Helicon Current Drive for the DIII-D Tokamak*

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Helicons (also called "whistlers" or "high harmonic fast waves") have the potential to drive current efficiently off-axis in tokamak discharges with high electron density and high electron temperature, which could transform prospects for steady-state fusion energy, and experimental tests are planned on DIII-D in 2016. High density is needed to reduce the radial propagation speed, which is Alfvén-like, and high electron temperature increases the damping strength. The combined effect of high density and temperture (high electron beta) is that the damping and current drive take place on a single pass in the mid-minor-radius region of the plasma. The high harmonic number also increases the damping strength, and importantly it creates the whistler-like behavior in which the rays tend to follow magnetic field lines. Ray tracing calculations indicate that for the parameters of a high performance discharge obtained in DIII-D the driven current is only weakly dependent on the value of the launched parallel index of refraction $n_{\|}$ over the range 3 to 4. The efficiency of the helicon current drive, $\zeta = e^3 I_{CD} R n_e / \varepsilon_0^2 P_{CD} k T_e$, is 2 to 4 times larger than the efficiency of the other current drive techniques, off-axis neutral beam injection and electron cyclotron current drive, available on DIII-D. Figure 1 shows that the helical current drive efficiency is approximately constant for factor of 2 changes in the electron temperature and/or density, although as the profiles are decreased the minor radius of the peak current drive gradually decreases. The wave can be launched using a periodic structure of inductively coupled radiating elements located outside the last closed flux surface on the low field side of the plasma. This structure, called a comb-line, launches a very narrow $n_{\|}$ spectrum with the electric field polarization that excites mainly the fast wave. The coupling efficiency of a prototype antenna will be tested in 2015. Helicon system tests at the 1 MW level are planned for the following year.

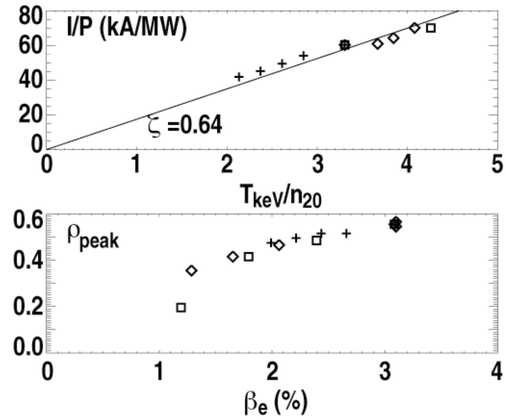

Fig. 1. (a) Helican current drive per unit power as a function of the ratio of electron temperature to density; (b) normalized minor radius where the driven current peaks as a function of electron beta. The symbols denote n_e and/or T_e scans.

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