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Peripheral Plasma Turbulence Measurement of Heliotron J plasmas

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Using a fast camera with tangential view motion of the filamentary structures in peripheral regions was observed. It was already confirmed that motion of this turbulence was dithering during "Phase I" in former SMBI (supersonic molecular beam injection) experiment. During "Phase I" Heliotron J plasma did not always reach the H-mode nor radiation collapse even though the electron density was larger than the threshold. Moreover, the electron density may be controllable in "Phase I" plasma. It was favorable for fusion reactor plasma. This time SMBI experiment with careful adjustment of gas puff quantity was demonstrated for realizing "Phase I" and it was successful to obtain higher confinement energy shot. In this paper the fast camera measurement of this experiment is described.

Keywords: turbulence, peripheral plasma, L-H transition, H-mode, Heliotron J, fast camera

1. Introduction

Fast cameras have been installed in Heliotron J [1,2] since several years [3-5]. Recent progress of fast cameras enables us to get information on the peripheral plasma turbulence. In particular, using a conventional gas puff, supersonic molecular beam injection (SMBI) [5], and solid target such as limiter [3] are very useful to visualize complex peripheral plasma behavior. Also, a combination of conventional peripheral plasma measurement (Langmuir probe, magnetic probe, etc) and fast cameras gives us the powerful method to study plasma turbulence [4].

In the first SMBI experiment of this year it was found that after SMBI a kind of improved confinement mode "Phase I" [6-8] appeared instead of the H-mode. Camera images show filamentary structure of peripheral plasma rotated with L-mode direction (if this was ErxB drift, Er is positive.), and sometimes the rotation changed to the H-mode direction (if this was ErxB drift, Er is negative). That was called "dithering", and this was one of the feature of "Phase I" in Heliotron J. In this experiment, low frequency MHD activity occurred after SMBI with large gas quantity (too high pressure), and the energy confinement degraded.

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However, some shots maintained, "Phase I" and they did not reach H-mode. The latter case the electron density rose more than the transition threshold.

In Heliotron devices the rise of the electron density after H-mode is uncontrollable, and usually plasma reach radiation collapse with short time after the transition.

This phase I sometimes did not reach H-mode, therefore the energy confinement is not better than H-mode. However, it did not reach radiation collapse and it is prominent improved mode to be able to control the density.

In this experiment the gas quantity of SMBI was adjusted carefully and higher confinement energy shot was realized after SMBI. In this paper the fast camera measurement of this SMBI shot was reported.

2. Experimental Setup

Heliotron J device is a medium sized helical-axis heliotron device (averaged R/a=1.2m/0.17m, B=1.5T) with l=1, m=4 helical coil configuration. Figure 1 shows top view of Heliotron J and main diagnostics used in this paper and the camera location.

In general the initial plasma is produced by ECH (70GHz, 0.45MW, non-focusing Gaussian beam) launched from a top port. Two NB system (BL-1,2; 30keV, 0.7WM) are installed with tangential port, and they faced each other. Selecting one of the two beam-lines or changing the direction of the confinement field, Co- or CTR-injection can be performed.

One SMBI and four conventional gas puff systems with piezoelectric valves are installed at the outer side and inner side ports, respectively.

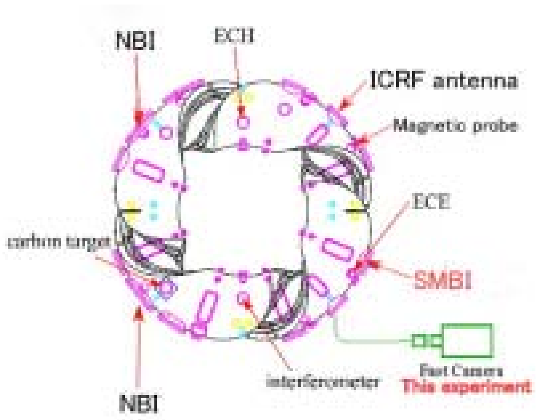

Fig.1 Top view of Heliotron J
The fast camera can view the ICRF antenna and SMBI.

3. Results and discussion

The waveforms with or without SMBI are shown in Fig.2 and 3, respectively. After SMBI the diamagnetic signal rose gradually, and ~13 ms later the diamagnetic signal began to decrease.

From ECE and AXUV signals (not shown in the figure) it was inferred that the electron temperature decreased due to SMBI [9,10] and the electron density increased. It seemed that these effects cancelled out each other, and the diamagnetic signal did not increased just after SMBI. Afterwards the diamagnetic signal increased gradually due to NBI. However, more precise profile information is needed to conclude this scenario.

The important thing is that after SMBI the electron density became larger than the threshold of the L-H transition, however, plasma did not reach H-mode. Therefore, plasma terminated without the radiation collapse. This feature is called 'Phase I' in Ref [5].

