J. Plasma Fusion Res. SERIES, Vol.7 (2006) 174-178

Measurement of NSTX Divertor Plasma Using Fast Camera

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(Received: 5 October 2004 / Accepted: 10 January 2006)

Abstract

To visualize the ELMs, fluctuations and associated impurity line emission near the lower x-point region, a new tangential observation port has been recently installed on NSTX. Many filaments are seen along the out board leg of the x-point in L-mode. Differences between L and H-modes are clearly seen near the outer separatrix region as well as in the inner separatrix region. Structure-like phenomena, which are not along the magnetic field line, are found in H-mode near the outer separatrix region. The propagation of at least three types of ELMS (I, III, V) is clearly seen from this view as well as MARFE-like region formed along the center stack.

Keywords:

divertor tangential view, fast camera, ELM, filament, L and H-modes, L-H transition

1. Introduction

Turbulence and / or fluctuation measurement is one of the most important research in fusion plasma physics. Because it is widely believed that the global particle / energy confinement was determined by turbulence. Therefore, understanding the turbulence physics is to get the good confinement plasma and this will lead us to achieve the cheep and safety fusion device. Turbulence in the edge region of tokamaks and other device has been studied for many years (One of recent reviews is cited like this [1]). Recently the great progress of the measurement systems for fluctuations and ELMs [2-6] is made in NSTX, which is a medium sized low-aspect ratio tokamak. Using a fast camera is a method for these measurements.

This paper describes that the initial results of the divertor plasma measurement with a tangential view using a fast camera.

2. Diagnostics

A new tangential observation port has been installed on NSTX recently. A description of this diagnostics is published elsewhere [2], and so only a brief description will be summarized here. NSTX has a horizontal port, which is located at approximately the height of a standard x-point. One of the passive plate tiles was removed to view the divertor region using this port, and to increase the field of view a re-entrant sapphire window was installed to reach near the cutout in the passive plate. Typical field of view from this tangential port is shown in Fig.1. The x-point of the standard configuration is located at near the center of this view. A lens and mirror inside the re-entrant port and a 400×400 coherent fiber optic bundle (4 mm × 4 mm, 2.7 m long) is used for transferring the plasma image to a fast camera (Photron Inc. Ultima-SE). The capability of this camera is 40500 frames per second (FPS) with 64 × 64 pixels,

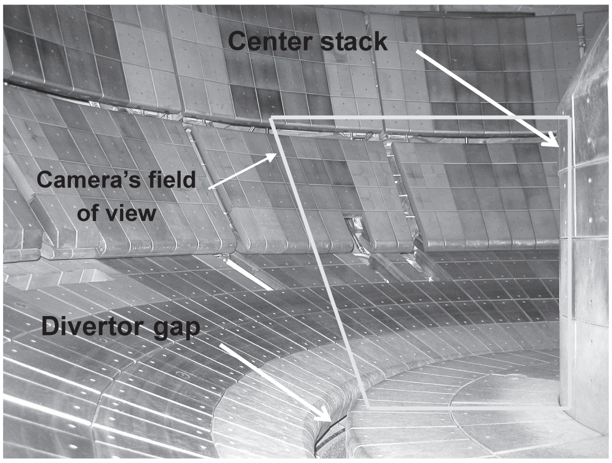

Fig. 1 Approximate field of view with divertor tangential port. Yellow (gray in B/W picture) box shows approximate field of view for Ultima-SE fast camera. The passive plate tile limits left side.

