PROGRESS IN EUROPEAN COLLABORATIVE GYROTRON DEVELOPMENTS FOR CEA AND GENERAL ATOMICS

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ABSTRACT

This paper summarizes recent progress at THALES on two continuous-wave (CW) industrial gyrotrons developed for fusion Electron Cyclotron Heating and Current Drive, namely the TH1511 for WEST [1] and the TH1512 for DIII-D [2]. Both programs combine THALES industrial design and fabrication with electromagnetic and electron-optics design activities at KIT and NKUA and target reliable Megawatt-class operation with high Gaussian mode output beam content, depressed-collector efficiency enhancement and compatibility with long-pulse operation. The developments address distinct plasma scenarios and magnetic-field constraints while preserving a common industrial architecture based on a diode magnetron injection gun, independently adjustable superconducting magnet circuits, advanced cavity cooling, quasi-optical mode conversion and a swept depressed collector. The TH1511 is specified for 105 GHz, 1 MW CW operation in the WEST tokamak, where three units will support steady-state plasma scenarios up to 1000 s. It operates in the $TE_{-20,8}$ cavity mode with electron beam parameters around 78 kV and 45 A. The TH1512 is specified for 117.5 GHz, 900 kW CW operation in the DIII-D tokamak, where two units will support 10 s pulses with accurate power modulation and deposition control. It operates in the $TE_{24,8}$ mode with beam voltage up to 92 kV and beam current above 35 A. Prototype fabrication was completed at THALES using qualified processes for vacuum integrity, high-voltage insulation, hydraulic cooling, and dimensional reproducibility. Short-pulse validation was performed at the KIT FULGOR facility with calorimetric power measurements, heterodyne frequency diagnostics, and infrared beam imaging [3]. For the TH1511, 1 ms non-depressed operation at 104.984 GHz yielded about 1.2 MW at 50 A, while depressed-collector operation provided 1 MW at about 46% efficiency and 1.1 MW in 3 ms pulses. For the TH1512, 1 ms non-depressed operation at 117.703 GHz exceeded 1.3 MW at 43 A and depressed-collector operation produced 1.03 MW with efficiency above 48% in 3 ms pulses. Long-pulse operation of the TH1511 tube delivered 1 MW at 45% efficiency for 5 s at CEA, where testing is continuing toward longer pulses. Long-pulse tests of the TH1512 gyrotron delivered 950 kW at 42.5% efficiency for 10 s at KIT, where the unit successfully passed the factory acceptance test. These results validate the common design approach across two frequency bands and two fusion devices and indicate that both gyrotrons have reached a maturity level consistent with technical requirements.

References

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