The fast camera images with 40000 FPS show that filamentary structure was seen near the ICRF antenna, and it was brighter when filament hit the antenna. Fig.4 shows the fast camera image during SMBI. Near ICRF antenna the motion of filamentary structure rotate with unti-clockwise firstly. However, after ~190ms sometimes rotation direction changed to clockwise. Therefore, it was recognized that plasma was 'dithering phase' after ~190ms. To visualize this motion clearly two-dimensional phase images of 8.75kHz frequency component were shown in Fig. 5.

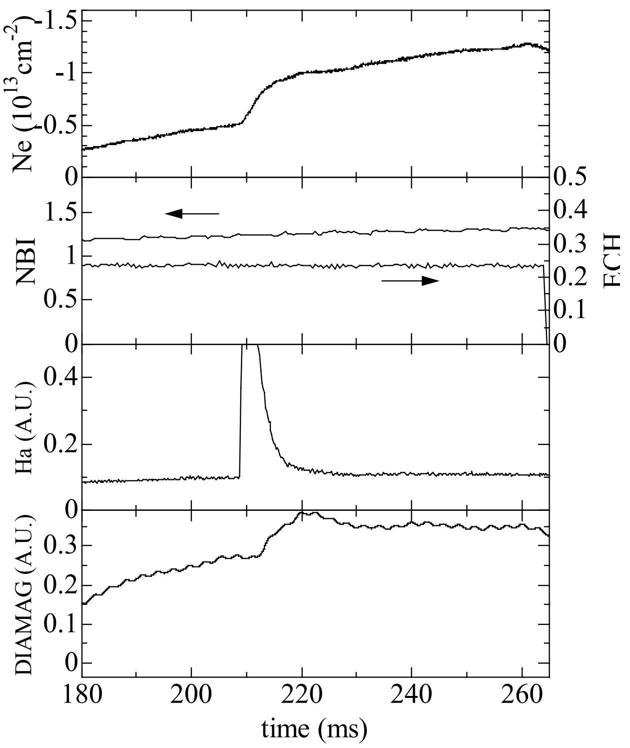

Fig.2 Typical waveform of Heliotron J plasma with SMBI (#32816)

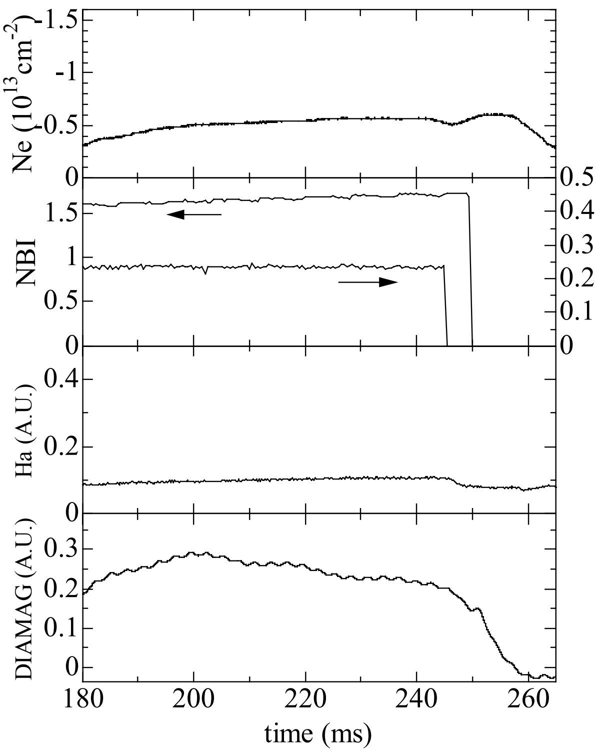

Fig.3 Typical waveform of Heliotron J plasma without SMBI (#32783)

