BL04B1
High Temperature and High Pressure Research

1. Introduction

BL04B1, which is a bending magnet beamline, mainly dedicated to energy-dispersive X-ray diffraction measurements and X-ray radiography observations under high-temperature and high-pressure conditions using white X-rays. The X-rays emitted from the bending magnet are directly introduced into the experimental hutch and white X-rays with a wide energy range are used in experiments. It is also equipped with a compact Si(111) double-crystal monochromator, which can perform angle-dispersive X-ray diffraction measurements and X-ray radiographic observations using monochromatic X-rays at 30–60 keV.

The beamline has two experimental hutches in series. Each one has a large, high-pressure press with a maximum load of 1500 tons. The SPEED-1500 Kawai–type high-pressure press (DIA-type press, upstream hutch) and the SPEED-Mk.II Kawai–type high-pressure press (D-DIA–type press, downstream hutch) are installed. SPEED-Mk.II is suitable for high-pressure deformation experiments using differential ram, which moves independently of the main ram (D-RAM) as well as high-pressure, high-temperature experiments of 30 GPa and 2000 K or higher using sintered diamond anvils.

In FY2019, a two-dimensional (2D) CdTe detector with a beam monitor for high-energy monochromatic X-rays and a high-resolution X-ray beam monitor for white X-rays were developed. These systems were introduced as part of the Partner User program with a Grant-in-Aid for Scientific Research by Dr. Ohuchi, Dr. Nishi, and Dr. Steeve of Ehime University.

2. Development of 2D CdTe detector with an integrated beam monitor

Acoustic Emission (AE) experiments were carried out at BL04B1 for several years to understand the mechanism of earthquakes. In these studies, a high-speed time-resolved experiment system was setup to investigate the elementary process of rock fracturing under high-pressure conditions. A CdTe detector (ADVACAM: WIDE PIX 5×5) was installed. Because this CdTe detector provides a higher S/N ratio than the existing 2D CCD detector (Rayonix: SX200), data for the analysis of the deviation stress was obtained at short exposure times even in the weak X-ray flux of BL04B1.

To enable simultaneous measurements of X-ray diffraction and radiography, a custom-made beam monitor was manufactured by Nikon Engineering (Fig. 1). The beam monitor is a device to convert X-rays into visible light using a fluorescence plate. Then the converted light is observed using a lens and an image sensor for visible light, which can

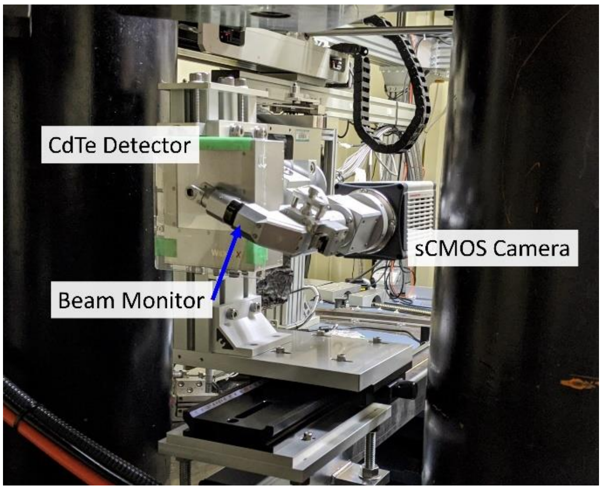

Fig. 1. 2D CdTe detector with an X-ray beam monitor.