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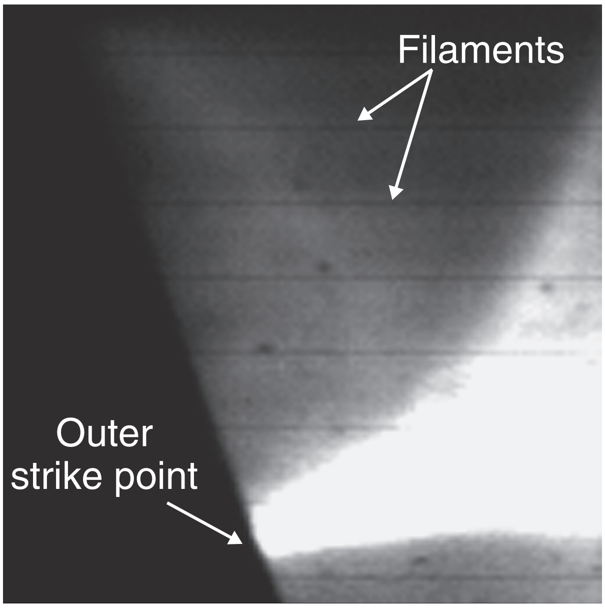
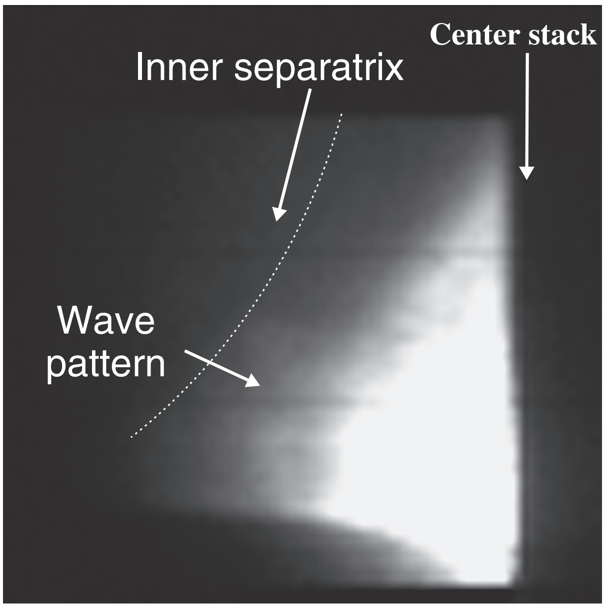
and 4500 FPS with 256 × 256 pixels. In front of the camera a lens and the filter wheel were set up to change the optical filter shot by shot remotely.

3. Experimental results and discussion

Fast visible camera had been using for the divertor plasma measurement since 2002. The data accumulated period is only two years, however, there are already many image data in NSTX. Therefore, only typical image data are presented in this paper.



(a)



(b)

Fig. 2 Fluctuations in L-mode. (a) Many filaments appear near the outer separatrix region in L-mode. (b) Wave pattern (finger) appears in the inner separatrix region in L-mode.

3.1 Fluctuations

One of the interesting things is that many filaments in L-mode are observed near the outer separatrix region, but no filament phenomena is observed in the inner separatrix region. Only wave pattern (finger-like pattern) are observed in the inner separatrix regions. In divertor view the filaments move downward and the fast camera can catch them over the speed of 13500 FPS. Figure 2 shows these fluctuations in L-mode. Apparently the fluctuations near the outer and inner separatrix regions are quite different. Due to the small aspect ratio of ST plasma the angles of the magnetic field line is quite different near the outer and inner regions. However, the filament structure usually expanded along the magnetic field line. The wave pattern does not look like the filament. Both filaments and wave pattern are suppressed during L-H transition. In H-mode a little filament can be seen (but not zero), however, the wave pattern does not disappear (not shown in the figure). Figure 3 shows another structure-like phenomena in H-mode near the outer separatrix region. It looks like a shower curtain, and this shower curtain is only seen in H-mode. The angles of the bright zone of the shower curtain are quite different from that of the magnetic field line. From GPI (gas puff imaging) experiment no spatial structure near the outer mid-plane was found in H-mode. Up to now it is unclear where is the origin of this shower curtain (the structure-like phenomena). Also, this shower curtain and the filaments can exist together during small ELMs

