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HOM Load Design and Fabrication experiments at Muons, Inc.
(Phase II SBIR Plans)

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Muons, Inc.

Beam Pipe HOM Absorber for 750 MHz RF Cavity Systems

- FIRM NAME: Muons, Inc. RESEARCH INSTITUTION:Cornell University
  PI: Michael Neubauer Prof. Georg Hoffstaetter, subgrant PI
- Superconducting RF (SRF) systems for accelerators typically contain unwanted frequencies or higher order modes (HOMs) that must be absorbed. Currently, ferrite or other lossy ceramic HOM absorbers and their attachments to drift tubes adjacent to SRF cavities are not robust enough, and tend to crack under tensile and thermal stresses.
- New processes, techniques, design and construction of improved HOM loads will be developed. A scaled-down version that can be assembled in the beam pipe of a 1.3 GHz Cornell cryo-module will be built, and the assembly processes can then be applied to larger diameters such as for high-gradient 750 MHz superconducting cavity systems. A process for applying a charge dissipative coating on the ferrite will be developed. The objective is a low cost, reliable, thermally efficient, broadband beam pipe HOM absorber that is scalable to reasonable diameters.
- What was done in Phase I
- Compression ring models were constructed and post brazing techniques were developed to evaluate the compression limits of the ferrite and the tensile limits of copper during the assembly processes. The compression ring sub-assembly allows for various ferrite materials to be used in a complete cost-reduced broadband beam pipe HOM assembly. Processes were experimented with to reduce charge buildup, and rugged stress tests showed the way to improvements in the design.
- What is planned for the Phase II project
- Since the 750 MHz cavity is still being developed, a scaled down version for 1.3 GHz will be produced. In Phase II this complete HOM load will be constructed for assembly with an existing ERL injector 2-cell cavity at Cornell. The assembly can then be tested in Cornell’s vertical test stand. The construction processes will also include a means for reducing charge buildup on the ferrite absorbers.
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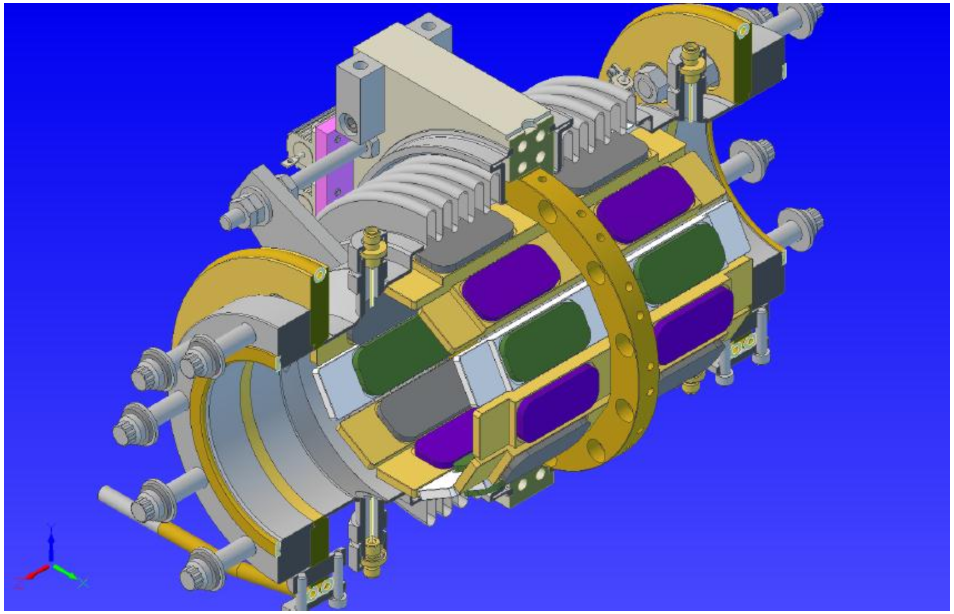
Outline of Presentation

