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Novel Radio Frequency Current Drive Systems for Fusion Plasma Sustainment on DIII-D

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The DIII-D National Fusion Facility is advancing the science and technology of steady-state fusion plasma sustainment through the implementation of two first-of-a-kind radio frequency current drive systems: the "helicon" or fast wave in the lower hybrid range of frequencies (LHRF), and high field side (HFS) launch of the lower hybrid slow wave.

Using existing DIII-D discharges, we have identified high performance scenarios that are predicted to have excellent wave penetration, strong single pass absorption and high current drive efficiency. Simulations predict this will raise ideal β_N limits in DIII-D and permit access to higher density advanced tokamak regimes. The higher B-field on the HFS improves wave accessibility and allows for use of lower n||, resulting in higher current drive efficiency for LHRF slow waves and damping at r/a~0.6-0.8 on the first pass. The 476 MHz helicon has better accessibility at lower B-field and higher density than the 4.6 GHz slow wave due to the lower frequency that can be used for the fast wave.

Calculations show that HFS launch of slow waves in the LHRF can lead to a physics current drive efficiency of 0.17x1020 A·W-1m-2 at r/a~0.6-0.8 in DIII-D and 0.4x1020 in a high B-field reactor. HFS LHRF represents an integrated solution that both improves core wave physics and mitigates PMI/coupling issues. An innovative, compact HFS LHRF antenna design has been developed combining a slotted waveguide poloidal splitter (used on C-Mod) and multi-junction toroidal splitter (used on Tore Supra, EAST). Models show good coupling properties for predicted edge density profiles.

Current drive by helicons is predicted to be significantly more efficient than either off-axis neutral beam current drive or conventional ECCD in high-density, high electron-beta regimes. A 12-module helicon antenna was developed and tested in DIII-D and demonstrated sufficient coupling at <0.4 kW. A ~1 MW proof-of-principle experiment using helicon waves at 476 MHz launched with a novel 'comb-line' traveling wave antenna with 30 elements will be performed on DIII-D starting in 2019.

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