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, the higher-harmonic-rejecting double mirrors, the TC slits, and the beryllium windows. Intensive studies have reduced the vibration of the double-crystal monochromator. 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 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. The 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 [1].

2. Recent activities

Research at BL29XU pursues the most advanced use of coherent X-rays such as coherent X-ray diffraction imaging (lensless X-ray microscopy) and total-reflection mirror optics with ultimate precision.

"CITIUS", a high-speed integrating-type detector for future synchrotrons and XFELs, has been developed by the RIKEN detector group and has a maximum count rate of 30 Mega (in the normal mode) to 600 Mega (in the extended mode) counts per second per pixel at 12 keV by implementing a novel charge-integrating architecture. The initial performance of this detector was intensively evaluated at BL29XUL. Resulting data showed linear response up to around 700 Mega counts per second per pixel at 10 keV, which is beyond the limit of state-of-the-art photon-counting detectors. To conduct system-level evaluation, a dedicated data-acquisition (DAQ) rack with PC servers and a cache data storage were placed in an adjacent room inside the radiation safety area beside the experimental hall. Dedicated optical fibers and ethernet communication cables will bepermanently laid between the DAQ rack and the internal space in experimental hutch (EH, EH3 and EH2) during the period between May and November, 2021. The DAQ performance test successfully demonstrated its designed performance. As a first feasibility study, XPCS experiments were conducted at a frame rate of 17.4 kfps. The most intense area of the images showed over 40 mega photons per second per pixel at 8 keV. The dynamics faster than 100 ms was also clearly measured owing to the fast frame rate of CITIUS.

Research at BL29XU has produced advanced scientific results in the field of coherent X-ray imaging. The following briefly summarizes the achievements.

The collaboration team of J. Yamada, Beam Line Development Team under XFEL Research and Development Division, demonstrated a simple and innovative method for constructing a scanning X-ray microscope equipped with a nanoprobe scanner. It ingeniously uses both X-ray prisms and X-ray focusing by total reflection mirrors. By rotating the prisms on the order of degrees, X-ray probe scanning with single-nanometer accuracy is easily achievable. The validity of the concept was verified by acquiring an image of a test pattern at a photon energy of 10 keV, where 50 nm line-and-space structures were resolved [2].

The collaboration team of Y. Takahashi, Tohoku University, demonstrated *in situ* hard X-ray ptychographic coherent diffraction imaging during the phase transition in the melting of Sn–Bi eutectic solder alloy particles. Ptychographic diffraction patterns of micrometer-size Sn–Bi particles were collected at temperatures from room temperature to 540 K. The projection images of each particle were reconstructed at a spatial resolution of 25 nm, revealing differences in phase shifts among the two crystal phases in the Sn–Bi alloy system and the Sn/Bi oxides at the surface [3].

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References:

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[3] Ishiguro, N. et al. (2020). *Microsc. Microanal.* **26**, 878–885.