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S-Band Sheet Beam Klystron Research and Development at SLAC

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Abstract: *Development of a 2.1 GHz, 200 kW CW sheet beam klystron (SBK) for the Navy's free electron laser (FEL) is discussed. Design parameters and simulations of the klystron are presented. Calculations of transverse electric (TE) mode instability and mitigation are addressed.*

Keywords: sheet beam; klystron; stability

Introduction

SLAC National Accelerator Laboratory is developing a sheet beam klystron that will drive the super conducting photonic band-gap accelerator structure being designed by Los Alamos National Laboratory for the Navy FEL S&T program [1]. A sheet beam topology was chosen over round beam to minimize the operating voltage and package size without sacrificing efficiency. The final design specifications are shown in Table 1. They were obtained while maintaining a drift tube width at cutoff to the drive frequency..

Table 1. Klystron Design Specifications

Beam Voltage (kV)	36
Beam Current (A)	10
Frequency (GHz)	2.1
Output Power (kW)	200+ CW
Beam Aspect Ratio	12:1
Beam Shape	Semi-Elliptical
Drift Tube Cutoff (GHz)	2.5
Efficiency (%)	55+

The sheet beam itself is semi-elliptical with a 12:1 aspect ratio as shown in Figure 1. The fill factor in the vertical dimension is 50%, a common fill factor for CW devices.

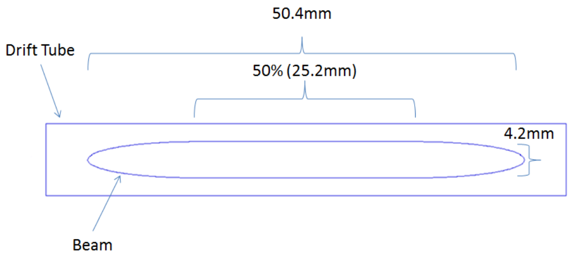

Figure 1. 12:1 Aspect Ratio Semi-Elliptical Sheet Beam in a Rectangular Drift Tube.

Electron Gun Design

The electron gun is specified to produce 10 Amps of current at 36kV. The final 3D MICHELLE simulation which achieves this design goal is shown in Figure 2. The final beam has the proper aspect ratio and low emittance. However, particles from the cathode stalk and edge are less laminar. These particles could intercept the drift tube and cause damage but they account for less than 1% of the beam current and simulations show they transport through permanent magnet focusing and solenoid focusing structures without interception.

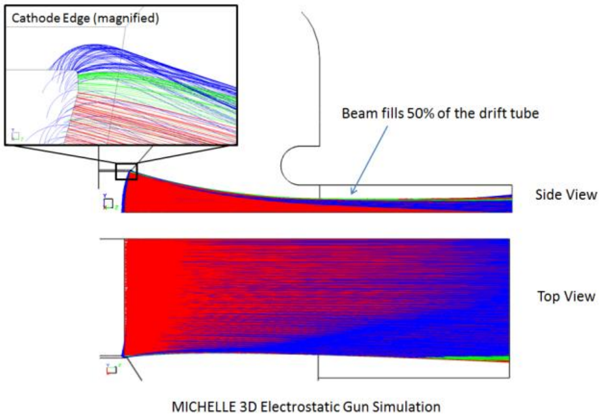

Figure 2. MICHELLE 3D Sheet Beam Gun Simulation Achieving 10A at 36kV.

RF Design

AJDISK and MAGIC2D were used to do the preliminary optimization of the RF design. MAGIC2D confirmed an output power of 200 kW CW at greater than 55% efficiency as shown in Figure 3. The 3D design is presently underway and will be simulated in MAGIC3D next.

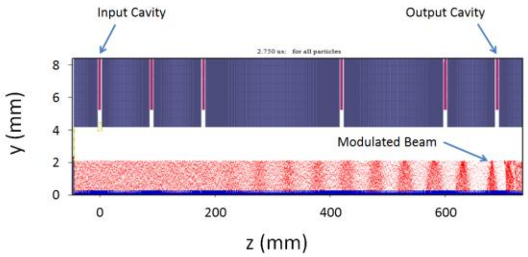

Figure 3. MAGIC2D Particle Simulation of the Solenoid Focused 6 Cavity Klystron Predicting 200kW of Output Power at Greater than 55% Efficiency.

