First Results with the NSTX Fast Divertor Camera

NISHINO Nobuhiro, ROQUEMORE Lane[1], KAITA Robert[1], ZWEBEN Stewart J.[1], JOHNSON David[1], KUGEL Henry W.[1], MAQUEDA Ricardo[2], BUSH Charles[3], MAINGI Rajesh[3], SOUKHANOVSKII Vlad[1], PAOLETTI Franco[4], SABBAGH Steven A.[4] and NSTX team[1]

Graduate school of Engineering, Hiroshima University, Hiroshima 739-8527, Japan

[1] Princeton Plasma Physics Laboratory, Princeton, NJ 08543-0451, USA

[2] Los Alamos National Laboratory, Los Alamos, NM 87545, USA

[3] Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA

[4] Department of Applied Physics and Applied Mathematics, Columbia University, NY 10027-6902, USA

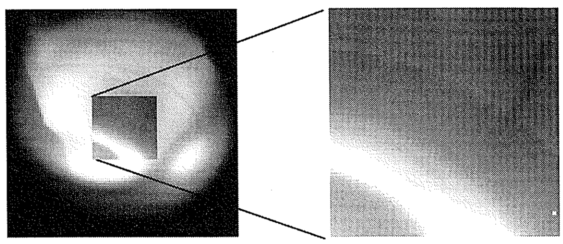
(Received 20 September 2002 / Accepted 15 November 2002)

Filamentary structures correlated with ELMs (Edge Localized Modes) in NSTX plasmas were observed by fast divertor camera. Filamentations always occurred with ELMs in the visible light emission in the divertor region. These filamentations appeared to occur along the magnetic field. It was found that the filamentary structures had a spiral pattern and were toroidal/poloidal asymmetric in the divertor region. Strong and numerous filamentations were observed with giant ELMs, whereas grassy ELMs occurred with weak filamentations. Based on our measurements, ELMs can be distinguished by the number and strength of filamentations.

Keywords:

ELM, L-H transition, toroidal/poloidal asymmetry, filamentation, divertor plasma

ELMs should be related to edge fluctuations, and an understanding ELM behavior is important to heat flux reduction. On the other hand filamentations in the visible light emission have been observed by fast cameras in many tokamaks [1-5]; it was initially believed that these filamentations were closely related to edge fluctuations because the light emission process depends on the electron density and temperature. Similar filamentations were observed in NSTX using a fast camera [6]. To investigate the structure of ELMs in ST's and to clarify the relationship between these fluctuations and ELMs, we measured NSTX divertor plasma by fast camera. NSTX has twelve-port sections toroidaly (BAY-A to L). The camera (FASTCAM-ultimaSE, Photron Inc.) was located at BAY-G (South-southwest) and looked down the divertor region at BAY-B & C (Northeast) at angles of almost 40 degrees. A typical view of the NSTX plasma with the divertor camera is shown in Fig.1. On the left side of the figure, the center



(a) 4500 fps with Dα filter (#109005) 256 x 256 pixels

(b) 40500 fps with Dα filter (#109069, L-mode) 64 x 64 pixels

Fig. 1 Typical view for the fast divertor camera

is magnified with a view from another shot taken at a higher time resolution. The center stack of NSTX is seen on the left side of Fig.1(a). In Fig.1(b), part of the bright light ring near the left lower corner shows an outer strike point.

Fig. 2(a), (b) show the line-integrated density and Dα signal of 800 kA plasma discharge with 4 MW NBI

author's e-mail: nishino@hiroshima-u.ac.jp

power, respectively. Fig.2(c) shows total light intensity of the lower divertor region as viewed with this camera. Each pixel of the camera sensor can be regarded as one detector. The sum of all signals from each pixel is very similar to what is seen on Dα monitor, and has better time resolution (~0.025 ms).

