Muons, Inc.

A novel injection-locked amplitude-modulated magnetron at 1497 MHz
DE-SC0013203 with Jefferson Lab
2/17/2015 through 12/16/2021 (NCE)

Magnetron R&D and Muons, Inc.

Outline

- Muons, Inc. company profile
- 1497 MHz magnetron
- NRL 3 GHz tunable magnetron
- Other magnetron R&D
- Summary

Muons, Inc. Profile

- Muons Inc.
  - Founded 2002,
    - subsidiaries - MuPlus, Mu*STAR
    - by Scientists from US National Labs
  - Funded by DOE contracts and SBIR-STTR grants
    - total of ~$30M
  - Tools and technology for particle accelerators
  - 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
    - Major focus of our companies

Work in Progress

- Magnetron commercialization based on innovations
- Ion Source commercialization – Contract negotiations for $2M Italian Fusion Device underway
  - Phase III from Phase II Ion Source BES SBIR with ORNL SNS
- NP Phase I Sheet e Beam Probe tomography
- Mu*STAR Collaboration
  - Muons, ORNL, BNL, PNNL, JLab, VT, VCU, TAMU, Burns & McDonnell, Deep Isolation
  - Proposals to ARPA-E & NE for SC Linac Driven MS Subcritical Reactors
  - BES Phase I Molten Salt reference electrodes (Mu*STAR) with VCU

Status of the 1497 MHz magnetron

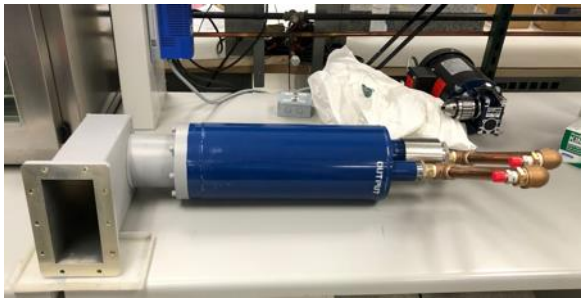
- Project delays
  - Change of ownership/focus of 1st manufacturing partner
  - Early retirement of key senior RF engineer
  - Covid-19
- 2021 Found new manufacturing partner
  - Richardson Electronics (RE) 10 miles from Company HQ
  - Equipment, tubes, and test assemblies moved to RE

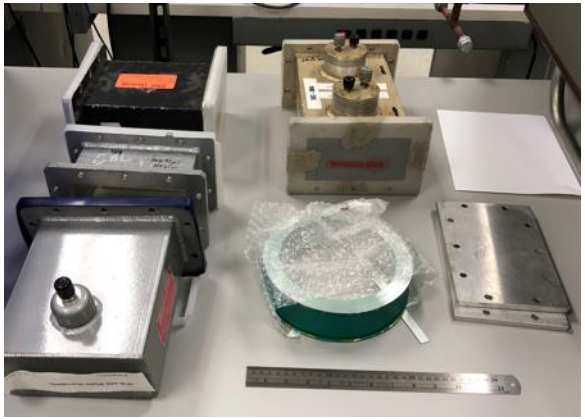
Status of the 1497 MHz magnetron

- Preparing to test at Richardson Electronics
  - Richardson has been around for a long time in the tube business.
  - They recently purchased and moved French tube facility to LaFox, IL (Covimag)
  - They called RoI and asked for help with the development of a 15 kW magnetron.

Status of the 1497 MHz magnetron

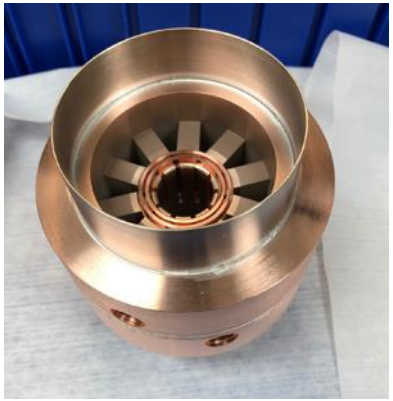
- JLAB facilities are not available right now, so 1497 MHz test equipment was moved from JLAB to LaFox along with the magnets we had delivered.





