ICANS XIX,
19th meeting on Collaboration of Advanced Neutron Sources
March 8 – 12, 2010
Grindelwald, Switzerland

PLANET: High-Pressure Neutron Diffractometer at MLF, J-PARC

Hiroshi Arima
J-PARC Center, JAEA, Tokai, Ibaraki, 319-1195, Japan

and

Takanori Hattori[a,b], Kazuki Komatsu[c], Jun Abe[a], Wataru Utsumi[a,b], Hiroyuki Kagi[c], Akio Suzuki[d], Kentaro Suzuya[a], Takashi Kamiyama[e], Masatoshi Arai[a], Takehiko Yagi[f]
[a]*J-PARC Center, JAEA, Tokai, Ibaraki, 319-1195, Japan*
[b]*QuBS, JAEA, Tokai, Ibaraki, 319-1195, Japan*
[c]*Graduate School of Science, The University of Tokyo, Tokyo, 113-0033, Japan*
[d]*Graduate School of Science, Tohoku University, Sendai, 980-8578, Japan*
[e]*J-PARC Center & KENS, KEK, Tsukuba, Ibaraki, 308-0801, Japan*
[f]*The Institute of Solid State Physics, The University of Tokyo, Chiba, 277-8581, Japan*

ABSTRACT

The powder diffractometer dedicated to high-pressure experiments (PLANET) is now being constructed on BL11 at the spallation neutron source of J-PARC. PLANET aims to study structures of hydrogen-bearing materials including dense hydrous minerals of the Earth's deep interior, magmas and light element liquids. The instrument will realize diffraction and radiography experiments for powder and liquid/glass samples at high pressures up to 20 GPa and 2000 K. It covers d spacing from 0.2 Å to 4.1 Å at 90° bank within the first frame. The construction of the instrument started in April 2009 and is scheduled to be completed by April 2011.Here we present design of PLANET and discuss the strategy for high-pressure device deplopment.

1. Introduction

The high-pressure science community in Japan has started the construction of the powder diffractometer dedicated to high-pressure experiments (PLANET) on BL-11 at the spallation neutron source of J-PARC. The beamline realizes the measurement of diffraction and radiography for powder and liquid/glass samples at high pressures up to 20 GPa and 2000 K. The beamline aims to study crystal structure of hydrogen-bearing materials including hydrous minerals of the Earth's deep interior and structure of magma and light element liquids. For this purpose, our beamline is suited for in-situ measurements of neutron diffraction not only at high pressure but also at high temperature with stable and uniform heating condition.

In order to achieve our goal, the beamline has two characteristics. One is the installation of a large-sized hydraulic press [1] and the other is using supermirror focusing guides [2,3]. Here, we will overview the future of the PLANET beamline.

2. Instrumental layout and performance [3]

The performance for the instrument required by users vary according to their research fields such as earth and space science, material science, and high-pressure physics and chemistry. Therefore, the instrumental design should incorporate wide Q range and have the flexibility for intensity-resolution optimization to improve versatility and efficiency in structure analysis of crystal and liquid at high pressure. Instrumental design was optimized based on the following concepts: (i) coverage of d-spacing from 0.2 Å to 4 Å in the first frame, (ii) worst acceptable instrumental resolution of 0.5% in $\Delta d/d$ at 90° bank; (iii) effective focus of neutrons with wavelengths less than 1 Å using a non-parallel supermirror guide, (iv) trade of resolution for intensity using slits and replaceable focusing devices.

Figure 1 shows the design of the instrument. The instrument views a decoupled liquid H_2 moderator with a cross section of 100 × 100 mm^2. The primary and secondary fight paths are 25 m and 1.5 m, respectively. The 11.5-m-long supermirror guide with elliptical shape starts at a distance of 11.5 m from the moderator. The guide has a rectangular cross-section and consists of four walls coated with supermirror material. Sample is placed at 2 m from the guide exit. The 90° detectors will be installed at 1.5 m from the sample position. Bandwidth of $\Delta\lambda$=5.8 Å is available using 25-Hz pulsed source. This allows diffraction data to be collected for d-spicing up to 4.1 Å. Accessible maximum Q value is 30 Å^{-1} using T0 chopper with 50 Hz drive.

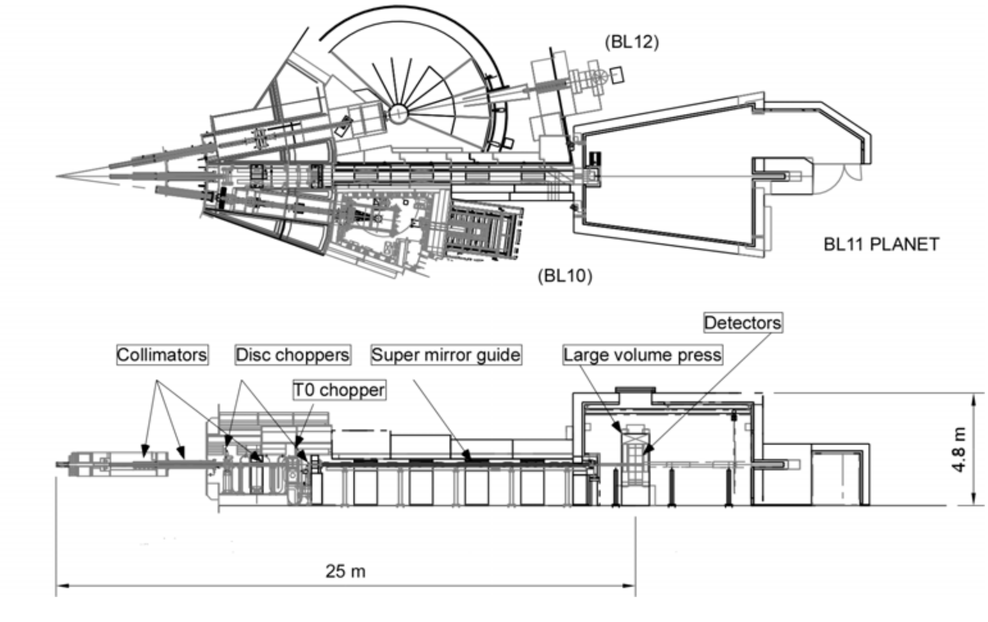

Fig. 1. Layout of PLANETat BL11 of MLF/J-PARC.

