ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-THPTS091

PHASE AND FREQUENCY LOCKED 350 MHZ MAGNETRON

M. Neubauer[†], A. Dudas, R. Johnson, S. Kahn, G. Kazakevitch, M. Popovic, Muons, Inc, 60510 Batavia, IL., USA

Abstract

The 350 MHz magnetron is being developed for a number of RF systems, chiefly among them, Niowave's 10 MeV accelerator. Industrial applications of the magnetron have also been explored. The CW magnetron can be operated in the pulse mode by a novel injection locking system. We report on the status of the program and progress to date.

INTRODUCTION

The 350 MHz magnetron is being built at Altair Technologies, Fremont, CA., under the supervision of Muons, Inc. RF measurements to support the optimization of the Qext are also made in the same location. The welding processes for the cathode stalk, primarily molybdenum-to-tungsten, molybdenum-to-iron and molybdenum-to-molybdenum are being done at Heatwave, Inc in Watsonville, Ca. The anode and magnet are fabricated by Device Technologies, Yorkville, IL.

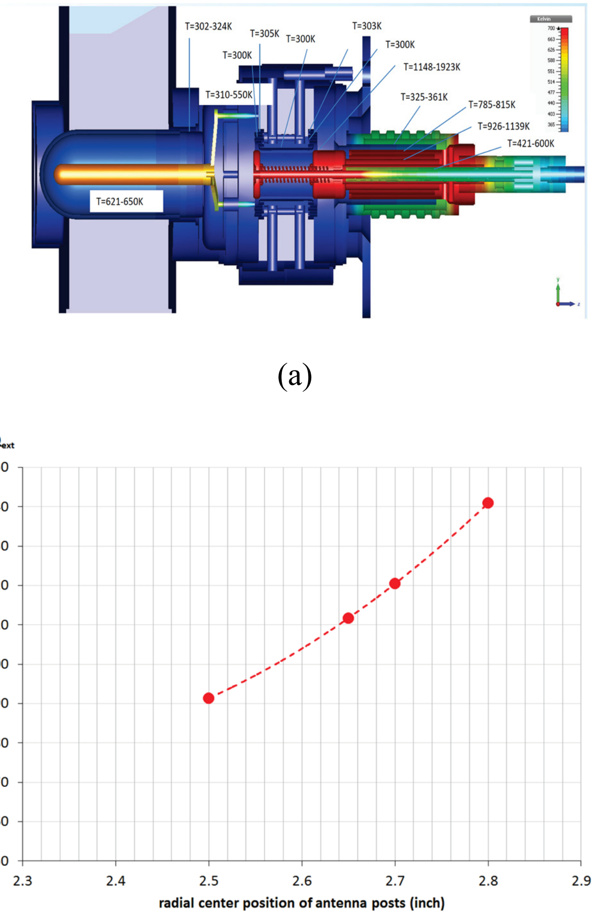
SUMMARY OF CALCULATIONS

The design of the magnetron was developed with the support of consultants: Tony Wynn and Ron Lentz. Muons, Inc using the software CST and Comsol did calculations of thermal, mechanical, and RF performance.

The important issue in heating is the temperature of the antenna. At 100 kW output that temperature was calculated to be 620-650K, as shown in Figure 1 (a). This is about at the limits for a copper antenna and will require careful monitoring during operation. A design was made for water-cooling the antenna, but was not incorporated in this prototype.

Just as important as the temperatures that will occur during the operation of the magnetron, is the thermal movement due to the expansion of parts in the cathode stalk. The temperature of the filament drives this movement and at 2100C, about 1.2 mm is expected even with compensation and must be designed around.

Calculations of Qext shown in Figure 1 (b) show the range expected based upon where along the length of the vane, the antenna legs are positioned. Qext is a measure of the coupling between the magnetron anode and output. These calculations will be verified during the measurement process, which should get underway shortly. The prototype magnetron anode is constructed to allow for testing these types of options for attaching the antenna as shown in Figure 2.



(a)

(b)

Figure 1: a) Thermal calculations with 100 KW output, b) Qext calculations as a function of location of the antenna connections to the vanes.

MANUFACTURING STATUS

There are three major elements of the magnetron: anode, antenna/window, and filaments.

Anode

The anode is completed and shown in Figure 2. The construction of the water jackets using formed and welded OFHC copper cylinders presented some problems in manufacturing. Since they are not part of the vacuum envelope they were easily fixed to hold the water pressure.

[†] mike@muonsinc.com

ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-THPTS091

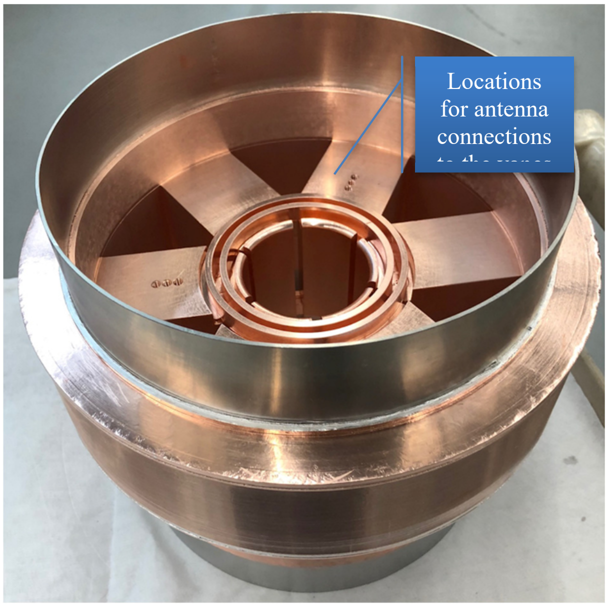


Figure 2: 350 MHz magnetron Anode ready for Qext measurements.

