Pulsed Radar Reflectometer for Density Profile and Fluctuation Measurements of Large Helical Device.

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1. Introduction

It is very important to know the edge density profile and fluctuation information for the magnetic confined plasma experiments. In order to measure these plasma parameters with high temporal and spatial resolution, we try to apply microwave reflectometer on Large Helical Device (LHD) [1, 2]. Reflectometer is a compact system, needs a small access to the device, and also has a higher resolution than conventional diagnostic methods. For these benefits, several types of reflectometer have been used in world fusion devices [3]. Since LHD has a complex magnetic field configuration and also has a large magnetic shear, the launched and the reflected microwave may have a complicated behavior such as the mode conversion or the polarization rotation [4, 5]. To study the effect of the strong magnetic shear, the pulsed radar reflectometer is a suitable reflectometric technique. Because pulsed radar reflectometry measures the delay time of the reflected wave from the cutoff layer in the plasma, it can distinguish between X-mode and O-mode polarized waves even if unexpected pulses are returned.

2. Pulsed radar reflectometer system

We construct V-band and R-band pulsed radar reflectometer systems. The schematic of V-band 2ch pulsed radar reflectometer system is shown in Fig. 1. 60GHz and 65GHz Gunn oscillators are used as sources. The output powers of both sources are 100 mW. PIN switches are used as a pulse modulator using the tuned signal of the generated impulse output. The microwave pulses pass through the oversized waveguide in order to avoid the deformation. The separate, transmitter and receiver horns are used in order to avoid the mixture of spurious reflecting components in the waveguides, vacuum window, etc. The antenna is a conical horn with a Teflon lens for focusing the microwave beam and can be moved horizontally and rotated using a remote controller. In a mixer the reflected wave picked up by the receiver horn is mixed with the local microwave, which the frequency of the local oscillator is 78 GHz. The intermediate frequency signal is divided and each signals are filtered by band-pass-filter with the bandwidth of –1.0 GHz then detected and converted from the envelope of the reflected wave to the pulse. The reference pulse for the TOF measurement is measured using V-band detector, which is located at just after the PIN switch to avoid the jitter of the pulse generator and the PIN switch. The pulse width is around 2 ns and the repetition rate is 100 kHz in the standard operations. The detected pulses are fed to a diagnostics room using the electro-optical converters and the optical cables. Then time-of-flight (TOF) measurement is carried. A constant fraction discriminator (CFD) is used to obtain the start and the stop pulse for the time-to-amplitude converter (TAC), because the pulse amplitude is changed during the plasma discharge. The obtained data is acquired by CAMAC (Aurora 14 with 12 bits 1 Mword memory) and stored by a windows-NT based personal computer.

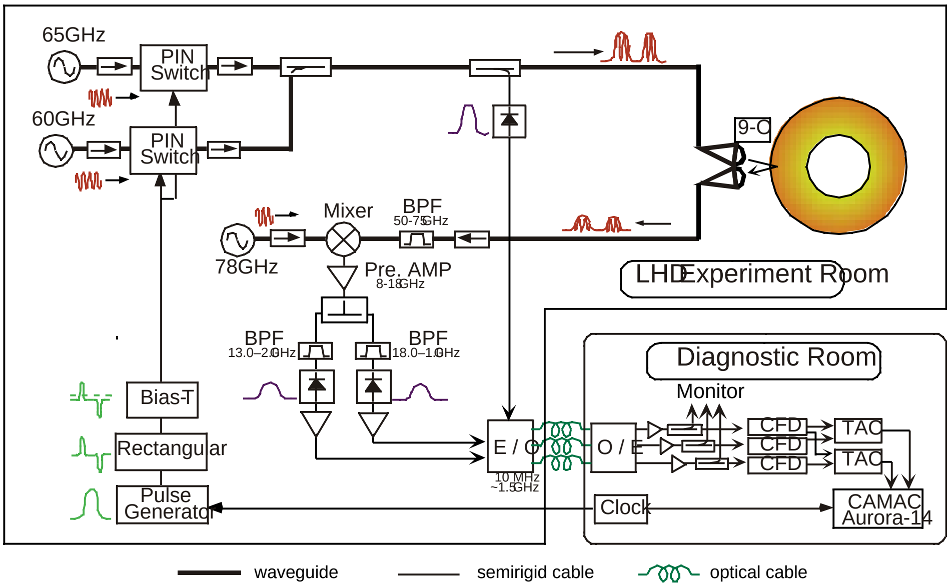

Figure 1. Schematic of 2ch U-band pulsed radar reflectometer system. The R-band system is similar; the probe frequencies are 33 and 39GHz, and the local frequency is 51GHz.

3. Experimental results

LHD plasma is usually initiated by ECH and then neutral beam is injected. Launching an X-mode microwave pulse the initial critical layer of the right-hand cutoff frequency of 60 GHz is located at R=4.3m and that of 65GHz is located at R=4.2m, where R is the major radius. Figure 2(a) shows the time evolution of the delay time. In this case both reflected pulses are appeared at the same time. When plasma is initiated by only NBI, the reflectometer signals show different behavior. In Fig. 2(b), 65 GHz reflected pulse appears at 0.415s and then 60 GHz reflected pulse appears with 20ms delay. It is clearly found that the plasma is initiated in the core region and then plasma is expanded in the case of NBI start-up plasma.

