BL27SU
(Soft X-ray Photochemistry)

1. Introduction

BL27SU is a soft X-ray undulator beamline dedicated to soft X-ray spectroscopy and microscopy under normal ambient pressure (helium) or high-vacuum conditions. The beamline consists of two branches. The B-branch provides higher energy soft X-rays (2.1–3.3 keV) via a Si(111) double crystal monochromator, while the C-branch, which is equipped with a varied-line-spacing plane grating monochromator (VLS-PGM), provides lower soft X-ray radiation in the 0.17–2.2 keV range. Here, we report an update of the VLS-PGM in FY2018.

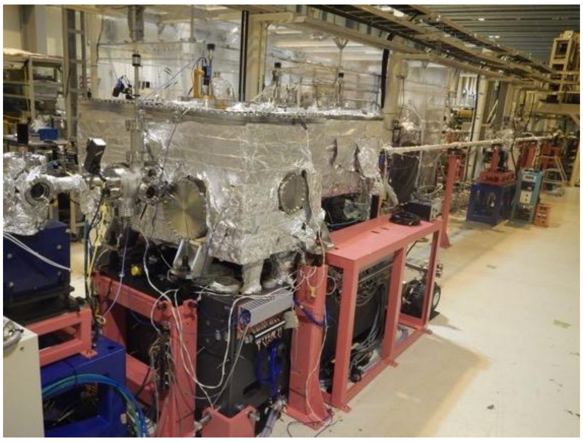

Fig. 1. Overview of new monochromator chamber installed on BL27SU.

2. Update of VLS-PGM installed on BL27SU

The monochromator installed in the C-branch is a Hettrick-type varied-line-spacing plane grating fixed deviation instrument [1]. The VLS-PGM consists of an entrance slit (S1), spherical mirrors (M21, M22), three gratings (G1, G2, G3), and exit slit (S2). The two spherical mirrors and three gratings allow an energy range from 0.17 keV to 2.2 keV to be scanned. VLS-PGM was installed in 1998, and the precision drive system has deteriorated after 20 years of use. In FY2018, we updated the main chamber and scanning mechanics of VSL-PGM during the summer shutdown.

Figure 1 shows a photograph of the new monochromator chamber. This upgrade did not change the optical parameters, and the previously used optics (focusing mirrors and gratings) were re-used after a surface cleaning. The previous monochromator could have three gratings, but the new monochromator chamber can support four gratings. Therefore, we added a new G1 grating with a gold-coated surface to improve the reflectivity (Fig. 2 and Fig. 3). In addition, because a vacuum leak was suspected in the water-cooling system of the previous entrance slit (S1), S1 and its vacuum chamber were also replaced. Besides maintenance and replacement of aging equipment, the following improvements were made to enhance the monochromator performance.

2-1. Upgrade of the mirror moving system

In the previous monochromator, when switching the optical elements, both the gratings and focusing mirrors moved horizontally on a rail. Hence, optical elements could not move vertically in the vacuum chamber, creating a serious limitation because the focusing mirror could not be adjusted to the optimum height position with respect to the incident photon beam.

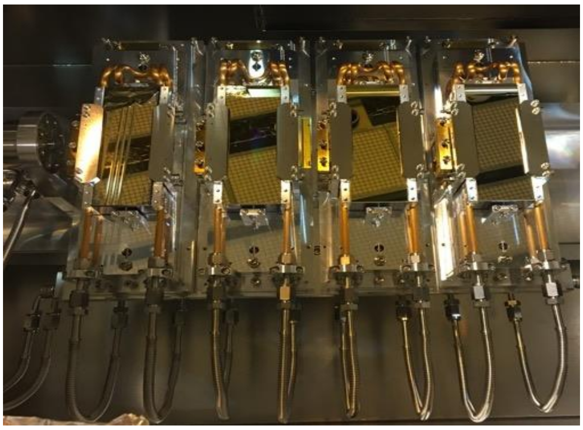

Fig. 2. Photograph of the four installed gratings with a new cooling system.

