DESIGN OF AN X-BAND, 50 MW, MULTIPLE BEAM KLYSTRON

Liqun Song, Patrick Ferguson, Lawrence Ives, George Miram, David Marsden and Max Mizuhara
Calabazas Creek Research, Inc.

Abstract

Calabazas Creek Research has designed a 50 MW, multiple beam klystron (MBK) with eight separate electron beams operating at 11.424 GHz with an efficiency of 54%. The MBK will be integrated with an electron gun in development on a current U.S. Department of Energy grant. The gun is being fabricated and will be tested in July, 2003. During the initial MBK development, several circuits capable of generating an RF output power of 50 MW were investigated. These circuits included ring resonators, hybrid cavities and standard reentrant cavities. The final design included an optimized, high efficiency (54%), eight cavity, interaction circuit, consisting of a mutually coupled set of input cavities, five discrete hybrid cavities for each circuit and a mutually coupled output cavities combined to transmit the RF power through a single window.

INTRODUCTION

Design of the klystron required a number of advanced computer simulation tools. The electron gun was originally designed using TOPAZ, and this design was verified using OMNI TRAK, both 3D codes. The circuits were simulated using KLSC, a 2 1/2D large signal code and MAGIC, a 3D, particle-in-cell (PI C) code.

The electrical and mechanical design parameters for a single circuit and for the MBK are listed in Table 1.

Description	Single Circuit	MBK
Peak RF output power	6.75 MW	54 MW
Center frequency	11.424 GHz	11.424 GHz
Instantaneous bandwidth	80 MHz	80 MHz
Efficiency	52%	52%
Electron beam voltage	190 kV	190 kV
Electron beam current	66 A	66 A
Beam perveance	0.8 μ pervs	0.8 μ pervs
Pulse width	3.0 μ s	3.0 μ s
Pulse repetition rate	120 Hz	120 Hz
Duty	0.036%	0.036%
Average RF output power	2.35 kW	18.8 kW
Average beam power	4.52 kW	36.2 kW

CIRCUIT DESIGN

As originally envisioned, the MBK would use ring resonators for all cavities. This configuration offered the potential to simplify the introduction of RF power into the MBK and the extraction of the RF output power. Figure 1 shows a cross section of the arrangement.

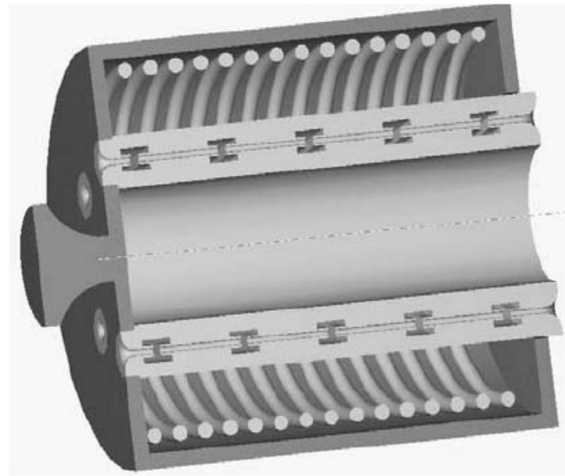

Figure 1. Solid model of multiple beam klystron with ring resonator cavities.

Simulation of a single input resonator where eight ports were introduce to accommodate the eight beams determined that the distributed shunt impedance and electric field were reduced significantly. Consequently, the effective wave-beam interaction was considerably less than the interaction for a single cavity. Extending this result to all ring resonators indicated that the saturated gain would be too low for efficient operation. Redefining the geometry increased the interaction strength but resulted in the introduction of higher order modes in the ring resonator. Adding loss to the resonator to suppress these modes was considered but rejected due to the complexity of the structure. A much simpler arrangement involves splitting the input power four times via three dB couplers and then dividing this power into two cavities. Figure 2 shows the input cavity assembly with four coax-waveguide transformers. Note that each input drives two klystron input cavities and thus the power at each port is divided to give equal power with constant phase at each beam tunnel.