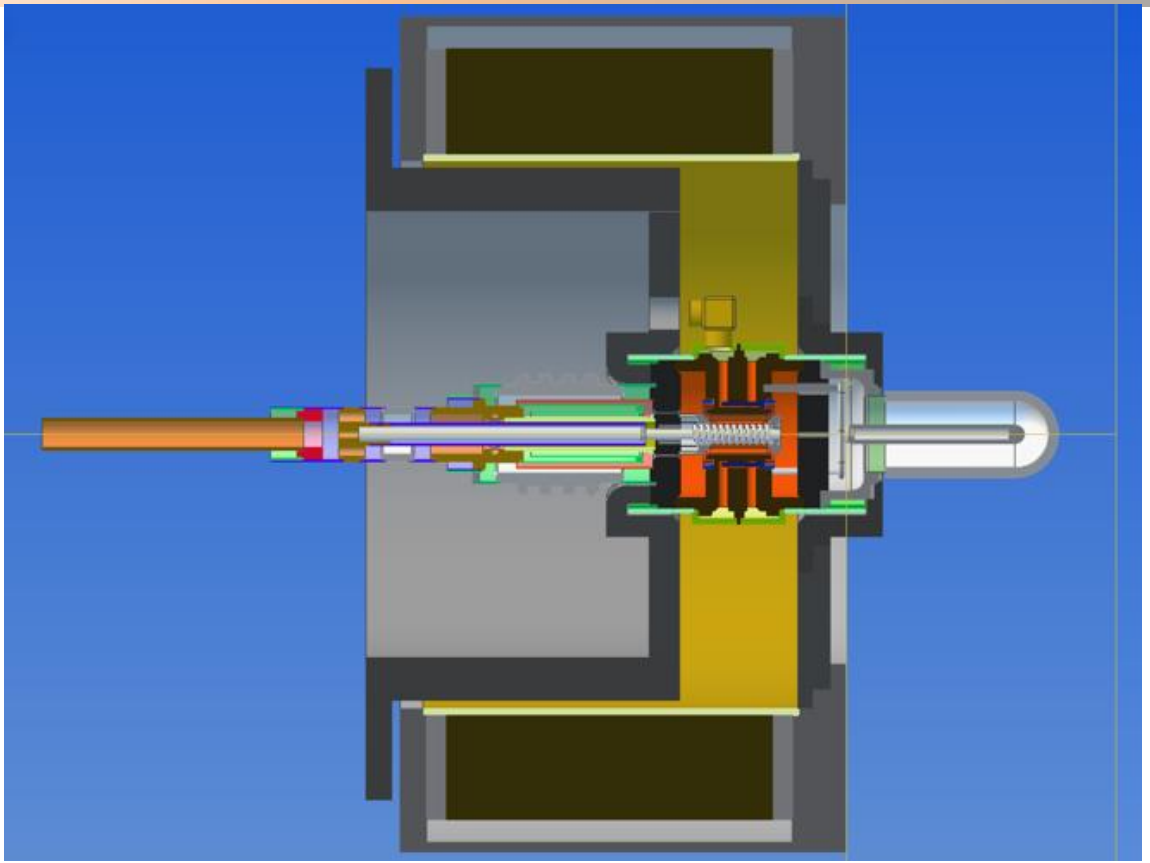
Material and Test Equipment

- Material moved in July and August to RE: Parts for the stainless steel anode which is the purpose of this Phase II: The amplitude modulated magnetron.



