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Study of Intermittent Edge Plasma Transport in LHD
LHD周辺領域で発生する間欠的プラズマ輸送現象の研究

Hirohiko Tanaka[1], Suguru Masuzaki[1], Noriyasu Ohno[2], Tomohiro Morisaki[1], Masahiro Kobayashi[1], Yoshiyuki Tsuji[2], Yuki Hayashi[3], Naomichi Ezumi[3] and LHD Experimental Group[1]
田中 宏彦[1], 増崎 貴[1], 大野哲靖[2], 森崎友宏[1], 小林政弘[1],
辻 義之[2], 林 祐貴[3], 江角直道[3], LHD実験グループ[1]

[1]National Institute for Fusion Science, 322-6 Oroshi-cho, Toki 509-5292, Japan
[2]Graduate School of Engineering, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-8603, Japan
[3]Nagano National College of Technology, 716 Tokuma, Nagano 381-8550, Japan
[1]核融合科学研究所 〒509-5292 土岐市下石町322-6
[2]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
[3]長野高等専門学校 〒381-8550 長野市徳間716

We have investigated electrostatic fluctuations measured by using fast scanning probes and a divertor probe array in LHD. Main topic in this study is to evaluate edge transport characteristics of coherent plasma structures, such as blobs, in the helical configuration. By the correlation analysis, local velocity of the propagation was estimated quantitatively on the assumption following the theory of the blobby plasma transport.

1. Introduction

In the edge region of tokamak devices, blobby plasma transport is a well-observed phenomenon. Propagation of plasma blobs are mainly detected by using a fast imaging camera and/or Langmuir probes. The propagation generally points to low-field side (LFS) direction and the velocity amplitudes of the blobs range from a few hundred meters to several kilometers per second at the different radii [1].

In the recent attempt, edge turbulence database composed of electrostatic fluctuations measured in tokamaks and several stellarators is being created. It indicates that there are common features such as positive skewness of ion saturation current, I_{sat}, outside of the last closed flux surface [2], implying an existence of the plasma blobs.

In the Large Helical Device (LHD), positive skewness was clearly observed at the LFS region of a divertor leg by using a fast scanning probe (FSP) [3]. The LFS direction from the divertor leg points to a private region. Thus, this result suggests that plasma blobs might broaden heat and particle fluxes on the divertor plate. However, propagation direction and typical velocity are not yet experimentally estimated in that analysis.

In this study, we have measured I_{sat} signals by using FSPs and a divertor probe array with high temporal resolution in LHD. By applying statistical analysis techniques and KMAG code [4], we investigated characteristics of the intermittent cross-field transport.

2. Experimental Setup

Figure 1(a) shows a Poincaré plot of magnetic field lines for R_{ax} = 3.6 m. Insertion trajectory of one of the FSPs is also depicted. Insertion speed was approximately 1-2 m/s. In the past, the FSP had two electrodes at interval of 5 mm horizontally, as shown in Fig. 1(b). In the 15th experimental campaign of this year, these electrodes have an interval of 5 mm horizontally and 5 mm vertically, as shown in Fig. 1(c). Sampling frequency was 1 MHz.

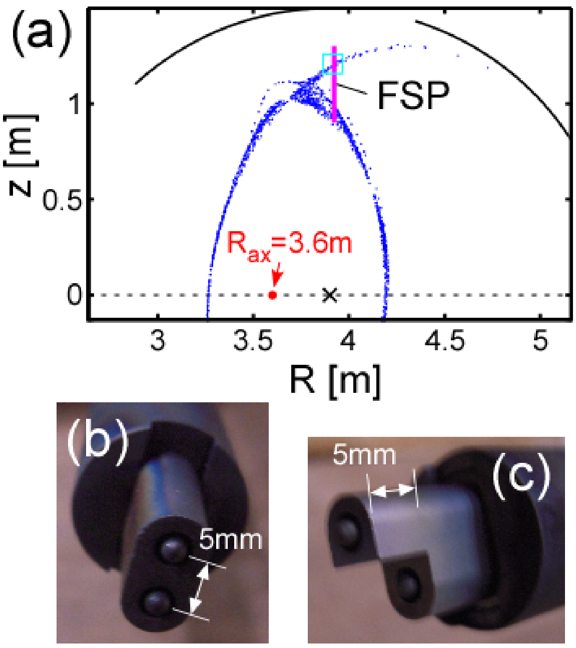

Fig.1. (a) Poincaré plot of magnetic field lines and (b)(c) photographs of probe heads.

3. Statistical Analysis of Fluctuations

Figure 2(a) shows I_{sat} signals measured with two electrodes of the FSP shown in Fig. 1(b) around the LFS region of a divertor leg. Figure 2(b) shows distributions of skewness, which is defined by $\left\langle \left(I_{\text{sat}} - \langle I_{\text{sat}} \rangle\right)^3 \right\rangle \Big/ \left\langle \left(I_{\text{sat}} - \langle I_{\text{sat}} \rangle\right)^2 \right\rangle^{3/2}$. Because of the interval between the two electrodes (ch 1 and ch 2), there is a gap of approximately 6 mm along *z*-axis between these distributions. Positive skewness is confirmed in wide *z* range at the LFS of the divertor leg.

