Controlling Divertor Plasma Detachment: The Role of Fluctuation Energy Intensity Flux and Broadening the SOL Width

X. Q. Xu[1], N. M. Li[1], M. L. Zhao[1], P. H. Diamond[2], X. Liu[3], Y. F. Wang[3], X. Lin[3], N. Yan[3], G. S. Xu[3], and T. D. Rognlien[1]

1) Lawrence Livermore National Laboratory, Livermore, CA 94550 USA
2) Center for Astrophysics and Space Sciences and Department of Physics, University of California San Diego, La Jolla, California 92093-0429, USA
3) Institute of Plasma Physics, Chinese Academy of Sciences, Hefei, China

BOUT++ turbulence simulations investigated small/grassy ELM characteristics by varying plasma current, edge electric field profile, pedestal pressure, and collisionality. Results showed that in the ELM-free regime, divertor heat flux width λ_q follows ITPA multi-tokamak scaling. However, in the grassy ELM regime, λ_q broadens due to outward turbulence spreading measured by fluctuation energy intensity flux Γ_ε at the separatrix. Spreading is controlled by factors like pedestal collisionality, pressure gradients, edge radial electric field, and the SOL plasma profiles. Operating in H-mode with small/grassy ELMs addresses ELM size reduction and SOL width broadening in future fusion reactors.

To reduce divertor heat flux and temperature, detached divertor plasma is crucial. Gas puffing and impurity seeding achieve this, but narrow SOL width can lead to confinement loss. Broadening the SOL width reduces peak divertor heat load and required upstream separatrix density for divertor-plasma detachment. UEDGE Simulations using radial diffusion coefficients (proxy for Γ_ε) illustrate the effect on ion saturation current and power width at the outer target. As diffusion coefficient (or Γ_ε) increases, λ_q increases and required separatrix density decreases at detachment onset, as indicated by the rollover of the ion saturation current. This result demonstrates a reduction in the need for excessive gas puffing and impurity seeding for achieving divertor-plasma detachment.

This work was performed for USDOE by LLNL under DE-AC52-07NA27344.