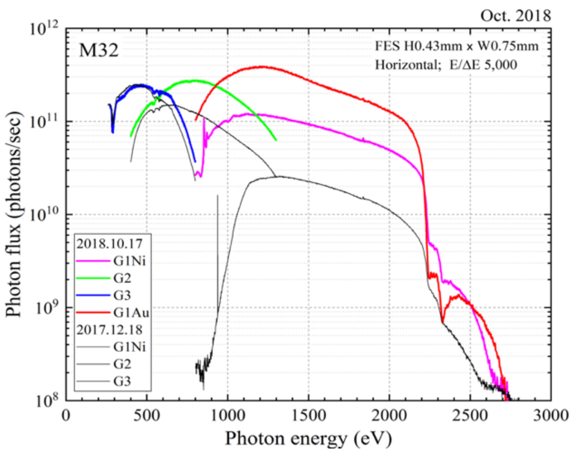

Fig. 3. Photon flux curve of BL27SU C-branch before and after the upgrade.

This problem decreased the photon flux because photons were missed at the focusing mirror (M21). In this upgrade, we modified the moving mechanism to move M21 in the vertical direction. As a result, M21 can now be adjusted to the correct position in a vacuum.

2-2. Upgrade of the cooling system

In the previous monochromator, to prevent vibrations caused by the flow of cooling water, an indirect cooling system using a liquid metal (InGa) bath was adopted to cool the optical elements. Because this system cannot bake the vacuum chamber at high temperatures, the pressure of the previous main chamber was insufficient for X-ray optics use (1×10^{-6} Pa), and the optical element suffered from carbon contamination. In this upgrade, we introduced a cooling system that cools the optics by a water-cooling plate (Fig. 2). The water cooling pipes are connected in series among each cooling plate without a liquid metal bath, and the optical elements are cooled by flowing water through cooling pipes at a flow rate of about 300 ml/min.

2-3. Baking of the optical elements

In addition, we applied a novel optics baking method using X-rays, which is called offset-baking. During offset-baking, the X-ray beam axis is slightly offset by adjusting the pre-mirror. Under this condition, X-rays are irradiated on each optic at a position that is shifted about 5 mm from the original irradiation position. Consequently, carbon contamination to the regular irradiation position on the focusing mirrors and gratings during baking can be prevented.

The front-end slit was initially set at 0.4 mm, and was expanded gradually to 2.2 mm [2]. Offset-baking was performed for 162 h. With the introduction of a new cooling system and the offset-baking method, the base pressure of the main chamber was 6×10^{-8} Pa. This pressure can be maintained on the order of 10^{-7} Pa during the measurement.

2-4. Commissioning results

Figure 3 shows the photon flux curve before and after the upgrade. Each flux curve was determined by measuring the photocurrent at the sample position using a Si-PIN photodiode. Especially, the photon flux increases in the energy region above 1 keV due to the accurate alignment of M21 and the introduction of a gold-coated grating. The sharp peak around 800 eV in the photon curve of the previous monochromator was due to stray light that missed the incident photons by M21. In the photon flux curve obtained after the upgrade, the lack of the peak indicates that M21 is adjusted to the correct position.

The energy resolution was confirmed to be $E/\Delta E > 10{,}000$ at 400 eV (G2) by the total ion yield (TIY) measurement of N_2 gas and at 870 eV (G1) by that of Ne gas. Simultaneously, it was confirmed that the cooling water does not generate a vibration that reduces the monochromator performance. The cooling power of the new cooling system to heat load was evaluated by measuring the peak shift of the TIY spectrum. The peak shift was 20 meV / 3 h. The monochromator chamber was updated during the 2018 summer shutdown. In the energy region above 1 keV, the photon flux is enhanced about ten-fold. In addition, offset baking and improved pressure should reduce the carbon contamination of the optical elements. We will continue to monitor the changes in the photon flux.

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References:

[1] H. Ohashi et al., *Nucl. Instruments Methods Phys. Res. A* **529**, 467-468 (2001).

[2] H. Ohashi et al., *Rev. Sci. Instrum.* **90**, 021704 (2019).