Calabazas Creek Research, Inc.

High Efficiency RF Source Developments

Lawrence Ives,
Calabazas Creek Research, San Mateo, CA. USA

- 100 kW, 1.3 GHz Magnetron w/ Phase & amplitude control
- 100 kW, High efficiency, L-Band klystron
- 200 kW S-Band Multiple Beam High Efficiency Klystron
- 16 MW S-Band Multiple Beam High Efficiency Klystron
- 10 MW L-Band Annular Beam Klystron
- 350 – 700 MHz, 200 kW Power Grid Tube RF sources
- 700 MHz Multiple Beam IOT

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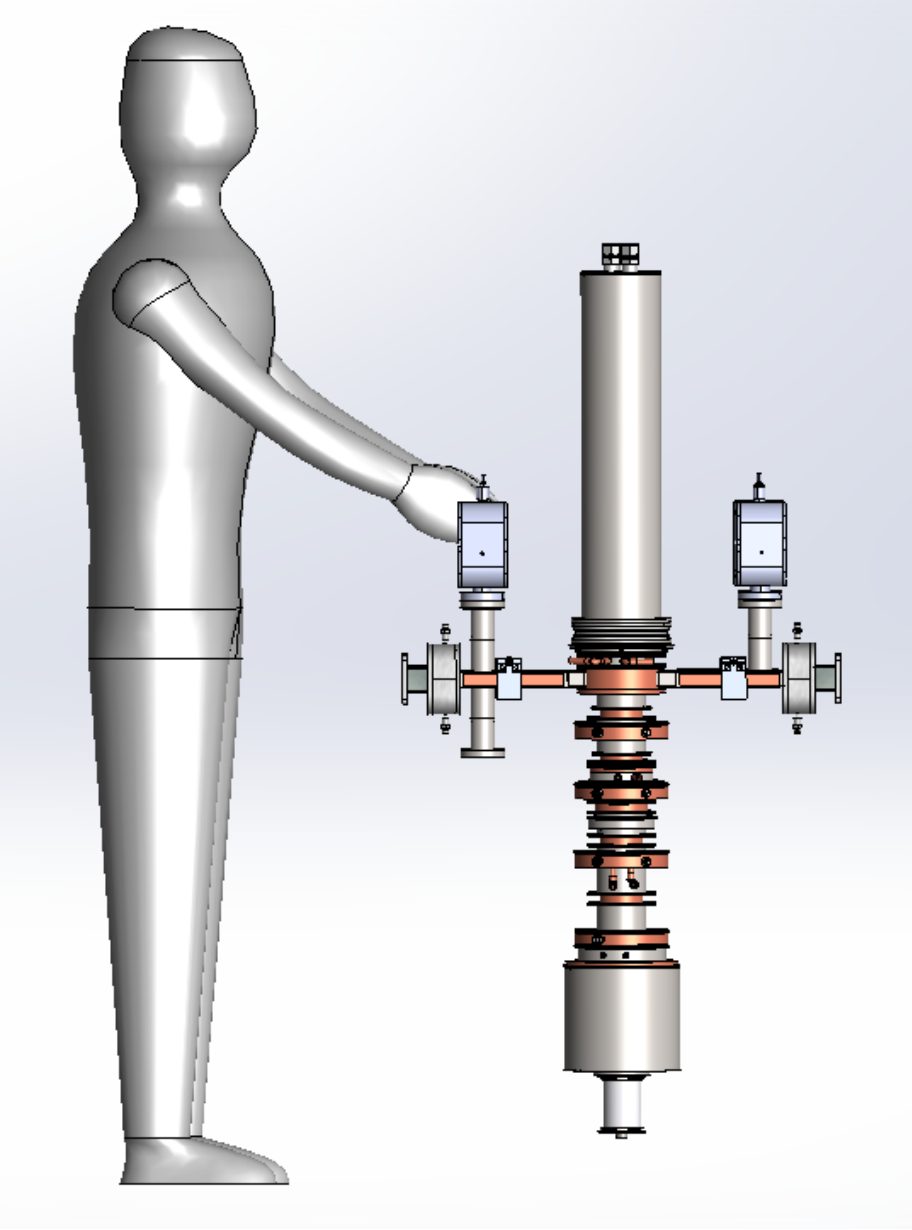
200 KW CW, S-Band MBK

