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Multi-Parameter Measurement Using Finite Electron Temperature Effect on Laser Polarimetry for Burning Plasma Reactor

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The authors have proposed a multi-parameter measurement system which identifies current density (j_phi), total plasma current (I_p), electron density (n_e) and electron temperature (T_e) from information of a laser polarimetry and a plasma boundary. This study carries out performance assessment of the multi-parameter measurement and proposes a new equilibrium solver suitable for the measurement. Laser wavelength, an injection laser layout and measurement errors were 57/119/171 micro-meter, 15 viewing chords, 0.1 degree error on the Faraday effect measurement, and 0.6 degree error on the Cotton-Mouton effect measurement, respectively. A reference profile of j_phi was supposed to be ITER operation scenario 2 (an inductive scenario), and n_e and T_e at the magnetic axis were supposed to be 10^{20} m^{-3} and 30 keV, respectively. The reconstruction error of j_phi (I_p), n_e and T_e were 3.8 %, 3.9 %, and 22 %, respectively. When the reconstruction is carried out with the given information of a plasma boundary, a finite element method is usually applied to the equilibrium solver. However, it is difficult to make equilibrium reconstruction in real time by using the finite element method because of optimization of mesh generation and mapping the measurement data to a local non-dimensional coordinate. The new equilibrium solver for the first time applies meshless methods to a non-linear problem of the Grad-Shafranov equation and can solve problems of applying the previous method to real-time plasma control. Modified meshless methods (RBF-MFS and Kansa's method) solved Grad-Shafranov equation ten to hundred times faster than the finite element method, to obtain a same accuracy. Since a laser polarimetry does not depend on time history and a plasma boundary can be detected by a time-history-independent diagnostics, the new reconstruction method including the new equilibrium solver is suitable for steady state operation (e.g. one year) to obtain multi-parameters (j_phi, I_p, n_e, and T_e) from a small number of diagnostics (e.g. a poloidal polarimeter and a reflectometer at least).

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