DPP14-2014-000538

Abstract for an Invited Paper
for the DPP14 Meeting of
the American Physical Society

High Power Heating of Magnetic Reconnection in Tokamak Merging Experiments

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Significant ion and electron heatings of magnetic reconnection up to 1.2keV were documented in two tokamak plasma merging experiment on MAST with the significantly large Reynolds number R $\sim 10^5$ [1]. Measured 2D contours of ion and electron temperatures reveal clearly the energy-conversion mechanisms of magnetic reconnection: huge outflow heating of ions in the downstream and localized ohmic heating of electrons at the X-point. Ions are accelerated up to the poloidal Alfven speed in the reconnection outflow region, and are thermalized by density pileups or fast shocks formed in the downstreams, in agreement with recent solar satellite observations and PIC simulation results. The magnetic reconnection efficiently converts the reconnecting (poloidal) magnetic field energy mostly into ion thermal energy through the outflow, causing the reconnection heating energy proportional to square of reconnecting (poloidal) magnetic field B_p^2. The guide toroidal field does not affect the ion heating, probably because the reconnection/ outflow speeds are determined mostly by the external driven inflow by the help of several fast reconnection mechanisms. The localized electron heating increases sharply with the toroidal field, probably because the toroidal field increases electron acceleration length along the X-line. 2D measurements of magnetic field and temperatures in the TS-3 tokamak merging experiment also reveal the detailed reconnection heating mechanisms mentioned above [2]. The high-power heating of tokamak merging is useful not only for laboratory study of reconnection but also for economical startup and heating of tokamak plasmas. It enables us to increase the plasma beta by 10-30% within a short reconnection time. In collaboration with the MAST team.

[1] Y. Ono et al. Plasma Phys. Cont. Fusion 54, 124039, (2012).
[2] Y. Ono et al, Phys. Rev. Lett. 107, 185001, (2011).