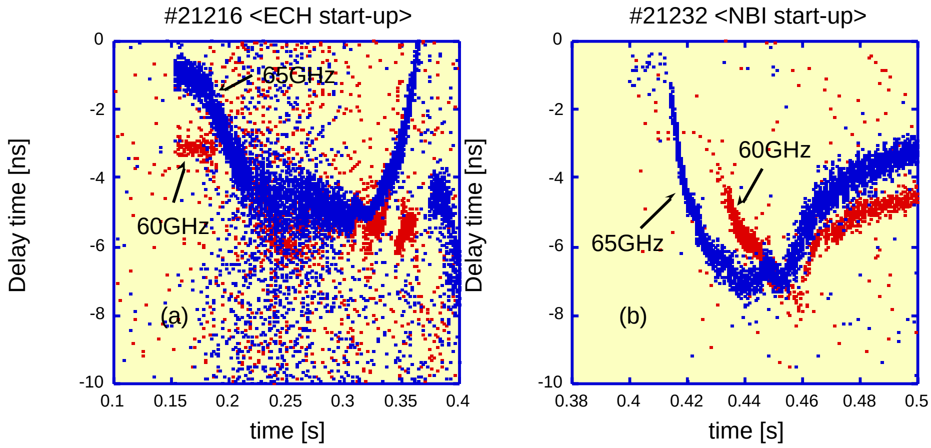

Figure 2. Time evolution of the delay time of reflected pulses. (a)ECH start-up plasma and (b) NBI start-up plasma.

Pulsed radar reflectometer has an ability to measure the density profile and density fluctuation, simultaneously. Figure 3(a) shows the time evolution of the delay time in an ECH initiated and ICH sustained plasma shot. After heating by ECH the fluctuation grows up and the core density decreases. The enlargement time evolutions are shown in Fig. 3(c) and (d). The coherent oscillation is measured by both diagnostics. This oscillation is density fluctuation with low frequency of 260 Hz.

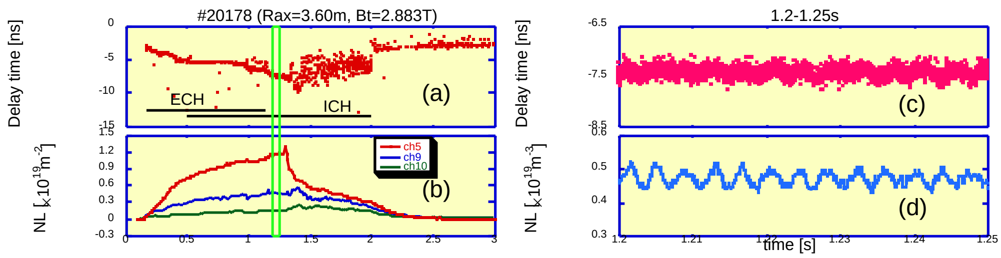

Figure 3. Time evolution of (a)the delay time of reflected pulse and (b)FIR interferometer signals. The enlargement time evolution from 1.2s to 1.25s of (c) reflectometer signal and (d)ch9 of FIR signal.

At O-mode operation using R-band reflectometer system, two pulses are reflected from corresponding positions of each plasma frequency. The time evolution of the delay time is shown in Fig. 4(b). In this figure, the dotted lines are the delay time measured by pulsed reflectometer and the solid lines are the calculated delay time using the density profile measured by FIR interferometer. The reflected pulses are appeared when the electron density reaches to be the corresponding cutoff densities. Both values of the delay time are almost agreement in the edge region, however they are not agreement in more core region. The dotted line shows the estimation of the delay time assuming X-mode microwave pulse propagates from the edge to the O-mode cutoff layer. Nevertheless this assumption is over estimation, the measured signal is not able to be explained. This disagreement is probably caused by the ambiguity of density profile reconstruction and/or by the error of estimation for the cutoff position. We need to study the detailed effect of the magnetic shear to the wave propagation using the simulation analysis.

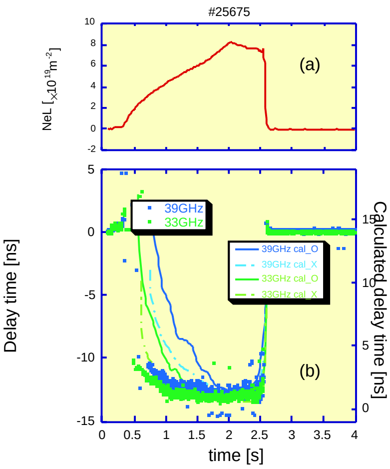

Figure 4. (a) Time evolution of the averaged density and (b) the dots are the delay time of reflected pulses, the solid lines are the calculated delay time using the density profile, and the dotted lines are the calculated delay time using the assumption that the waves propagate as X-mode.

Acknowledgements

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