DEVELOPMENT OF A 10 KW CW, S-BAND, PPM FOCUSED KLYSTRON

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Abstract

This paper describes a 10 kW CW, S-Band klystron that is being developed for use in high energy accelerator applications. Focusing for the beam is provided by a PPM structure. The principal components of the device, including the RF structure, electron gun, and magnetics are described.

INTRODUCTION

Calabazas Creek Research Inc. (CCR) on a DOE SBIR Grant is developing a 10 kW CW, 2.815 GHz klystron for driving accelerators with superconducting cavities. The klystron will use periodic permanent magnet (PPM) focusing, thus avoiding the usual loss in efficiency due to the power required for a solenoid. The PPM structure elements, in lieu of the generic "C-shaped" magnets that enclose the circuit cavities, will be formed by four disk (pill box) magnets with a clover-leaf shaped iron pole piece. The azimuthal gaps between the magnets permit the introduction of liquid cooling directly into the seven individual cavities of the RF circuit. A solid model of the klystron is shown in Figure 1 .

RF STRUCTURE

The RF circuit is designed using the large signal codes KLSC and TESLA[1]. KLSC is a fully relativistic code employing an eight deformable ring electron beam traversing an N-cavity interaction circuit. The cavity electric fields as calculated using SUPERFISH are inputted directly, thus eliminating the need for approximation of the electron beam – wave interaction using analytical algorithms. TESLA is a fully relativistic, large signal code capable of including the actual magnetic field from the PPM structure and providing accurate modeling of electron beam injection and trajectories. Simulations using both codes indicate that seven cavities will provide an efficiency of 61% with a beam perveances of 0.35 micropervs at a beam voltage of 20 kV. The predicted saturated gain is 52 dB. We are employing a six cavity bunching circuit with a single, thermally robust, output cavity. For the bunching circuit, there is an input cavity, two gain cavities and three

