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Taming Thermonuclear Plasma with a Snowflake

Novel heat handling method holds promise for future tokamak reactor designs

CHICAGO—Physicists working on the National Spherical Torus Experiment (NSTX) at the Princeton Plasma Physics Laboratory are now one step closer to solving one of the grand challenges of magnetic fusion research—how to reduce the effect that the hot plasma has on fusion machine walls (or how to tame the plasma-material interface). Some heat from the hot plasma core of a fusion energy device escapes the plasma and can interact with reactor vessel walls. This not only erodes the walls and other components, but also contaminates the plasma—all challenges for practical fusion. One method to protect machine walls involves divertors, chambers outside the plasma into which the plasma heat exhaust (and impurities) flow. A new divertor concept, called the “snowflake,” has been shown to significantly reduce the interaction between hot plasma and the cold walls surrounding it.

Strong magnetic fields shape the hot plasma in the form of a donut in a magnetic fusion plasma reactor called a tokamak. As confined plasma particles move along magnetic field lines inside the tokamak, some particles and heat escape because of instabilities in the plasma. Surrounding the hot plasma is a colder plasma layer, the scrape-off layer, which forms the plasma-material interface. In this layer, escaped particles and heat flow along an “open” magnetic field line to a separate part of the vessel and enter a “divertor chamber.” If the plasma striking the divertor surface is too hot, melting of the plasma-facing components and loss of coolant can occur. Under such undesirable conditions, the plasma-facing component lifetime would also be an issue, as they would tend to wear off too quickly.

While the conventional magnetic X-point divertor concept has existed for three decades, a very recent theoretical idea and supporting calculations by Dr. D.D. Ryutov from Lawrence Livermore National Laboratory have indicated that a novel magnetic divertor—the “snowflake divertor”—would have much improved heat handling characteristics for the plasma-material interface. The name is derived from the appearance of magnetic field lines forming this novel magnetic interface, as shown in Figure 1.

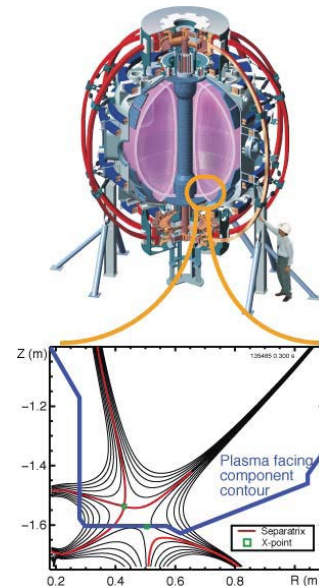


Figure 1. A “snowflake” divertor – a novel plasma-material interface is realized in the National Spherical Torus Experiment.

This magnetic configuration was recently realized in NSTX and fully confirmed the theoretical predictions. The snowflake divertor configuration was created by using only two or three existing magnetic coils. This achievement is an important result for future tokamak reactors that will operate with few magnetic coils. Because the snowflake divertor configuration flares the scrape-off layer at the divertor surface, the peak heat load is considerably reduced, as was confirmed by the divertor heat flux on NSTX (Figure 2a). The plasma in the snowflake divertor, instead of heating the divertor surface on impact, radiated the heat away, cooled down and did not erode the plasma-facing components as much, thus extending their lifetime. Shown in Figure 2b-c are the plasma TV images that show more divertor radiation in the snowflake divertor plasmas in comparison with the standard plasmas. Importantly, the snowflake divertor did not have an impact on the high performance and confinement of the high-temperature core plasma, and even reduced the impurity contamination level of the main plasma.

These highly encouraging results provide further support for the snowflake divertor as a viable plasma-material interface for future tokamak devices and for fusion development applications.

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[Abstract: JI2.00002 Taming the Plasma Material Interface with the ``Snowflake'' Divertor in NSTX](#)

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Session **[JI2: Edge and Divertor Physics](#)**, Grand Ballroom CD, Tuesday, November 9, 2:30PM - 3:00 PM

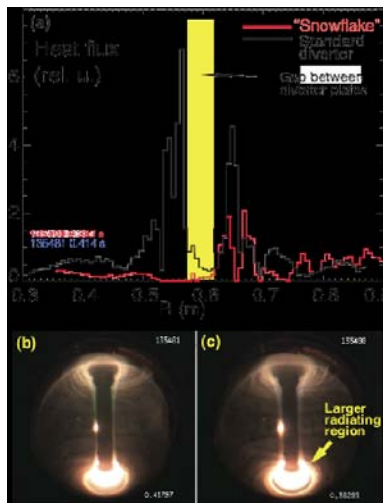


Figure 2. (a) Comparison of heat flux profiles in the “snowflake” and standard divertor configurations; (b) Plasma TV image of the standard divertor discharge; (c) Plasma TV image of the “snowflake” divertor discharge.