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Double-pass Thomson scattering diagnosis on the TST-2 spherical tokamak device

TST-2球状トカマクにおけるダブルパストムソン散乱計測

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A double-pass Thomson scattering system, in which a laser pulse makes a round trip through the plasma, has been constructed. Using a fast detection unit, backward and forward scattering pulses in the signal can be resolved. Since these scatterings reflect electron temperature along different directions, electron temperature anisotropy can be estimated by the system. As a result, electron temperature anisotropy can be measured within the error bar of 10%. In order to search off-axis temperature anisotropy, new collection optics have been implemented. Using four polychromator units, electron temperature at four points in plasma can be measured simultaneously. In this conference, preliminary results by the double-pass multi-point system will be presented.

1. Introduction

Multi-pass Thomson scattering scheme is attractive for low-density plasma and electron temperature anisotropy measurements. Especially, direct measurement scheme of electron temperature anisotropy has not been established, while temperature anisotropy has important effects on plasma equilibrium and transport.

A significant improvement in the signal-to-noise ratio was achieved using a multi-pass Thomson scattering scheme on TEXTOR [1]. However, it is difficult to apply a similar multi-pass system to other devices because of the use of the intra-cavity configuration. In contrast, the configuration using a confocal spherical mirror is simple. The theoretical performance of this system was analyzed and confirmed experimentally [2]. Bowden *et al.* measured temperature anisotropy using a single-pass Thomson scattering for electron-cyclotron-heated low density plasmas (T_e ~ 1 eV and $n_e \sim 10^{17}$ m^{-3}) [3]. They switched the direction of the incident laser and measured reproducible plasmas. They detected slight temperature anisotropy.

When the plasma is in a collisionless regime, $T_{e\perp}$ can be higher than $T_{e\|}$ in the high field side, and $T_{e\|}$ can be higher than $T_{e\perp}$ in the low field side. Therefore, temperature anisotropy distribution is expected in this case. For preliminary study of multi-pass configuration, and in order to search for the anisotropy distribution, we have developed a double-pass multi-point Thomson scattering system.

2. Double-pass Thomson scattering system

On the Tokyo Spherical Tokamak 2 (TST-2) device, a compact and bright Thomson scattering diagnostic system using a large numerical-aperture fiber and a high power injection laser (Nd:YAG) was developed [4,5]. In order to measure electron temperature anisotropy, a double-pass Thomson scattering configuration has been implemented to the compact Thomson system using a spherical mirror [6]. Contrary to multi-pass configuration, double-pass configuration is relatively simple and easy to construct, since only one mirror should be aligned on the double-pass configuration. Figure 1 shows a schematic diagram of the principle of temperature anisotropy measurement by double-pass Thomson scattering scheme. Injected laser travels through the plasma and reflected back by a concave mirror, and scattering light pulse at each laser transit is measured by one polychromator unit. In order to distinguish these scattering pulses from each laser transit, a fast and low-noise detection system was developed, and the measured full width at half maximum (FWHM) of the laser pulse was about 10 ns [7]. Combining the double-pass configuration with the fast detection system, the forward and backward scattering pulses can be detected almost simultaneously (i.e., within the time separation of a few tens ns). Therefore, we can measure electron temperature anisotropy even if plasma reproducibility is poor. This is important when we study phenomena related to instabilities. When the angle between $\vec{k}_s$ - $\vec{k}_i$ and the toroidal field is far from 45 $^\circ$, the double-pass configuration provides the opportunity for temperature anisotropy measurements.

As a pilot experiment for the temperature anisotropy measurement, electron temperatures at the center of ohmic plasma has been measured by the double-pass system. In such region, temperature anisotropy is not expected. Figure 2 shows a typical waveform by the double-pass configuration. As a result, the degree of temperature anisotropy is

$$\left\langle \frac{T_{e\perp} - T_{e\parallel}}{T_{e\perp}} \right\rangle = 3\% \pm 10\% \qquad (1)$$

for high density ohmic plasmas. This result shows that electron temperature anisotropy can be measured within the error bar of 10%. Thus, result (1) implies that the significant temperature anisotropy was not found at the center of high density ohmic plasma.

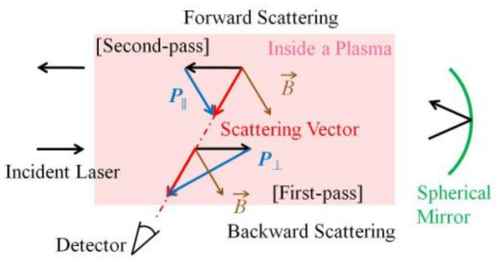

Fig.1. Principle of temperature anisotropy measurement by the double-pass system

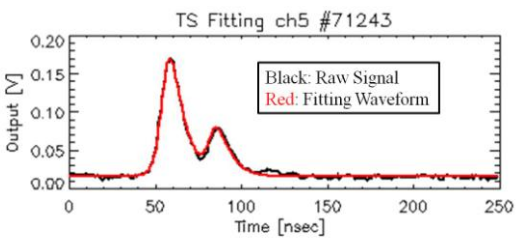

Fig.2. Typical waveform of the double-pass measurement

3. New collection optics for off-axis temperature anisotropy measurement

In order to search for the off-axis temperature anisotropy in collisionless regime for ohmic plasmas, new collection optics has been implemented (Fig. 3). A larger collection mirror and a new fiber bundle were installed. Using four detectors (polychromators) and four fibers, measurement can be performed at four points in plasma simultaneously, in which electron temperature can be measured around low field side, high field side and center of plasma.

Combining the double-pass and the new collection optics (double-pass multi-point system), radial distribution measurement of electron temperature anisotropy has been performed.

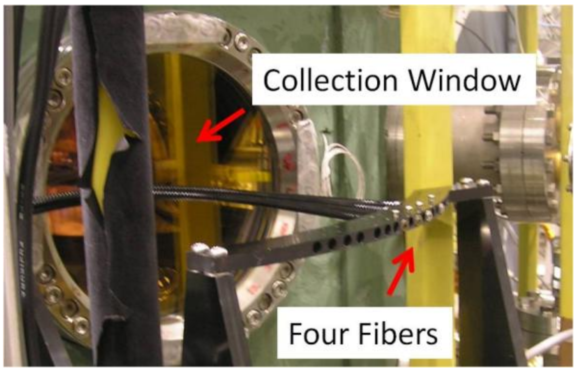

Fig.3. Photograph of the collection window and four fibers

Acknowledgments

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References

[1] M. Yu. Kantor. *et al*. Plasma Phys. Control. Fusion 51, 055002 (2009).

[2] J. Hiratsuka *et al*., Plasma Fusion Res. **5**, 044 (2010).

[3] M. D. Bowden. *et al*. J. Appl. Phys. 73 (6), 15 (1993).

[4] S. Kainaga. *et al*. Plasma Fusion Res. 3, 027 (2008).

[5] T. Yamaguchi. *et al*. Plasma Fusion Res. 5, S2092 (2010).

[6] J. Hiratsuka. *et al*. Plasma Fusion Res. 6, 1202133 (2011).

[7] A. Ejiri. *et al*. Plasma Fusion Res. 5, S2082 (2010).