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Correlation between plasma blob and its related structural change of plasma column in detached plasma

非接触プラズマにおけるPlasma Blob発生とプラズマ柱内部の構造変化の相関

[1]Takuya Onda, [1]Noriyasu Ohno, [2]Shin Kajita, [3]Hirohiko Tanaka, [2]Tatsuya Kuwabara
[1]恩田 卓哉, [1]大野 哲靖, [2]梶田 信, [3]田中 宏彦, [2]桑原 竜弥

[1]Graduate School of Engineering, Nagoya University, Furo-cho, Chikusa-ku, Nagoya, Aichi 464-8603, Japan
[2]EcoTopia Science Institute, Nagoya University, Furo-cho, Chikusa-ku, Nagoya, Aichi 464-8603, Japan
[3]National Institute for Fusion Science, Oroshi-cho, Toki, Gifu 509-5292, Japan
[1]名古屋大学大学院工学研究科，〒464-8603　名古屋市千種区不老町
[2]名古屋大学エコトピア科学研究所，〒464-8603　名古屋市千種区不老町
[3]核融合科学研究所，〒509-5292　岐阜県土岐市下石町322-6

Control of detached plasmas is one of the most important issues in next generation fusion devices, in terms of the reduction of heat loads to the divertor plate. In the detached plasma, the enhancement of cross-field plasma transport has been observed, which could be attributed to plasma blobs. In this report, the generation of plasma blob in the detached plasma was observed using a high-speed camera in the linear divertor plasma simulator NAGDIS-II (NAGoya DIvertor plasma Simulator II). It is found that plasma blobs are generated at the peripheral region of the plasma column associated with plasma instability. The mode number of the instability was analyzed based on 2D light emission profiles.

1. Introduction

The most of plasma particle flux flowing out from the core plasma enters into divertor region through a scrape-off layer (SOL). When this particle flux reaches to the divertor plate directly, the divertor plate receives the heat loads of several tens MW/m^2 and being damaged. Neutralization of the plasma, so-called detached plasma, is considered as an effective method to reduce the heat load on the divertor plate. Therefore, control of detached plasmas becomes one of the most critical issues in next generation fusion devise such as ITER.

The intermittent cross-field convective plasma transport, so called plasma blob, have been observed in SOL in several magnetically confined plasma devices [1]. Plasma blob has a filamentary structure along the magnetic filed line and a higher density than the SOL plasma. Interestingly, the cross-filed plasma transport associated with plasma blobs was found to be enhanced in the detached plasma condition in linear plasma devices [1-3], helical devices [1, 4] and tokamaks [1, 5, 6]. On the other hand, recent 3D simulation aiming at linear plasma devices predicted that resistive drift instability leads to generation of plasma blobs [7, 8]. However, the mechanism of enhancement of blobby plasma transport in detached plasmas has not been understood yet.

In this work, we have observed dynamical change of plasma column accompanied with the generation of plasma blobs in detached plasma of the linear plasma device using a high-speed camera and performed the mode analysis of plasma instability.

2. Experimental setup

The experiment was performed in the linear divertor plasma simulator NAGDIS-II (NAGoya DIvertor plasma Simulator II). Figure 1 shows the experimental setup of the measurement. In order to observe the dynamic behavior of detached plasma structures, a high-speed camera (ULTRA CAM HS-106E: NAC Image Technology, Inc.) was used at a frame rate of 100,000 fps. A viewing port made of quartz glass was installed at the end of NAGDIS-II to observe the plasma in parallel to the magnetic field.

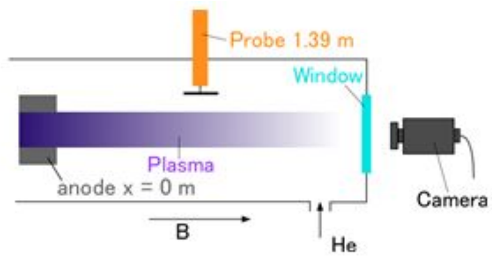

Fig 1. Experimental setup

The high-speed camera enables us to capture successive 2D images without disturbing the plasma. Further, the measured signal is a line-of-sight integral of emission intensity from plasma, and it depends on not only the electron density but also the electron temperature [9].

