03aD17P

マグネトロン入射型電子銃におけるラミナー電子流の形成機構

Mechanism for Forming Laminar Electron Beam in a Magnetron Injection Gun

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In gyrotrons, the magnetron injection gun (MIG) is a critical component, which must generate a high quality electron beam with a small velocity spread. As the current density increases, the space-charge effect becomes large and increases the velocity spread. To reduce the space-charge effect, formation of a laminar flow is essential [1]. A conventional design parameter has been a slant angle θ_E of an emission surface to a magnetic field line [2].

We have considered the mechanism of laminar flow formation to provide guidelines for MIG designs. It is found that the laminarity depends not only on θ_E, but also on a potential profile in a region surrounded by a cathode, a first and a second anodes (K-A region) [3]. By optimizing the potential profile, a MIG is designed for a 265 GHz, 3 kW gyrotron. It produces a 20 kV, 0.5 A laminar beam with a pitch factor (ratio of perpendicular to parallel velocities to magnetic field line) of α = 1.3 at the cavity.

Figure 1(a) shows electrodes shapes and beam trajectories calculated with EGUN. Since electrons on inner and outer trajectories are emitted from different axial positions, they have different rotating phases in a plane perpendicular to the magnetic field line. This makes the laminarity worse. However, with an optimum potential profile, α-values of electrons on the outer trajectory become always smaller than those of inner ones at each axial point in K-A region (Fig. 1(b)). Thus, electrons on the outer trajectory travel a longer distance than the inner ones during one cyclotron motion. As a result, the phase differences between the rotating trajectories become small (indicated by signs "→| |←" in Fig. 1(a)). After passing the K-A region, the trajectories are distributed almost uniformly and a well laminated flow is formed.

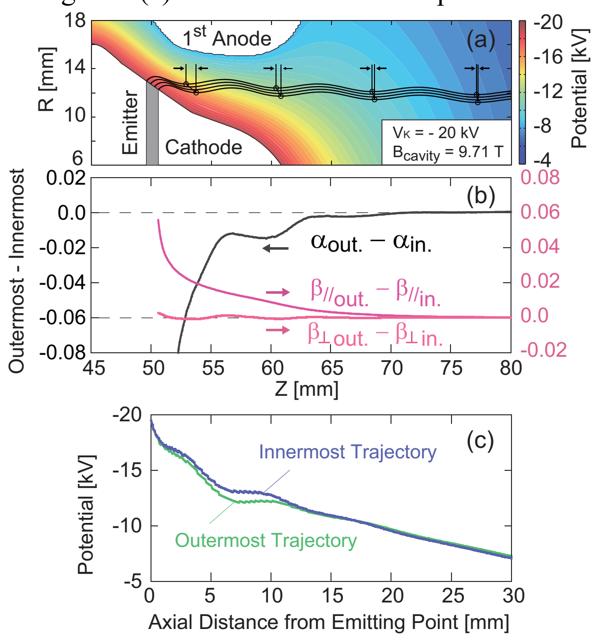

Fig. 1. Beam parameters for a designed MIG. (a) Beam trajectories. (b) Difference in α–values, $\beta_{//} = v_{//} / c$ (c: speed of light in free space), $\beta_{\perp} = v_{\perp} / c$ and (c) potential on innermost and outermost trajectories.

Here, the differences in α-values are produced by differences in the parallel velocities ($\beta_{//}$) (Fig. 1(b)). According to different potential slopes shown in Fig. 1(c), electrons on the inner and outer trajectories are differently accelerated to have appropriate values of $\beta_{//}$ in the K-A region.

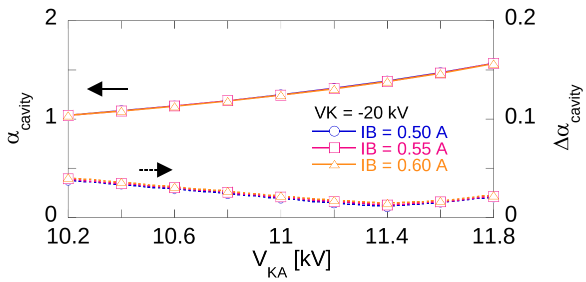

Fig. 2. Pitch-factor α and its spread $\Delta\alpha$ as a function of V_{KA} for 20 kV, 0.5 A electron gun.

A high performance MIG with a wide operation window is obtained. In Fig. 2, α_{cavity} and the spread $\Delta\alpha_{cavity}$ (= [$\alpha_{max.} - \alpha_{min.}$] / $\alpha_{average}$) are plotted as a function of the voltage between the cathode and 1st anode (V_{KA}). The very small $\Delta\alpha_{cavity}$ less than 5 % is achieved for a wide range of α_{cavity} = 1.0~1.5.

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