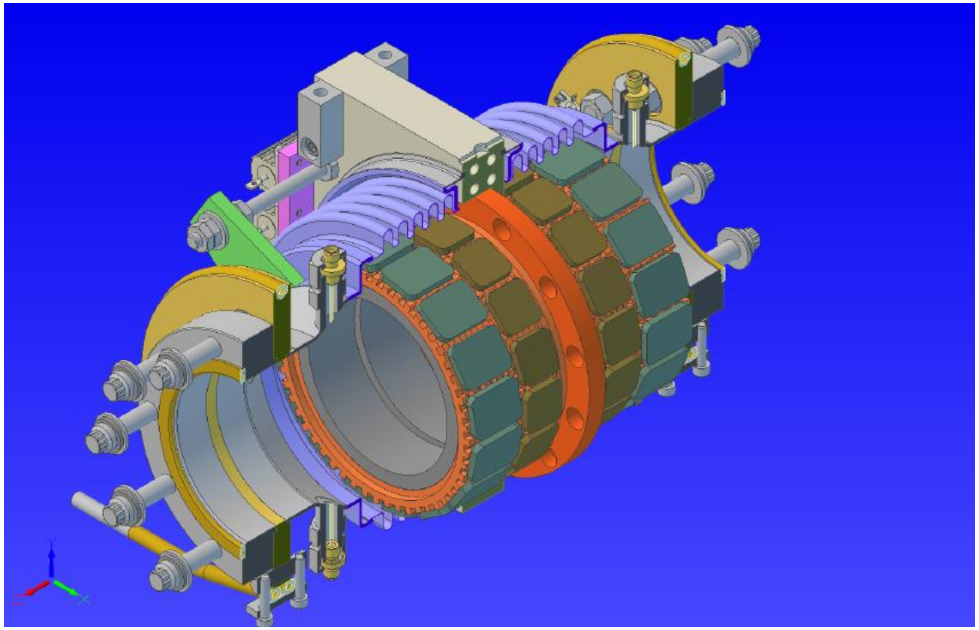
- Beam Pipe HOM Load Assembly
  - Existing Design and Proposed Design
- Phase I Summary of Goals and Accomplishments
  - Construction of a solid ferrite ring in compression
  - Calculations of RF loss
  - Coating for charge dissipation
- Phase II Summary of Project Plans

Existing Cornell Design



- 48 tiles need a perfect braze to Elkonite, a copper alloy used to match the thermal expansion of the ferrite.
- This assembly is expensive with many small parts.
- There is a high risk of failure from small defects.
- The tiles may charge up on the ID and create beam instability.

Proposed Design



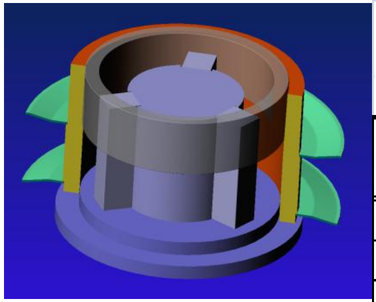
- Solid Rings of ferrite are used on the ID in a compression joint without braze
- Tiles on the OD are brazed to small flexible posts.
- A proprietary lossy coating on the Ring ID is used for charge dissipation.

Results of Phase I

- We have demonstrated by both analytical calculations and experimental verification that we can build a HOM load compression ring assembly by two different methods.
- Based upon our analytical work, we can decide how many rings of what kind of material would provide sufficient losses to damp the modes we are most concerned with at LN temperatures.
- If ferrite tiles need to be connected to the outside diameter of a cylinder, we have developed a process and determined a scale size, for assembling stress free joints to the ferrite.
- We have also initiated some experiments to develop a process for coating ferrites to dissipate charge buildup in the presence of a beam.

Hot Compression Ring Assembly

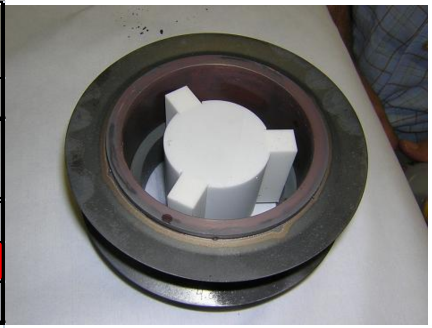
- Insertion of the ferrite into the copper sleeve is performed by heating the assembly several hundred degrees Centigrade in a kiln with an inert gas (argon) flow. While both the ferrite and the copper sleeve expand, the copper sleeve expands radially about 1.6 mils faster per 100 °C than the N40 ferrite toroid, until the ID of the sleeve has expanded beyond the OD of the ferrite. Gravity allows the toroid to drop into the sleeve, and the kiln is slowly cooled to RT.
- Three assemblies were built with varying degrees of expected stress at LN temperatures in the copper (tension) and ferrite (compression) based upon the interference fit at room temperature..



	*% of Copper Tensile Strength at -200C**			*% of Ferrite Compressive Strength at -200C***		
	Thickness of Copper Ring			Thickness of Ferrite Ring		
Interference Fit at 20C (in)	**.25 in**	**.30 in**	**.35 in**	**.25 in**	**.30 in**	**.35 in**
0.01	74%	65%	54%	78%	70%	70%
0.0075	64%	56%	46%	62%	56%	56%
0.005	55%	48%	40%	47%	42%	42%

*Yield Strength of Copper at -200C 370 Mpa @60% Cold Drawn

**Compressive Strength of Ferrite at -200C ~450 Mpa



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Room Temperature Compression Ring Assembly

- The room temperature assembly process was performed by simply immersing the ferrite toroid in LN (-200C) and the copper compression ring in boiling water at 100°C. This process included a precision milling machine to drive the ferrite into the copper as shown below. This RT assembly process allowed for only a .005 interference fit.

