

Pre-ionization Experiments in the DIII-D Tokamak Using X-mode Second Harmonic Electron Cyclotron Heating*

G.L. Jackson,¹ M.E. Austin,² J.S. deGrassie,¹ J. Lohr,¹ C.P. Moeller,¹ and R. Prater¹

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

²*University of Texas-Austin, Austin, Texas, USA*

Pre-ionization using second harmonic resonant electron cyclotron waves with X-mode polarization has been observed in the DIII-D tokamak using both the previously installed 60 GHz gyrotrons [1] and the present 110 GHz system. In these experiments, the pre-ionization, i.e. ionization before the application of an inductive voltage, was reproducible and breakdown initially occurred at the 2nd harmonic resonance location. Startup scenarios for future tokamaks such as ITER and KSTAR will likely require simultaneous electron cyclotron heating (ECH) and inductive voltage for plasma initiation since thicker vacuum liners and superconducting coils limit the maximum inductive voltage to values that are marginal for plasma breakdown and burnthrough. In addition, ECH pre-ionization and startup in DIII-D can minimize runaway electron production, allow faster burnthrough and discharge reproducibility, and be applied in proposed non-inductive startup experiments in DIII-D.

In these DIII-D low field side experiments an ECH launch angle scan showed that pre-ionization required perpendicular injection for breakdown (i.e. perpendicular to the toroidal magnetic field). A power threshold of approximately 0.4 MW (60 GHz) and 0.8 MW (110 GHz) was required for ionization. A comparison between 2nd harmonic X-mode (1.05 T) and fundamental O-mode (2.1 T) using the 60 GHz launcher showed that both achieved the same pre-ionization line-integrated density, but breakdown was delayed by several milliseconds with 2nd harmonic X-mode pre-ionization.

We will present the characteristics of these ECH plasmas and parameter scans of power, neutral fill pressure, and the resonance location. The temporal evolution of pre-ionization plasmas will be discussed including modeling of single electron collisionless heating and plasma expansion from the 2nd harmonic radius. The effects of poloidal magnetic field nulls and connection length on plasma initiation will also be discussed.

¹R. Prater, S. Ejima, R.W. Harvey, *et al.*, 7th Topical Conf. on applications of Radio Frequency Power to Plasmas (AIP, New York, 1987) 9.

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