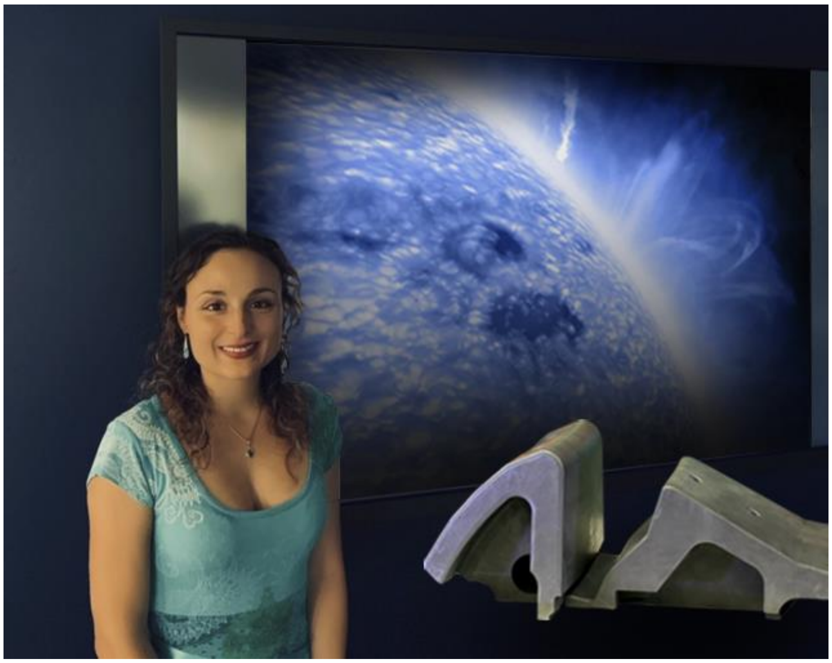
September 2020

Keeping it Cool While Maintaining Core Performance

Researchers address challenge of integrating the hot core and the cooler edge of a fusion plasma.

[Image]



[Image credit]
Image courtesy of General Atomics

[Image caption]
Livia Casali stands with the Small Angle Slot (SAS) divertor model. L. Casali and her team combined the SAS configuration with impurity injection to improve integration between the hot core of a plasma and the cooler edge.

The Science

One of the great challenges in fusion tokamaks is how to keep the core of a plasma hot enough that fusion can occur while maintaining a temperature at the edge of the plasma low enough that it doesn't melt the walls. This requires dissipating the heat and particle flow as it moves toward the walls without reducing the performance of the core. Physicists refer to this challenge as core-edge integration.

Researchers at the DIII-D National Fusion Facility recently developed a pathway to improving core-edge integration. They did this by combining injection of impurities at the edge of the plasma with an optimized geometry for the divertor, a device that removes excess heat and particles from the edge. Once injected, these impurities convert the heat flux into electromagnetic radiation, which allows it to be dissipated before contacting the walls.

The Impact

The work represents an important step toward practical fusion energy through improved understanding of various mechanisms that govern the interaction of the core and edge of the plasma. As tokamaks become more powerful and efficient, core-edge integration will become an even more important area of research. This study offers a promising solution to reduce divertor power loads without degrading the core performance. The results are significant for ITER and for the design and operation of future reactors.

Summary

Researchers developed a new way to address the core-edge integration challenge by combining a new divertor geometry recently installed at DIII-D with impurity radiation. For the first time, impurities were used in DIII-D's new small angle slot (SAS) divertor to reduce divertor heat flux. A closed divertor like SAS allows maximum cooling across the divertor area, which is subject to heat levels that can exceed those found in rocket nozzles.

This study was enabled by unprecedented diagnostic coverage in a closed divertor. This improved approach allowed the team to perform the first simultaneous observation of plasma cooling on the entire suite of diagnostics without degradation of core performance. The experiments showed that plasma cooling and impurity leakage have a strong relationship with divertor geometry and the type of impurity injected in the edge. Insights were enabled by state-of-art edge simulation tools that, for the first time at DIII-D, included impurities and full treatment of certain plasma flows known as drifts. The researchers analyzed different impurity species and found that Neon showed improved radiative performance as long as the content of the impurity is well controlled. Neon is the impurity being considered for use in ITER.

The research indicates that the feasibility of fusion reactors can be improved with a combination of the appropriate radiative impurity species, an optimized divertor geometry, and tailored drifts for controlling particles.

Contact

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Funding

This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Fusion Energy Sciences, using the DIII-D National Fusion Facility, a DOE Office of Science user facility, under Awards DE-FC02-04ER54698.

Publications

L. Casali et al. "Improved core edge compatibility using impurity seeding in the small angel slot (SAS) divertor at DIII-D" Physics of Plasmas **27**, 062506 (2020) Featured Article [DOI: https://doi.org/10.1063/1.5144693. OSTI: https://www.osti.gov/biblio/1632683-improved-core-edge-compatibility-using-impurity-seeding-small-angle-slot-sas-divertor-diii]

L. Casali et al. "Neutral leakage, power dissipation and pedestal fueling in open vs closed divertors", Nucl. Fusion **60** 076011 (2020) [DOI: https://iopscience.iop.org/article/10.1088/1741-4326/ab8d06. OSTI: https://www.osti.gov/biblio/1632399-neutral-leakage-power-dissipation-pedestal-fueling-open-vs-closed-divertors]

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