Measurement of peripheral plasma turbulence using a fast camera in Heliotron J

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1. Introduction

Study of peripheral turbulence is very important issue for fusion research due to the relationship to the energy confinement and H-mode physics. Fast cameras have been installed in Heliotron J [1] to get information on the peripheral plasma turbulence since several years ago. In our previous work, using a combination method of a fast camera (Ultima-SE, Photron) and a small movable carbon target, a structure of a low frequency (5-6kHz) edge plasma oscillation in high electron density ECH discharges was observed just after the L-H transition [2]. Also a combination of a fast camera (FX-K4, NAC image technology), movable probe and directional gas puff technique gave us important information that the spatial profile of turbulent burst in the edge plasma were observed as a filamentary structure in the L-mode [3-5]. Each burst of the ion saturation current was corresponding to that the filamentary structure hit the probe simultaneously.

Recently the turbulent structures during the L-mode and H-mode were observed by the latter camera with/without directional gas puff [6]. It was clear that the spatial structure of peripheral turbulence during the L-mode was different with that of the H-mode. Relative wide structure along the magnetic field was observed in the H-mode however, narrower structure along the magnetic field was observed in the L-mode. Moreover, these filamentary structures were sometimes disappeared in the H-mode.

In this paper the obtained results included in the latest results of Heliotron J plasmas by the fast camera are reported.

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2. Experimental Setup

The tangential port was provided with the fast camera to measure peripheral plasma behavior easily. Fig.1 shows the tangential port position (green) and horizontal port position (blue) for the fast camera. These measurements could not be done simultaneously because of the same fast camera (FX-K4, NAC image technology).

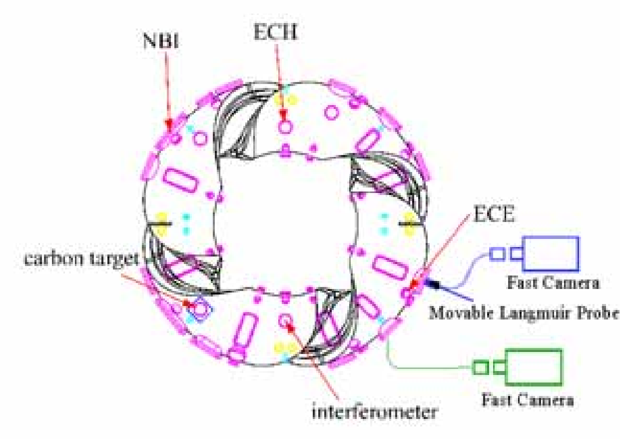


Fig.1. Location of tangential view for the fast camera in Heliotron J

Fig. 2 shows the tangential view of the fast camera. This view is the initial phase of Heliotron J plasma discharge. The first bright string in the images became thicker and darker, and the equilibrium state was obtained.

Unfortunately the adjustment of the up-down direction in the image was not completed this time, however, it was clear to see the port and its position. In the image the grids were each fiber of the coherent bundle fiber.

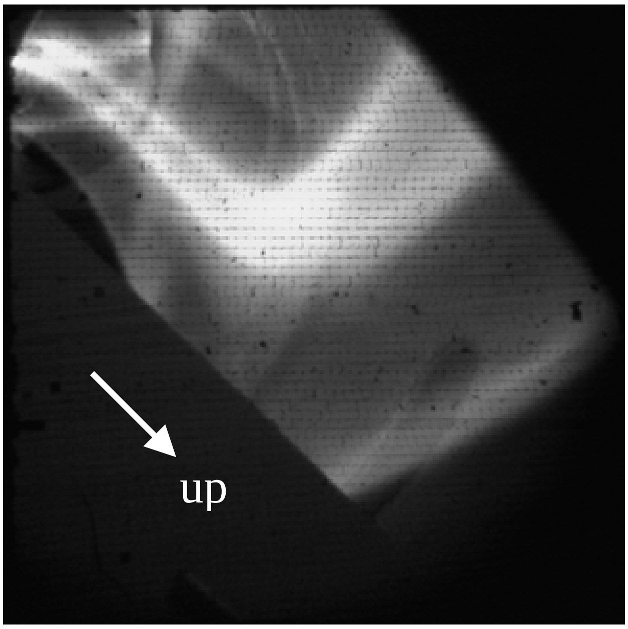


Fig.2 Tangential view from the fast camera
A part of the original image (448x368pixels, 10000FPS)

