§1. Improvements of Data Quality of the LHD Thomson Scattering System in High-Temperature Region

Yamada, I., Narihara, K., Funaba, H., Hayashi, H., Kohmoto, T.

In the Large Helical Device (LHD) low electron density ($n_e$), high electron temperature ($T_e$) experiments, $T_e$ more than 15 keV has been observed by the LHD YAG Thomson scattering diagnostics. Since the LHD Thomson scattering system has been optimized for the temperature region, 50 eV $\leq T_e \leq$ 10 keV, data quality tends to be worse in higher $T_e$ region exceeding 10 keV. In order to accurately determine $T_e$, in the high-$T_e$ experiments, we tried to increase laser pulse energy. In addition, another two signal accumulation methods were also tested.

For improvements of the data quality of the Thomson scattering diagnostics in low-$n_e$ plasma experiments, increasing laser pulse energy is one of the useful techniques. In the 13th LHD experiment campaign, we tried simultaneous firing of up to three lasers to improve data quality in low-$n_e$, high-$T_e$ ECRH plasma experiments. Figure 1 shows an example of raw signal waveform detected by a wavelength channel in a polychromator, and gate pulse applied to analog-to-digital converter. A comparison of $T_e$ profiles obtained by 1 laser and 3 lasers is shown in Fig.2. The electron densities were $\sim 0.3 \times 10^{19}$ m$^{-3}$ in both discharges. As shown in the left figure, $T_e$ errors are large in the temperature range above $\sim$10 keV whereas those are small below $\sim$8 keV. By using three lasers, $T_e$ error bars have been successfully decreased by 50 % around the plasma center. When two lasers are used, $T_e$ error bars are decreased by 45 %. Degree of improvement of data quality is more significant around the plasma center, $T_e \geq 10$ keV.

Next, we tried the raw data accumulation method on fixed plasma discharges to decrease statistical uncertainties. Total 29 fixed plasma discharges were carried out. The line electron densities were $\sim 0.3 \times 10^{19}$ m$^{-2}$, and the reproducibility was within $\pm$10%. In this case, each $T_e$ profile was measured with 1 laser pulse. Figure 3 shows $T_e$ profiles obtained by raw data accumulation of fixed 1, 3, 9, and 29 plasma discharges. Relative errors around the plasma center, $\delta T_e(0)/T_e(0)$, are 26 %, 15 %, 8.8 %, and 5.5 %, respectively. The other data accumulation method was also tested. In this method, raw signals in a few time frames within a stationary temporal period are summed up. By using this method, data quality has been improved by 54 % and 39 % when 3 and 5 temporal frames are added, respectively.

Figure 4 shows the summary of degree of improvement of $T_e$ data quality. Horizontal axis stands for the number of laser pulses or accumulated raw data, and vertical axis shows the uncertainty of $T_e$ normalized to unity at $n=1$. The results in the simultaneous laser firing mode are plotted as crosses. A series of diamonds and triangles are obtained by the shot accumulation method and the frame accumulation method, respectively. Solid curve shows $n^{-1/2}$. Roughly speaking, normalized $T_e$ errors in the three different methods show similar behavior, as $n^{-1/2}$. This suggests that the $T_e$ data quality is mainly determined by the statistical uncertainty in low-$n_e$, high-$T_e$ plasma experiments.