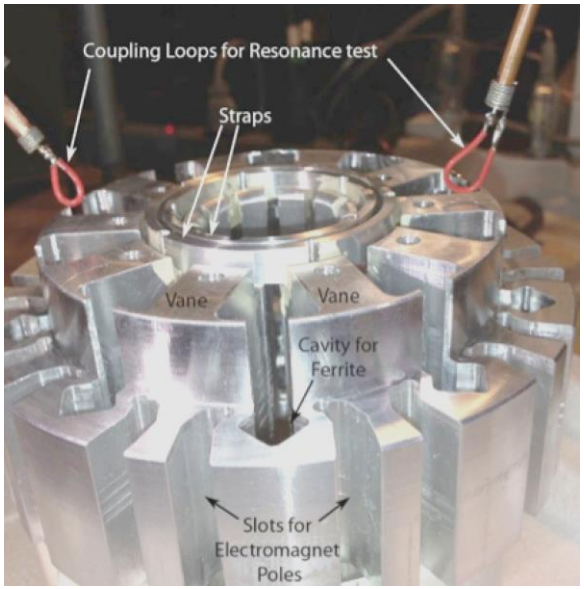
Magnetron design, development, and manufacturing by Muons, Inc.

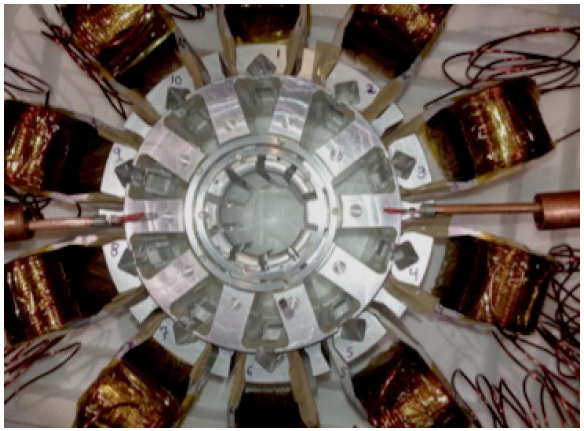
Mike Neubauer

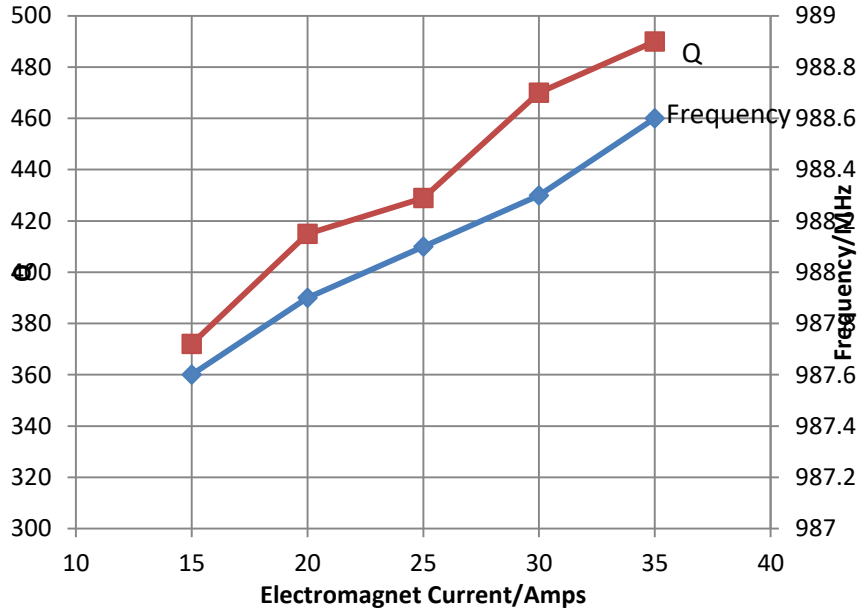
Outline

- Magnetron Programs (funded)
  - Phase I and II ferrite in cells (DE-SC0002766)
    - 2012
  - 350 MHz (Funded by Muons, Inc.)
    - 2014
  - 1497 MHz (Phase I and II: DE-SC00013203)
    - 2016
  - Office of Naval Research (N0017320C2006)
    - 2019
- Injection Locking System Requirements
- New Opportunities (2-port magnetron?)
  - SBIR Proposal

Phase And Frequency Adjustable Magnetron: DOE Phase I and II







Resonant frequency and Q of anode with G-810 ferrites in two diametrically opposite ferrite cavities vs electromagnet current. Unloaded Q was 526