Final Assembly of the 1497 Maggy

- external solenoid now
- Permanent magnets later



1497 MHz magnetron on RE Bakeout Station

Richardson and Muons

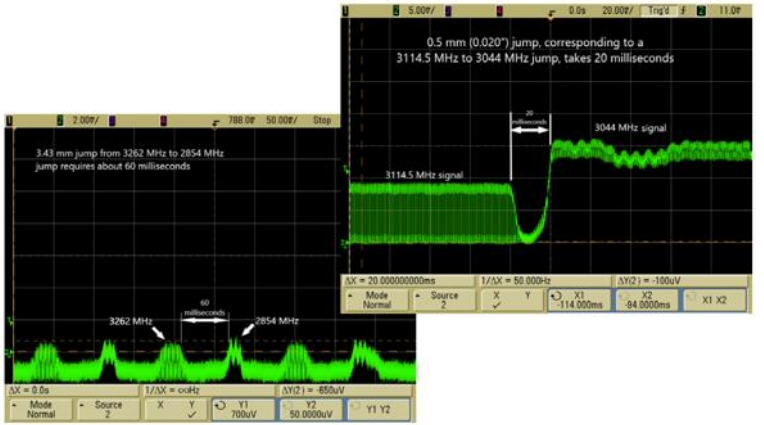
- Milorad has modeled their magnetron and suggested improvements for Qext and magnetron performance.
- Our consultants Ron Lentz and Tony Wynn have added their input to the Richardson design issues.
- They in turn are providing test facilities and will help in the development of our other magnetron related projects.

Muons Activities at RE

- 1497 MHz Bench Tests Underway
- 1497 Setting up Power Tests (using JLab load)
- 1497 MHz s.s. Anode Tube braze and test
- 3 GHz NRL tube preparations for assembly/tests
- 2.45 GHz RE tube improvements being tested
- 325-350 MHz tube ready for assembly/tests

NRL Tunable Magnetron

- Muons, Inc is developing a 1500 Watt 3 GHz tunable magnetron for NRL: goal of 10% at < 5 ms



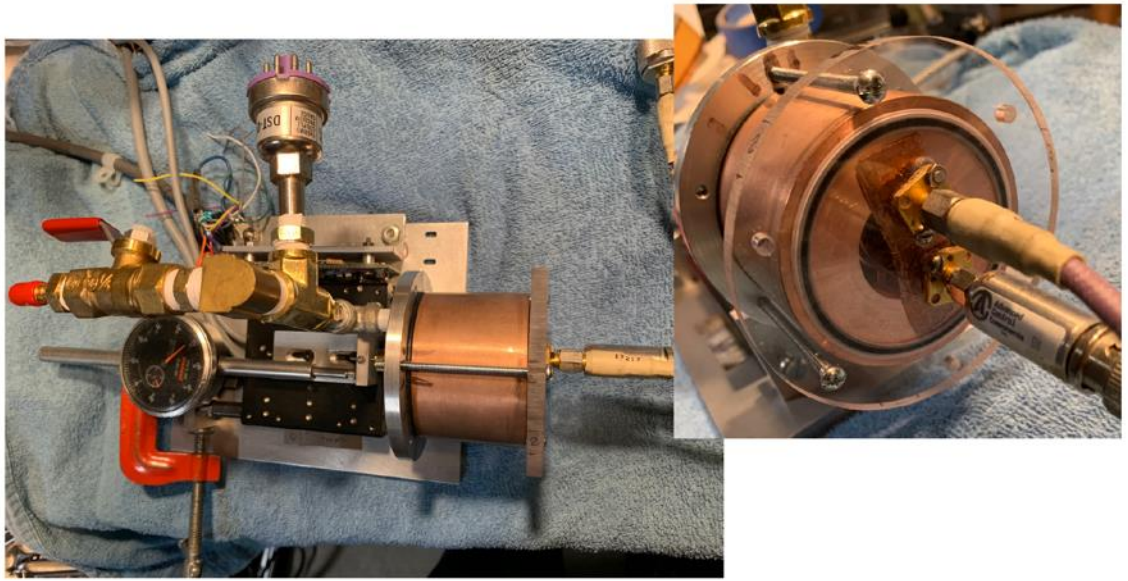
- 3262 MHz to 2854 MHz in 60 ms
  - 3.43 mm
  - 408 MHz in 60 ms or 6.8 MHz/ms
- 3114 MHz to 3044 MHz in 20 ms
  - 0.5 mm
  - 70 MHz in 20 ms or 3.5 MHz/ms

NRL Tunable Magnetron

- Ph I and Ph II DOD STTR with Ph III contract
  - Enabled by the 1497 MHz NP STTR that is the subject here
- Investigated motors for strength and positioning
  - Initial PI linear motor strength maxed out
  - H2W Voice Coil Motor final choice for strength.

