§ 22. Ultra-Short Microwave Pulse for Plasma Diagnostics

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Microwave diagnostics are standard techniques in plasma experiments. Microwave reflectometry is one of the most active fields where many new ideas are developed and applied. Here we report two reflectometers; one uses ultra-short microwave to measure density profile, and the other is used with a radiometer composing an Electron Bernstein Wave (EBW) temperature measurement system.

An ultrashort-pulse reflectometer (USRM) has been developed for LHD. In order to apply an USRM to high density plasmas, we have employed a frequency doubler to increase frequency components of an impulse. A schematic of the system is shown in Fig. 1. The impulse is chirped in a WRD-750 waveguide and fed to an active doubler to generate a pulse with double frequency. The upper transmission frequency attains up to 40 GHz. The incident and received powers are insufficient for the diagnostics due to large transmission losses in long coaxial cables. This problem can be solved by inserting a wide-band power amplifier in the transmitter and low noise amplifiers in the receiver section. The reflected wave is then directly fed to a high-speed digitizing scope with 50 GHz bandwidth for the signal record analysis (SRA).

The USRM measurement on LHD has started from February 2003. The reflectometer signals observed in the initial experiments are shown in Fig. 2. The large signal at the late stage of time (without plasma) is the reflected wave from the back wall. It disappears when the plasma exists. The time-resolved frequency spectra (wavelet spectrum) revealed that the reflection occurred at the edge region of the plasma. The reasons that the signal to noise (SN) ratio is not good will be due to the mixture of reflected wave from other reflectometers installed in the adjacent diagnostic port, and also due to the long data-taking time (~ 1 sec) since the plasma will not be stable during the time scale. The improved system using a fast-digitizing scope and notch filters will increase the SN ratio in the next stage of LHD operation.

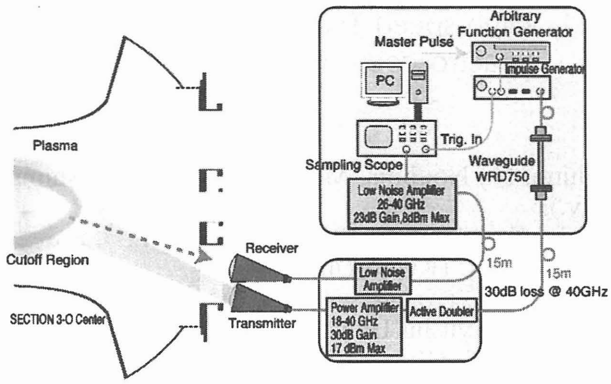

Fig. 1. Schematic of the USRM system on LHD.

The temperature diagnostics using electron Bernstein wave (EBW) emission is an alternative to the standard ECE for overdense ($\omega_{pe} >> \omega_{ce}$) plasmas. Since EBW is electrostatic mode, it should be mode-converted to electro-magnetic wave to be emitted from the plasma. In ST plasmas, right-hand and left-hand cut-offs and upper-hybrid resonance compose a triplet around plasma peripheral and EBW is expected to be efficiently mode-converted to electromagnetic wave.

A system that consists of a radiometer and a reflectometer has been made to measure the EBW emission, and the density gradient around the triplet, which determines the mode-conversion efficiency. In 2002, the frequency coverage was expanded to 5-16 GHz and the local oscillator is upgraded to a fast scanning system. The obtained temperature profile of TST-2 is shown in Fig 2. The central electron temperature is consistent with T_{e0} measured by X-ray pulse height analysis. For detailed comparison, it is necessary to know where the received EBW is emitted. For that purpose, a new ray-tracing code is under preparation.

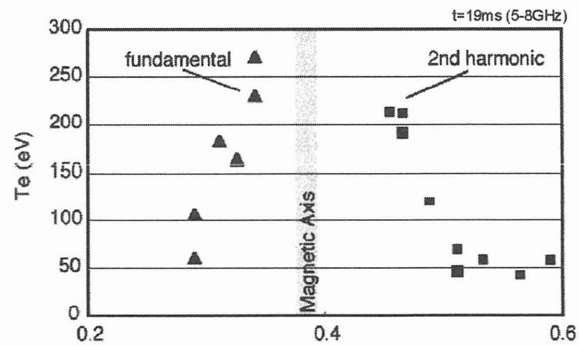

Fig. 2 Temperature profile of TST-2 spherical tokamak measured by the radio-reflectometer.