Figure 2 shows the geometry of a multi anvil press. For the powder diffraction measurements using multi-anvil press, an incident neutron beam passes through the vertical anvil gaps and irradiates the sample in the pressure medium. Diffracted neutrons go through the other anvil gaps at a 90° direction. Accordingly, 90° detectors are well compatible with a multi-anvil press. We are planning to install pinhole collimator and/or compact focusing device near the sample in order to produce a beam spot below the sample size of a few square millimeters. In addition, radial collimators will be placed between the sample and the detectors to restrict the field of view of the detectors to the sample volume and eliminate background scattering from thesurrounding materials right next to the sample.

Figure 3 shows the simulated incident neutron fluxes on the sample position in several configurations. Here, widths of the slit at guide exit in high-resolution mode and high-intensity mode are 5 mm and 21 mm, respectively. In the first frame (0.3-5.8 Å), the incident neutron fluxes are 9.6×10^7 n/s/cm^2 in high-intensity mode and 2.0×10^7 n/s/cm^2 in high-resolution mode when the neutron source operates at 1 MW. The high resolution mode achieves resolution 0.3% in $\Delta d/d$. In the high intensity mode, a resolution calculated from a simulated profile is 0.5% in $\Delta d/d$.

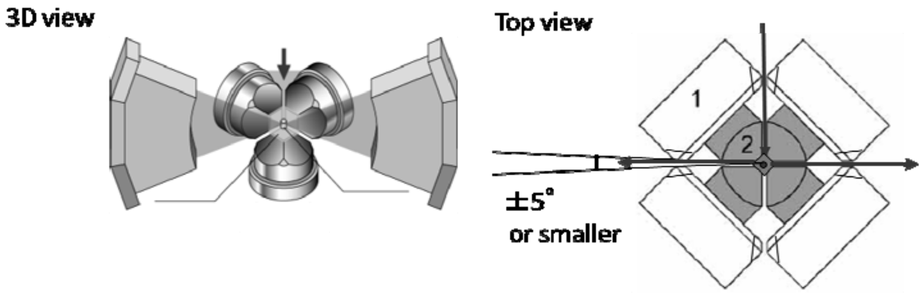

Fig. 2. Geometry of a multi anvil press

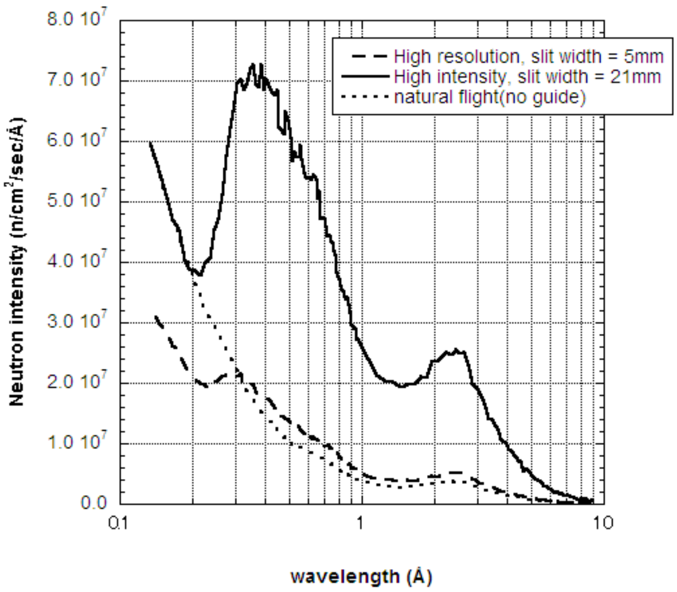

Fig. 3. The incident neutron fluxes on the sample position in several configurations

3. High pressure devices

The highlight of this beamline is, of course, developing original high-pressure devices. A toroid-type high-pressure apparatus with a so-called "Paris-Edinburgh press" [4] is a standard high-pressure device for neutron study. It can generate pressures to 10 GPa on samples with volumes of 100 mm^3 by an uni-axial compression, and pressures higher than 30 GPa with its special design. On the other hand, diamond anvil cell (DAC) and many other high pressure devices have been used in the synchrotron radiation experiments.

Key requirements for the devices at PLANET are large sample volume and solid angle available for detector coverage. The design of the high-pressure devices is proceeding in two categories. The first is the large-sized hydraulic press which can apply forces of 1500 ton to the sample. Such presses have produced many successful results on high-temperature experiments at synchrotron facilities. It has an advantage for stable high-pressure (up to 20 GPa) and high-temperature (up to 2000K) generation. The second is a new opposed-anvil cell [5] with nano-polycrystalline diamond (NPD) [6], which is intend to generate pressures of more than 50 GPa for sample with volume of 1 mm^3.

4. Acknowledgements

The authors wish to acknowledge the support of Grant-in-Aid for Creative Scientific Research (19GS0205) from the Japan Society for Promotion of Science and Grant-in-Aid for Scientific Research on Innovative Areas (No. 20103001) from the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan.

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