Unable to minimize ferrite losses
US PATENT US2011/0254443 A1

350 MHz Magnetron

- Built to a stage that requires more funding to continue the manufacturing of a prototype
  - RF source for multiple low frequency cavities in particle accelerators
  - Replacement for Niowave's 60 kW tetrodes
  - Industrial applications in microwave heating
- Basis for multiple RF simulations (Comsol, CST)
  - Qext, Thermal, Mechanical
- Developed a team including magnetron consultants Tony Wynn, and Ron Lentz from California Tube Labs (bought by Litton Industries)
  - Used ALTAIR Technologies as the manufacturing arm

Parts Status 350 MHz

1497 MHz AM magnetron for JLAB

- AMing the magnetron with magnetic field
- Modeling the eddy currents identified a need for a bi-metallic anode.
  - patent: US 2020/0243294 A1
- Bi-metallic anode completed along with standard anode.
- Two magnetrons being built.

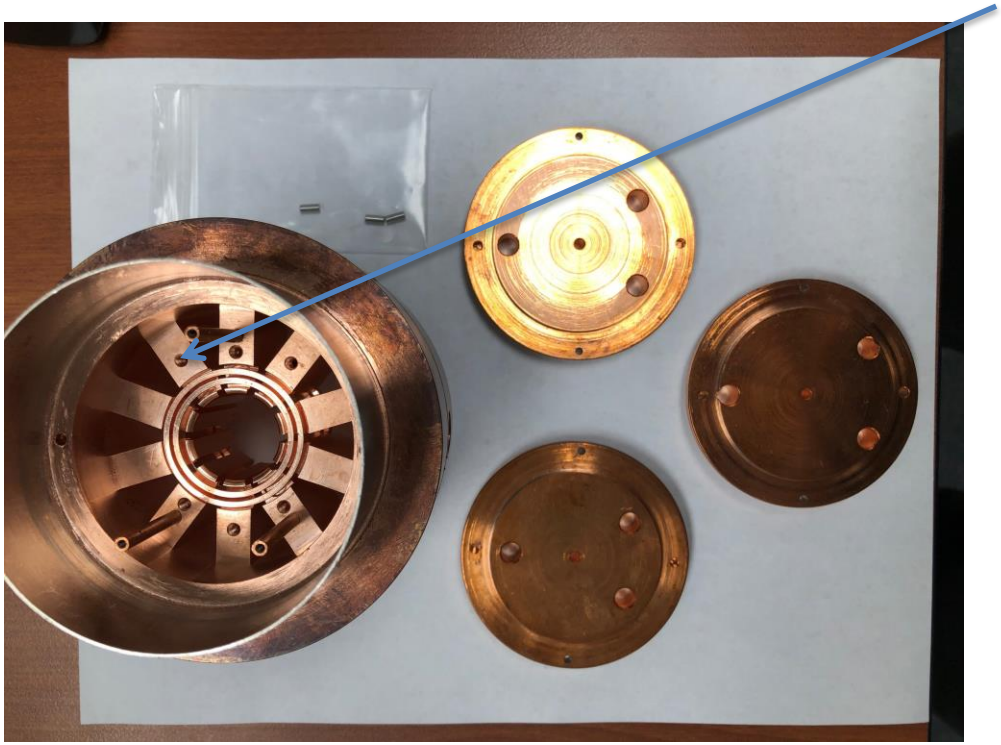
1497 MHz magnetron #1

standard all copper anode

Leak tight assembly after repair for a machining operation that put a hole in one of the water channels to vacuum.

“A problem that occasionally occurs in microwave tube manufacturing.”

1497 MHz magnetron #1



Picture from slide #16 from last years exchange meeting

The anode was already damaged. The holes used for testing Qext with antenna connections were “leakers” thru to the water channels.

