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Study of plasma dynamics in attached and detached plasmas

接触・非接触プラズマ中の動的挙動に関する研究

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Considerable attention is given to the static and dynamic behaviors of detached plasma, because utilization of the detached divertor is thought to provide a promising method for reducing the heat flux to plasma facing components. In this study, we performed a electrostatic probe measurement when changing a state of plasma from attached to detached by increasing a neutral gas pressure rapidly. As a result, it is clearly found that transition from an attached plasma to a detached plasma changes the phase relation between a density and a potential.

1. Introduction

In ITER, to reduce large amounts of heat and particle fluxes, detached divertor will be used. The detached divertor utilizes a plasma detachment phenomenon, which is performed by increasing a neutral gas pressure inside the divertor region and reducing a plasma heat flux by the interaction of plasma and gas [1]. Therefore, plasma detachment is one of the most important issues to lead a ITER project to a successful conclusion.

A comprehensive investigation has been performed for the static and dynamic behaviours of detached recombining plasmas in the linear divertor plasma simulator NAGDIS-II [2, 3]. In this study, we will investigate a dynamic behaviour of plasma fluctuation characteristics by using a Langmuir probe when changing the plasma from attached to detached by increasing a neutral gas pressure rapidly.

2. Experimental Setup

Figure 1 shows a illustration of the NAGDIS-II. This device has two 2000 L/s turbomolecular pumps at the side of discharge region and divertor test region. In this experiment, to achieve a sudden change of the neutral gas pressure, we operated a gate valve installed between the divertor test region and the pump. When we close the gate valve, the neutral gas pressure rapidly increases from approximately 1 to 25 mTorr, and we can generate the detached plasma. In this study, both the measurements of the electrostatic fluctuations and neutral gas pressure were performed at a distance of 1.06 m from the anode. Gas species was He.

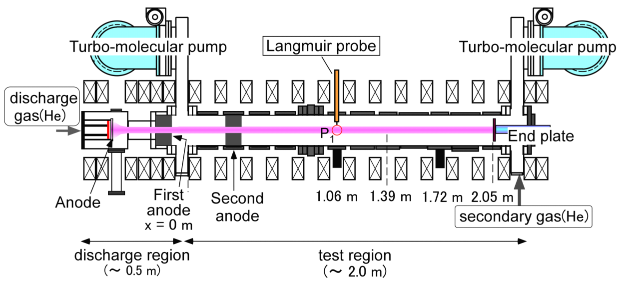

Fig.1. Diagrammatic illustration of the linear plasma divertor simulator NAGDIS-II.

3. Experimental Result

Figure 2 shows the result of triple probe measurement at the radius of 15 mm distance from the center of the plasma column when the neutral gas pressure (P) was changed. From the probe measurement, we obtained the time evolutions of the moving average of electron temperature (T_e), electron density (n_e), floating potential (V_f) and space potential (V_s). With increasing P rapidly at t = 0.8 s, T_e and V_s decreased and n_e and V_f increased considerably. After that, T_e and V_s increased and n_e and V_f decreased gradually. Finally, detached

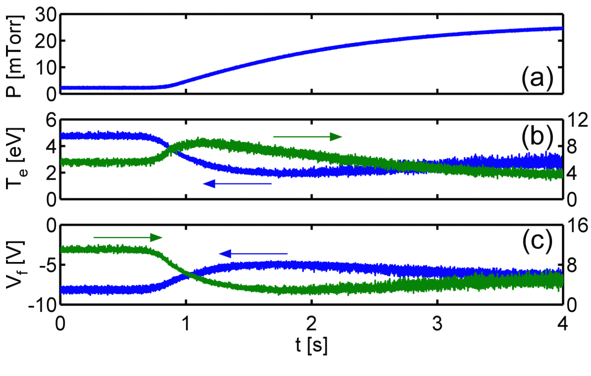

Fig.2. Time evolutions of the moving average deviations (a)P, (b)T_e, n_e, (c)V_f and V_s.

plasma was generated. From the comparison between the attached and detached states, T_e and n_e decreased.

