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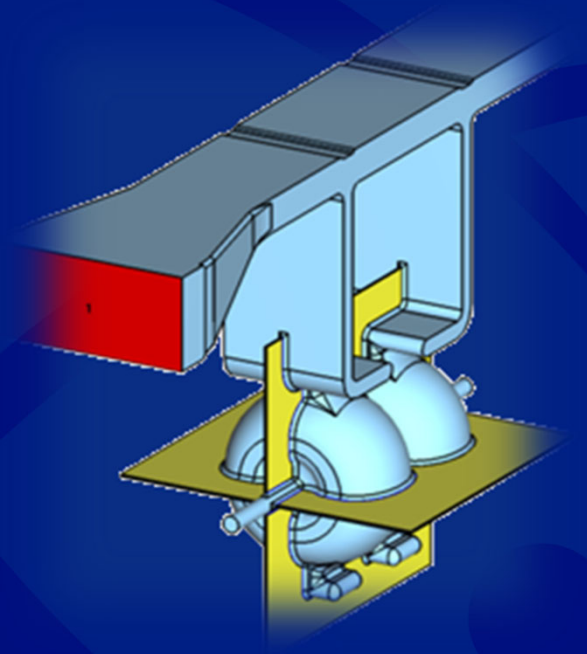
Wakefield Suppression in High-Gradient C-band Accelerating Structures



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Cool Copper Collider Workshop
October 7, 2024

Outline of this talk

- Introduction and LANL C-band project overview
- Simulations of HOM suppression with NiCr absorbers
- Two-cell test cavity with NiCr aborbers
- LANL C-band high gradient testing infrastructure
- Summary and near-term plans

LANL High Gradient C-band research

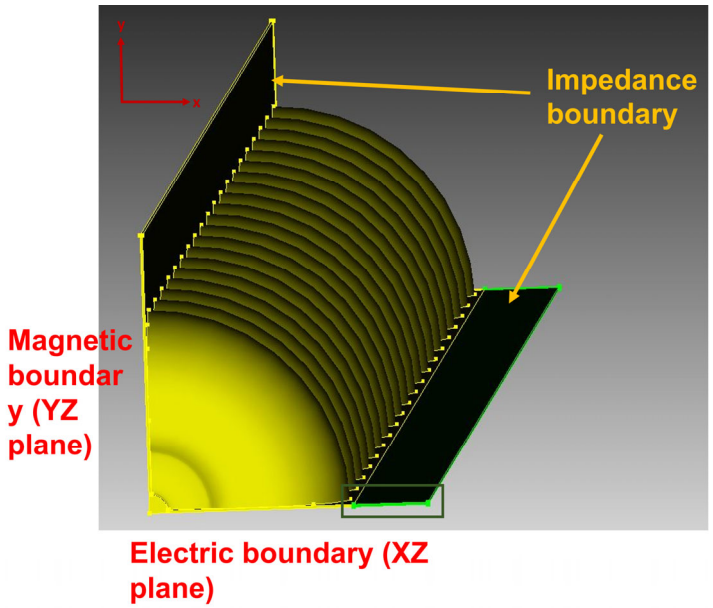
The goals for LANL's high gradient project are

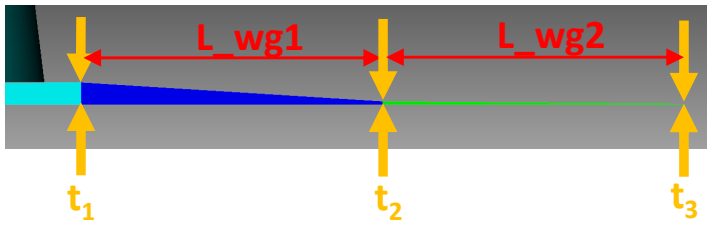
- To build a C-band (5.712 GHz) high gradient rf breakdown study facility (2019-2022).
- To build a C-band cryo-cooled photoinjector study facility (2022-2025).
- To conduct material studies – this includes HOM absorber material study.

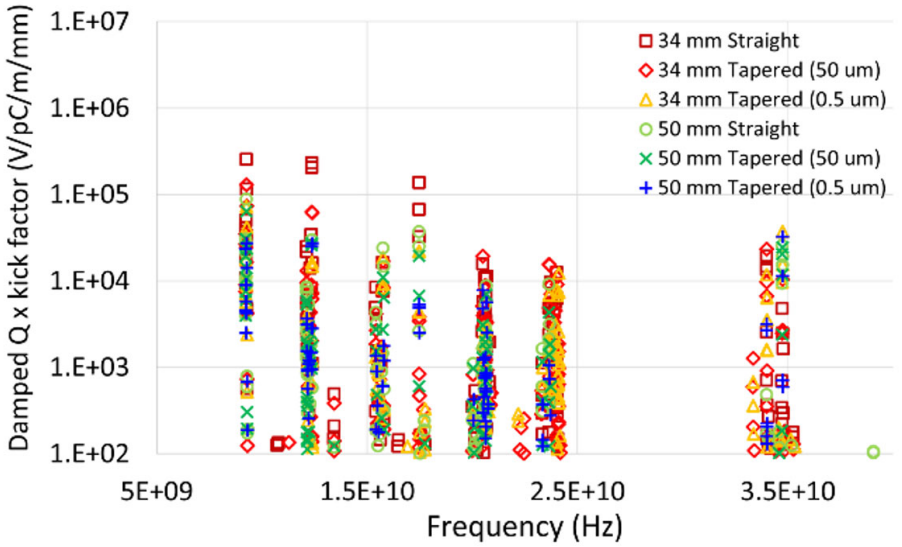
Los Alamos National Laboratory internal funding comes from LANL Laboratory Directed Research and Development (LDRD) program, LANL Internal Infrastructure Investments, and Technology Evaluation and Development (TED) funds.

NiCr absorbers for HOM suppression

We conducted extensive optimizations of HOM suppression in a 20-cell C-band accelerating structure with NiCr absorbers.

