High field application of merging/reconnection plasma startup in the ST40 and TS-6 spherical tokamaks

H. Tanabe[1], M. Gryaznevich[2], S. Mcnamara[2], J. Wood[2], H. Tanaka[1], M. Akimitsu[1], Y. Cai[1], D. Osin[2], P. Buxton[2], A. Rengle[2], O. Asunta[2], C. Z. Cheng[3], M. Inomoto[1] and Y. Ono[1]
[1] University of Tokyo, [2] Tokamak Energy Ltd., [3] Princeton plasma physics laboratory (PPPL)
e-mail: tanabe@k.u-tokyo.ac.jp

Here we present the latest report of our application/ exploration of high field reconnection heating in ST40 and TS-6 merging spherical tokamak formation experiments. High power heating in keV temperature regime as in the MAST spherical tokamak has successfully been reproduced in ST40 and supporting heating/transport physics has been investigated both in ST40 and TS-6. From the formation of first plasma in 2018 in both projects, ST40 demonstrated successful application scenario: high temperature plasma formation through magnetic reconnection and its semi-steady confinement. While, TS-6 enables full-2D ion temperature profile measurement with gyro-scale spatial resolution using 96CH/320CH ion Doppler tomography and detailed heating/transport characteristics have been revealed. Based on outflow heating mechanism ($\Delta T_i \propto B_{rec}^2$), magnetic reconnection forms high temperature region in the downstream of outflow jet and forms fine structure. Blob-like structure in the diffusion region is ejected toward downstream and forms clear hot spots after merging, while the hot spots on the closed flux surface formed by reconnected field lines are transported on the field line direction with the weight of $\kappa^i_{/\!/}/\kappa^i_{\perp} = 2(\omega_{ci}\tau_{ii})^2 >> 1$ under the influence of high guide field and finally forms poloidally ring-like structure. In the practical application scenario, the detachment from merging driving coils during reconnection heating is a key for the practical application scenario for spherical tokamak. In the attached case, the double-peak hollowness has quickly disappeared due to active heat loss on the field line which is directly connected to merging driving coils. While in the detached case, ion temperature profile sustained the hollow profile much longer than the merging time $\tau_{sustainment} >> \tau_{merging}$ and it was found that the optimization of attached/detached configuration controlled by other vertical field coils which control the separation is essential for practical application scenario.

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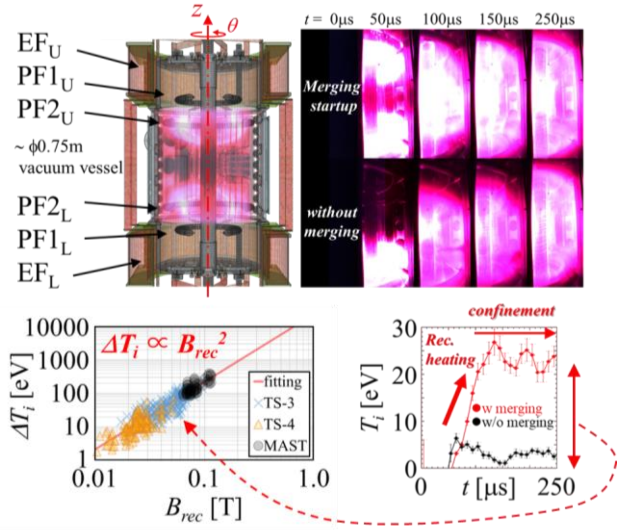

Figure 1 Merging/reconnection plasma startup in TS-3U. The released magnetic energy of reconnecting field B_{rec} is converted to plasma thermal energy and increases ion temperature: $\Delta T_i \propto B_{rec}^2$ as verified in many experiments.

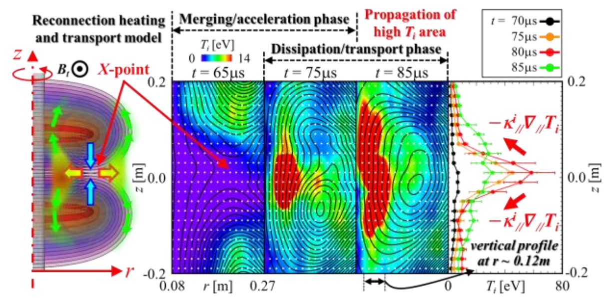

Figure 2 Full-2D imaging measurement of T_i during magnetic reconnection in TS-3U. Global 2D ion heating/ transport has clearly been visualized in experiment.

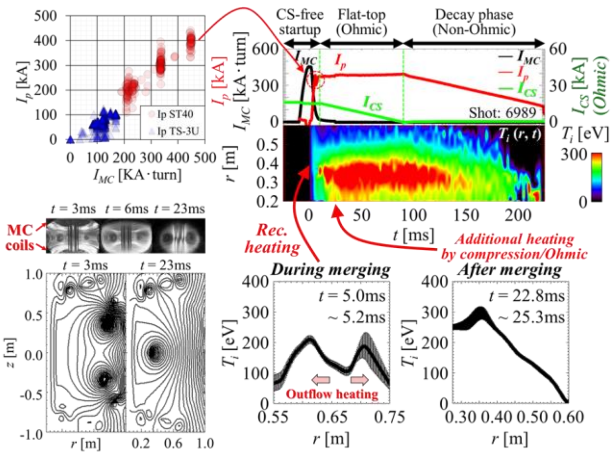

Figure 3 Application of merging startup scenario on ST40. The rapid high power reconnection heating and its connection to steady operation has been demonstrated.