Rapid Communications

Observation of the Periodical Movement of Ionized Front in a Closed-Divertor Simulator

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The dynamics of plasma and the reversal flow of neutral particle are investigated experimentally in a closed-divertor simulator. It is observed that the ionized front periodically moves in and out of the closed divertor region, as the neutral gas is injected sufficient amount for achieving plasma detachment in the divertor region. Such movement can be related to the reversal flow of the neutral particles injected.

Keywords: closed divertor, ionized front, periodical movement, linear divertor simulator

Divertor plasmas have been simulated by using linear devices with detached divertor regimes which have been recognized as a standard operation mode in magnetic confinement devices [1-6]. Here, we report the discovery of the periodical macroscopic motion of an ionized front in a closed divertor regime.

The experiment was carried out in the linear divertor simulator TPD-II at National Institute for Fusion Science (see Fig. 1) [6]. The helium plasma was continuously generated by dc discharge between the anode and the LaB_6 cathode (discharge current is 100 A). Typical plasma parameters were following: electron density is $10^{20}m^{-3}$, electron temperature is ~10 eV in the axial magnetic field of 0.2 T. The plasma goes into the simulated edge plasma region (E-region), and then into the closed divertor region (D-region). The orifice of 20 mm in diameter that was somewhat larger than the plasma diameter was located at 0.7 m distant from the target. This orifice plays a role of a baffle for the closed divertor in confinement devices. Plasma detachment appears in the D-region where the helium neutral gas are injected with a flow rate of Q~0.02 Pa m^3s^{-1}, and a natural gas pressure at the D-region of P_D, is ~1 Pa.

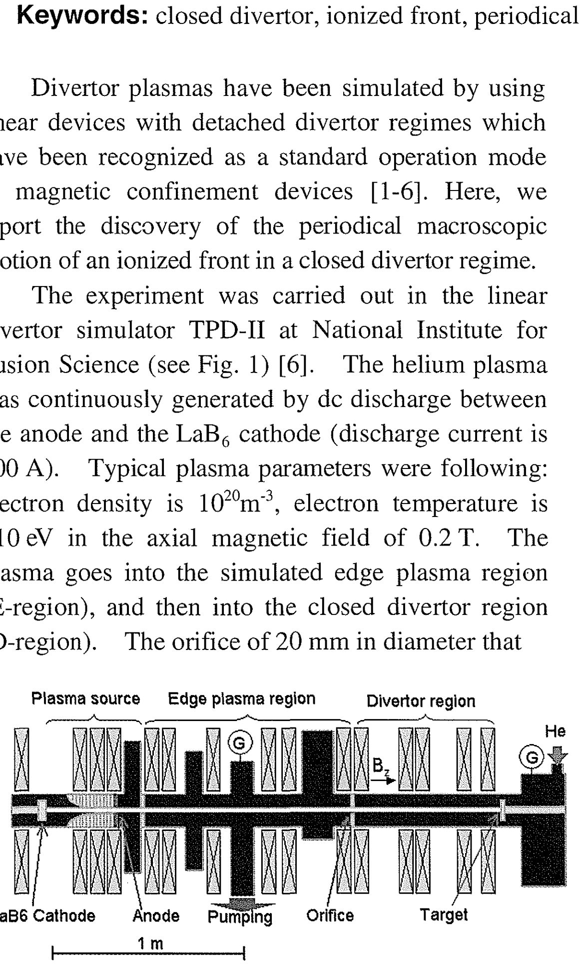

Fig.1 Schematic diagram of TPD-II.

The periodical movement of the ionized front can be observed for the condition of $0.03 \leq Q \leq 0.1$ Pa m^3s^{-1}. If the value of Q is set in such range, the equilibrium is lost; the increase of P_D and the movement of the ionized front toward the upstream begin together. Then, periodical movement occurs. If the value of Q is set more than 0.2 Pa m^3s^{-1}, the system returns to equilibrium state, and the ionized front is settled at the E-region.

