Update on C-band high gradient testing at Los Alamos

Evgenya Simakov, Dmitry Gorelov, Mark Middendorf, Tsuyoshi Tajima, MD Zuboraj
Los Alamos National Laboratory
Valery Dolgashev, Emilio Nanni, Mitchell Schneider, Sami Tantawi
SLAC National Accelerator Laboratory

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Outline of this talk

- Introduction and LANL C-band project overview
- Experimental activities
  - ✓ High gradient C-band test stand
  - ✓ First tests of C-band cavities
  - ✓ Conditioning of mode-launchers and 3-cell cavity testing
- Summary and near-term plans

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Introduction: why Los Alamos

Achieving high-gradient performance (low breakdown rates, low field emission, new materials for HOM absorption, etc.) is a *materials science* problem.

Los Alamos is, at core, a materials science laboratory with particular expertise and interest in metallurgy.

Thus, Los Alamos has both an institutional interest in, and capability to address, this problem space.

LANL must develop accelerators for various national security needs

LANSCE accelerator upgrades:

Applications such as pRad desire higher proton beam energy
→ add a booster to current LANSCE linac to increase beam energy to 3-5 GeV

New capabilities: improve accessibility

Material science at LANL will benefit from powerful directional high repetition rate X-ray sources
43 keV photons can be produced with 42 MeV electron beam
43 keV photons are DMMSC relevant

Compact Accelerators: enabling feasibility

Achieving high gradient performance (low breakdown rates, low field emission, new materials for HOM absorption, etc.) is a material science problem.
LANL is, at core, a material science laboratory

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Overview of LANL High Gradient C-band project

The goals for LANL's high gradient project are

- To establish the benchmark point for the rf breakdown probability at C-band (5.712 GHz).
- To conduct material studies.

This work was funded by Los Alamos National Laboratory (LANL) Laboratory Directed Research and Development (LDRD) program and Technology Evaluation and Development (TED) funds.

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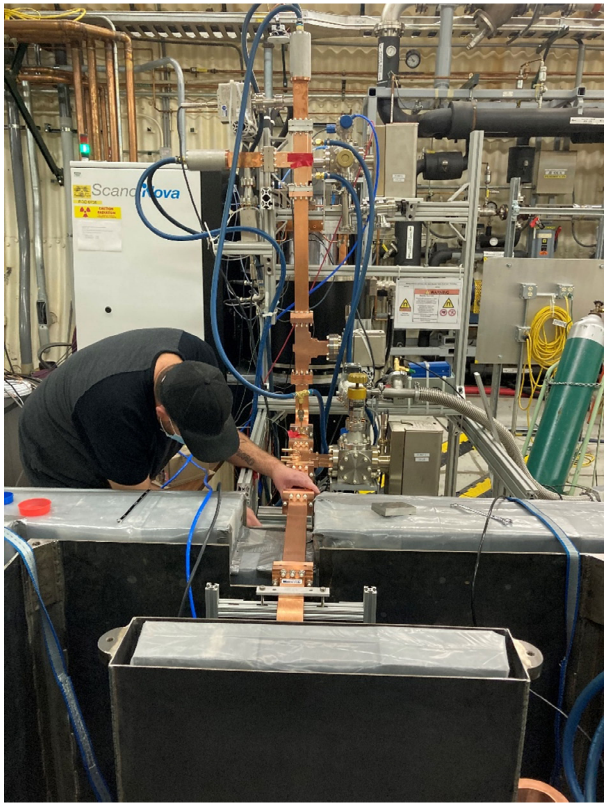
LANL C-band Engineering Research Facility (CERF-NM)

