Implementation of Computer Optimization for Design of Electron Guns

R. Lawrence Ives, Thuc Bui, Adam Attarian[a], Steven Davis[a], Sean Gadson[a], William Tallis[a], Hien Tran[a], Michael Read, and Mattie Posth[b]
Calabazas Creek Research, Inc. 690 Port Drive, San Mateo, CA 94404
RLI@calcreek.com, (650) 312-9575

[a]North Carolina State University, Raleigh, NC USA
[b]Consultant, San Francisco, CA

***Abstract*— Computer optimization can dramatically reduce the time and cost to design electron beam devices. It also allows design of complex, 3D devices that would be impractical with manual design. Recent implementation of a magnetic solver into a 3D finite element electron beam trajectory code is allowing optimized design of the electrostatic, optical and magnetic configuration of 3D device. The process and examples will be presented.**

I. Program Description

Electron guns are implemented in numerous devices to convert electrical power to some other useful purposes, including, RF power generation in klystrons and traveling wave tubes (TWTs), electron beam welding, lithography, and high power beams for scientific, industrial, and medical accelerators. Until recently, two dimensional codes were sufficient for device design. Current interest, however, is focused on distributed beam devices to increase performance. These include sheet beam and multiple beam klystrons.

The goal of this research program is to develop tools to allow the computer to explore the parameter space to achieve user-designed performance goals. Advanced optimization routines can analyze performance changes as parameters are modified and rapidly and efficiently determine optimal regions of parameter space to explore. This process can be fully automated, increasing the parameter space explored and achieving better designs while simultaneously reducing the cost. This presentation will describe the tools developed to achieve optimized gun designs and describe results for several devices.

II. Simulation Tools

The principal commercial programs in the development are SolidWorks and Beam Optics Analysis (BOA). SolidWorks is a parametric, 3D, solid modeling program. Its capabilities are similar to other CAD programs, including Pro-E, Solid Edge, and AutoCAD 3D. The requirements are that the CAD program be parametric, allow design modifications using design tables, and generate ACIS or Para-Solid formatted files.

BOA inputs the geometry, adds parametric values for the electrical, magnetic, emitter, and material properties, and simulates propagation of electrons through the problem domain. BOA is a finite element, adaptive mesh, charged particle analysis program. BOA includes electric and magnetic field solvers, so optimized design can be simultaneously achieved for both the electrical and magnetic circuits.

The final tools are the optimization routines and control program that evaluate the performance and update the design tables. The optimization routines can modify the geometry of the components, including cathodes, anodes, iron structures, and coil geometries. The routines can also modify parameters, such as voltages and coil currents.

III. Sheet Beam Devices

Previous research demonstrated computer optimization for Pierce electron guns in a fixed magnetic field [1]. The program also explored doubly confined multiple beam guns and sheet beam guns for high frequency RF applications. Current research is including design of the magnetic circuit.

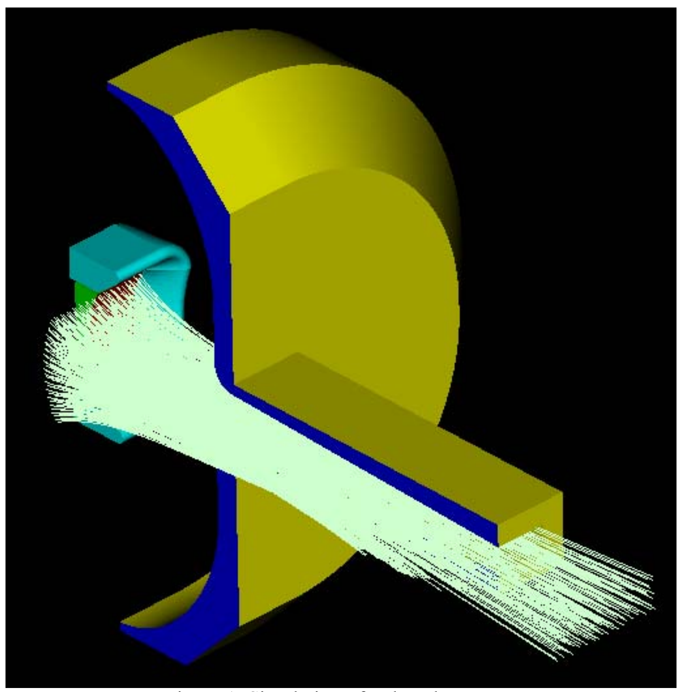

Figure 1. Simulation of a sheet beam gun

Figure 1 shows a sheet beam gun optimized at X-Band and Figure 2 shows a simulation of a magnetic circuit for a 220 GHz sheet beam gun. Figure 3 shows simulation of the sheet beam through the circuit region and beyond the collector polepiece. The purpose of this particular research effort is to

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determine if strategically placed iron around the circuit can compensate for the ExB force that causes the sides of the beam to curl. Currently, efforts are on generating a goal function that quantifies the shape of the sheet beam at the sides to measure deviation from straight propagation. Routines are also requires to filter out spurious electron trajectories that can misrepresent the ExB drift effect. This primarily includes electrons emitted near the corners of the cathode. Figure 4 shows an end view of such a beam where spurious trajectories in the upper left and lower right partially mask the curling seen in the opposite directions.

