Suppressed Ion-Scale Turbulence in the C-2/C-2U FRC - Recent Experimental and Simulation Results

L. Schmitz[1,2], D.P. Fulton[1], C. Lau[3], T. Tajima[1,3], M. Binderbauer[1], B.H. Deng[1], H. Gota[1], I. Holod[3], Z. Lin[3], and the TAE team[1]

[1]*Tri Alpha Energy, Inc., Rancho Santa Margarita, California 92688, USA*
[2]*University of California Los Angeles, Los Angeles, CA 90095-7799, USA*
[3]*University of California Irvine, Irvine, CA 92697, USA*

Ion-scale modes are found to be stable in the core of the C-2 and C-2U neutral-beam-sustained Field-Reversed Configurations (FRCs) [1]. An inverted toroidal wavenumber spectrum is measured in the closed flux surface region via Doppler Backscattering (DBS). Local, electrostatic gyrokinetic simulations via the modified GTC code [2] attribute the absence of ion-scale core fluctuations to a combination of Finite Larmor radius effects, large ion- to electron temperature ratio (T_i/T_e ~5), short field line connection length, and the radially increasing magnetic field gradient. Near-classical ion energy confinement is inferred from transport analysis, in qualitative agreement with the observed lack of core turbulence. In contrast, ion-range and electron-range modes with an exponential wavenumber spectrum are observed in the FRC scrape-off layer (SOL), with radially increasing fluctuation levels ($2 \leq k\rho_s \leq 40$, $0.05 \leq k\rho_s \leq 0.45$, where k is the toroidal wavenumber and ρ_s, ρ_e are the ion-sound gyroradius and the electron gyroradius). Linear, electrostatic flux-tube gyrokinetic simulations confirm unstable SOL drift wave and trapped electron modes, driven by the radial electron temperature and density gradients, across a fairly wide wavenumber range. Electostatic passive or active divertor biasing of the SOL plasma (via plasma guns with a central biased electrode, passive annular divertor electrodes, or a large radius LaB_6 electron emitter) maintains sufficient $\boldsymbol{E}\times\boldsymbol{B}$ rotational shear just outside the FRC separatrix to establish an effective radial transport barrier with reduced radial turbulence correlation. SOL fluctuation levels are reduced substantially compared to unbiased FRCs, sustaining an increased radial density gradient. The measured SOL critical density gradient is comparable to the linear instability threshold predicted by local gyrokinetic simulations, but increases with $\boldsymbol{E}\times\boldsymbol{B}$ rotational shear, opening the prospect of active boundary and transport control in view of FRC reactor requirements.

[1] M.W. Binderbauer, T. Tajima *et al.*, *Phys. Plasmas* **22**, 056110 (2015).
[2] D.P. Fulton, C. Lau, I. Holod, *et al.*, *Phys. Plasmas* **23**, 012509 (2016).