Electron temperature measurements using the LHD Thomson scattering system having four scattering configurations

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Introduction

The Large Helical Device (LHD) Thomson scattering system has routinely measured electron temperature (T_e) and density (n_e) profiles of LHD plasmas. [1][2] The LHD Thomson scattering system has two scattering configurations: backward and forward Thomson scatterings, as reported in the previous EPS conferences [3][4]. There are two objectives of the upgrade; extension of the measurable electron temperature (T_e) range and the search for the electron temperature anisotropy in fusion plasmas. We installed new light collection optics to observe T_e component parallel to the LHD magnetic field line around the plasma center. We describe the LHD Thomson scattering system having four scattering configurations and the first result obtained by using the new light collection optics.

Scattering configuration of the LHD Thomson scattering system

Figure 1 shows the schematic diagram of the LHD Thomson scattering system. In the original design of the LHD Thomson scattering system, the backward Thomson scattering light is observed. By installing a beam returning system, the LHD Thomson scattering system now can observe both the backward and forward Thomson scattering lights. The typical scattering angles are 167 ^{o} and 13^{o} for the backward and forward scattering configurations respectively. In the original design, a rectangular window, whose dimensions are 600 mm x 350 mm, was installed, and 144 optical fibers and

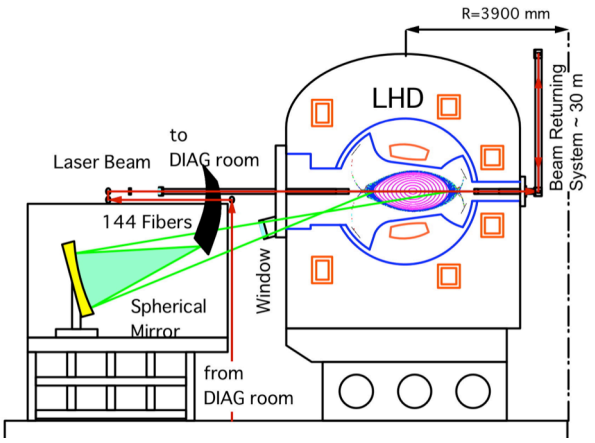


Fig. 1. Schematic diagram of the LHD Thomson scattering system.

polychromators have been used to measure $T_e s$ and $n_e s$ at 144 spatial points along the LHD major radius. In addition to the main light collection system, we now installed the second window, whose diameter is 340 mm. The center of the second window is located on the LHD mid-plane as shown in Fig. 2. A schematic diagram of the geometrical configuration of the two windows is show in Fig. 3. The scattering angles in the new system are 171.2° and 8.8° for the backward and forward scattering configurations, respectively. At the present, the second light collection optics observes T_e and n_e at a spatial point (plasma center). The number of measurement points will be increased by adding optical fibers and polychromators.

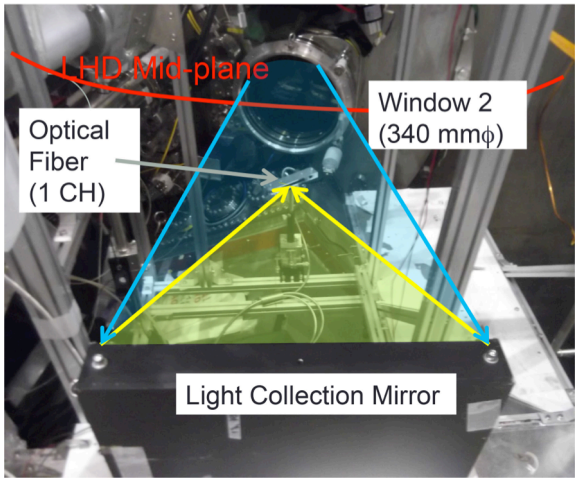


Fig. 2. Newly installed second light collection optics.

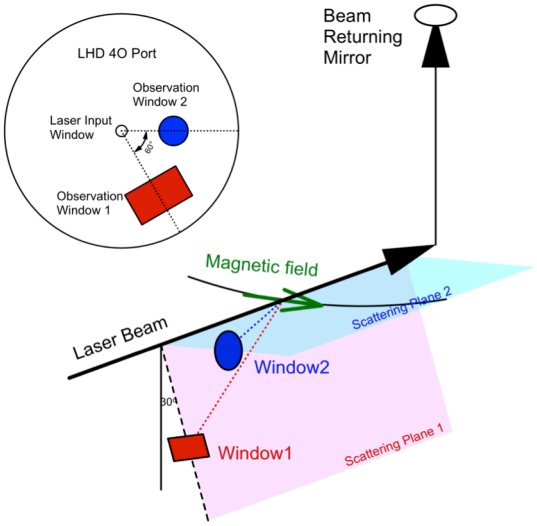


Fig. 3. Schematic diagram of the two view windows.

By using the two windows and the two scattering configurations, total four directional components of $T_e s$ are obtained. Figure 4 shows the angles between the magnetic field line and the four T_e components. The magnetic axis is located at R = 3.65 m, and the positions of the last closed magnetic surface is R = 2.5 m and 4.9 m. In the backward scattering measurements, the angles between the magnetic field line and measured temperature direction are about 90° for both the Windows 1 and 2 in 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 T_e component parallel to the magnetic field line in the plasma edge and center regions, respectively.

