Evaluation of a Low Voltage High Current Operation Point for a High-Frequency and Very-High Order Mode Gyrotron

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ABSTRACT

The HEATQIS project, funded by the Federal Ministry of Research, Technology and Space (BMFTR), develops key technologies for future high magnetic field fusion power plants, focusing on plasma electron cyclotron resonance heating (ECRH). The project includes the investigation of ECRH components such as superconducting magnet systems, diamond windows, and launcher systems for future stellarator-based fusion reactors such as Proxima Alpha. Central to the project is the development and manufacture of a 238 GHz, 1.7 MW $TE_{49,29}$ mode coaxial-cavity gyrotron for 100 s long-pulse operation. Here, the gyrotron will be investigated under two alternative operating regimes: Low Voltage High Current (LVHC, 75 kV, 75 A) and High Voltage Low Current (HVLC, 90 kV, 63 A). The comparison focuses on the influence of both concepts on electron gun performance, beam–wave interaction in the cavity, After-Cavity Interaction (ACI), and collector efficiency, with particular attention to the challenges associated with high-frequency gyrotrons operating at high mode indices and the resulting differences compared to already established gyrotrons.

The electron gun design is evaluated with respect to peak electric field strength and the associated risk of arcing for both operating points. In addition, the interaction efficiency is compared for cavity designs individually optimized for the LVHC and HVLC regimes. The analysis includes the impact of the operating point on ACI effects [1], also considering the implications for the dimensions of the quasi-optical launcher. The collector performance is investigated with emphasis on the slowest electrons reaching the collector and their influence on collector efficiency and with the points before the overall gyrotron efficiency. The study aims to evaluate the suitability and limitations of both operating regimes for efficient and reliable operation of the HEATQIS gyrotron.

References

[1] A. SCHMIDT in Journal of Infrared, Millimeter, and Terahertz Waves 47, May 2026