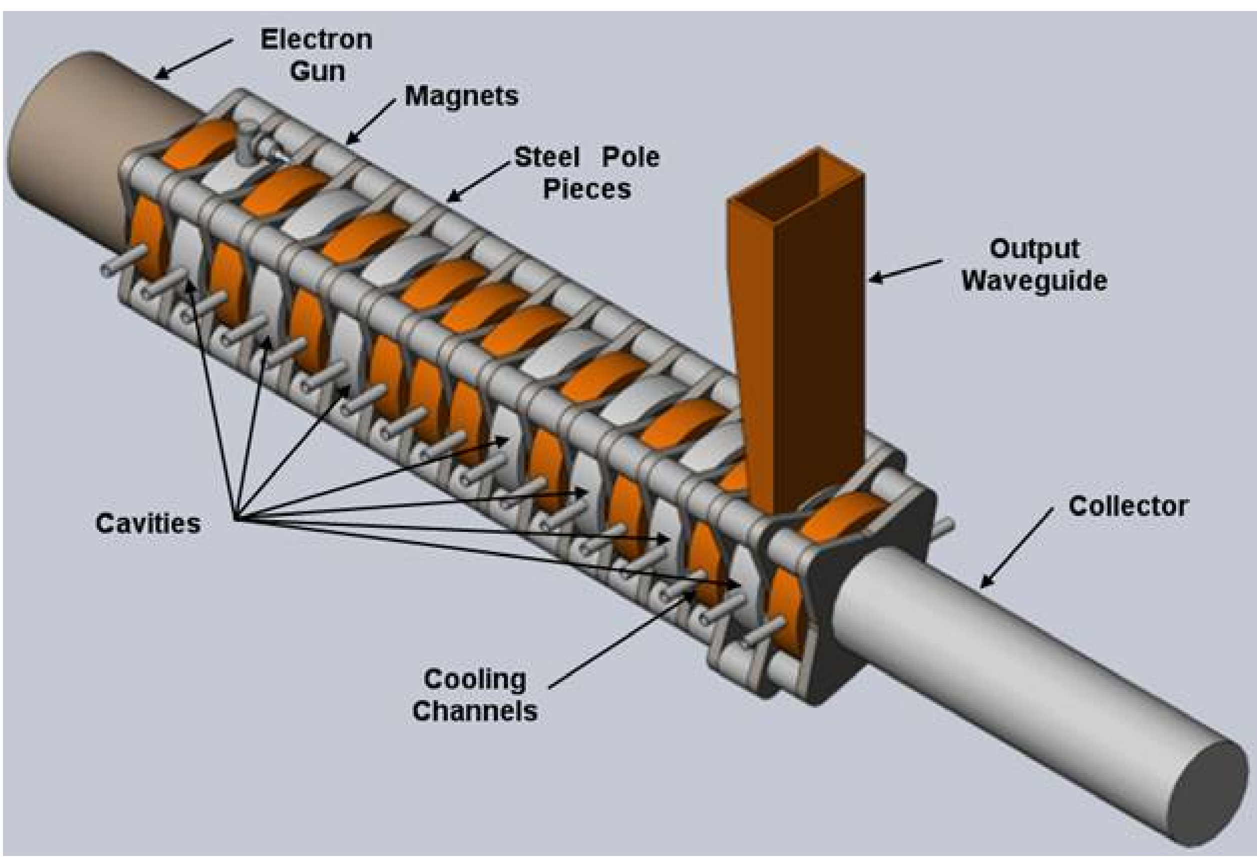

Figure 1: Solid model of the 100 kW S-Band klystron.

inductive cavities tuned above the band for efficiency enhancement. These three inductive cavities reduce cavity gap voltages and, in addition, increase the "thermal efficiency" by spreading the absorbed RF power over larger area.

The performance predicted by both KLSC and TESLA is given in the following:

Beam Voltage	20 kV
Beam Current	1.0 A
Beam Perveance	0.35 micropervs.
Efficiency	61%
RF Output Power	12.3 kW
Saturated Gain	52 dB
1 dB Bandwidth	6.5 MHz
Beam filling factor	0.65
Magnetic Field	0.1 T
Thermal Efficiency	93%

ELECTRON GUN

We have employed the CCR in house 3D code Beam Optics Analysis (BOA) for simulating the electron beam through the PPM structure and for simulating the spent electron beam in the CW collector. The peak magnetic field is 1000 Gauss, which is twice the Brillouin value to insure high beam transmission. The beam filling factor is 65%. The maximum electric field is just 33% of the empirically determined maximum gradient for CW electron guns.

PPM Structure

Initially, the PPM structure was simulated using the 2D PANDIRA code from the LANL POISSON suite of codes. These simulations provided the basic geometry for the individual iron pole pieces and the approximate dimensions for the permanent magnets. These dimensions also provided the initial starting point for determining, using the MAXWELL 3D magnet code, the 4 magnets with the "clover leaf" shaped pole pieces for the final PPM structure. A quarter of the structure (as modeled) is shown in Figure 2 . Because the magnets are located well away from the center, and there is some saturation of the iron, the field near the axis is very uniform. This is shown in Figure 3.

The RF output window will be face-brazed to facilitate cooling. We will use a recently discovered low loss alumina ceramic for this window to reduce RF loss.

This CW klystron is designed for high reliability, with simple construction, robust cooling and high efficiency. We emphasize high efficiency because of the need for long life through reduced thermal loading of the RF circuit and collector.

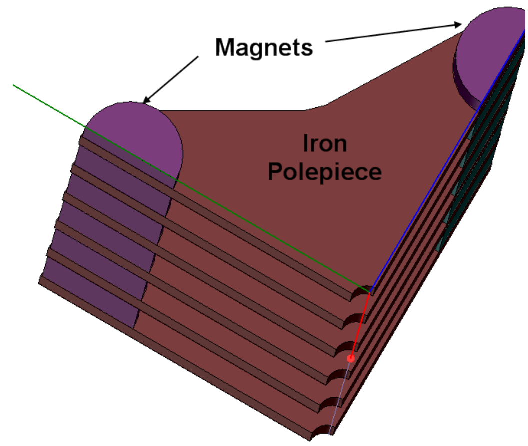

Figure 2: One quarter of a section of the PPM structure.

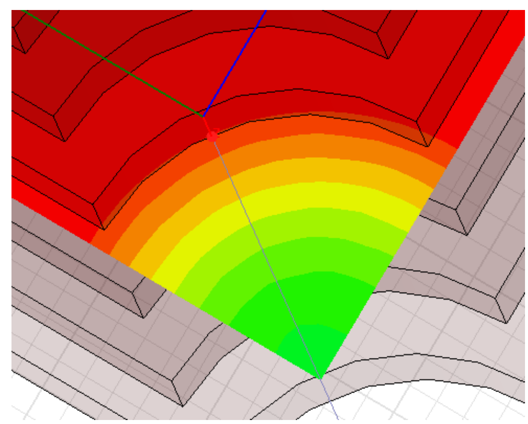
Figure 3: Plot of the magnitude of the magnetic field on a cross section of the beam tunnel showing the uniformity of the field around the azimuth. The variation of the colors shown is about 5 Gauss.

ACKNOWLEDGEMENT

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REFERENCES

[1] S.J. Cook, et al, "Validation of the large-signal klystron simulation code TESLA", IEEE Trans. Plasma Sci, Vol. 32, Issue 3, pp. 1136-1146, June 2004.