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Measurement of Temperature Fluctuation in TST-2 Sprical Tokamak

TST-2球状トカマク装置における温度揺動計測

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Edge electron temperature fluctuation is measured by fast voltage swept Langmuir probes on TST-2. The validity of obtained current-voltage characteristic curve was checked by comparing the time evolutions of the raw floating potential and that obtained from the fast voltage sweeping method. Good agreement between them was confirmed except that they shows a constant (DC) offset. We also found that fitting errors in the evaluation of the electron temperature itself are less than 10% of the rms fluctuation amplitude of the electron temperature. We also found that electron temperature fluctuation level may not be negligible in evaluating the electric field fluctuation.

1. Introduction

In magnetically confined fusion plasmas, edge turbulence determines a major part of transport losses across the last closed flux surface (LCFS) into the scrape-off layer, and plays a key role in the whole confinement condition. In order to understand the mechanism of turbulent transport, measurement of the local electric field fluctuation is necessary for evaluating the values of radial particle transport and Reynolds stress. The local electric field fluctuation is usually evaluated by the difference between floating potentials (V_fs) at two adjacent points separated by ~2–3mm [1], and the usage of I-V curves in evaluating electric field is limited [2]. The V_f is related to the plasma potential (V_{pl}) and the electron temperature (T_e) via $V_f = V_{pl}$-2.94T_e. Electron temperature fluctuations are usually considered to be negligible in a toroidally confined low temperature plasma [3]. However, in high-beta plasmas like spherical tokamak (ST) plasmas, this assumption is not guaranteed, and may lead to an erroneous result. Therefore, we measured electron temperature fluctuation in TST-2 edge plasma to investigate its influence on the potential fluctuation measurement by using the method of a proceeding work [4].

2. Experimental Setup

TST-2 is a small ST device with major radius R ~ 0.38 m, minor radius a ~ 0.25 m (aspect ratio A ≥ 1.5), elongation κ ≤ 1.2-1.8, and toroidal magnetic field B_t ≤ 0.3 T. Typical plasma parameters are: plasma current $I_p \leq 100$ kA, line-averaged electron density $n_e \leq 2 \times 10^{19}$ m^{-3}, central electron temperature at plasma center T_e = 100-300eV, and discharge duration ≤ 30ms. Plasmas in this experiment are ohmically heated.

Data were obtained with a multi-channel composite probe system. The composite probe is located on the midplane, and can be moved radially. Two other fixed probes are used to check discharge reproducibility. Figure 1 shows a photograph of the composite probe head and assignments of the electrode usage in this experiment. There are 4 electrodes on the front surface. One electrode is used to obtain I-V characteristics by applying a sinusoidal voltage of -250 to +50 V at 100 kHz. Other electrodes measure floating potentials (V_f). The current and voltage waveforms of the I-V characteristic are directly sampled by isolation analog-to-digital convertors with a sampling rate of 20 MHz without phase delay between the current and the voltage.

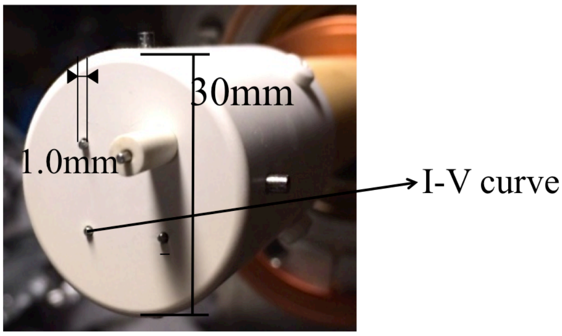

Fig.1. Photograph of the composite probe and the electrode used to measure I-V curve.

3. Experimental result

Since the sweeping frequency is a little higher or close to that of turbulence fluctuation, the effect of capacitive current due to coaxial cables of the signal transmission line, which can cause hysteresis of I-V curve, cannot be neglected. Therefore, capacitive current is subtracted from the raw probe current. After processing the data, the hysteresis of the I-V curves for $dI/dt > 0$ and at $dI/dt < 0$ during voltage sweep is not observed. The validity of data is checked by comparing the time evolution of floating potential and that acquired from I-V characteristics [5]. This comparison is valid when the observation location is inside the LCFS where the plasma potential can be considered to be approximately constant on the same flux surface. Figure 2 shows raw V_fs and V_f obtained from I-V characteristics. Although they show a DC offset of about 10 V, the time evolutions (i.e., AC components) are very similar and the difference between them is within the error bars calculated from the I-V curve fitting.

From the fitted curve, the electron temperature fluctuation is evaluated. The data used in the fitting are in the vicinity of the floating potential where the electron current collected from the plasma is smallest. Fluctuation amplitudes of T_e is about 5eV, whereas the mean T_e is 20 eV at LCFS, and fitting errors of electron temperature is less than 3%. The fluctuation level of T_e is about 25 %. On the contrary, the V_f fluctuation amplitude is 30 V, and the fluctuation level of T_e is about 1.5, larger than unity. Thus, T_e fluctuation level is half of that of V_f. This indicated that the plasma potential fluctuation should not be determined only by the floating potential fluctuation, but from both the floating potential and the electron temperature fluctuations in TST-2 plasmas.

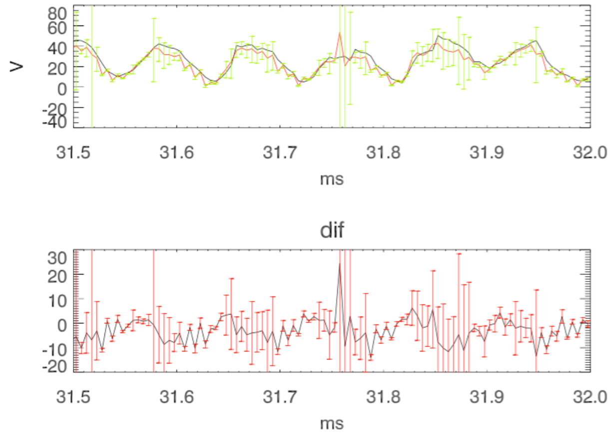

Fig.2. (a) Plots of raw V_f (black) and V_f acquired from I-V curve (red). (b) Plots of AC value of the difference between two V_fs.

4. Summary

Electron temperature fluctuations were measured by using fast voltage sweeping method in the edge of the TST-2 spherical tokamak plasmas. The validity of fitting is evaluated by comparing V_fs acquired by I-V curve fitting and by high impedance resistor independently. The fluctuation level of T_e is about 25%, which may not be negligible in evaluating the plasma potential fluctuation accurately. However, there is a possibility that the effect of the temperature fluctuation can be canceled in evaluation the electric field fluctuation. For future study, the obtained fluctuation of the electron density will be investigated under the mixing length assumption. In addition, comparison among the plasma potential, the floating potential, electric field and velocity fluctuations should be performed in detail.

Acknowledgments

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