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LHD トムソン散乱計測における GPU を用いた 並列計算による電子温度・密度評価

Evaluation of electron temperature and density by parallel processing with GPU in the LHD Thomson scattering diagnostics

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Parallel processing with GPU (Graphical Processing Unit) is widely used in general-purpose computing. In the field of the plasma diagnostics, the KSTAR Thomson scattering system adopts CUDA (Compute Unified Device Architecture) for the real-time measurement [1, 2].

Since a Thomson scattering system has usually many signal channels which depends on the numbers of the spatial positions ($N_{\rm poly}$) and the spectral channels ($N_{\rm ch}$), the data analysis may be suitable for the parallel processing. In the Thomson scattering system of the Large Helical Device (LHD) [3], the number of signal channels is more than 740. The calculation of the electron temperature, $T_{\rm e}$, and the electron density, $n_{\rm e}$, is made for each timings of the laser pulse. Since the usual laser is operated in 30 Hz on LHD, the number of timings ($N_{\rm time}$) is in the order of 10^4 when the long pulse experiment is operated.

The evaluation of $T_{\rm e}$ is usually made by the χ^2-method, where the $T_{\rm e}$ value is derived by minimizing χ^2 which represents the deviation between the measured signals and the predicted signals for a specific $T_{\rm e}$. The minimum χ^2 is derived from after many calculations for preset $T_{\rm e}$ values. The number of the preset $T_{\rm e}$ (N_{Te}) is almost 5000 $\sim$ 10000. Figure 1 shows a schematic diagram of data processing in the Thomson scattering system on LHD. Typical numbers of signals and numbers of independent calculations for the case of $N_{\rm poly} = 144$, $N_{\rm ch} = 5$, $N_{\rm time} = 1000$, and $N_{Te} = 7000$ are also shown. $N_{\rm time} = 1000$ corresponds to the operation of the laser for about 33.3 sec.

In this study, the CUDA calculation is tested for the χ^2 derivation where the number of the independent calculations becomes in the order of $10^9 \sim 10^{10}$. One GPU board of NVIDIA GeForce RTX 3090, which has 10496 CUDA cores, is used. As a reference, the calculation time by CPU (Central Processing Unit) without parallel processing for deriving χ^2 in the first 1000 timings of a long pulse plasma (Shot No. 179273) is measured. It takes about 36.6 s in the CPU case. In the GPU case, the calculation time is about 1.1 s, however, extra times of 1.3 $\sim$ 1.8 s are required for the data transferring between the memories of CPU and GPU before and after the GPU calculations.

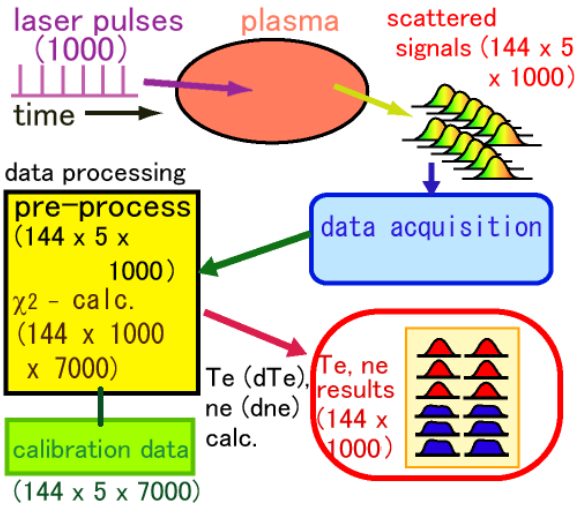

Fig. 1. Schematic diagram of signal and data processing in the Thomson scattering system on LHD. Typical numbers of the signals and numbers of independent calculations in a plasma operation are shown. ($N_{\rm poly} = 144, N_{\rm ch} = 5, N_{\rm time} = 1000$, and $N_{T\rm e} = 7000$)

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