Stress Test Results

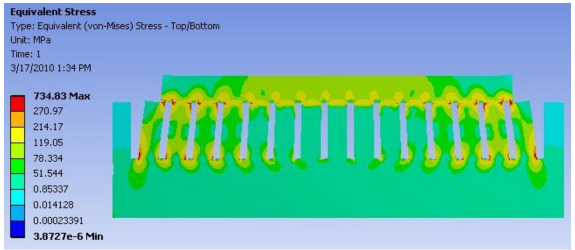
- We developed three sets of stress tests to determine the limits of our assembly processes and our understanding of the material properties of the copper and ferrite.
  - The first set of stress tests were the most aggressive. We simply immersed the assemblies in LN until the temperature was stabilized. Under those conditions the copper cooled down rapidly because of its thermal conductivity being about 70 times greater than the ferrite.
    - Ferrite survived, the copper ring exceeded its tensile stress limits and stretched
  - In a second stress test, we cooled an assembly slowly so that the temperature of both the copper and the ferrite remained the same going down to LN temperatures.
    - The ferrite's compressive strength was exceeded and the ferrite toroid was crushed.
  - In the third test we reduced the temperature of the assembly slowly to -100°C, and cycled it five times.
    - Neither the ferrite nor the copper exceeded their stress limits.

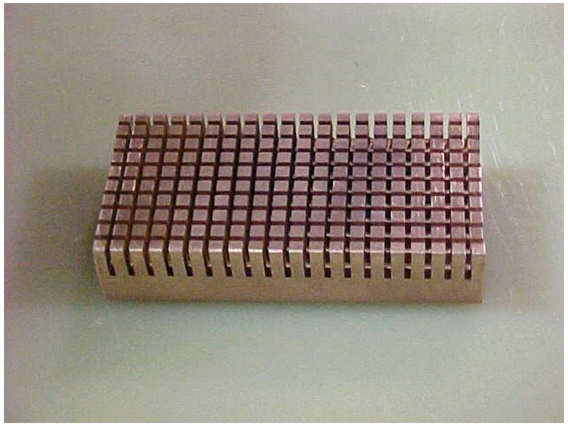
Stress Test Conclusions

- Compression ring assemblies can be built by two methods (Room temperature and Hot).
- The stress limits of the materials can tested and the design verified.
- Modifications to the design include a compression ring assembly made with a copper alloy which better matches the ferrite such as elkonite or similar materials.

Stress Free Post Braze

- In the stress free design, the joint between the copper and the ferrite is made over a small distance by brazing the ferrite to an array of posts.
- In addition to minimizing the sheer stress in the joint, the posts also absorb the differential expansion during operation as a form of buffer layer.
- The shorter the posts the lower the temperature difference between the top of the ferrite and the bulk of the copper.
- A copper screen could then be the backing behind small tiles to make the assembly process more manageable.

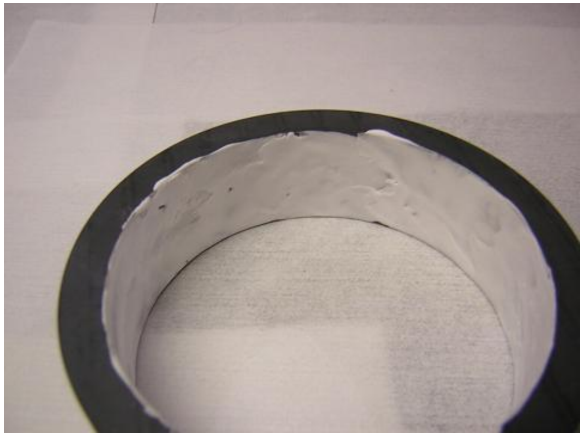




Glass Coating for Charge dissipation

- Coating experiments were done on the ferrite with a glass that was designed to match the CTE of Kovar. It adhered well to the ferrite, survived the kiln assembly process, and immersion in LN.

- Further experiments will include adding loss to control the surface resistivity



Loss Calculations for solid torroids

- Using the data supplied by Valery Shemelin the losses in a three inch long cylinder of ferrite at -190°C was calculated using COMSOL, as shown in Table 1.

