§1. Thomson Scattering Diagnostic in the LHD High-temperature, Low-density Plasma Experiments

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In the 14th LHD experiment campaign, electron temperature (T_e) more than 20 keV was observed by the LHD YAG Thomson scattering system. Since the LHD Thomson scattering system has been optimized for the temperature region, T_e=50 eV-10 keV, data quality tends to be worse in higher T_e region exceeding 10 keV. Furthermore, since electron density (n_e) is low in usual high-T_e experiments, both signal intensity and signal-to-noise (S/N) ratio are also low. This makes accurate measurements difficult. In order to accurately determine T_e in the high-T_e, low-n_e experiments, we tried to increase effective laser pulse energy. In addition, another three signal accumulation methods were also tested.

For improvements of the data quality of the Thomson scattering diagnostic in high-T_e, low-n_e plasma experiments, increasing laser pulse energy has been verified to be an effective method.[1-3)] In the 13th LHD experiment campaign, we tried simultaneous firing of up to three lasers to improve T_e data quality. In the 14th experiment campaign, we tried to increase S/N ratio by narrowing the gate width from 200 nsec to 85 nsec. Figure 1 shows an example of laser pulse waveform in the simultaneous firing operation. The vertical arrow shows the peak position of each laser pulse. Next, we tried following three raw data accumulation methods in order to increase signal intensity.

1) Fixed plasma shot data accumulation
2) Frame data accumulation of three neighboring time frames
3) Position data accumulation of three neighboring position channels

The three data accumulation methods can be applied simultaneously. In the data accumulation methods, signal intensity can be increased, but improvement of S/N ratio is not expected. In the simultaneous laser firing method, both signal intensity and S/N ratio are increased.

Figure 2(a) shows T_e profiles obtained from 1 laser pulse and without any data accumulation methods (1 plasma discharge, 1 time frame, and 1 position channel). Figure 2(b) shows T_e profile obtained from 3 laser pulses,

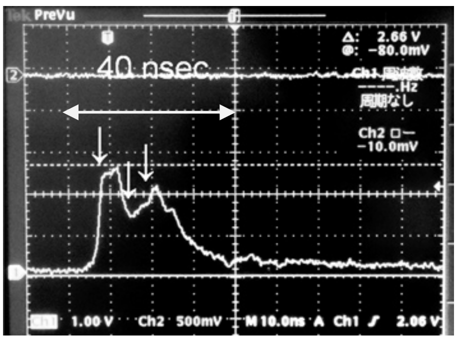

Fig.1. Laser pulse waveform in the simultaneous firing operation.

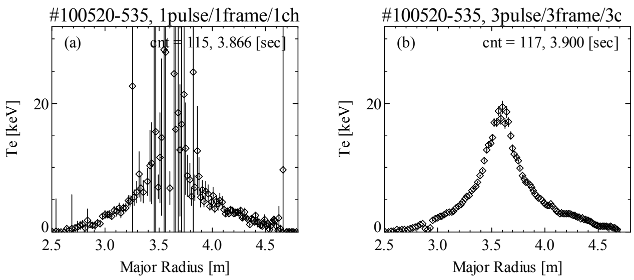

Fig. 2. (a) Te profile without simultaneous laser firing and data accumulation methods, (b) simultaneous laser firing and all data accumulation methods were applied.

15 fixed plasma discharges, 3 time frames, and 3 position channels. The electron densities were 0.2×10^{19} m^{-3} in the plasma discharge. As shown in the figure, T_e errors have been significantly improved especially in the temperature range, $T_e \geq 10$ keV, and clear T_e profile is observed by using above the methods.

Figure 3 shows the summary of degree of improvement of T_e data quality. Horizontal axis stands for the laser pulse energy included in data analysis, and vertical axis shows the uncertainty of $dT_e(0)/T_e(0)$. In the case of single laser pulse, 1.6J, 1 plasma discharge, 1 time frame, 1 position channel, $dT_e(0)/T_e(0)$ is about 100 %. When signals are accumulated by adding signals from (3 laser pulse) x (15 fixed plasma discharge) x (3 time frames) x (3 position channels), signal intensity can be increased by 400 times, corresponding to the laser pulse energy of 600 J. Figure 3 clearly shows that $dT_e(0)/T_e(0)$ decreases as the laser pulse energy (PE) increases, as $PE^{-1/2}$. This suggests that statistical uncertainty is dominant in the experimental error in high-T_e, low-n_e plasma experiments, and further improvement of data quality can be expected by increasing laser pulse energy.

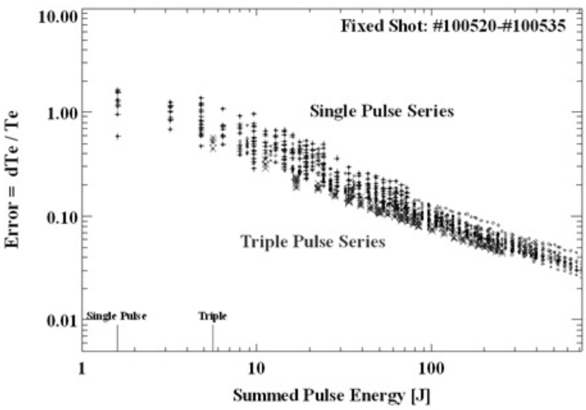

Fig. 3. Degree of data quality improvement.

1) Yamada, I. *et al.*, Rev. Sci. Instrum., 72, 1126 (2001).
2) Yamada, I. *et al.*, Annual Rep. NIFS, 2000-2001, 149, (2001).
3) Yamada, I. *et al.*, Rev. Sci. Instrum., 81, 10D522 (2010).