5th Asia-Pacific Conference on Plasma Physics, 26 Sept-1Oct, 2021, Remote e-conference

Control of in-plane electric field during guide field magnetic reconnection in torus-type laboratory experiment

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Magnetic reconnection serves as a fast energy conversion process from magnetic energy to plasma kinetic energy, as observed in solar flares, etc. Most part of the released magnetic energy is converted to the ion kinetic energy [1] in the downstream region where the plasma moves in company with the reconnected field lines, in other words, plasma motion is described as an ExB drift where electric field is perpendicular to the magnetic field.

A guide magnetic field, that is parallel to the reconnection electric field, is usually involved in the reconnection process in the solar, astro, and laboratory plasmas. Parallel acceleration of charged particles, particularly electrons, takes place in the vicinity of the X-point where electric and magnetic fields are nearly parallel [2]. This parallel acceleration will generate electrons' energetic tail component but the total energy converted to the electron kinetic energy is much smaller than that to the ion kinetic energy because the parallel acceleration takes place only in the small region near the X-point and separatrices [3].

Similarly at the X-point, electric field is induced in the wide downstream region due to the motion of the field lines (i.e. change in magnetic flux) and it is largely parallel to the magnetic field that includes the guide field and the reconnected field. However, plasma motion due to the parallel electric field invokes charge separation that creates a static in-plane electric field suppressing the parallel component of the reconnection (induced) electric field, resulting in the MHD condition with the electric field perpendicular to the magnetic field in the saturated steady state.

In this study, the role of boundary conditions of the reconnection downstream region was investigated in the UTST plasma merging experiment. Particularly in the laboratory experiment of torus plasma merging, two kinds of boundary condition are available: the one is the toroidally continuous conducting boundary provided by the vacuum vessel. Due to the eddy current flowing on the vessel, the magnetic field lines do not contact the boundary. The other is the conducting boundary that is separated in toroidal direction but continuous in the poloidal direction (i.e. in the reconnection plane). The field lines in the downstream region could touch the conducting boundary at two distant locations, leading to the short-circuit connection of the magnetic field lines.

Figure 1 shows the temporal evolution of the self-generated axial electric field observed along the radial direction that corresponds to the longitudinal of the reconnection current layer. The black dotted curve shows the radial position of the X-point. In-plane electric field up to 20–30 times as large as the toroidal electric field was generated in the inboard-side (positive E_z) and the outboard-side (negative E_z) of the downstream regions when the magnetic field lines do not touch the boundary (Fig. 1 (a)). This in-plane electric field cancels the parallel component of the reconnection electric field and degrade the electron acceleration efficiency.

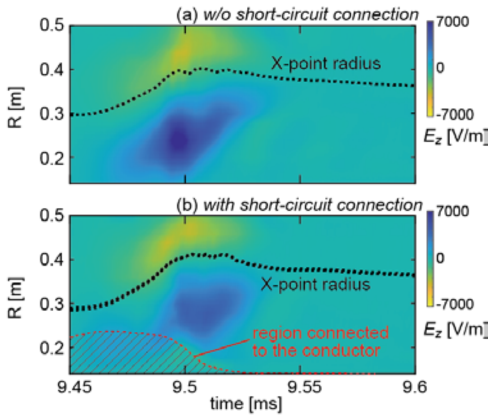

Fig.1 Time evolution of in-plane electric field E_z (a) without short connection and (b) with short connection on the inboard-side boundary of the reconnection downstream region.

Figure 1 (b) shows the in-plane electric field in the case with short-circuit connection condition on the inboard-side boundary. The red curve indicate the location where the magnetic field lines are connected to the conductors. It was found that the in-plane electric field on magnetic field lines connected to the conductor was largely reduced. This suppression effect was attributed to the short circuit connection of the magnetic field lines to hinder the axial charge separation and then a significant part of the parallel electric field remained. These experimental results suggest that changing the boundary condition enables us to control the energy budget to electrons and ions.

References

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