Strong Reduction of Ion Flux to a Target Plate in a Magnetically Contracting Detached Plasma

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Ion flux into a target plate in expanding and/or contracting magnetic field configuration has been measured under detached plasma condition in the linear plasma device NAGDIS-II. When the magnetic field was contracting towards the target plate, the strong reduction of the ion flux into the target was observed. This result indicates that the contraction in magnetic field should contribute to enhancing the degree of detachment. The magnetic-field-induced enhancement of electron density and the reduction of ion flow velocity due to the mirror effect in contracting magnetic field could lead to increasing volumetric recombination as well as the coupling between ions and electrons.

Keywords: NAGDIS-II, detached plasma, ion flux, magnetic field configuration

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In magnetically confined fusion devices with poloidal divertor configuration, plasma detachment is considered as the most effective method to reduce plasma heat loads onto a divertor plate. Influence of magnetic field configuration in the divertor region on plasma detachment is an important issue from the viewpoint of both formation and stability of detached plasmas.

A conventional poloidal divertor configuration accompanies the contraction of magnetic flux towards a divertor plate (i.e. expansion of magnetic flux towards X-point). Under the detached divertor condition, theoretical analysis suggested that impurity and hydrogen radiation regions move towards the X-point to form X-point MARFE as plasma detachment proceeds, because plasma in wider magnetic flux interacts with neutral particles more strongly [1]. This thermal instability degrades the core plasma confinement.

Advanced magnetic structures such as super-X divertor (SXD) [2] and snowflake divertor (SFD) [3] were proposed for reducing the parallel heat flux into divertor materials. SXD and SFD have advantages to increase the connection length and plasma wetted area of target achieved by magnetic flux expansion, which is also supposed to stabilize radiation front far from the X-point.

As mentioned above, it seems that magnetically expanding plasma towards the divertor plate has an advantage of stability of the plasma detachment. On the other hand, higher plasma density and lower plasma parallel flow velocity are required to produce detached plasma more effectively, because the higher plasma density and lower parallel flow velocity should enhance the volumetric recombination. In magnetically expanding plasmas towards the divertor plate, plasma density goes down along the magnetic field due to the flux expansion and plasma flow increases owing to a contrary effect of a magnetic mirror. These effects weaken the volumetric recombination.

In this Rapid Communication, the effects of magnetic field expansion and contraction on the detached plasma formation are investigated in the linear plasma device NAGDIS-II.

NAGDIS-II [4] generated helium plasma in a steady state. The length of the plasma column was approximately 2 m, and it was terminated with a target plate with the diameter of 12 cm. When the neutral gas pressure was increased, the detached plasma was formed, while the parameters in the plasma source region were almost constant. In this experiment, the neutral pressure was 16 mTorr. Figure 1 shows magnetic field strength at the center of vacuum vessel induced by the 20 solenoidal magnetic coils. In order to form the magnetic field expansion and contraction in axial direction, it is possible to change the currents for 12 magnetic coils in upstream and 8 coils in downstream sides, respectively. The magnetic field strengths were 0.1 T in the upstream (B_u) and 0.05 - 0.2 T in the downstream (B_d). The ion saturation current to the target was measured with biasing the target plate to −200 V.

Figure 2 shows the ion saturation current measured at the target plate as the function of the magnetic field strength in the downstream. With increasing B_d, the ion flux monotonically decreased, especially when $B_u > B_d$. The result indicates that the magnetic field expansion strongly degrades the formation of plasma detachment, and magnetic field contraction should contribute to enhancing the degree of detachment. When $B_u < B_d$, the effect of

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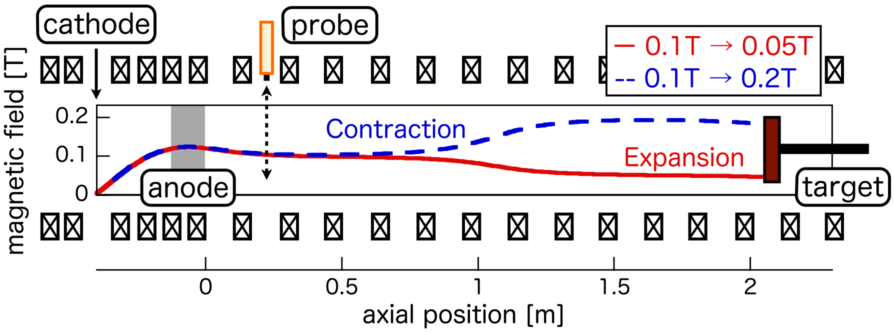

Fig. 1 Magnetic field strength at the center in NAGDIS-II.

