Muons, Inc.

A novel injection-locked amplitude-modulated magnetron at 1497 MHz

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Outline

- Muons, Inc. company profile
- 1497 MHz magnetron status
- NRL 3 GHz tunable magnetron and 10 GHz phased array magnetron
- Summary

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Muons, Inc. Profile

- Muons Inc.
  - Founded by Rolland Johnson in 2002
    - subsidiaries - MuPlus, Mu*STAR
  - Funded by DOE and DOD contracts and SBIR-STTR grants
    - total of ~$30M
  - Tools and technology for particle accelerators and magnetrons
  - 8 US university and 11 national lab research partners
    - extraordinary people work with us
  - Supported 18 post-docs and 7 Ph.D. students
  - SC accelerator-driven molten-salt nuclear reactors

Work in Progress

- Contract to build an Ion Source of Deuterium and Tritium for ENEA Italy
- 3 DOE Phase I contracts 1 Phase II contract
  - NP Phase II Vadim's sheet e probe for Tomography
  - NP Phase I Vadim Microanalysis
  - NP Phase I Innovative Magnetron
- 2 DOD NRL contracts
  - 3 Ghz Tunable magnetron
  - 10 GHz magnetron for a phased array.

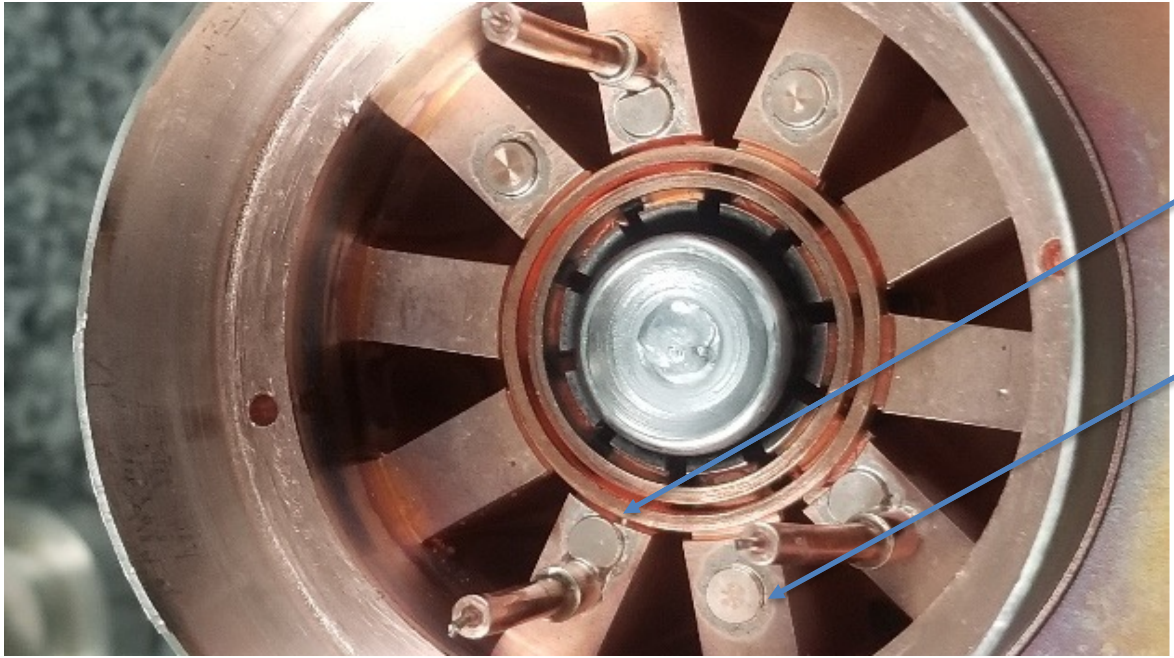
AM magnetron Phase II Plan

- Started in 2/17/2015…. NCE to 3/31/2022
- Build and test 2 magnetrons for operation at 1497 MHz:
  - All copper to verify frequency, Qext, and magnetic design
  - Bi-metallic anode to allow for khz variation of magnetic field without eddy current losses.
- AM of the output power by 1-2 db with a trim coil

Status of the 1497 MHz magnetron

- First low power tests at REL in Sept 2021 found the tube to be at 1.64 GHz.
  - The repair at Altair for a water leak had developed a short between the vane straps.
  - Removed the output window and found a braze ball between the straps and the outer wall.
  - Removed the braze ball, put the maggy back together
    - Retested with resonance at 1.53 GHz before bakeout

Shorted strap by a braze ball



This is the braze ball that was removed

These are plugs that were brazed in place to repair a machining error that caused the braze ball.