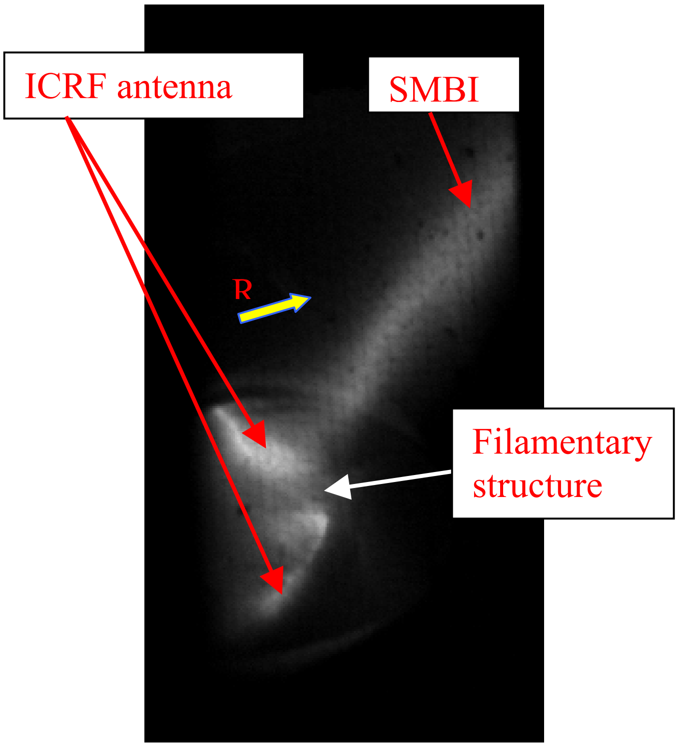

Fig.4 Fast camera image during SMBI

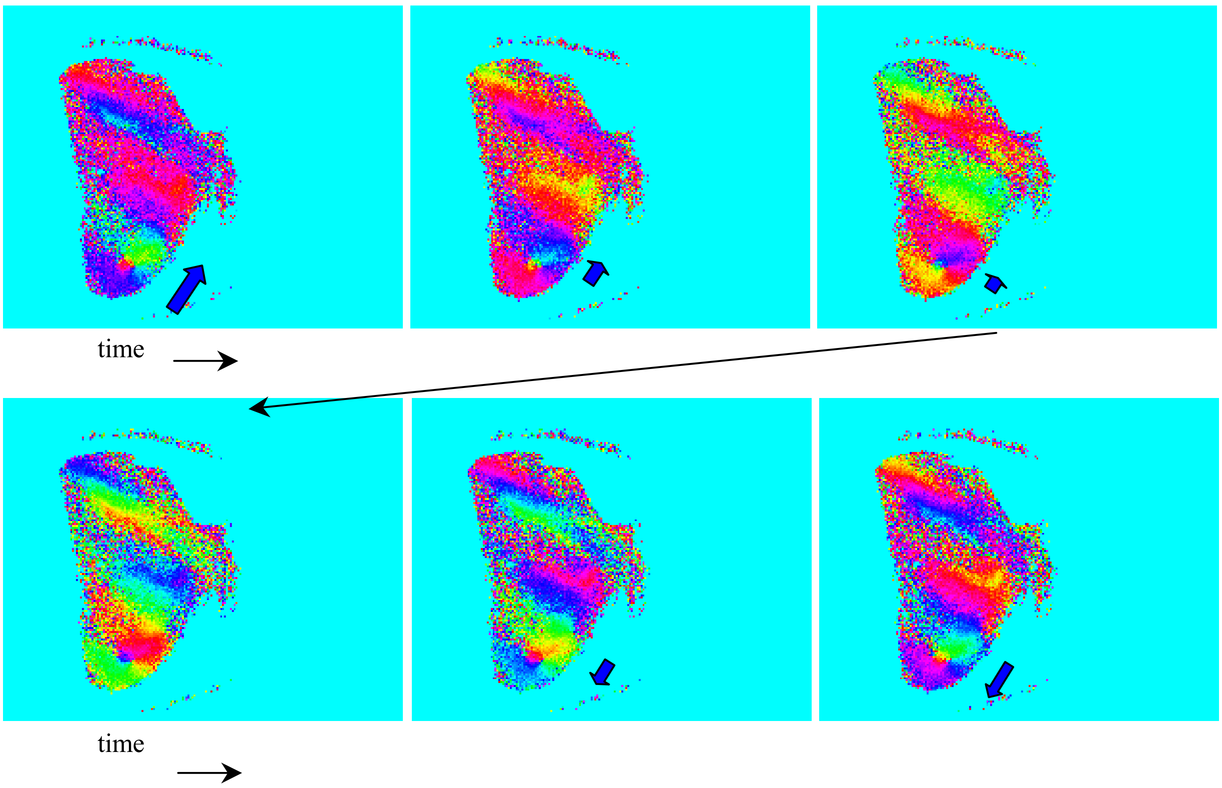

Fig.5 Two-dimensional phase images during “dithering phase”
A part of images near the ICRF antenna are shown.

The way to create these images is that first the frequency peak in the power spectra from FFT during suitable period for one pixel data in ROI (region of interest) is selected, and second the phases of the same frequency for all pixels are colored by color chart. Therefore, this phase images show the wavelength of the turbulence at the selected frequency and its motion. If there was no frequency peak in the spectra obtained by pixel data in ROI, typical frequency of the turbulence in Heliotron J plasma could be selected.

This time typical frequency of 8.75kHz in the frequency range of the peripheral turbulence (5-10kHz) in Heliotron J plasma was selected.

