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 an 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 diagrammatic 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.

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 $V_f$ decreased and $n_e$ and $V_s$ increased considerably. After that, $T_e$ and $V_f$ increased and $n_e$ and $V_s$ decreased gradually. Finally, detached
plasma was generated. From the comparison between the attached and detached states, $\tau_0$ and $n_e$ decreased.

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

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

From the result of the cross-correlation coefficient in Fig. 3(b), the correlation between the $n_e$ and the $V_i$ can be divided into three characteristic time domains, i.e. (i) $\tau < 0.8$ s, (ii) $0.8$ s $< \tau < 2.3$ s, and (iii) $\tau > 2.3$ 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 $\tau$ 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.

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

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References