Figure 2(c) shows cross-correlation coefficient between high-passed I_{sat} ($f \geq 10$ kHz) measured with the two electrodes, $C_{12}(\tau)$. Positive correlation is observed at $\tau \sim 0$ around z = 1.19 m where the skewness of two electrodes are positive and negative. At z > 1.2 m, positive correlation is distributed at around $\tau \sim 4$ μs. Positive peak at $\tau > 0$ means that I_{sat} fluctuation of ch 2 is delayed compared to that of ch 1. Therefore, blobs would propagate from the electrode of ch 1 to that of ch 2.

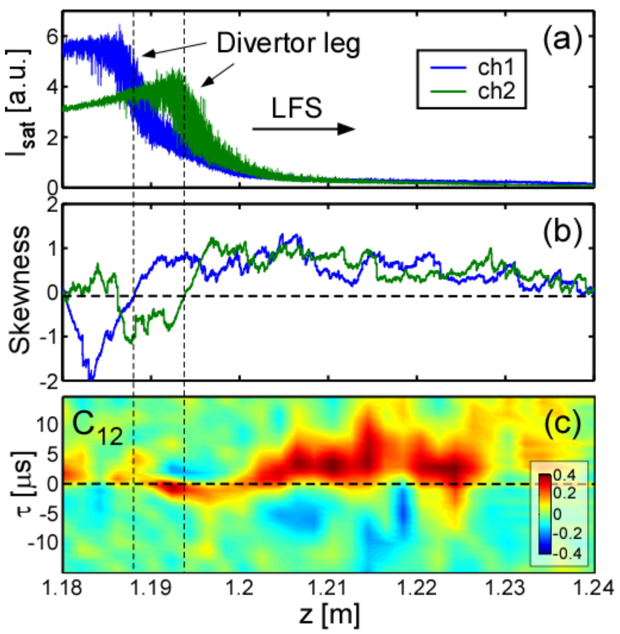

Fig.2. (a) Distributions of I_{sat}, (b) skewness, and (c) C_{12}.

4. Analysis of Magnetic Field Configuration

In order to interpret the analysis results, we investigated three-dimensional magnetic field configuration around the LFS of the divertor leg.

Figure 3 shows the magnetic field configuration inside a cube 100 mm on a side. One axis indicates a depth from the *R*-*z* plane shown in Fig. 1. Rough position of the divertor leg is displayed as isosurfaces where the connection length, L_c, is equal to 20 m. From this figure, it can be confirmed that the electrode of ch 2 enters the divertor leg earlier than that of ch 1 during an insertion. In addition, streamlines along the gradient of the magnetic field, ∇B, are depicted. At z > 1.2 m, both the electrodes are distant from the divertor leg, and the LFS direction corresponds to the vector passing through the electrodes from ch 1 to ch 2.

If perpendicular length of the plasma blobs was much larger than that of interval between the electrodes, typical speed of the blobs propagating toward the LFS direction, v_b, could be estimated. Effective distance between the electrodes along $-\nabla B$ axis is approximately 4.6 mm. Therefore, on the above assumption, $v_b \sim 4.6\ \text{mm}/4\ \mu\text{s} = 1.15\ \text{km/s}$. It is comparable value to that of tokamaks.

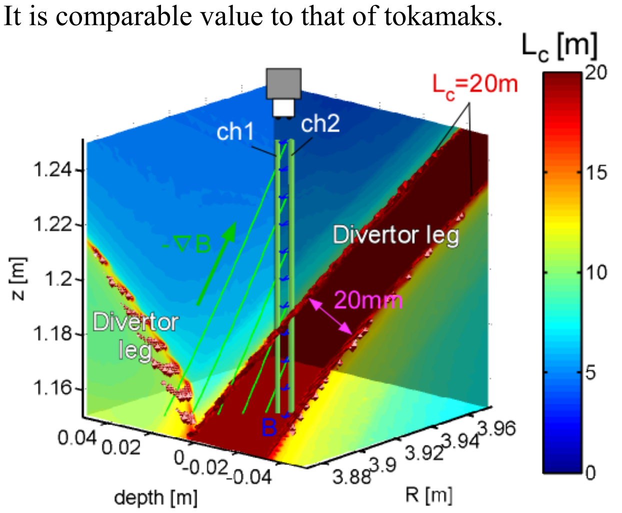

Fig.3. Magnetic field configuration and insertion trajectory of the two electrodes of the FSP.

5. Summary and Discussion

We have estimated the typical velocity of the blob propagation on the assumption.

At z ~ 1.196 m where both the skewness are positive, $C_{12}(\tau)$ peak is located at τ ~ -1 μs, as shown in Figs. 2(b)(c), meaning that positive spikes propagated from the electrode of ch 2 to ch 1. This position is located near the divertor leg which would be generation region of the plasma blobs; thus, this result might reflect the time delay related not to the propagation but the generation.

Acknowledgments

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