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

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Reflectometry is considered to be one of the key diagnostics to measure density profiles and density fluctuations of fusion oriented plasmas. The electromagnetic wave launched into a plasma is reflected at the cutoff layer of the ordinary (O) mode or the extraordinary (X) mode. The plasma density profile can be obtained by taking the phase difference or the group delay (time-of-flight) between the incident wave and the reflected wave as a function of incident frequency. We apply ultrashort-pulse reflectometry (USPR) to large helical device (LHD) at National Institute for Fusion Science (NIFS).

The detailed description of the USPR is shown in elsewhere.[1] In FY-2009 the study of X-mode reflectometry has been performed for measurement of wide range of density profiles. The O-mode cut-off depends only on the local electron density. On the other hand, the X-mode cut-off depends on the local electron density and the magnetic field strength. Though the reconstruction in the X-mode system is more complicated than the one in the O-mode system, the initial point of the density profile is expected to be obtained in the case of the X-mode system.

Figure 1 shows the expected cutoff frequency of each position for various magnetic field strength. The density profile of the edge region seems to be obtained for the frequency range of 18-40 GHz in the magnetic field strength of B_0=1.0-2.0 T. It is expected to reduce the assumed range drastically.

In the X-mode system, the numerical methods is utilized instead of the conventional Abel inversion. The phase difference of the n th frequency is described as,[2, 3]

$$\phi_p(f_n) = \frac{4\pi f_n}{c}\int_0^{r_c}\mu_X(r, f_n)dr \quad , \tag{1}$$

where μ_X is the refractive index of the X-mode propagation. For the next frequency f_{n+1}, the measured phase can be represented as

$$\phi_p(f_{n+1}) = \frac{4\pi f_{n+1}}{c}\left[\int_0^{r_c}\mu_X(r, f_{n+1})dr + \frac{1}{2}\Delta r\mu_X(r_n, f_{n+1})\right], \tag{2}$$

where Δr is the distance between the n th and the (n+1) th cutoff layer. All the other quantities, except Δr, are known because the profile for f_n is known. Then Δr is described as

$$\Delta r = \frac{2}{\mu(r_n, f_n)}\left[\frac{c}{4\pi f_{n+1}}\phi_p(f_{n+1}) - \int_{r_n}^{r_c}\mu_X(r, f_{n+1})dr\right] \tag{3}$$

The density profile can be extended in a step by step manner using the above algorithm. The analysis program is confirmed its effectiveness by the simulation.

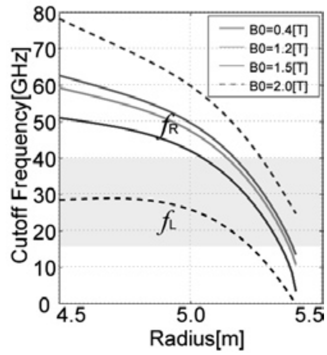

Fig. 1. Cutoff frequency for various values of magnetic field strength.

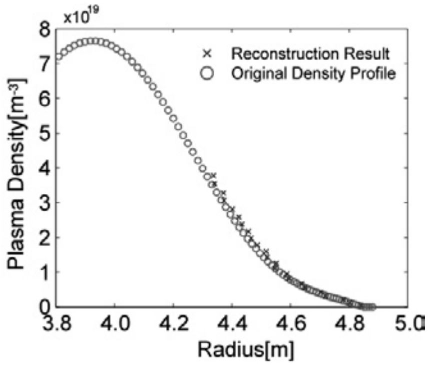

Fig. 2. Reconstructed density profile using a step by step manner. Circles shows the original density profile. Cross mark shows the reconstruction result.

Figure 2 shows the reconstruction result of the X-mode case obtained by the numerical simulation. Note that the reconstruction process of the X-mode works correctly.

In summary, an ultrashort-pulse reflectometry has been installed in LHD for measurement of density profiles in the edge region. The reflectometer can be operated as the X-mode system as well as the O-mode system by rotating the waveguides. The whole system can be controlled from a remote site using Super-SINET. The reflected waves from the O-mode or the X-mode system can be obtained especially in the case of high density and stable plasmas. In the X-mode system, the density profile of the edge plasma seems to be obtained by considering the present magnetic configuration by using the numerical method.

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1) A. Mase et al., Plasma Devices and Operations, **17** (2009) 98.

2) Y. Yokota, A. Mase, Y. Kogi, T. Tokuzawa, K. Kawahata, Y. Nagayama, H. Hojo, J. Phys. Conf. Series (2010). (to be published).

3) Y. Yokota, A. Mase, M. Sato, H. Hojo, T. Tokuzawa, K. Kawahata, Y. Nagayama, Proc. 13th Int. Conf. on GPR, Lecce (2010). (to be published)