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Transformation of energy conversion by active control of in-plane electric field in high-guide-field magnetic reconnection

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Merging formation [1-3] is one of the candidates for center-solenoid-free start-up scheme of high-beta spherical tokamak (ST) plasma. Two initial STs are formed inductively by using outer poloidal field coils and merge through magnetic reconnection that provides efficient conversion from magnetic to kinetic/thermal energy. Dominant heating source during magnetic reconnection is the ion outflow with ExB drift velocity.

Figure 1 (a) shows the magnetic flux surfaces during merging of two ST plasmas. The electric and magnetic field components in the reconnection downstream region is illustrated in Fig. 1 (b). Here, the electric field consists of toroidal inductive field and dominant poloidal static field generated by the charge separation [4]. Thus it is expected that the motion of charged particles is converted into parallel acceleration when the static poloidal electric field is artificially suppressed. In this study, a control system of the static electric field by using multiple electrodes (see Fig. 1 (a)) and fast switching devices was installed on the UTST experiment to demonstrate the transformation of energy conversion process in magnetic reconnection.

Figure 2 shows the evolution of radial profiles of (a) toroidal and (b) axial electric field in open condition with electrodes disconnected. The inductive toroidal electric field up to 100 V/m was induced in the wide area of the downstream region (R<0.35 m), and the static axial electric field reached 6000 V/m in the downstream region due to the high toroidal magnetic field. In the close conditions with electrodes connected, the static poloidal electric field was significantly suppressed as shown in Fig. 2 (d). The radial profiles of the axial and parallel electric field at t=9.502 ms are shown in Fig. 3 (a)(b). The axial static electric field was largely suppressed about to half in the downstream region. The parallel electric field shows some increase near the X-point (R>0.25 m). This increase in the parallel electric field is considered to enhance the electron acceleration as indicated by the SXR emission profile shown in Fig. 3 (c). Note that this enhancement was not observed in the far downstream region (R<0.3 m) because the parallel electric field in the open condition changed its sign because of the excessive static electric field. This parallel electric field reversal is possibly required to form a toroidal current density profile suitable for the merged ST equilibrium.

References
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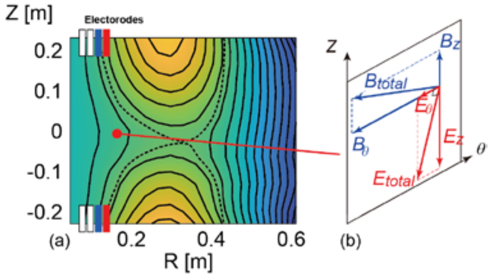

Figure 1 (a) Magnetic flux surface during merging and (b) cartoon of the magnetic and electric field components in the reconnection downstream region.

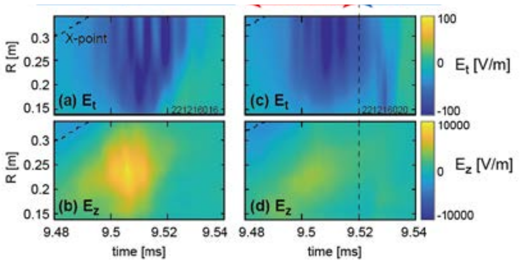

Figure 2 Spatiotemporal plot of (a,c) toroidal (inductive) electric field and (b,d) poloidal (static) electric field measired at z=0 for open condition (a-b) and for close condition (c-d).

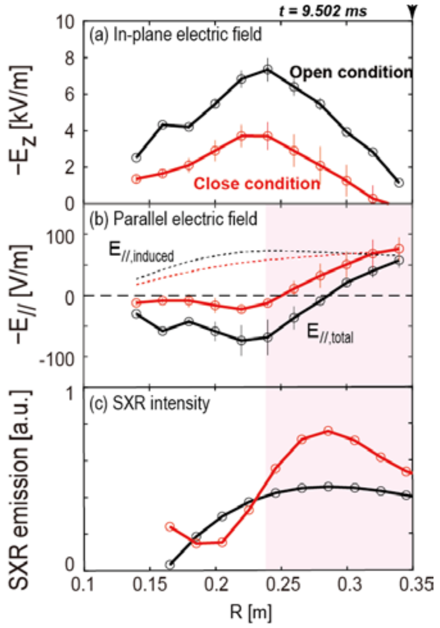

Figure 3 Radial profile of (a) in-plane electric filedm (b) parallel electric field and (c) SXR intensity for open and close conditions.