FILLING GAS PRESSURE DEPENDENCE OF PANTA PLASMA PROPERTIES INVESTIGATED WITH TOMOGRAPHY

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ABSTRACT

In a linear plasma device, PANTA, the plasma properties are controlled by changing filling pressure, heating power, and magnetic field strength. The changes in the plasma properties are studied with non-perturbed measurement using a 3D tomography system. In this paper, we focus on the observation results of the gas pressure dependence of the PANTA plasma characteristics. In addition, it is found, under certain conditions, that a phenomenon is observed in which the plasma emission intensity signal repeatedly transitions between two states.

KEY WORDS

tomography, linear cylindrical plasma

1. INTRODUCTION

Fusion power generation is expected to produce a clean and sustainable next-generation energy source. Various studies are underway to realize a fusion reactor using a magnetically confinement plasma. However, anomalous transport due to plasma turbulence remains a significant issue that degrades magnetic confinement performance. To overcome the problem, it is necessary to elucidate the physical mechanism of turbulent transport in a magnetically confined plasma.

In a magnetically confined plasma, turbulence is self-organized by the formation of meso-scale structures such as zonal flows and streamers. These structures couple with microscale fluctuations through nonlinear interactions and significantly impact plasma dynamics. For understanding the fundamental processes to form plasma turbulence requires simultaneous two-dimensional (2D) measurements of turbulent fluctuations across different scales over the entire plasma cross-section.

In our laboratory, elemental plasma properties including such fundamental processes in plasma turbulence have been investigated using 3D tomography in a linear cylindrical device named Plasma Assembly for Nonlinear Turbulence Analysis (PANTA). In this presentation we report the results to investigate the gas pressure dependence of plasma characteristics using a tomography measurement system developed for PANTA.

2. PANTA AND TOMOGRAPHY SYSTEM

The PANTA device is designed to study turbulence in cylindrical plasmas. Its length and diameter are 4 m and 0.45 m, respectively. The device produces a cylindrical plasma with a diameter of 0.1 m, with RF heating at 7 MHz. As shown in Figure 1, a tomography system is installed at z = 0.35, 0.60, and 0.85 m along the axial direction of PANTA. This system comprises 128 detectors surrounding the plasma and can measure the distribution of plasma emission without disturbing the plasma.

In the estimate of local plasma emission, the plasma cross-section is divided into a mesh-like grid and the emission value (εj) at each grid point is related to the line-integrated data (yi) from each detector by the following equation:

$$yi = \Sigma j\ Cij\ \varepsilon j. \qquad (1)$$

Cij denotes the probability of detecting light from grid j by detector i. The Maximum Likelihood Expectation Maximization (MLEM) method is employed for 2D image reconstruction of the plasma emission distribution [1].

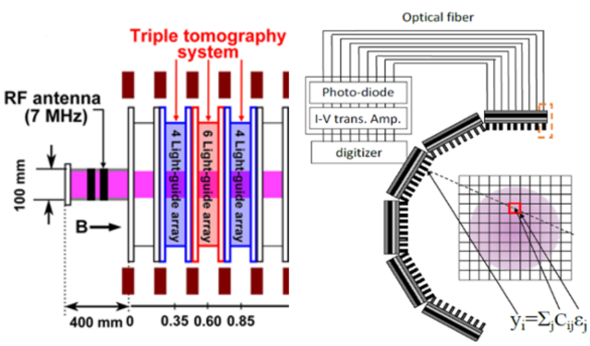

Fig.1: Overview of Tomography System

3. RESULTS

In this experiment, argon plasma is produced with a constant magnetic field of 900 G and RF heating power of 3 kW at gas pressures of 3.07, 3.51, 4.19, and 4.67 mTorr. ArII emission was measured using tomography, and its dependence on gas pressure was investigated at z = 0.35, 0.60 and 0.85 m.

3.1 Mean emission profile

The changes in the plasma properties were examined separately for the mean emission profile and its fluctuations. First, the dependence of the total emission on gas pressure is shown in Figure 2(a). Next, the temporal average emission profile of Argon ions (ArII) is divided into the symmetric (or m=0 component) and the axisymmetric part (or m≠0 component), using the Fourier-Bessel (FB) function.

Figure 2(a) shows that the total emission decreases with increasing gas pressure at all Z positions, while Figure 2(b) shows the symmetric parts of the average emission profiles at different gas pressures. There is a significant decrease in total emission from Z=0.35m to Z=0.6m due to the recombination of argon ions. In Figure 2(b), a hollow radial profile was observed at low gas pressure, while a centrally peaked profile was observed at high gas pressure. It was also observed that the shape changed along the axial direction.