3. Results and discussion

In high density ECH discharge of STD configuration (-86%, -87%, –88%, -89% of the magnetic field strength) the abrupt drop of Dα signal were observed and the H-mode plasmas were obtained. In these shots the reproducibility was very good. Typical waveform of H-mode shot is shown in Fig.3. Fig.4 shows the ion saturation current of the movable probe of the same shot. The power spectra of this ion saturation current show the low frequency fluctuation were suppressed during H-mode (not shown here).

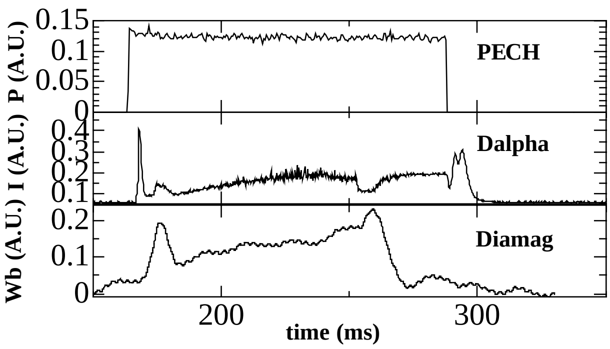


Fig.3 Typical waveform of H-mode in ECH discharge

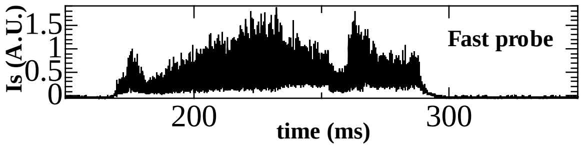


Fig.4 Ion saturation current signal

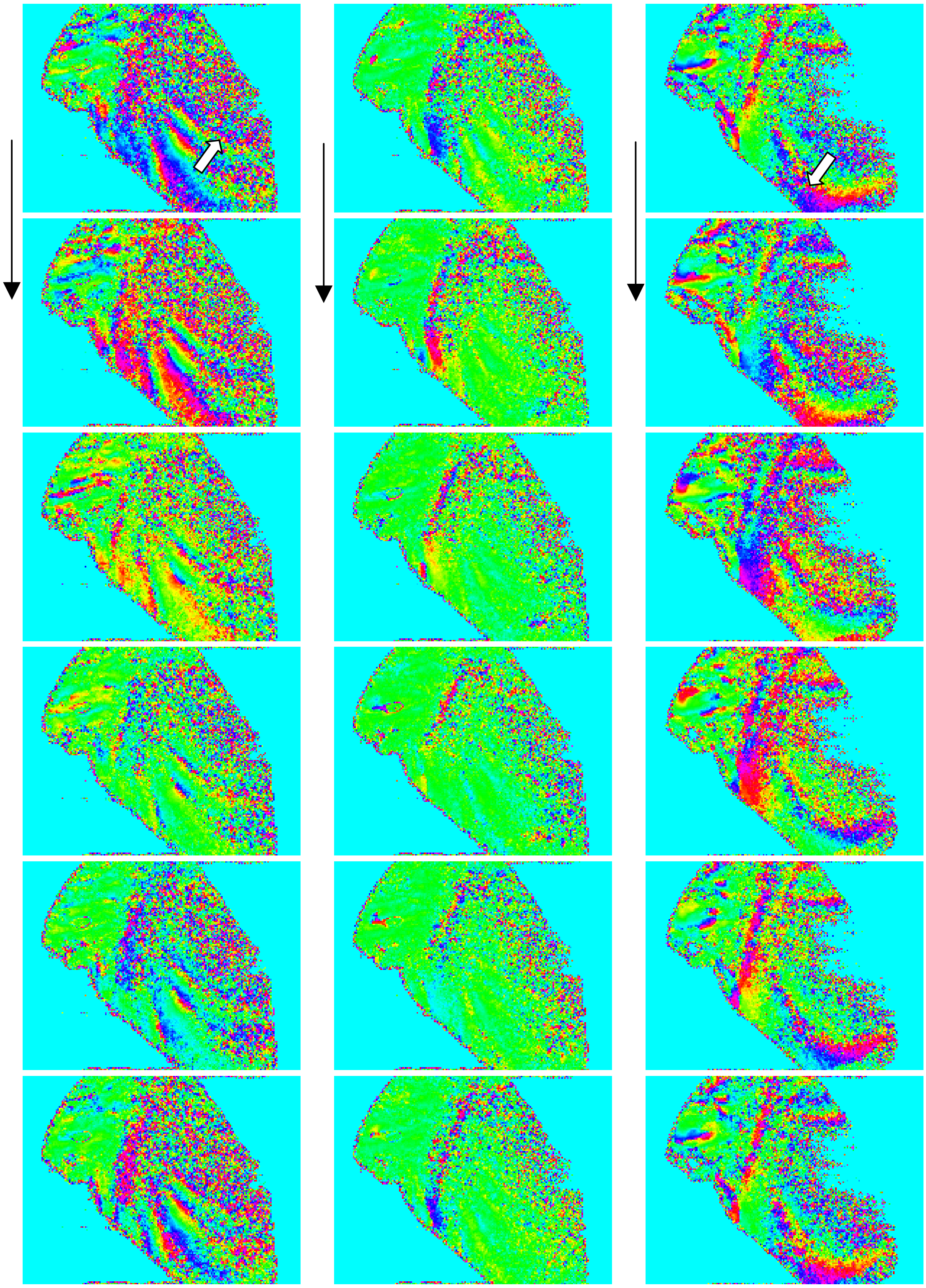
From the tangential view images the plasma rotation was observed clearly, moreover, it was observed that plasma rotated counterclockwise in the images during the L-mode and stopped to rotate during the L-H transition, at last plasma rotated clockwise in the images during the H-mode. The magnetic field direction and the camera viewing direction were counterclockwise from the horizontal plan (see Fig.1) in these shots. Therefore, if plasma would rotate by E_rxB drift, E_r should be positive in the L-mode and E_r should be negative in the H-mode in Heliotron J plasmas. These results were consistent with the past results on the H-mode in Heliotron J [7]. The low frequency of 8.75kHz signal was relative strong during L-mode in the power spectra of the camera pixel data and no strong peak was obtained during H-mode. To evaluate rotation effect with two-dimension this low frequency fluctuation was chosen to see how behaves during the L- and H-modes.

Fig.5 shows two-dimensional phase images using time-dependent FFT analysis from the original camera images. The column of the left shows images during the L-mode, the center shows images during the L-H transition, and the right shows images during the H-mode. The time progresses downward where time difference between each frame is 25μs at each column.

