A Modular 5 MW X-Band Multi-Beam Klystron

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Abstract: *A novel modular combining scheme for multi-beam klystrons (MBK) is proposed and applied to the development of a 5 MW X-band MBK.*

Keywords: multi-beam; klystron;

Introduction

SLAC is developing a 16 beamlet X-band multi-beam klystron capable of delivering 5 MW of peak output power. In this design each beamlet has its own output cavity which feeds power into a waveguide combining scheme as shown in Figure 1. Since the beamlets do not share a common output cavity they can be individually designed as a single beam klystron in isolation and then combined later at a rate of $(2N)^2$ beams to achieve the desired total output power. This approach is based on the research done for the delay line distribution system pulse compression scheme developed at SLAC [1].

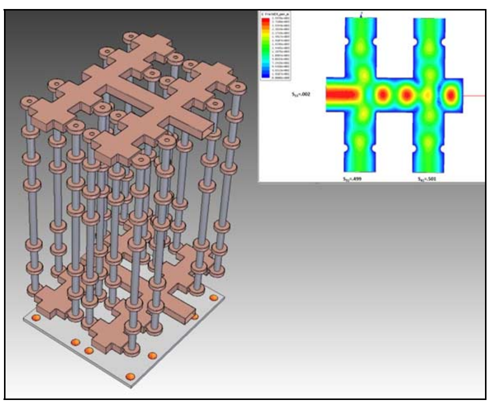

Figure 1. 3D Mechanical Layout Showing 16 Six Cavity Klystrons and Combining Scheme.

The specifications for the 5 MW X-band MBK is given in Table 1. The beam voltage is limited to 60 kV so that the MBK can run in air. At this design voltage and assuming periodic permanent magnetic focusing (PPM), a minimum number of 16 beamlets is required to achieve the desired efficiency.

Table 1. Klystron Design Specification

Beam Voltage (kV)	60
Beam Current (A)	8.8
Frequency (GHz)	11.424
Output Power (MW)	5
Beamlets	16
Beam Focusing	PPM
Cathode Loading (A/cm^2)	< 10
Efficiency (%)	60+

Electron Gun Design

The electron gun is a pierce gun designed in EGUN (Figure 2). A compression of ~40 was used to minimize the loading on the cathode.

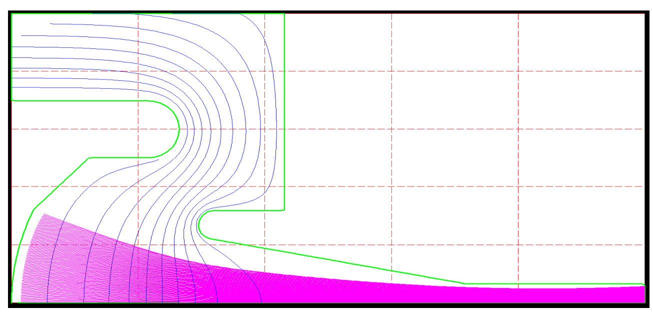

Figure 2. Pierce Gun Design as Simulated in EGUN.

Circuit Design

Optimization of the design was first accomplished in one dimension using AJDISK. The preliminary design optimization showed that a relatively high magnetic field and short PPM period would be required. To accommodate both these requirements the iron in the PPM stack will be coated with copper so that it can double in functionality as a cavity wall. Figure 3 shows the final cavity geometry in Superfish and Figure 4 shows one period of the PPM stack. In these images it can be seen that the cavity fits into the void between pole pieces in the PPM period.

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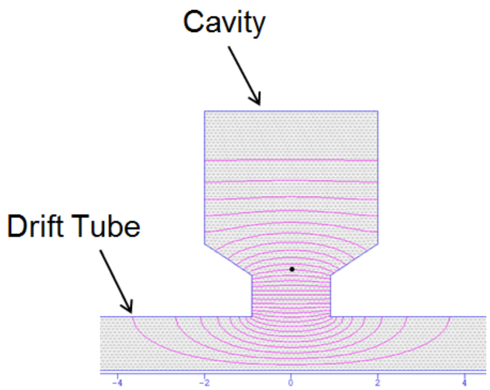

Figure 3. RF Cavity Geometry.

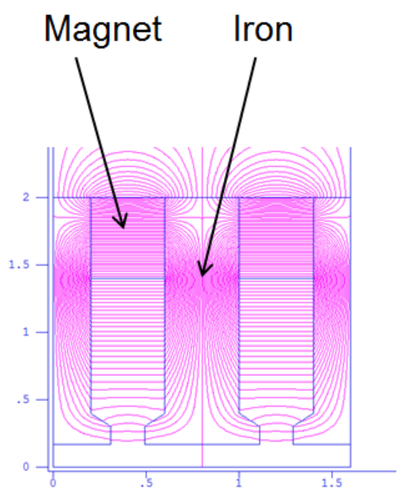

Figure 4. One Period of the Periodic Permanent Magnet (PPM) Design.

The next step in the circuit design is to optimize the field strength in the PPM field as a function of position to match the increasing charge density in the beam as it bunches. Figure 5 shows the preliminary PPM field profile with respect to the Brillouin field. This field was used in MAGIC2D to evaluate the transport of the beam through the circuit with RF as shown in Figure 6.

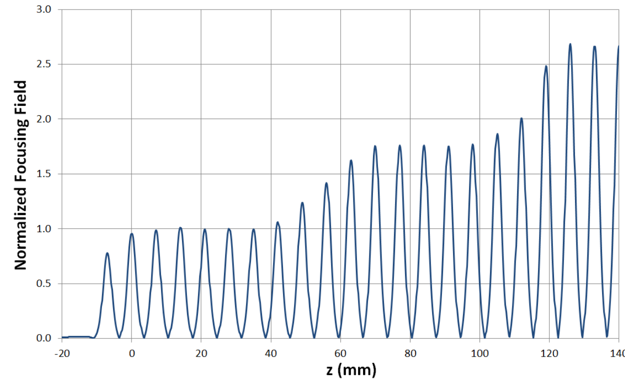

Figure 5. PPM Field Magnitude Normalized by the Brillouin Field.

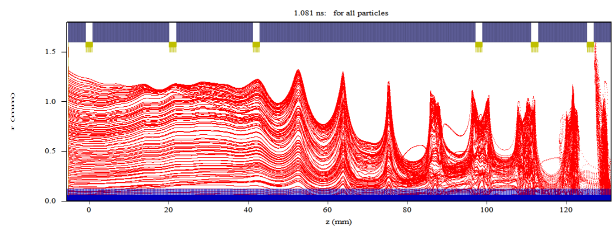

Figure 6. MAGIC2D Particle-In-Cell Simulation of the PPM Focused 6 Cavity Beamlet.

Conclusions

SLAC is developing a 16 beamlet X-band multi-beam klystron capable of delivering 5 MW of peak output power. By using a novel modular combining scheme each beamlet can be designed in isolation and combined as $(2N)^2$ to achieve the desired output power. After the tube has been hot tested it will be extended to higher power levels, with the next target being 50 MW.

Acknowledgment

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References

1. S. G. Tantawi et. al., "Multimoded RF Delay Line Distribution System for the Next Linear Collider," *Physical Review ST Accel. Beams 5*, 032001 (2002).