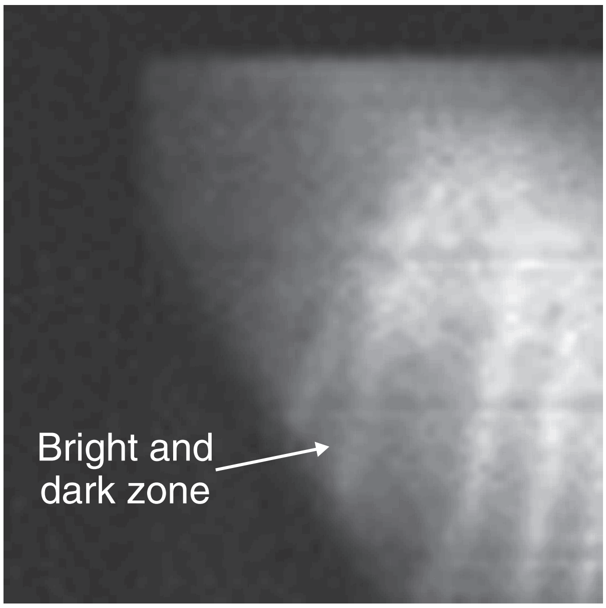


Fig. 3 Spatial structure in H-mode. Spatial structure-like phenomena were found near the outer separatrix region only in H-mode. The angles of this bright zone are very different from that of the magnetic field line.

of TYPE V (not shown in the figure). To summarize the observed results, the filaments and wave pattern were suppressed during L-H transition. However, the filaments and wave pattern were not disappeared even in H-mode. On the other hand the shower curtain could be seen only in H-mode.

3.2 ELMs

Many ELMs of TYPE I, III and V were observed in NSTX during experiments in 2004. The categorization of ELMs is useful, but sometimes it is imprecise [7]. In this paper, the ELMs are also categorized by the effect on the energy confinement. Sometimes giant ELM, medium ELMs and small ELMs are used here, however giant ELM associated with severe energy loss (up to 30 % in NSTX) is usually labeled TYPE I, and medium ELM associated with small energy loss (a few % in NSTX) is labeled TYPE III here. At last small ELM associated with tiny energy loss or no energy loss is labeled TYPE V. This TYPE V ELM is found recently in NSTX.

Figures 4-6 show that giant ELM, medium ELM, and small ELM in the outer separatrix region respectively. Giant ELM (TYPE I) has no precursor of the magnetic probe signals (0.2 – 400 kHz). Figure 4 shows giant ELM in outer separatrix region. Type I ELMs clearly blow off the MARFE-like region all the way to the target. The MARFE-like structure rebuilds on the order of tens of msec. It is believed that TYPE I is probably caused by the ideal ballooning mode.

Medium ELMs are classified into three types by the precursor of the magnetic probe signals (0.2 – 40 kHz). One has 2 kHz MHD odd-n (odd toroidal number) low frequency precursor, second has a weak precursor, and the last has no precursor. Figure 5 shows the propagation of medium ELMs labeled TYPE III, which has the precursor clearly. In this figure ELMs occur periodically. In the other medium ELMs also similar scene had been taken by fast camera. Among the pictures of three medium ELMs, a little difference of the recovery process can be seen (not shown in the figure). However, the difference of these medium ELMs is not clear in NSTX, but it is believed that the cause of TYPE III ELM is the resistive ballooning mode.

Small ELMs labeled TYPE V was first reported at 2002 [8], but it is categorized recently. This ELM (TYPE V) has $n = 1$ precursor of the magnetic probe signals. From soft-X ray signals it is found that TYPE V ELMs almost originate near x-point, and propagate upward. Figure 6 shows periodically TYPE V ELM using the fast camera. These pictures reveal that how TYPE V ELM does birth near x-point. The left side of