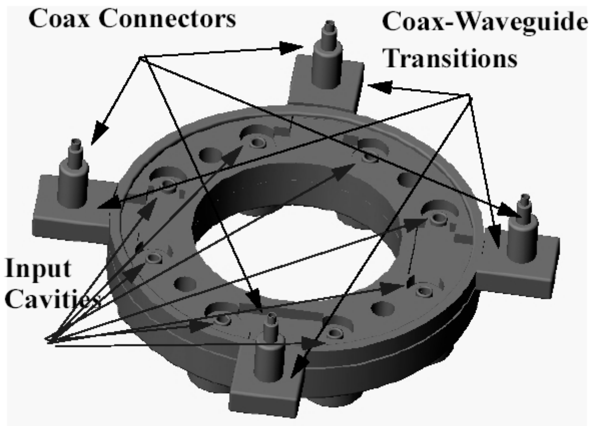

Figure 2. Input cavity assembly showing four coaxial inputs to waveguide transitions.

Bunching Circuit

The bunching circuit consists of eight sets of input cavities and five reentrant cavities. An exploded view of the bunching circuit is shown in Figure 3. The cavities and cooling holes are shown in the sections.

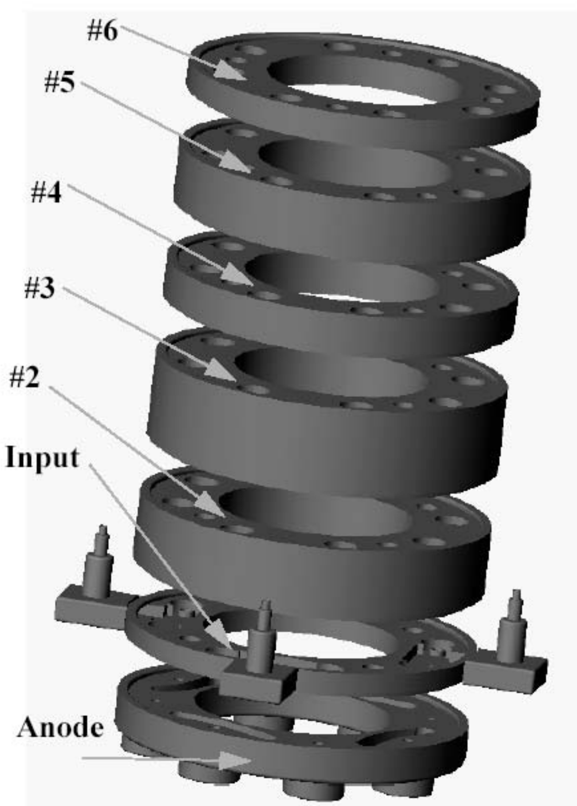

Figure 3. Exploded view of circuit assembly for first six cavities

Output Cavities

In order to extract the RF power in phase efficiently from each of the eight outputs, two different configurations were analyzed. The first configuration utilized a compact waveguide twist [1] for each cavity, each twist feeding into a common circular guide, as shown in Figure 4. An evaluation of the power handling capability of the waveguide twists is being finalized. An alternate arrangement is shown in Figure 5. This arrangement combines the RF power from each output cavity into a TM_{040} cavity, which is then coupled to a TM_{010} cavity. The RF power is then extracted into two normal waveguide twists coupled into a TE_{01} waveguide.

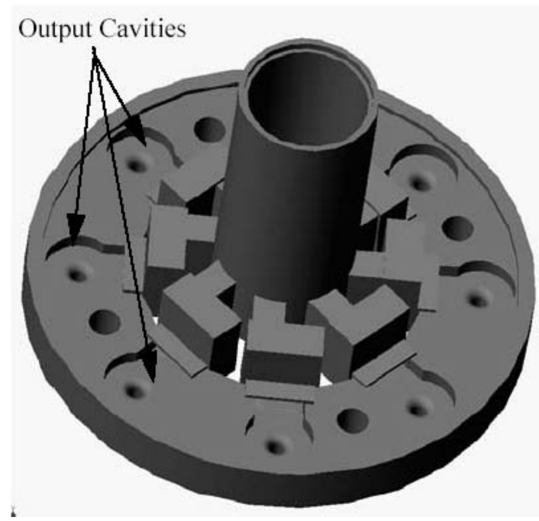

Figure 4. Output waveguide system consisting of eight waveguide twists, a TE_{01} circular waveguide, and the TE_{01} window

