Possibility of experimental observation of the electron temperature anisotropy in the LHD Thomson scattering diagnostic system

I. Yamada[1], R. Yasuhara[1], H. Funaba[1], K. Narihara[1], H. Hayashi[1],
E. Yatsuka[2], T. Hatae[2], and H. Tojo[2]
[1] National Institute for Fusion Science, Toki, Japan 509-5292
[2] Japan Atomic Energy Agency, Naka, Japan, 311-0193

Introduction

The Large Helical Device (LHD) Thomson scattering system has been upgraded as a hybrid backward and forward Thomson scattering system, as reported in the 40th EPS conference [1-3]. There are two objectives of the upgrade; extension of the measurable electron temperature (T_e) range [2] and the search for the electron temperature anisotropy in fusion plasmas [3]. In this article, we discuss the improvement with emphasis on the second objective.

Scattering configuration of the LHD Thomson scattering system

The typical scattering angles are 167 ^{o} and 13 ^{o} for the backward and forward scattering configurations, respectively, in the original design that uses a rectangular window; Window 1 in Fig. 1. In addition, we have installed new light collection optics using another circular window, Window 2 of which the center is located in the LHD mid-plane. Typical scattering angles in the new system are 171.2 ^{o} and 8.8 ^{o} for the backward and forward scattering configurations, respectively. By using the two windows and the two scattering configurations, a total of four directional components of electron temperature are obtained. Figure 2 shows an example of the angles between the magnetic field line and the four components. The magnetic axis is located at R = 3.65 m, and the last closed magnetic surface is located at R = 2.5 m and

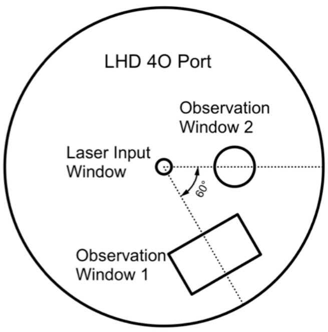

Fig. 1 Observation Windows 1 and 2. Window 2 is newly installed.

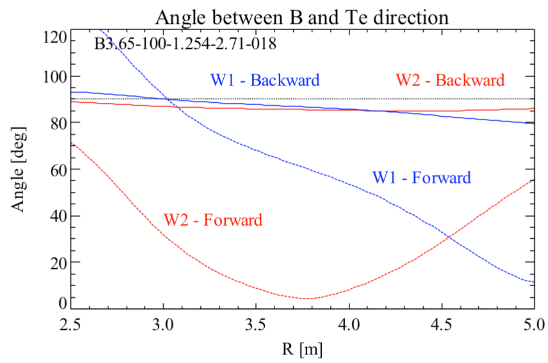

Fig. 2 Angle between the magnetic field line and observed T_e direction. The magnetic axis is located at R=3.65 m

4.9 m in the magnetic configuration, which is one of the most frequently used configurations in the LHD experiments. In the backward scattering measurement, the angles between the magnetic field line and measured temperature direction are about 90° for both Windows 1 and 2, for the whole observation region. On the other hand, the angles are about 0° at R = 5 m and 3.7 m for the forward scattering measurements using the Windows 1 and 2, respectively. Therefore, forward scattering measurements using the Windows 1 and 2 are suitable for the observation of the component parallel to the magnetic field line near the plasma edge and center regions, respectively.

Improvement of polychromator

The polychromators have been designed for backward scattering measurements using Window 1. For this reason, experimental uncertainty is large for the forward scattering measurements in the low temperature region, $T_e \leq 1$ keV. Figures 3(a) and 3(b) show the spectral response and estimated temperature error for a standard five-channel polychromator. The temperature range over which both the errors in the backward and forward scattering measurements are less than 10 % is T_e = 1.3 keV-10.9 keV. In order to search for electron temperature anisotropy, both the backward and forward scattering temperatures must be

