§10. 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 which 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.

The detail of the USRM system was shown in elsewhere.[1)] Remote control system using super science information network (super-SINET) has been introduced to the USRM system since 2003. Bandwidth of the main backbone and branch line is 10 Gbps and 1 Gbps, respectively. The control client can operate the control server by using this network. 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 USRM via GPIB. The operations such as the adjustment of supply voltage fed to amplifiers and the frequency doubler, timing control of the impulse, data acquisition and monitoring can be performed from the remote site. The monitor can display the current view of a sampling scope for various times and their analyzed data as well as the machine parameters. In FY2004, the position of the transmitter and receiver antennas can be controlled remotely as sown in Fig. 1. The two antennas can be rotated in order to observe the cutt-off layer depending on the various plasma conditions even between the plasma shots. In Fig. 1 the solid line from the antenna corresponds to the radiation angle, and the dotted line correspond to the maximum radiation angle when the antenna is rotated.

The directly recorded signal by the sampling scope is analyzed and reconstructed by means of the signal record analysis (SRA) method.[2)] In Fig. 2 are shown the examples of reconstructed density profiles for the high density and low density plasma experiments of LHD. We assumed here the initial position where the electron density equals to 0 corresponds to the one of the separatrix. It is noted that for the high density operation the incident wave is reflected at the position close to the vacuum wall comparing with the low density operation, which means that the plasma is filled in wide region of the vacuum chamber for the high density operation..

In the LHD experiment, a multi-channel far-infrared (FIR) laser interferometer is utilized for measurement of density profiles. However, in the edge plasma region ($n_e < 2.0\times10^{19}$ m^{-3}), the FIR laser interferometer can measure only two chords or less. The behavior of the edge plasma and the plasma position is quite important for the control of the plasma. This USRM system seems to be useful for this purpose

In summary, we have completed a remote operation system of an USRM, and succeeded to reconstruct electron density profiles using SRA method. As an upgrade of the present system, it is planned to widen the frequency regime of an incident pulse from 26-40 GHz to 12-40 GHz.

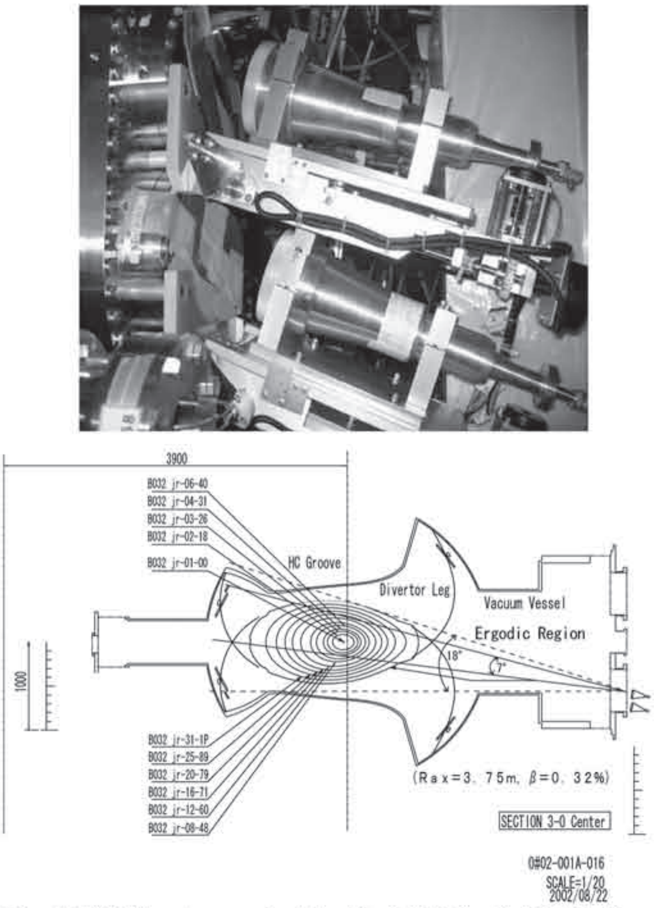

Fig. 1 USRM antennas installed in LHD (top), Distribution of antenna patterns (bottom).

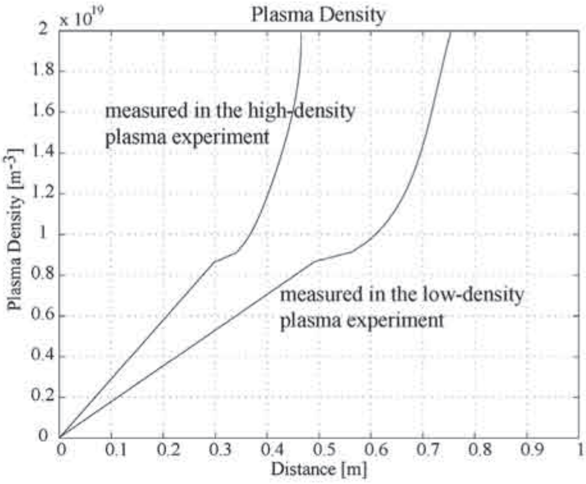

Fig. 2 Profile reconstruction by signal record analysis.

References
1) Kogi, Y. et al., Rev. Sci. Instrum. **75**, 3837 (2004).
2) Bruskin, L. Mase, A., Yamamoto, A., and Kogi, Y. et al., Plasma Phys. Control. Fusion **43**, 1333 (2001).