# §29. Optimization Study of Density Reconstruction Method by Microwave Reflectometry in Large Plasma Devices

Mase, A., Yokota, Y., Kogi, Y. (KASTEC, Kyushu Univ.),
Hojo, H. (Univ. of Tsukuba),
Kawahata, K., Tokuzawa, T.

We have applied an ultrashort-pulse reflectometry (USPR) to LHD. The USPR system utilizes an impulse with 22 ps pulse width as a source. Since the bandwidth of an impulse has an inverse relation to the pulse width, we can cover the frequency range of micro- to millimeter waves with a single source. The density profiles can be reconstructed by collecting time-of-flight (TOF) signal of each frequency component of an impulse reflected from each cutoff layer. We utilize signal record analysis (SRA) method to reconstruct the density profiles from the TOF signal. The effectiveness of the SRA method is confirmed by a simulation study of the USPR using a finite-difference time domain (FDTD) method.[1)]

The detailed description of the USPR system is shown in elsewhere.[2, 3)] In FY2007 a simulation study of the USPR has been performed to investigate the suitability and efficiency of the SRA method. The basic equations to be solved are Maxwell's equations for electromagnetic wave fields, $\boldsymbol{E}$ and $\boldsymbol{B}$, and the equation of motion for the induced current density $\boldsymbol{J}$. The simulation method is a popular computational electrodynamics modeling technique. It is easy to understand and is straight forward to implement in a software. Since it is a time-domain method, the solutions can cover a wide frequency range for a single simulation run. In the simulation, the wave is launched from the lower density region. The reflected wave is measured at 0.5 m from the edge. To calibrate this position, a wave reflected from a metal plate located at a distance of 0.8 m from the edge is used. The experimental wave is used as an incident wave. Figure 1 shows the simulation result of the profile reconstruction. A given plasma density is indicated as the open circles. The dashed line is obtained by assuming a plasma edge as an initial point and assuming a value of $\tau$. In the case of assuming the cutoff density corresponding to 18 GHz as an initial point, which is shown as the solid line, the reconstructed density profile agrees well. The problem is that we have to assume the position of the cutoff layer at 18 GHz in the experiment. In the practical sense, the determination of the initial position is easier than assuming the value of TOF.

In the present system, the reflected wave can be obtained in every 0.4 s, and the measurable density should be $(0.4\text{-}2.0)\times10^{19}$ m$^{-3}$ by taking into consideration of the 18-40 GHz frequency range. In the experiment, the reflected wave could be obtained especially in the case of high density plasma. This is because the cutoff layer becomes like a wall in the edge region due to the rapid change. Figure 2 shows the example of the experimental reconstruction result. In this time, the measurable density is limited to $(0.4\text{-}1.6)\times10^{19}$ m$^{-3}$. It is because the reflected wave is attenuated in the high frequency region due to higher extinction ratio. The result was compared with the one obtained by the Thomson scattering method. We use the data of Thomson scattering method as an initial point. It seems to be in good agreement between the profiles obtained by the USPR and the Thomson scattering. It is difficult to measure the edge density region by other methods. On the other hand, we can estimate it with reasonable accuracy. The behaviors of edge plasma and plasma position are important for stability control of magnetically confined plasmas. The USPR system seems to be useful for this purpose.

In summary, an ultrashort-pulse reflectometry has been installed in LHD for measurement of the edge density profiles. From the simulation study, we can confirm the effectiveness of the SRA method and consider that it is better to assume the position of cutoff density corresponding to 18 GHz as an initial point. In the experiment, the reflected wave is obtained and compared with Thomson scattering method with reasonable agreement.

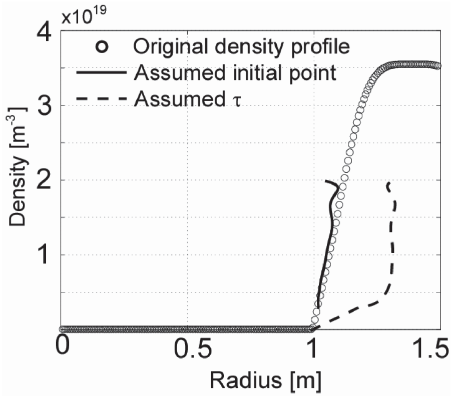


Fig. 1. Simulation result obtained by the SRA method.

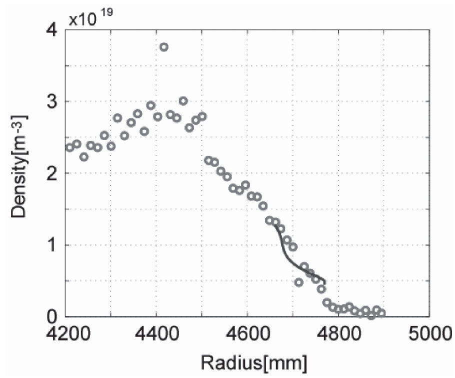


Fig. 2. Reconstructed density profiles together with the profile data obtained by Thomson scattering method.

1) Yokota, Y., Mase, A., Kogi, Y., Hojo, H., Bruskin, L., Tokuzawa, T., Kawahata, K., Plasma Fusion Res. **3** (2008) 008.
2) Mase, A., Yokota, Y., Uchida, K., Kogi, Y., Ito, N., Tokuzawa, T. Kawahata, K., Tanaka, K., Nagayama, Y., and Hojo, H., Rev. Sci. Instrum. **77** (2006) 10E916.
3) Yokota, Y., Mase, A. *et al.*, Rev. Sci. Instrum. (in press).