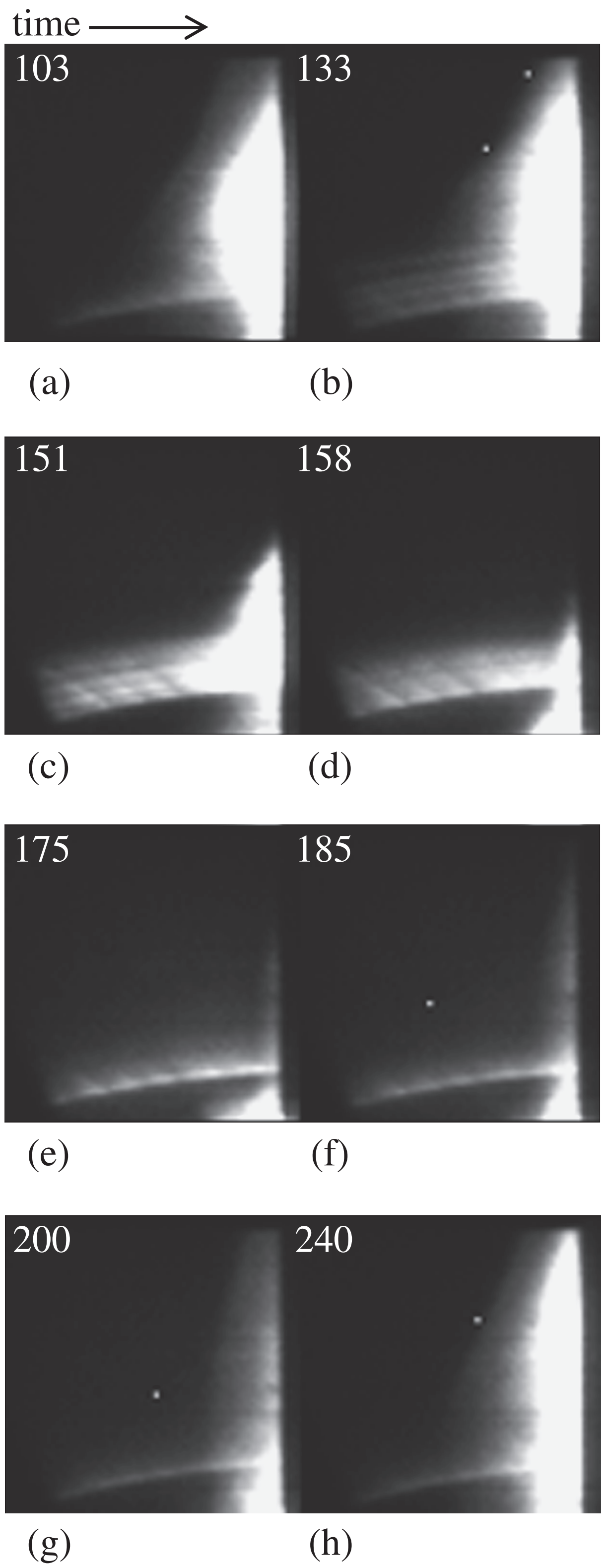


Fig. 4 Giant ELMs in divertor region. The speed of shutter is 40500 FPS. Frame numbers are indicated in each pictures. This ELM is labeled TYPE I (giant ELM). The bright lines in the lower part of each frame are outer strike point.

x-point in these pictures behaves up and down repeatedly and a shaded light cloud goes upward along the magnetic surface.

