BL28B2
White Beam X-ray Diffraction

1. Introduction

BL28B2 is dedicated to multiple techniques using white X-rays in various research fields. It is a bending magnet beamline that provides white X-rays from a bending magnet source without passing through any optical devices. The techniques involve X-ray diffraction, X-ray microtomography (micro-CT), and ultrafast X-ray radiography. Thus, the beamline supports various experiments such as the evaluation of structure materials using white X-ray diffraction and the three-dimensional observation of metallic objects and highly dense materials such as fossils and concrete using high-energy X-ray micro-CT. To improve and upgrade the measurement techniques using this beamline, the research and development of experimental techniques and instruments was conducted in FY2023.

2. Upgrades of Measurement Techniques and Instruments

2-1. X-ray diffraction

BL28B2 can enable diffraction experiments using white X-rays. Since white X-rays automatically satisfy the diffraction conditions, it is possible to obtain a diffraction signal regardless of the sample state. Therefore, users often measure the diffraction signal while controlling the sample environment using their own equipment. In such cases, multiple devices, including the user's equipment, need to be operated in a specific sequence.

The software used to control devices at BL28B2 is created in LabVIEW. LabVIEW has a graphical user interface (GUI), making it easy to understand the operations intuitively. However, creating sequences requires knowledge of LabVIEW, and not all users can handle sudden sequence changes during beamtime.

Therefore, software has been developed to enable the definition of experimental sequences through text-based commands. Figure 1 shows the user interface of the software. To execute a sequence, users simply select the corresponding text file and click the "execute" button. Figure 2 shows an example of a sequence for executing the following: connect to the specified IP address (tcp2_op 192.168.147.209 1001), open the main beam shutter (mbs_op), move stage 7 by 0.22 mm (mv 7 0.22), wait for 6000 ms (sleep 6000), send a command to the previous IP address [tcp2 "ImgSave(Current,data2tif,S:¥user¥test¥sample01 ¥sample01_0001.tif,1)"], close the main beam shutter, and finally, close the TCP connection.

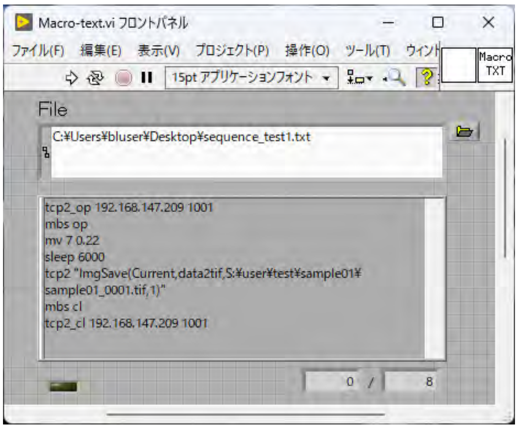

Fig. 1. User interface of the software. This software processes text-based scripts to execute sequences.

For common operations such as motor stage movement and step scanning synchronized with a counter, we have prepared separate dedicated software. Since almost all users can create text-based sequences, this software is highly useful for sudden changes in sequences and for creating specific sequences that are not frequently used.

Fig. 2. Example of a sequence.

2-2. Rearrangement of multilayer monochromator for high-resolution X-ray micro-imaging

X-ray micro-imaging usually requires a high photon flux density for high-resolution observation. In this point of view, white X-rays from the bending magnet source are suitable for not only high-resolution observation but also wide field-of-view observation. So far, high-energy X-ray micro-CT at the 200 keV region has been developed and applied to various samples such as fossils and metallic devices. In this case, high-energy X-rays could be easily extracted from the white X-rays merely by placing a heavy metal absorber on the beam to eliminate lower energy X-rays [1]. On the other hand, in the use of X-rays in the region from 20 to 40 keV it is necessary to use a monochromator to extract proper X-ray energy. In general, a double-crystal monochromator is used to select the desired energy in SPring-8. For X-ray micro-imaging, however, the photon flux density is more important than the monochromaticity of the beam. Therefore, a multilayer monochromator is more suitable for obtaining higher photon flux density for high-resolution measurements. Here, the multilayer monochromator, which was previously installed for other purposes [2], was rearranged to create an environment in which high-resolution X-ray micro-imaging and other applications can be performed.