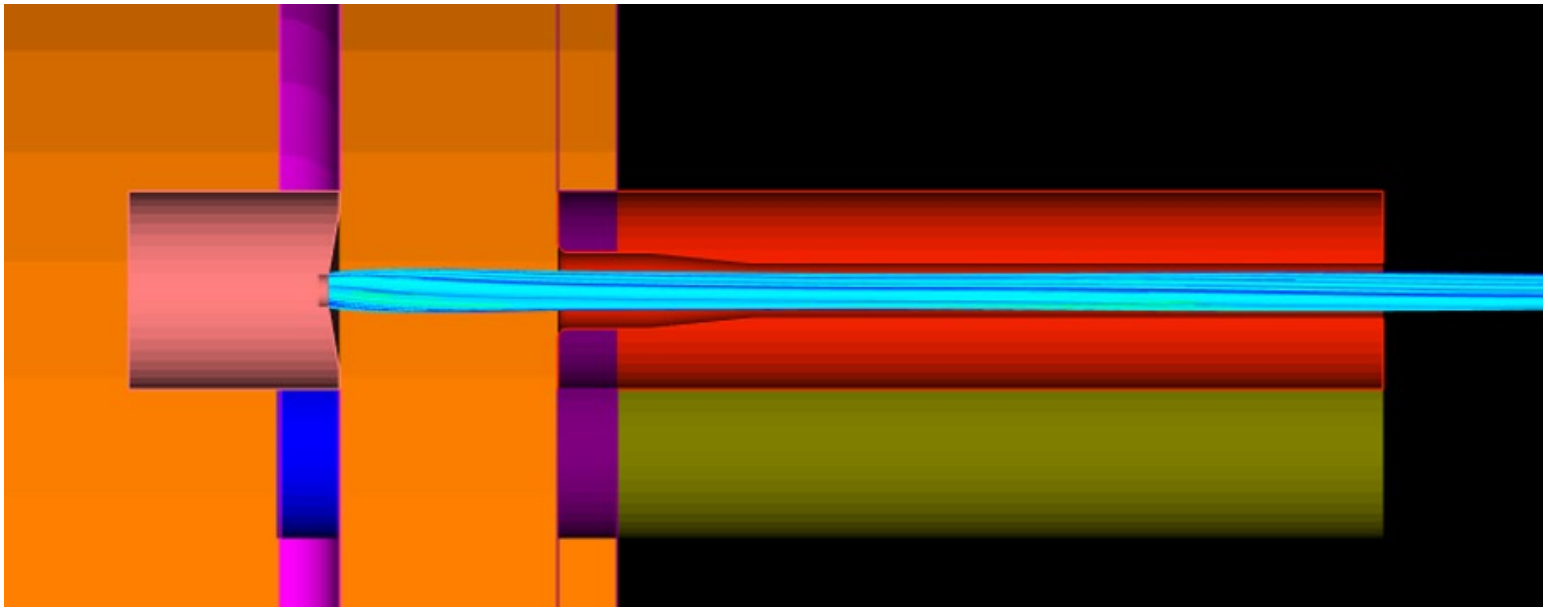
- Core Stabilization Method
  - 5 fundamental cavities
  - 2 2nd harmonic cavities
  - 1 3rd harmonic cavity
- 6 beams
- Two outputs for field symmetry in output cavity
- Goal efficiency – 80%



DOE Grant No. DE-SC0023803

Electron Gun Design

- Final design in 3D with Beam Optics Analyzer
- Zero compression to improve beam quality
- 9.8 A/cm^2 cathode loading higher than optimum

