June 2018

Seeing all the Colors of the Plasma Wind

Two-dimensional velocity imaging is being used by fusion researchers to understand the role of ion winds in the boundary of tokamak plasmas.

The Science

When it comes to plasma winds in a tokamak, researchers are always looking for the Goldilocks solution – one that is just right. Winds that are too high or too low can reduce plasma efficiency, so researchers at the DIII-D National Fusion Center are using a new type of imaging to help get the plasma wind moving at just the right speed.

Plasma winds are more commonly referred to as flows. Flows with speeds over 40km/s can transport heat and particles long distances in the boundary plasma of a fusion tokamak. When these flows are travelling too fast, or if they become stagnant, they can hurt plasma performance by allowing the buildup of impurities. Coherence Imaging, a new diagnostic employed on the DIII-D tokamak, is being used to benchmark sophisticated fluid modeling of the divertor that can be used in this design effort. The diagnostic measures red- and blue-shifted emission from ions radiating in the visible spectrum by combining an interferometer with a fast camera. The resulting images are then used to calculate the velocity throughout the camera's field of view. A better understanding of these ion velocities will help to design effective exhaust solutions that improve fusion plasma performance and raise efficiency.

Figure 1: Coherence Imaging measurement of the line-integrated velocity of carbon ion winds in the boundary of a high performance DIII-D plasma. Velocity data is mostly near the center of the machine where the ion light is brightest. Red denotes positive velocity (into the page) whereas blue is negative velocity. Image courtesy of LLNL.

The Impact

Characterizing both impurity and main-ion flows is crucial for understanding particle and heat transport in the plasma boundary. The evolution from line-of-sight spectroscopy to fully 2D ion velocity imaging is a substantial improvement that enables the detailed model/experiment comparison required to further develop our modeling capability. In addition to greater spatial detail, the new dataset includes high-temperature and high-performance plasmas and can be used to investigate 3D flow phenomena.

Summary

2D helium ion velocities in the scrape-off-layer and divertor regions of the DIII-D tokamak have been compared to state-of-the-art fluid modeling simulations using the UEDGE modeling code. The velocity of singly charged helium travelling along magnetic field lines were predicted well by the model in the region close to the divertor plate where He^{+} is the dominant ion and electron-physics dominates the momentum balance. Further upstream, where doubly-charged helium (He^{2+}) is the main ion species and ion physics

becomes more important, fluid modeling underestimates the velocity by a factor of two to three. These results indicate that better understanding is required to be able to predict the ion population's behavior in these challenging conditions and that there is still much to be learned about the role of ions in the tokamak divertor.

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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, DE-AC52-07NA27344 and DE-AC05-00OR22725. DIII-D data shown in this paper can be obtained in digital format by following the links at https://fusion.gat.com/global/D3D_DMP.

Publications

C.M. Samuell, G.D. Porter, W.H. Meyer, T.D. Rognlien, S.L. Allen, A. Briesemeister, A.G. Mclean, L. Zeng, A.e. Jaervinen, and J. Howard . "2D Imaging of Helium Ion Velocity in the DIII-D Divertor" *Physics of Plasmas* (submitted).

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