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The distribution characteristics of the particle flux on HL-2A tokamak

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One effective way to mitigate the heat flux on the divertor target is to increase the depositional area on the divertor target through changing the magnetic topology by RMP [1] and lower hybrid current drive (LHCD) [2]. However, they have a strong dependence on the external means, which may bring some incompatible technical issues in ITER [3]. The $\mathbf{E}\times\mathbf{B}$ drift, which works as an inherent physical process, is receiving more attention in the edge plasma physics.

Double strike points (DSP) of the particle flux have been observed on the outer divertor target during the HL-2A electron cyclotron resonance heating (ECRH) plasma discharge in the normal magnetic field direction using the Langmuir probe arrays, as shown in Figure 1. The saturation ion current density is relative low and has a single strike point (SSP) before the ECRH, and it shows an obvious DSP accompanied by an increment of the saturation ion current density when the ECRH is turn on, but the phenomenon is weakened due to the increment of the normalized electron density. There is no DSP on the inner divertor target. No DSP in the temperature distribution is observed as well, which suggests the generation of the DSP could not be attributed to the change of the magnetic topology. It is interesting to observe that there is an obvious outward shifted of the temperature peak compared with that of the particle flux, and the staggered peaks are helpful to mitigate the heat flux on the divertor, as shown in the figure 1(f). What is more, there is a slight increase of plasma-wall interaction (PWI) during the duration of the DSP. The experiment statistical results show that the DSP phenomenon occurs in the high ECRH power and low density region.

The analysis shows that the poloidal $\mathrm{E}\times\mathrm{B}$ drift velocity, which is estimated to be the same order as the ion-acoustic velocity, plays an important role in the formation of the particle flux dip. However, the DSP shows a different dependence on the toroidal magnetic field from previous results observed in other devices [4], which could be attributed to the long leg divertor of HL-2A tokamak: The large radiation near the separatrix causes the electron temperature peak (the plasma potential peak) to be shifted outside compared with that of the particle flux near the divertor target, and a positive radial electric field is generated around the particle flux peak, which causes a reversed poloidal $\mathbf{E}\times\mathbf{B}$ drift flow near the outer divertor in the normal magnetic field scenario when the ECRH power is large enough. This physics mechanism was supported by the SOLPS simulation, and it reproduces the dependence of the DSP on the density as well, which is consistent with experiment result.

This work highlights the important role of the poloidal $\mathbf{E}\times\mathbf{B}$ drift and the long leg divertor in the control of the particle and heat flux, which provides some reference for the heat flux mitigation in the future fusion devices.

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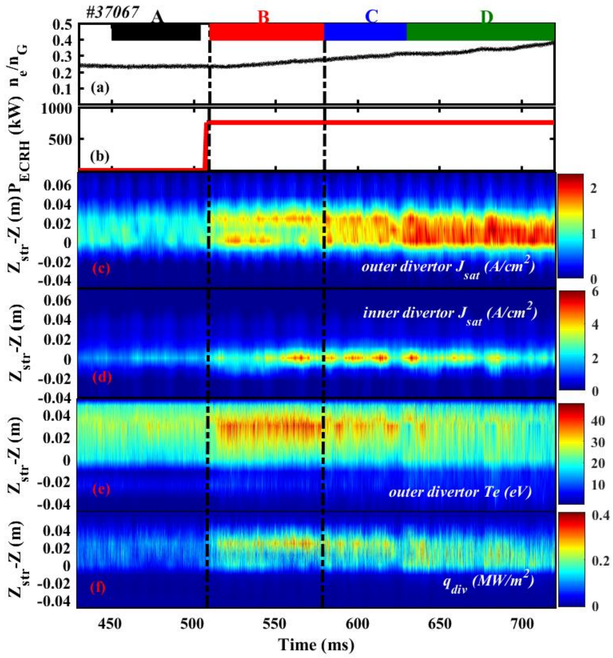

Figure 1. The typical experimental observations of the DSP of the particle flux during the ECRH plasmas: (a) the normalized electron density; (b) ECRH power; the distributions of saturation ion current density on the outer (c) and inner (d) divertor target; the electron temperature (e) and heat flux (f) distributions on the outer divertor target.