The main specifications of the multilayer monochromator installed in the beamline are as follows: the working energy is 25 keV at the glancing angle of 5.11 mrad, a depth graded W/Si multilayer structure is deposited on a single-crystal silicon substrate, the energy resolution E/ΔE is 9.8, and the mirror dimensions are 1000 mm (L) × 60 mm (W) × 50 mm (H). Since the mirror surface was facing downward in the previous configuration, it was changed to face upward to improve the accessibility to the beam at the experimental hutch. Photographs before and after the rearrangement of the multilayer monochromator are shown in Fig. 3. A total reflection mirror located downstream of the multilayer monochromator in the previous configuration was removed. In the new configuration, two sets of water-cooled linear-introduction-type filters were newly installed at the upstream position of the multilayer monochromator. It is possible to install four different filters for one set, and the proper filter can be selected to suppress the total reflection components from the multilayer monochromator. The metallic filter can also be used to suppress the heat load on the sample or equipment when using white X-rays.

After rearranging the multilayer monochromator, the energy spectrum from the multilayer monochromator was measured. The θ–2θ scan was performed using a silicon (111) crystal under the Bragg condition. The X-ray energy spectrum when the glancing angle to the multilayer monochromator was 5.114 mrad is shown in Fig. 4.

In this scan, an aluminum filter with a thickness of 1 mm was used. The spectrum shows the peak energy of 24.98 keV and the full-width at half-maximum of 2.756 keV, resulting in an energy resolution of 9.06 (bandwidth of 11%). It was confirmed that the energy resolution was almost as expected. Although it deviates from the ideal condition, the output energy from the multilayer monochromator could be changed from 20 keV to 40 keV by adjusting the glancing angle.

In the future, the multilayer monochromator is expected to be applied to high-resolution and high-definition measurements at submicron pixel size and ultrafast X-ray radiography by taking advantage of its high photon flux. In this beamline, an automatic CT system based on 200 keV high-energy X-ray micro-CT is already in operation [3], and it is also expected to be expanded to automatic measurement with high-resolution X-ray micro-CT using the multilayer monochromator.

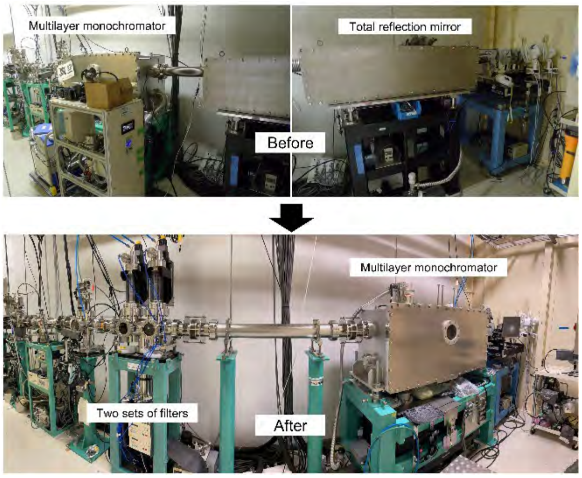

Fig. 3. Photographs of a multilayer monochromator (top) before and (bottom) after rearrangement.

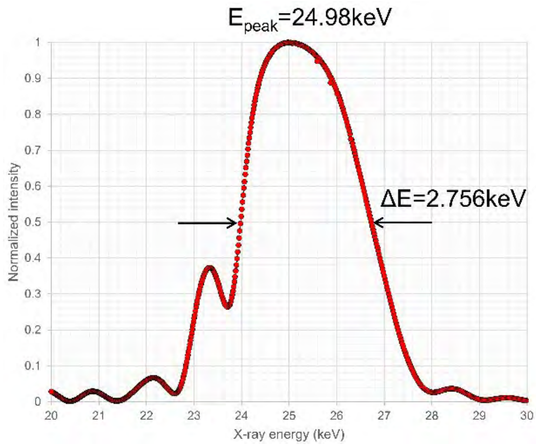

Fig. 4. X-ray energy spectrum from a multilayer monochromator at the glancing angle of 5.114 mrad.

HOSHINO Masato, KAJIWARA Kentaro, and UESUGI Kentaro

Japan Synchrotron Radiation Research Institute

References:

[1] Hoshino, M. Uesugi, K. Shikaku, R. & Yagi, N. (2017). *AIP Adv*. **7**, 105122.

[2] Momose, A. Takano, H. Hoshino, M. Yashiro, W. & Wu, Y. (2016). *Proc. SPIE*, **9967**, 99671E.

[3] Hoshino, M. Kajiwara, K. Uesugi, K. & Yasutake, M. (2022). *SPring-8/SACLA Annual Report FY2022*, 64-67.