Also, it is observed that another ELMs near the inner

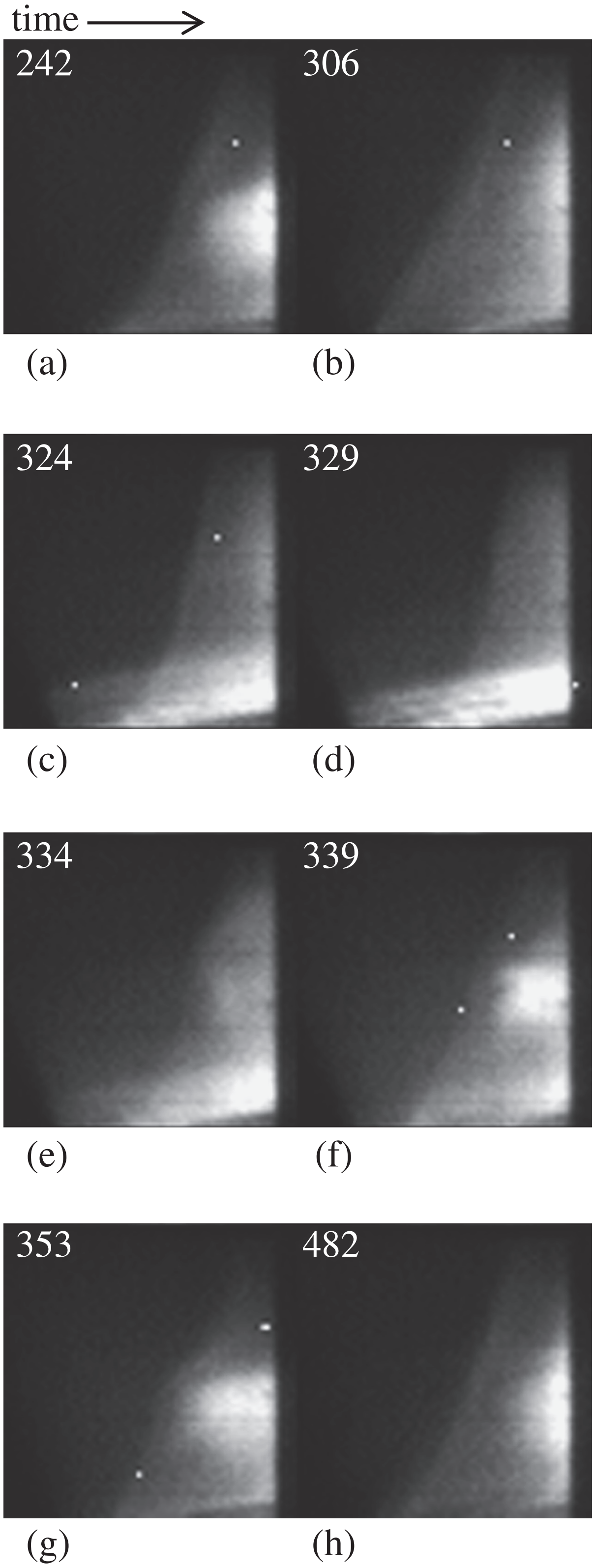


Fig. 5 Medium ELM in divertor region. The speed of shutter is 40500 FPS. Frame numbers are indicated in each pictures. This ELM is labeled TYPE III (resistive ballooning mode). The bright lines in the lower part of 324 to 329 frames are outer strike point.

region in double null (DN) configuration (not shown in the figure). This ELM is very interesting. Because it

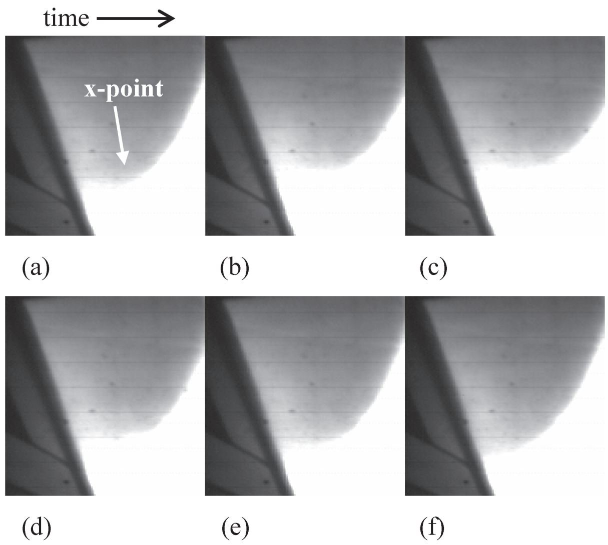


Fig. 6 Small ELM in divertor region. ELM grows in order of time (a) to (f); each frames are at 222 μsec intervals. This ELM is labeled TYPE V, which originate near x-point and is going up toward the inner region.

bounces almost from down to up, but sometimes from up to down. Moreover this ELM bounces from down to near the inner midplane and goes down, and vice versa. Merely this ELM goes up to the inner midplane and split in two; one is going up, and the other is going down. This ELM is labeled TYPE VI. TYPE VI ELM was only observed near the center region and was not observed in the outer separatrix region. Due to the limit of the camera performance it cannot catch TYPE VI ELM with wide spatial range at high-speed. Therefore, to find the origin location of this ELM more than two cameras are needed to measure the same ELM at the different positions simultaneously.

The physics of TYPE V and VI ELMs are not known. The analysis of these ELMs will be very near future work.

4. Conclusions

It was found that many ELMs and fluctuations were observed in NSTX. ELMs of TYPE I, III and V (labeled recently) were clearly seen in the divertor region. Even D_α filter images from the fast camera these ELMs can be distinguished. Also, L-H transition was seen near the outer and inner separatrix regions, and new structure was found in H-mode. The angles of this structure were very different with that of the magnetic field line, and sometimes the filaments and this structure were observed together. Much analysis of all image data is needed and it will be near term work for us.

Acknowledgements

This work is supported by US-Japan collaborative activity.

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