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P3.16: Gun Emittance of a Space Charge Limited Diode Due to Temperature Effects and Surface Roughness

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Abstract: *The emittance of a space charge limited diode is investigated under thermal emission and with a simple surface roughness model.*

Keywords: emittance; surface roughness; space charge limit; thermal emission.

Introduction

As the operating frequency of vacuum electronic devices increases and the dimensions of the devices decrease, the emittance of the electron beam is an increasingly significant factor affecting device performance. Also, as diode dimensions decrease, cathode surface roughness becomes more important, requiring a new investigation of the effects and interactions of a non-planar emitter and space charge in high current electron guns. The topics of emittance and surface roughness have been studied theoretically, but under different assumptions [1,2]. To date, there has been very little quantitative modeling and analysis of these effects with full space charge and beam thermal spread. To address this deficiency, we introduce several models and compare them to established theory and MICHELLE [4] simulations (mostly with 2-dimensional geometries); conclusions are then drawn from the models.

Approach

Our approach is illustrated in Figure 1. The starting point (**A**) is the 1-D analytical problem of a planar diode operating in the space charge limit with a cathode that emits a monoenergetic beam. This problem has a virtual cathode-like solution for large emitted current densities in which a typically large portion of the emitted current is reflected back to the cathode. The presence of this reflection constitutes the working definition of the space charge limit. The starting point has no inherent emittance because it is a purely 1-D problem with no transverse velocities.

It is from this point that we develop a simple model of surface roughness. Block (**B**) is a 2-D modification of block (**A**) where a "small" bump is added to the cathode surface (the bump is either hemispherical or pointed), yet the initial beam is still monoenergetic and emitted perpendicular to the surface. This model was studied with selected MICHELLE simulations in order to compare appropriately to other models in the literature [1,2,3] and the analytical model of block (**C**), which we now describe.

Block (**C**) is an analytic model for diffuse emission from a rough surface in which the roughness height is much smaller than the virtual cathode position. In this case the mechanisms for initial velocity spread and the effects on the spread due to space charge are separate. This model is solved in a manner similar to the Langmuir solution for a beam with a thermal velocity spread, but the initial velocity distribution follows Lambert's Law for diffuse emission. This can be solved numerically in a similar manner to the general solution of the space charge limited thermionic cathode.

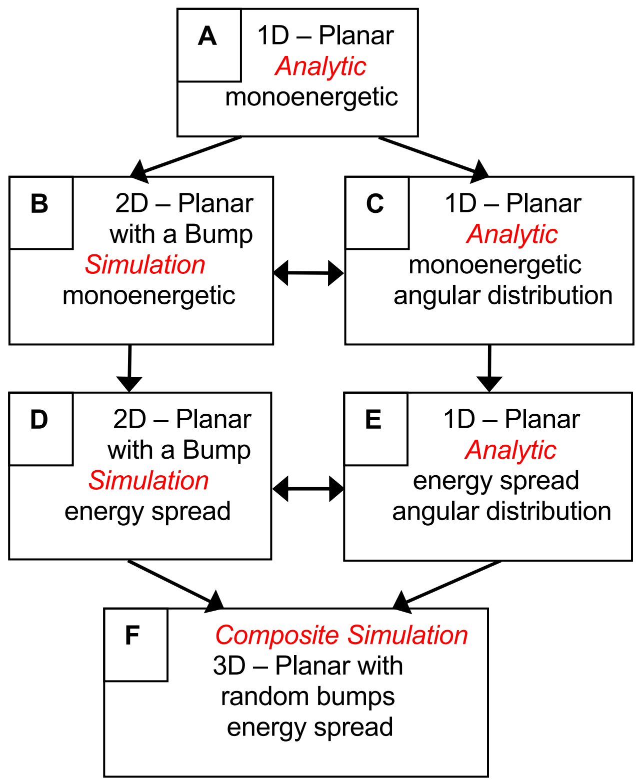

Figure 1. Hierarchy of models for generation of beam emittance.

