§42. Ultra-Short Microwave Pulse for Plasma Diagnostics

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In the last few decades, microwave and related technology have been developed very quickly. Introduction of those new techniques and specific R&D for each purpose make new methods in microwave diagnostics. Ultra-short microwave pulse and pin switch are one of such new tools, and we are developing new and better microwave diagnostics using them. Here we report two topics; one uses ultra-short microwave for reflectometry and the other uses a pin switch for interferometry.

Ultra-short microwave pulse is defined as a microwave with the pulse width less than about 100 ps, and the pulse has only one or a few cycles. As a result, it has a very wide frequency range. This is very useful for diagnostics where wide frequency range is required. Ultra–short pulse reflectometry uses this feature, and we are developing a system to measure the density profile of the LHD plasma. For LHD, frequencies around 80 GHz is required. This is made by the following four stages; (i)impulse (3 V/22 ps) generation, (ii)waveguide propagation to limit the frequency range to 12-18 GHz and to stretch the pulse into a chirped pulse, (iv)amplification, (v)frequency up-conversion to 80GHz range.

In order to test the first two stages we made a reflectometry system and applied to an inductively coupled steady state plasma (ICP). The reflected wave is recorded on a sampling scope with 50 GHz bandwidth. Since the plasma is in steady state, we can accumulate the recorded signal which is produced at the maximum repetition rate of 1 MHz. An example of the raw reflected signal is shown in Fig. 1 (upper trace). The initial peak at t<72.5 ns (dotted line) shows the reflection from a vacuum window. The second peak at t=72.7-74.5 ns (solid line) is attributed to the plasma. The recorded signal can be directly analyzed by using time-frequency analysis such as wavelet, and the density profile can be reconstructed from the group delay as a function of frequency. We also propose the Signal Record Analysis (SRA) method of profile reconstruction which relies on a raw signal waveform rather than on the group delay. The algorithm of profile reconstruction is described in detail in Ref. 1). Comparing with the wavelet-based phase extraction method, the SRA algorithm yields plasma profiles of reasonable quality even for the data sets unacceptable for the time delay algorithm.

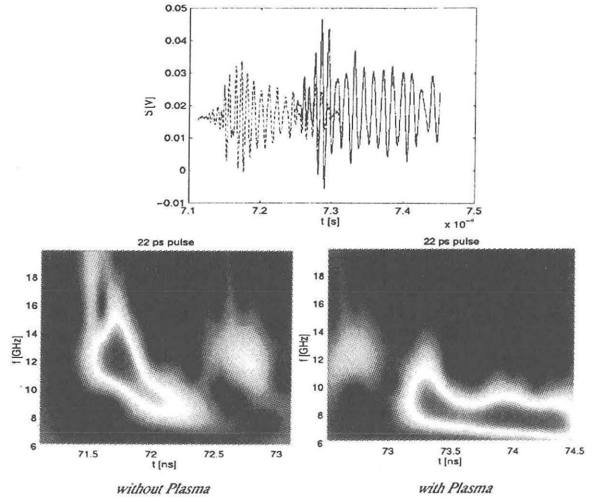

Fig. 1. Reflected wave from an ICP, without plasma (dotted line) and with plasma (solid line). Time-frequency spectra of reflected wave using wavelet transform, without plasma (left), and with plasma (right).

A pin switch is a microwave waveguide switch with a quick response. We have tested and used a two-port pin switch for switching between two paths in an interferometry. For this purpose, the switch should have a switching speed high enough to follow density evolutions and it should also have good isolation between two ports to avoid cross-talk. An interferometer with the probe frequency of 104 GHz has been installed on the TST-2 spherical tokamak. The pin switch is used to switch the two interferometry chords. One chord passes the center and the other passes the outer region of the plasma. The switching frequency is up to 250 kHz, which is synchronized to an ADC. Figure 2 shows the time evolution of the line integrated density at the two chords. The pin switch is very useful to make multi-channel system with only one set of sources and detectors.

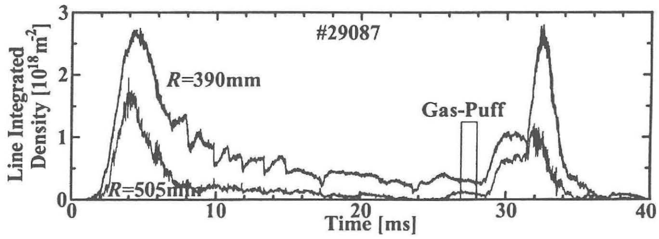

Fig. 2. Time evolution of line integrated density at two chords (R=390, 505mm) in TST-2 tokamak.

Reference

1) Bruskin, L.G, Mase, A., Yamamoto, A., Ohashi, M., Deguchi, T., Japan. J. Appl. Phys. (to be published).