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AFFORDABLE, EFFICIENT INJECTION INJECTION-LOCKED MAGNETRONS FOR SUPERCONDUCTING CAVITIES*

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Abstract

Existing magnetrons that are typically used to study methods of control or lifetime improvements for SRF accelerators are built for much different applications such kitchen microwave ovens (1kW, 2.45 GHz) or industrial heating (100 kW, 915 MHz). In this Phase I SBIR project, Muons, Inc. will work with Richardson Electronics LLC (RELL) to develop fast and flexible manufacturing techniques to allow many ideas to be tested for construction variations that enable new phase and amplitude injection locking control methods, longer lifetime, and inexpensive refurbishing resulting in the lowest possible life-cycle costs. In Phase II, magnetron sources will be tested on SRF cavities to accelerate an electron beam. A magnetron operating will be constructed and tested with our novel patented subcritical voltage operation methods to drive an SRF cavity. The critical areas of magnetron manufacturing and design affecting life-cycle costs that will be modelled for improvement include: Qext, filaments, magnetic field, vane design, and novel control of outgassing.

INTRODUCTION

Our plan is to use existing magnetron designs and try to modify them to create magnetron tubes that will satisfy the needs of particle accelerators. For example, we will consider a tube that will include a means to inject the locking signal directly into the tube.

To meet these goals, we are in process of studying two magnetron designs:

1. A strapped magnetron, where the RF power extraction method will be modified. For the purpose of injecting a phase locked signal, we are planning to introduce an additional port in one of the resonant cavities of magnetron.
2. A coaxial magnetron design will have a cooling structure that will allow CW operation and generate tens of kW of RF power. A phase lock signal will be introduced via an antenna attached to one of the vanes.

THE STRAPPED MAGNETRON OPTION

The tube below shown in Figure 1 is a 20kW CW, 1497 MHz tube designed and built by Muons Inc [1]. The tube has 10 strapped cavities and is water cooled. The power is extracted using a three-legged antenna that is enclosed in a ceramic dome.

The cathode stalk has a 2 liter per second ion pump and connectors for high voltage and filament power input.

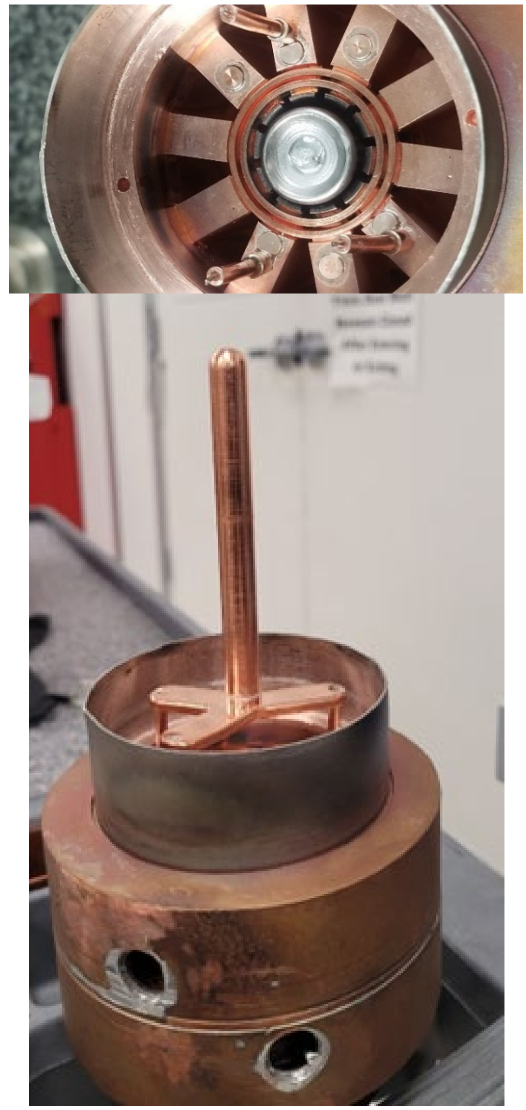

Figure 1: Photos show internal structure, ten cavities, straps and antenna attached to anode body. The new antenna design will have five legs.

In the new design under development, the antenna will have five legs and be attached to every other vane. The initial simulation shows that the corresponding (inner) strap can be removed without compromising mode separation. A five leg design will allow more power to be coupled out of

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the magnetron. This will allow us to load the structure less for the same power output.

We are also considering the introduction of a pillbox cavity that will have a high Q-factor and the Q-external of the system much higher than in the conventionally coupled magnetron via a waveguide (shown in Figure 2).

