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TE- and TM-mode Competition in Subterahertz Gyrotron Using Axis-Encircling Electron Beam

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For a long time, most gyrotron oscillators have avoided utilizing TM modes because of the concerns about strong bunching competition and relatively weak beam-wave coupling. However, this work demonstrates that an axis-encircling electron beam with high mode selectivity is adapted to preclude most parasitic modes and makes the TM12-mode oscillation in an open-cavity-type gyrotron system feasible. Considering the modes excited at the fundamental cyclotron harmonic, the TE12 mode remains the only competitor to the targeted TM12 mode, however, it will be effectively suppressed by the axial velocity spread. Operating with 70 kV beam voltage and 1 A beam current, the output power of the TM12 mode may reach the several-kilowatt level, verified by both nonlinear frequency-domain and time-domain simulations. Nonetheless, as the modes at high cyclotron harmonics are included, the second-harmonic TE24 mode and the third-harmonic TE36 mode would potentially hazard the proposed TM12-mode operation. Even so, the particle-in-cell CST simulation results still show a tunable window of the TM12 mode, where all parasitic TE-mode oscillations are fully suppressed. This work manifests the importance of considering the competition from TM modes in the designs of gyrotron devices, especially for the cases employing axis-encircling electron beams. Currently, the proposed system is being constructed at Peking University, Beijing, with preliminary tests supporting the findings of this study.

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