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Edge- and divertor and plasma behavior in high power high performance double-null plasmas

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We identify major challenges to reducing divertor heat flux in high power, high performance near-double null DIII-D plasmas, while still maintaining sufficiently low
density to allow for application of RF heating. The plasmas discussed here are characterized by: β_N ≃ 3–4, H_98 ≃ 1.5–1.7, dR_SEP ≃ -5 mm, and P_IN up to 20 MW. The scaling of the peak heat flux (q⊥p) at the outer target of the primary divertor was proportional to P_SOLˆ0.92 and Ipˆ0.92 in the range P_SOL = 8 -19 MW and Ip = 1.0–1.4 MA and is consistent with standard ITPA scaling for single null configurations. Three distinct divertor heat flux reduction techniques were tested. First, the puff-and-pump radiating divertor was less effective in reducing divertor heat flux when β_N was raised to 3.7 than occurred for lower values of β_N and P_IN. In the higher β_N case, gas puffing during puff-and-pump resulted in an increase in τ_E and τ_p and led to more rapid fueling of the core. This set an upper limit on the D_2 injection rate that can be tolerated without losing density control, thereby undermining the effectiveness of puff-and-pump. We are investigating how a decrease in ELMing frequency during D_2 injection at higher power and β_N may drive this process. Second, increasing the poloidal flux expansion at the outer target of the primary divertor did not produce the expected reduction in q⊥p that would have been expected from geometrical arguments, e.g., almost doubling the poloidal flux expansion reduced q⊥p by only ˜20%. Preliminary analysis suggests that cross-field diffusion effects appear to counteract poloidal flux expansion. Third, we show how q⊥p was reduced by 25-50% when an open divertor is closed on the common flux side of the outer divertor target ("semi-slot"divertor). Steady carbon buildup in the main plasma became significant during higher P_IN operation, and was largely due to sputtered carbon from graphite tiles on the horizontal surface above the pumping plenum entrance (and not from the "divertor floor). Our results strongly suggest the necessity of further study before relying on either radiating divertor or poloidal flux expansion to adequately control divertor heat flux in high power, high performance DN plasmas.
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