Rapid Communications

Visualization of Intermittent Blobby Plasma Transport in Attached and Detached Plasmas of the NAGDIS-II

OHNO Noriyasu[1)], FURUTA Katsuhiro[2)] and TAKAMURA Shuichi[2)]

[1)]*Center for Integrated Research in Science and Engineering, Nagoya University, Nagoya 464-8603, Japan*

[2)]*Graduate School of Engineering, Nagoya University, Nagoya 464-8603, Japan*

(Received 30 November 2003 / Accepted 8 March 2004)

We investigated the intermittent convective plasma transport in a attached and/or detached plasma condition of the linear divertor plasma simulator, NAGDIS-II. Images taken by a fast-imaging camera clearly show that in attached plasmas, blobs are peeled off the bulk plasma, and propagate outward with an azimuthal motion. In detached plasmas, plasma turbulence observed near the plasma recombining region drives strong intermittent radial plasma transport, which could broaden the radial density profile.

Keywords:

convective transport, blobs, fast-imaging camera, divertor plasmas

Intermittent convective plasma transport across magnetic field lines, so-called "blobs" has been one of the most important issues in fusion-related edge plasma physics, and is thought to play a key role for cross-field plasma transport in the tokamak scrape-off layer [1]. Several experiments have been performed regarding blobby plasma transport, in which intermittent bursts of fluctuation in ion saturation currents measured by Langmuir probes were analyzed to obtain a basic property of the blob's motion. Such bursty fluctuation has been also observed in other plasma devices [2,3]. Then, the blobby plasma transport is thought to be common phenomena in magnetically confined plasmas.

In order to reveal the blob's motion, at least two dimensional observation should be necessary because the projected blob trajectory on the plane perpendicular to the magnetic field lines would be a spiral. There is few direct observation of the blob's motion [4]. In this Rapid Communication (RC), we present the observation of the blob motion measured with a fast-imaging camera in the linear plasma divertor simulator NAGDIS-II. The image taken with the fast-imaging camera clearly shows the radial motion of the blobs peeled off from the bulk plasma. It is also found that in the detached plasmas strong plasma turbulence occurs, and plasma is spinning out toward a wall.

The NAGDIS-II [5] can generate high density helium plasmas with an electron density up to 10^{20} m^{-3} in a steady state. The diameter of a plasma column is about 20 mm. By increasing neutral pressure P in the divertor test region, we can achieve a detached plasma condition. Ion saturation currents I_{sat} were measured with a Langmuir probe. Images of light emission from a plasma were taken by the fast-imaging camera located at the end of the vacuum chamber.

Figure 1 shows five sequential frames of the total light emission from the attached plasma at a gas pressure of 5 mTorr. The frame rate is 13500 [f/s] with a time difference of 74 μs between frames. The magnetic field strength B is 0.2 T. Plasma around r = 20 mm is found to rotate with a velocity of 20 m/s in the $E \times B$ direction, where r is a radial distance from the center of the plasma column. The rotation velocity is almost equal to the $E \times B$ velocity. In Figure 1(b), the prominence of the light emission is observed at the upper region of the bulk plasma column, and extends radially and azimuthally (Fig. 1(c)). This prominence could be due mainly to density perturbation. Finally, the prominence is peeled off (Fig. 1(d)). It moves radially and disappears probably due to a reduction of the electron temperature of the peeled plasma blob as shown in Fig. 1(e). Langmuir probe measurements show that electron temperature T_e is about 6 eV at the center and drops to 2.0 eV at r = 20 mm. Above r = 30 mm, T_e is almost constant (0.6 eV). These experimental observations reveal a basic feature of the blob's motion in the linear plasma devices. Plasma blobs generated due to an instability such as Rayleigh -Taylor instability can be peeled off from the bulk plasma to move radially and azimuthally.

Figure 2 shows four frames with a time difference of 74 μs in the detached plasma at a gas pressure of 11 mTorr. The inset photograph depicts the viewing angle of Fig. 2 which is slightly inclined in comparison with that of Fig. 1 in order to take images near the plasma recombining region (z = 1 m) in the downstream. In order to avoid strong light emission near the anode region, the central region of the each image is masked. Dashed lines in the figures indicate the plasma column in the attached plasma. We used two interference filters with a central wavelength of 471 nm and 468

author's e-mail: ohno@cirse.nagoya-u.ac.jp

This article is based on the invited talk at the 20th Annual Meeting of JSPF (Nov. 2003, Mito).

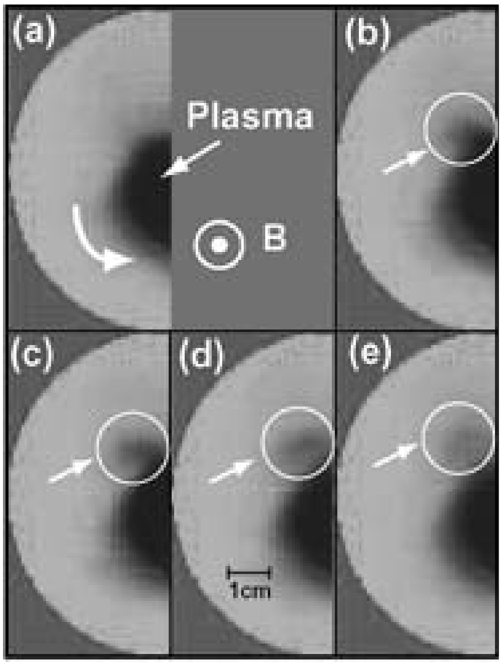

Fig. 1 Five frames of total light emission from plasma taken by the fast-imaging camera, showing the blob's motion in the attached plasma with a neutral pressure of 5 mTorr.