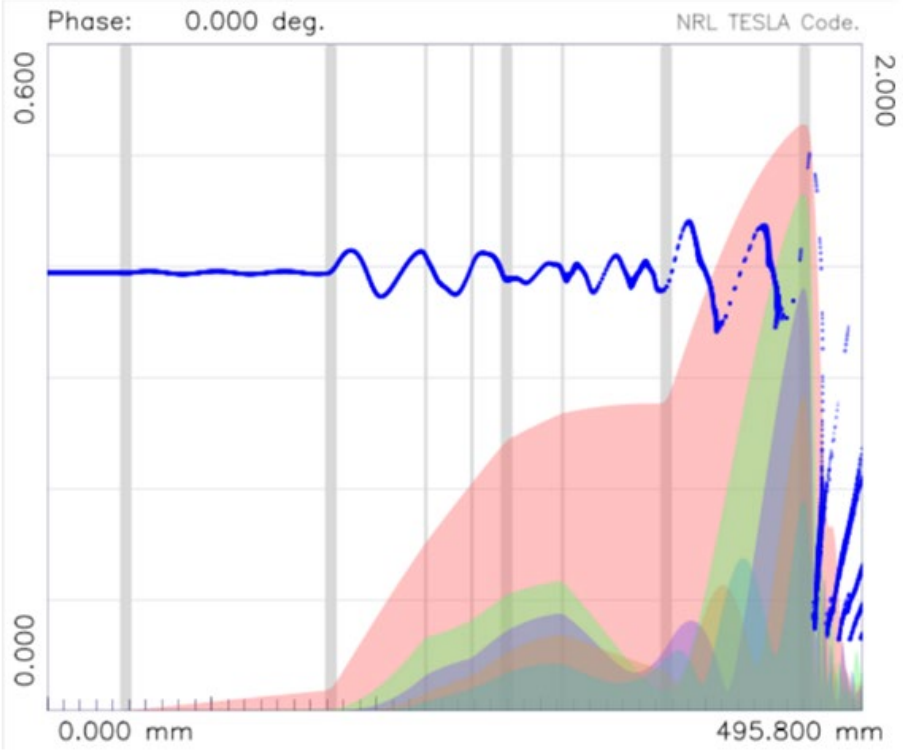


RF Circuit Design

Analyzed using HFSS, KlyC (81%), and Tesla (79%), Ansys

Challenges:

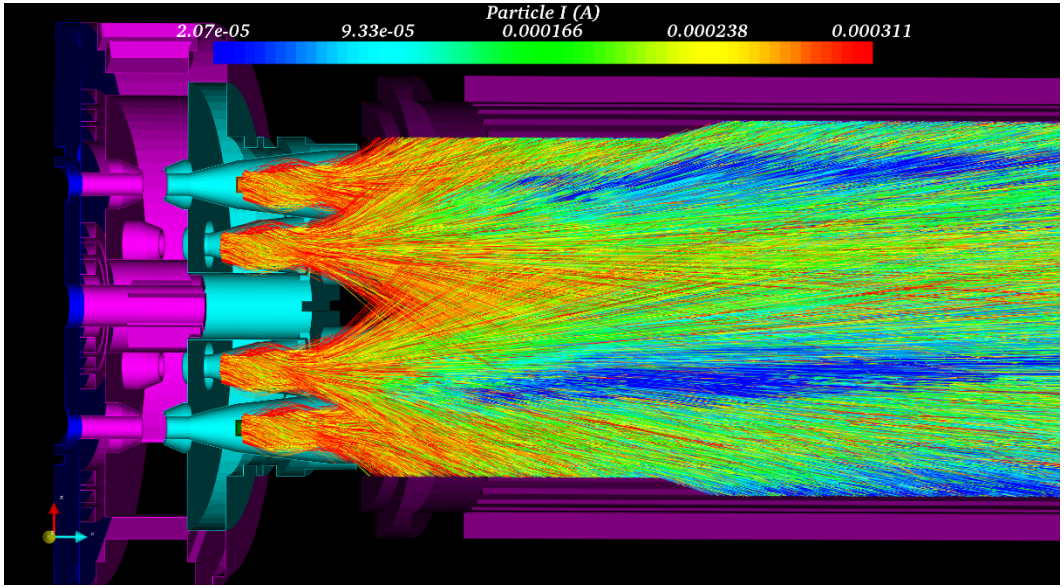
- Alignment of beam, circuit and magnetic field
- Cavity frequency accuracies
  - Stub tuners in most cavities
  - Bellows tuners in three cavities
- Thermal loading in output cavity



Normalized beam velocity, beta, and RF current (solid curves)

Collector

- Significant power loading early in collector
- Consideration for space charge depression due to high efficiency (low axial velocity)



