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Using Airport Screening Technology to Visualize Waves in Fusion Plasma

Millimeter-wave imaging helps scientists better understand and manage plasma instabilities.

DENVER—Millimeter-wave imaging technology is widely used in airborne radar, automotive sensors and full-body scanners for passenger screening at airports. A new, quasi-optical radar technique images millimeter-wave radiation reflected from fusion plasmas in 2D, time-resolved images. This novel application lets researchers image waves in fusion plasmas in startling detail, and provides vital information to devise strategies to avoid instabilities which can reduce fusion power output. This enhanced imaging diagnostic of the tokamak interior was developed by a collaboration of fusion scientists from the University of California at Davis and the U.S. Department of Energy's Princeton Plasma Physics Laboratory.

Fusion experiments burn far hotter than the surface of our sun, too hot even to emit visible light. This renders typical photographic techniques all but useless. However, just as millimeter-waves penetrate the light clothing of passengers screened at airports and reflect from denser, concealed objects, millimeter-wave imaging reflectometry (MIR) illuminates the plasma with radio waves that penetrate the thin outer layers and reflect off small density fluctuations within the plasma interior.

In plasma, waves can eject particles that ride the waves like surfers to the shore. Or the particles can grow uncontrollably until the entire discharge is lost. On the DIII-D tokamak at General Atomics in San Diego, MIR is paired with an Electron Cyclotron Emission Imaging (ECE-I) camera that radiometrically detects small variations in electron temperature.

In this way, both the density and temperature fluctuations caused by waves can be imaged in the same place and at the same time. Furthermore, because these diagnostics do not rely on an energetic particle beam, they can take 2D pictures continuously during the discharge without perturbing the plasma conditions. The results are images that help scientists understand how and why the waves grow and how to maintain plasma stability.

"The 2D and 3D structure of plasma fluctuations are important components of the magnetohydrodynamic (MHD) theory that allows us to predict the behavior of a future burning plasma fusion power plant," said physicist Benjamin Tobias who participated in the research. "With this new visualization capability, we can perform the kinds of ambitious experiments that will accelerate our progress toward a viable new energy resource."

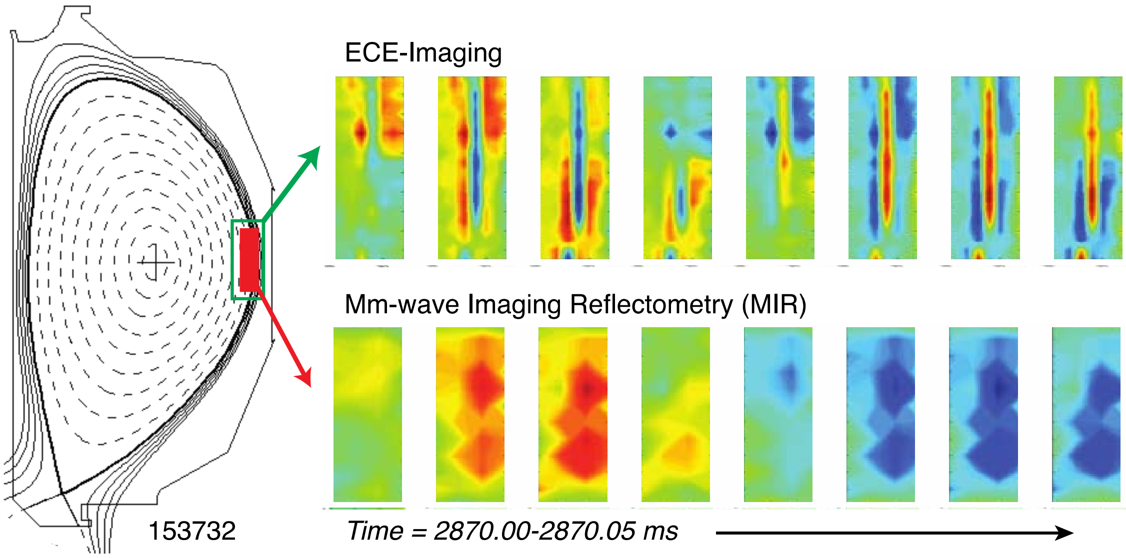

Figure 1: ECE-Imaging and the new diagnostic, MIR, sample overlapping regions of the tokamak plasma and produce 2D images of turbulence and fluctuations. ECE-Imaging measures the radiation temperature of electrons orbiting around magnetic field lines, while MIR detects changes in the electron density. In the series of frames shown, an instability associated with the formation of internal magnetic islands can be seen rotating through the diagnostic field of view.

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Abstracts:

BP8.00049	**Synthetic analysis results for Microwave Imaging Reflectometry on the DIII-D tokamak (X. Ren)**
Session	**BP8: Turbulence, Tokamak, Z-Pinch, and DIII-D** 9:30 AM-12:30 PM, Monday, November 13, 2013 Room: Plaza ABC
JP8.00079	**Implementation of a Microwave Imaging Reflectometer on DIII-D (D.M. Kriete)**
Session	**JP8: Education and Outreach, MHD, Alpha Heating & Computational Methods**

	2:00 PM-5:00 PM, Tuesday, November 14, 2013 Room: Plaza ABC
UP8.00002	**Hardware overview of the Microwave Imaging Reflectometer on DIII-D (X. Hu)**
UP8.00030	**Diagnosis of 3D perturbed equilibrium states of DIII-D (B. Tobias)**
UP8.00044	**Commissioning of the Microwave Imaging Reflectometer on DIII-D (C.M. Muscatello)**
Session:	**Session UP8: Tokamak and Related Diagnostics, Complex Dynamics, Sheaths, Strongly Coupled and Dusty, Low Temperature Fusion Technology, DIII-D** 2:00 PM-5:00 PM, Thursday, November 16, 2013 Room: Plaza ABC