§4. Electron Density Profile Measurements along the Minor Axis in the Horizontally Elongated Plasma Using Ultrashort Pulsed Radar Reflectometer

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Recently we have been developing a new type of reflectometer which is used an ultrashort sub cycle pulse. It is called as an ultrashort pulsed radar reflectometer. An ultrashort pulse has broad band frequency components in a Fourier space. It means one ultrashort pulse can take the place of a broad band microwave source. Also this ultrashort pulsed radar reflectometer is operated by the time-of-flight (TOF) measurement technique. This TOF measurement has an advantage which we can easily distinguish between the ordinary polarized wave and the extraordinary polarized wave involving the reflected wave from the plasma, because each cut-off position in the plasma is separated.

The ultrashort pulsed radar reflectometer system was shown in the previous annual report. We use as a source that is an impulse of -2.2 V, 23 ps full-width half-maximum. From this impulse we can extract the probing microwave of the desired frequency range (26-40 GHz). The reflected wave from the cut-off layer is received and detected by a super heterodyne technique. Currently this ultrashort pulsed radar reflectometer operates on six channels using a filter bank system for measuring the edge density profile and slow plasma oscillation. The frequencies of each channel are 39, 37, 35, 33, 31, and 29 GHz. By using the ordinary wave the measured flight time of each frequency pulse reflected from the plasma has been described by

$$\tau_p(\omega_0)=\left(\frac{\delta\phi(\omega)}{\delta\omega}\right)_{\omega=\omega_0}=\frac{2}{c}\int_{r_a}^{r_c(\omega_0)}\frac{1}{\sqrt{1-\frac{\omega_{pe}^2(x)}{\omega_0^2}}}dx\,, \qquad (1)$$

with r_a the edge of the plasma, c the velocity of the light, ω_o the probing frequency, ω_{pe} the plasma frequency, and $r_c(\omega_o)$ the position where the plasma frequency equals the probing frequency, respectively. The result of TOF measurement as a function of the probing frequency is shown in Fig. 1. The delay time is defined by the travelling time from the assumed plasma edge to each cut -off layer. The inverse for calculating the positions of the corresponding critical density layer is given by

$$r_c=\frac{c}{\pi}\int_0^{\omega_0}\frac{\tau(\omega)}{\sqrt{\omega_0^2-\omega^2}}d\omega\,. \qquad (2)$$

From this integral equation we can see that the cut-off position can be calculated by integrating the total TOF profile from zero up to the probing frequency. As the TOF profile is only measured at a discrete and limited number of points, the profile has to be interpolated between the data points. Additionally below the lowest probing frequency, the density profile has to be assumed. Therefore we have calculated the positions of each cut-off layer by the above Abel inversion technique and the reconstruction of the electron density profile has been done as shown in Fig. 2. Here we assume that the delay time of the reflected pulse from the edge plasma is zero sec and also the TOF profile is supplied by the spline interpolation. In this figure the reconstructed density profile measured by FIR interferometer is also shown. There is not little difference between these reconstructed density profiles. It might be considered from the evidence that in the very edge region both measurements are used the assumption of the edge location and the profile shape independently. Also the difference of the diagnostics configuration which reflectometer measures along the minor axis in the horizontally elongated plasma but FIR interferometer measures along the long axis in the vertically elongated plasma is some possibility of having an influence on this result; e.g. the effect of the divertor plasma. As the above reason, the improvements of the edge measurement are expected and the system has been upgrading now.

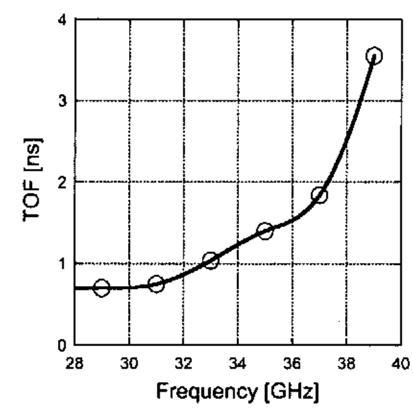

Fig. 1. The profile of the measured delay time of each channel as a function of the probing frequency

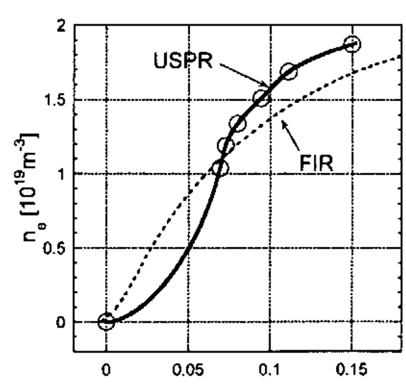

Fig. 2. The reconstructed density profiles using Abel inversion from both data measured by reflectometer (the solid line) and by FIR interferometer (the dotted line). Here the horizontal axis is defined as the distance from the plasma edge which is assumed.