

# §1. Proposal of New Methods to Extend Measurable $T_e$ Range of the LHD Thomson Scattering System

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In the LHD high electron temperature experiments, 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. We already proposed a simultaneous laser firing technique and three data summing-up methods to improve data quality in the  $T_e$  region. They have been successfully applied.[1][2] In addition to these methods, we are also planning to apply another two methods to improve data quality in high  $T_e$  range.

First we have installed the sixth wavelength channel that observes shorter wavelength region in some polychromators. The LHD Thomson scattering standard-type polychromators have five wavelength channels, and observe the wavelength region of 670-1055 nm. The sixth channel observes the wavelength region of 520-640 nm. There is a gap between 640-670 nm to avoid  $H\alpha$  line. We estimated  $T_e$  and  $n_e$  errors by using mock Thomson scattering signal data. Figure 1 shows the estimated experimental errors in  $T_e$  and  $n_e$  when wavelength channels #1-#4, #1-#5 and #1-#6 are used in the data analysis. We note that the error estimations are carried out at electron density of  $5.0 \times 10^{19} \text{ m}^{-3}$ . In the LHD Thomson scattering diagnostic, main error source has been found to be originated from shot noise in measured Thomson scattering signals, the  $\delta T_e/T_e$  at different densities can be easily estimated from  $\delta T_e/T_e \propto n_e^{-1/2}$ . In the case where #1-#5 wave length channels are used, the  $T_e$  error becomes rapidly larger above 10 keV, and reaches 100 % at 50 keV. This agrees well with the experimental results. On the other hand, the  $T_e$  error is less than 10 % even at 30 keV when the signal of the 6th channel is taken into account. About density error  $\delta n_e/n_e$ , the difference among the three cases is small, and all of them are less than 5 % in the  $T_e$  range studied.

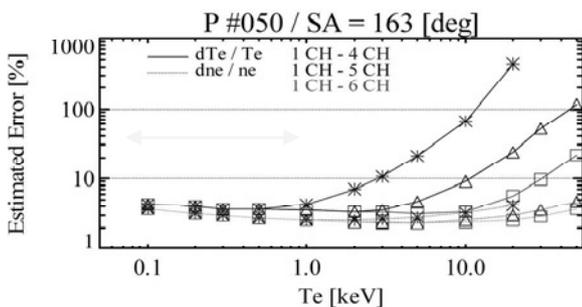


Fig.1. Estimated  $T_e$  (solid curves) and  $n_e$  (dashed curves) errors. Crosses, triangles, and squares show  $T_e$  and  $n_e$  errors when wavelength channels #1-#4, #1-#5, and #1-#6 are used respectively.

Next, we are planning to utilize a forward scattering configuration with the scattering angle of 17 degree whereas a backward scattering configuration with the scattering angle of 163 degree has been applied in the LHD Thomson scattering system. Data quality improvements at high- $T_e$  is expected by using forward scattering configuration, because the width and peak shift of the Thomson scattering spectrum becomes narrower and smaller respectively then the matching condition between Thomson scattering spectrum and wavelength region observed by polychromators is improved. Figures 2 a) and b) show comparisons of estimated  $T_e$  and  $n_e$  errors respectively, in backward scattering and forward scattering configurations. In the estimation, wavelength channels #1-#5 were used. As expected, the forward scattering configuration provides better results for the temperature range above 5 keV, whereas it is not good for lower  $T_e$  range. When such forward scattering configuration is applied,  $T_e$  error,  $\delta T_e / T_e$  will be reduced less than 10 % even at 50 keV. About the  $n_e$  error, backward scattering configuration provides better result in almost whole region studied. In the figures, experimental errors are also plotted for the case where both backward and forward scattering signals are simultaneously accumulated. Even in this situation,  $\delta T_e / T_e$  is estimated to be less than 10 % even at 50 keV.

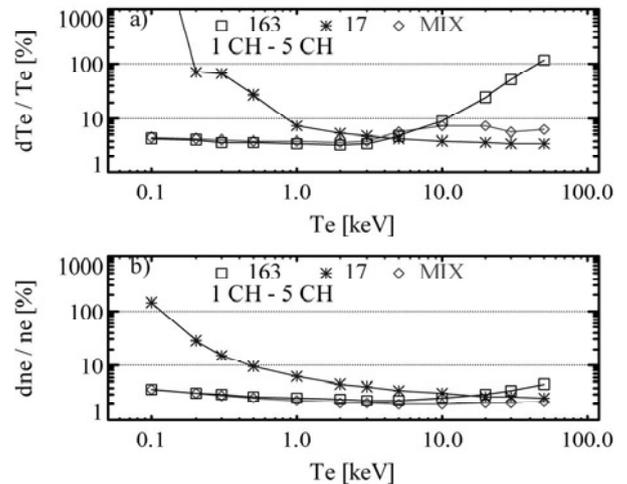


Fig.2. Estimated  $T_e$  and  $n_e$  error when the wavelength channels #1-#5 are used for the backward scattering configurations, squares and forward scattering configurations, crosses. Diamonds show the result for the hybrid backward-forward scattering configuration..

- 1) Yamada, I. *et al.*, Rev. Sci. Instrum., 81, 10D522 (2010).
- 2) Yamada, I. *et al.*, J. Instrum, accepted (2012).