The divertor challenge anticipated for SPARC – reactor level heat fluxes in a compact, high-field tokamak designed to demonstrate net fusion energy

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SPARC (presently at a “V1C” design) is a compact (R_0=1.78 m, a=0.55 m, κ=1.75), high-field (B_0=12.5 T) tokamak with a Q_{fus}>2 mission using 25 MW of Ion Cyclotron Range of Frequency T(3He) minority heating as the sole auxiliary power input. The mission is made possible due to an on-going accelerated R&D program that capitalizes on the development of high-temperature, high-field Yttrium Barium Copper Oxide (YBCO) superconductors. A team of over 100 scientists and engineers is on track to develop a model toroidal field coil by 2021, with the goal of constructing the SPARC device by 2025. SPARC presents the opportunity to demonstrate net fusion energy on a cost-scale and timeline that is attractive to the private sector.

SPARC will push tokamak boundary physics beyond what is expected in reactor-class devices like ITER and ARC in key parameters such as plasma density and power density. With a maximum plasma current of 8.65 MA at q*=3.05, the outboard midplane poloidal magnetic field on SPARC V1C will be twice the maximum field in the existing multi-machine database that provides the Eich scaling of the boundary heat flux width, λ_q. This scaling projects to a λ_q = 0.16 mm for SPARC V1C. In comparison, Goldston’s heuristic drift model predicts λ_q =0.34 mm. Both predictions will lead to upstream peak parallel heat fluxes at least an order of magnitude higher than demonstrated to date (>10 GW/m^2). Furthermore, based on the Eich ELM energy fluence scaling, SPARC is projected to have peak parallel ELM energy fluences comparable to ITER (10-30 MJ/m^2), posing a significant challenge for machine operations.

To meet this challenge, SPARC is designed with conservative plasma physics assumptions and will not rely on complete divertor detachment to ensure divertor target survivability. The relatively short pulse length (~25 second pulse, with a ~10 second flat top) eliminates the need for intra-shot cooling of plasma facing components, simplifying the design and reducing risk of failure due to a coolant leak in an activated environment. The current baseline scenario estimates the conducted power entering the scrape-off layer to be 20 MW and assumes a moderate, 50% radiation fraction in the divertor. A ~1 Hz strike point sweep spreads the heat flux over a large divertor target surface area and keeps surface temperatures within tolerable levels. Although the baseline design does not depend on divertor detachment, SPARC will be equipped with sufficient gas injection capability to reach detached divertor conditions.

Recognizing that the baseline scenario for heat flux management in SPARC will not scale to a reactor, the poloidal field coil requirements necessary to test ‘advanced divertor’ concepts in SPARC are currently being assessed and will be presented. This talk will summarize the current status of SPARC, and the various boundary modelling efforts, as well as highlight the opportunities presented by SPARC for advancing divertor physics and technology.

Research supported by Commonwealth Fusion Systems.