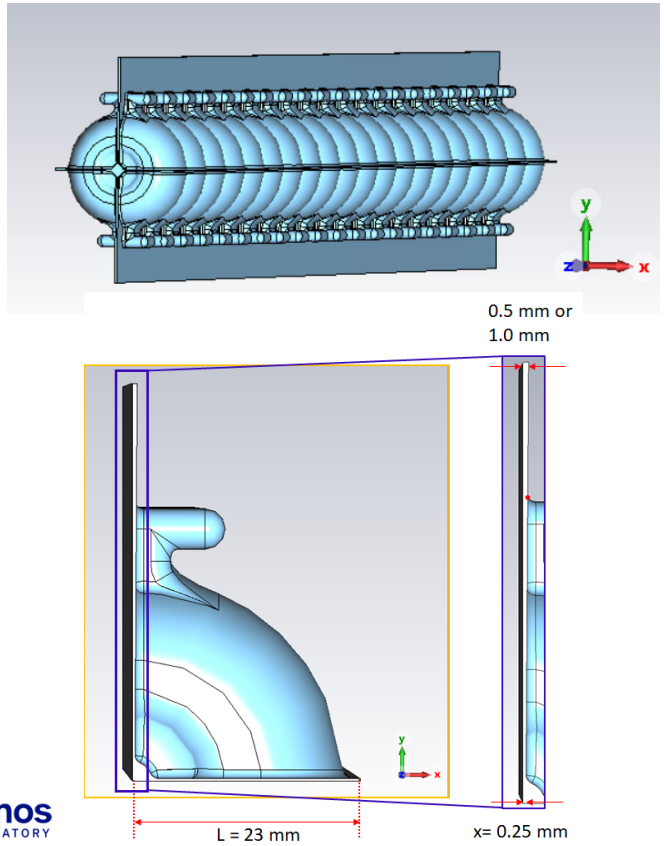


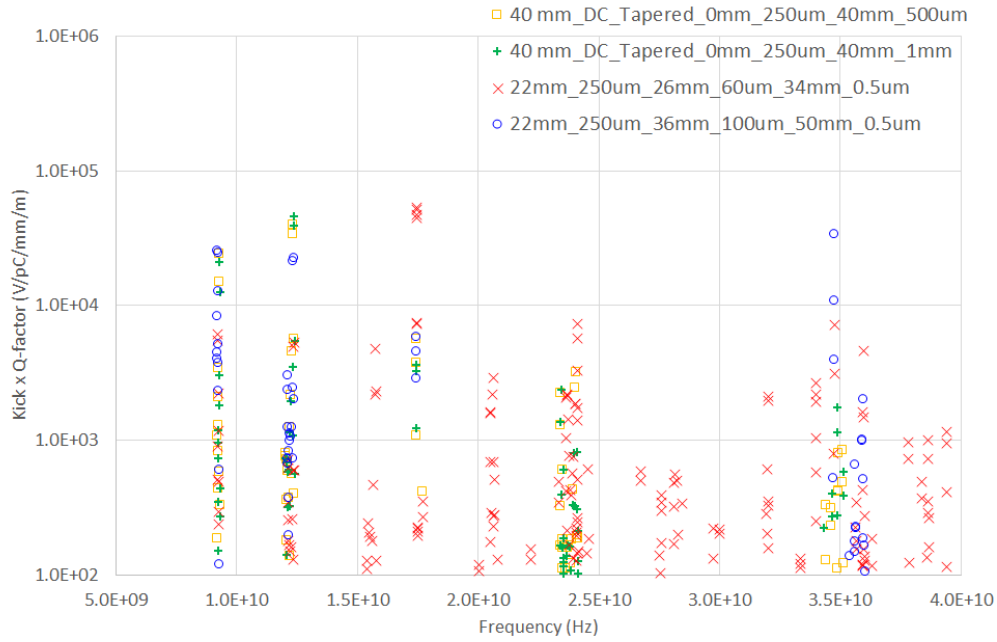




NiCr absorbers in the cavity with distributed coupling

Coupling features change HOM damping characteristics.





