Localized Density Fluctuation in the Downstream of Detached Plasma

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The density fluctuation was measured with a 70-GHz microwave interferometry system in the linear divertor plasma simulator NAGDIS-II while changing from the attached to the detached states. In the detached plasma, a large amplitude fluctuation of ≤ 10 kHz appeared in the peripheral region. The fluctuation has a maximum value at the neutral gas pressure of 30 - 34 mTorr. Further, the measurement of the light emission associated with the plasma recombination indicates that the large amplitude fluctuation is located at just downstream of the recombination front, in which the recombination process is the most enhanced.

Keywords: density fluctuation, recombination front, detached plasma, microwave interferometer, NAGDIS-II

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For the success of ITER and future DEMO reactor, reducing plasma heat loads on the divertor plate is an essential issue. In this regard, detached plasma is considered as the most effective method. However, the reduction of the particle and heat loads has not been fully understood in the detached plasma and not simulated perfectly [1]. There are two important mechanisms to reduce peak particle and heat loads onto the divertor plate. One is volume plasma recombination process and the other is enhancement of cross-field transport.

In the linear plasma device NAGDIS-II, the enhancement of the blob-like cross-field transport as well as volume plasma recombination have been observed under the detached plasma condition [2, 3]. When the ion flux dramatically decreases due to an increase of the neutral gas pressure, a large amplitude ion flux fluctuation with ≤ 10 kHz components was detected by using a circular end-target plate with a diameter of 50 mm [4]. Three-dimensional simulation suggested that such axisymmetric-mode fluctuation generates intermittent plasma structures in the periphery [5], however, there were a few measurements of this fluctuation. In addition, it is not known where the large amplitude fluctuation occurs in the detached plasma. The knowledge of the location of the fluctuation is able to reveal the mechanism of plasma instability in the detached plasma.

In this study, we investigate plasma density fluctuation at around the recombination front, where the volume recombination process is the most enhanced, in NAGDIS-II. The density fluctuation is measured with a 70-GHz interferometer [6], and the location of the recombination front is identified by a spectroscopy. Figure 1 shows the schematic diagrams of this experiment. The interferometer is installed ~1 m from the end-target and at vertically 3 cm distance from the plasma center. The neutral gas pressure P is simultaneously acquired at ~0.3 m from the density measurement position (see Fig. 1 (a)). By controlling the gate valve in front of the vacuum pump, the neutral gas pressure is increased [4, 7] in order to move the recombination front from near the end-target to the upstream region during the detached plasma condition, as shown in Fig. 1 (b).

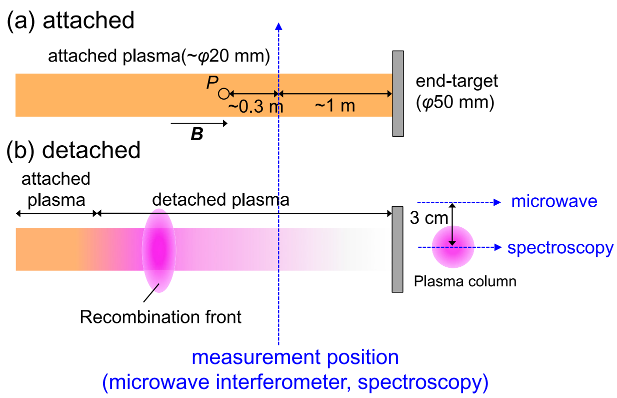

Fig. 1 Schematic diagrams of the experimental system during (a) attached and (b) detached plasma conditions.

Figures 2 (a) and (b) show the time evolutions of P and the spectrogram of the density fluctuation. In Fig. 2 (b), a periodic fluctuation of ~10 kHz is observed at $t \sim 1.5$ -

