§29. Application of Ultrashort-Pulse Reflectometer to LHD

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Ultrashort pulse reflectometry (USRM) is one of the methods to measure density profiles of plasmas. The frequency source of the reflectometer is replaced by an ultrashort pulse whose pulse width is less than 100ps. 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.[1, 2]

An impulse generator (Picosecond Labs, 4015C) is utilized as a source. The pulse width, height, and the impulse repetition rate 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 frequency range of 7-20 GHz. The chirped pulse is fed to an active doubler 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 wave guide as a transmission line. The chirped pulse is then amplified by a power amplifier (18-40 GHz, 30dB gain and 1 dB compression point of 17 dBm). The transmitter and receiver are identical conical horn antennas each having a collimating lens. The antenna gain is 30-34 dB in the range of 18-40 GHz. The reflected wave is amplified by low noise amplifiers (50 dB total gain) to compensate the transmission loss of the another coaxial cable. The signal is then digitized by a sampling scope with an equivalent sampling frequency of 250 GHz. The directly recorded signal by the sampling scope is analyzed and reconstructed by means of the signal record analysis (SRA) method.[1)]

In the end of FY 2002, the remote experiment system via internet called super science information network (Super-SINET) has been introduced to the USPR system. The internet backbone connects research institutes at 10 Gbps and the leading research facilities in each institute are directly connected at 1 Gbps. The control client can operate the control server by using the super-SINET. The general-purpose interface bus (GPIB) card is installed in the control server. The remote console, which has graphical user interface (GUI) is prepared to control the instruments of the USRM via GPIB. The operations such as adjustment of supply voltage fed to the amplifiers and the doubler, the timing control of the impulse, and the data acquisition and monitoring can be performed from the remote site (Kyushu University). The monitor can display the current view of sampling scope for various times and their analyzed data such as the frequency spectra as well as the machine parameters. In FY 2004, the position control of the transmitter and receiver horn antennas has been installed. The angle between the two antennas can be adjusted depending on the various plasma conditions even between the plasma shots. The two antennas can be rotated ±8°in steps of 0.1°in order to observe the appropriate cut-off layer. Control system was programmed by Visual Basic NET, and is constructed GUI.[2)]

Figure 1 shows the examples of the plasma density profiles. The solid lines are the profiles obtained by the USRM and the dotted lines are those obtained by a Thomson scattering method. We can obtain the reflected wave in every 0.4 s with the present USRM system. The measurable density should be $(0.4\text{-}2.0)\times10^{19}$ m^{-3} by taking into consideration of the frequency range of 18-40 GHz. In the present experiment, the measurable density is limited to $(0.4\text{-}1.6)\times10^{19}$ m^{-3}. It is because the reflected wave was attenuated in the high frequency region due to higher extinction ratio. The frequency spectrum of the reflected wave mostly distributes in the range of 18-36 GHz. It is next work to compensate these high frequency components. We assumed the TOF τ in the range of 0-18 GHz with a straight line when we integrated τ to calculate the distance. We may have to apply the other method of assumption because this assumption affects the reliability. The density profiles, specifically, the density gradients between two methods (the USRM and the Thomson scattering method) seem to be in good agreement. It is rather difficult for us to measure the low density ($n_e<0.3\times10^{19}$ m^{-3}) by Thomson scattering. On the other hand, we can measure it with reasonable reliability by using the USPR when we chose the frequency. In the LHD experiment, a multi-channel far-infrared (FIR) laser interferometer is utilized for measurement of density profiles, however, the FIR laser interferometer can also measure only a few chords in the present density region. The behaviors of edge plasma and plasma position are quite important for the control of magnetically confined plasmas. The URSM system seems to be useful for this purpose.

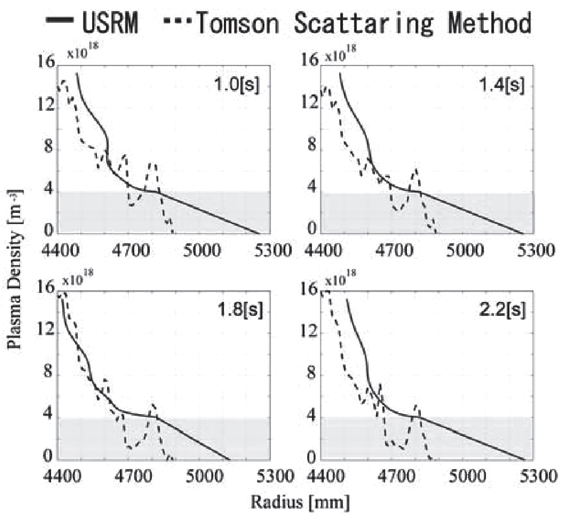

Fig. 1. Comparison of the density profiles obtained by the UPRM and Thomson scattering method.

References

1) Yokota, Y., Mase, A., Kogi, Y., Tokuzawa, T., and Kawahata, K., Plasma Fusion Res. **1**, 40.1 (2006).
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**, 10E916 (2006).