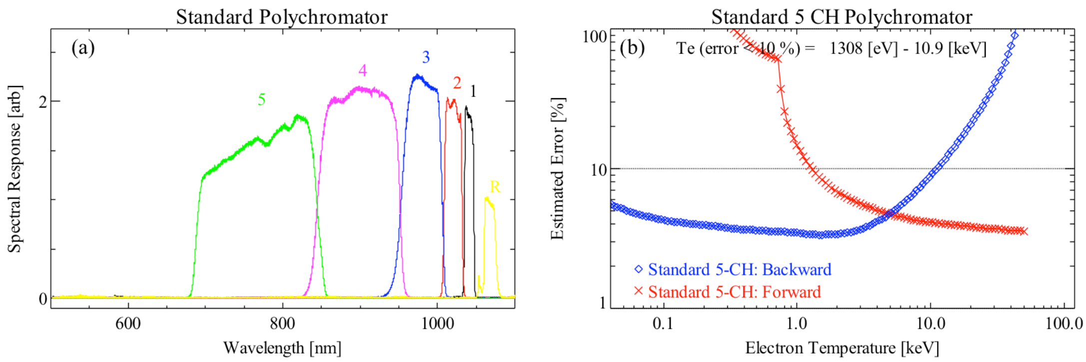

Fig. 3. Spectral response of the standard type polychromator, (a), and estimated error, (b).

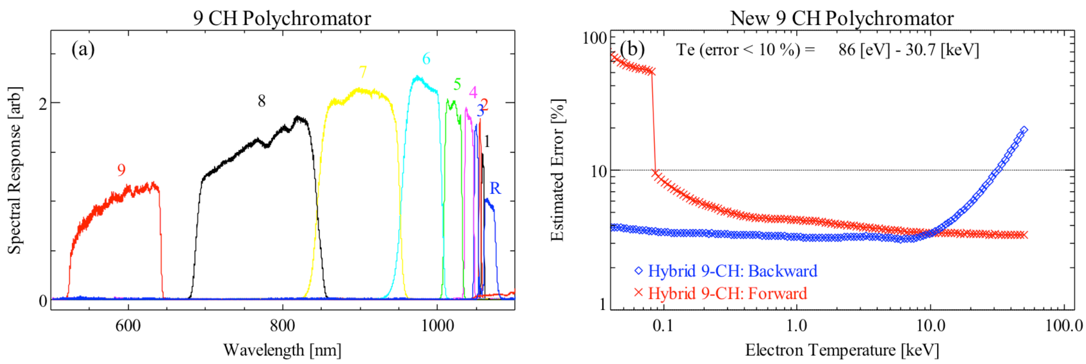

Fig. 4. Spectral response of the nine-channel polychromator, (a), and estimated error, (b).

accurately measured. So, we plan to develop a nine-channel polychromator, the spectral response of which is shown in Fig. 4(a). The channels #4-#8 are the same as the channels #1-#5 of a standard polychromator. The left channel, #9, is added to reduce the experimental error for the backward scattering measurements at $T_e \geq 10$ keV. The right channels, #1-3, are added to reduce the experimental error for the forward scattering measurements at low temperatures. The error estimation is shown in Fig. 4(b). By using the nine-channel polychromator, the temperature range over which the experimental error is less than 10 %, in both the backward and forward scattering measurements, is expected to be expanded to T_e = 86 eV-30.7 keV.

Calibration of the transmittance of the light collection optics

Until now, we did not carry out the complete calibration of the light collection system because, from the manufacturer's specification data, the wavelength dependence was assumed to be almost flat. However, the secular change might occur. So, we experimentally measured the wavelength dependence of the light collection system. The light collection system of the LHD Thomson scattering system consists of an observation window, light collection mirror, and optical fibers, as shown in Fig. 5. We measured the wavelength dependence of the total transmittance at six locations by using a light source and spectrometer. The total transmittance is the product of the window transmittance, mirror reflectance, and fiber transmittance.

