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Two-dimensional fluctuation measurement of the edge turbulence in the TST-2 spherical tokamak

TST-2における周辺乱流の空間２次元計測

Masateru Sonehara, Yoshihiko Nagashima[1], Hidetoshi Kakuda, Yuichi Takase[2], Akira Ejiri[2], Junichi Hiratsuka, Takuya Oosako[2], Osamu Watanabe[2], Takashi Yamaguchi[2], Takuya Sakamoto[2], Takuma Wakatsuki, Takanori Ambo[2], Ryouta Shino, Hirokazu Furui[2], Takahiro Hashimoto, Kunihiko Kato[2] and Takahiro Shinya[2]

曽根原正晃, 永島芳彦[1], 角田英俊, 高瀬雄一[2], 江尻晶[2], 大迫琢也[2], 渡邉理[2], 平塚淳一, 山口隆史[2], 坂本拓也[2], 若月琢馬, 安保貴憲[2], 篠遼太, 古井宏和[2], 橋本貴博, 加藤邦彦[2], 新屋貴浩[2]

Graduate School of Science, the University of Tokyo
5-1-5,Kashiwanoha, Kashiwa, 277-8561
[1]Research Institute for Applied Mechanics, Kyushu University
6-1, Kasugakouen, Kasuga, 816-8580
[2]Graduate School of Frontier Sciences, the University of Tokyo
5-1-5,Kashiwanoha, Kashiwa, 277-8561
東京大学理学系研究科〒277-8561千葉県柏市柏の葉5-1-5
[1]九州大学応用力学研究所 〒816-8580 福岡県春日市春日公園6-1
[2]東京大学新領域創成科学研究科〒277-8561千葉県柏市柏の葉5-1-5

In order to investigate the poloidal structure of edge turbulence of ohmically heated plasma in Tokyo Spherical Tokamak-2 (TST-2), the experiments were conducted using two-dimensionally movable Langmuir probes. With monitoring floating potential and ion saturation current, the radial and poloidal profiles of edge turbulence are observed. High coherence of fluctuations at f ~10 to 100kHz measured with two probes 90° toroidally distant from each other is also observed. In order to investigate the nonlinear structure of the turbulence, bispectral analysis was used, and the observed auto-bicoherence pattern suggests the presence of the coupling and energy transfer between different modes.

1. Introduction

In fusion plasma research, study on anomalous transport by turbulence is important to control the transport and plasma operation. Recent researches of turbulence have paid special attention on nonlinear, non-local, and non-stationary properties of multi-scale turbulence. In many magnetic confinement toroidal plasma devices, poloidal asymmetry of fluctuations on the same flux surface has been observed [1,2]. Furthermore, recent research progress highlighted nonlinear couplings among multi-scale fluctuations as well as their spatial variation and non-locality [3]. Therefor, measurement of poloidal profiles of multi-scale fluctuations on the same flux surface is important to understand linear/nonlinear processes of fluctuations behind the saturated turbulence fluctuations and transport. In the poster, we introduce the progress of edge turbulence measurement across the broad range of the low-field side edge plasmas in the TST-2 spherical tokamak.

2. Experimental device

Typical design parameters of TST-2 are major radius $R \leqq 0.36$m, minor radius $a \leqq 0.23$ m, aspect ratio $A \geqq 1.6$, elongation $\kappa \leqq 1.8$, toroidal field $B_t \leqq 0.4$ T, plasma current $I_p \leqq 0.2$ MA, and discharge duration $\tau \leqq 40$ ms. Inductive start-up discharges are initiated by EC wave (2.45 GHz/5 kW) in this study. The target plasma parameters are: $I_p \sim 100$ kA, electron density $\bar{n}_e \sim 1\text{-}10 \times 10^{18}$ m^{-3}, $B_t \sim 0.2$ T, and Deuterium gas was used.

The analysis target plasmas is the stationary edge turbulence (several ms durations) without significant reconnection events. Edge turbulence was measured with a number of Langmuir probes (LP) installed at the low-field side: a midplane LP and upper/lower LPs. Each LP has several electrodes, and can measure the floating potential V_f and ion saturation current I_{is} simultaneously. Electron temperature (T_e) is also measured by sweeping the bias voltage every 1 ms.