Figure 2 shows sequential photographs of the periodical movement for the case of $Q = 0.06$ Pa m^3s^{-1}. One can see that the ionized front moves periodically in and out of the D-region. The extent of the movement is ~0.5 m. The period is ~8 s for the present case. Note that the period decreases if the value of Q is increased. The neutral pressures measured at the D- and E- regions (P_D and P_E) are shown in Figs. 3(a) and 3(b), respectively. Vertical lines of t1~t4 in Fig.3 denote each phase which corresponds to the phase indicated

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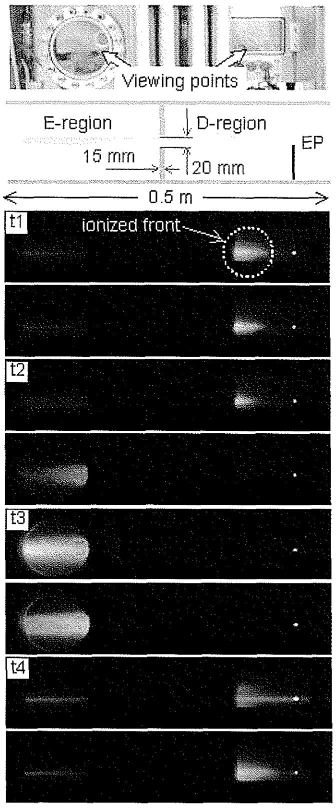

Fig.2 Sequential photographs of the periodical ionized front movement (taken every 1 second). EP means an emissive probe.

respectively as t1~t4 in Fig.2. Following the variation of P_D from t1 as a beginning, we can see that P_D increases until t3. In this stage the ionized front moves toward the upstream of the plasma flow (see Fig.2). At t3 the value of P_D reaches its maximum value, P_D^{max}, of ~13 Pa, and the ionized front moves into the E-region. The value of P_D^{max} is of the same order of the upstream plasma pressure defined as $P_i = n_i kT_i$, implying that P_D^{max} is limited by P_i. After t3, P_D decreases immediately while P_E increases drastically. This indicates that the neutral gas accumulated in the D-region flows into the E-region. When P_D is reduced to half of its maximum value (at t4), the ionized front comes into the D-region. At this moment the plasma in the D-region appears to be as energetic as the plasma in the E-region; the gas target divertor seems not to work well at the moment.Then, as P_D increases gradually, the ionized front begins to move toward the upstream again.

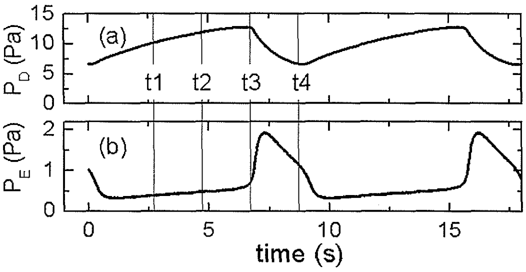

Fig.3 Variations of the neutral pressures measured at D-region, P_D, in (a) and E- regions, P_E, in (b).

A possible interpretation of the periodical movement is given as follows: It is noted that the neutral gas is pumped at the E-region (1 m^3s^{-1}), so the neutral particle tends to flow into the E-region through the orifice. During the stage in which the plasma flows through to orifice, the friction due to the plasma prevents the reversal flow. This causes the suppression in the effective conductance at the orifice for the reversal flow. Then, P_D increases, and both the friction and recombination become significant. As a result, the momentum loss of the plasma increases, and the ionized front begins to move toward the upstream. When the ionized front goes into the E-region, the effective friction becomes weak at the orifice; the neutral gas accumulated in the D-region flows into the E-region. As a consequence of the less friction loss, the ionized front moves into the D-region again. Thus, the periodic movement occurs.

This periodicity can be due to the dependence of the effective conductance of the orifice for the reversal flow on the position of the ionized front. Such periodical nature is observed here for the first time. The study of this phenomenon may contribute to a deeper understanding of the stability of the position of ionized front and may aid in the design of the closed divertor in confinement devices.

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