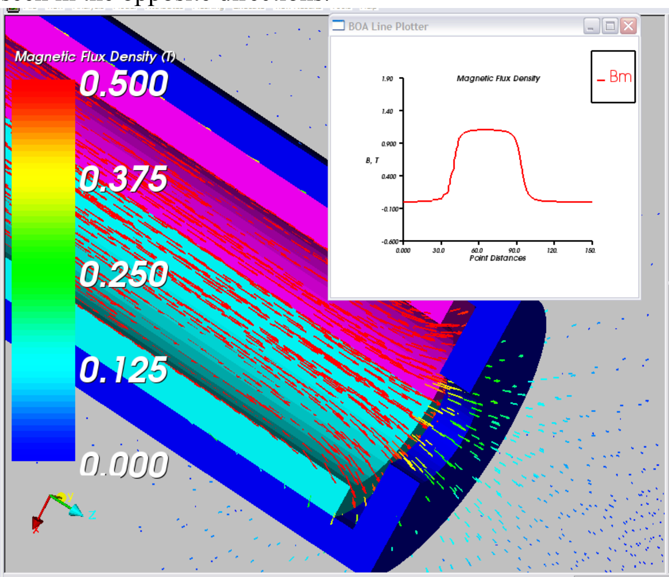

Figure 2. Magnetic field vectors in 3D analysis of circuit for a 220 GHz sheet beam gun. The field on the axis is also shown.

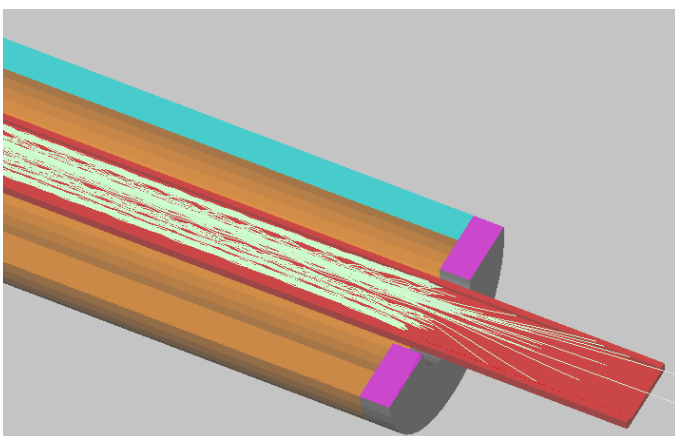

Figure 3. Propagation of sheet beam through a magnetic circuit. Termination of the magnetic circuit by the iron polepiece results in beam interception on the beam tunnel walls.

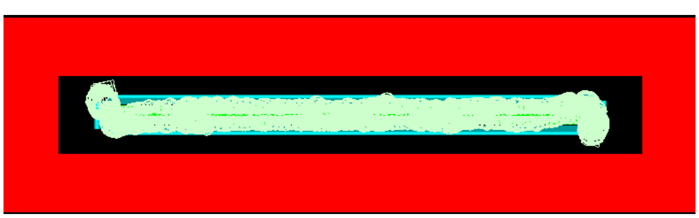

Figure 4. End view of sheet beam electron trajectories. Electrons in upper left and lower right are spurious electrons from corners of the cathode.

The research is addressing issues related to performance. A procedure is being established to execute BOA on multiple platforms over a network to accelerate the optimization process. This is different from the on-going effort to implement performance enhancement by parallel processing using multiple CPUs on a single computer. The parallel processing pushes particle through the problem domain while executing a single BOA analysis. The optimization process analyses different geometries and parameters on different computer.

IV. Future Analysis and Summary

Analysis of 3D geometries presents numerous challenges for magneto static, electrostatic, and beam optics design. This program is identifying issues related to magnetically focused and confined sheet beam and multiple beam devices. The approach is to model simple geometries and add complexity using optimization routines to control geometric and parametric features to achieve a predetermine performance specification. The challenge is to insure that the basic electromagnetic and beam optics analysis is accurate and that the goal functions and variables are clearly defined to achieve the goals.

V. References

[1] J. David, R.L. Ives, H.T. Tran, T. Bui, and M.E. Read, “Computer Optimized Design on Electron Gun,” IEEE Trans. on Plasma Science, Vol. 36, No. 1, pp. 156-168, February 2008.

VI. Acknowledgements

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