With these kinds of repairs it proves one of the advantages of magnetrons. They are relatively simple structures and can be successfully repaired.

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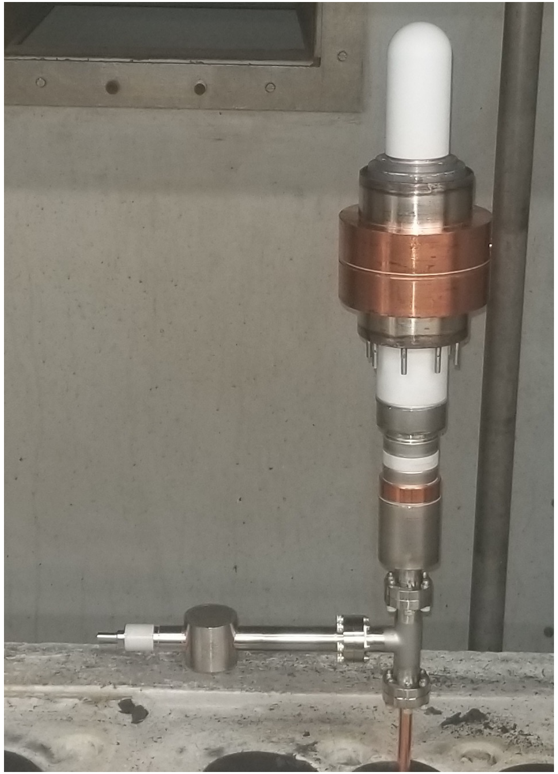
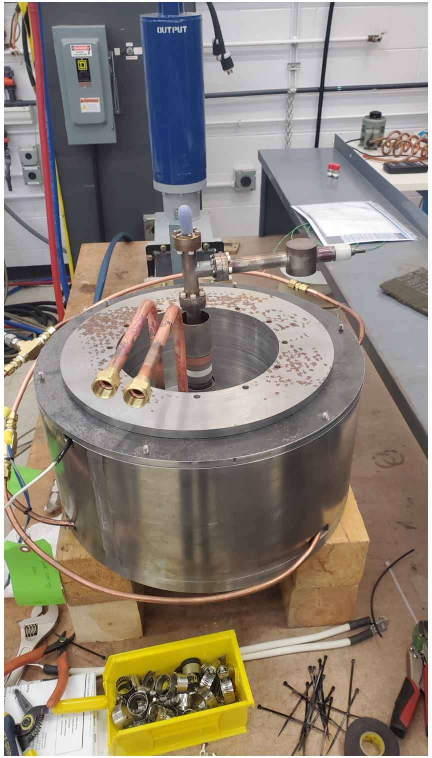
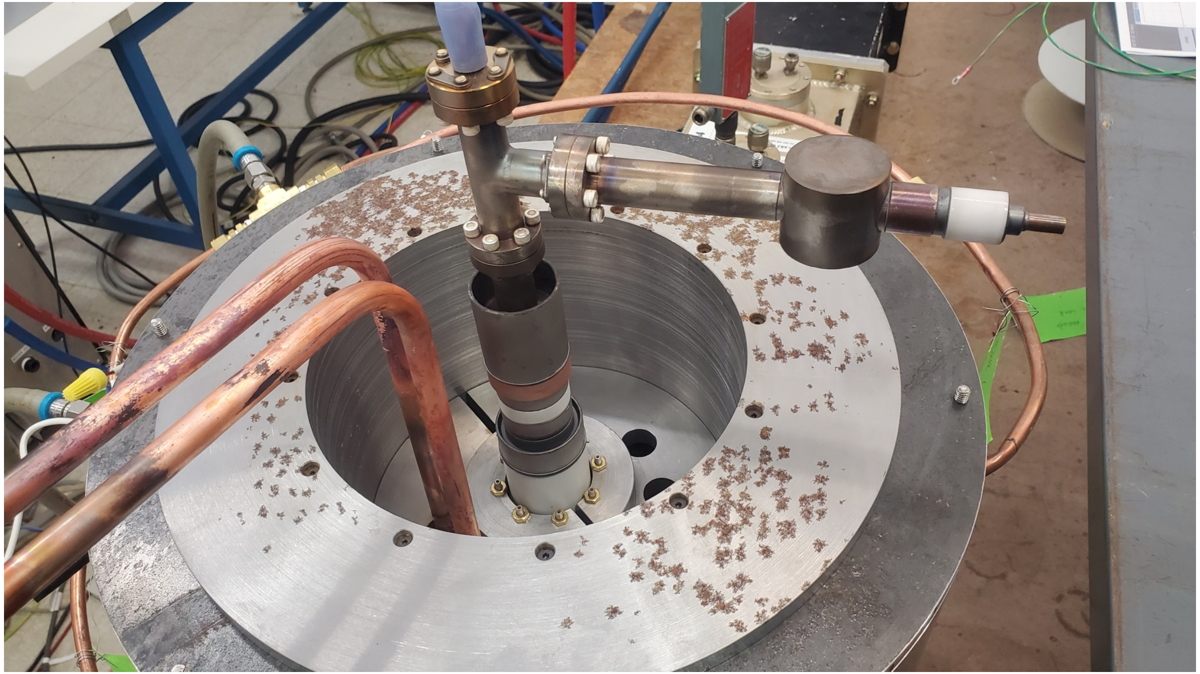
Final Bakeout and Assembly