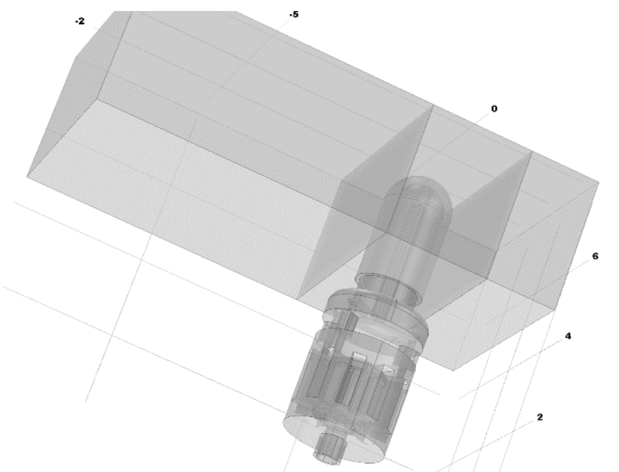

Figure 2: conventional coupling of the magnetron to a waveguide.

The second modification of the recently built tube will be the introduction of a port for injection of the phase lock signal [2, 3]. A connector, Fig. 3, will be attached to the body of the magnetron on the cathode side which will have a central connector attached to one of the vanes.

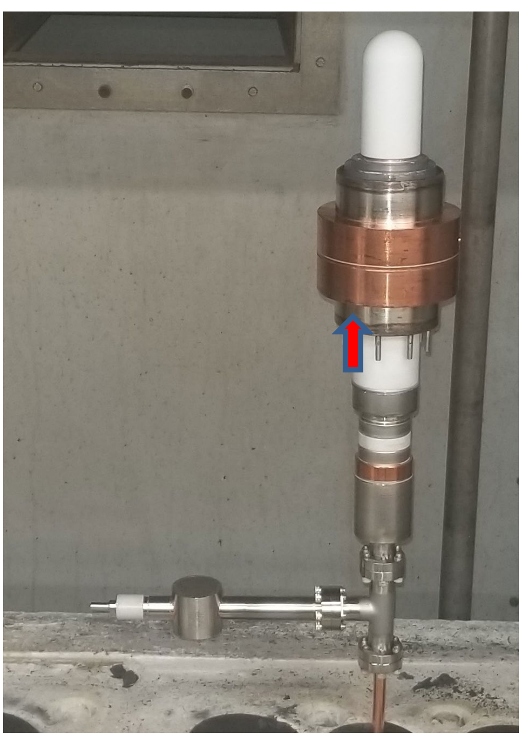

Figure 3: Tube with input port (in red).

THE COAXIAL MAGNETRON OPTION

Figure 4 shows an example of coaxial magnetron [4].

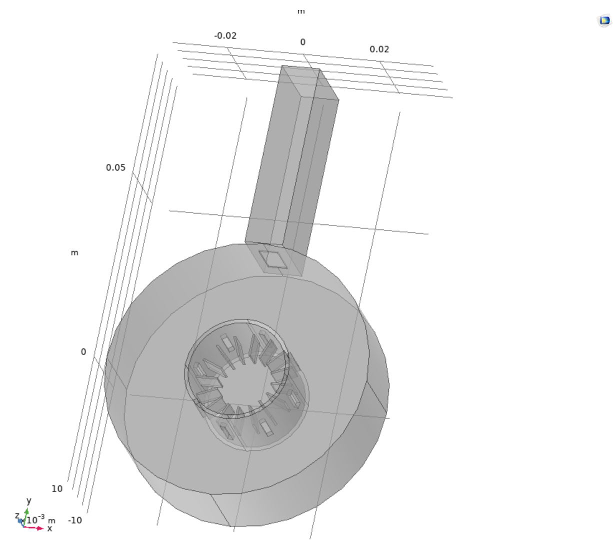

Figure 4: COMSOL model of a Coaxial Magnetron.

The magnetron has 16 vanes, with a coaxial cavity dimensioned to support TE011 mode at 10 GHz. The magnetron is coupled directly to WR90 waveguide using coupling slots. Dimensions of the vanes and anode are adjusted so the structure oscillates with pi-mode frequency which will be the same as coaxial cavity's TE011 resonance.

Figure 5 shows the pi-mode in the center of the magnetron body and the TE011 mode in coaxial cavity.

