BL29XU
RIKEN Coherent X-ray Optics

1. Introduction

BL29XU is a 1-km-long beamline for which 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 for making 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 experiments such 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 or 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 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 are working intensively 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.

The X-ray diffused light formed for the calibration of the X-ray telescope mirror in FY 2022, using 1st-order light from a Fresnel zone plate (FZP) having a long focal length of around 2 m, was expected to produce an approximately 90 mm beam at EH4 inside the 1 km beamline building. The observed beam, however, manifested circular shadows on the 90 mm beam, which was assumed to result from the vacuum pipes blocking the X-rays (Fig. 1). We analyzed the geometry and concluded that the shadows with the largest and second largest diameters were probably produced by the vacuum pipes located near the pump housings of #49-#50 and #60 among 64 housings, respectively (where the smaller number of the housing corresponds to further upstream). From the calculated result, the positions of the vacuum pipes are planned to be shifted in two dimensions near vacuum pump housings #49 and #50 by 40 mm upwards and 20 mm towards the SACLA building side (north) during the summer shutdown of FY 2024. With this shift, the shadow with the largest diameter is expected to be eliminated.

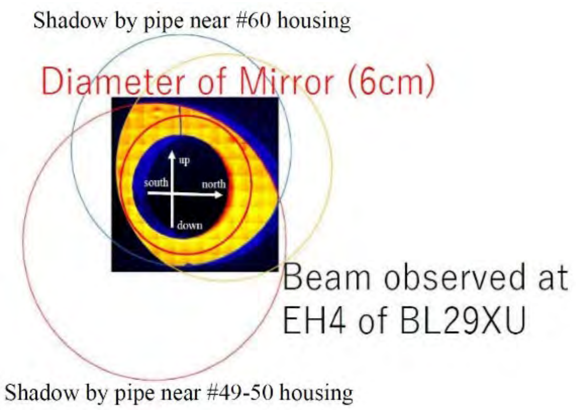

Fig. 1. Blockage of X-ray beam by multiple vacuum pipes located between EH3 and EH4 of BL29XU.

Hereafter, we present the research highlights achieved at BL29XU during FY2023.

A research team headed by Prof. Matsuyama and Dr. Inoue at Nagoya University has demonstrated the ideal property of lithium niobate piezoelectric single crystals for an X-ray mirror, where the surface was smoothed at the atomic level (surface roughness: 0.2 nm RMS), and an X-ray mirror with a linearity of deformation with respect to voltage of 0.06 nm, apparently exceeding the atomic level, was realized [1]. By incorporating this mirror into a microscope as a reflective objective lens, they successfully demonstrated the world's first adaptive X-ray microscope, which corrected aberrations with an accuracy of $\lambda/16$ and successfully realized high-resolution X-ray microscopy images.

A research team headed by Profs. Takahashi and Hoshino at Tohoku University has been working to demonstrate an approach for analyzing particle motion in heterogeneous solutions over a wide spatial and temporal scale by combining X-ray photon correlation spectroscopy (XPCS) and dynamic coherent X-ray diffraction imaging (dynamic CXDI). In a dynamic CXDI experiment with a triangular aperture, a reconstructed image of an object was obtained from a single diffraction intensity pattern, which enables the object's position to be traced as a function of time. With a sample of colloidal gold particles dispersed in a polyvinyl alcohol aqueous solution, the calculated temporal correlation between the scattering images measured at different times showed that the correlation for the larger scattering wavenumber is lost in a shorter time, clearly indicating the feature of Brownian motion [2].

Dr. Mitsuishi and his colleagues at Nagoya University succeeded in launching their X-ray telescope system for the first solar X-ray flare-sounding rocket experiment of the FOXSI-IV NASA project. The calibration experiments of the 6-cm-diameter nickel-deposited Walter type-I X-ray total reflection mirror were performed at EH4 of the 1-km-long beamline of BL29XU, which was indispensable in the precise determination of the sharpness of the core in the point spread function (PSF), which was better than 1”, and the weak scattering in the tail of PSF. The attained performances enabled unrivaled clear images of the solar X-ray flare to be obtained. The diffuse X-ray light enabled the group to irradiate the X-rays onto the entire field of view of the mirror and to take snapshots of the images at the focal plane. This setup enabled them to easily calibrate these astronomical X-ray mirrors with minimum alignment procedures over a wide energy range [3].

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References:

[1] Inoue, T. et al. (2024). *Optika* **11**, 621.

[2] Takazawa, S. et al. (2023). *Phys. Rev. Res.* **5**, L042019.

[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