23P045-P

Density Fluctuation Excitation Experiments using Supersonic Gas Puffing
超音速ガスパフによる密度揺動励起実験

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Density fluctuation excitation experiments using supersonic gas puffing (SSGP) has been carried out in the Large Helical Devise (LHD). High-frequency injection (500 Hz) was confirmed in preliminary experiments on a test stand using the fast solenoid valve for SSGP. In the plasma experiment in LHD, the density fluctuation of 50 Hz was excited by SSGP. Higher harmonics of up to 200 Hz was also observed simultaneously. Experimental results obtained in the test stand and LHD, together with the optimum operation condition of SSGP for density fluctuation excitation will be discussed in this presentation.

1. Introduction

Density and/or temperature fluctuations related to the MHD instabilities and micro instabilities are always observed in plasma experiments. Especially, anomalous transport driven by micro instabilities is thought to be playing an important role in determining the confinement property of the plasma. It is therefore desired to find a method to control the instabilities of the order of kHz to MHz to mitigate the anomalous transport and improve the confinement property.

On the other hand, density modulation of the order of 1 Hz using normal gas puffing has been carried out to estimate the particle transport coefficient [1]. Repetitive injection of small hydrogen ice pellet of the order of 10 Hz has been shown to be effective for controlling ELMs in tokamaks [2]. It has been, however, difficult to drive the density fluctuation of the order of kHz.

Recently, a supersonic gas puff (SSGP) device has been installed on the Large Helical Device (LHD) [3]. In SSGP, high-pressure gas is ejected through a fast solenoid valve equipped with a Laval nozzle, which produces the convergent gas flow. SSGP is characterized by the high working pressure of up to 8 MPa and the high time response of up to 1 kHz. The former is effective for achieving high fueling efficiency reaching ~30 % [3], while the latter makes a possibility of fast density fluctuation excitation by SSGP.

In this presentation, basic characteristics of the SSGP device (Section 2) and results of the density fluctuation excitation experiment carried out in LHD (Section 3) are discussed.

2. The SSGP Device and Test Results

The SSGP device in LHD consists of three solenoid valves equipped with different Laval nozzles of 0.1, 0.3 and 0.6 mm throat diameter. By selecting nozzles and backing pressure, one can adjust the flow rate of SSGP from ~1 to ~1000 Pam^3/s. The SSGP device is set on a lower port of LHD and therefore the gas flow is upward. The distance from nozzle to plasma is ~4 m.

Preliminary experiments using the solenoid valves and Laval nozzles were carried out in a test stand [4,5]. To visualize the gas flow, the working gas was cooled by using a refrigerator and cluster beams were formed. Continuous visible laser light intersecting the gas flow at a few cm from the exit

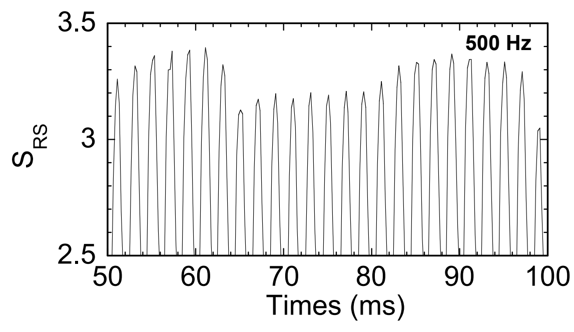

Fig. 1. Temporal evolution of the scattered signal from the hydrogen cluster beam ejected through the fast solenoid valve.

of the Laval nozzle was applied and the laser light scattered by the cluster beam was detected by a fast camera. Figure 1 shows typical time evolution of the scattering signal from the supersonic hydrogen cluster beam. In this case, the valve was operated at 500 Hz with the pulse length of 50 μs. Then, the scattered light fluctuating at 500 Hz was observed as shown in Fig. 1.