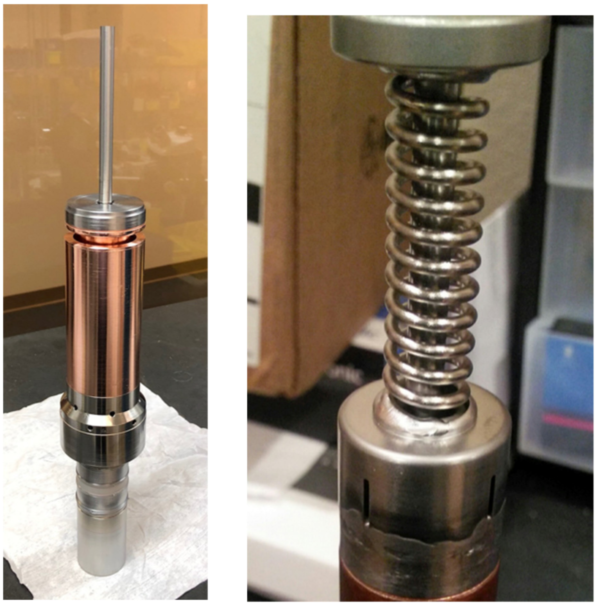
Output Window

The output window is shown in Figure 3. The assembly of this part was straightforward and presented no problems. It is expected that high fields in the window area will create the potential for multipactor. With this in mind a coating of TiN about 15 angstroms thick will be applied to the internal surfaces by evaporative techniques.

Figure 3: Output window braze completed awaiting TiN coating.

Cathode Stalk

The cathode stalk shown in Figure 4 is awaiting welds. These welds are critical to the thermal performance of the filament and will be done by Heatwave Labs. The welds are molybdenum-to-molybdenum, molybdenum-to-tungsten, and molybdenum-to-steel with nickel. These processes put a film of material on the filament, so the subsequent operation is one of cleaning.



(a) (b)

Figure 4: a) Cathode stalk ready for filament welds, b) example of the filament welds to be made.

The cathode stalk assembly is placed in a bell jar and thermal measurements are made along with measurements of the spacing between the turns of the filament windings as it is heated. The filaments are heated to the operating temperature of 2100C and visual observation of the welds confirms their integrity. After the thermal processing, the turn-to-turn measurements of the filament are made to confirm their stability, and a visual check of the cleanliness of the filaments is made.

Final Assembly

The three major assemblies: window, anode, and cathode stalk along with a vac-ion pump assembly are welded together for the final assembly. Bakeout occurs at 500C for 24 hours.

INJECTION LOCKING

Injection locking of the magnetron occurs with a signal that is 20-30 db down from the output power, achieving essentially 20-30 db of gain. This type of gain has been achieved by a number of researchers over the last 30-40 years most recently by H. Wang and others at JLAB[1].

The critical piece of equipment required for injection locking is a circulator. A proposal was received from AFT for a 70 kW 4-port circulator in half height waveguide, but other circulators were found from discontinued programs such as APT, that will suffice.

During research by Muons, Inc, a means for operating a CW magnetron in a pulse mode without a modulator was observed, and the 350 MHz magnetron will be a candidate for this type of operation with an injected signal [2].

Pulse Modulation with Injected Signal

As shown in Figure 5, the pulsing of the CW magnetron occurred coincident with the input pulse of the injection-locking signal. This occurs because the voltage chosen for operation is just below the voltage required to turn on the magnetron, so the magnetron is off. The RF voltage generated by the injected signal overcomes the initial condition for oscillation and turns on the magnetron. The relationship between the CW voltage and the injected signal power level required to turn on the 350 MHz magnetron will be determined during testing.

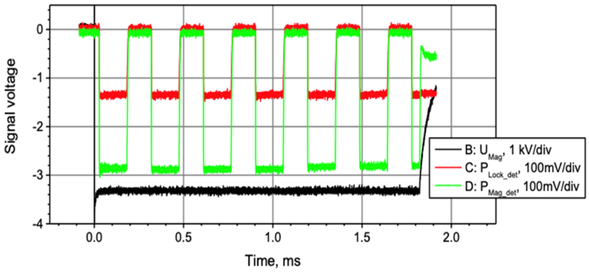


Figure 5: Black Trace is Magnetron Voltage, Red trace is the injection-locking signal, Green trace is the magnetron output signal.

The magnetron design elements that support this type of operation are not well known. For example, there may be an optimum size interaction gap or an optimum filament voltage generating sufficient amount of space charge. During the testing phase some of these questions will also be answered.

CONCLUSION

The magnetron is well on its way to completion. Minor manufacturing problems were addressed during the various assembly stages. The operating conditions of the magnetron are laid out to accomplish significant goals such as pulse operation without an expensive modulator.

REFERENCES

[1] H. Wang *et al.*, “Use of an Injection Locked Magnetron to Drive a Superconducting RF Cavity”, in *Proc. 1st Int. Particle Accelerator Conf. (IPAC'10)*, Kyoto, Japan, May 2010, paper THPEB067, pp. 4026-4028.

[2] G. Kazakevitch *et. al*, “Phase and Power Control in the RF Magnetron Power Stations of Superconducting Accelerators,” arXive_1709.04526