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Exciting Results on Exciting Waves in Plasmas

Innovative antenna efficiently transforms radio wave energy into waves traveling around the magnetic field in fusion plasma.

Like books leaning on each other on a partially filled shelf, the distinctively tilted 12 modules of the comb-line traveling wave antenna are mounted on the plasma-facing surface of the DIII-D vacuum vessel, surrounded by a picture frame of protective graphite tiles. The larger modules partly obscured by the researcher's head are another kind of wave-launching antenna.

The Science

One of the challenges in creating a fusion reactor on earth is to find ways of sustaining an electrical current inside the super-hot gases (the plasma) in which the fusion reactions take place. One means of performing this 'current drive' involves converting high-power radio waves into waves traveling through the plasma which then transfer their energy to the plasma's charged particles (usually the electrons) in such a way as to sustain an electric current. This process of radio frequency (RF) current drive can be performed with several different kinds of plasma waves acting as the intermediary between the radio waves and the electrons in the plasma. One such plasma wave which has so far not been tested extensively for this purpose is called the 'helicon'. For RF current drive in a future fusion reactor, the helicon is projected to have several advantages over the waves that have been used for this purpose so far. Scientists and engineers at the DIII-D magnetic fusion research facility in San Diego have constructed and tested an innovative kind of antenna, termed a 'comb-line traveling wave antenna' to excite the helicon wave in a tokamak. The results from the test comb-line antenna show that a follow-up antenna will be able to transform more than 75% of 1 million watts of radio frequency power into helicon waves traveling in the plasma in the tokamak.

The Impact

Evaluation of radio frequency current drive using helicon waves has been impeded for decades by the lack of an efficient means to excite these waves in the plasma; the demonstration of an efficient wave launcher could enable future experiments to establish this technology, which is very well suited to the task of driving electric current in the core of a fusion reactor.

Summary

A comb-line traveling wave antenna consisting of 12 modules was constructed and tested in the DIII-D tokamak at very low power levels of up to 300 W at 476 MHz to measure the coupling efficiency in high-performance DIII-D plasmas. The antenna was intended to excite the helicon, also known as the 'whistler' or 'fast wave in the lower hybrid frequency range', and not the other possible wave mode (the 'lower hybrid wave' or 'slow wave'). Results showed that more than 75% of the applied rf power can be transformed into helicon waves propagating in the plasma and carrying the energy away from the antenna. When the tilt of the modules is approximately aligned with the tilt of the magnetic field lines adjacent to the antenna surface, the fraction of the applied power that goes into (undesired) slow waves appears to be small, though there is no means presently available to directly measure the polarization of the excited waves in the hot plasma and thereby verify this. The projection to 75% coupling efficiency depends on the achievement of reasonable improvements in the module design between the low-power prototype and the final high-power version to reduce the resistive losses in the modules, and on the high-power version of the antenna having about 30 modules compared to the 12 modules in the low-power prototype.

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Funding

[Explanation of funding ***including citation of all significant sources, including non-DOE sources if applicable***; formatting is flexible: can be a bulleted list, a sentence, or a short paragraph.]

Publications

R. Prater, C.P. Moeller, R.I. Pinsker, M. Porkolab, O. Meneghini and V.L. Vdovin, "Application of very high harmonic fast waves for off-axis current drive in the DIII-D and FNSF-AT tokamaks." *Nuclear Fusion* **54**, 083024 (2014).

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