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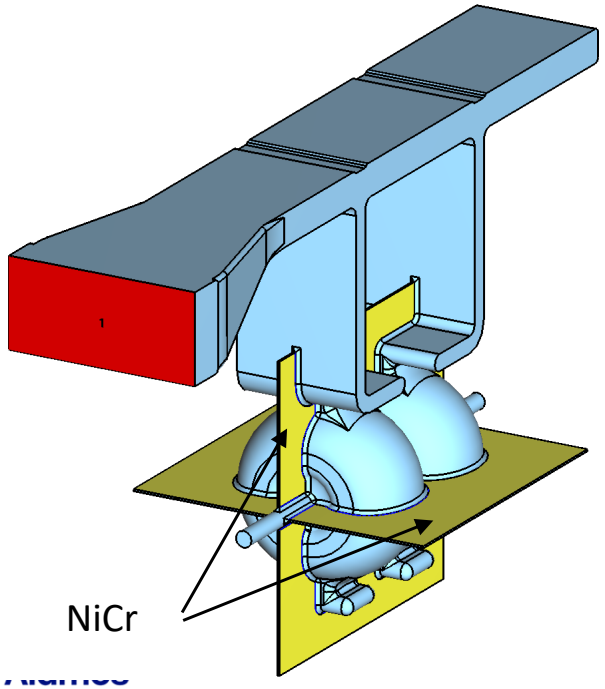
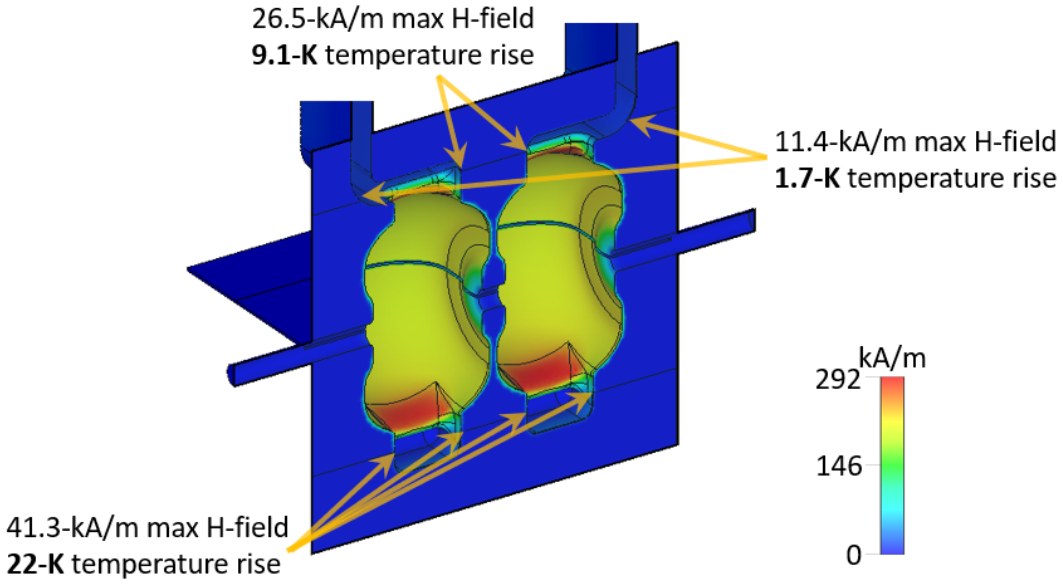
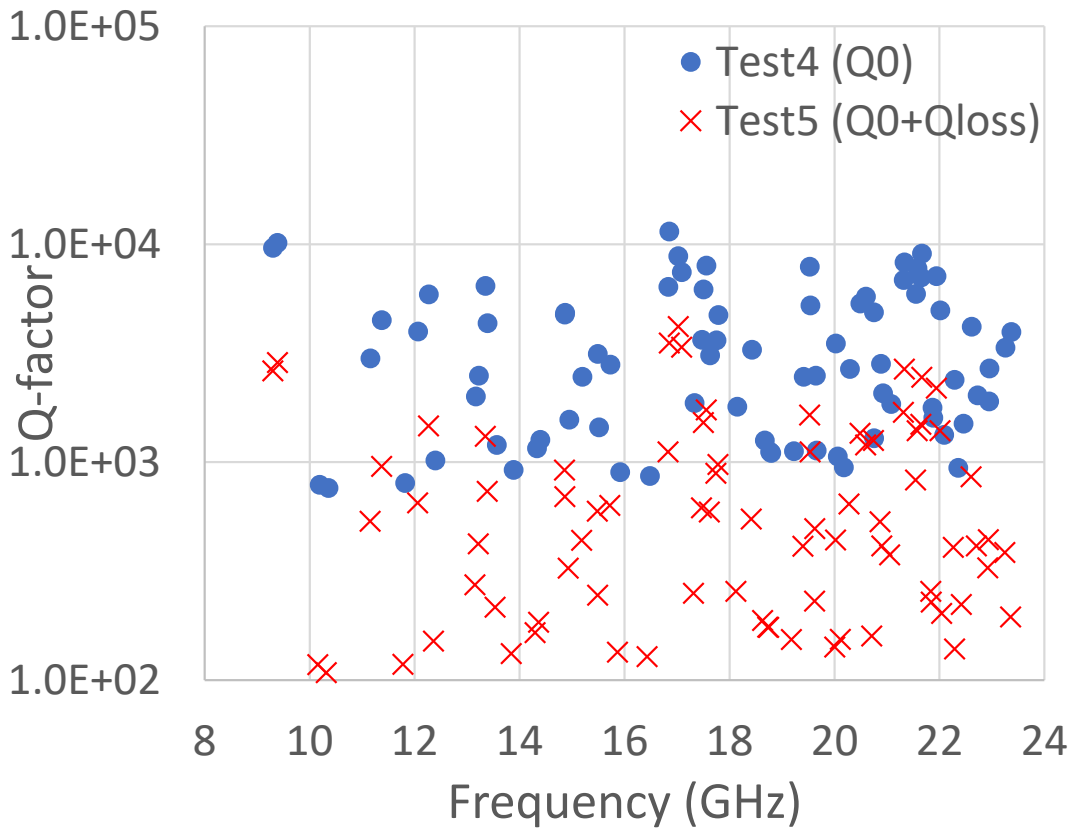
Two-cell test cavity with NiCr absorbers

- A two-cell cavity was designed to test if a structure with NiCr aborbers can be conditioned to high gradients.
- Issues to be studied: pulse heating, HOM generation during breakdown.





HOM suppression in two-cells with HOM absorbers

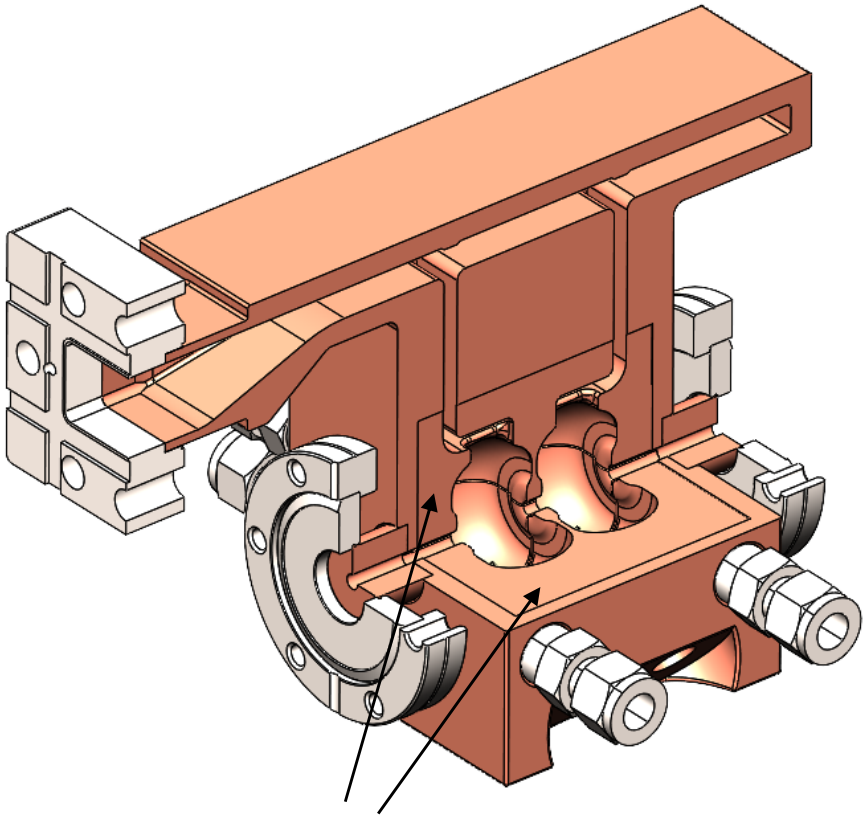


CST without damping		CST with straight damping loads	
Frequency (GHz)	Q-factor	Frequency (GHz)	Q-factor
9.3730	11521	9.3728	8239
12.250	8489	12.249	3292
17.509	7295	17.509	5382
17.569	10466	17.570	4442

