§42-23 Detailed Electron Velocity Distribution Function Measurement by Thomson Scattering

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This study mainly aims to investigate anisotropic electron temperature of low-collisionality plasma in LHD. The anisotropy of electron temperature might affect profiles of plasma pressure and plasma current driven by pressure gradient. Recently, as described in the following paragraphs, we developed new collection optics of the Thomson scattering which is sensitive to the onset of the anisotropy, and we tried to establish a new analytical method of the waveform of Thomson scattering signal.

Spectra of Thomson scattering reflects the electron velocity distribution function along a certain direction which is determined by both direction of propagation of the incident laser beam and the line of sight. Therefore, we applied the double-pass Thomson scattering to measure electron temperatures along two different directions. However, until the last year, electron temperatures almost perpendicular to the magnetic field (first pass) and approximately 70 degrees inclined from the magnetic field (second pass) were measurable due to the configuration of the Thomson scattering system in LHD. In order to sensitively detect the anisotropy of electron temperature, we developed a new collection optics which observes LHD plasma horizontally while the conventional collection optics observed from obliquely downward. The new collection optics enables us to measure electron temperature along the direction approximately 12 degrees inclined from the magnetic field using the spectra resulting by the second pass beam. Figure 1 shows the waveform of the Thomson scattering (wavelength band is 1043-1052 nm) first measured with the new collection optics. Two peaks of scattering signal were clearly observed, and small noise was detected between the first and second peaks.

First, we confirmed that electron temperature measurements using spectra from first and second beams agree well for high collisionality plasma. Figure 2 shows the comparison of electron temperatures measured by spectra from first and second pass beams with the new collection optics. In Fig. 2, typical density was 3×10^{19} m^{-3}.

Although the shorter wavelength channel is crucial to measure high electron temperature, shortest spectral channel of the spectrometer for the new collection optics did not work properly. We used spectra from second passes of both the conventional and the new collection optics instead of first and second passes of the new collection optics. Spectra from second pass beam are generally much narrower than those of the first pass because of the difference of the scattering angle. Electron temperature along the direction 70 degrees and 12 degrees inclined from the magnetic field (hereafter written as T_{70} and T_{12} for convenience) are measureable with this setup.

We compared the electron temperature along above mentioned two directions. Most of plasma discharges with typical electron temperature and density of 5 keV and 1×10^{19} m^{-3} did not show the electron temperature anisotropy unless the collisionality was the order of 10^{-2}. On the other hand, there are 11 plasma discharges that show discrepancy of T_{70} and T_{12} during the electron cyclotron heating (ECH). Figure 3 (a) shows the comparison of electron temperatures during ECH for plasma discharges in which the temperature discrepancy was observed. As shown in Fig. 3 (b), the spectra evaluated from the measured signal did not agree well with those calculated with assumption of the Maxwellian velocity distribution function[1)]. Improvements of signal to noise ratio and accuracy of the spectral calibration might be needed to verify the certainty of the onset of the electron temperature anisotropy.

It is crucial not only to improve the signal to noise ratio with appropriate setups of the hardware but also the new analysis method applicable for low signal to noise ratio for the further detailed investigation. We applied the Singular Value Decomposition (SVD) method for analyses of waveforms of Thomson scattering signal. We found that the effect of noise component in the temperature was suppressed significantly when the signal and noise levels were comparable[2)].

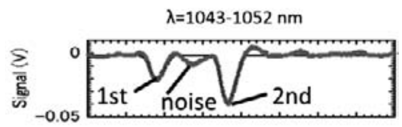

Fig. 1. Waveform of Thomson scattering first measured with the new collection optics.

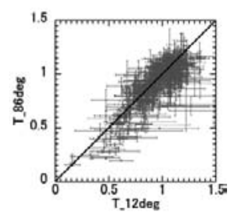

Fig. 2. Comparison of electron temperature measured with the new collection optics.

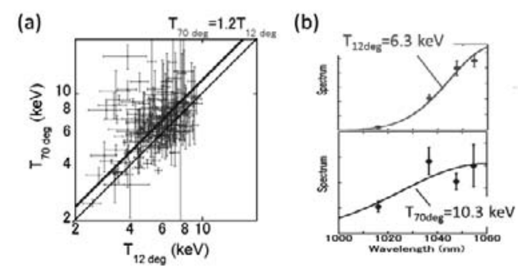

Fig. 3. Comparisons of (a) T_{70} and T_{12} and (b) spectra.

1) Yatsuka, E. et al.: 70th Annual Meeting of Japan Physical Society 24pAP-7 (2015).
2) Tojo, H. et al.: Rev. Sci. Instrum. **85**, 11D865 (2014) .