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A MAJOR STEP FOR FUSION ENERGY

One of the most attractive solutions for humankind's future energy needs is controlled thermonuclear fusion. Controlled fusion with magnetically confined plasmas in a doughnut-shaped tokamak is actively being pursued by countries worldwide to bring this energy source to fruition. In a commercial tokamak reactor, hundreds of megawatts of power are released in the form of charged particles that must be accommodated in the reactor chamber. The snowflake power divertor, developed in collaboration with Princeton Plasma Physics Laboratory (PPPL), the École Polytechnique Fédérale de Lausanne Center for Research in Plasma Physics (CRPP) in Switzerland, and Oak Ridge National Laboratory, reduces the hot plasma exhaust generated in doughnut-shaped tokamaks and other magnetic fusion energy sources.

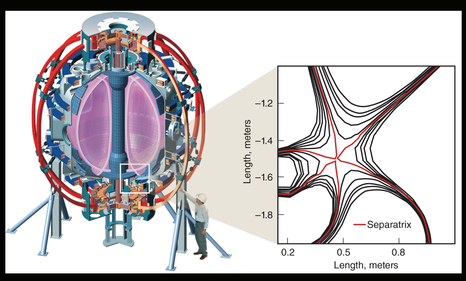
A Simple Solution

The snowflake power divertor uses a newly discovered configuration of the divertor magnetic field—a configuration that spreads out the magnetic field in a shape reminiscent of a snowflake. The magnetic field lines spread the exhaust over a larger area, effectively reducing the heat flux by a factor of 10 to a manageable 10 megawatts per square meter.

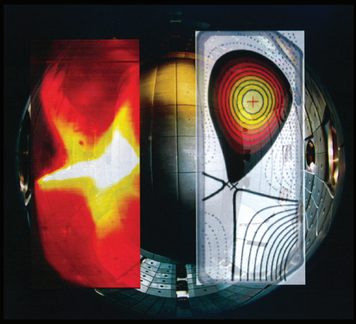
In the new configuration, a large zone of a very weak poloidal magnetic field is created in the divertor. This zone induces a large flaring of the plasma flow and dramatically decreases the heat fluxes in the divertor. The redistribution is technologically simple but remained unnoticed prior to this discovery. The tokamaks at PPPL and CRPP have quite different plasma shapes, but in both of them, the confinement of the hot core plasma remained good when the snowflake configuration was achieved.

Wide Acceptance

The beauty of the snowflake power divertor is that it does not require any expensive or complex changes to the overall configuration of a tokamak. Nor does it call for significant changes in the already well-developed scenarios for operation of a commercial tokamak. Several new experimental tokamak facilities plan to install the snowflake power divertor. One facility is an upgraded version of the existing experimental facility at PPPL, whose higher magnetic current and power will serve as a testing ground for fusion reactors still in the planning phase. Other tokamaks that will incorporate the snowflake power divertor are being designed in Italy and China.



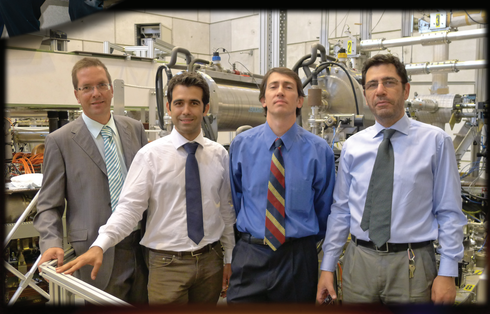
A "snowflake" power divertor is installed at the bottom of the tokamak at the National Spherical Torus Experiment at Princeton Plasma Physics Laboratory (PPPL). (inset) A snowflake magnetic configuration shows the characteristic hexagonal shape of the separatrix, which is the singular magnetic field line that determines the overall field geometry.



A vertical cross section of the divertor region of the experimental tokamak at the École Polytechnique Fédérale de Lausanne Center for Research in Plasma Physics (CRPP) in Switzerland shows (left) the snowflake-shaped spreading of the exhaust plasma and (right) its magnetic field lines on the background of the confining vessel.

Livermore development team for the snowflake power divertor: (from left) Thomas Rognlien, Maxim Umansky, Dmitri Ryutov, and Ronald Cohen; (inset) Vsevolod Soukhanovskii.

(from left) Jean-Marc Moret, Francesco Piras, Stefano Coda, and Basil P. Duval (CRPP).



(from left) Egemen Kolemen (PPPL), Jonathan Menard (PPPL), and Joon-Wook Ahn (Oak Ridge National Laboratory).

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