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



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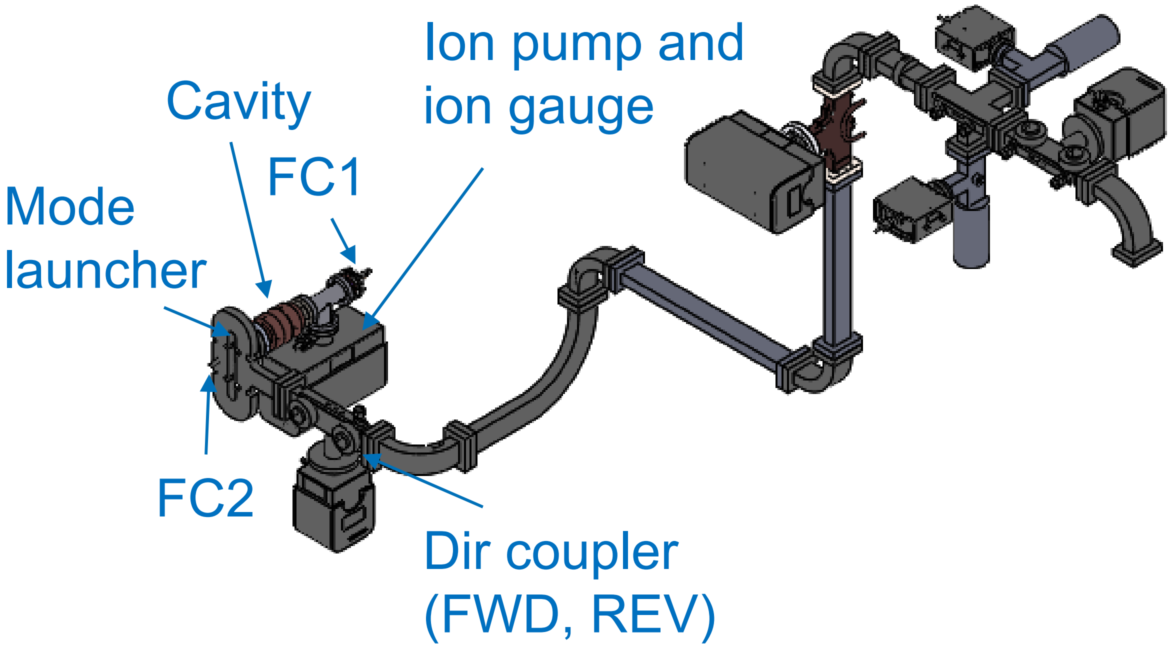
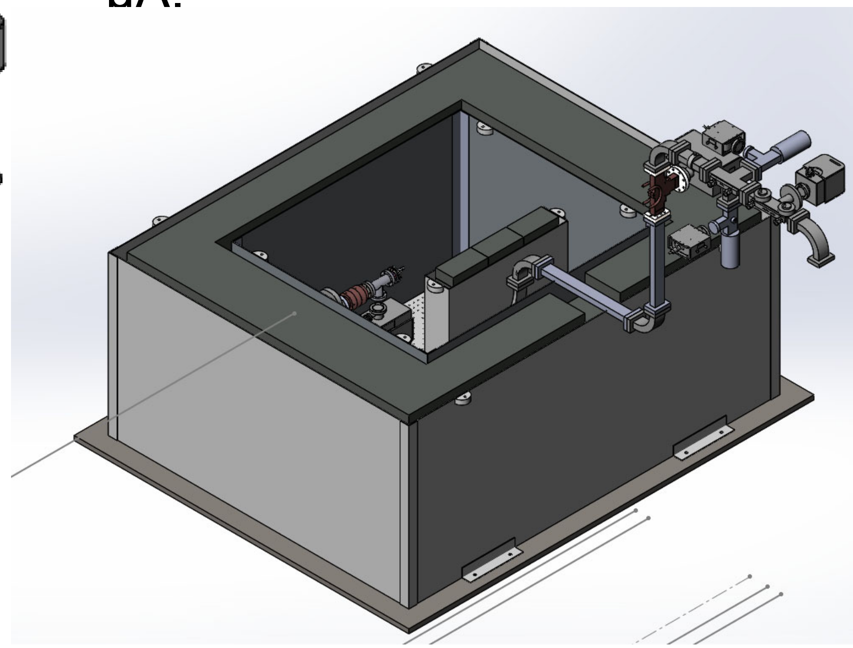
Schematic of the C-band test stand