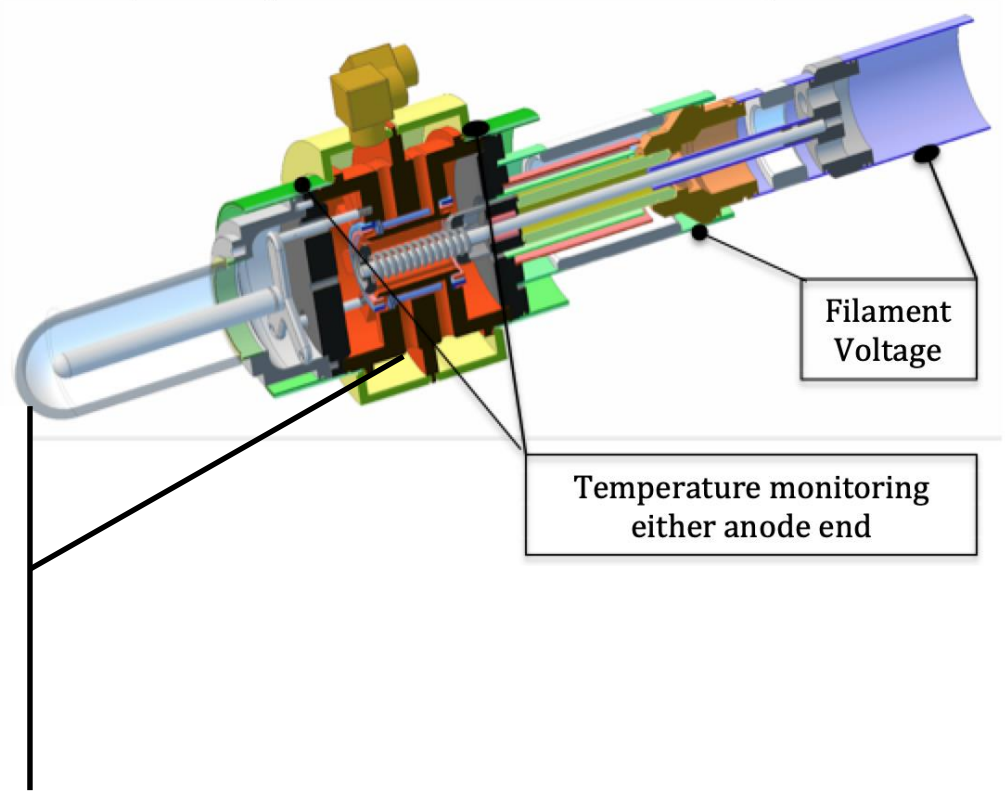
In the repair, the magnetron was taken apart and the holes plugged. The antenna posts re-attached. (Not the best but adequate.)

Demonstrating Altair’s ability to refurbish magnetrons given the type of construction the 1497 magnetron was designed for.

1497 MHz magnetron #1

Bakeout and Filament Processing

c. This process could take as long as 24 hours to allow the pressure to asymptote to less than 10^{-6} or 10^{-7} torr with the power applied to the filaments, and temperature of the anode not exceeding 500C.

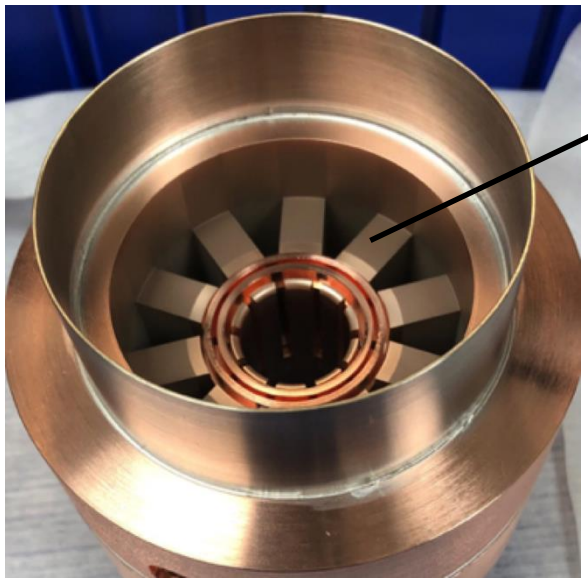


Thread a thermocouple into the water channel to monitor the temperature closest to the vane tip to prevent damage during 2000C operation of the filaments in the oven at the end of bakeout.

7.5V 75A (500-600 watts.)