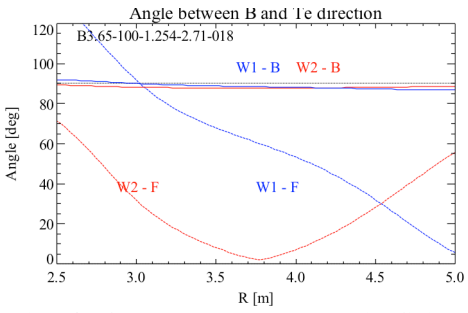


Fig. 4. Angle between magnetic field line and the observed direction of electron temperature.

Experimental

In the experiment, we used a newly constructed 7-wavelength channel polychromator. It is specially optimized to both the backward and forward scattering measurements. The spectral response is shown in Fig. 5. In the forward scattering measurement, the three longer wavelength channels, CH.1-3, play an important role because the width of forward Thomson scattering spectrum is much narrower than that for backward scattering. On the other hand, all the seven channels are used to determine backward scattering $T_e s$. In the experiment, we used a fast digitizer system based on four fast oscilloscopes to observe both the backward and forward scattering signals simultaneously. Figure 6 shows an example of Thomson scattering signals measured by two polychromators that see around the plasma center through Windows 2 and 1. The upper two figures show the backward and forward scattering signals obtained by

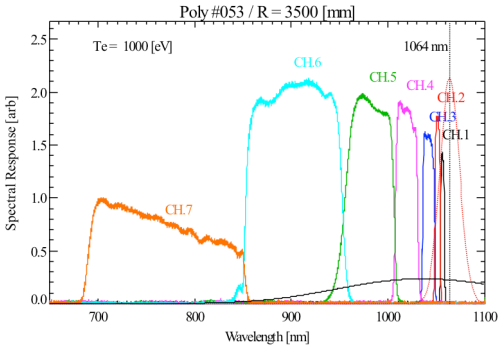


Fig. 5. Spectral response of the 7-channel polychromator. Thomson scattering spectrum for the backward and forward scatteings at 1000 eV are also plotted.

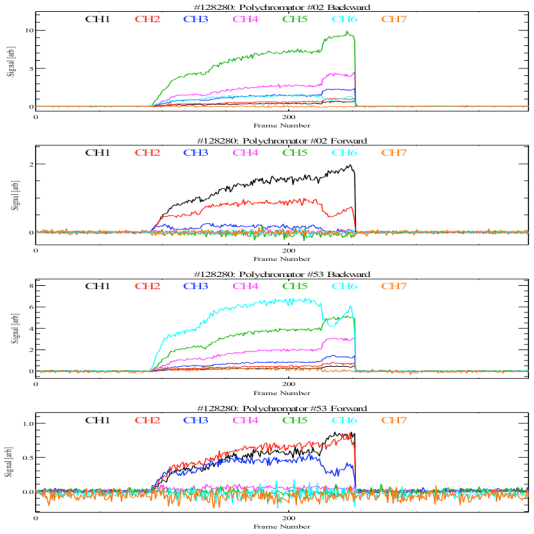
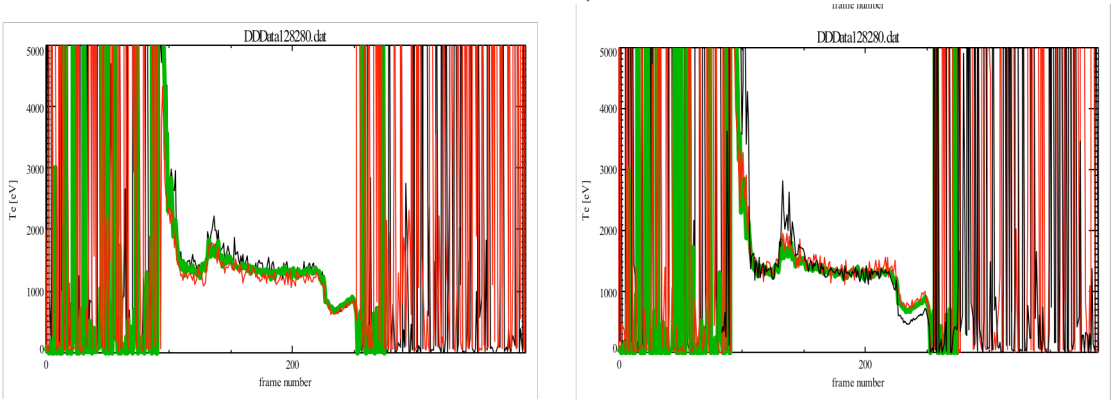


Fig. 6. Thom scattering signals obtained by two polychromators.

a) b)



Figs. 7. Figures a) and b) show comparisons of the backward and forward scattering electron temperatures obtained by using Window 2 and Window 1 respectively. Thick curves in the figures show Te obtained by the main LHD Thomson scattering system. They show good agreements within the experimental errors of ~10-20 %.

a polychromator for the Window 2. The lower two figures show those for a polychromator for the Window 1. A T_e component is obtained from each set of the Thomson scattering signals

Figures 7 a) and b) show backward and forward scattering T_e*s* obtained by the new and main light collection optics respectively. The T_e determined from the main LHD Thomson scattering system is also plotted (thick curves). The T_e*s* show good agreements within the experimental errors of about 10-20%, suggesting the system for measuring four T_e*s* components works well.

Summary and Future Plan

We have installed new experimental apparatus on the LHD Thomson scattering system to observe four electron components by using backward and forward scattering configurations, and two light collection optics. The first result shows that the system works well. However, further optimization of polychromators and development of data analysis procedure will be needed to reduce experimental errors.

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