light source will no longer be needed.

Figure 4 shows the general setup of the nano-XMCD in the fluorescence mode. The replacement of the 7-element SDD with a 4-element SDD together with DSP [4] is expected to significantly improve the efficiency of nano-XMCD measurements in the fluorescence mode.

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