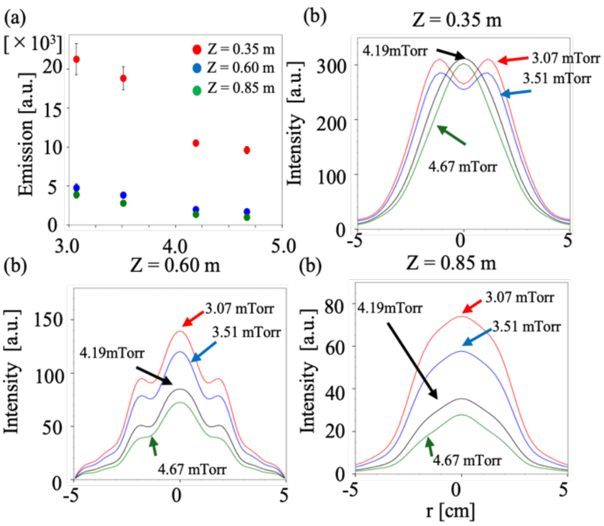

Fig.2: (a) Total emission, (b) Axisymmetric component radial profile

3.2 Power Spectral Density

Power spectral density analysis was performed on total emission. Figure 3 shows the power spectral densities (PSD), which shows the presence of sharp peaks; for example, approximately at 2 kHz and 4 kHz at a gas pressure of 3.07 mTorr, and approximately at 1.2 kHz under all gas pressure conditions except the case of 3.07 m. The total fluctuation powers tend to decrease with a gas pressure increase.

3.3 Spontaneous transitions

An interesting feature, repetitive transitions between two states, was found in temporal evolution of plasma emission at a gas pressure of 3.51 mTorr. Figure 4 shows the temporal wave form to show the repetitive transitions between the two states that show the characteristics at a gas pressure of 3.07 and 4.19 mTorr. A similar phenomenon has been reported in probe measurements of a linear cylindrical plasma in LMD-U [2]. The phenomenon is confirmed with the present studies using 3D tomography measurements. Figure 4(a) shows the time evolution of the total emission in the transition state. Figure 4(b) shows the power ratio of the incident wave to the reflected wave in the helicon plasma source, which indicate that the fluctuation in the power ratio was less than 1%. This fact may suggest that the change in power ratio should be small to cause the transition.

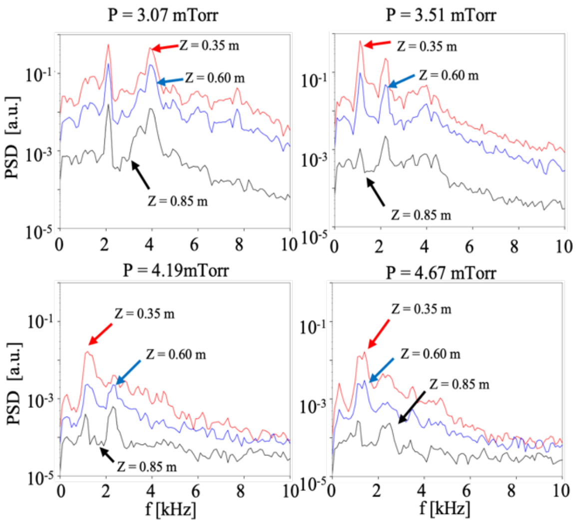

Fig.3: Filling gas pressure dependence of power spectral density

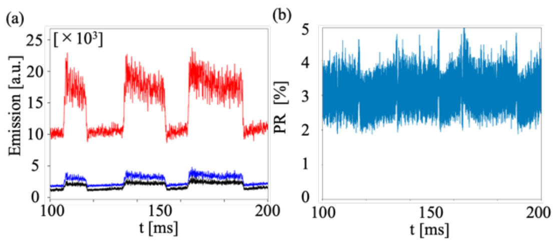

Fig.4: (a) Time evolution of total emission in transition state (100~200 ms), (b) variation of reflected power with respect to plasma incident power.

4. SUMMARY

Initial results on the gas pressure dependence of the plasma structure and fluctuations were obtained using PANTA's 3D tomography. In this presentation, we will also report on further observation results and the progress of experimental analysis of the transition phenomenon.

REFERENCES

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