BL10XU
(High Pressure Research)

1. Overview

BL10XU is a public beamline dedicated to high-pressure X-ray diffraction measurements using monochromatic X-rays. The scientific fields cover high-pressure physics and chemistry, materials sciences, and Earth and planetary sciences. Integration of a high-pressure apparatus diamond anvil cell (DAC) and cryostat/laser heating allows X-ray diffraction experiments ranging from cryogenic temperature to over 3,000 K to be performed under high pressure conditions. Over the last two decades, we have been developing X-ray focusing optics, diffractometers, and detectors suite for high-pressure X-ray diffraction. High-pressure and high-temperature X-ray diffraction using the laser-heated DAC technique is well established for studying crystallography, phase relation, and *P*-*V*-*T* equation of state of deep Earth materials. Recently, the number of high-pressure and high-temperature synthetic studies has increased rapidly using this technique. Studies include hydrogen-rich materials called hydrides. Precise laser-heating-controlling techniques and accurate temperature measurements are required to enhance X-ray diffraction under extreme conditions over 5,000 K and to synthesize new materials. Additionally, there is a growing need for observations of pressure-induced phenomena of liquid/amorphous materials, including changes in the coordination number and polyamorphism. To meet these requirements, we developed a laser heating system and a high-energy X-ray focusing refractive optics in FY2018. Here, the details are described.

2. New developments in the laser-heating system with *in situ* synchrotron high-pressure X-ray diffraction

The stability of the laser spot and fast temperature measurements are key components to *in situ* high-pressure and high-temperature X-ray diffraction measurements. The conventional online laser heating system installed at BL10XU made it very difficult to keep the laser spot in one position for a long time. However, a long exposure time is necessary to determine the temperature.

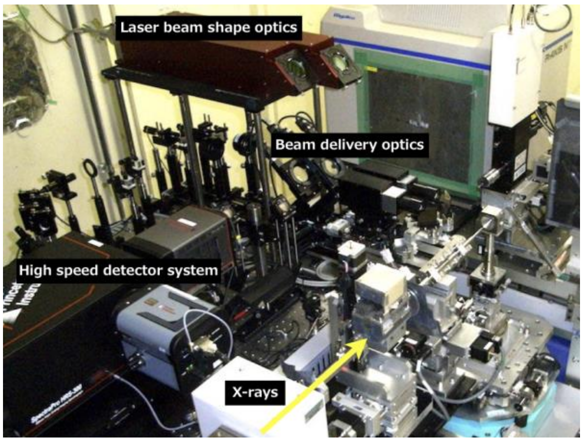

Fig. 1. Photograph of the *in situ* laser-heating system for high-pressure X-ray diffraction with the DAC.

In FY2018, we introduced a few modifications to improve the laser pointing stability and temperature measurements for laser heating. Improvements included installing high-power laser optics capable of accurate beam shape control, laser beam delivery optics to a sample in the DAC, and high-speed CCD detectors (Fig. 1). In the new beam delivery optics, we changed the mounting method for X-ray transparent silver-coated glassy carbon mirrors, adopted the gimbal mechanism in the mirror mounts, and placed a 100-mm-thick honeycomb optical table to meet the requirements for rigidity, vibration isolation, system stability, and user-friendliness for laser heating. This setup also controls the laser beam spot with a precision of a few µm. Currently, we are optimizing the flat-top optics for a high-power laser beam and developing an interface program that combines temperature measurements and diffraction pattern collection.

3. X-ray–focusing refractive optics at a high energy of 62 keV

High-energy focused X-ray probes are essential for high-pressure X-ray diffraction with a DAC involving minute samples. An X-ray focusing technique using a compound refractive lens (CRL) was developed over the last two decades at the SPring-8 BL10XU beamline. To realize high-pressure X-ray diffraction using high-energy monochromatic micro X-ray beam, X-ray–focusing SU8-CRL manufactured by synchrotron deep X-ray lithography was installed in experimental hutch 2. SU8-CRL, which has a focal length of 500 mm and a physical aperture size of 80 µm, is used to focus the 62-keV incident X-ray. In combination with a pre-focusing aluminum CRL installed in optics hutch, the beam size, which is defined as the full width at half maximum (FWHM) of the intensity profile, is approximately 10 µm both in the horizontal and vertical directions at the sample position in the experimental hutch. The flux is 3×10^{10} photons/s at a storage ring current of 100 mA when using an incident slit size of 80 µm × 80 µm and a 30-µm cleanup pinhole. This new X-ray probe will enhance amorphous/liquid X-ray diffraction measurements, and should allow for a deeper understanding of the Earth's liquid outer core and non-crystalline structures.

4. Next-generation hard X-ray undulator

A new in-vacuum undulator, which consists of a magnetic attractive force cancellation system, was built as an insertion device of the X-ray source at BL10XU. Performance tests were launched in 2018. This undulator realizes synchrotron-based multi-probe measurements using X-ray energy ranges that could not be achieved using the previous hybrid-type undulator with a shorter period suitable for high-energy X-ray generation. The new device will be installed at BL10XU in FY2019.

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