TOPIC: EX-D

Divertor Heat Flux Mitigation in High-Performance H-mode Plasmas in the National Spherical Torus Experiment.

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Experiments conducted in high-performance 4-6 MW NBI-heated H-mode plasmas with a high flux expansion radiative divertor in NSTX demonstrate that significant divertor peak heat flux reduction and access to detachment may be facilitated naturally in a highly-shaped spherical torus (ST) configuration. Radiative (detached) divertors and optimized divertor geometry are considered candidate techniques for steady-state mitigation of divertor heat flux and erosion of divertor material in ITER and the ST-based Component Test Facility concept and the proposed National High-power Advanced-Torus eXperiment. Improved plasma performance approaching the performance level of CTF with high beta 15-25 %, a high bootstrap current fraction 45-50 %, longer plasma pulses, and an H-mode regime with smaller ELMs has been achieved in lower single null NSTX plasmas with higher end elongation 2.1-2.4 and triangularity 0.5-0.7. Because of the high poloidal magnetic flux expansion factor (12-23) and higher SOL area expansion, the divertor peak heat flux is 20 - 40 % lower than in similar plasmas with lower-end shaping parameters. Access to detachment was demonstrated using additional deuterium injection and divertor radiation from intrinsic carbon and residual helium. A partially detached divertor (PDD) phase was induced at several SOL power levels within 20-50 ms from the start of gas injection while maintaining good core confinement and pedestal characteristics. Measured properties of the PDD regime indicated much similarity with large aspect ratio tokamak experiments: a 30-60 % increase in divertor plasma radiation, a peak heat flux reduction up to 60 %, measured in a ~ 0.1 m radial zone, a 30 - 80 % increase in neutral compression, and a significant volume recombination rate increase. A five-region SOL heat conduction model with constant heat and particle sources and sinks predicts that large radiated power and momentum loss fractions are required to achieve detachment in the NSTX range of parallel SOL heat flux 25-60 MW/m^2 and connection lengths 6-10 m. Because of a large SOL magnetic shear, the parallel connection length rapidly decreases in the outer SOL thereby radially limiting the detachment zone, whereas the plasma volume available for the radiated power and ion momentum loss is maximized in the region of longer connection length. This work was supported by the U.S. DOE in part under Contract DE-AC52-07NA27344.