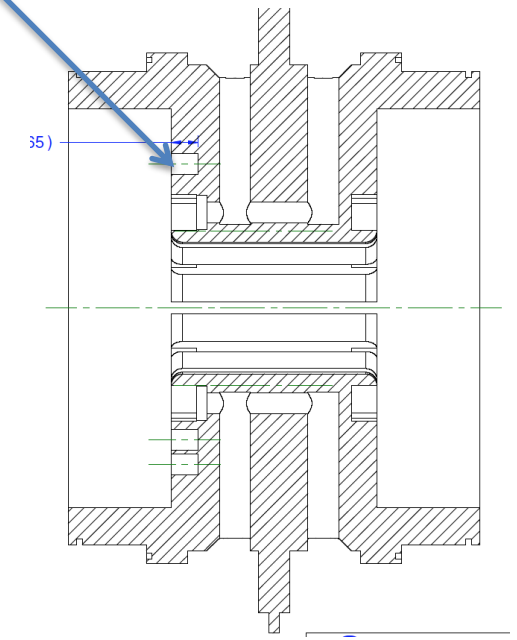
1497 MHz magnetron #2

bi-metallic anode



Ready for holes to be drilled into the vanes for the antenna connection

This will be done with adequate notification of the absolute maximum depth of the holes for the antenna connection. Discussion with machinist, etc.



Note that the copper plating was not thick enough for subsequent brazing operations, but is adequate for the next level of assembly and operation of the prototype.

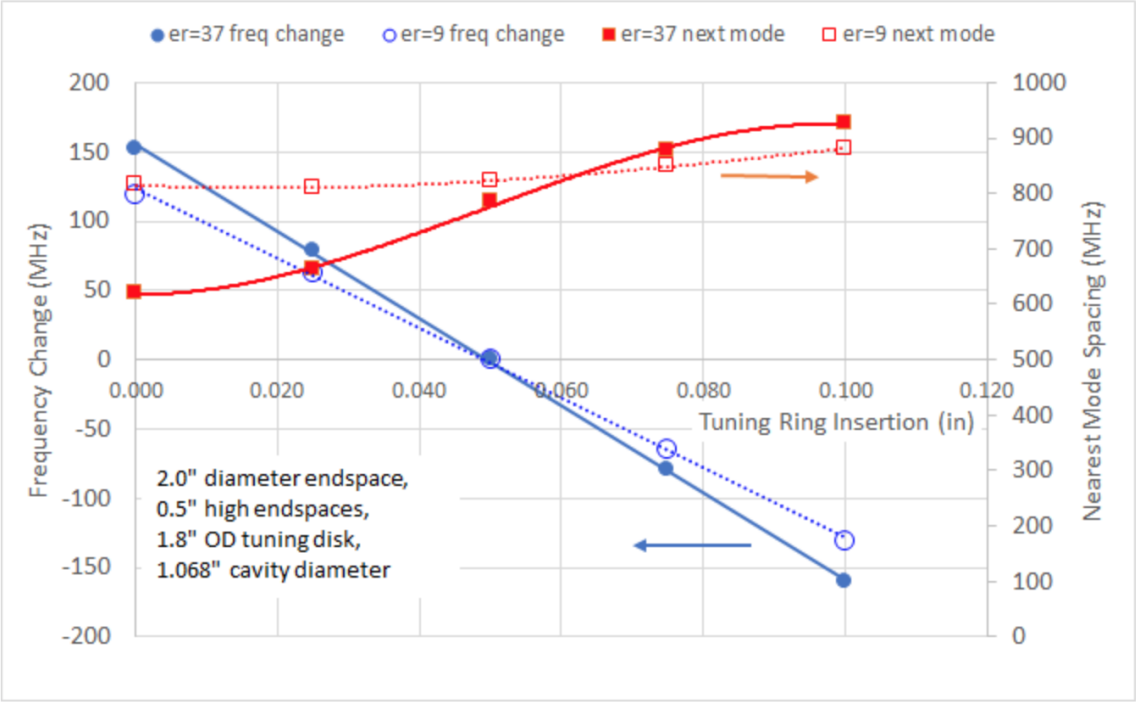
Tunable-Frequency Phase-Locked Magnetron for NRL

- N0017320C2006 is a Firm Fixed Price Federal Contract Award to Muons, Inc.
  - Dec 2, 2019 to Dec 2, 2020 current completion date ($322K)
  - If options are granted Dec 2, 2020 to Dec 2, 2021 ($620K)
- First year is design and prototype testing
- Second year is building a tube with the modifications.

Tunable-Frequency Phase-Locked Magnetron for NRL

Design completed for a tuning range of ~10% centered at ~3 GHz.

Currently procuring parts and assemblies to test the tuning range with a goal of ~1ms for frequency shift.



