§11. First Result from Hard X-ray CCD in LHD

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Hard X-ray measurement is important to investigate the behavior of suprathermal electron. Experimental results have been also obtained in Tokamaks with advanced technology of hard X-ray spectroscopy, especially semiconductor CdTe detectors. From the results, the energy distribution and the diffusion coefficient of suprathermal electrons have been estimated with using Fokker Planck equation. Measurement and analysis of hard X-ray is progressed in tokamak systems. [1]

In helical systems a development of instruments to measure hard X-ray is also necessary to obtain the information concerning suprathermal electrons. On the contrary the hard X-ray spectroscopy is pioneering region in helical systems. Because few reports associated with the existence of suprathermal electrons has been published as the authors know. Suprathermal electrons hardly yield in helical systems, since acceleration mechanism to supply suprathermal electron is fewer than tokamaks.

A trial for hard X-ray measurement has been also carried out in Large Helical Device (LHD). [2] As a result, hard X-ray spectrum up to 200 keV has been successfully observed with an apparatus equipped a germanium semiconductor X-ray detector. The observed spectrum has been obtained from plasma heated by electron cyclotron heating.

In the present article the first measurement of hard X-ray image in LHD is reported as the performance of an assembly mainly equipped with a CsI implemented CCD camera.

As a first step of the measurement, hard X-ray between 20 keV and 60 keV has been chosen, since the quantum efficiency of a 1-mm-thick-CsI-photo luminescence plate attached in front of 512×512 semiconductor pixels of the CCD is good enough.

The assembly consists of the CCD, a 2-mm-thick tungsten plate with a 2 mm diameter pinhole, a vacuum-tilt beryllium window, an evacuating system, and a linear motion mechanism for primary hard X-ray filters made of aluminum. The mechanism is controlled by a computer through RS-232C. The CCD comprises a data acquisition system, a cooling system for semiconductor, and the CsI plate mounted inside a vacuum enclosure. Consequently, X-ray emitted from LHD plasma is reduced by only the filters and the window.

The assembly has been installed on a horizontal port of LHD and successfully operated with a computer. As a result, hard X-ray images have been obtained. Figure 1 shows the observed image of LHD plasma. The image is reversed, since the assembly works as a pinhole camera. In the figure the entrance of the horizontal port also appears as a parallelogram at the horizontal edge of the image. The accumulation time is approximately 1 sec in a single shot. While the diameter of the pinhole is fixed to 2 mm, the magnification is adjustable around the standard configuration of the pinhole and the CCD. The magnification has been set to 100:3.4 in the case of the experiment as is shown in the figure. Accordingly, the divergence of the sight line is corresponding to a spatial resolution of 20 mm at the plasma center.

In the present research the development of an advanced assembly is in progress. The advanced assembly will make it possible to estimate simultaneously the energy and spatial distributions of high energy electrons in LHD.

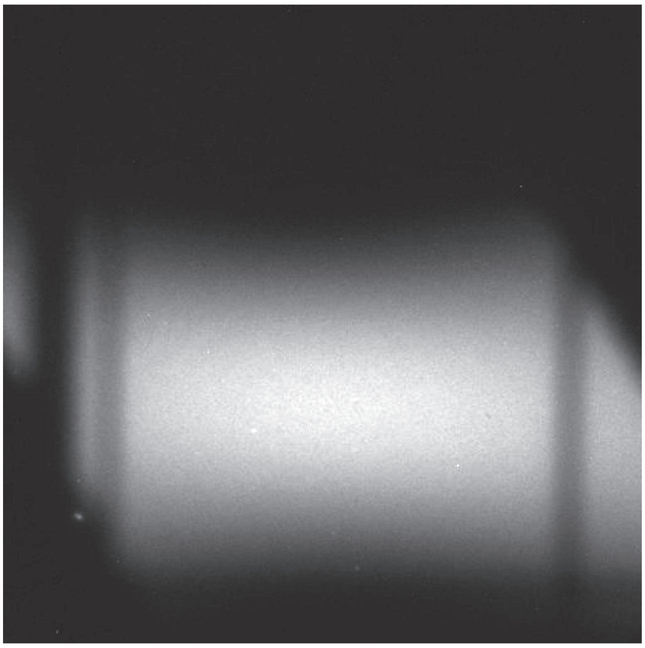

Fig.1. The hard X-ray image observed with the assembly of CCD. The horizontal axis represents the poloidal direction of the LHD plasma. The vertical axis is corresponding to the radial direction of the plasma.

References

[1] Y.Peysson and R.Arslanbekov, Nucl. Instr. And Methods, **380** (1996) 423.
[2] Muto S., *et. al.*, Rev.Sci.Instrum. **74**(2003)1993.