§26. 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 double-pass Thomson scattering method. Advantages of double-pass Thomson scattering method are: (1) expansion of the measurable range in the high temperature by forward scattering; (2) available for *in-situ* calibration of optical transmissivity[1)]; (3) available for anisotropic electron temperature measurements[2)]. For the anisotropic electron temperature measurements, the angle between the magnetic field and the scattering plane, formed by direction vectors of incident laser propagation and Thomson scattering, is also important. The ideal configuration is as follows: the magnetic field is parallel to the bisector of the angle formed by the direction of laser propagation and Thomson scattering or is perpendicular to this bisector.

Recently, a beam returning mirror with an optical delay path of 30 m has been installed outside the 4-I port for performing double-pass Thomson scattering measurements. We started double-pass scattering measurements using the original LHD Thomson scattering system. In the double-pass Thomson scattering, the sum of the two scattering angles is 180°, and typical scattering angle for forward scattering is 13° in LHD. Since two Thomson scattering spectra resulting from forward and back scatterings have significantly different broadnings, 7-channels polychromator was used for measurements. Four of them (ch1-4) are same channels as the low-T_e polychromator in LHD, and these are employed for accurately resolving forward scattering spectra. Remaining three channels (ch5-7) are same as conventional polychromator in LHD, and these are employed for accurately resolving back scattering spectra. Figure 1 shows an example of difference of Thomson scattering spectra of 10 keV plasma measured by forward (scattering angle of 10 deg.) and back (that of 170 deg.) scatterings. As preliminary results, two electron temperatures measured by forward and back scattering spectra seem to be consistent for low temperature (less than 1 keV) plasma. However, there is a significant difference between the intensities of forward and back scattering spectra. The reason might be combination of loss at the optical delay path, misalignment of returned beam with the collection optics and mismatch of returned beam divergence. Using a stimulated Brillouin scattering phase conjugate mirror (SBS-PCM) instead for a conventional mirror will be a key component for resolving latter two issues (alignment and divergence) because light reflected by a SBS-PCM propagates reversely against its original path.

In addition, a new collection optics which views plasma horizontally is being developed for anisotropic electron temperature measurements. Figure 2 shows the top view of the LHD equatorial plane. The new collection optics utilizes the laser and the returning mirror with an optical delay for the original LHD Thomson scattering system. In this collection optics, the magnetic field is approximately-parallel to the scattering plane. Thomson scattering spectra resulting from forward scattering reflects the electron velocity distribution function (EVDF) approximately along the magnetic field. On the other hand, backscattering reflects EVDF approximately perpendicular to the magnetic field (see Fig. 3). In addition, capability of more detailed EVDF measurements through double-pass Thomson scattering spectra measured by both the original and the new collection optics has been considered. From the 17[th] campaign, it is expected to measure the anisotropic electron temperature employing the new collection optics.

1) Tojo, H. *et al*.: Plasma Fusion Res. **6** (2011) 1302018.
2) Yatsuka, E. *et al*.: Nucl. Fusion **51** (2011) 123004.

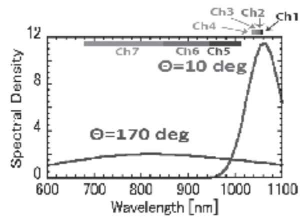

Fig. 1. Difference of Thomson scattering spectra of 10 keV plasma measured by forward (10 deg.) and back (170 deg.) scatterings.

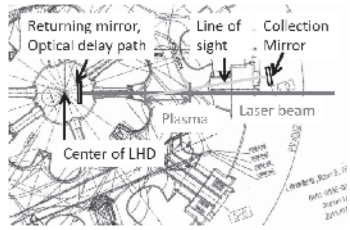

Fig. 2. Geometry of new collection optics (top view).

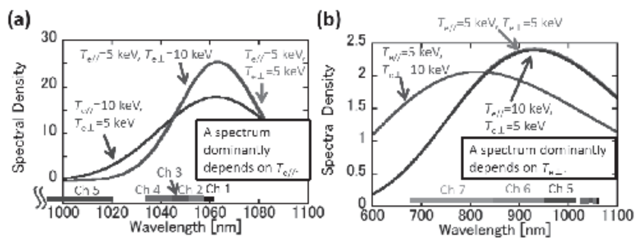

Fig. 3. Example of spectra; (a) forward scattering, (b) backscattering.