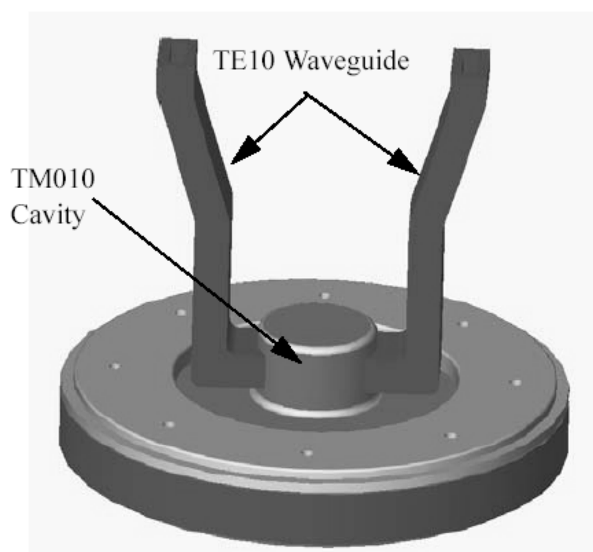

Figure 5. Output configuration consisting of TM_{040} cavity coupling to TM_{010} cavity.

A complete cross-section of the MBK with the first output circuit configuration and TE_{01} high power window is shown in Figure 6. Also shown are two individual circuits and a common electron beam collector.

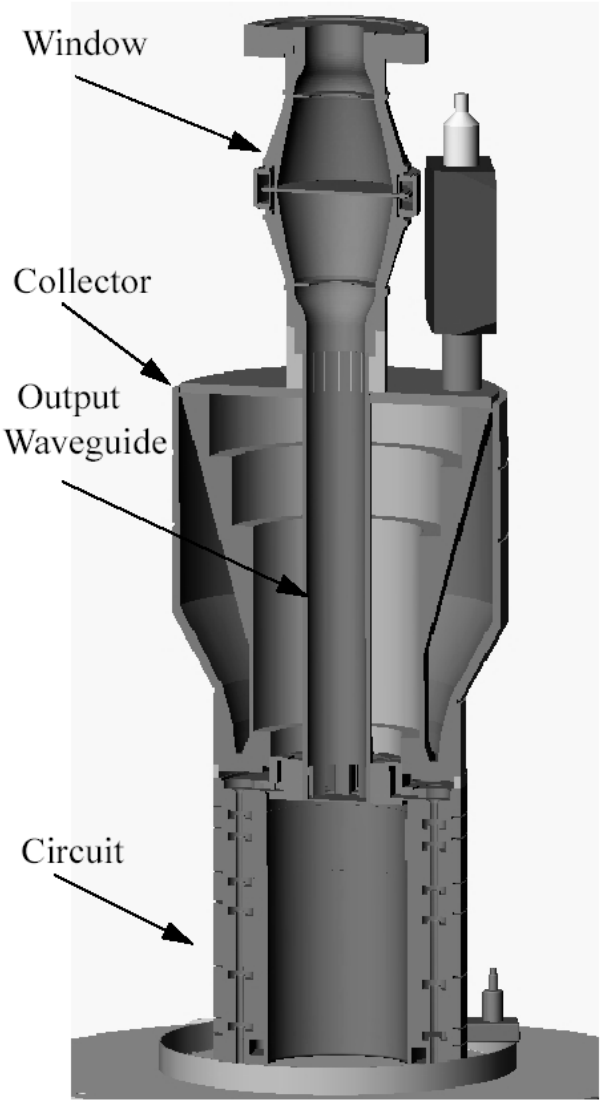

Figure 6: Cross-section of MBK

SUMMARY

Initial design was completed for a 50 MW multiple beam klystron at 11.424 GHz. The klystron is designed to incorporate and eight beam gun currently being constructed. The predicted performance of the klystron meets or exceeds the goals of the program. Successful construction and test of this klystron would represent a significant advance in RF source technology and could facilitate the development of new accelerator and collider systems.

ACKNOWLEDGEMENTS

This research was funded by U.S. Department of Energy Small Business Innovation Research Grant Number DE-FG03-02ER83379.

REFERENCES

[1] Uwe Rosenberg, Jens Bornemann, Smain Amari, "A compact and Broadband 90-Degree Waveguide Twist Transformer for Integrated Waveguide Systems," http://www.ece.uvic.ca/~jbornema/Conferences/087-01eumc-rba.pdf