Fabrication of the cavity with absorbers (delivery expected in October, 2024)

The cavity is fabricated in four quadrants and several steps:

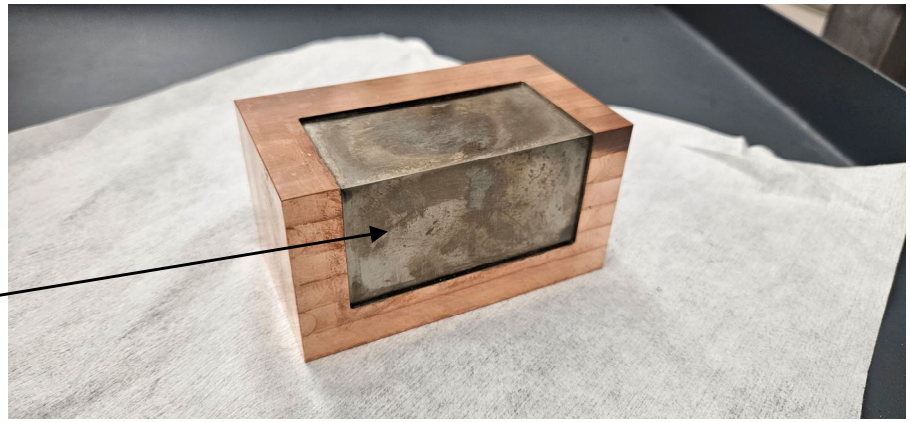
- Pre-fabrication of quadrants with HOM damping manifolds.
- Deposition of Ni and Cr layers.
- Fabrication of all cavity features that will remove unwanted NiCr layer.
- Final brazing and heat treatment of NiCr.

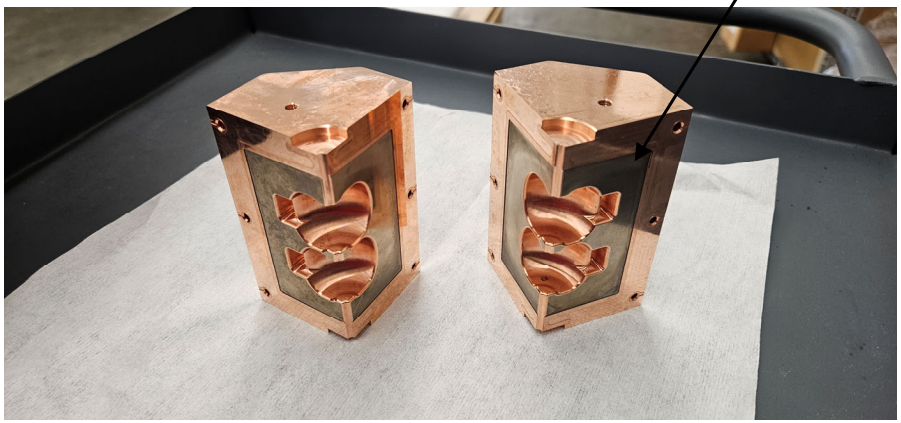


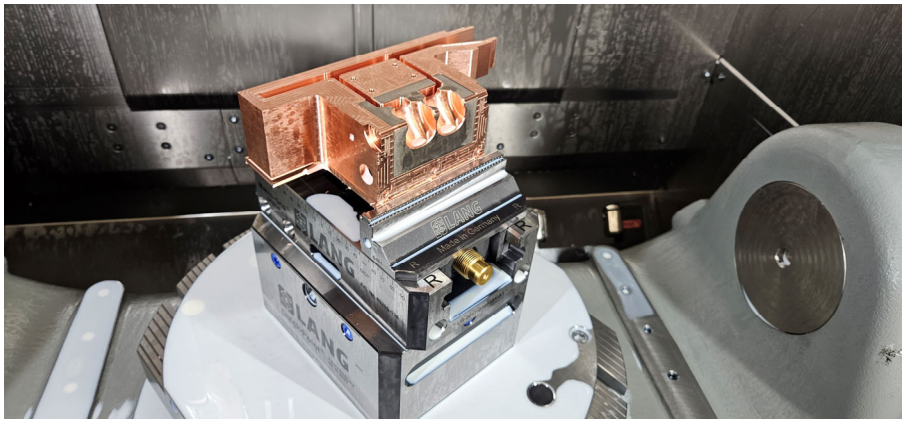
Absorber slots will be covered with NiCr

Latest fabrication update

- Pre-fabrication, and Nickel and chromium deposition performed.
- Cells were machined.
- Brazing and annealing step to follow.

