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Seeing All the Colors of the Plasma Wind

Plasma scientists reveal new camera footage used to measure the velocity of ion winds in the boundary of fusion plasmas.

MILWAUKEE, Wis.—There is a striking resemblance between the boundary of a fusion plasma and the Earth's atmosphere, each has its own kind of weather. In addition to chaotic storms and the occasional lightning bolt, the boundary of a fusion plasma features strong winds that constantly encircle the confined plasma. These winds can move very quickly; routinely, they reach speeds of 40 km/s (90,000 mph). When these winds are in the wrong direction, travel too fast, or become stagnant, they can hurt plasma performance by allowing the build-up of impurities. A better understanding of these effects will help us to design effective exhaust solutions that improve performance and raise efficiency. Recently, new instruments have been installed on the DIII-D tokamak in San Diego, CA to directly measure plasma winds.

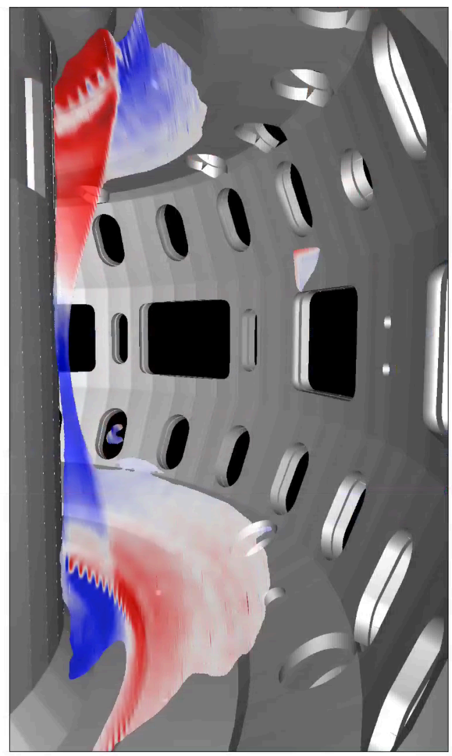

Figure 1: Coherence Imaging measurement of the line-integrated velocity of carbon ion winds in the boundary of a high performance DIII-D plasma. Velocity data is mostly near the center of the machine where the ion light is brightest. Red denotes positive velocity (into the page) whereas blue is negative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

The new diagnostic instrument measures the particular colors of the light emitted by the plasma to measure the velocity of the particles; ions moving towards you will appear a little more blue than normal, and ions moving away from you will appear a little more red. Using a novel diagnostic technique called "Coherence Imaging," a camera can be used to "photograph" these redshifts and blueshifts so that the color of these winds can be used to calculate the velocity (Figure 1).

Historically, measuring the plasma wind has been very difficult due to the extreme temperatures of fusion plasmas. Dr. Cameron Samuell from Lawrence Livermore National Laboratory (LLNL) has been using Coherence Imaging to get around this problem.

“We are building a little sun inside a box,” Samuell said. “Since our version can’t be as big as a real star, we need to make ours much hotter to achieve fusion. Our plasma is 10 times hotter than the center of the sun so you can’t just wet your finger and put it in there to work out which way the wind’s blowing. Luckily, the plasma itself is very bright and we can use that light to learn about the physics that is driving those winds without having to put anything into the plasma, itself.”

The key difference between Earth and Tokamak weather is that plasma is made up of charged particles and so they can be controlled by magnetic fields. This is one of the key ideas in the field of Magnetically Confined Fusion (MCF), where complicated magnetic fields are used to help control the flow of particles and heat. This allows fusion scientists to direct the hottest parts of the plasma boundary towards specially engineered components that can withstand the plasma’s high heat loads. Samuell was quick to explain that it’s not all bad news, “While it’s true that these winds can sometimes be damaging, in truth, we do not need or want to be able to stop them. It would be worse for us if they weren’t there. By carefully designing our reactor, we can ensure our plasma winds are of the friendly good-natured persuasion; they will blow impurities away and help keep the plasma clean.”

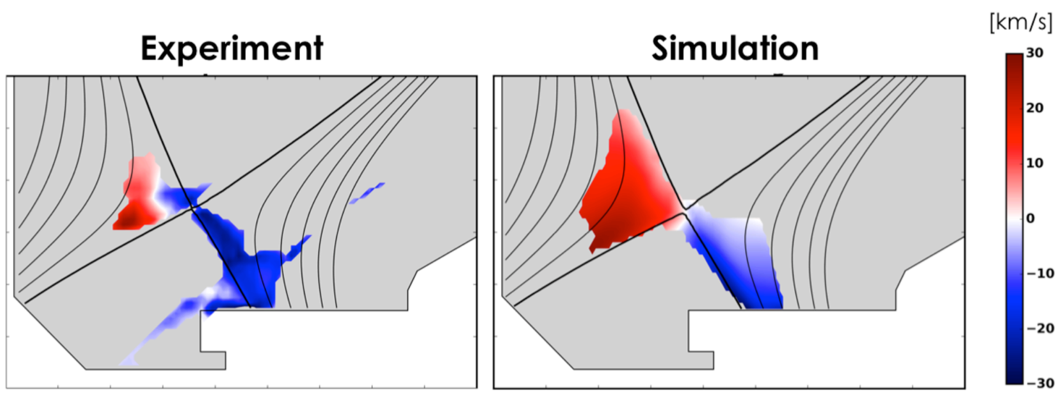

Figure 1: Measured and simulated helium ion velocity near the lower divertor of a DIII-D plasma. The experiment and the numerical simulation display similar velocity magnitude and direction. Images courtesy of LLNL.

Results from the Coherence Imaging diagnostic will be presented at the 59th annual conference of the American Physical Society Division of Plasma Physics in Milwaukee. By comparing experimental results to sophisticated simulations (Figure 2), Samuell is assessing how well we are able to predict the speed and direction of the plasma wind.

“Our results indicate that there is actually surprisingly good agreement between the models and the experiment which shows that under some conditions we have a really good feel for what’s going on,” Samuell said. “There are cases, though, where there are many competing forces to be accounted for, and then the agreement is harder to get. Predicting plasma weather is hard!”

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Abstract	
YI2.00002	Imaging Main-Ion and Impurity Velocities for Understanding Impurity Transport in the Tokamak Boundary
Session	YI2: SOL and Divertor 9:30 AM–12:30 PM, Friday, October 27, 2017 Room: 102ABC