§17. Development of Wide Band and Compact X-ray Spectrometer

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X-ray spectrometer so far developed for LHD plasma diagnostics using various impurities covers narrow energy band of 8-20 eV around He-like resonance lines of Ar, Ti, Cr,or Fe to measure an ion temperature. Though this system (ref. 1) has been working well, it is also important to measure wide band spectra, since it can determine charge state distribution as a measure of electron temperature. On the observation of astrophysical plasma, we will be able to use X-ray micro-calorimeter (XRS, ref. 2), which has an excellent energy resolution and good detection efficiency for X-rays above several keV in comparison with spectroscopic instruments so far in orbit. Such instrument will give us important data on the high temperature plasma, having similar temperature of fusion plasma in laboratory.

Thus we started to develop wide band and compact X-ray spectrometer. Since there is a small space around the available observing port of LHD, we need to make a compact system. Basic design of this system is shown in Figure 1. As the first step of this development, we chose iron as a target impurity and adopted LiF (2d=0.2848 nm) curved-crystal spectrometer in the

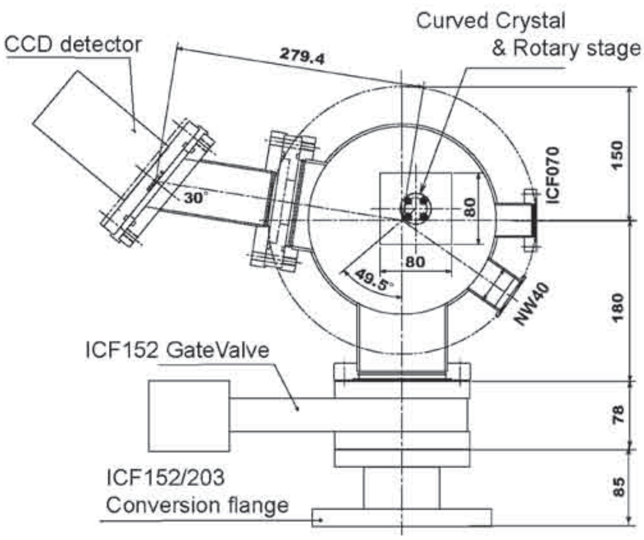
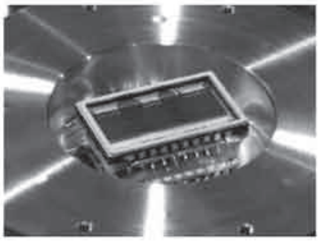


Fig. 1. Wide band and compact X-ray spectrometer system

Johann configuration to cover K-lines of all charge states of iron for 6.4-7.0 keV.

The curvature of the crystal is 215 mm and the size of the crystal is 15 x 15 mm^2, which is provided by Saint Gobain. This curved crystal is set in a crystal holder, which is directly connected to an electric pulse motor and rotated by an external controller to adjust a Bragg angle.

The back-illuminated CCD (ANDOR model DO420-BN) is selected as a X-ray detector and is mounted on a vacuum flange (see Fig. 2a) and connected to the spectrometer. The CCD surface normal direction is tilted with an angle of 30 deg. to the line of sight of the spectrometer, in order to put the CCD on the Rowland circle. The X-ray detection efficiency is 45-35 % at 6.4-7.0 keV(see Fig.2b). The total size of the CCD is 26.6 mm(1024 ch; direction of dispersion)horizontally and 6.7 mm(256 ch) vertically. The pixel size is 26 x 26 μm.



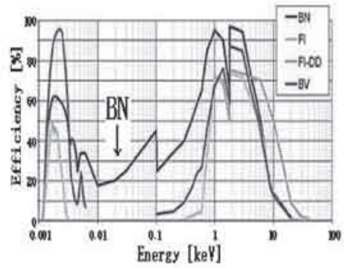


Fig. 2a. Photograph of the CCD (Andor model DO420-BN)

Fig. 2b. X-ray detection efficiency

The distance between the crystal and the detector is 279.4 mm at the CCD center and energy dispersion is 0.6 eV/ch. Energy resolution of the spectrometer is estimated and is shown in Fig. 3. Due to the geometrical deviation in Johann geometry, results show anti-symmetric wide line profiles except for 6.7 keV X-ray, where the configuration is adjusted to get best performance. But these are still better than XRS, which are shown as Gaussian profile.

This X-ray spectrometer will be set at #1-0 port of LHD. The line of sight of the crystal spectrometer is tilted tangentially with an angle of 22 deg.

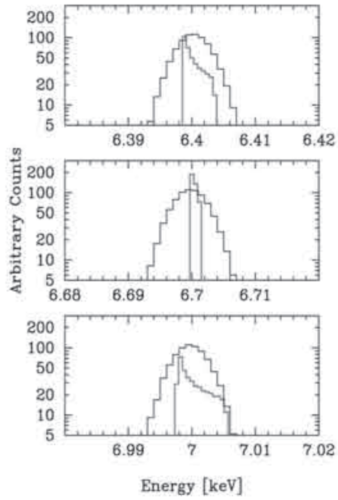


Fig. 3. Expected profiles of the spectrometer (narrow ones) Wide Gaussian profiles are those of XRS for comparison.

Reference

1) Morita, S. and Goto, M., Rev. Sci. Instrum., **74**, 2375 (2003)
2) Mitsuda, K. et al., Proc. SPIE, **5488**, 177-186 (2004).