Both models B and C produce a finite emittance. Figure 2 plots the results of a model C calculation with a diffuse velocity spread for various values of injection current. The emittance decreases as the total amount of injected current increases past the monoenergetic beam space charge limit (indicated by the solid vertical line).

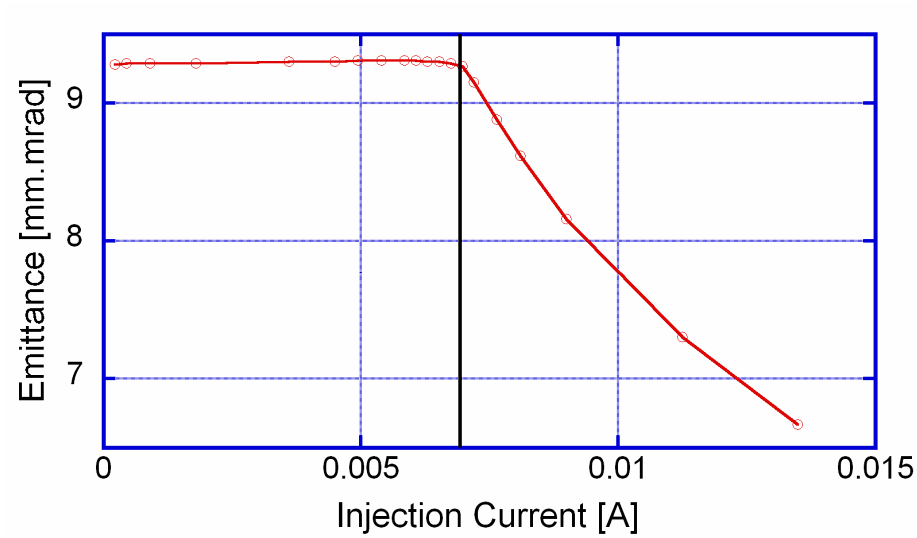

Figure 2. Emittance vs. Injected Current from model C.

This is an effect of space charge and the existence of a potential minimum on the electron distribution.

Block (**D**) represents a refinement of the model of block (**B**) in which the emitted beam is given an energy spread. Application of this model requires multiple simulations with different bump sizes, temperatures and currents. The results of these simulations will be compared with the analytic model of block (**E**), which is the refinement of block (**C**) to include a beam energy spread as well as a distribution of angles. This analytical model will show how the addition of these two effects might add without complications of the space charge limit – this will be useful for the comparison with block (**D**), from which a solid claim as to the effects of the surface roughness can be established. From this relationship, a set of scaling laws (a confirmation and/or adjustment of previous scaling laws [1,2,3] possibly) will be developed to describe the emittance of a space charge limited diode with a bumpy emitter.

The last block (**F**) is a composite of the other blocks, intended to confirm the scaling laws by performing a 3D simulation with random bumps of arbitrary size. This is designed as both a culmination and confirmation of previous work, and for further validation of the simulation results.

Acknowledgement
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References

1. Lau, Y.Y., "Effects of Cathode Surface Roughness on the Quality of Electron Beams," *J. Appl. Phys.*, vol. 61, no. 1, pp. 36-44, January 1986.
2. Finn, M., T.M. Antonsen, W.M. Manheimer, "Space-Charge-Limited and Temperature-Limited Electron Flow in the Vicinity of Edges and Conical Points," *IEEE Trans. Plasma Sci.*, vol. 16, no. 2, pp. 281-289, April 1988.
3. Tsimring, Sh.E., "On the Spread of Velocities in Helical Electron Beams," *Radiophysics and Quantum Electronics*, vol. 15, no. 8, pp. 952-961, August 1972.
4. Petillo, J., *et al.*, "The MICHELLE Three-Dimensional Electron Gun and Collector Modeling Tool: Theory and Design," *IEEE Trans. Plasma Sci.*, vol. 30, no. 3, pp. 1238-1264, June 2002.