§11. Measurement of Two Dimensional Electron Temperature Profiles with Hard X-ray CCD Camera on LHD

Liang, Y., Ida, K.,
Kado, S. (Tokyo Univ.),
LHD Experimental Group

Two-dimensional profiles (38x18 spatial channels) of energy spectra of x-ray emission are measured with the photon counting hard X-ray CCD camera by optimizing the intensity of x-ray with attenuation by Be and Al filters in Large Helical Device (LHD).

The hard x-ray CCD camera used in this diagnostic is Princeton Instruments LCX-TE/CCD-1242-ERH/1 with EEV 1242x1152_3ph frame transfer back illumination CCD detector [1-5]. Since half of the pixel is devoted to storage area, the imaging area has 1242x576 pixels. An amount of charge in each pixel of CCD created by the individual x-ray photon is proportional to the energy of x-ray. Therefore, the x-ray energy spectra can be obtained by counting the number of x-ray photons at given intensity (photon counting mode) by choosing appropriate combinations of size of pinholes and thickness of Be and Al filters. The hard x-ray CCD detector is sensitive to the energy range of 10keV to 30keV. The x-ray energy calibration of the CCD camera was done using various x-ray radio-isotope (RI) sources, such as Mn (5.96keV), Np (13.95keV), Ag (22.1keV) K-α and Ag K-β (24.95keV) and L-α (2.9keV) lines. The slope of the calibration line is 31.6eV/electron (121.5eV/ADC-count). The Fe K-α line is fitted by Gaussian plus linear, and the full width of half maximum (FWHM) is 729eV at 5.96keV. Although the energy resolution of the hard x-ray CCD camera is too poor to measure impurity lines, it is good enough to derive the electron temperature from the slope of the x-ray energy spectra. The time resolution is determined by the mechanical shutter and it is ~100ms. The spatial resolution of the x-ray CCD camera is determined by the number of zones divided in the image area (1242x576 pixels). The imaging area of the CCD detector is divided to 684 zones (38x18), and one zone corresponds to one spatial channel. One energy spectrum is derived by counting the number of photons in one zone (32x32 pixels).

Figure 1 shows the two-dimensional profiles of plasma electron temperature derived from energy spectra measured using the hard x-ray CCD camera with 850μm Be and 200μm Al filters for the ECH heated plasma in LHD. The vacuum magnetic axis is 3.5m and the magnetic field is 2.864T. Twenty reproduced shots are integrated to increase the number of photons and improve the statistics of x-ray photons. The x-ray emission of the plasma with different temperature is integrated along the line of sight. This integration effect is larger especially while inner side of the plasma at R<3.5m because the line of sight passes the whole plasma, even at the chord corresponding to the edge. However, the integration effect is relatively small in the outer side of the plasma at R>3.5m.

The electron temperature profiles derived from 2D x-ray energy spectra measured with the tangential hard x-ray CCD camera agree with that measured with YAG Thomson scattering (TS) for the plasma heated with ECH and NBI, respectively, as shown in Fig. 2. This fact suggests that the energy distribution of electrons is close to the Maxwellian in the energy range of the YAG and the x-ray CCD measurements.

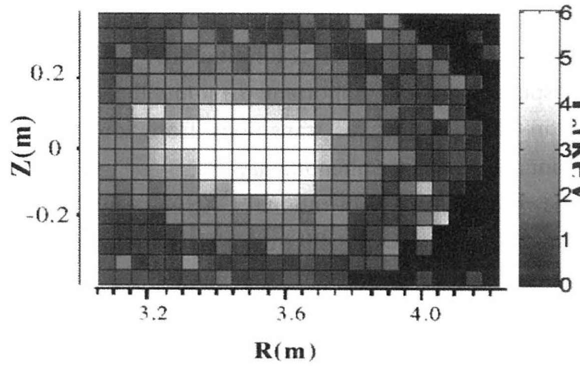

Fig. 1 Two-dimensional electron temperature profiles measured with the hard x-ray CCD camera in case of the LHD low density ECH heated plasma.

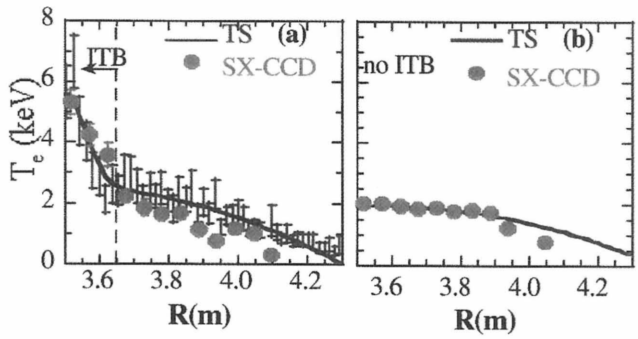

Fig. 2 Electron temperature radial profiles measured with the hard x-ray CCD camera and the YAG TS in cases of the LHD plasmas heated by (a) ECH and (b) NBI, respectively.

References

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