Beam Characteristics of Mechanically Tunable Magnetron Injection Guns

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The electron beam of a gyrotron is typically generated by a magnetron injection gun (MIG). A single anode MIG (Fig. 1) capable of mechanical tuning was developed by National Tsing Hua University (NTHU)[1]. Previous gyro-TWT[1] assumes that the operating point of the mechanically tunable MIG is in the temperature limited region. The cathode current is thus dominated by the cathode temperature. However, a slight adjustment in position of the center electrode of the mechanically tunable MIG can significant modify the electric-field profile. The beam current of the mechanically tunable MIG is thus not only dependent on the cathode temperature, but also the relative position of center electrode.

The cathode current density J_c from Longo's empirical formula[2] can be expressed as a combination of the temperature limited current density J_{TL} and space-charge limited current density J_{SC} .The J_{SC} and J_{TL} calculated from Langmuir's and Richardson's laws. An improved computer program is employed to simulate electron trajectories of the mechanically tunable MIG.

A mechanically tunable MIG[1] was developed at NTHU for a Ka-band , TE_{11} mode gyro-TWT. The specifications of the gyro-TWT were V_b=93.6 kV, I_b=3 A, B_0=12.5 kG, α=0.9, and $\Delta v_z / v_z < 4\%$. Figure 2 displays the variation of the beam current with the axial magnetic field in the mechanically tunable MIG. The velocity ratio decreased with increasing the axial magnetic field, and the simulated beam currents do not appear to be dependent on the axial magnetic field. Figure 3 displays the beam characteristics as functions of the compression ratio. Velocity ratio increased with the compression ratio increased, while the beam current remained constant. The measurement results are consistent with the simulation results.

Figure 4 displays the simulated and measured beam currents of the mechanically tunable MIG at the different beam voltages. As Fig. 4a illustrates, the space-charge limited current increased with the anode voltages. Meanwhile Fig. 4b shows the measurement results of the MIG. The simulation results are consistent with the measured results. Figure 5 displays the beam characteristics as functions of the relative positions of the center electrode. Figure 5a indicates that the simulated and measured beam currents decrease as the relative positions of the center electrode increase. The discrepancy between the measured and simulated results would be attributed to the current density can not be completely described in Longo's empirical formula. Longo's empirical formula calculates the space-charge current density from Langmuir's law, a formula that is appropriate for a parallel plane diode. If the relative position variation of the center electrode is obvious, the parallel plane diode model appears inappropriate for simulating the electric field between the cathode and anode of the mechanically tunable MIG.

To degrade the variation of the beam current, an improved mechanically tunable MIG design is developed as shown in Fig. 6. The center electrode divides into two separate parts, movable and fixed center electrodes. Meanwhile, the beam characteristics of the MIG as functions of the relative position of the center electrode are shown in Fig. 7. The variation of beam current and quality is less than for the pervious MIG (Fig. 1). Consequently, the MIG (Fig. 6) appears insensitive to the relative position of the center electrode.

References

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2. R.T. Longo, "A study of thermionic emitters in the regime of practical operation," *Int. Electron Devices Mtg.*, p467-470, 1980.

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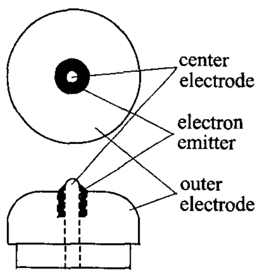


Fig. 1. Front view and side view of the cathode assembly.

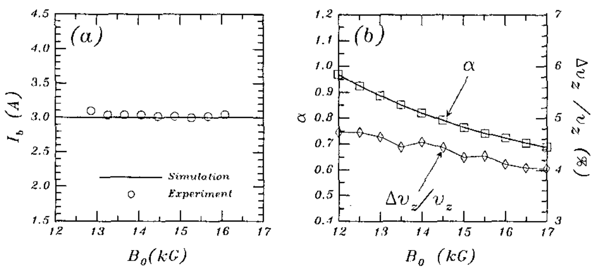


Fig. 2. displays beam currents, simulated velocity ratio and axial velocity spread as functions of the axial magnetic field.

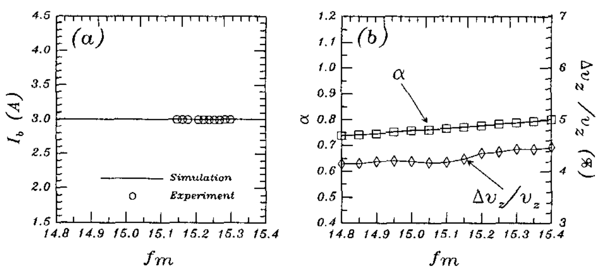
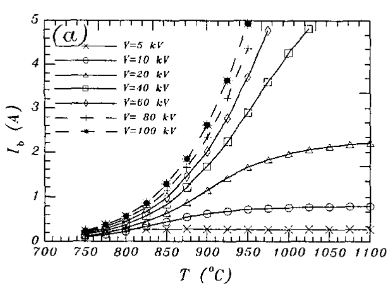
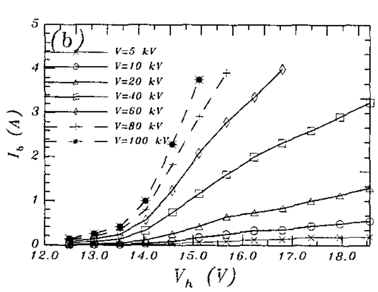


Fig. 3. displays beam currents, simulated velocity ratio and axial velocity spread as functions of the compression ratio.





Figs. 4a and 4b display the simulated and measured beam current as functions of the cathode temperature, respectively.

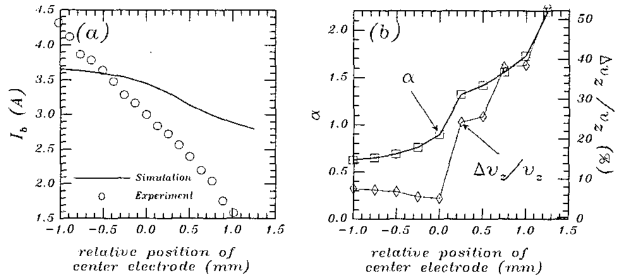


Fig. 5. displays beam currents, simulated velocity ratio and axial velocity spread as functions of the relative position of the center electrode.

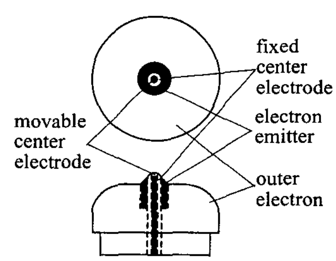


Fig. 6. Front view and side view of the cathode assembly of the improved mechanically tunable MIG

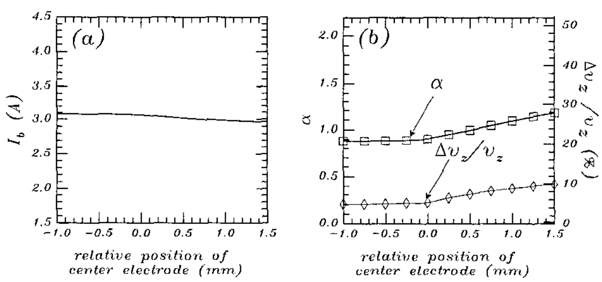


Fig. 7. displays beam currents, simulated velocity ratio and axial velocity spread as functions of the relative position of the center electrode.