200 kW CW Sheet Beam Klystron Research and Development

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Abstract: *Development of a 200 kW CW sheet beam klystron for the Office of Naval Research. Specifications, beam stability, and cathode bell jar testing are discussed.*

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].

The klystron was designed to operate in air with PPM focusing. The drift tube was cutoff to the fundamental to mitigate the risk of TE mode instabilities [2]. Further simulation indicated that TE modes would cause beam interception until the drift tube was cut-off to the second harmonic, ~4.3 GHz. Ultimately, solenoid focusing was used to stabilize the beam and to maintain the original design goals and beam parameters, as shown in Table 1.

Table 1. Klystron Design Goals

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 (%)	65

The mechanical design for the sheet beam klystron (SBK) is nearly complete and is shown in figure 1. Drawings for the gun have been completed and several of the gun components have been fabricated. The solenoid, shown in yellow, is an existing solenoid used by the SLAC accelerator gallery klystrons, but with a slightly modified entrance and exit pole piece to minimize beam rotation.

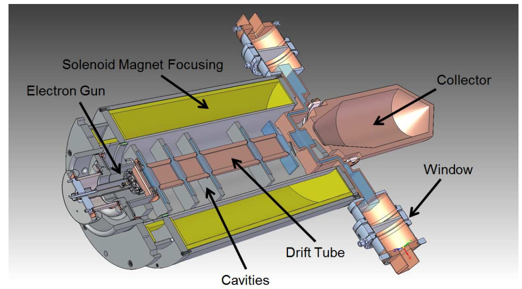

Figure 1. 3D Mechanical Assembly of the Sheet Beam Klystron.

Electron Gun Design

The electron gun was simulated in 3D using MICHELLE as shown in Figure 2. The resulting beam was laminar and met all specifications. Additional MICHELLE simulations were done in the presence of solenoid focusing and predict ~100% transmission.

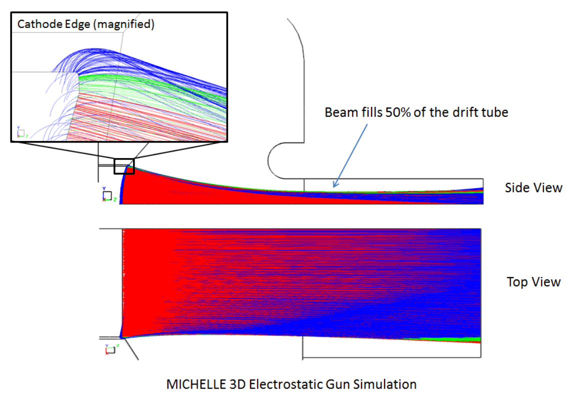

Figure 2. MICHELLE 3D Sheet Beam Gun Simulation Achieving 10A at 36kV.

RF Design

Figure 3 shows the final 3D RF simulation of the 6 cavity SBK. The beam from the 3D MICHELLE gun simulation was imported into MAGIC3D and transported through the 3D solenoid field simulated by MAXWELL. The 3D simulation predicted ~100% transmission and achieved the desired 200 kW of output power at an efficiency greater than 60%.

Work supported in part by US Department of Energy under contract DE-AC02-76SF00515.

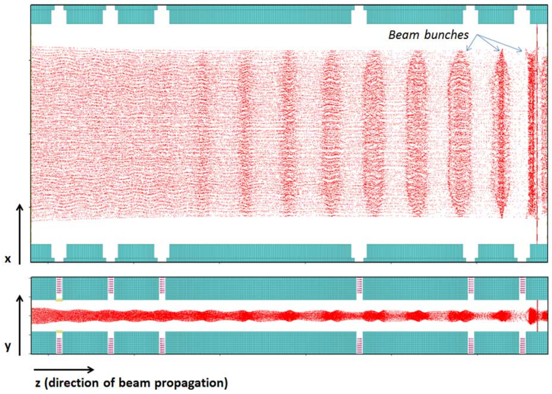

Figure 3. MAGIC3D Particle-In-Cell Simulation of the Solenoid Focused 6 Cavity Klystron Predicting 200kW of Output Power at Greater than 60% Efficiency.

Cathode Bell Jar Testing

The cathode (Figure 4) was delivered by Spectra-Mat and bell jar tested (Figure 5) at SLAC with the focus electrode and support assembly. The measured temperature variation on the cathode face was less than 2 degrees Celsius, which was consistent with ANSYS simulation.

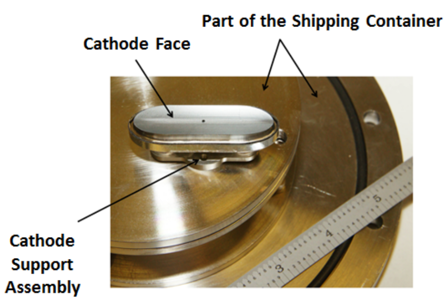

Figure 4. 4:1 Aspect Ratio Sheet Beam Cathode.

Figure 6. Top-Down View of the Cathode Face and Focus Electrode During Bell Jar Testing.

Beam Instability Analysis and Mitigation

TE mode instability is a critical issue in sheet beam klystrons [2] which wiggle the beam in the transverse direction (Figure 7) and ultimately cause beam interception.

The growth rate of different TE modes were analyzed and shown to be stable or damped out by the circuit material when a strong solenoid focusing field is used (Figure 8).

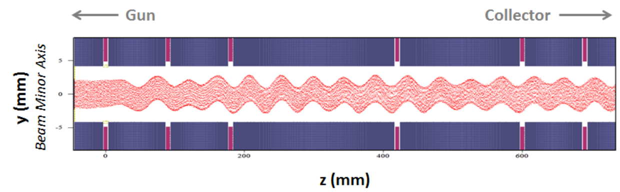

Figure 7. Transverse Deflection of the Electron Beam by a Trapped TE Mode.

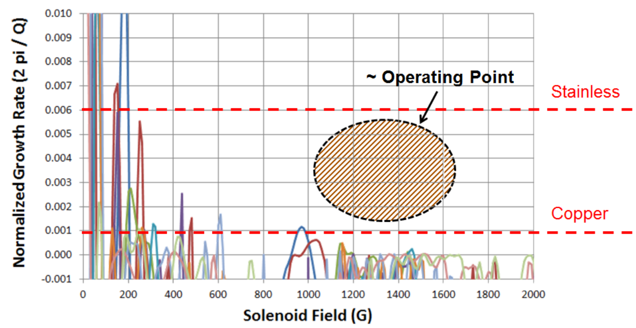

Figure 8. Growth Rate Analysis of 14 Trapped TE Modes in the 6 Cavity SBK. Stability is Calculated Versus the Solenoid Focusing Field.

Conclusions

SLAC has nearly completed both the electrical and mechanical design for a 2.1 GHz, 200 kW CW RF source for the Office of Naval Research. Bell jar testing of the cathode has been completed and PIC simulations predict the sheet beam klystron will achieve all desired specifications. The drift tube is cutoff to the fundamental operating frequency but suffers from TE mode instabilities if PPM focusing is used. The final design uses confined flow solenoid focusing to suppress TE mode oscillations.

Acknowledgements

The authors wish to thank Dr. Quentin Saulter and the Office of Naval Research for their support of this project.

References

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2. Bane, K., A. Jensen, Z. Li, G. Stupakov, and C. Adolphsen, "Sheet Beam Klystron Instability Analysis," *SLAC-PUB-13602*, May 2009.