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Global ion heating/transport process of magnetic reconnection in flux tube merging experiments

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Here we report the recent progress of our experimental studies on ion heating/transport of magnetic reconnection under the influence of high guide field in the merging/ solenoid-free spherical tokamak formation experiments in TS-6 and ST40. Using our clear 2D imaging of the flux tube merging process using 96CH/320CH ion Doppler tomography and in-situ probe arrays, we have found several new features such as blob-like fine structure formation around X-point and globally rotating characteristic of heating profile whose polarity clearly depends on toroidal/guide field direction. Based on our series of reconnection heating scaling experiments, ST40 successfully explores high field application frontier to form keV regime plasmas. With the better plasma confinement by high guide field and auxiliary heating (NBI), 100MK plasma formation has successfully been demonstrated for the first time in spherical tokamak.

Figure 1 shows the overview of reconnection heating experiments in TS-6 and ST40. As shown in the simplified model and visible light image with two plasma rings at the top and bottom of the device, magnetic reconnection occurs at the midplane (z = 0m). Anti-parallel field lines reconnect at the X-point and the reconnected field lines propagates toward downstream region to form thick layer of closed flux surface after merging. Inflow plasmas from the upstream get accelerated through reconnection process and ejected as outflow toward the downstream region. Its flow energy is then converted to thermal energy and ion temperature increases in the outflow region to form double-peak structure. The increment of ion temperature ΔT_i depends on the square of reconnecting field B_{rec} which is in proportion to poloidal field B_p or plasma current I_p: $B_{rec} \sim B_p \propto I_p \propto I_{PF}$, and $\Delta T_i \propto B_{rec}^2$ scaling has been confirmed in many merging experiments. The high power heating is routinely used for an efficient/rapid high temperature plasma formation method and the connection of the attractive startup parameters to quasi-steady confinement phase is successfully demonstrated in many experiments as in the examples in Figure 1 (TS-6 and ST40).

The heating and transport process during/after merging is quite dynamic process and we have investigated how magnetic reconnection heats ions and how the formed hot spots are equilibrated/transported after merging using several high resolution 2D imaging measurements such as 96CH/320CH ion Doppler tomography and ~200CH 2D magnetic probe arrays. Figure 2 shows *full-2D* imaging of global ion heating/transport process during magnetic reconnection in the TS-6 merging spherical tokamak formation experiment. As in the simplified model of acceleration/heating/transport, ion temperature increases through the dissipation of flow energy of accelerated ions in the downstream region of outflow jet. At the heating area, ∇T_i has large radial component (~1keV/m) but the cross field component is strongly suppressed by guide field with the weight of $\kappa^i_{//}/\kappa^i_{\perp} = 2(\omega_{ci}\tau_{ii})^2 >> 1$. The poloidal asymmetry is equilibrated in microsecond time scale and forms hollow profile. In addition to those clear results, other new experimental findings/frontiers will be presented in the conference.

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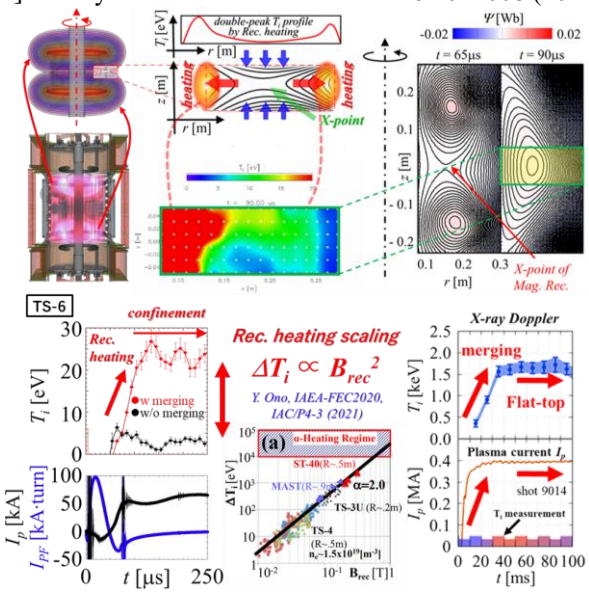

Figure 1 Merging/reconnection experiments and its application for high temperature plasma formation

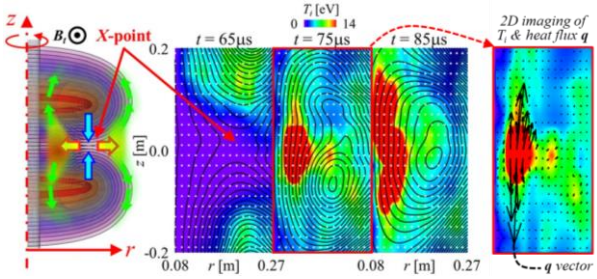

Figure 2 *Full-2D* global imaging of ion heating/transport process during merging/reconnection in TS-6 experiment.