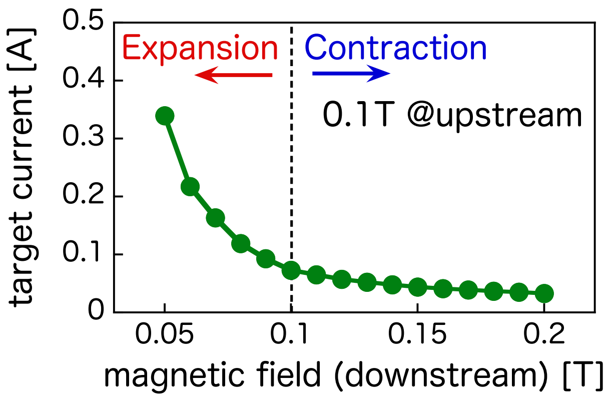

Fig. 2 Dependence of the current to the target with biasing −200 V on the magnetic field in downstream.

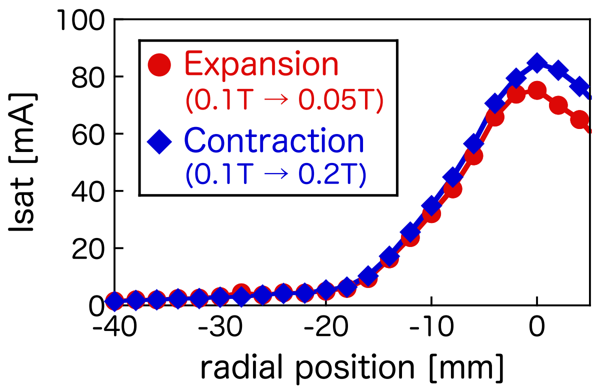

Fig. 3 Radial profiles of ion saturation current measured at the upstream before the magnetic field expanding (circle) and contracting (square).

magnetic mirror may also contribute to the reduction of ion flux. As shown in Fig. 3, it is noted that the radial profiles of ion saturation current, I_{sat} measured in upstream region by using an electrostatic probe (see Fig. 1) almost did not change when B_d was changed.

Figure 4 shows the axial profiles of line emission intensity showing the transition from highly excited level

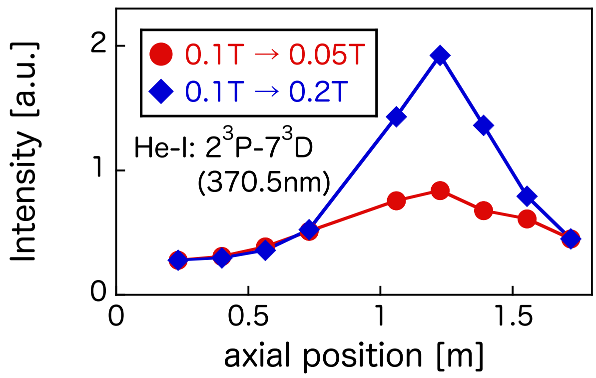

Fig. 4 Axial profiles of line emission intensity showing He-I 370.5 nm when the magnetic field is expanding (circle) and contracting (square) towards the target.

(He-I 370.5 nm) due to the volumetric recombination. When B_d = 0.2 T (magnetic field contraction), the stronger emission from highly excited level was observed than B_d = 0.05 T (magnetic field expansion). Increased electron density by the magnetic field contraction and reduction of ion parallel flow velocity due to the effect of magnetic mirror could increase the coupling time between ions and electrons and enhance volumetric recombination. These results demonstrate that the magnetically contracting plasma towards the target may have an advantage for the formation of detached plasma as compared to the magnetically expanding plasma.

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