§28. Development of Silicon-on-Insulator Type Pixel Detector for Energy Resolved X-ray Images in LHD

Miyoshi, T., Arai, Y. (High Energy Accelerator Research Organization, KEK),
Tsuru, T. (Kyoto Univ.),
Tsukada, K. (Nagoya Inst. of Technology),
Nakanishi, H., Muto, S., Tamura, N., Ito, Y.

High temperature plasmas emit soft X-ray spectra in an energy range from 1.0 keV to 10 keV. The spectra consist of continuum as bremsstrahlung emitted from electrons and K_α lines emitted from impurities such as ionized argons, and transition metals.

These lines are strong enough to study impurity transport. Recently, the radial profiles of time-resolved soft X-ray spectra have been measured with pulse height analyzers in LHD. From the experimental results, the diffusion coefficient and convective velocity of argon have also been estimated [1].

An X-ray video camera has been developed for LHD. The camera is equipped with a Silicon-on-Insulator type pixel detector (SOIPIX) [2]. The SOIPIX has both thick high-resistive radiation sensor and CMOS readout circuit in a single chip.

We have started to develop the SOIPIX at the 7-O horizontal port in LHD. The signal is read out in 0.5 μs/pixel. The detector has 256×256 pixels and the pixel size is 14 μm square. The thickness of the sensor is 500 μm to obtain the X-ray in a range from 1.0 keV to 10 keV, effectively. The data and control signals are transferred through an Ethernet I/F consisting of an on-board FPGA.

It is important to reduce the leakage current of the SOIPIX sensor to obtain enough energy resolution to distinguish impurities in plasma. Therefore, the SOIPIX is mounted in a vacuum chamber with a cooling system as shown in Fig.1.

The plasma images are measured by an optical configuration of pin-hole camera. The optics consists of a 250-μm-thick beryllium filter and a 100-μm-diameter pinhole manually adjustable with a precision of 10 μm. The filter separates vacuum between the LHD and the vacuum chamber, and causes loss of low-energy x-rays. The transmission of argon K_α (E = 3.2 keV) and iron K_α (E = 6.7 keV) are 18.4 % and 85.3 %, respectively. The distances between the pinhole and the plasma center (R_{ax} = 3600 mm), the pinhole and the sensor are 16.85 m and 65.5 mm respectively. Eventually, at the plasma center, the SOIPIX covers approximately 0.8-m-square region.

In FY2015, the cooling system was updated. The system consists of a pulse tube refrigerator and heat synch made of copper to connect the cooling head to the SOIPIX sensor board. For effective high heat transfer, four 8-mm-squre-cross-section copper wires were used in parallel to avoid so much joints. By using these wires the SOIPIX sensor was cooled to -20 °C. To set to lower temperature, the cooling head has to be closer to the SOIPIX sensor and increase the copper volume. Additionally, in the heat synch, there was a joint between copper metal rods, which was directly connected without gasket. Thin disc made of indium will be inserted as the gasket for more effective cooling. In the FY2016, the cooling system update will be continued and then start to study the sensor performance under high neutron background in the future LHD deuteron experiment.

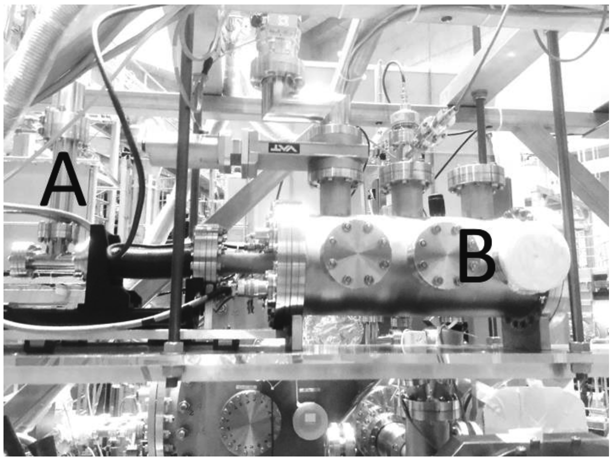

Fig. 1. Photograph of the vacuum chamber for the SOIPIX. The “A” and “B” represent the refrigerator (cooling head) and the vacuum chamber, respectively.

1) S.Muto *et al.*, Plasma and Fusion research **2,** S1069, 2007.
2) Y. Arai, *et al.*, Nucl. Instr. and Meth A. Vol. 636, Issue 1,Supplement, pp. S31-S36. doi:10.1016/j.nima.2010.04.081.