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Role of parallel electron current channel in high guide field magnetic reconnection

M. Inomoto[1], T. Mihara[1], K. Kondo[2], K. Kusano[1], T. Tanabe[1], Y. Ono[1], S. Kamio[3]
[1] Graduate School of Frontier Sciences, The University of Tokyo, [2] Graduate School of Engineering, The University of Tokyo, [3] National Institute for Fusion Science
inomoto@k.u-tokyo.ac.jp

Conversion from magnetic to kinetic/thermal energy through magnetic reconnection has a potential to heat plasma within a short period and is utilized as an initial ion heating method in some fusion plasma experiments by, e.g., plasma merging technique. Most part of the magnetic energy is converted to ion energy in magnetic reconnection where the reconnection electric field is perpendicular to the magnetic field. As for electrons, significant direct acceleration will take place in magnetic reconnection region where inductive reconnection electric field has parallel component to the total magnetic field. In magnetic reconnection with high guide field, electrons are effectively accelerated to form significant parallel current channel. In this paper we report the role of parallel induced current in the spherical tokamak merging experiment UTST [1].

Inside the reconnection current layer where the in-plane magnetic field is small, localized parallel current channel was generated in the vicinity of the X-point. This current channel modified the in-plane magnetic field structure to form a small closed flux region. As the contained flux increases, the flux tube suffered from radial position instability and finally exhausted from the current layer towards downstream region [2].

On the other hand, the electron acceleration by a parallel electric field induced in the downstream region will bring about charge separation and resulting in growth of an in-plane electric field which suppresses the parallel component of the reconnection electric field. Thus, it is considered that little acceleration effect takes place in the downstream region of a steady state magnetic reconnection with a guide field. However, finite magnetic flux reconnects in many situations and thus the cancellation of parallel electric field should be treated as a transient process [3], depending on a reconnection period, electron current density flowing along the field line, equivalent capacitance of the downstream region, etc.

In the UTST experiment, we modified the boundary condition of the device to investigate this transient process. Figure 1 (a) shows the parallel current density at the surface of the electrode (solid), which is several times larger than the reconnection current density at the X-point (dashed) when two electrodes located in the downstream region are connected. This experimental condition simulates that the equivalent capacitance of the downstream region is sufficiently large. The parallel current in the downstream region will push the inflow plasma away, possibly leading to the reduction of reconnection electric filed as shown in Figure 1 (b).

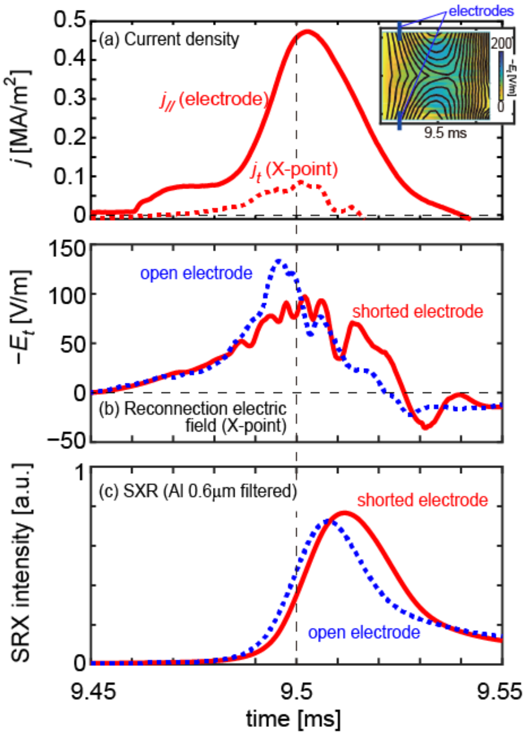

Figure 1 Time evolutions of (a) reconnection and parallel current density, (b) reconnection electric field.

In another respect, keeping the induced electron current channel may help to enhance the energy conversion rate to electrons. As shown in Figure 1 (c), even higher soft X-ray emission (Al 0.6μm filtered) was observed in the slower reconnection case with shorted electrodes. More detailed parallel current profile will be presented in the conference.

There will be the optimum condition for electron acceleration/heating in the guide field reconnection, which will beneficial to apply magnetic reconnection as an electron heating method in fusion plasma development.

References

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