The frequency of each frame was 8.75kHz and the fast camera operated with 40000 frames per second (FPS). We used 32 frames for time-dependent FFT. The color is corresponding to the phase $-\pi$ to π. The same color region has the same phase. Therefore, these images show the propagation phenomena and/or wave at the selected frequency.

The rotation speed of 3000m/s was roughly estimated in the images during H-mode and it was about half during L-mode. Therefore, according to this rough estimation from the images Er is -2kV/m during the H-mode, and Er is +1kV/m during the L-mode. The magnetic field is about 1.5T. These results were consistent with Ref[7].

Transition period of the L-H transition was also deduced in the images. The number of the camera frames that rotation stopped is only one at 40000 frames per second. That shows the transition period in Heliotron J plasma is below than 50μs, because to get the light emission the shutter was open in these shots.



L-mode L-H transition H-mode

Fig. 5 Phase images during the L-mode, the L-H transition, and the H-mode
Time progresses downward, and time difference between each frame is 25μs.

4. Conclusion

Using fast camera peripheral plasma turbulence was measured successfully. In particular, it was observed that the direction of plasma rotation was changed due to H-mode. Moreover, the transition period was estimated by fast camera images because the plasma stopped to rotate during the transition.

The fast camera usage for two-dimensional plasma diagnostics is started recently in Heliotron J and we believe this method will be very hopeful to get the image of the plasma parameters in the future.

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