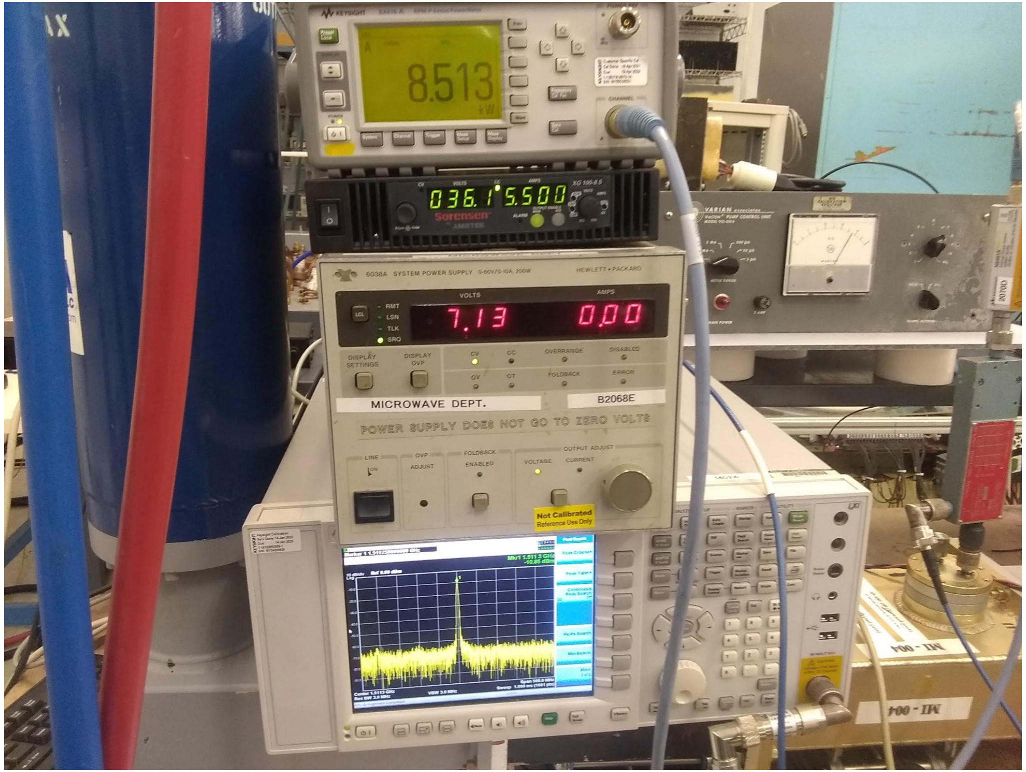
Muons, Inc. Status of the copper anode 1497 MHz magnetron



