§3. Applications of Double-pass Scattering for Thomson Scattering Diagnostics

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Since typical scattering angle in the original LHD Thomson scattering system is 167°, LHD is one of the best devices to investigate the electron temperature measurement capability by the difference in the scattering angle of back and forward scatterings measured by the double-pass Thomson scattering method. One of the objectives is investigating the anisotropic electron velocity distribution function (electron temperature) of low collisionality plasma. Demonstration of the *in-situ* calibration of spectral transmissivity from plasma to detector is also the scope of this study. In future experiments, e.g. deuterium operation in LHD, JT-60SA and ITER, spectral transmissivity may degraded in an experimental campaign due to neutron and gamma irradiation to the optical components.

In the 17th cycle of LHD plasma operation, double pass Thomson scattering measurements were carried out for various kinds of plasma discharges. The spectra of scattered radiation resulting from the first pass of the laser beam injection reflect the distribution of the electron velocity almost perpendicular to the magnetic field. On the other hand, those from the second pass reflect the distribution of the electron velocity tilted approximately 70° from the magnetic field. We report only the case of electron temperature of lower than 4 keV, since the spectral transmissivity in the shorter wavelength region should be re-calibrated.

Figure 1 shows the ratio of electron temperatures measured by the scattered spectra resulting from the first and second passes of the laser beam injection as a function of the collisionality. The inverse aspect ratio was approximately 0.015 for the measurement point. Electron temperatures measured by two different spectra agree, particularly for high collisionality plasma.[1)] In the present setup, ratio of electron temperatures parallel and perpendicular to the magnetic field is written as follows:

$$T_{\perp} / T_{//} = 8.77\ T_1/T_2 - 7.77 \qquad (1)$$

where, T_1 and T_2 denote electron temperatures measured by spectra resulting from the first and second passes, respectively. It was confirmed that electron temperature is approximately isotropic ($T_{\perp}$ and $T_{//}$ do not differ manyfold) with the collisionality ν^* of more than 0.1. A new collection optics which has horizontal lines of sight is under development. For the new collection optics, the constants of proportionality and offset in Eq. (1) will vary from 8.77 and 7.77 to 1.04 and 0.04, respectively. Measurement sensitivity on anisotropy will be improved for further investigation.

Moreover, the *in-situ* spectral transmissivity calibration from plasma to the detectors was tried with LHD experimental data. The same method has already been demonstrated in TST-2 spherical tokamak in which typical electron temperature and scattering angle of the first pass are less than 0.3 keV and 120°, respectively. In this study, reliability of the *in-situ* spectral transmissivity calibration with higher electron temperature (up to 2 keV) and larger scattering angle (167°) was demonstrated. The scattered spectra in LHD are broader relative to those in TST-2. The *in-situ* spectral transmissivity calibration provides only the calibration of transmissivity averaged in each spectral channel of the polychromator. In other words, fine structure of spectral transmissivity in a spectral channel cannot be obtained from this method. Electron temperature is measured by the ratio of spectra resulting from first and second passes. Figure 2 shows electron temperatures measured by (horizontal axis) the scattered spectra resulting from the first pass of the laser injection; and (vertical axis) the ratio of spectra resulting from first and second passes. Electron temperature measured with the *in-situ* spectral calibration matches with measurements by the conventional method in which the spectral transmissivity was calibrated before the experiments. We have confirmed that the spectral transmissivity of the Thomson scattering system can be calibrated during the plasma discharges in LHD.[2)] This method would be applicable for the deuterium operations in LHD and JT-60SA.

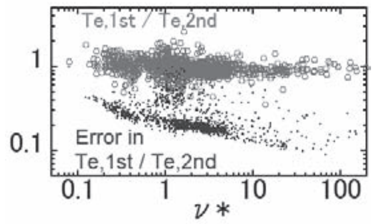

Fig. 1. Ratio of electron temperatures measured by the scattered spectra resulting from the first and second passes as a function of the collisinality.

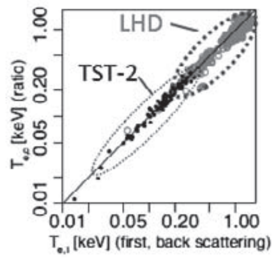

Fig. 2. Electron temperatures measured by (horizontal axis) the scattered spectra resulting from the first pass of the laser injection; and (vertical axis) the ratio of spectra resulting from first and second passes.

1) Yatsuka, E. et al.: 69th Annual Meeting of Japan Physical Society 28pAX-4 (2014).
2) Tojo, H. et al.: submitted to Fusion Eng. Des.