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Edge Ion Saturation Current Fluctuation Measurement in PANTA
PANTAにおける周辺プラズマイオン飽和電流揺動計測

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Fluctuations of ion saturation current at distant positions are simultaneously measured with a 5-pins radial probe array and a 5-pins azimuthal probe array in the linear magnetized plasma device PANTA. In the edge region, large-amplitude positive bursts are observed and the probability density function (PDF) is positively skewed. The propagation velocities of bursts are estimated both in radial and azimuthal directions by the time delay estimation method.

1. Introduction

The understanding of plasma turbulence is strongly required to realize fusion reactors since turbulence-driven transport has a significant effect on plasma confinement. Intermittent coherent structures (e.g. plasma blobs) are observed in the scrape-off layer of magnetic fusion devices [1] and linear devices [2]. The nonlinear nature inherent to intermittent fluctuation signals appear as non-Gaussianity of their probability density function (PDF). Intermittent heat pulses to the wall should be avoided in the future fusion plasma device such as ITER and the understanding of intermittent phenomena is a great challenge in plasma turbulence physics.

In this study, we will report ion saturation current bursts observed in the edge region of PANTA. The spatio-temporal structures are measured with Langmuir probes. The radial structure of statistical properties of this phenomenon is presented along with propagation velocities of burst signals in radial and azimuthal directions.

2. Experimental Setup

A cylindrical plasma with a diameter of approximately 0.1 m and axial length 4 m is generated by helicon wave (7 MHz, 3 kW) in the linear device PANTA. The operational conditions are a magnetic field of 0.09 T and neutral argon gas pressure of 0.8 mTorr. Ion saturation current (I_{is}) and floating potential (V_{f}) are measured with a movable Langmuir probe array. Two probe arrays, each of which have five tungsten tips, are installed at the axial position z = 1.675 m to estimate

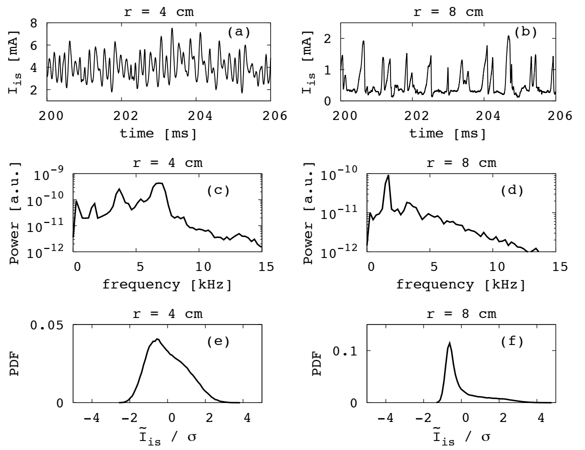

Fig.1. (a), (b) Typical time evolution, (c), (d) power spectrum, (e), (f) PDF of I_{is}

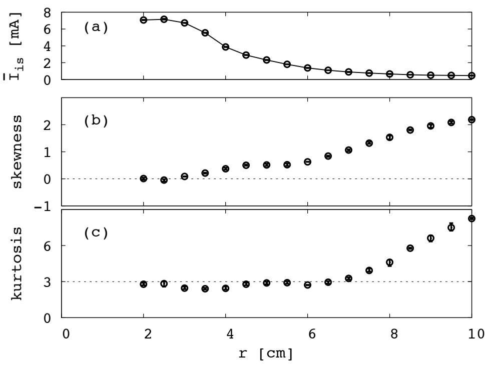

Fig.2. Radial profiles of (a) average, (b) skewness and (c) kurtosis of I_{is}

propagation velocity of signals. One has a separation of 3 mm between tips in the azimuthal direction and another a separation of 10 mm in the radial direction. The data sampling frequency is 1 MHz.

3. Statistical Analysis and Fluctuation Properties

Typical time evolutions of I_{is} at r = 4 cm and r = 8 cm measured with a 5-pins radial probe array are shown in Fig. 1 (a) and (b), respectively. Radial gradient of $\bar{I}_{is}$ ($\nabla_r \bar{I}_{is}$) is maximal at r = 4 cm and time-averaged fluctuation level ($\tilde{I}_{is}/\bar{I}_{is}$) reaches its maximum at r = 8 cm. The power spectra shown in Fig. 1 (c) and (d) have peaks at the same frequency f = 1.7 kHz and the coherence is high (~0.9) at that frequency. By using a 64-channel azimuthal probe array, it was found that f = 1.7 kHz has azimuthal mode number m = -1 (propagating in ion diamagnetic direction) at r = 4 cm.

A degree of deviation of PDFs from the Gaussian distribution is indicated by skewness (S) and kurtosis (K). The values are S=0 and K=3 for a Gaussian distribution. PDFs at the two positions are shown in Fig. 1 (e) and (f). At r = 8 cm, PDF is positively skewed with S=1.5 and K=4.6 whereas S=0.4 and K=2.4 at r = 4 cm. Radial profiles of $\bar{I}_{is}$ as well as S and K of $\tilde{I}_{is}$ are plotted in Fig. 2. Skewness gradually increases with the observed radii, from r = 2 cm to 10 cm. Kurtosis stays around K=3 inside r = 6 cm and increases with the radius to K=8.2 at r = 10 cm.

4. Velocity of Burst Signals

The simultaneous multi-point measurement of I_{is} allows us to estimate propagation velocities. Velocities of burst signals ($\tilde{I}_{is}/\sigma > 3$) are estimated by the formula $v=d/\Delta t$ where d is the distance between two probe tips and Δt is the time delay obtained by using cross correlation between two signals. At r = 8 cm, estimated azimuthal velocity v_θ is ~1000 m/s and propagation is in ion diamagnetic direction. Radial velocity v_r varies widely but is ~1400 m/s (outward) on average.

5. Discussion and Summary

The radial structure of statistical properties of ion saturation current fluctuations is investigated at a neutral pressure of 0.8 mTorr and a magnetic field of 0.09 T. Skewness and kurtosis increase with the radial position in peripheral region (r > 6 cm). This indicates that the fluctuations become more intermittent as going away from the density steep region. Fluctuations are characterized by the power spectra and the PDFs in the plasma core (r = 4 cm) and edge (r = 8 cm). The spectra have a common peak at f = 1.7 kHz with high coherence. Azimuthal and radial velocities of burst signals are found to be ~1000 m/s and ~1400 m/s at r = 8 cm, respectively. These results indicate there can be some coherent structures propagating in the edge region whose formation is strongly related to the mode (m, f) = (-1, 1.7kHz) at r = 4 cm. We will investigate the relationship between this intermittent phenomenon and the existence (or strength) of the mode m = -1 in various operational conditions. Also we have the future plan to investigate the effects of shear flows induced by end-plate biasing on the statistical properties of ion saturation current fluctuations.

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