3. Density Fluctuation Excitation

Figure 2(a) shows the typical waveform of the line density at the plasma edge region measured by a far infrared laser interferometer (FIR) [6]. In this experiment, the working gas was hydrogen and the backing pressure was ~1 MPa. The magnetic field strength on the magnetic axis was 1.5 T. The major radius and the minor radius of the plasma torus were 3.75 m and 0.6 m, respectively. The line-of-sight of FIR No.1 channel passes through the plasma edge region including the so-called ergodic layer in LHD. The pulse length and the injection cycle of SSGP were set to 1 ms and 50 Hz, respectively. SSGP was injected during 3.5 - 4.3 s. As seen in the figure, the density fluctuation was excited by SSGP. The increasing rate of the density signal was changed at ~3.7 s. This might be reflecting the density dependence of the fueling efficiency of SSGP [3]. Further investigation on this is, however, remained for future studies.

Figure 2(b) shows the Fourier spectrum of the line density signal shown in Fig. 2(a). A large peak is recognized at 50 Hz, which corresponds to the injection cycle of SSGP. Higher harmonics that might be related to the peak of 50 Hz are also observed at 100 and 200 Hz (and presumably at 150 Hz, although it is unclear).

To excite the density fluctuations, the Laval nozzle and the backing pressure, *i.e.*, the flow rate of SSGP, should be chosen carefully. Even at a high backing pressure of 2.5 MPa, the 0.1 mm Laval nozzle was not effective for density fluctuation excitation since the density perturbation by each pulse was so small that cannot be detected by FIR. High frequency injection from 0.3 mm Laval nozzle was effective as shown in Fig. 2. In the case of 0.6 mm Laval nozzle, on the other hand, the density perturbation was too large and the density of the target plasma increased as a result. The optimum flow rate for density fluctuation excitation in LHD was 40 – 100 Pam^3/s, which was realized by the 0.3 mm Laval nozzle with the backing pressure of 1 – 2.5 MPa.

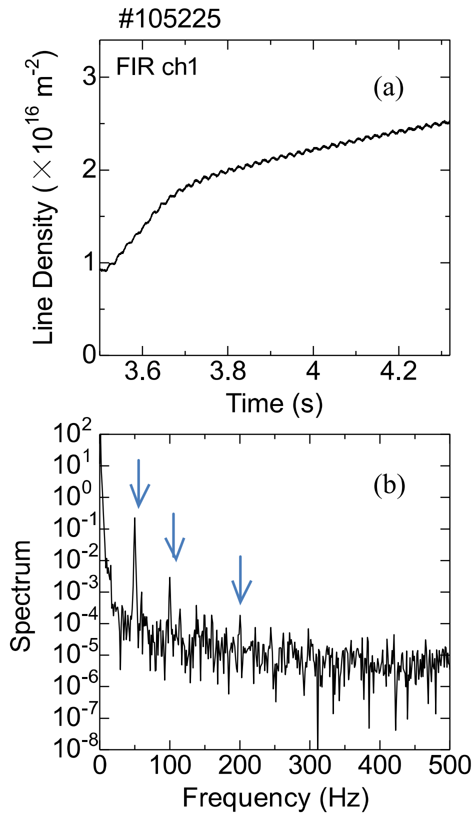

Fig.2. (a) Typical temporal evolution of the line density of FIR ch.1, and (b) the Fourier spectrum of the density fluctuation. SSGP was injected from t = 3.5 s to 4.3 s.

4. Summary

The density fluctuation has been successfully excited by using SSGP in LHD, although the achieved frequency of 50 Hz is still smaller than that demonstrated in the test stand of 500 Hz. Higher harmonics of up to 200 Hz was simultaneously observed with the 50 Hz density fluctuation. The optimum operation condition for density fluctuation excitation was found at the flow rate of 40 – 100 Pam^3/s.

Acknowledgments

The authors would like to thank all of the members of LHD Experiment Group. This work has been financially supported by the Ministry of Education, Sports, Culture, Science and Technology, Grants-in-Aid for Scientific Research (S) 20226018 and NIFS09ULFF006.

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