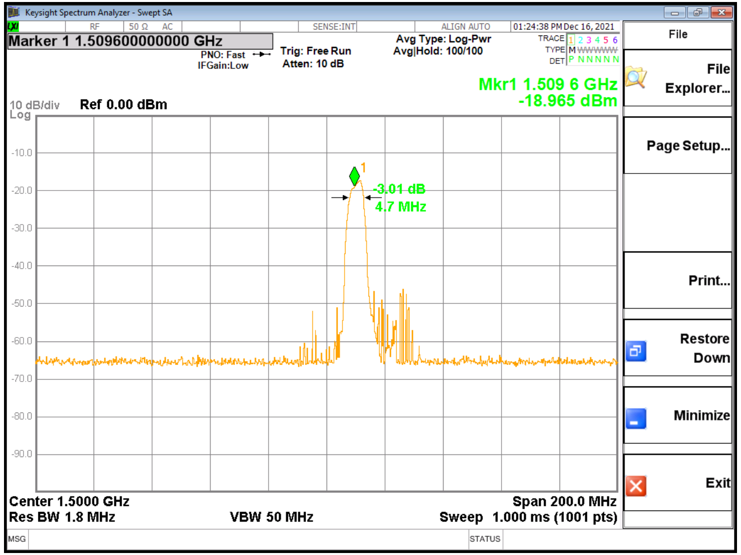
Dressing the tube in the electro-magnet. With water fittings.



Status of the copper anode 1497 MHz magnetron



Testing to 8.5 kW @ 1.508 GHz limited by power supply current capability at REL (12kV 1.6 A).

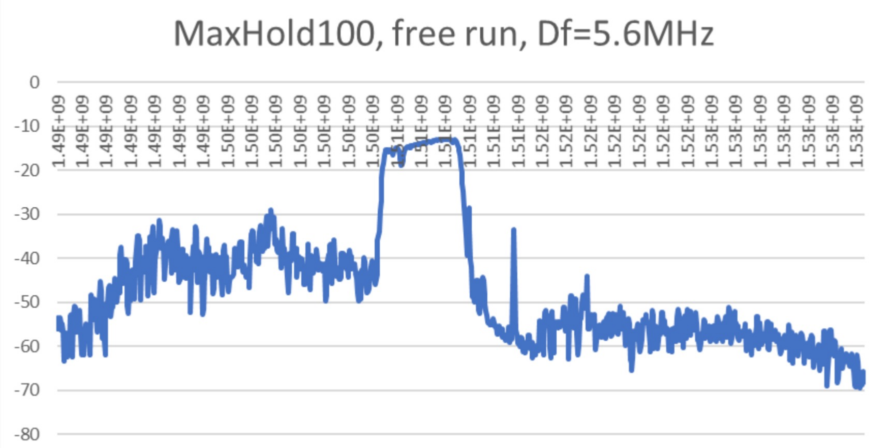


Summary of Power Tests to date

- Cooling temperatures indicate we have enough cooling for 30 kW of dissipated power
- Power supply requirement must be 4 A at 12 kV
- Electro-magnet is adequate for the designed power level of 13kV
- Back bombardment of the filament suggests a foldback circuit is required to keep the filament at nominal operating temperature and may be accomplished with zero volts on the filament (NP Phase I).
- 13 kW seems to be easily achievable with this design. JLAB tests to confirm.
- No need for the vac ion pump during operation. Everything is running pretty cool.
- Robust design.

Test Results of Frequency Operation

- The tube was measured before bakeout at 1530 MHz
- Tested at 1509 MHz with a 5.6 MHz bandwidth for a 21 MHz reduction after bakeout.
  - This is normal and needed as a benchmark for bi-metallic anode (NP Phase I).
- With the desired frequency of 1497 MHz, can this copper anode tube with injection locking work at 1497?