Figure 6 shows the result as well as the spectral response of a standard type polychromator. It is noted that they are normalized to 1 at a wavelength, λ = 1050 nm. The wavelength range of the polychromator is λ =690-1050 nm. The total efficiency shows a weak wavelength dependence. Also position dependence is seen as shown in Fig. 7. The later would be caused due to variation of geometrical factors. For reference, the window transmittance, fiber transmittance, mirror reflectance, and their product are shown in Fig. 8. They were individually measured two years ago, and there is a difference between the present and these two year-old results. Geometrical factors were not taken into accounts in the previous measurements. However, it is the completely same as the actual configuration in the present calibration. So, data obtained henceforth will

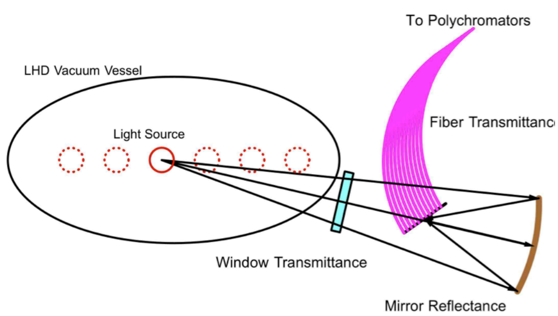

Fig. 5. Light collection system of the LHD Thomson scattering system. The total transmittance was measured by introducing a calibrated light source inside the LHD vacuum vessel.

be more reliable. Experimental error will be further reduced by taking the wavelength dependence and the position dependence into account. The improvement of polychromators and careful calibration of the total transmittance are required to obtain reliable data on temperature isotropy.

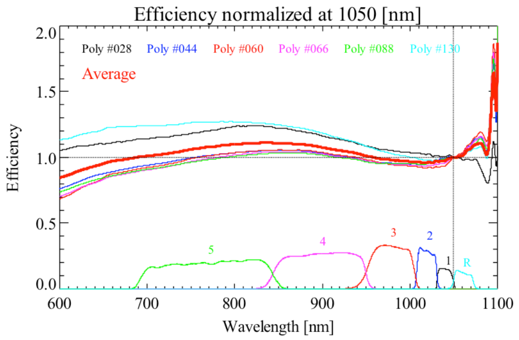

Fig. 6. Efficiency of the light collection optics and spectral response of a standard-type polychromator.

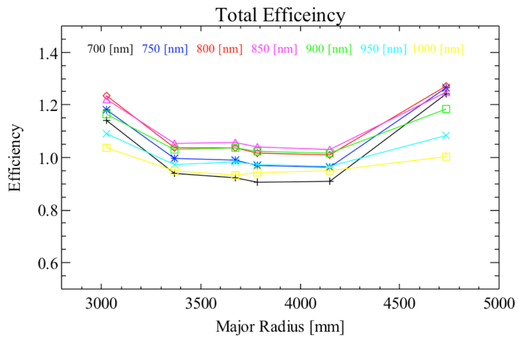

Fig. 7. Position dependence of the total transmittance.

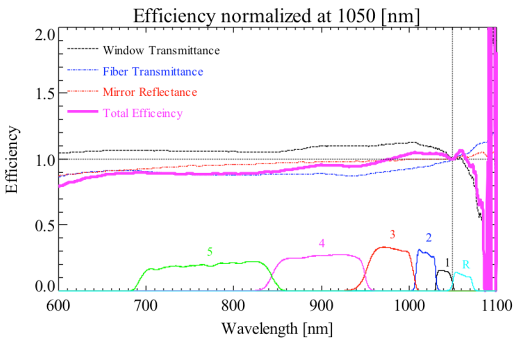

Fig. 8. Previous result for the window transmittance, fiber transmittance, mirror reflectivity, and their product.

Acknowledgements

This work was supported by the NIFS LHD project budgets (NIFS12ULHH005 and NIFS13ULHH005) and JSPS KAKENHI Grant Number 25289341.

References

[1] I. Yamada *et al.*, Fusion Sci. Tech., 58, 345 (2010).

[2] I. Yamada *et al.*, Rev Sci. Instrum., 83, 10E340 (2012).

[3] I. Yamada *et al.*, Europhysics conference abstracts, 37D, O2.112 (2013).