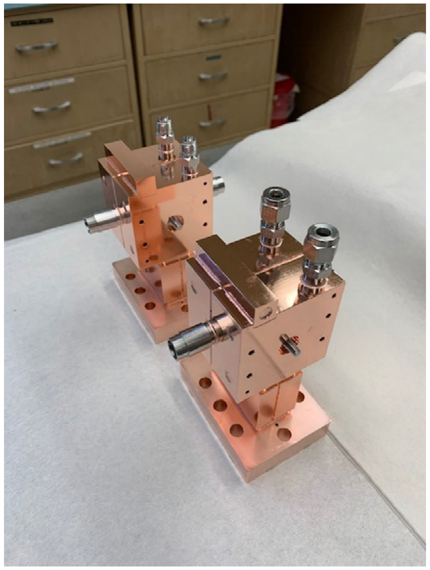


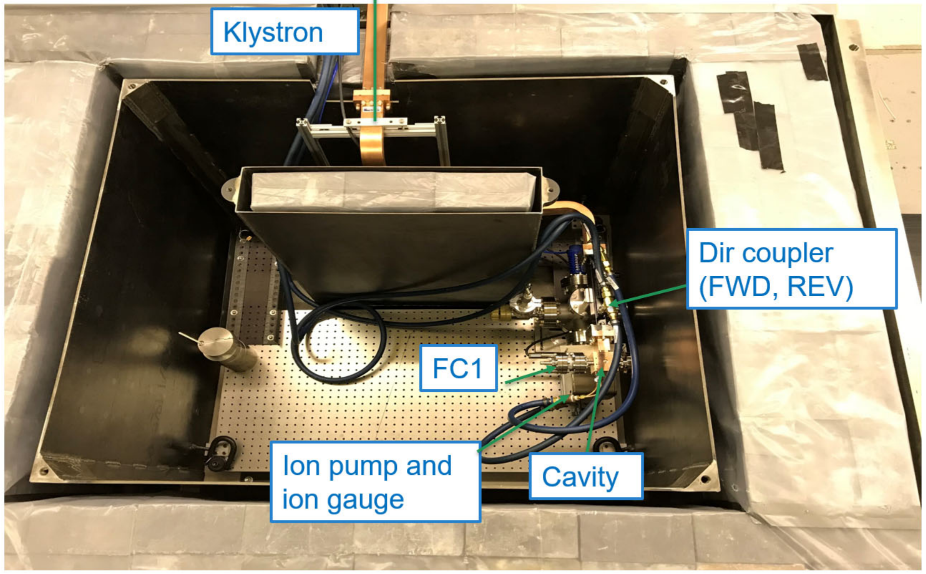
Radiologically certified for dark currents up to 5 MeV and 10 uA.

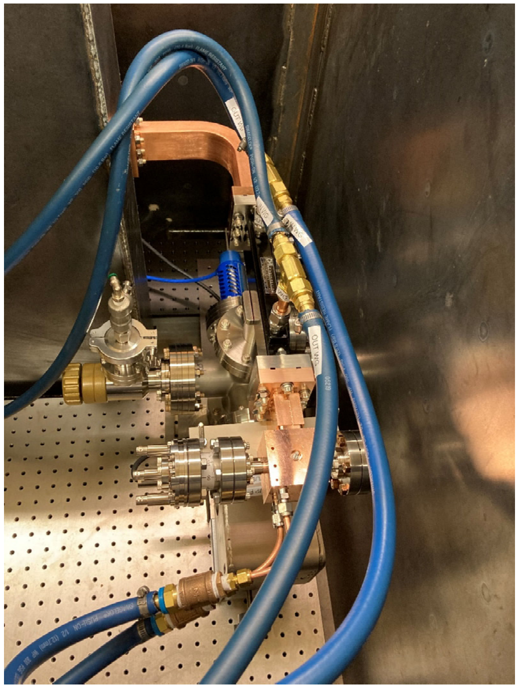


The first two high gradient cavities were tested at CERF-NM in FY21

This C-band high gradient test facility is nationally unique. The first cavities tested at CERF-NM were manufactured at SLAC.