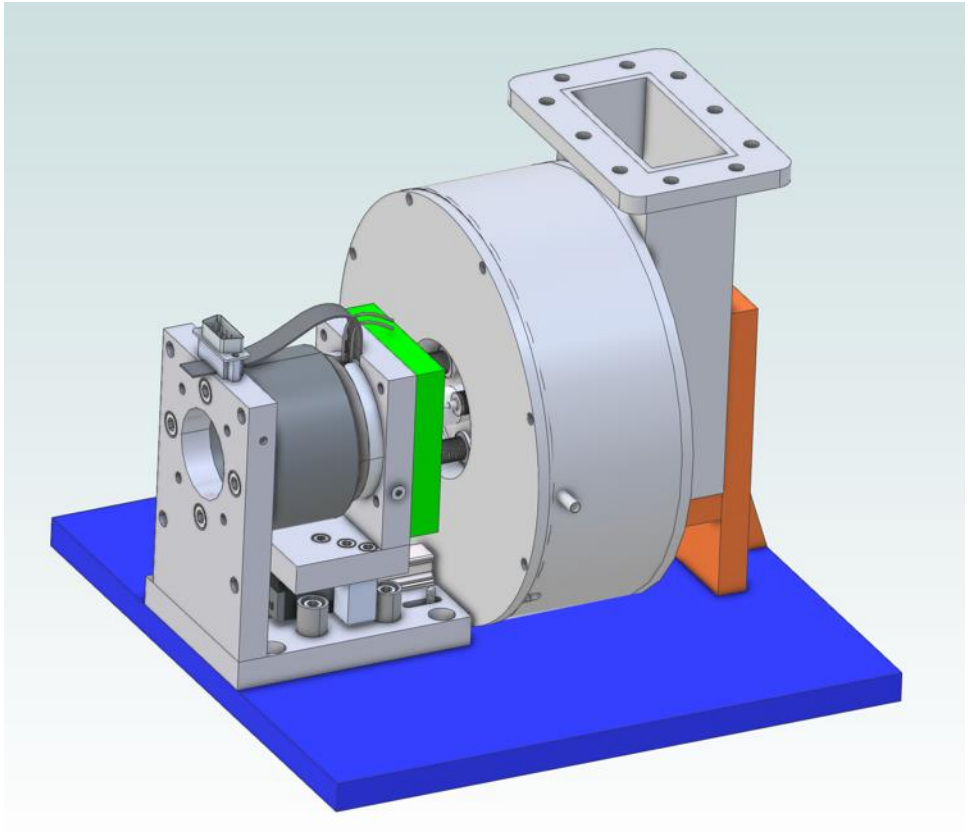
NRL Tunable Magnetron

- Anode test assembly for studying vacuum forces
- Impact on the PI motor and tuning range/speed



NRL Tunable 3 GHz Magnetron

(10in cube)



Prototype with electromagnet
Completion in December

Other Magnetron R&D

- 350/325 MHz tube (most parts built, need brazing etc.), possible customers are
  - Niowave for Molly-99 production,
  - European Spallation Neutron Source for efficiency improvements,
  - SE Asia Chemistry applications,
  - Mu*STAR, and
  - FNAL PIP
- Kazakevitch study of subcritical voltage magnetrons to drive Hi-Q superconducting RF cavities
  - Patents on subcritical voltage magnetron operation
  - Experimental Development underway - CRADA with Fermilab at TD

Summary

- 1497 MHz tube getting ready for tests at RE
  - Then to JLab to be tested as CEBAF klystron replacement
  - S.S. anode version to be constructed and tested
- NRL tunable magnetron scheduled for December completion
- Other magnetron R&D projected to be at RE