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Formation of Hot, Stable, Long-Lived Field-Reversed Configuration Plasmas on the C-2W Device

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TAE's research has been devoted to producing a high temperature, stable, long-lived field-reversed configuration (FRC) plasma state by neutral-beam injection (NBI) and edge biasing/control. C-2U experiments have demonstrated drastic improvements in particle and energy confinement properties of FRC's, and the plasma performance obtained via ~10 MW NBI has achieved plasma sustainment of up to 5 ms and plasma lifetimes of 10+ ms [1]. The emerging confinement scaling, whereby electron energy confinement time is proportional to a positive power of the electron temperature T_e, is very attractive for higher energy plasma confinement; accordingly, exploration of the observed scaling law at 10× higher T_e is one of the key research objectives.

TAE's new experimental device, C-2W (also called "Norman"; the world's largest compact-toroid device), has been constructed with the following key subsystem upgrades from C-2U: (i) higher injected power (up to ~21 MW), optimum and adjustable energies (15-40 keV), and extended pulse duration (up to ~30 ms) of the NBI system; (ii) installation of inner divertors with upgraded edge-biasing electrode systems, which allow for higher biasing voltage and longer pulse operation (30+ ms); (iii) increased overall stored energy in the FRC formation pulsed-power system; (iv) fast external equilibrium/mirror-coil current ramp-up capability for plasma ramp-up and control; (v) installation of trim/saddle coils for active feedback control of the FRC plasma; and (vi) enhanced overall diagnostic suite. A remarkable side note is the fact that TAE spent only ~1 year to construct the C-2W device and produce its first plasma. C-2W experiments have already produced a dramatically improved initial FRC state after translation and merging. As anticipated by design and also in our simulations, the merged initial FRC state exhibits much higher plasma temperatures (T_e >250 eV; total electron and ion temperature >1.5 keV) and more trapped flux, providing a very attractive target for effective NBI. Edge biasing/control experiments have also demonstrated stabilization of the FRC, thereby improving plasma confinement and prolonging FRC lifetime (up to ~10 ms), in which overall plasma performance is already equivalent to or better than that obtained in C-2U.

[1] H. Gota et al., Nucl. Fusion 57, 116021 (2017).

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