New Opportunities

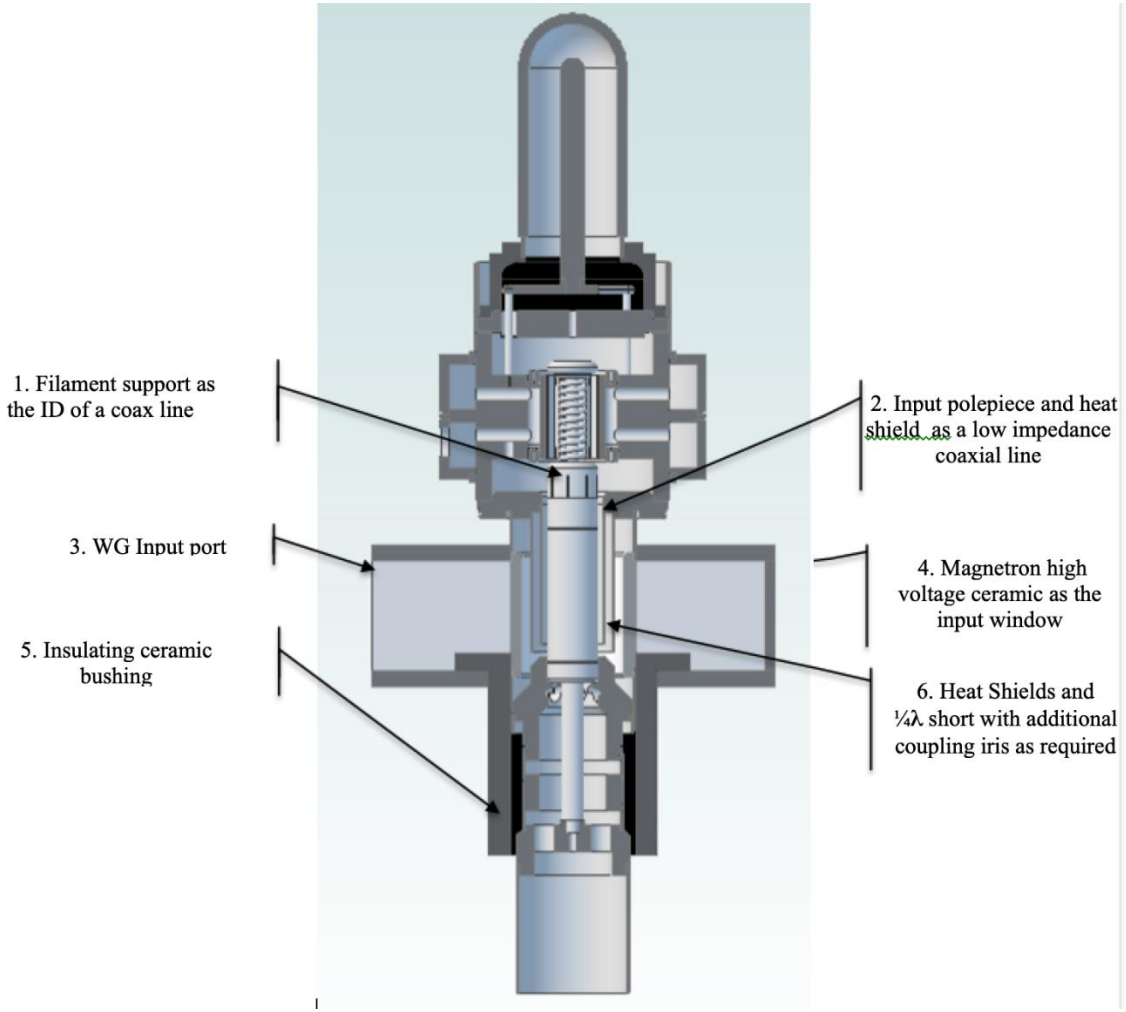
Injection-Locking requirements

- Magnetrons as replacements for klystrons in DOD or DOE systems require injection-locking systems for phase stability and >20 db gain.
- Injection-locking magnetron systems currently include two 3-port circulators (or one 4-port) capable of handling the output power of the magnetron. The magnetron is a one-port device.
- Is there a way to inject a signal into the magnetron either without a circulator or with a low power circulator at the level of the injected signal?
  - A two port magnetron? (not a CFA)

Two port magnetron (not a CFA)’

the next frontier

DOE SBIR 2020 Muons, Inc. proposal was rejected for a number of issues. We’ll continue to improve upon our ideas and re-submit.



Summary

- Two 1497 magnetrons still working their way through the manufacturing process
  - #1 will be in bakeout by the end of the month
  - #2 will be in bakeout by the end of September
- Current magnetron NRL project is on schedule in the current environment
- New projects are needed to fully implement magnetrons as kylstron replacements
  - DOD and DOE