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One of the critical 3D components of the RF design are the cavities. Figure 4 shows the 3D cavity geometry with a rectangular drift tube.

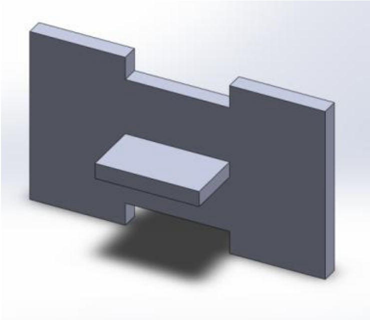

Figure 4. Nominal Sheet Beam Cavity Geometry.

The otherwise 2D planar cavity is terminated into a quarter wave match with an increased "a" dimension. This match creates a uniform axial bunching field as shown in Figure 5. Field flatness ensures uniform RF bunching across the width of the beam.

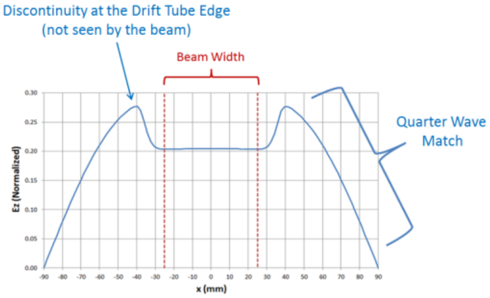

Figure 5. Axial Electric Field Versus Beam Width for the Nominal Sheet Beam Cavity.

Beam Instability Analysis and Mitigation

Beam stability is a critical issue for sheet beam klystrons. Transverse Electric (TE) modes can be trapped between cavities ultimately leading to beam interception on the drift tube walls [2]. Figure 6 shows the onset of such an instability where the beam begins to deflect in the transverse direction.

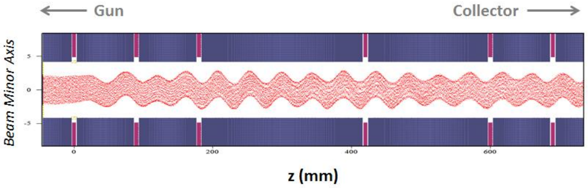

Figure 6. Transverse Deflection of the Electron Beam by a Trapped TE Mode.

To prevent this instability in this design the drift tube was cutoff to the operating frequency. However, upon further simulation and analysis the beam was still found to be unstable unless the drift tube was cutoff well above the second harmonic.

Two methods were used to calculate beam instability. The first approach was to run a particle in cell (PIC) simulation of the RF circuit and observe the growth rate of any instabilities. The second approach calculated growth rate directly from the eigenmodes of the full 6 cavity circuit. Both methods produced comparable results.

Both methods of calculating TE stability predicted periodic permanent magnet (PPM) focusing will be unstable for all practical periods and field strengths but that solenoid focusing becomes stable above approximately 300 G (the Brillioun field for this device). The beam loaded Qs from the eigenmode approach are shown in Figure 7 versus solenoid focusing field. PPM focusing will be studied further but solenoid focusing will be used for this design.

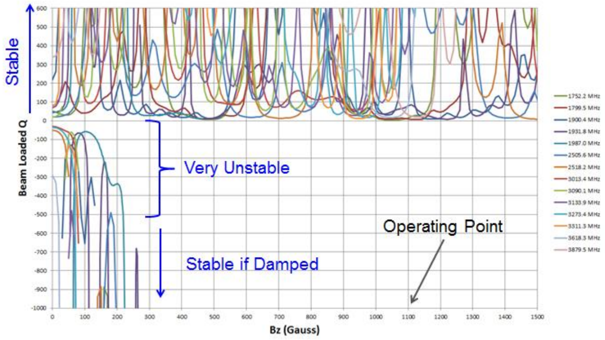

Figure 7. Beam Loaded Q Stability Analysis of 14 Trapped TE Modes in the 6 Cavity SBK. Stability is Calculated Versus the Solenoid Focusing Field.

Conclusions

SLAC is developing a 2.1 GHz, 200 kW CW, solenoid focused sheet beam klystron for the Navy's free electron laser. Simulations confirm the klystron will be stable and meet all design specifications. Mechanical design and drafting are underway and parts will start being machined in January.

Acknowledgements

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References

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