JLAB tests of 2.45 GHz magnetron

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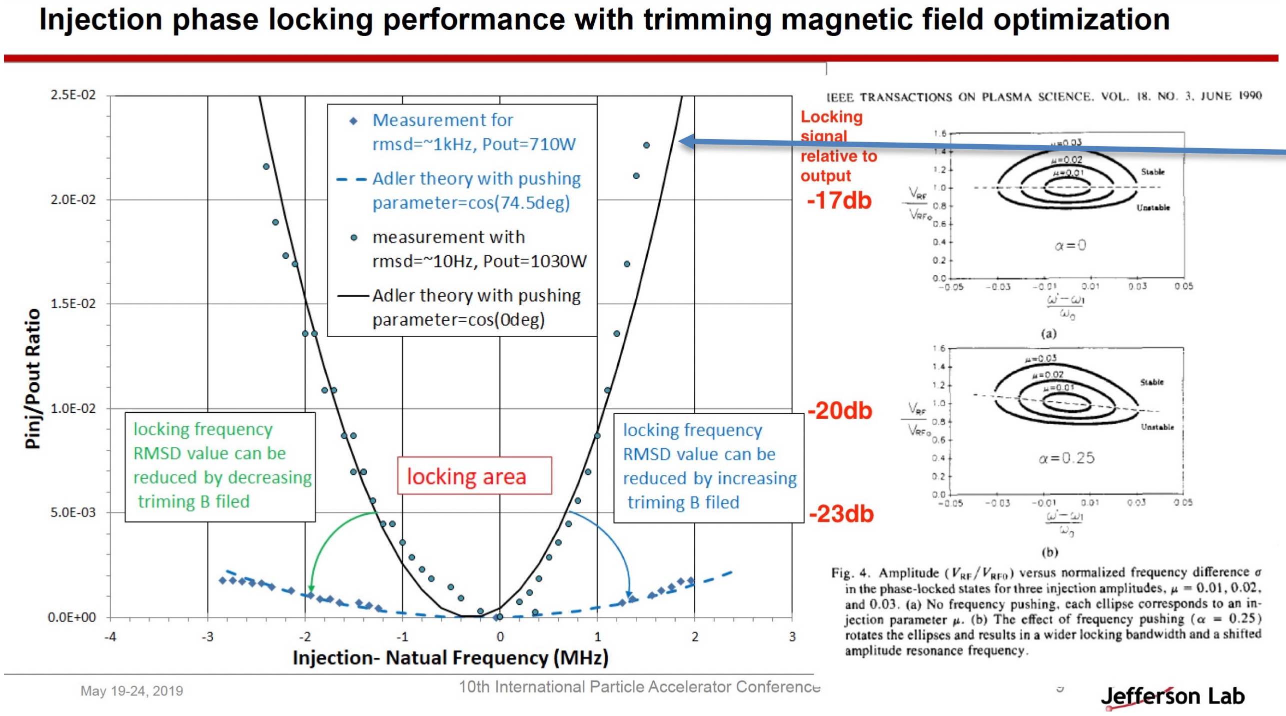
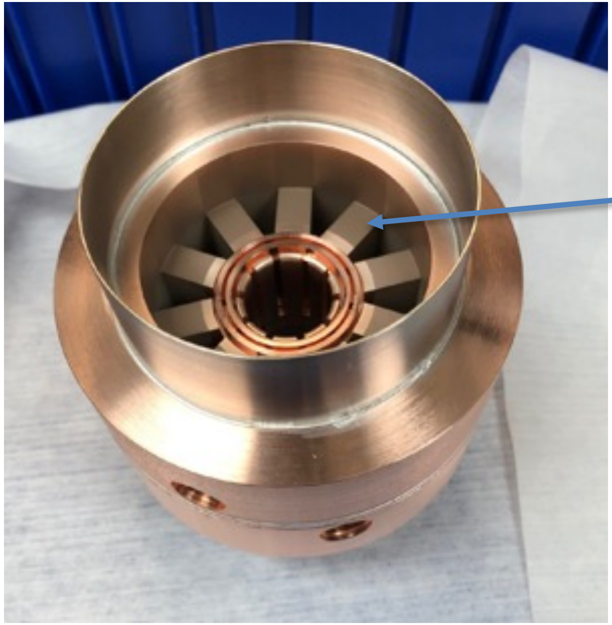


Haipeng's tests indicate about 4-5 MHz for the 2.45 GHz magnetron at -17db injection locking power.

