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Scientists Pioneer New "Helicon" Method of Driving Electrical Currents in Tokamak Plasmas for Fusion Energy Production

Helicon current could represent path to fusion power plants.

LONG BEACH, Calif. — Fusion tokamaks use very large electrical currents to confine super-hot plasmas and create fusion reactions. These currents are millions of amperes and create strong magnetic forces to confine the plasma particles. This in turn allows the plasma temperature to be raised to about five times the temperature at the center of the sun, which is needed for fusion reactions on earth.

Injecting high-power microwaves into the plasma can sustain the electric current in a steady state. Plasma current driven by injected microwaves is an essential part of what is known as the "advanced tokamak" design for a fusion reactor. Various microwave systems have been used to drive current in previous fusion devices, but no single approach is the obvious choice to provide efficient current drive in the larger and hotter devices that more closely approximate the conditions predicted for a future fusion power plant.

Helicon current drive is a microwave injection approach that was originally proposed in the 1980s as a solution for sustaining plasma current in fusion power plants. Compared to other types of microwaves, the "helicon wave" exhibits highly desirable propagation in the hot, dense plasmas needed for fusion power plants. Early experiments hoping to demonstrate helicon current drive were not successful, however, as the plasma conditions were insufficiently similar to those of a fusion power plant and the technology available at the time could neither efficiently launch microwaves with the necessary properties nor sensitively detect the effects of the launched waves inside the plasma.

An international team of scientists and engineers from universities, industry, and U.S. national laboratories revisited helicon current drive at the DIII-D National Fusion Facility tokamak in San Diego. Advances in wave launching technology, sophisticated measurement techniques, and plasma heating systems — including the capability to preheat a region in the plasma center to make it sufficiently reactor-like — made it likely that this approach would now produce a measurable impact on the plasma.

After development of a complete helicon current drive system with a new type of helicon wave-launching structure called a comb-line traveling wave antenna that could launch microwaves with the characteristics needed for strong absorption by plasmas in the DIII-D tokamak (Figure 1), experiments achieved the first successful detection of helicon current drive in a tokamak plasma. The measured helicon-driven plasma current was

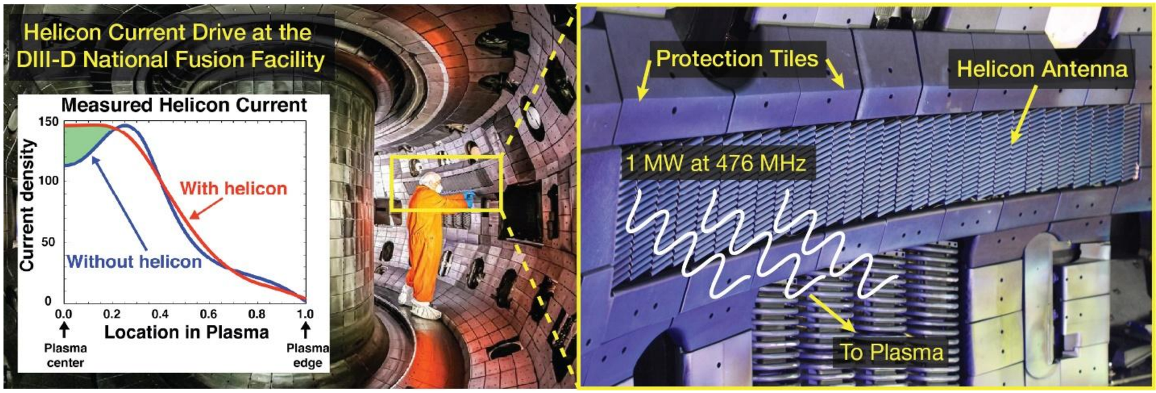

Figure 1: The helicon antenna system is shown within the DIII-D tokamak. The graph inset on the left shows the measured current in the plasma, with the region shaded in green around the center of the plasma representing the current driven by the helicon waves. The total amount of helicon-driven plasma current is approximately 20 kA, all in the region close to the hottest part of the plasma in its center.

observed in the hottest part of the plasma near the center, consistent with theoretical modeling. This success supports the application of helicon current drive in future tokamak-based fusion reactors.

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Abstract

NI03.5	First Experimental Observation of Helicon Current Drive in the DIII-D Tokamak
Session	NI03: Invited Session MFE: Energetic Particles, Current Drive, and Burning Plasmas
	9:30 AM–12:30 PM, Wednesday, November 19, 2025
	Room: Grand Ballroom II