	Freq,	ε		μ		
Material	GHz	Re	Im	Re	Im	Loss, db
TT2-111R	**10**	11	0.25	0.4	1	2.6
TT2-111R	**15**	11.1	0.06	0.4	0.4	5.6
TT2-111R	**20**	11	1	0.6	0.1	4.3
TT2-111R	**25**	11	0.01	0.8	0.002	0.9
TT2-111R	**30**	12.77	0.27	0.80	0.004	0.9
HexMz	**10**	19	0.9	3	0.5	4.3
HexMz	**15**	18	0.9	1	1	6.9
HexMz	**20**	18	0.9	0.4	0.9	1.9
HexMz	**25**	18	0.9	0.5	0.7	1.7
HexMz	**30**	18.32	0.98	0.53	0.176	1.9
137ZR10	**15**	18	2.3	1	0.08	8.1
137ZR10	**20**	21	5	0.9	0.008	2.8
137ZR10	**25**	22	6	0.9	0.03	1.7
137ZR10	**30**	17.5	3.81	0.98	0.007	2.6

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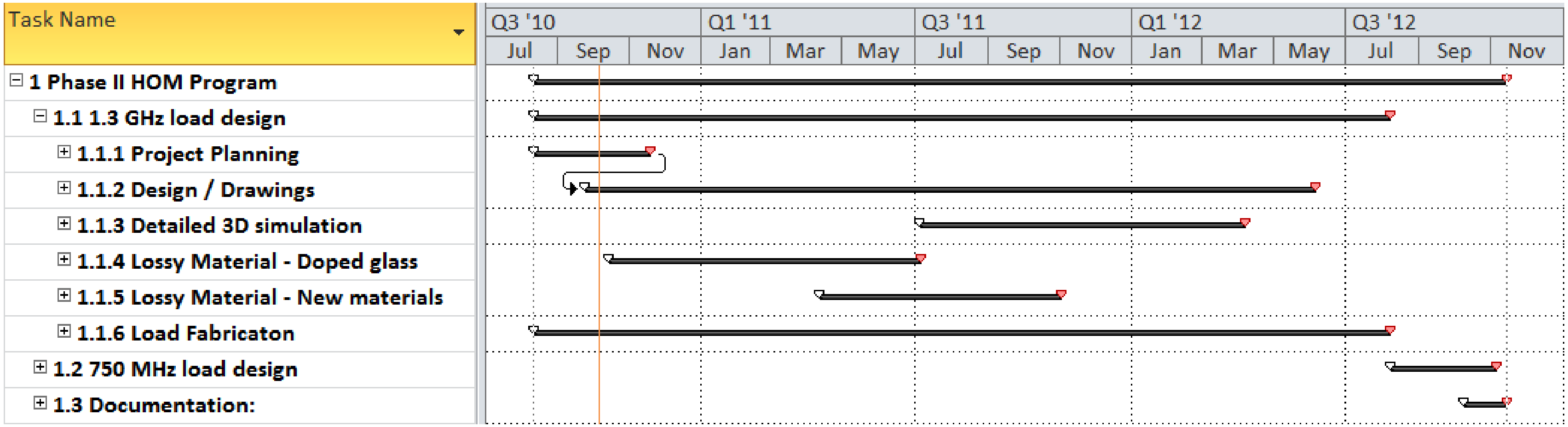
Program Plan for Phase II



Task Name
⊟ **1 Phase II HOM Program**
⊟ **1.1 1.3 GHz load design**
⊞ **1.1.1 Project Planning**
⊞ **1.1.2 Design / Drawings**
⊞ **1.1.3 Detailed 3D simulation**
⊞ **1.1.4 Lossy Material - Doped glass**
⊞ **1.1.5 Lossy Material - New materials**
⊞ **1.1.6 Load Fabricaton**
⊞ **1.2 750 MHz load design**
⊞ **1.3 Documentation:**

Active Muons Inc. Projects

Year	Project	Expected Funds	Research Partner
2008-11	Pulsed Quad RLAs	$850,000	JLab (Bogacz)
2008-11	Fiber Optics for HTS	$800,000	NCSU (Schwartz)
2009-12	HOM Absorbers*	$850,000	Cornell (Hoffstaetter)
2009-12	Quasi Isochronous HCC	$850,000	FNAL (Neuffer)
2009-10	DC Gun Insulator	$100,000	JLab (Poelker)
2009-12	H-minus Sources	$850,000	ORNL/SNS (Stockli)
2009-12	Hi Power Coax Coupler*	$850,000	JLab (Rimmer)
2009-10	Hi Field YBCO Magnets	$100,000	NCSU (Schwartz)
2009-12	ϕ & f –locked Magnetrons*	$850,000	FNAL (Popovic)
2009-10	Mono-E Photons	$172,588	2 contracts w PNNL
2009-10	Project-X and MC/NF	$260,000	contract w FNAL
2009-10	MCP and ps timers	$108,338	contract w ANL
2010	MAP	$ 55,739	2 contracts w FNAL
2010	805 MHz RF Cavity *	$230,000	contract w LANL
2010-11	ps detectors for MCDE	$100,000	U Chicago (Frisch)
2010-11	Crab Cavities*	$100,000	JLab (Rimmer)
2010-11	Epicyclic PIC	$100,000	JLab (Derbenev)
2010-11	MC detector bkgnds	$100,000	NIU (Hedin)

*new projects in RF technology – kudos to Mike Neubauer!