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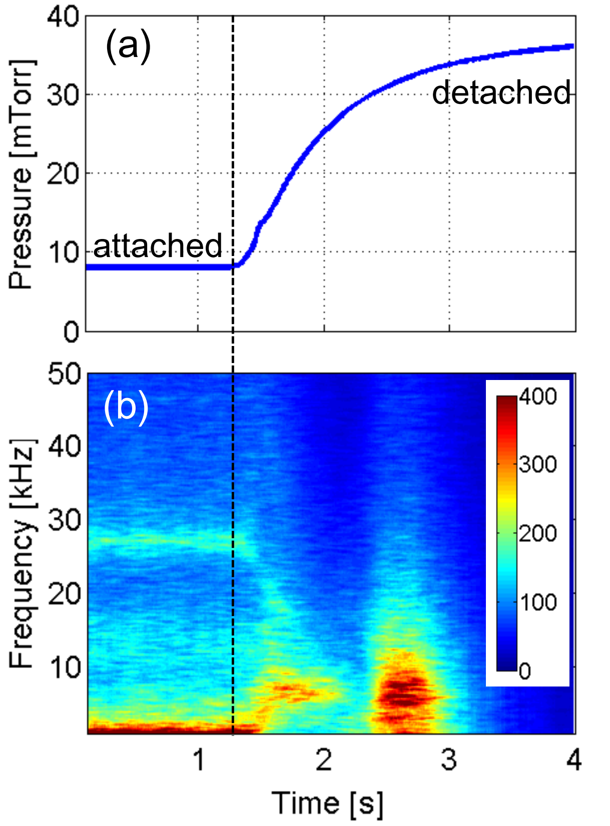

Fig. 2 (a) Time evolution of P. (b) Spectrogram of the density fluctuation.

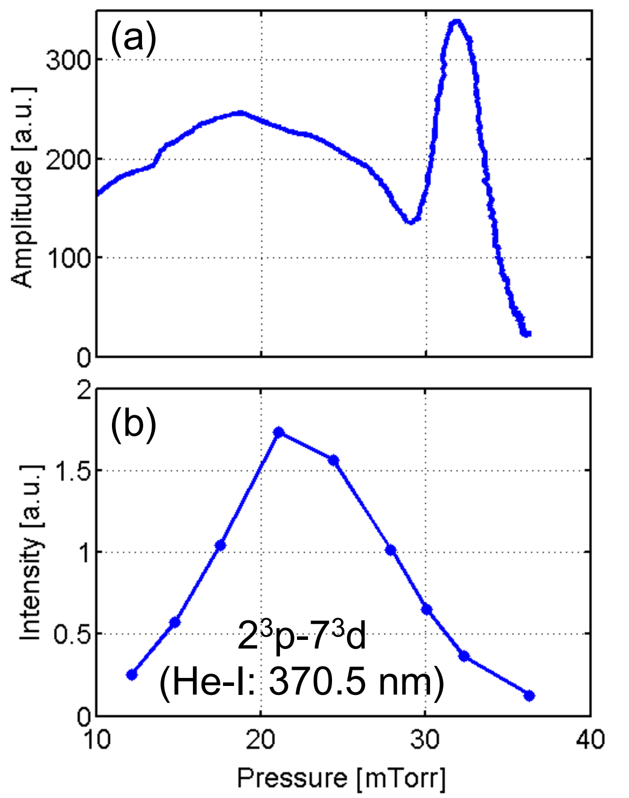

Fig. 3 Pressure dependences of (a) the amplitude of ~10 kHz fluctuation and (b) the emission intensity from the recombination (He-I: 370.5 nm).

2.0 s. This fluctuation would be due to the rotation of the spiral structure in the detached state [3]. After that, at t ~ 2.4 - 3.0 s, a large amplitude fluctuation of ~10 kHz clearly appears.

Figure 3 (a) shows the pressure dependence of the amplitude of ~10 kHz fluctuation. This has a peak at 30 - 34 mTorr, which corresponds to t ~ 2.4 - 3.0 s in time. We also measure a density fluctuation at ~0.7 m upstream from the measurement position along the magnetic field, and there is no such the "large-amplitude fluctuation" with similar spectral shape when the neutral gas pressure was increased up to 40 mTorr. These results mean that the large amplitude fluctuation localized along the magnetic field. In order to investigate the relationship between the large amplitude fluctuation and the recombination front, the light emission associated with the plasma recombination (He-I: 370.5 nm) is measured at the same position with the interferometer along the magnetic field and vertically at plasma center in steady states, as shown in Fig. 3 (b). The emission intensity has a maximum at 20 - 25 mTorr. The recombination front is in the measurement position at that time. Over the 20 - 25 mTorr the recombination front is moved to upstream region. These results demonstrate that the large amplitude fluctuation localized just downstream of the recombination front and reveal the location of the large amplitude fluctuation in detached plasmas.

In future, we are planning to investigate two-dimensional behaviors of the large amplitude fluctuation perpendicular to the magnetic field and the relation to the cross-field transport by using a radially and azimuthally separated end-target. Further, to better understand the axial characteristics of the large amplitude fluctuation, we are also planning to measure multi-point fluctuations along the magnetic field.

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