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プラズモイド放出を用いた動的ダイバータの実験的・数値的実証
Experimental and numerical studies of dynamic divertor by plasmoid ejection

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We demonstrated periodic ejections of "plasmoid" -closed magnetic island- from the main plasma, its transportation and reconnection with a divertor plate using our TS-4 spherical tokamak experiment and our 2-D MHD simulation code[1,2]. The series of operations are keys for a new “Dynamic divertor” whose unique magnetic separation of divertor plasma is expected to significantly reduce heat flux to the divertor plate.

The divertor is a key component for fusion reactors to remove helium ash with heat flux from the main plasma. The severe heat load limitation for the divertor plate can tolerates the grassy (small) ELM (Edge Localized Mode) but not the Type-I ELM, regulating the high-beta tokamak operation. The super-X type and the snowflake type divertors increase the wetted divertor plate area to reduce the heat load. Unlike these new-type divertors, the dynamic divertor has the divertor plate magnetically isolated from the main plasma and the heat flux is transported in forms of the plasmoid (in other word, the heat flux is confined in the closed magnetic field line), brings a number of advantages. The long distance (or small conductance) between the core plasma and the divertor plate means less transportation of injected neutral gas or impurities and separation by the magnetic field means no recycling ions. We can easily handle the power of the plasmoid by the radiation cooling of Argon gas puff and/or pellet injection.

Figure 1 shows R-Z poloidal flux contours of plasmoid ejected from the main plasma to the divertor in one cycle of the dynamic divertor motion, which were measured by two-dimensional (2-D) arrays of pickup coils in the TS-4. The main ST plasma was formed on the left side both by inductions of the flux cores and the center solenoid coil. In our present experiments, the inductive current drive by the center solenoid (CS) causes expansion of the main plasma at the bad curvature corner at t~603μs, generating a plasmoid from t~603 to 627μs and then ejecting it to the divertor coil region by the help of pull force of the divertor coil. We demonstrated for the first time one cycle of the dynamic divertor operation, though the plasmoid ejection occurs once due to the waveform limitation of the coil current under the present setup.

Figure 2(a) shows our ion orbit simulation results in the SOL region (v_{th}=5eV, Z=-0.4m) in the case of figure 1. The blue region indicates SOL ions are confined in the plasmoid, not diffuse directly to the divertor plate. The common flux for the main and divertor plasmas have to be reduced to zero together with the plasmoid forming alternatively at the right and left sides in our ideal doublet dynamic divertor configuration. In this case, we can transport all particle/heat flux from the core plasma to the plasmoid, therefore, the alternate left-side and right-side plasmoid ejections can maintain the continuous blue region, as shown in figure 2(b).

These results verified the controlled plasmoid ejection from the main ST plasma together with the SOL heat flux transportation to it. The remaining challenge of our experiment is to annihilate the common flux between the core and the divertor plasmas for the heat flux suppression and to simulate the radiation cooling effect of gas puff / impurity pellet injection using the measured magnetic configuration.

[1] S. Inoue *et al.*, IEEJ Trans. FM, 131, 11, 963 (2011).
[2] S. Inoue *et al.*, 24th IAEA FEC, PD/P8-17 (2012).

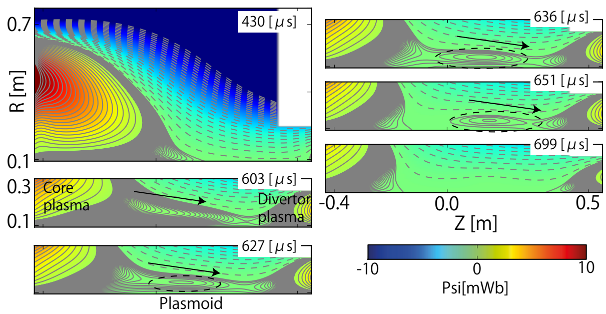

Fig. 1 Poloidal flux contours of plasmoid ejected from the main plasma to the divertor in the TS-4.

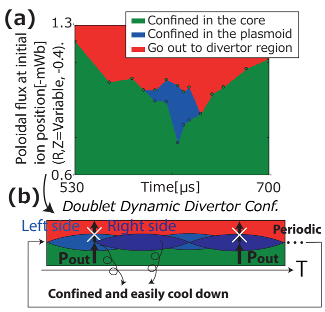

Fig. 2 (a) Particle orbit simulation of SOL ions, (b) SOL ion transport in the doublet dynamic divertor motion.