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THE MANY APPLICATIONS OF ECH ON THE DIII-D TOKAMAK

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THE DIII-D PHYSICS AND OPERATIONS TEAMS

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Electron Cyclotron (EC) waves have been used in a very wide range of applications in discharges in DIII-D. Over the past decade, EC waves have become less an object of study and more a supplier of heat and current drive for other purposes in the experiments on DIII-D.

The characteristics [1] of EC wave heating (ECH) are quite different from those of neutral beam injection (NBI), the other main heating method for DIII-D. Unlike NBI, ECH power can be highly localized in space, giving a large power density. For most purposes, the heat conductivity along a flux surface is sufficiently large that the ECH and electron cyclotron current drive (ECCD) can be considered to be a function only of the normalized minor radius ρ. ECH power is deposited only in the electron fluid, unlike NBI which splits the power with most of the power going to ions, and also unlike NBI it does not provide either torque or a particle source. In these regards, ECH is an excellent proxy for plasma heating by fusion products. EC waves launched with a toroidal velocity component can provide a toroidal current [1], and for carefully chosen launch geometry the current density can be quite high since the radial extent of the current drive can be as small as $\Delta\rho=0.02$. This narrow width can make the peak ECCD current density relatively large.

These unique chacteristics of ECH and ECCD support the application of EC power in a wide range of experiments on DIII-D. The ECH system on DIII-D has six gyrotrons operating at 110 GHz and producing power absorbed in the plasma up to 3.5 MW on a daily basis. The six launchers [2] can be independently aimed in the vertical and toroidal directions, and the incident polarization can be set to launch either the X-mode or O-mode for any launch angle. The frequency corresponds to the second harmonic of the electron cyclotron frequency at a magnetic field of 2.14 T, which is in the range of the normal operating space of DIII-D.

The ECH system is an important part of the DIII-D program. In the 2010 campaign, for example, there were 2524 discharges, for which substantial EC power was injected in 895, or 35%. Applications of EC heating included torque-free electron heating for studies of intrinsic rotation and on the effect of core rotation on SOL flows; on the effect of pure electron heating on the H-mode threshold power; on T_e profile control for validation of the NBCD model; on RWM control in slowly rotating high beta plasmas; on suppression of some types of Alfven eigenmodes by ECH; on modeling ITER startup and rampdown; on 2^{nd} harmonic preionization and heating; on modifying the temperature gradient for studying the transition to turbulence dominated by the trapped electron mode; and on QH-mode with co-injection of neutral beams. ECCD was applied to drive currents in the plasma in ITER demonstration steady-state discharges; for distributed current drive in support of fully noninductive operation at high beta; for control of neoclassical tearing modes for experiments on resistive wall modes in low rotation, high beta discharges; for neoclassical tearing mode control using oblique electron cyclotron emission as a diagnostic to determine robustly the optimum location of the ECCD; for studies of the validation of resistive MHD models; and for development of model-based current profile control. Some key results from recent applications of EC waves will be presented.

We are proposing to increase the ECH power to 15 MW (12 MW incident on the plasma). The primary objective is to have sufficient electron heating power that high performance discharges can be obtained with $T_e > T_i$ without introducing levels of torque that are unreasonable for fusion reactors. This is important because fusion reactors will have this condition due to the dominance of electron heating by fusion products, while gyrokinetic modeling indicates that the temperature ratio T_e/T_i has a strong influence on the types and amplitudes of turbulence that will dominate transport. Our studies have shown that gyrotrons operating at 117.5 GHz rather than 110 GHz will interface better with high performance configurations in DIII-D at the maximum toroidal field in DIII-D of 2.1 T. The power will be raised by developing new gyrotrons to operate at 1.5 MW of power, which raises the system power for six gyrotrons to 9 MW, and by adding three new gyrotron systems, for a total of 15 MW. In addition to supporting operation in the reactor regime of $T_e > T_i$, this system will contribute to overall program objectives by accessing the advanced steady-state conditions and suppressing multiple tearing modes that interfere with operation.

References

1. *Prater, R.* Heating and current drive by electron cyclotron waves // Phys. Plasmas 2004. V. 11. P. 2349-2376.
2. *Ellis, R. A. Jr., Hosea, J., Wilson, J., Prater, R. and Callis, R.,* Design of a dual high-power, long pulse, steerable ECH launcher for DIII-D // 14th Topical Conf. Radio Frequency Power in Plasmas, AIP Conf. Proc. 2001. V. 595. P. 318-321.

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