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High-alpha and low-spread electron beam for terahertz gyrotrons

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Gyrotrons, based on the electron cyclotron maser, convert the kinetic energy of the electrons to the electromagnetic radiations. The properties of the electron beam determine the overall performance of gyrotrons. High-velocity ratio, i.e., the pitch factor $\alpha = v_\perp / v_z$, improves the interaction efficiency. On the other hand, the low-velocity spread of the beam ($\Delta v_\perp / v_\perp$) indicates that the electrons behave in unison, which also facilitates the interaction efficiency. This study presents the study of a single anode magnetron injection gun (MIG) for a frequency-tunable gyrotron centered at 203 GHz.

First, I will give an overall picture of the development of the electron beam for various applications. Then, I will briefly talk about two types of the electron guns, magnetron injection gun (MIG) and magnetic cusp gun (MCG), for gyrotrons [1, 2]. Finally, I will focus on the development of the MIG for frequency tunable gyrotrons [3, 4].

The gyrotrons generally demand an electron beam with high pitch factor and low-velocity spread. For the frequency tunable gyrotrons, the oscillation frequency can be adjusted by changing either the magnetic field (B_0) or the beam voltage (V_b) [5]. The desired beam radius (R_b), the magnetic field at the interaction zone (B_0), and the compression ratio (F_m) give the preliminary geometrical and electrical parameters at the cathode region [1, 6]. The EGUN code is used to calculate the trajectories of the electrons. The results are validated with the Particle Studio of the computer simulation technology (CST). By optimizing the geometrical parameters and the magnetic field profiles, we achieve high pitch factor (~1.5), low transverse velocity spread (~7%), with the guiding center radius of 0.44 mm, ideal for TE_{02} mode, 203 GHz gyrotron operation [4].

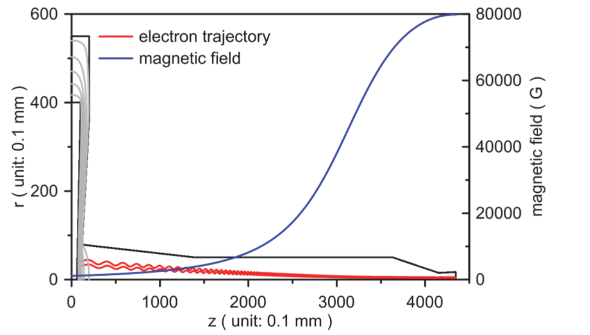

Figure 1: Structure, the axial magnetic field profile, and the calculated electron trajectories in EGUN. The black line indicates the geometric structure of the gun on an *r*-*z* plane. The grey lines represent the equal-potential lines. The blue curve is the applied magnetic field. The red curves show the calculated electron trajectories.

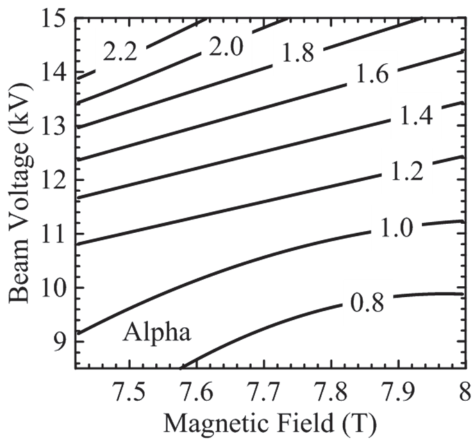

Figure 2: Simulated pitch factor (alpha) versus the magnetic field (B_0) and the beam voltage (V_b). The calculated values using the CST and EGUN code agree well with the transverse velocity spread of ~7%.

The guidelines for high-performance electron guns are reported. Designing a MIG gun with high alpha and low spread is demonstrated. Results exhibit a good agreement between our expectations and simulations with the pitch factor of 0.9-1.8 and the transverse velocity spread of ~7%. We will employ the gun and perform the frequency-tunable gyrotron experiment soon.

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