Radiative Snowflake Divertor Studies in DIII-D

V.A. Soukhanovskii¹, S.L. Allen¹, M.E. Fenstermacher¹, D.N. Hill¹, C.J. Lasnier¹, M.A. Makowski¹, A.G. McLean¹, W.H. Meyer¹, D.D. Ryutov¹, E. Kolemen², R.J. Groebner³, A.W. Hyatt³, A.W. Leonard³, W.H. Meyer¹, D.D. Ryutov¹, E. Kolemen², R.J. Groebner³, A.W. Hyatt³, A.W. Leonard³, T.H. Osborne³, T.W. Petrie³, and J.G. Watkins⁴

¹Lawrence Livermore National Laboratory, 7000 East Ave, Livermore, CA 94550, US
²Princeton Plasma Physics Laboratory, PO Box 451, Princeton, NJ 08543-0451, USA
³General Atomics, PO Box 85608, San Diego, CA 92186-5608, USA
⁴Sandia National Laboratories, PO Box 969, Livermore, California 94551-0969, USA.

Recent DIII-D results using the snowflake (SF) divertor configuration demonstrate that the SF geometry enables significant manipulation of divertor heat transport for power spreading in attached and radiative divertor regimes, between and during edge localized modes (ELMs), while maintaining good H-mode confinement. The results complement the initial NSTX and DIII-D SF divertor studies and contribute to the physics basis of the SF divertor as a promising concept for high power density tokamaks.

Enhanced heat transport through the low poloidal field null-point region and divertor legs resulting in increased scrape-off layer width and heat flux spreading over additional strike points (SPs) were observed in the nearly-exact SF. In SF configuration variants, the SF-minus and SF-plus, geometry effects also play an important role. The deposited heat flux is reduced due to the increased plasma-wetted area (poloidal magnetic flux expansion). The parallel heat transport is mostly affected by heat spreading over additional SPs, and increased connection length. The amount of heat measured in additional strike points is often proportional to input power and density.

Recent measurements support the theoretically predicted SF property critical for ELM heat transport, i.e. the fast convective plasma redistribution through the null point region due to the onset of a flute-like instability. Direct measurements of divertor null-region poloidal beta, using a unique DIII-D divertor Thomson scattering diagnostic, were performed. The measured divertor \( \beta_p \sim 50–100 \) was about 2–3 orders of magnitude higher than midplane \( \beta_p \), and the high beta region was broader in the SF configuration. During an ELM, the \( \beta_p \) was increased by up to an order of magnitude.

Type I ELM heat transport was significantly affected by the SF divertor geometry. While the peeling-ballooning mode stability in the H-mode discharges was not significantly affected, the ELM frequency and size were changed by 10%–20%. The stored energy lost per ELM was reduced. In gas-seeded radiative regimes, SF geometry led to a significant reduction of peak heat fluxes between and during ELMs, while maintaining good H-mode performance.

This work was performed under the auspices of the US Department of Energy (US DOE) by LLNL under DE-AC52-07NA27344, the US DOE under DE-AC02-09CH11466, DE-FC02-04ER54698, and DE-AC04-94AL85000.

Fig. 1. (a) Near-exact SF configuration, with a contour around the X-point region showing the extent of low \( |B_p/B_m| = 0.10 \) region, where the poloidal magnetic field \( B_p \) is normalized to its midplane \( B_m \) value, (b) divertor heat flux profile, (c) parallel heat flux \( q_\parallel \) profile projected to midplane, and the Eich function fit, for the standard and SF configurations.