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Taking New Angle to Enable More Efficient, Compact Fusion Power Plants

New microwave injection system at the DIII-D National Fusion Facility doubles current-drive efficiency and demonstrates for the first time efficient off-axis current drive in a tokamak.

Fort Lauderdale, Fla.—Researchers at the DIII-D National Fusion Facility in San Diego have demonstrated a new approach for injecting microwaves into a fusion plasma that doubles the efficiency of a critical technique that could have major implications for future fusion reactors. The results show that launching the microwaves into the plasma via a novel geometry delivers substantial improvements in the plasma current drive.

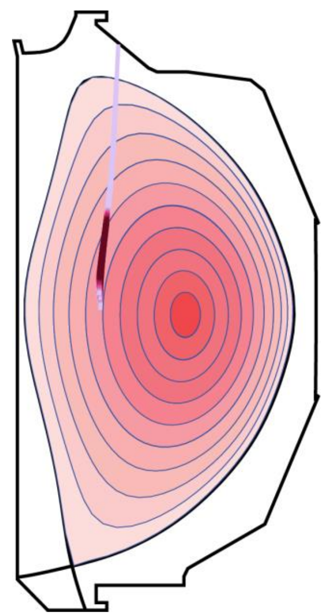

Figure 1:The red line shows the driven current density along the microwave trajectory in a DIII-D plasma, with the darker red showing where the larger current is driven into the plasma. This figure was modeled with the TORAY-GA ray-tracing code. Credit: Xi Chen, DIII-D National Fusion Facility.

Dr. Xi Chen will present the team's findings at this week's APS Division of Plasma Physics annual meeting.

Building economical fusion reactors in the future will require driving electric current efficiently in specific regions of the plasma—a technique known as off-axis current drive. Electric current enhances the stability of the magnetically contained plasma in doughnut-shaped fusion reactors known as tokamaks. The current allows the plasma to remain cohesive as it is heated to more than 150 million degrees, where atoms of hydrogen start to fuse and release large amounts of energy. One of the techniques to drive current, known as Electron-Cyclotron Current Drive (ECCD), uses extremely powerful microwaves to heat electrons in the plasma. The more efficiently the microwaves interact with the energetic electrons, the greater the current drive in the plasma.

The ECCD microwaves were traditionally injected from the outer curve of the tokamak toward the heart of the plasma. Recent computer modeling at DIII-D, however, predicted efficiency could be substantially improved by moving the injection point toward the top of the tokamak and carefully directing it to precise points away from the center (Figure 1). Based on that modeling, Dr. Chen led a team that designed and installed a new system that allows the microwaves to be injected from the top. This new top-launch configuration aligns the microwave trajectory with the magnetic field and energy distribution of the plasma, so that the microwaves selectively interact with only the most energetic electrons, doubling drive current efficiency.

The experimental results were startling in how closely they aligned to the gains predicted by the computer models (Figure 2).

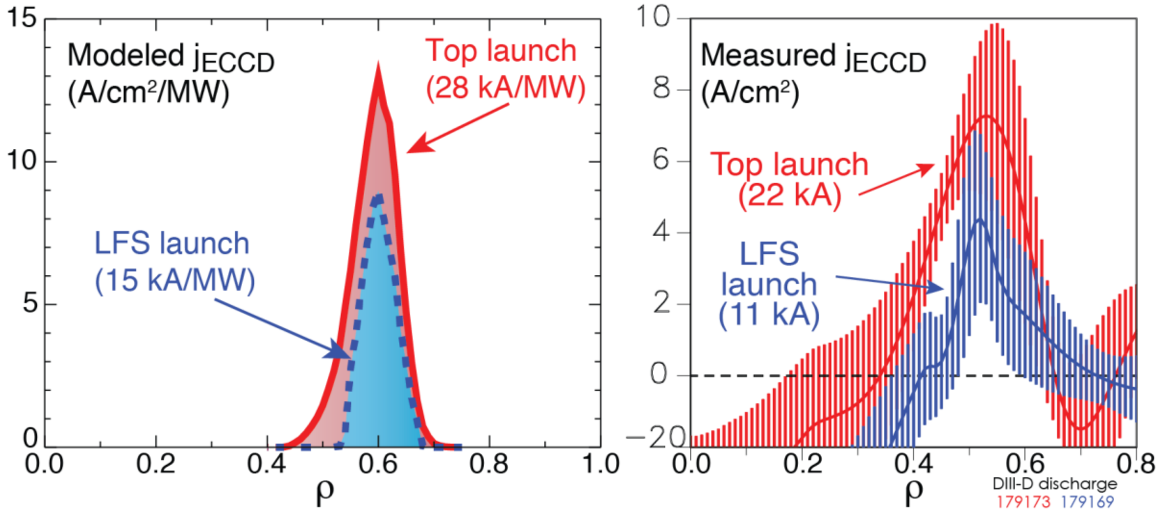

Figure 2:The prediction of doubling the off-axis current-drive efficiency due to more selective wave energy damping via a top-launch ECCD system has been validated by recent experiments at DIII-D. Left is prediction using the CQL3D quasi-linear Fokker-Planck code and right are measurements. Credit: Xi Chen, DIII-D National Fusion Facility

"I had high expectations that we were going to see improvements based on the modelling, but were surprised at how clearly and quickly we doubled the efficiency in the real measurements," said Dr. Chen. "We are very excited to see these results and we think this could prove to be very significant." These results provide experimental validation of the top-launch ECCD approach and could be a major consideration in planning for future tokamaks.

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Abstract

YI3.00006	Higher Off-Axis Electron Cyclotron Current Drive Via `Top Launch' Approach
Session	Session YI3: Invited MF: Scrape-Off Layer, Divertor, Wall, Post-Deadline 9:30 AM – 12:30 PM, Friday, October 25, 2019 Room: Floridian Ballroom CD