

BL19LXU

RIKEN SR Physics

1. Introduction

BL19LXU is a hard X-ray beamline equipped with a 27 m in-vacuum undulator in one of the four long straight sections of the SPring-8 storage ring. Experimental hutches (EHs) 1, 2, and 3 have been in operation since FY2000, and EH4 was constructed in FY2001.

The beamline has been continuously updated as follows. Major updates in the optics hutch include the installation of a transport-channel (TC) mirror to reject higher harmonic radiation (FY2004), the installation of precision four-jaw slits (FY2010), the renewal of the stages (FY2013), the installation of the cooling pipes in the double-crystal monochromator (DCM) for enhanced stability (FY2015), the installation of an in-line beam monitor made of a diamond thin film (FY2015), and the replacement of the vacuum system from turbomolecular pumps to an ion pump (FY2017) to keep the surfaces of the monochromator crystals and the mirrors clean. In FY2017, the minimum photon energy was lowered from 7.270 to 7.092 keV, which is below the iron K edge at 7.112 keV, by changing the minimum gap size of the undulator.

For micro- and nano-focusing, Kirkpatrick–Baez (KB) mirror systems were permanently installed in EH 3 (FY2014) and EH4 (FY2010). The outdated Ti:sapphire laser system was updated (FY2016), and the repetition rate was increased from 1 to 10 kHz, which improved efficiency in time-resolved experiments. In accordance with the 10 kHz system, the X-ray chopper was also upgraded to select a single bunch at 9.49 kHz (FY2016). To improve the experimental

environment, the lighting in the hutches was changed from fluorescent tubes to LEDs (FY2015), the precision air-conditioning systems in EH1 and EH3 were upgraded (FY2016), and the doors of EH1 and EH3 were motorized (FY2017). The PLC system was upgraded to allow users to select the active hutch and to always operate in a remote mode for users' convenience (FY2018). The regles of the doors of EH1 and EH3 were backfilled to seamlessly join the floors inside and outside the hutch, which makes it much easier for users to carry heavy apparatuses into the hutch (FY2019). A heavy-load Z stage was installed in EH2 (FY2020). The Z stage mounts the X-ray chopper, a four-jaw slit, and the diamond thin-film beam monitor, and can easily adjust these components to the beam axis. In recent years, no major update of the instruments has been conducted. Still, the stabilization of the TC mirror (FY2022) and the liquid-nitrogen cooling system of DCM (FY2023) was done to promote precision experiments.

2. Recent activities

The FE slits were designed to have a rectangular aperture. However, the X-ray beam at the experimental stations was nearly triangular rather than rectangular. One corner was not sharp, which was caused by the distortion of the slit body. Such an X-ray beam was inconvenient, especially for imaging applications. Furthermore, part of the incoming beam was blocked, reducing the X-ray flux. During the spring shutdown of FY2024, the FE slits were repaired, and the edges became sharp enough to pass through a rectangular beam.

The outdated holder for the first crystal of DCM was also replaced with the latest one. This new holder has a superior cooling performance compared with the old one. This allows users to utilize more X-ray flux. For example, using the old holder, the maximum aperture of the FE slits was limited to 1.4 mm (H)×0.48 mm (V) at an undulator gap of 20.36 mm and a photon energy of 14.413 keV. Now, the vertical size can be increased to 0.52 mm, resulting in approximately 10% more flux. In addition, the thermal stability was improved, i.e., the angular drift of the first crystal stops faster than before. This contributes to the efficient use of the beam time. One drawback of the new holder is the fact that the X-ray beam is slightly convergent.

Various user experiments, which require brilliant X-rays, and R&D programs for X-ray free-electron laser experiments are performed at each experimental hutch. In FY2024, the experiments performed in EH1 included X-ray quantum optics using X-ray parametric down-conversion and nuclear resonance vibrational spectroscopy to study hydrogenase. Most of the experiments were performed in EH3, such as research on the X-ray pumping of the thorium-229m isomeric state, high-energy X-ray diffraction for the stress-strain analysis of iron materials, linear dichroism in HAXPES, scanning tunneling microscopy (STM) combined with X-rays, and time-resolved X-ray diffraction experiments with the synchronized Ti:sapphire laser system.

The outcome of the user experiment is an X-ray spatial modulator ^[1]. This modulator can dynamically pattern an X-ray beam with a spatial

frequency up to 24 mm⁻¹ and a pixel size of 2.8 μm (Fig. 1). The modulation is achieved by using the transient strain induced by the Ti:sapphire laser pulse. This unique optical device is now available for novel research, such as single-pixel imaging, where beam pattern control is essential. It should be noted that the X-ray flux of the patterned beam is much lower than the output of DCM, because the modulator needs the X-ray chopper to select single bunches at the repetition rate of the laser system.

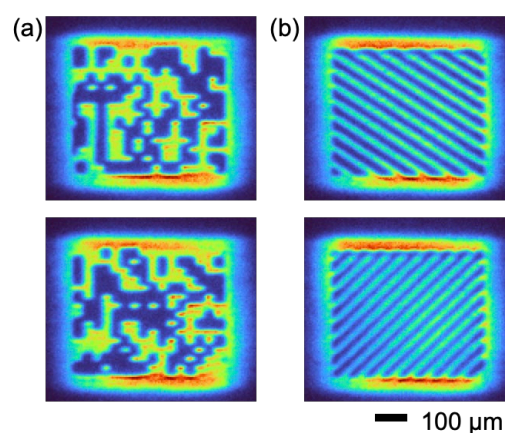


Fig. 1. Examples of beam patterns created by the X-ray spatial modulator. (a) Random binary patterns. (b) Sinusoidal fringe patterns.

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References:

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