IMPROVED COLLECTOR ANALYSES AND MEASUREMENTS ON HIGH-POWER GYROTRONS

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Several magnetic fusion facilities now employ megawatt-class gyrotrons for use in a variety of electron cyclotron heating and current-drive applications. With the increased usage of these gyrotrons, the applicability of the initial design limits placed on the gyrotrons can be examined. At CPI, two different, gyrotron designs fall into this category. The first of these designs is for the 110 GHz, 1 MW, 10-s pulsed gyrotrons that are employed by General Atomics in experiments on the D-IIID tokamak. Three of the 110 GHz, 1 MW gyrotrons began operation at General Atomics in the 2000-2001 timeframe and the fabrication and test of a second set of three 110 GHz, 1 MW gyrotrons are nearing completion. The second of the high-power designs is for a 140 GHz, 900 kW CW gyrotron for use in experiments on the Wendelstein 7X stellerator at the Max Planck Institute for Plasma Physics in Greifswald, Germany. The 140 GHz gyrotron reached 900 kW CW operation in March 2005.

During the design phase for each of the two gyrotrons, three elements of the gyrotron were identified as high-risk areas due to the high-power specifications for the devices. These areas included the diamond output window, interaction cavity and the electron beam collector. In the early stages of tests on tubes of both designs, two different problems were experienced with the diamond output windows.[1] These problems appear to have been solved by implementing design and processing changes. None of the gyrotrons have experienced any failures of the interaction cavity where the highest power densities exist in the gyrotrons. However, there have been recent difficulties in the collectors of both tube designs that indicate that reliable, long-term operation of the tubes requires design improvements.

Both the 110 GHz and 140 GHz gyrotron collector designs involve magnetic sweeping of the electron beam to reduce the power density incident on the collector walls to acceptable levels. The magnetic sweeping involves application of a time-varying current to the magnet coils located near the collector. This approach is complicated by the attenuation of the time-varying magnetic field due to eddy currents in the collector walls. In addition, the profile of the magnetic field is also affected by the presence of the eddy currents and varies for different modulation frequencies.[2] During tests, collector-power-density measurements are made to verify the time-averaged power density that is present on the collector for a given set of operating parameters. The details of the collector sweeping designs and measurements made during tests of both types of tubes will be summarized and design enhancements aimed at eliminating the difficulties encountered in the collectors will be presented.

References

[1] K. Felch, et al., "Recent tests on 500 kW and 1 MW, multi-second-pulsed gyrotrons," Proc. 12th Joint Workshop on Electron Cyclotron Emission and Electron Cyclotron Heating, G. Giruzzi, ed., May 2002, pp. 565-570.

[2] S. Illy, B. Piosczyk, I. Danilov, S. Raff, "Design studies of the collector sweeping system for the 2 MW 170 GHz coaxial gyrotron for ITER", in Conference Digest for 2004 Joint 29th Int. Conf. Infrared and Millimeter Waves and 12th Int, Conf. Terahertz Electronics, M. Thumm and W. Wiesbeck, eds., September 2004, pp. 231-232.