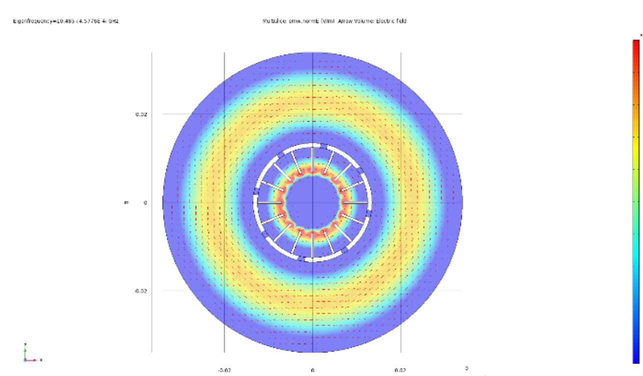

Figure 5: pi-mode and TE011 mode.

The main modification of this design will be to enlarge the size of the vanes and the anode body to allow the addition of water-cooling channels, which will allow CW generation of RF power.

By design, the coaxial magnetron has RF output with good mode separation, shown in Fig. 6.

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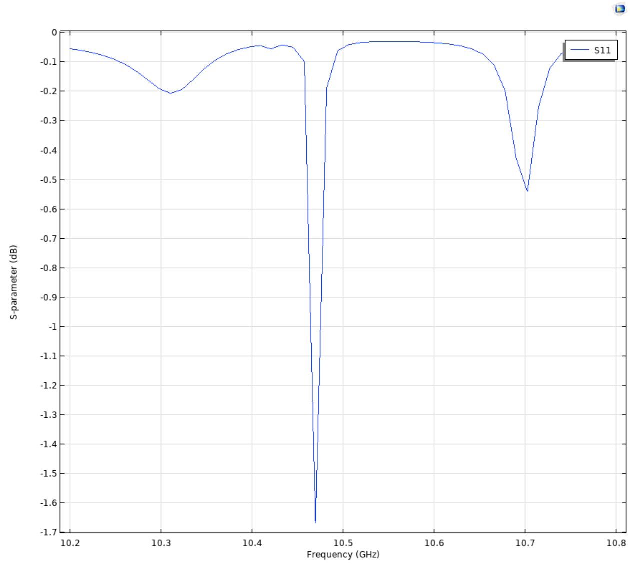

Figure 6: RF power output from co-axial magnetron showing that pi-mode is well separated from other modes.

Coaxial magnetrons generate RF power with narrower output frequency spread as can be seen in Fig. 7.

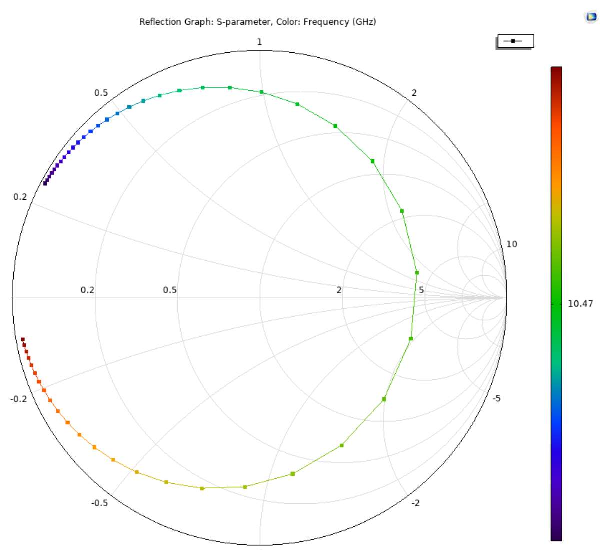

Figure 7: Smith Chart shows that coupling is ~5.

From Fig. 7 it is clear that the cavity is very strongly coupled to the wave guide, beta~5. The Qo of the cavity is around 11500, so Q_ext~2000, for this system.

As in the case of the strapped magnetron, we are planning to build an input port attached to the one of the vanes. The phase lock signal is envisioned to be generated using a standard 1 kW solid state amplifier. This amplifier will have built in circulators. We may also consider a magic -T as an additional way of protecting the driving circuit from power generated in the magnetron.

CONCLUSION

This paper is a report on work in progress. In the next six months we are planning to choose between the two designs. In Phase I of the project proposed here, Muons Inc. will design a magnetron prototype to satisfy the needs of some accelerator that will allow testing of our concepts to drive RF cavities. The efficiency will be also optimized. The vane (and/or strap) anode design will incorporate design improvements to the high current region of vanes (the straps) by optimizing their geometries.

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