Program Status

- Design complete
- All long lead-time parts on order
  - electron gun (due April)
  - HV & window ceramics (due March)
- Remaining parts due by end of April
- Solenoid out for quote
- Anticipate tests in early-mid summer

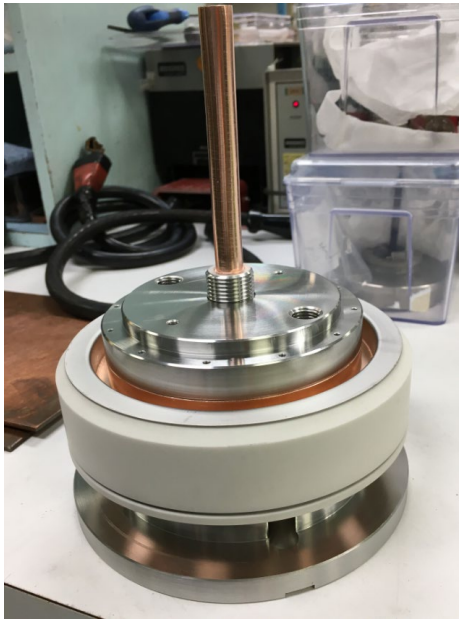
16 MW, S-Band MBK

- New program starting next week
- 2.856 GHz, ~10 µsec, 30 kW average power
- Efficiency goal – 60%
- Goal 80 MW with pulse compression

Calabazas Creek Research, Inc.

Multiple Beam Power Grid Tubes

Lawrence Ives, Michael Read, James M. Potter, David Marsden,
Thuc Bui, Ricky Ho, Tom Cox,
Calabazas Creek Research
Microwave Power Products, Inc.
JP Accelerator Works

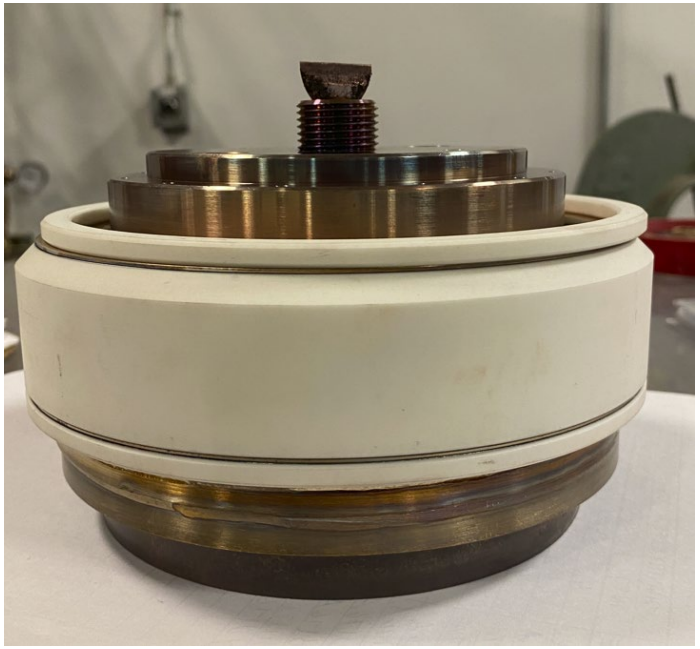


This research funded by DOE SBIR Grant DE-SC0018838

Multiple Beam Triode for 200 KW RF Source

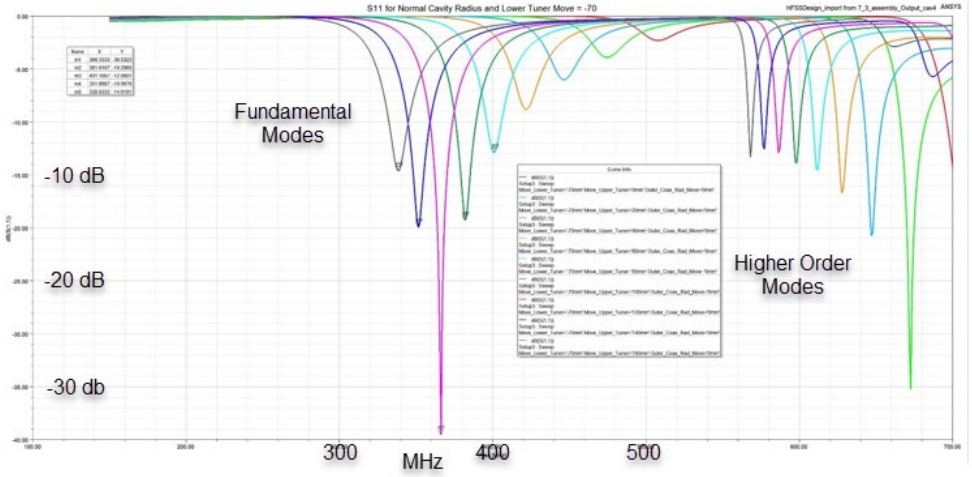
Multiple beam triode provides beam for external cavities converting beam power to 200 kW of RF power .