Just after SMBI the whole plasma began brighter and the whole picture was the same color in two-dimensional phase image, but afterwards the turbulent motion was recognized. The apparent filamentary structure motion was recognized "dithering phase", and that meant plasma was "Phase I".

Without SMBI shot the "dithering phase" was confirmed after ~190ms, and it was believed that plasma was "Phase I"

This SMBI experiment reproduced the former SMBI experiment very well, and it was not found the difference of the filamentary structure motion between the camera images before and after SMBI.

Figure 6 shows the magnetic probe signal for MHD activity. The time slices of the spectrum of this signal are shown in Fig. 7.

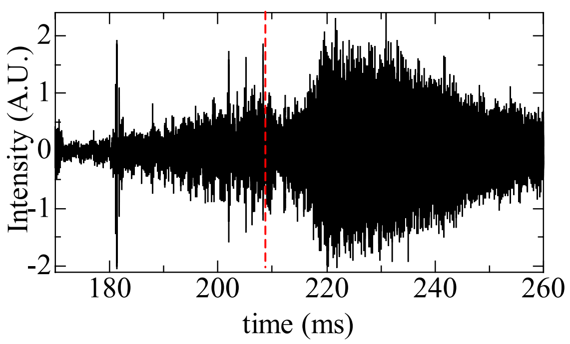

Fig.6 Magnetic probe signal (raw data)
Red line shows SMBI time. MHD activity was decreased due to SMBI.

The MHD activity in low frequency range of 10-20kHz grew from ~190ms and after 210ms (time of SMBI) this activity was decreased temporary. Afterwards (~220ms) this activity was growing again. It seemed that the effect of SMBI reduced this activity. There were another frequency peaks in high frequency range and those were thought as GAE mode (global Alfven eigen-mode). However, those GAE mode existed with no relation to SMBI, therefore GAE mode in this experiment did not affect the characteristics of the energy confinement.

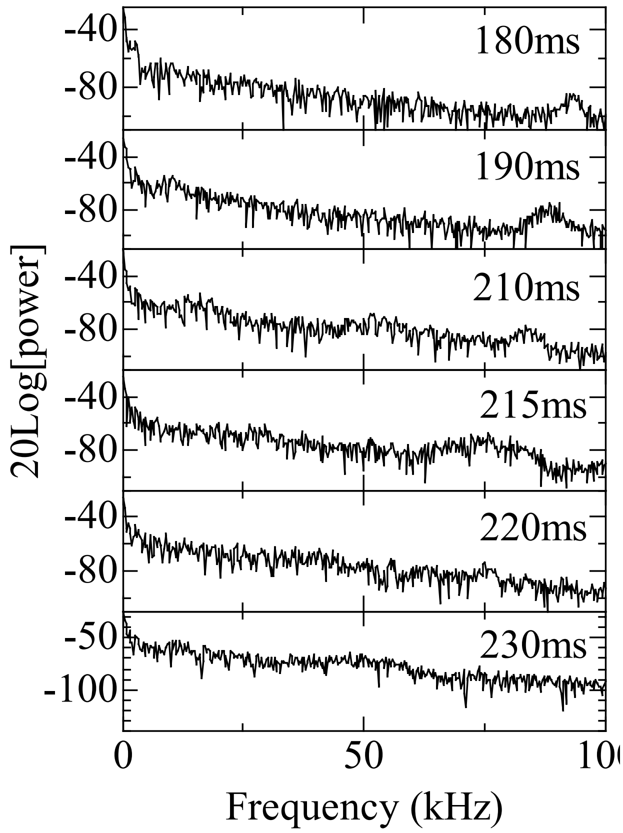

Fig.7 Spectra of magnetic probe signal
SMBI starts at 209ms and reduction of low frequency activity at 215ms was recognized.

Only difference between with or without SMBI was the former low frequency MHD activity. Thus, it possibly relate to the energy confinement of Heliotron J plasmas.

Unfortunately in this experiment plasma was not so bright before and after SMBI, and the camera images could be taken up to 40000 FPS. Therefore, the turbulence of these frequency ranges could not be obtained. Plasma is very bright during SMBI using the view port of this experiment, thus the view port at other toroidal section is needed for turbulence measurement included in SMBI period. Because Hα signals strongly depend on the toroidal section during SMBI.

This is the experimental problem to be solved.

4. Conclusion

Using SMBI high confinement energy shots, which could not be reached by conventional gas puff, were obtained. Also it was confirmed that these shots were a kind of improved mode "Phase I" by the fast camera images.

Further investigation is necessary to understand the physical mechanism why “Phase I” plasma did not reach H-mode even though the electron density is over the threshold of the L-H transition. For this purpose the experiments are in progress in Heliotron J.

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