BL29XU
RIKEN Coherent X-ray Optics

1. Introduction

BL29XU is a 1-km-long beamline, where the light source is a standard undulator with a length of 4.5 m. This beamline consists of an optics hutch and four experimental hutches. Various R&D projects are performed on the instruments in the front-end and transport channel sections, such as the double-crystal monochromator, higher-harmonic-rejecting double mirrors, transport channel slits, and beryllium windows. Infrastructure development for advanced scientific studies is intensively carried out at BL29XU, especially in order to make full use of the spatial coherence of the X-rays. The efforts include the reduction of the number of beryllium windows placed along the optical axis and the reduction of vibrations of the monochromator in the transport channel. These developments directly affect the quality of such experiments as coherent X-ray diffractive imaging (lensless X-ray microscopy) and total-reflection mirror optics experiments with ultimate precision.

The downstream mirror, which rejects higher harmonics, contains two strips of parabolic mirrors with a focal length of approximately 48 m. This is equal to the distance between the mirror and the light source. The glancing incidence angle can be set to 5 and 3 mrad. The downstream mirror also contains a strip of a flat mirror. Parabolic mirrors can provide a parallel X-ray beam by reflecting X-rays emitted from the source, which is approximately 48 m upstream. By reflecting 8 keV X-rays on a parabolic mirror with a 5 mrad incidence angle, the measured vertical angular divergence is reduced from 9 μrad without mirrors to 0.4 μrad.

2. Recent activities

We work diligently to fulfill another important task of BL29XU, the calibration of various state-of-the-art X-ray detectors and X-ray optical components developed by SPring-8 users and outside users. In FY2022, a unique X-ray diffused light that could accelerate the calibration of X-ray astronomical total reflection mirrors was developed. X-rays are focused with a Fresnel zone plate (FZP) having a long focal length of around 2 m and are diffused to form a relatively homogeneous beam with the approximate diameter of 6 cm at experimental hutch 4 (EH4) of BL29XU (Fig. 1). This beam visualized the positional offset of the vacuum pipes, ~2–4 cm in each axis along two dimensions (Fig. 2), after their positional correction undertaken about 12 years ago. This positional offset of vacuum pipes will be corrected after a careful survey of their locations.

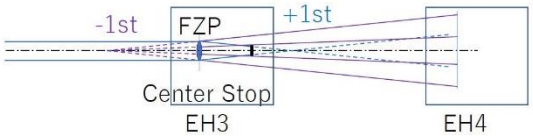

Fig. 1. Schematic diagram showing the X-ray optics utilized to realize X-ray diffused light. Diffused light was realized using a gold FZP having a diameter of 1 mm and a focal length of approximately 2 m. A 4 arcsec angular resolution was achieved during the calibration of astronomical mirrors.

Fig. 2. Blockage of X-ray beam by the offset of multiple vacuum pipes located between EH3 and EH4 of BL29XU.

As for the easier switching of user experiments in terms of the vacuum pipe settings, pipe holders inside EHs of BL29XU are replaced with very light ones having a fixed height. This replacement was conducted in EH3 during FY2022. Moreover, new software to electronically open and close the vacuum valves was developed during FY2022. This software is installed on network PCs and is assigned to specific IP addresses.

Hereafter, we present the research highlights achieved at BL29XU during FY2022.

Dr. Fukunaka of Gunma University and Dr. Shimura of RIKEN & International Medical Center conducted a study on the relationship between aluminum intake and diabetes symptoms in mice, using a scanning fluorescence X-ray microscope at BL29XU to observe pancreatic β cells in a mouse model of human diabetes and found that the amount of zinc decreased sharply before the onset of diabetes, and iron loss additionally occurred as diabetes progressed. In addition, the decline of the mitochondrial function of pancreatic β cells was observed in accordance with iron reduction, suggesting that the decrease in the amounts of iron and zinc may be involved in mitochondrial function and the decline of insulin secretion [1].

Prof. Je and his group members at Pohang University of Science and Technology (POSTECH) proposed a neural-network-based approach for 3D reconstruction of alveolar ducts and alveoli in intact mice lungs at expiration using the synchrotron X-ray in an unsupervised manner. Their method helped to remove some degree of the effect by the slight motion of the alveoli, which are kept so as to maintain their shape, but not completely owing to unexpected micromotion such as the beating of the heart [2]. They expect that their approach will help to accurately visualize other living organs hampered by micromotion.

Dr. Mitsuishi and his colleagues at Nagoya University conducted a calibration experiment of a 6-cm-diameter nickel-deposited Walter I X-ray total reflection mirror for the first solar flare sounding rocket experiment. X-ray diffuse light with a diameter of 6 cm was realized in EH4 of the 1-km-long beamline of BL29XU. This enabled them to irradiate the entire field of view of the mirror and to take snapshots of the images at the focal plane. This setup turned out to be ideal for the calibration of these astronomical mirrors because of the energy tunability and the achievable angular resolution [3].

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References:

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[2] Shin, S. et al. (2023). *Sci Rep.* **13**, 1738.

[3] Mitsuishi, D. et al. (2022). *X-ray・EUV Imaging Optics News Letter* **54**, 1–10. https://jspc.sakura.ne.jp/sun_tour/sun_tour2021/list/NAOJ_FOXSI.pdf