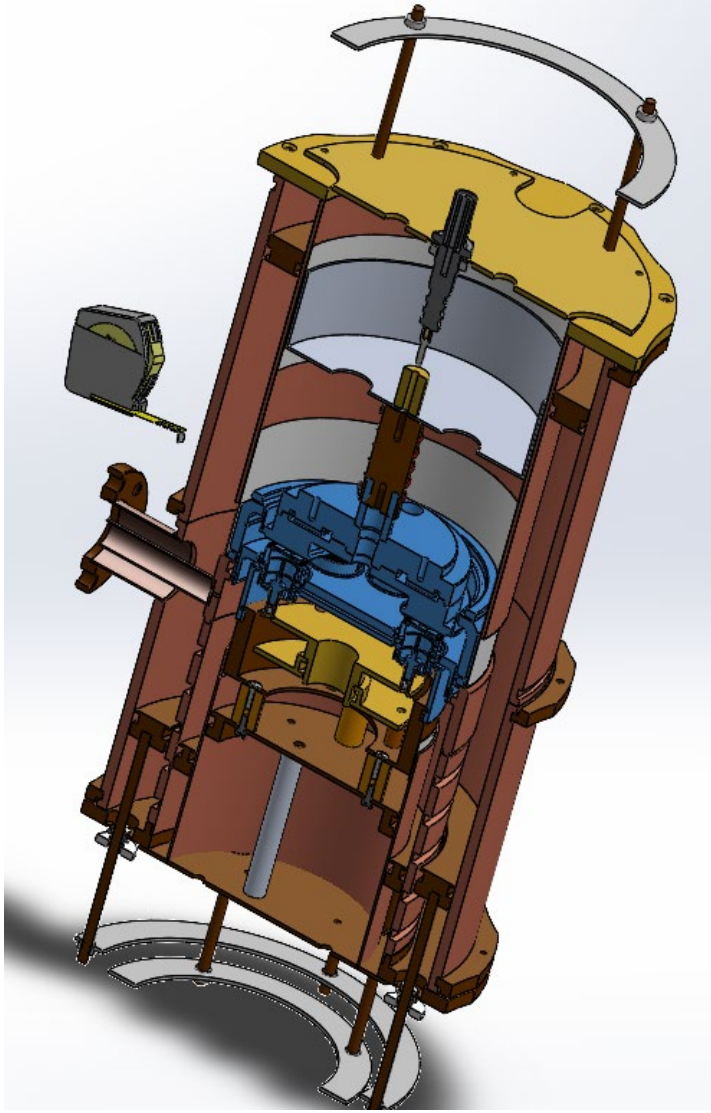
Frequency range : 300 MHz to 1 GHz



RF Cavities

- MB triode tube installs from top (blue)
- Frequency range defined by external cavities
- Cavities are NOT under vacuum and built primarily from aluminum with mechanical fasteners





Cost and Performance

Cost - < 50 ¢/watt
(Klystron ~ $4/watt
Magnetron ~$1/watt)

Performance with the driver

Power	200 kW CW
Tuning Range	350 – 500MHz
Net Gain	28 dB
Net Efficiency	>75%

Need to rebuild MB triode
Plan to extend frequency to 850 MHz

Summary

- 200 kW S-Band MBK at 80% under assembly with tests scheduled summer 2026
- 16 MW S-Band MBK design starting
- Development of 200 kW multiple beam triode in progress for low cost, high efficiency RF source in UHF frequency band up to 900 MHz.