To investigate a dependence of a phase relation between n_e and V_f on the neutral gas pressure, we analyzed the time evolution of the moving cross-correlation coefficient, which is defined by the following equation:

$$C(\tau) = \frac{\left\langle \tilde{n}_e(t)\tilde{V}_f(t+\tau)\right\rangle}{\sqrt{\left\langle \tilde{n}_e^2(t)\right\rangle}\sqrt{\left\langle \tilde{V}_f^2(t)\right\rangle}}. \quad (1)$$

From the result of the cross-correlation coefficient in Fig. 3(b), the correlation between the n_e and the V_f can be divided into three characteristic time domains, i.e. (i) $t < 0.8$ s, (ii) $0.8 \text{ s} < t < 2.3$ s, and (iii) $t > 2.3$ s. In period (i), attached plasma was generated. In this time, negative correlation was observed around $\tau = 0$ s. In period (ii), although the phase relation between them does not change, the period of $C(\tau)$ fluctuation along τ becomes long. After that in period (iii), transition of the phase relation can be clearly observed. This result implies that there is a threshold in between the attached and detached states.

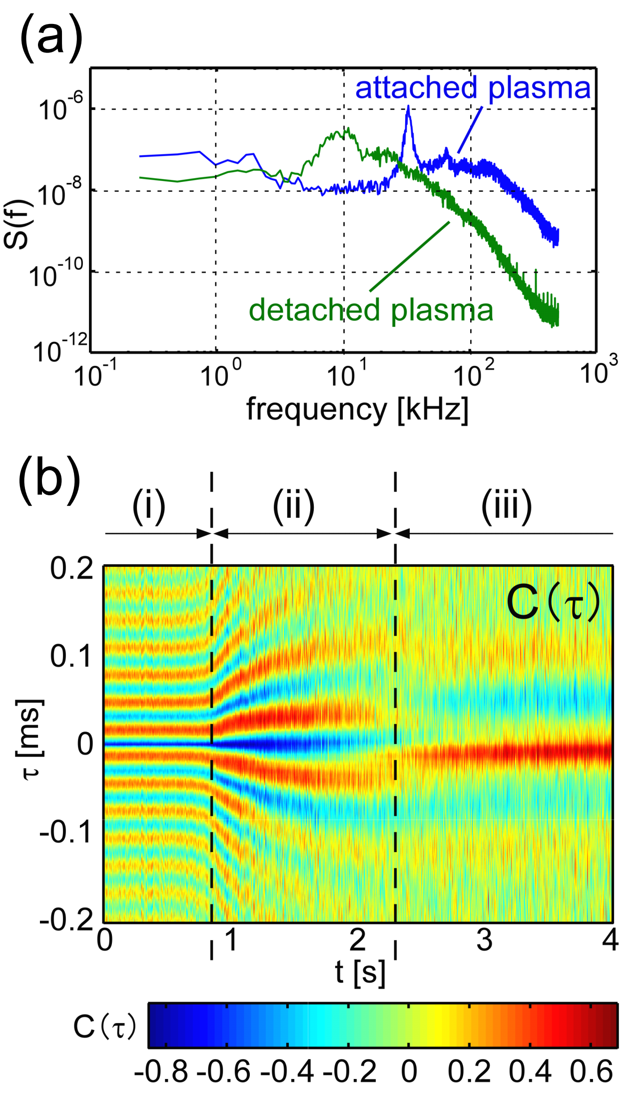

Fig.3. (a) Power spectra of n_e under the attached and the detached plasma. (b) Time evolution of the moving cross-correlation coefficient between the n_e and the V_f.

Figure 3(a) shows the power spectra of n_e, $S(f)$, under the attached and the detached plasma conditions. Here, $S(f)$ of the attached plasma was obtained at (i). It is found that there is a strong peak around 35 kHz. On the other hand, $S(f)$ of the detached plasma which was obtained at (iii) have a peak around 10 kHz. Therefore, by increasing the P, the peak of $S(f)$ shifted to the low-frequency range.

4. Summary

We measured time evolutions of an electron temperature and a electron density, floating and space potentials by using a Langmuir probe in the transient state from the attached to the detached states. It was confirmed that an electron temperature and density decreased by changing from an attached plasma to a detached plasma. Result of a moving cross-correlation coefficient between the electron density and floating potential shows that there is a significant difference between an attached plasma and a detached plasma. In the future, clarification of a detached plasma physics is expected by understanding a change of phase difference with a PIC simulation and so on.

Acknowledgments

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