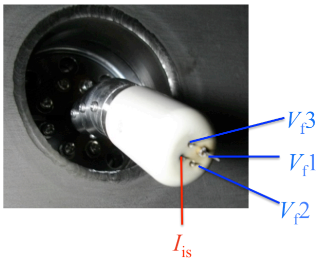

Fig. 1. (Color online) Enlarged view of the upper Langmuir probe. It has 4 electrodes and one electrode measures I_{is} and others V_f.

3. Results

First, we will give the information about the amplitude of fluctuations. The magnitude of V_f/T_e is roughly similar to that of $\tilde{I}_{is}/\bar{I}_{is}$ at R=630 mm, but $V_f/T_e > \tilde{I}_{is}/\bar{I}_{is}$ inside the plasma boundary. This result is similar to other tokamak experiments [4]. The typical auto-power spectra of the edge floating potential fluctuations show two spectral peaks at ~10 kHz and at ~100 kHz. In particular, the second peak is especially prominent for V_f.

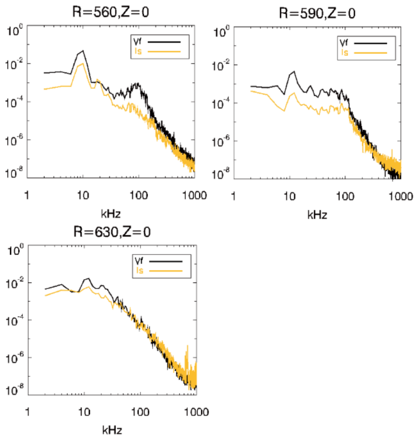

Fig.2 (Color online). Power spectra of V_f/T_e (black) and $\tilde{I}_{is}/\bar{I}_{is}$ (orange). Coherent peak observed at 10kHz is considered to be MHD-type fluctuation. (R=560 mm), a spectral peak is observed at ~100 kHz.

The both spectral peaks are prominent at inner area, and the magnitudes of these peaks decay as probe tips move away from the plasma boundary. The 10 kHz peak shows strong coherence between V_f and magnetic perturbation, thus the 10 kHz fluctuation is considered to be an MHD type mode. The second peak at several 10s kHz shows the increase as the probe tips go inside the boundary.

In studying the nature of the transport, the coherence and phase between density and potential fluctuations are important. When we assume that the electron temperature fluctuation is considerd to be negligible, V_f and I_{is} reflect potential and density fluctuations respectively.

In the radial and poloidal profiles of coherence and phase angle between V_f and I_{is}, high coherence was observed only in the radially limited edge region (R~570-600 mm), and phase shift varies from -0.2π to -0.7π according to the location.

In order to explore the nonlinear structure of the edge turbulence, bispectral analysis was applied to V_f. The total bicoherence has distinct peaks at f ~ 10 kHz and several 10s kHz, where corresponding spectral peaks of power spectrum are prominent.

These patterns indicate significant nonlinear couplings between the second spectral peaks and the turbulent fluctuations with the frequency higher than the second spectral peak, suggesting that the turbulence cascading of the fluctuation with the second peak occurs.

The high coherence of several kHz to 100 kHz measured with two probes 90° toroidally and ~75° poloidally distant from each other are also observed. This suggests the two probes were connected through the magnetic field line, and the correlation length of turbulence along the line is very long.

4. Discussion

The coherence and phase between V_f and I_{is} varies significantly around the edge region, suggesting the difference in transport in those regions. The bispectral analysis shows the presence of nonlinear coupling between the MHD mode at 10 kHz, the coherent mode at 70 kHz, and background microscopic fluctuations. It should be noted A. Ishizawa, and N. Nakajima pointed out that a macro-MHD mode is excited as a result of micro turbulence and zonal flow [5]. However, when the turbulence intensity has radial profile, oscillation of the magnetic flux surface may modulate turbulence intensity, and this may cause nonlinear coupling between MHD mode and turbulence. Further study is necessary to confirm nonlinear energy transfer from turbulence to MHD mode on the basis of equation of motion.

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References

[1] G. Antar, et al.: Phys. Plasmas **12**, (2005) 032506.
[2] J Stockel, et al.: Plasma Phys. Control. Fusion **47** (2005) 635.
[3] Y. Nagashima, et al.: Phys. Plasmas **16**, (2009) 020706.
[4] S.J. Zweben, et al.: Nucl. Fusion. **25**, (1985) 171.
[5] A. Ishizawa, N. Nakajima: Phys. Plasmas **14** (2007) 040702.