Gyrotron and Power Supply Development for Upgrading the Electron Cyclotron Heating System on DIII-D

Joseph F. Tooker[a], Paul Huynh[a], Kevin Felch[b], Monica Blank[b], Philipp Borchard[b], and Steve Caufman[b]

[a]*General Atomics, PO Box 85608, San Diego, California 92186-5608, USA*
[b]*Communications & Power Industries,. 607 Hansen Way, Palo Alto, CA 94304, USA*
Corresponding author: tooker@fusion.gat.com

An upgrade of the Electron Cyclotron Heating System (ECH) on DIII-D to almost 15 MW is being planned and implemented. The ECH system has had six 1 MW 110 GHz gyrotrons supporting plasma physics experiments [1]. A depressed collector 1.2 MW 110 GHz gyrotron is being commissioned. A new 117.5 GHz 1.5 MW depressed collector gyrotron has been designed, and the first article will be the eighth gyrotron for DIII-D. Two 1.5 MW gyrotrons will be added next, increasing the DIII-D ECH system to ten total gyrotrons, and six more 1.5 MW gyrotrons will subsequently replace the existing 1 MW gyrotrons.

Communications and Power Industries (CPI) has completed the design of the 117.5 GHz VGT-8117 gyrotron. It has been optimized for nominal 1.5 MW operation at a beam voltage of 105 kV, collector potential depression of 30 kV, and beam current of 50 A. However, it has been designed to allow for operation at beam currents and output power levels as high as 60 A and 1.8 MW, respectively. The design employs a diode electron gun, an edge-cooled CVD diamond output window, and a depressed collector constructed from a strengthened copper alloy in a configuration that locates the depression ceramic below the superconducting magnet so that the collector and the output window are at ground potential. The interaction cavity operates in the $TE_{20,9,1}$ mode, which is converted to a Gaussian output beam using an internal converter consisting of a numerically optimized dimpled-wall launcher, two phase-correcting mirrors, and a toroidal third mirror. The design of the collector permits modulation approaching 1 kHz and higher to be done with either the body power supply or the cathode power supply, or a combination of the two, while modulation below 100 Hz must be performed using only the cathode power supply.

General Atomics (GA) is pursuing the development of solid-state power supplies for this upgrade: a solid-state modulator [2] for the cathode power supply and a linear high voltage amplifier for the body power supply. The solid-state modulator has series-connected insulated-gate bipolar transistors (IGBTs) that feed an inductor-capacitor filter network and that are switched at a fixed frequency by a pulse width modulation (PWM) regulator to control the output voltage. Small-scale tests confirmed the practicality of this topology at reasonable currents, and the complete design of a 80 kV, 80 A CW solid-state modulator is being developed in order to build it in the near future and test it at 50 kV, 50 A for 30 seconds into a dummy load and to demonstrate modulation at up to 1 kHz. The design of the linear high voltage amplifier has series-connected transistors to control the output voltage. Proof-of-principal tests were successfully performed at voltages up to 2 kV dc and with modulation to greater than 5 kHz. The design of a complete 45 kV, 250 mA power supply is proceeding.

The design features of the 117.5 GHz 1.5 MW gyrotron and the solid-state cathode and body power supplies will be described and the current status and plans will be presented.

[1] J. Lohr, et al., J. Infrared, Millimeter and Terrahertz Waves **32**, 1 (2011).
[2] J.F. Tooker, et al., Fusion Eng. Design **84**, 1857 (2009).

This work was supported in part by the US Department of Energy under DE-FC02-04ER54698.