Development of a CUSP-Type Electron Gun for a W-Band Helical Gyro-TWT

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ABSTRACT

In the age of semiconductors and integrated circuits, vacuum electronic microwave devices, in particular gyro-devices, are used to generate high output power for millimeter and sub-millimeter waves. This is achieved by utilizing the weakly relativistic electron cyclotron maser interaction principle [1].

A special type of gyro-device is the gyro-traveling wave tube (TWT) with a helically corrugated interaction region, also called helical gyro-TWT [2]. This type of gyro-TWT requires a so-called CUSP-type electron gun [3-6], in which an axis-encircling large-orbit electron beam (LOB) is generated by a non-adiabatic reversal of the magnetic field (cusp). To ensure broadband interaction, a high-quality LOB with low velocity spreads and a small guiding center radius is required.

In this work, a CUSP-type electron gun, capable of generating such a beam, is developed for a 94 GHz helical gyro-TWT. A methodology has been developed to find good initial geometry dimensions for a numerical optimization. It was found that a crucial point for a low velocity spread is a constant magnetic flux through the ring-emitter over its entire surface, which corresponds to magnetic field lines parallel to the emitter surface. With the proper initial geometrical dimensions and an adequate magnetic field distribution over the emitter, numerical optimizations using the in-house electron-beam-optics code ESRAY [7] are conducted.

The final electron gun is optimized for the generation of an electron beam with a 50 kV acceleration voltage, 1.5 A current, and a ratio of perpendicular to longitudinal velocities (pitch factor α) of $\alpha = 1.0$ with an RMS spread as low as 3.45 %.

Additional tolerance studies, including the influence of deviations in the emitter position and the surface roughness of the emitter, find that a high emitter surface roughness increases the velocity spread. Therefore, only a small surface roughness of up to 2.3 µm can be tolerated. On the other hand, the electron beam is rather indifferent towards deviations in the electrode geometry. Only the position of the emitter with respect to the cathode has to be closely monitored.

References

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