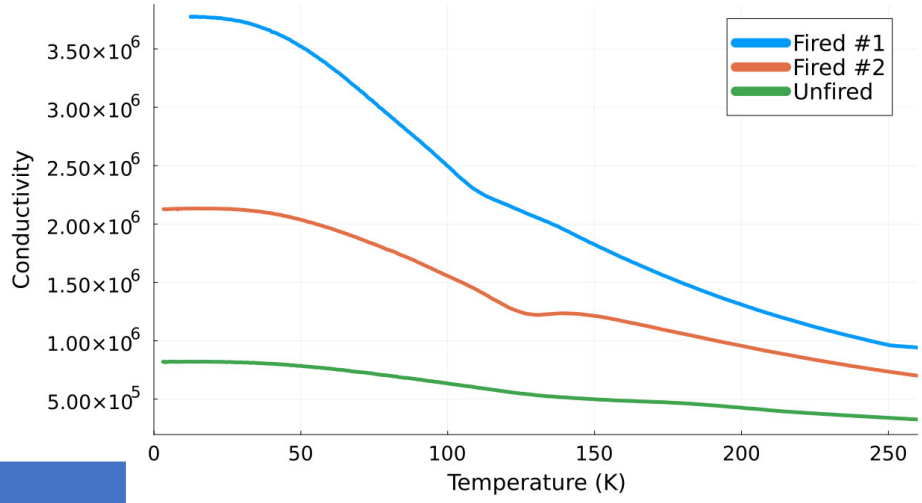




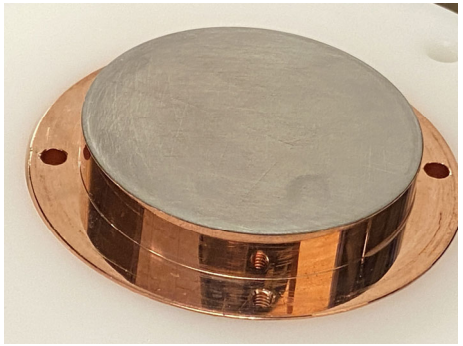


NiCr coupon testing at SLAC

- Unfired sample seemed to maintain low conductivity.
- Fired samples started lossy, but approached Copper values as temperature rose.
- Visual observation suggests some of the coating may have degraded in the firing.



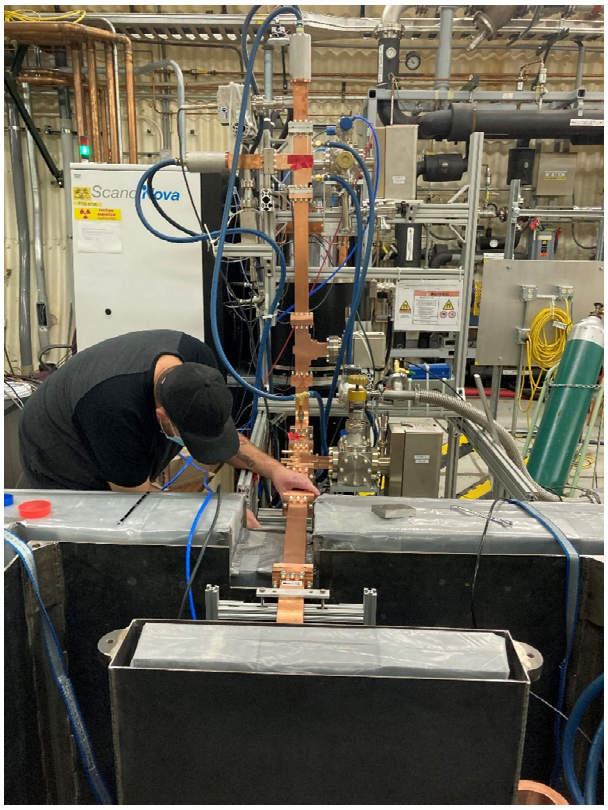
Sample @ 77K	Q0	Qe	β	Qs	σ
Fired #1	44826	214023	0.209	35092	3 MS/m
Fired #2	32783	206483	0.159	27252	1.8 MS/m
Unfired	19072	208524	0.09	17056	706 kS/m



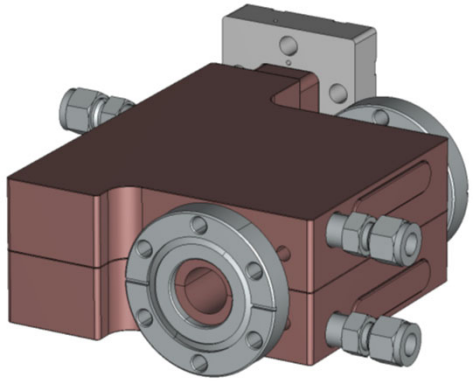
LANL C-band Engineering Research Facility (CERF-NM)

CERF-NM was built with $3M of LANL's internal infrastructure investment.

- Powered with a C-band Canon klystron
- Conditioned to 50 MW
- Frequency 5.712 GHz
- 300 ns – 1 µs pulse length
- Rep rate up to 200 Hz (typical 100 Hz)
- Nominal bandwidth 5.707-5.717 GHz

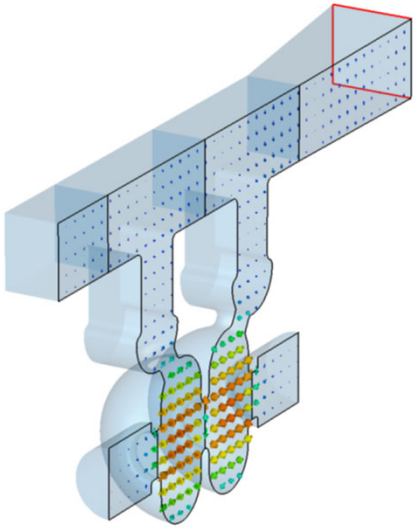


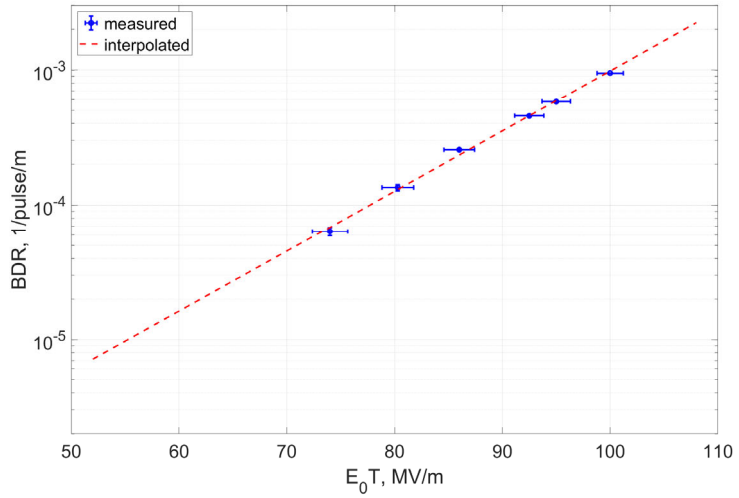
CERF-NM actively works to test various C-band accelerator cells

