Scrape-off layer density shoulder formation mechanisms in JET ITER-like wall L-mode and H-mode plasmas†

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The characteristics of the SOL plasma (Scrape-Off-Layer) determine the level of power loading and erosion of, and DT implantation in, surrounding material surfaces, and thus help determine the viability of a tokamak-based fusion energy reactor. For example, the appearance of low-field side (LFS) SOL flattened or long e-folding length density profiles (so-called density 'shoulders' [1]) raise the density (neutral and ion) at main chamber surfaces, accompanied by plasma surface interactions. This study, which examines the potential mechanisms leading to SOL density shoulders in JET tokamak with the ITER-like wall (ILW), includes a factor of 2 range in plasma current, compares the effect of vertical (closed) vs horizontal (open) outer divertor target configurations, as well as the effect of divertor nitrogen (N_2) seeding vs deuterium (D_2) fuelling, primarily for L-mode plasmas.

There is evidence against local SOL ionization directly increasing SOL densities as a mechanism for shoulder formation. It is also found that a second, and commonly referred-to mechanism – the change of parallel resistivity in the SOL (characterized through $\Lambda_{div} = [L_{||}\nu_{ei}\Omega_i]/c_s\Omega_e$ [2]) leading to changes in SOL turbulence velocity and size – is anti-correlated with SOL density shoulder formation; while core density ramps through D_2 fuelling leads to increases in shoulder amplitude and Λ_{div}, N_2 seeding increases Λ_{div} but not SOL shoulder amplitude. The most consistent quantity that correlates with formation of SOL density shoulders is the amount of divertor recycling (quantified through Balmer D_α): a) shoulders form at the transition of the divertor plasma from sheath-limited to high-recycling condition; b) strike point sweeping in major radius changes divertor D_α and shoulder amplitude concurrently without changing Λ_{div}; c) N_2 seeding lowers both shoulder amplitude and divertor D_α while raising Λ_{div}; and d) switching the outer divertor leg from the horizontal to vertical target both lowers divertor D_α and shoulder amplitude. In attached divertor plasmas Balmer D_α light emissivity is a measure of the amount of charge exchange and ionization reactions which can change flows in the divertor, lowering or increasing the loss (sink) of ions from the upstream SOL and thus modify the density there. A comparative study of H-mode discharges indicates that similar conclusions about shoulder formation mechanisms are drawn for H-mode.

[1] B. LaBombard et al, Nuclear Fusion, **40** (2000) 2041
[2] J. Myra et al., Physics of Plasmas, **13** (2006) 092509

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