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

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For the Thomson scattering system in LHD, a typical scattering angle is 167°, and the LHD has a very large scattering angle in Thomson scattering systems other than a LIDAR system. Therefore, LHD is the optimal device in order to investigate the measurement capability of the electron temperature by the difference in the scattering angle of back scattering and forward scattering employing 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 measurement[2)]. To realize the double-pass Thomson scattering method, use of the phase conjugate mirror based on stimulated Brillouin scattering (SBS-PCM)[3)] is promising. Since a reflected beam by the SBS-PCM returns on the same path as the incident beam by means of the phase conjugation, alignment free operation is available except for an initial adjustment.

Since the Brillouin gain coefficient is inverse proportional to line width of the laser, the single longitudinal mode laser is necessary to obtain high reflectivity of the SBS-PCM. Combining two existing commercial lasers, we have developed a high-output-energy and high-repetition-rate laser system with single longitudinal mode to investigate measurement capability of the electron temperature in LHD as shown in Fig.1(a). We have successfully obtained 1.1 J of output energy at the 50-Hz operation as a laser performance. The laser beam of the new laser system has been injected into LHD plasma from the cycle 15th experiment, and the Thomson scattering measurement has started using new laser system. We have confirmed that it is normally measurable. The electron temperature and density profiles are measured by the new laser as shown in Fig.1(b). Figure 1(c) shows time history of laser power, the laser is fired at 50 Hz entire plasma shot. The steady measurement employing the new laser system has been attained.

Although anisotropic pressure plays an important role in plasmas, it has not been actively investigated in high temperature plasma experiments. Recently, it takes more interest in the Thomson scattering diagnostics for measurement of electron anisotropic pressure. It is necessary to measure the Thomson scattering spectra with a specific scattering angle configuration for measuring the anisotropic electron temperature. 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, and the sum of the two scattering angles is 180°. The last condition can be achieved by employing the double-pass Thomson scattering method. When the direction of the magnetic field is ideal, one of the spectra resulting from forward or backward scattering can be approximately determined only from the parallel electron temperature ($T_{//}$), and the other spectrum is approximately determined only from the perpendicular electron temperature ($T_{\perp}$). We have considered anisotropic electron temperature measurement in LHD. Considering the optical configuration, since the existing optical configuration using a 4-O-6 observation window (Fig.2(a)) does not satisfy the above-mentioned conditions, $T_{\perp}$ and $T_{//}$ are inseparable as shown in Fig.2(b). However, it found that an optical configuration using a 4-0-4 observation window (Fig.2(a)) is close to the ideal configuration and is available to measure $T_{\perp}$ and $T_{//}$ separately as shown in Fig.2(c). We are planning to measure the anisotropic electron temperature applying double-pass Thomson scattering method with the 4-0-4 observation window, and start design of new collection optics at 4-0-4 observation window.

1) Tojo, H. *et al.*: Plasma Fusion Res. **6** (2011) 1302018
2) Yatsuka, E. *et al.*: Nucl. Fusion **51** (2011) 123004
3) Hatae, T. *et al.*: Rev. Sci. Instrum **77** (2006) 10E508

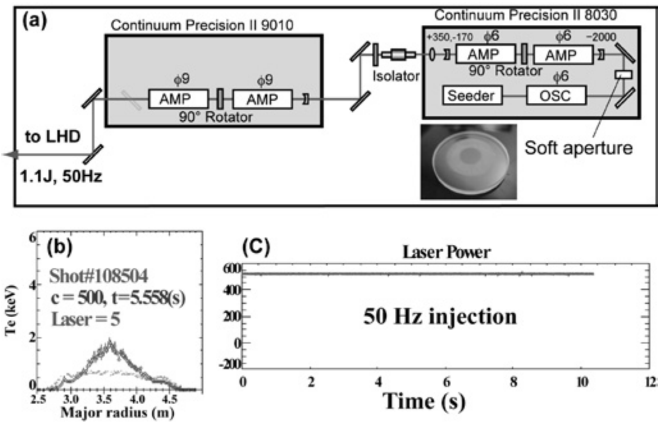

Fig. 1. (a)Optical layout of YAG laser system, (b) measured data using the YAG laser, (c) time history of the laser power.

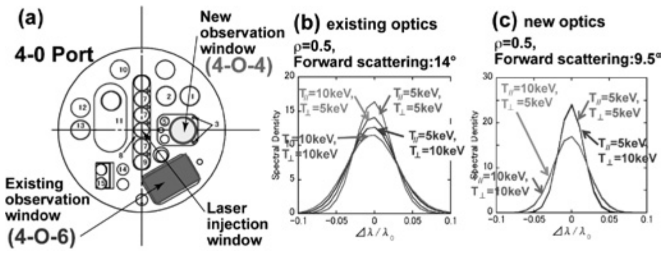

Fig.2. (a) window allocation for anisotropic electron temperature measurement, (b) Thomson scattering spectra using existing optics, (c) Thomson scattering spectra using new optics