Fusion diagnostic sheds light on plasma behavior at EAST

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An instrument developed by researchers at the U.S. Department of Energy's Princeton Plasma Physics Laboratory (PPPL) has enabled a team at the EAST fusion experiment in China to observe--in startling detail--how a particular type of electromagnetic wave known as a radiofrequency (RF) wave affects the behavior of hot ionized gas.

In the experiment at EAST (the Experimental Advanced Superconducting Tokamak located at the Institute of Plasma Physics in Hefei, China), scientists employed a high-resolution, X-ray imaging crystal spectrometer (XICS) to observe how an RF wave changed the way a hot ionized gas known as a plasma moved in a vacuum vessel. Radiofrequency waves are similar to microwaves and are used to heat and drive current in plasma.

The experimenters already knew that the RF wave, also called a lower-hybrid wave, drives current in the plasma. What they found was that the lower-hybrid wave also caused the plasma to flow as a whole and at high velocities through the vacuum vessel, a property they refer to as toroidal rotation. The spectrometer provided a two-dimensional look at the plasma, recording data at a rate of about 50 frames a second. That's important because not all parts of the plasma move uniformly. For example, if the inner part of the plasma near the vessel's core is moving at a different rate – or even in a different direction -- than the rest of the gas, researchers want to know those details. Understanding the plasma flows is vital because it could lead to better approaches to confinement.

The results were published in the June 6 edition of *Physical Review Letters* by researchers from the EAST team and PPPL's Manfred Bitter and Kenneth Hill. Bitter and Hill are experimentalists who have collaborated for more than 35 years.

"With plasmas, you are dealing with very high temperatures and flow velocities," Bitter said. "Those must be determined from the radiation emitted by the plasma." The spectrometer designed by Bitter and Hill measures both the plasma temperatures and flow velocities, and it appears to offer a window onto the world of fusion plasmas.

The observed plasma flow could be beneficial to progress in fusion research, according to the PPPL scientists. "ITER and future reactors cannot rely on the injection of neutral beams to impart momentum to the plasma and control the toroidal flow," Bitter said, noting that this is due to the scale of the experimental reactor presently under construction in France. ITER must rely on self-generated or RF-driven flow, meaning that this research is highly relevant to those projects.

The new spectrometer allows researchers to study self-generated and RF-driven flow with the goal to control it in future reactors so that plasmas can be more carefully contained.

The DOE supports the spectrometer collaboration between the U.S. and the People's Republic of China (PRC) through the U.S.-PRC Fusion Cooperation Program. The spectrometer project includes researchers from EAST, PPPL, and the National Fusion Research Institute (NFRI) in Korea. Bitter and Hill helped design the instrument, which was installed on EAST.

X-ray crystal spectrometers measure the frequencies and intensities of X-rays emitted by plasma impurities. Researchers can identify the impurity by the pattern of frequencies, or spectrum, of the X-ray light emitted to help them determine the plasma ion temperature, as well as the rotational velocity of the bulk plasma, from the Doppler broadening and Doppler shift of an X-ray peak. "This Doppler shift or change in frequency is exactly the same phenomenon as the change in the pitch of a train horn as the train passes by an observer," Hill said.

The spectrometer designed by Bitter and Hill is made up of several components. It includes a "spherically bent crystal," a tiny piece of quartz that has been molded into a sphere. It also contains a two-dimensionally imaging X-ray detector and a beryllium window. EAST scientists have installed a second spectrometer on the tokamak based on the first spectrometer's design. Similar spectrometers designed by Bitter and Hill have been installed on experimental fusion machines in Korea and Japan, and at the Plasma and Fusion Science Center at the Massachusetts Institute of Technology, as well.

Provided by DOE/Princeton Plasma Physics Laboratory

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