A Langmuir probe from the upper side of the device and I_{sat} signal was measured in the periphery of the plasma column.

3. Experimental results

3.1 Snapshots of plasma blob generation

Figure 2 shows the contour plots of the dynamic behavior of the detached plasma taken by the high-speed camera. As reported in previous studies [2, 3], plasma column rotates in the direction of $\boldsymbol{E} \times \boldsymbol{B}$, and emits plasma blobs. In this experiment, for the first time, we have successfully measured the dynamic behavior of the plasma column at the timing of plasma blob generation. Firstly, quasi-axisymmetric plasma column deforms with non-axisymmetric strong emission. Then, a plasma blob is ejected in the radial direction from near the high-intensity region, and emission in the plasma column becomes original level. Because the blob-generation continues during a finite time and the generation position rotates in the $\boldsymbol{E} \times \boldsymbol{B}$ direction, the blob shape becomes a spiral structure. After that, a plasma blob disappears. This process repeats.

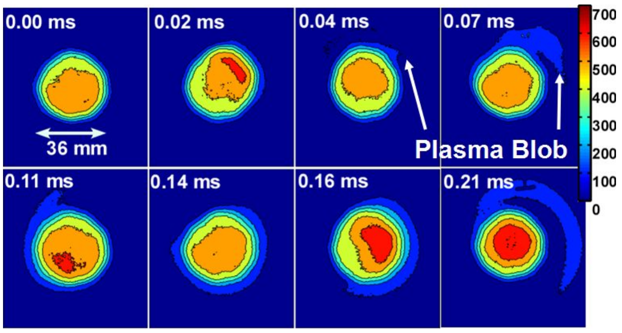

Fig 2 . A contour plot of snapshots of the image captured by the high-speed camera at frame rate of 100,000 fps.

3.2 Mode analysis of the instability

The mode structure analysis was performed using 2D images taken by the high-speed camera. The overall behavior of modes were examined by considering averaged amplitudes $E_m(t)$ which is defined in Ref. [8]. The $n_m(r, t)$ and $E_m(t)$ are expressed by the following equations:

$$n_m(r,t) = \frac{1}{2}\int_0^{2\pi} n(r,\theta,t)\, e^{-im\theta} \mathrm{d}\theta\,, \tag{1}$$

$$E_m(t) = \int_0^{R} \left| n_m(r,t) \right| r\, \mathrm{d}r\,. \tag{2}$$

The $n_m(r, t)$ is amplitude which is calculated by Fourier transform using the signal component of the plasma intensity $n(r, \theta, t)$. And the r is the position from the center of the plasma column.

Figure 3 shows the time traces of the amplitudes E_0, E_1, and E_2. It is found that there was no periodic oscillation. This experimental results matches the simulation one well [7]. Further, this time evolution of mode intensity shows that the structures with m = 1, 2 grows when the amplitude of m = 0 mode becomes large.

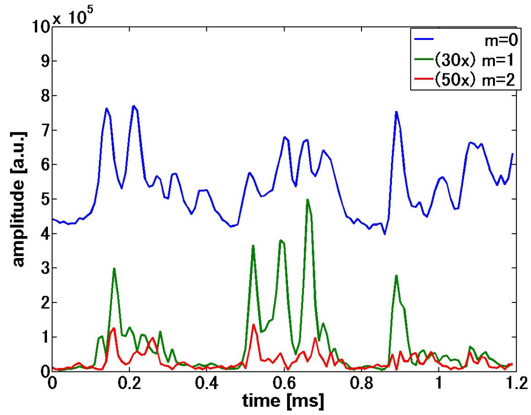

Fig 3. Time traces of the amplitudes E_0, E_1, and E_2.

In addition, from the detailed investigation of the time of plasma blob generation, it was found that plasma blobs would be ejected with the growth of the m = 1 mode.

Acknowledgments

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