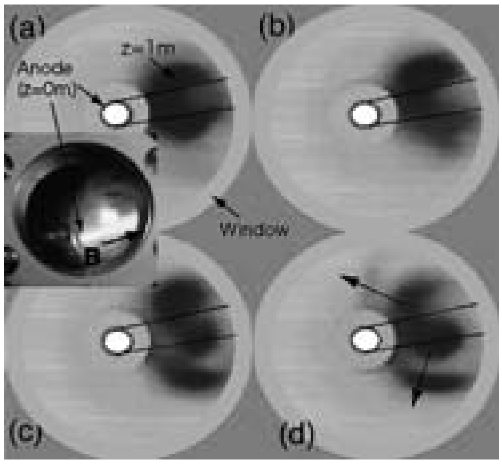

Fig. 2 Four frames of line emission from He neutrals (HeI: 471 nm) in detached plasma condition with a neutral pressure of 11 mTorr.

nm installed on the fast-imaging camera. These lines correspond to the spectral lines from He neutrals (HeI: 471 nm) and He ions (HeII: 468 nm), respectively. The image of light emission from He ions, which is not shown in this RC, clearly shows that the plasma becomes unstable near the plasma recombining region [6]. Associated with this plasma instability, the images of the light emission from He neutrals in Fig. 2 indicate that the plasma blob spins rapidly out toward the wall [7]. The propagation mechanism of the plasma blob in attached and detached plasmas could be identical, however, these plasma blobs might be generated by different instability.

Figure 3 shows the time evolution of the ion saturation current I_{sat} measured at the periphery (r = 60 mm) in the downstream. Many positive spikes in I_{sat} were observed. As P is increased to produce fully detached plasma, positive spikes in I_{sat}, which could be related to be the plasma blob observed in Fig. 2, becomes wider and their amplitudes increase. Then, the averaged value of I_{sat} increases with P at r = 60 mm as shown in the inset of Fig. 3, although the averaged I_{sat} at the center of the plasma column dramatically drops. These experimental results indicate that the plasma blobs due to the instability in the detached plasma drives strong convective radial transport, which leads to a broadening of the plasma profile. This could play an important role in the reduction of the particle and heat flux to the divertor plate as well as the plasma recombination processes in plasma detachment.

The authors would like to express their sincere gratitude for the cooperation of the program committee of NIFS (National Institute for Fusion Science), Japan in providing the FASTCAM camera during the experiments.

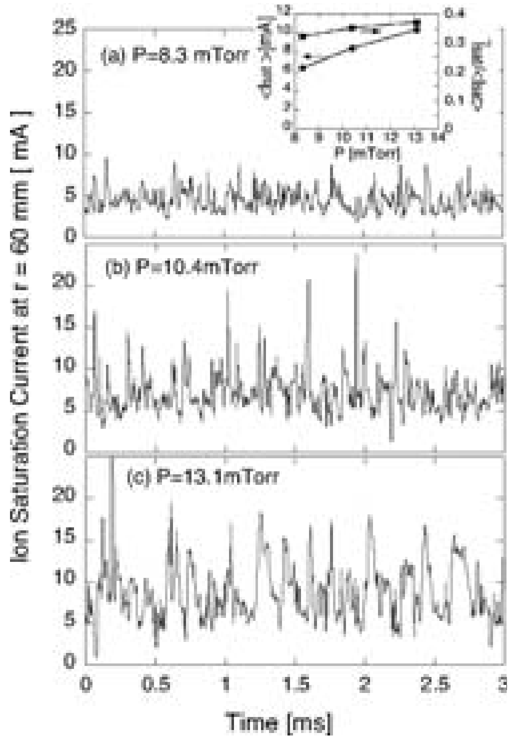

Fig. 3 Neutral pressure dependence of time evolution of I_{sat} at r = 60 mm.

[1] S.I. Krasheninnikov, Phys. Letters A, **283**, 368 (2001).
[2] D.A. D'Ippolito *et al.*, Phys. Plasma **9**, 222 (2002).
[3] G.Y. Antar *et al.*, Phys. Rev. Lett. **87**, 065001-1 (2001).
[4] J.A. Boedo *et al.*, Phys. Plasma **8**, 4826 (2001).
[5] N. Ohno, D. Nishijima, S. Takamura, Y. Uesugi *et al.*, Nucl. Fusion, **41**, 1055 (2001).
[6] http://jspf.nifs.ac.jp/Journal/PDF_JSPF/jspf2004_04/animationHell
[7] http://jspf.nifs.ac.jp/Journal/PDF_JSPF/jspf2004_04/animationHell