We estimate theJLAB magnetron must be within ~8-9 MHz to be useable at 1497.

Tests at JLAB in about 2 months will verify that estimate.

Bi-metallic 1497 MHz Magnetron

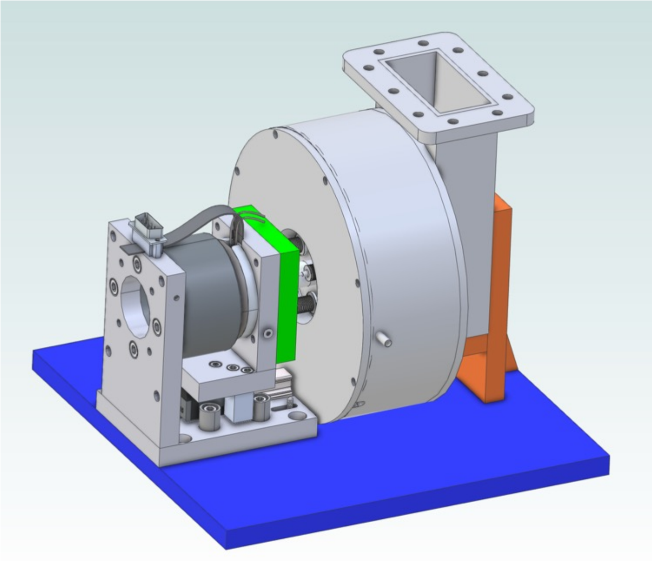


Currently at REL for final assembly and bakeout (NP Phase I)

1. Additional copper plating will be added to the vanes. (We did not adequately plan for diffusion of copper into the stainless steel portion of the anode.)
2. Holes for the antenna will be added and measurements of Qext.
3. Frequency needs to be no greater than ~1520 MHZ. Deforming straps may be necessary (a common tuning technique).
4. Cathode/Filament assembly is ready.

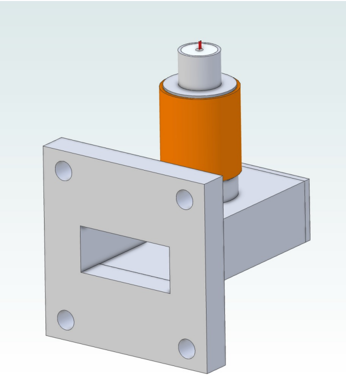
NRL 3 GHz Tunable Magnetron

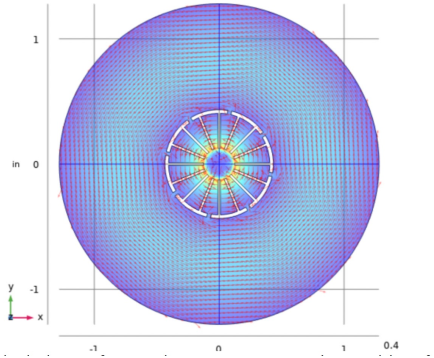
- Tuner construction ongoing at REL
  - Alumina tuner
  - Attachment mechanisms being experimented with to form the assembly
- Tuner motor and actuator has been test
- Two anodes built
- No cost extension for another 6 months



NRL 10 GHz phased array radar magnetron

- Two designs initiated for 100 watt device:
  - Vane and strap
  - Coaxial magnetron
- Down select design choice at the third month of the study (Sept)
  - Thermal analysis
  - Tolerance analysis
  - Form fit and function





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Summary

- 1497 MHz tube getting ready for tests at JLAB in 2-3 months
  - Bi-metallic version to be assembled, baked out and tested in 2-3 months (NP Phase I)
- NRL tunable magnetron scheduled for early 2023 completion
- NRL 10 GHz phased array magnetron design March 2023