§18. Development of Long-distance Correlation Diagnostic for Turbulence Structure Analysis and its Application to HJ-LHD Comparative Studies

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Microwave reflectometers are widely used for the density profile and density fluctuations [1,2]. The advantage of electron density profile measurement by reflectometer are that the time evolution of local electron density profile is possible to measure during a plasma discharge with good time and spatial resolutions. It has few limitation of installation port and does not need any assumption of the shape of magnetic surfaces. Several types of reflectometer have been developed such as FM reflectometer, AM and pulse radar reflectometer. The electron density profile measurement by AM reflectometer has been carried out in T-10 tokamak [3], W7-AS [4], TJ-II [5] and HL-2A [6]. The advantages of AM method are that it can suppress the effect of density fluctuations in profile measurement and can avoid the fringe jump by setting the whole of phase shift less than 2π.

The main concept of this reflectometer is to measure the long-range correlations as well as the electron density profile in wide confinement region. As a first step, however, the low density plasma i.e., $n_e \leq 1.0\times10^{19}$ m^{-3} is targeted. The sweeping time of the carrier frequency is set as less than 1ms, which is shorter than the typical energy confinement time in HJ plasmas.

X-mode is selected as the propagation mode. By using the carrier microwaves of 33-56 GHz, it is possible to obtain density profile over the full range of plasma radius for low-density plasmas. A pulse generator supplies a triangular-wave of 1 kHz to a VCO of 8.25-14 GHz. The frequency band of 33-56GHz is generated by the VCO and ×4 frequency multiplier. Q-band fundamental waveguide of 8 m long are used for transmission in order to suppress the resonant attenuation which is observed when using oversize waveguides. After transmission, the microwaves are modulated in amplitude with the frequency of 100 MHz by using a PIN modulator. Low-pass filters are assembled to remove the effect of 70 GHz ECH. Horn antennae are used for launching and receiving microwaves. A heterodyne detection system is applied to detect the reflected signal. A phase meter consists of a frequency down-converter and a phase-detector. The phasemeter also measures the RF signal power to correct the power dependence of the phase comparator. The outputs of pulse generator, RF input amplitude, phase difference are stored by a data acquisition system with the sampling time of 1μsec. The output frequencies are controlled stably by the VCO input voltage and the output intensities are almost constant regardless of the VCO input voltage. In the whole range of carrier frequencies, the phase output is found almost flat. The phase measurement has been tested by using an aluminum reflection plate instead of plasma. The length of the transmission line is changed by moving the plate in the range of 30 cm at 1 cm interval. The phase shift agrees well with that expected from the change of the plate position if the amplitude dependence is taken into account. The density profiles are reconstructed with the error less than 5 % in the center region. This indicates that the program can reconstruct density profile in the whole of plasma region with the sufficient accuracy for density profile measurement. For high-density model (2.0×10^{19} m$^{-3} \leq \bar{n}e \leq 3.0\times10^{19}$ m^{-3}), the density gradient can be evaluated within 10 % accuracy.

The measurement results in a test stand show that each microwave component works well and the phase shift is measured as designed. A program to reconstruct density profile from the relative phase shift data has also been developed. The program has been examined by using modeled density profiles such as flat and hollow ones. The reflectometer system is under installation in HJ. In order to measure the profile with satisfactory accuracy, it is necessary to improve detection system sensitivity and signal-to-noise ratio. Therefore, we will install more sensitive detector and Q-band microwave amplifier. The electron density profile will be measured in ECH, NBI and ICRF plasmas in the near future.

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