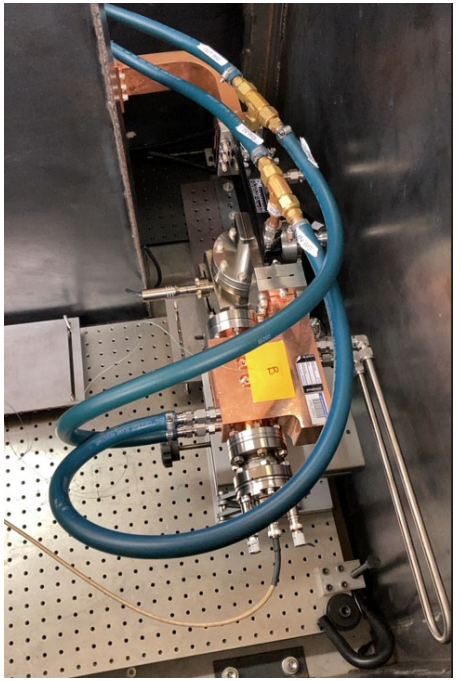


The prototype booster cell for LANSCE upgrade was tested in FY23

The goal of this experiment was to measure the breakdown rates at accelerating gradients up to 100 MV/m.





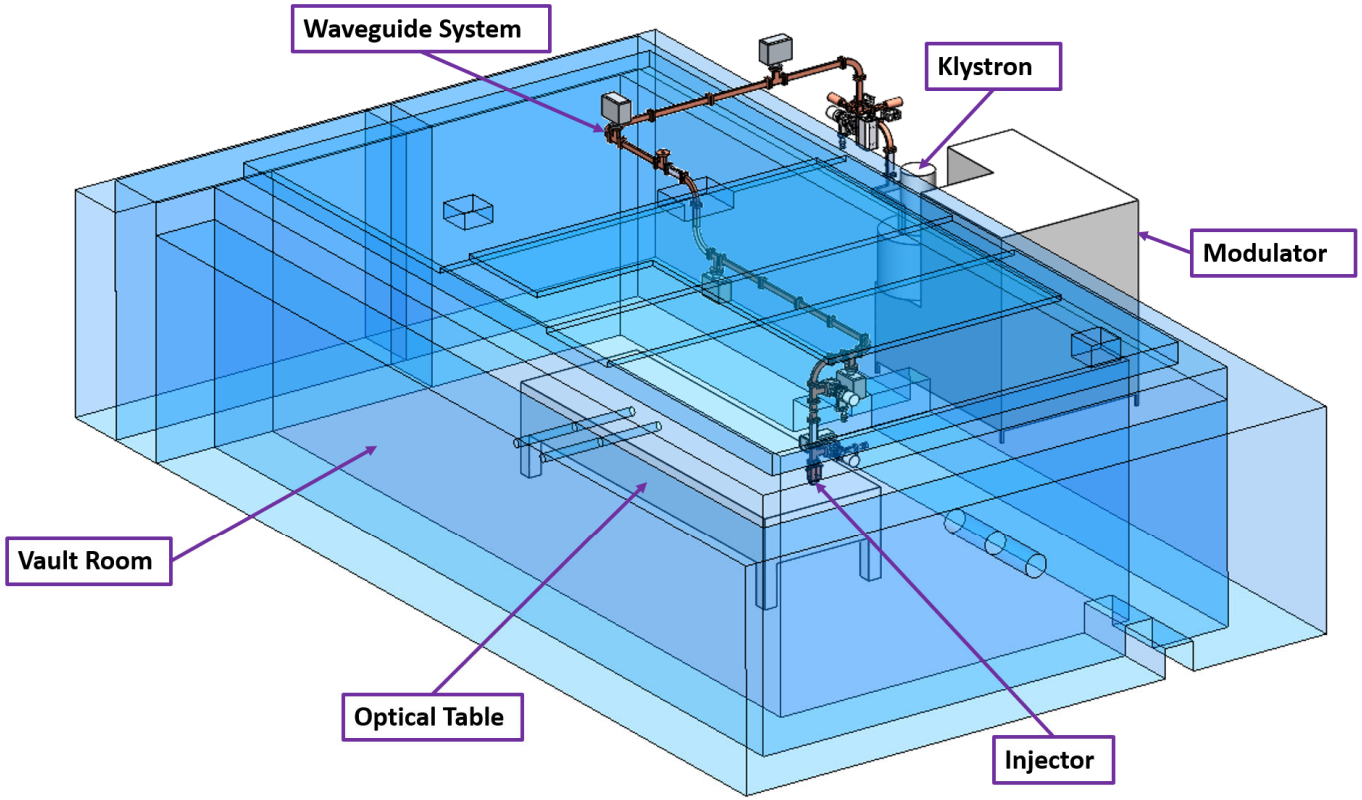


MD Zuboraj *et al.*, Phys. Rev. AB. **27,** 021001 (2024).

CARIE vault

- A location was identified on LANSCE mesa that can accommodate a 20 kW electron beam.
- The vault was cleaned for the new experiment.
- A modulator for the 50 MW C-band klystron has finally arrived.
- The klystron is installed. Conditioned to 35 MW of the output power, 1.5 μs pulse width, 50 Hz rep rate.

