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

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Reflectometry is widely used to measure plasma density profiles and/or density fluctuations without perturbing the plasma. When the electromagnetic wave is launched into the plasma, the wave is reflected at the corresponding cutoff layer. The reflectometry measures the time of flight (TOF) or group delay of the reflected wave. The advantages of the reflectometry lie in its high spatial resolution, non-invasive nature, and minimal requirement for port access. 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. We utilize signal record analysis (SRA) method to reconstruct the density profiles from the TOF signal.[1)] The effectiveness of the SRA method is confirmed by a simulation study of the USPR using a finite-difference time domain (FDTD) method.[2)]

The detailed description of the USPR system is shown in elsewhere.[3)] An impulse generator (Picosecond Labs, model 4015C) is utilized as a source. The pulse width, height and the impulse repetition are 22 ps, 3 V and 1 MHz, respectively. The output of the impulse generator is fed to a 30 cm WRD-750 waveguide to obtain a chirped pulse with 7-20 GHz frequency range. The chirped pulse is fed to an active multiplier after passing through a 15 m low-loss coaxial cable in order to double the frequency range. The frequency is limited to 18-40 GHz by using WRD-180C24 waveguide as a transmission line. The chirped pulse is then amplified by a power amplifier. The transmitter and receiver are identical conical horn antennas each having a collimating lens. The antenna gain is 30-34 dB in 18-40 GHz range. The reflected wave is amplified by compensate the transmission loss of another coaxial cable. The signal waveform is then digitized by a sampling scope (Tektronix Model: TDS8000) with an equivalent sampling frequency of 250 GHz. Therefore, a filter bank and a time-of-flight analyzers are not needed for the profile reconstruction process.

In the present system, the measurable density should be $(0.4\text{-}2.0) \times 10^{19}$ 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 mirror wall in the edge region. Figure 1 shows the time evolution of density profiles. We use the data obtained by the LHD-Thomson scattering as an initial point. A good agreement is obtained between the two profiles. The USPR profiles can be obtained at every 0.4 sec. For the cases where the S/N ratio permits reducing the integration time (summation of separate pulses), the time interval can also be shortened. It is difficult to measure the edge 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.

The first application of the X-mode USPR to the LHD plasma has also been performed in FY2008. Since the X mode cutoff depends on magnetic field strength as well as local electron density, the initial point of the density profile is expected to be obtained. The reconstruction algorithm of the X-mode USPR and the application to the reflected waves have also been studied. Also, it is noted that the remote control system using super science information network (super-SINET) has been introduced to the USPR system. The operations such as adjustment of supply voltage fed to the amplifiers and the active multiplier, the timing control of the impulse, and the data acquisition and monitoring can be performed from the remote site (Kyushu University). This remote system is exclusive, and it seems to be quite effective for collaborating experiment of ITER.

In summary, an ultrashort-pulse reflectometry has been installed in LHD for measurement of the edge density profiles. The density profiles are obtained and compared with Thomson scattering method, with reasonable agreement. The X-mode operation will give the information of an initial point of the profile reconstruction. The assumption of the initial point using the other diagnostics such as Thomson scattering will not be necessary.

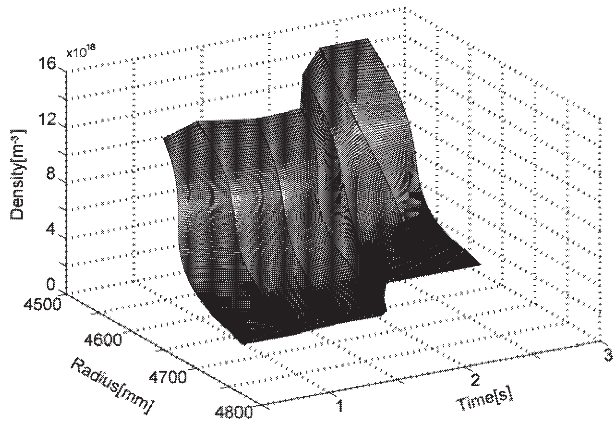

Fig. 1. Time evolution of the reconstructed density profiles.

1) Yokota, Y., Mase, A., Kogi, Y., Bruskin, L., Tokuzawa, T., Kawahata, K., Rev. Sci. Instrum. **79** (2008) 056106.
2) Yokota, Y., Mase, A., Kogi, Y., Tokuzawa, T., Kawahata, K., Nagayama, Y., Hojo, H., Rev. Sci. Instrum. **79** (2008) 10F112.
3) Mase, A, Kogi, Y., Ito, N., Akaki, K., Kawahata, K., Nagayama, Y., Tokuzawa, T., Yamaguchi, S., Hojo, H., Oyama, N., Luhmann, Jr., N. C., Park, H. K., Donné, A. J. H., Plasma Device and Operations **17** (2009) 1.