§ 21. Development of Ultrashort-Pulse Reflectometer

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An plane wave of an electromagnetic wave which is launched perpendicularly in the direction to the external magnetic field into a plasma is distinguished between the ordinary mode (O-mode) and the extraordinary mode (X-mode) for the direction of the electric field component. When these waves arrive at the critical regions, they can not propagate and then reflect. In the case of O-mode operation, the critical layer is determined by only the electron density profile. In order to measure the electron density profile and fluctuation in LHD plasmas, we have been developing a new reflectometer system using an ultrashort-pulse. A reflectometer has higher resolution for time and space than other conventional methods. The ultrashort-pulse has broad band frequency components. When they are launched into the plasma, they reflect from the corresponding each cut-off layers. When the time-of-flight measurement of each frequency component pulse is done, the electron density profile can be determined.

To extract the desired range of the millimeter wave from the impulse, we use a rectangular waveguide. When an ultrashort-pulse is launched into the waveguide, it is transformed into electromagnetic waves including a broad frequency spectrum. This transformation is owing to the dispersion effect of the waveguide. The waveform of the ultrashort-pulse is shown in Fig. 1. It is -2.2 V, 23 ps FWHM impulse. A 50 cm R-band rectangular waveguide is used to disperse the impulse. Output from the waveguide is shown in Fig. 2(a). The resultant frequency component calculated by using the zero-cross method is shown in Fig. 2(b). In consequence the frequency changes from high to low gradually and we obtain 26 - 40 GHz millimeter wave for the measurement. Our reflectometer system is shown in Fig. 3. The chirped wave is amplified by a power amplifier and divided from the incident wave to get the reference wave by the directional coupler. The reference wave is detected by a Schottky barrier diode and then sent to a constant fraction discriminator (CFD).

As a method to receive the reflected waves a heterodyne system is adopted. The reflected wave is mixed with a 42 GHz continuous wave of the local oscillator. The output is amplified by the intermediate frequency (IF) amplifier (2 - 18 GHz) and then divided to six. Each IF signal is filtered by bandpass filters which the center frequencies are 3, 5, 7, 9, 11, and 13 GHz and each band width is ±0.5 GHz. The detected pulses at the Schottky barrier diode are amplified by the pulse amplifier and sent to CFDs. In front of the mixer the bandpass filter (26 - 40 GHz) is set to avoid the unexpected frequency component.

Positions of cut-off layers are estimated by the time-of-flight measurement. The reference pulse from CFD is used to the start signal and the reflected pulse is used to the stop signal for a time-to-amplitude converter (TAC). The TAC outputs the analog voltage proportional to the time differences between the start signal and the stop signal. The TAC outputs are sent to CAMAC and the data is acquired by a personal computer.

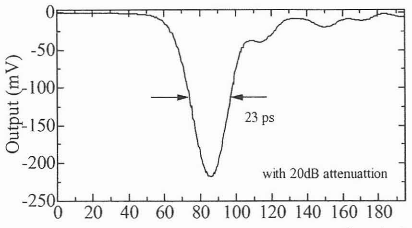

Fig 1. -2.2 V, 23 ps FWHM impulse signal from impulse forming network

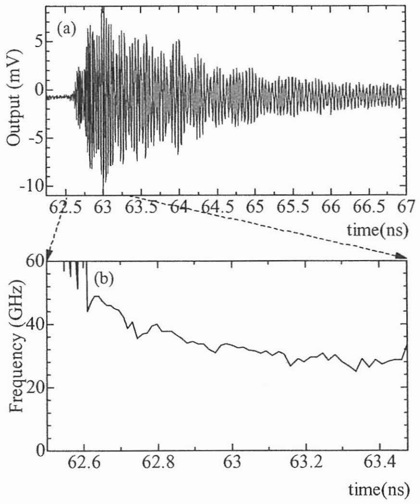

Fig 2.(a) 40 - 26 GHz chirped waveform propagating through a 50 cm R-band waveguide and (b) Time evolution of the frequency component of the chirped waveform from 62.5 ns to 63.5 ns.

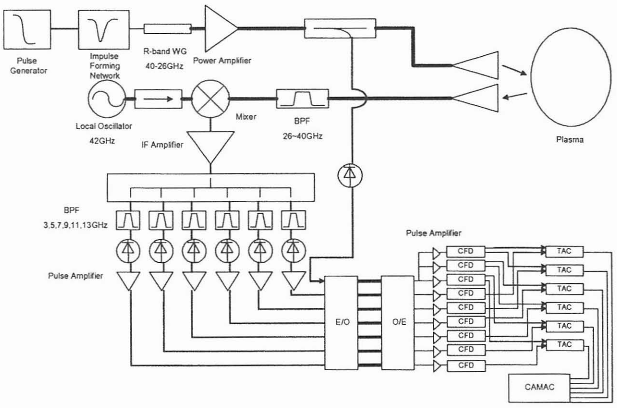

Fig 3. Schematic of ultrashort-pulse reflectometer system.