CARIE vault facility lineout – design with a magic T

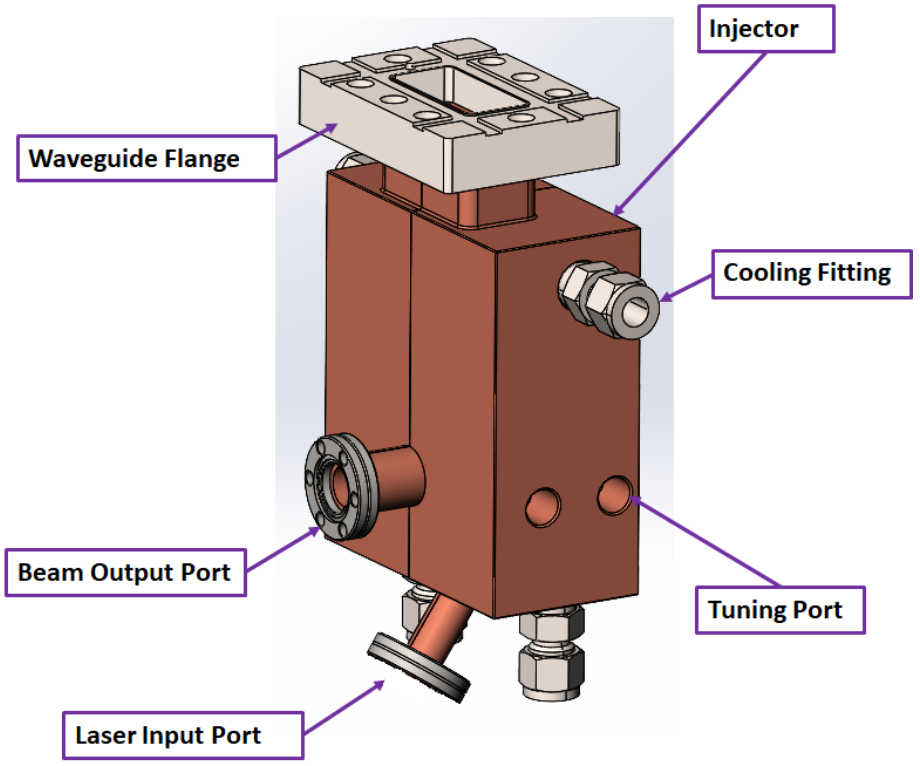


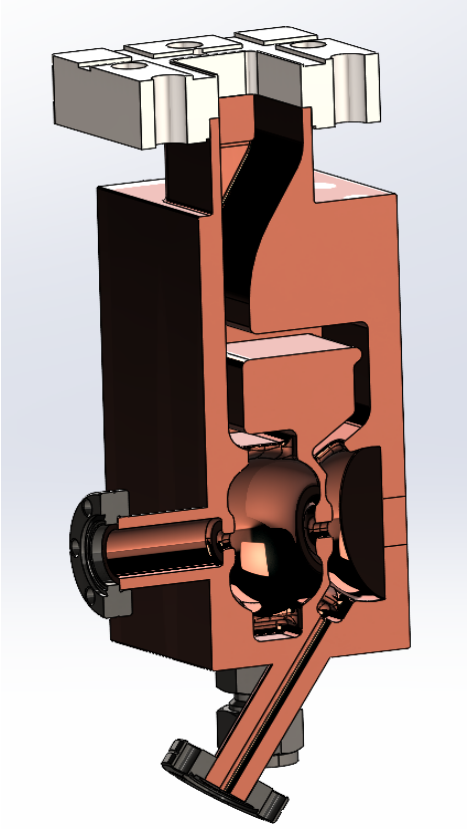
50 MW power circulator for CARIE

- Fabricated by Microwave Techniques LLC.
- Received at LANL in January, 2024.
- Designed to operate at 50 MW of power, 1 μs pulse, 100 Hz repetition rate.
- Must be filled with SF6 at 55 psi.
- Problem: CML WR187 windows are designed for 40 psi, Microwave Techniques WR187 windows are designed for 35 psi.
- Microwave Techniques states that if filled to 30 psi, should operate up to 10 MW of power.
- High gradient conditioning of the circulator starts in October, 2024.

CARIE high gradient RF photoinjector

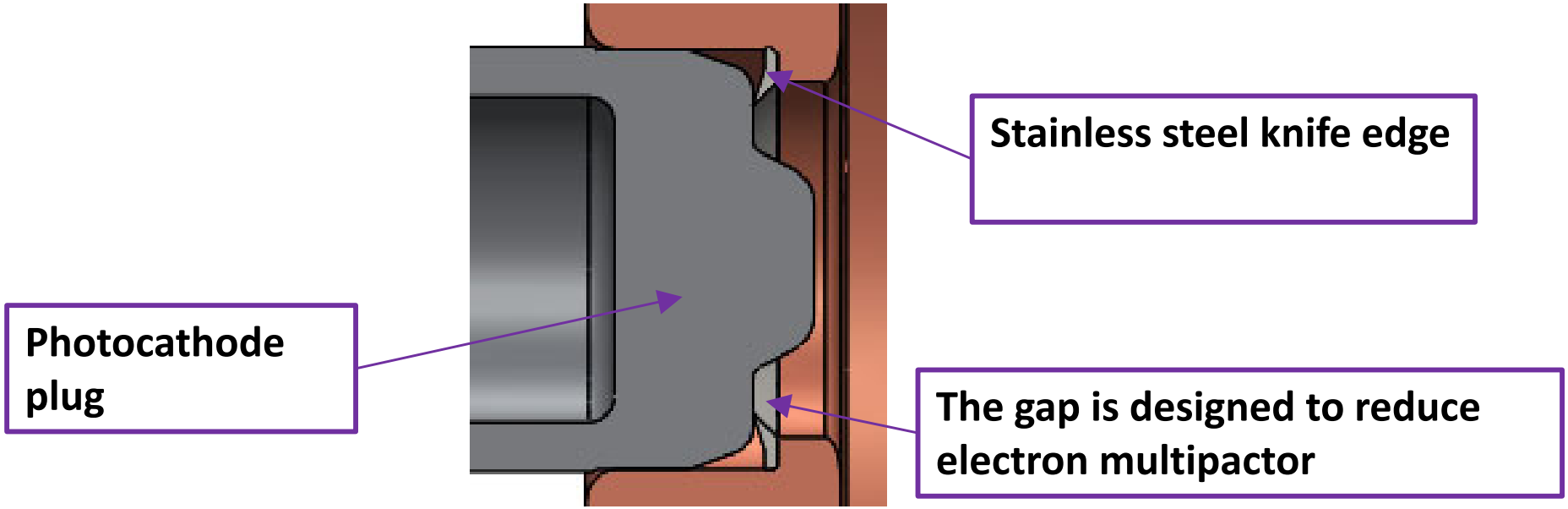
- 1.6 cell injector, two waveguides couple the half-cell and the full cell with 180^0 phase advance.
- Power for E_{cath}= 240 MV/m is about 8 MW.
- The cavity was received and tuned at LANL in October, 2023.
- Tuned frequency 5710.53 MHz in air (5712.15 MHz in vacuum). Measured Q-factor 11869.