The camera view of the L-mode in this shot has already been shown in Fig.1(b). Fig.3 shows various camera views during H-mode. The timing of the L-H transitions (Fig.1(b)&Fig.3(a)) and the ELMs (Fig.3(e), (b)–(d)) are indicated by arrows in Fig.2(c). There are many filamentations in the L-mode, and relatively few filamentations in the H-mode. In general, views during the H-mode are relatively dim; however, filamentations

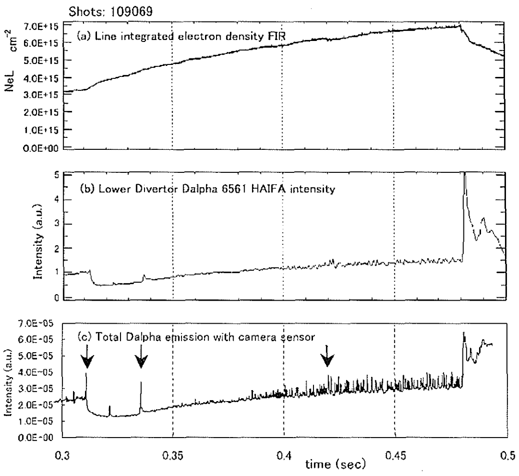


Fig. 2 Density and Dα signal of shot no. #109069 (a) line integrated density by FIR (b) Dα signal viewing lower divertor BAY C (c) Dα signal with fast camera viewing lower divertor BAY B&C.

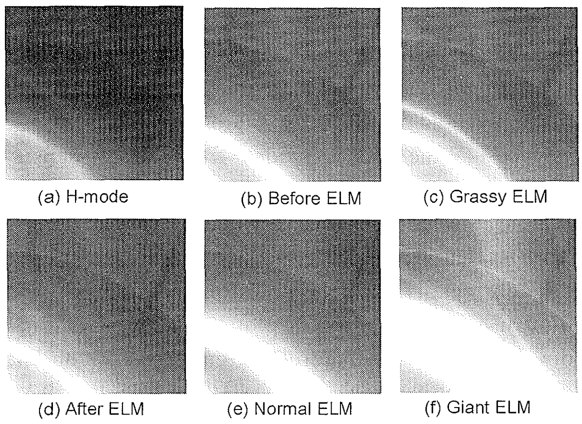


Fig. 3 Various camera view during L-H transition ((a)–(e) #109069, (f) #109059, 40500pfs with Dα filter , (e) normal is used for neither grassy nor giant.)

sometimes are clearly visible even in the quiet H-mode.

The filamentations are clearer during the grassy ELM shown in Fig.3(b)–(d). The common pattern, which can be seen in both figures, is a spiral structure along the lines of the magnetic field. These spiral structures, associated with ELMs and/or the filamentations in the divertor region, may be related to the cross-hatching seen on tiles damaged from plasma exposure. At the vacuum vent after the 2002 run, the surfaces of the divertor tiles were investigated. This investigation is not yet finished; however, many spiral patterns have been seen on the surface of all the lower divertor tiles. Fig.3(e), (f) show the camera views during various types of ELMs [7]. In Fig. 3(e), "normal" means the middle strength ELM between grassy and giant ELM. The strike point region of the camera view is saturated during normal and giant of ELMs. Moreover, almost the entire viewing region is sometimes saturated during giant ELMs, due to excess brightness of the light emission. Even with poor photographs, many strong filamentations can be observed clearly when giant ELMs occur. On *Dα* light emission images, the type of fluctuations cannot be identified. However, ELMs can apparently be distinguished by the number and strength of filamentations. Filamentations are weak and few with grassy ELMs, and strong and numerous with giant ELMs. The toroidal/poloidal asymmetric structure of ELMs has already been pointed out in conventional tokamaks [e.g. 8]. Using a fast camera, evidence was obtained that ELM-related fluctuations have a spatial structure with toroidal/poloidal asymmetry as shown in Figs.1 and 3. If ELMs are symmetry phenomena, the outflux due to ELMs would be symmetric. Therefore, these camera views show that ELMs most likely have toroidal/poloidal asymmetry.

[1] S.J. Zweben and S.S. Medley, Phys. Fluids **B1**, 2058 (1989).
[2] R. Maqueda and G. Wurden, Nucl. Fusion **39**, 629 (1999).
[3] M. Endler *et al.*, Nucl. Fusion **35**, 1307 (1995).
[4] J.L. Terry, *Proc. 14th PSI*, Rosenheim, Germany, 2000.
[5] G.R. McKee, C. Fenzi and R.J. Fonck, Phys. Plasmas **9**, 177 (2002).
[6] R. Maqueda *et al.*, Rev. Sci. Instrum. **1**, 931 (2001).
[7] V.B. Lebedev *et al.*, Phys. Plasmas **2**, 3345 (1995).
[8] N. Oyama *et al.*, Plasma Phys. Control. Fusion **43**, 717 (2001).