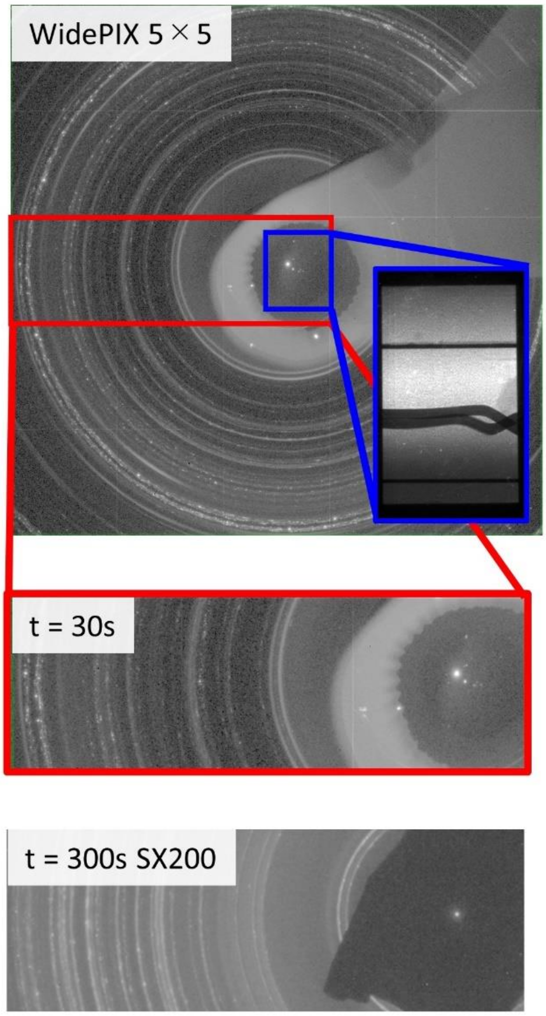

Fig. 2. 2D X-ray diffraction pattern and X-ray transmission image of oceanic crustal rocks (top). Magnified image with an exposure time of 30 s (middle). Diffraction image from an existing CCD detector with an exposure time of 300 s (bottom).

obtain an X-ray absorption image easily. This developed beam monitor is especially compact and can be installed on the front of the CdTe detector. Moreover, the CdTe detector, sCMOS camera, and flipper slit can be automatically changed by software to acquire X-ray transmission images and X-ray diffraction data every few dozens of seconds.

Figure 2 shows the X-ray diffraction data of oceanic crustal rocks. This CdTe detector obtained similar S/N data with about 1/10 of the exposure time compared to the existing large-area CCD detector. Although the blind area in Fig. 2 is obstructed by the beam monitor, the position of the blind area can be changed according to the purpose of the experiment as the beam monitor is movable.

3. High-resolution X-ray beam monitor

In FY2019, a compact beam monitor was developed to reduce the camera length and to provide high-resolution X-ray absorption images (Fig. 3). This beam monitor is used for elastic wave velocity measurements. Since the elastic wave velocity is calculated by dividing the sample length by the travel time of the ultrasonic method, the accuracy of the elastic wave velocity is highly dependent on the accuracy of the sample length measurement. When the distance between the sample and the beam monitor is long, the resolution of the X-ray absorption image is reduced due to X-ray scattering. Hence, shortening the camera length should provide a high-resolution image. To further enhance the resolution, 30-μm-thick GAGG:Ce was used for the fluorescence plate. A mirror is located just below

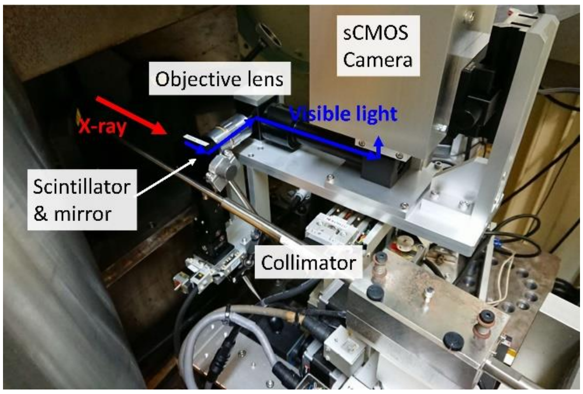

Fig. 3. Setup status of the high-resolution beam monitor.

the scintillator, which is collimated by an objective lens, and two additional mirrors guide the visible light outside the guide block to form an image on a high-sensitivity sCMOS camera (Hamamatsu Photonics: C11440-22CU).

This development can provide images just after the guide block of a high-pressure press, which enables high-resolution X-ray absorption images to be acquired.

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