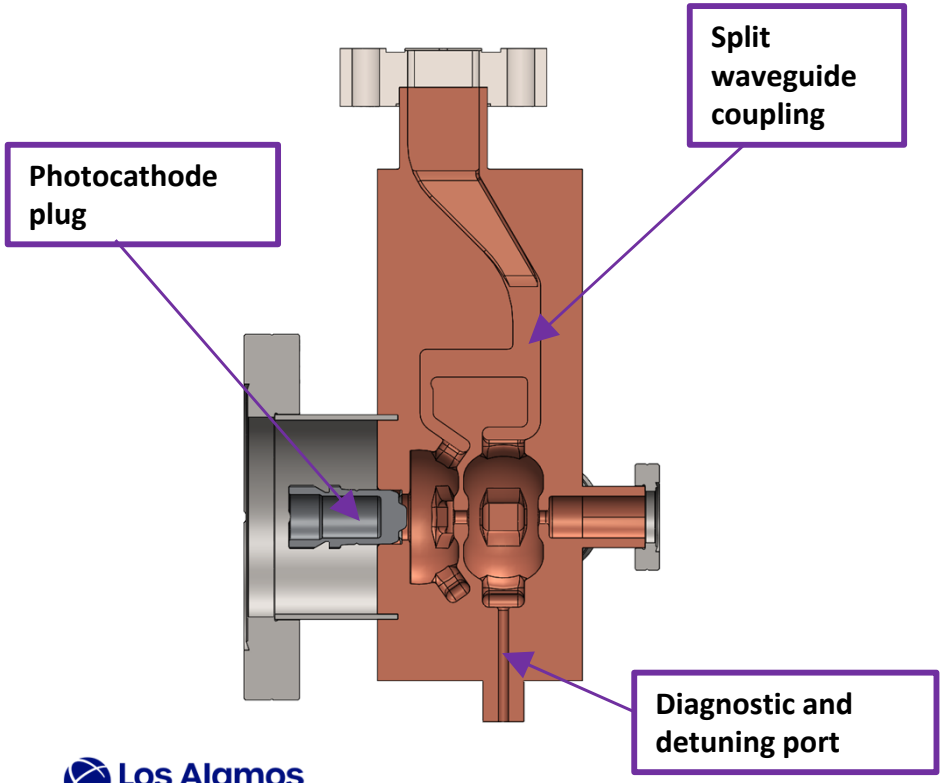
Photoinjector with a cathode plug

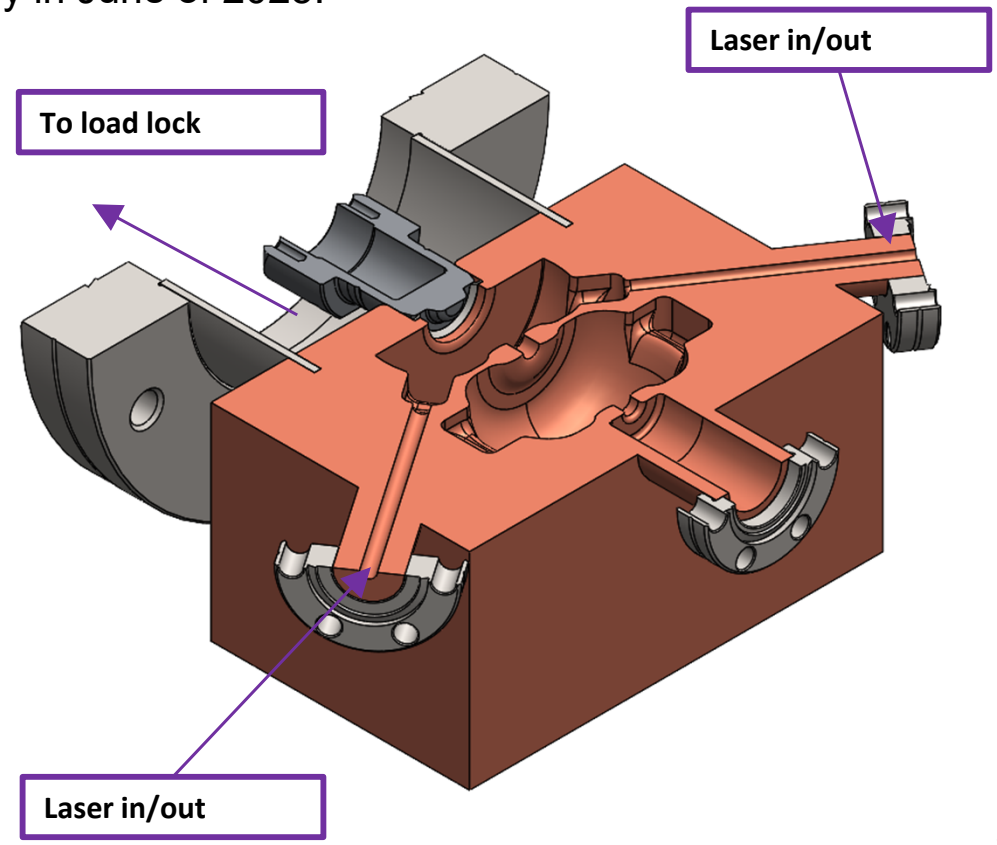
- CARIE facility will be used to study behavior of cathodes at high gradient.
- INFN-style cathode plug will be used for inserting cathodes.
- The choke cavity will reject the fundamental mode coupling into the plug insertion hole.



CAD design of the injector with a plug

- This design is in fabrication with estimated delivery in June of 2025.





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Conclusions and future plans

- LANL will perform high gradient testing of the two-cell structure with NiCr absorbers in 2025.
- We plan to first test the structure at room temperature, and then conduct tests at cryogenic temperatures at CARIE.
- We also conduct simulations of wakefield suppression in multi-cell structures that includes both damping and detuning.