

## Development of Helicon Current Drive in DIII-D\*

R. Prater<sup>1</sup>, C.P. Moeller<sup>1</sup>, R.I. Pinsker<sup>1</sup>, O. Meneghini<sup>1</sup>, D.C. Pace<sup>1</sup>, J.F. Tooker<sup>1</sup>,  
M. Hansink<sup>1</sup>, C.J. Murphy<sup>1</sup>, M. Porkolab<sup>2</sup>, C. Lau<sup>3</sup>, E.F. Jaeger<sup>4</sup>, and V.L. Vdovin<sup>5</sup>

<sup>1</sup>*General Atomics, P.O. Box 85608, San Diego, California 92186-5608, USA*

<sup>2</sup>*Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA*

<sup>3</sup>*Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, Tennessee 37830-8050, USA*

<sup>4</sup>*XCEL Engineering Inc., 1066 Commerce Park Dr., Oak Ridge, Tennessee 37830, USA*

<sup>5</sup>*Kurchatov Institute, ploschad' Akademika Kurchatova, 1 Moscow, Russia*

Current drive with high efficiency is required for operation of a tokamak with long duration pulses. For steady-state operation of a reactor, the current must be driven off-axis in order to enable plasma pressure sufficient to generate a large fraction of bootstrap current. A study using equilibria and profiles developed for a Fusion National Science Facility showed that off-axis electron cyclotron current drive was relatively expensive and lower hybrid current drive launched from the low-field side was unable to penetrate past the top of the pedestal. But fast waves at very high harmonics of the ion cyclotron frequency (“helicons” or “whistlers”) were shown to drive off-axis current at significantly higher efficiency [1].

For helicons, the high frequency (of order 50<sup>th</sup> harmonic) provides two important physics aspects: it slows down the radial trajectory of the wave and it increases the damping rate. Combined, these effects result in full absorption of the wave off axis in plasmas with high electron beta. The high electron beta requirement comes from needing high density to help reduce the radial propagation rate and high electron temperature to develop wave absorption. The absorption process is thermal, so no extended tail on the distribution function is developed or needed. The current drive is about the same in amplitude and location whether calculated by the ray tracing code GENRAY using the Ehst-Karney formulation, the Fokker-Planck code CQL3D including quasilinear effects, or the full wave code AORSA.

The physics of the helicon propagation, absorption, and current drive will be tested in the DIII-D tokamak. A primary challenge is launching the wave, because, like LHCD, there is a gap between the launcher and the plasma core where the wave is evanescent. The wave launcher must also impose the desired value of parallel index of refraction  $n_{\parallel}$ , and the electric field polarization at the launcher must excite primarily the fast wave. The comb-line antenna addresses these requirements by using a sequence of radiators, only the first of which is driven by the power source. This arrangement allows a large number of radiators to determine a narrow  $n_{\parallel}$  spectrum, and power not directly coupled to the plasma by each radiator is passed on to the next, thereby reducing the effect of the evanescence. The radiators are tilted perpendicular to the local magnetic field and a Faraday screen is used to reduce the parallel electric field as required to launch the fast wave. Calculations show that the heat load from the plasma and from fast unconfined neutral beam ions is tolerable.

A low power prototype comb-line antenna will be installed in the DIII-D vessel in April 2015. Coupling measurements from this antenna will be used to fine-tune the design of the high power antenna. A 1 MW 476 MHz klystron will provide the power for definitive experiments in 2016.

[1] R. Prater, *et al.*, Nucl. Fusion **54**, 083024 (2014).

\*This work was supported in part by the U.S. Department of Energy under DE-FC02-04ER54698 and DE-AC05-00OR22725.