Real-time Thomson scattering diagnostics and data processing for plasma control on LHD

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The real-time Thomson scattering diagnostics on the Large Helical Device (LHD) has been operated in order to provide the data of the electron temperature, T_e, and the electron density, n_e, profiles for a plasma control system as input. This plasma control system is called Assimilation System for Toroidal plasma Integrated simulation (ASTI) [1], which is based on the data assimilation. ASTI is developed to control and predict the fusion plasma by constructing the digital twin in the numerical space and evaluating many complex elements such as inside state of the plasma itself, heating, fueling, diagnostics, and so on.

The Real-time data acquisition of the Thomson scattering diagnostics is realized by the ”RTRetrieve” system on LHD [2]. It takes almost 60 ms from the laser timing to the end of the data reading. The time for calculating T_e, and n_e, is about 23 ms and the total delay time is more than 100 ms at present. Although this value is relatively large as the real-time measurement system, the energy confinement time is much longer than that and the transport calculations in ASTI requires about 60 ms, it is allowed for the experiment of ASTI on LHD.

Figure 1 shows the relation between the real-time measurement and ASTI. The real-time Thomson scattering data is obtained in 10 Hz but they are used in every 300 ms. The plasma is considered both in the real space and in the numerical space. The state vectors in the numerical space consists of T_e, n_e, ion temperature, T_i, transport coefficients for electrons and ions, χ_e, χ_i, and heating power by the electron cyclotron heating (ECH), P_{ECH}, and so on. At t = -0.3 s (1 in Fig. 1), the state vectors are developed until t = 0.0 s by many transport calculations in parallel. When the real-time T_e data become available (2 in Fig.1), the state vectors are filtered and more precise prediction for t = 0.0 s can be made. Then, the P_{ECH} is commanded which gives the new target T_e at t = 0.0 s (3 in Fig. 1). In the previous experiment campaign of LHD, gradient in the T_e profiles was controlled by the ASTI system.

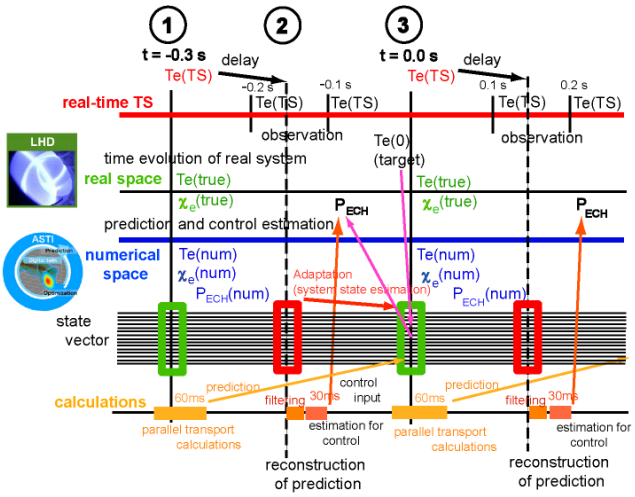

Figure 1. Relation between real-time Thomson scattering diagnostics and plasma control by ASTI.

[1] Y. Morishita, *et al.*, Sci. Rep. **14** (2024) 137.
[2] H. Nakanishi, *et al.*, IEEE Trans. Nucl. Sci. **63** (2016) 222.

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