This snowflake will tame thermonuclear plasma

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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 the magnetic fusion research —"Taming the Plasma-material Interface." A new concept called the "snowflake" divertor has been shown to improve co-existence of the hot plasma and 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. Confined plasma particles move along infinite magnetic field lines inside the tokamak. Some particles and heat, however, tend to escape because of transport and magnetohydrodynamic plasma instabilities. The plasma-material interface includes a plasma layer surrounding the hot confined plasma. In this layer, called the scrape-off layer, the escaped particles and heat flow along an "open" magnetic field line to a separate part of the vacuum vessel called a "divertor chamber."

The divertor surface must be able to withstand steady-state heat loads up to 10 MW/m^2 (a limit imposed by the present day technology-material lifetime and cooling constraints). If the plasma incident on 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.

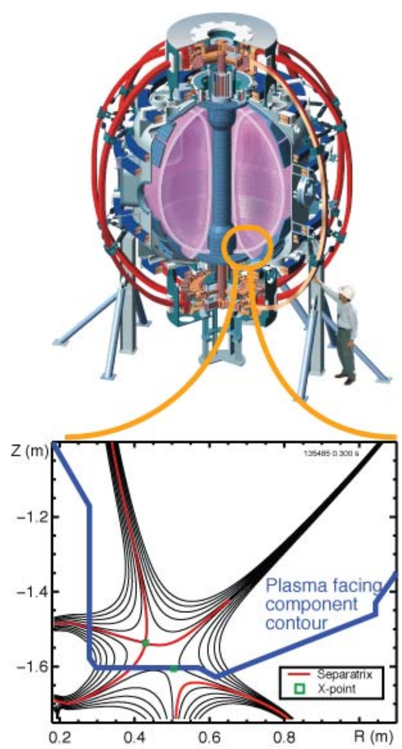

Figure 1. A "snowflake" divertor – a novel plasma-material interface is realized in the National Spherical Torus Experiment.

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 [1-3]. The name is derived from the appearance of magnetic field lines forming this novel magnetic interface, as shown in Figure 1.

This magnetic configuration was recently realized in NSTX and fully confirmed the theoretical predictions. The snowflakedivertor configuration was created by using two 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. In Figure 2b-c the plasma TV images demonstrate more radiative snowflake divertor 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.

The highly encouraging results from NSTX provide further support that the snowflake divertor configuration may be a viable plasma-material concept for future tokamak devices and for fusion development applications.

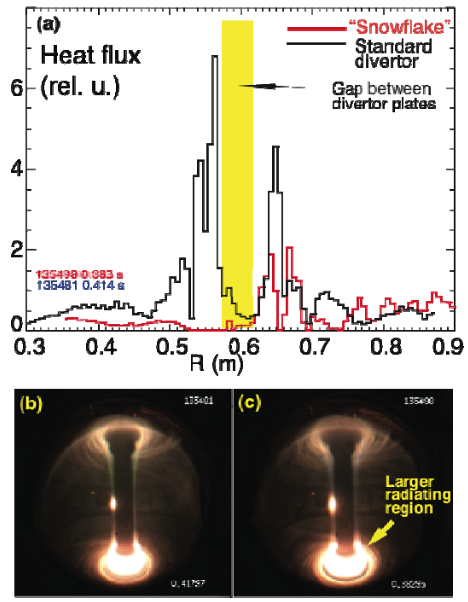

Figure 2. (a) Comparison of heat flux profiles in the “snowflake” and standard divertor configurations; (b) Plasma TV image of the standard divertor discharge; (c) Plasma TV image of the “snowflake” divertor discharge.

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