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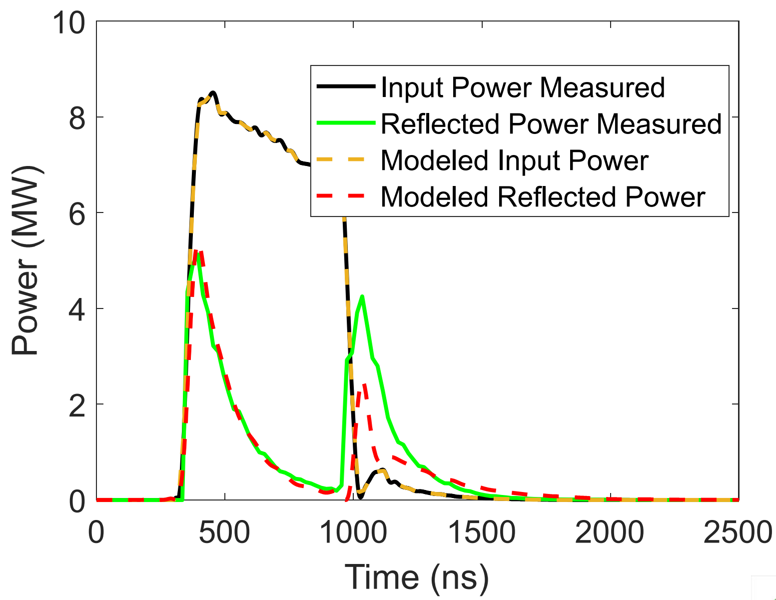
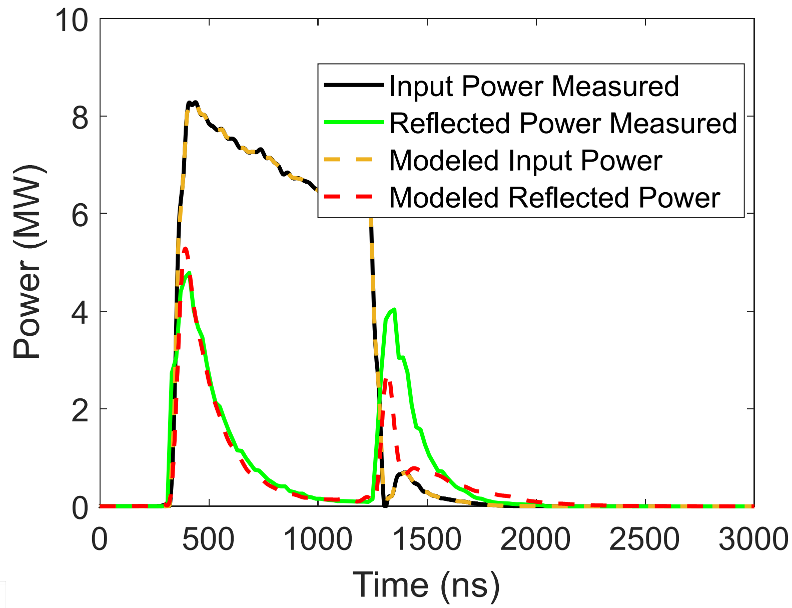
First high gradient testing of a C-band accelerating cavity in the US.

Two cavities were conditioned to the maximum gradient at pulse lengths of 300 ns, 400 ns, 700 ns, and 1 microseconds.

700 ns pulse

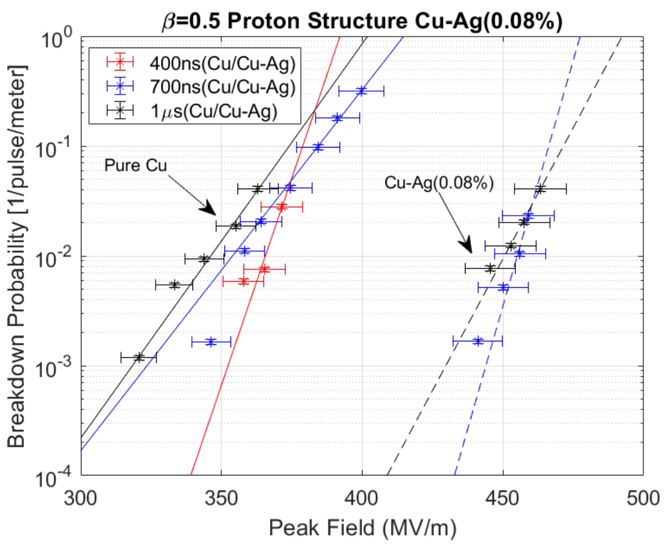


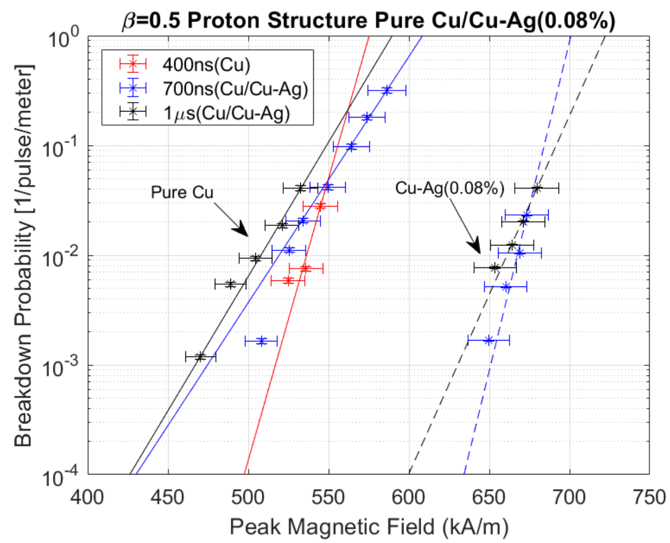
1000 ns pulse

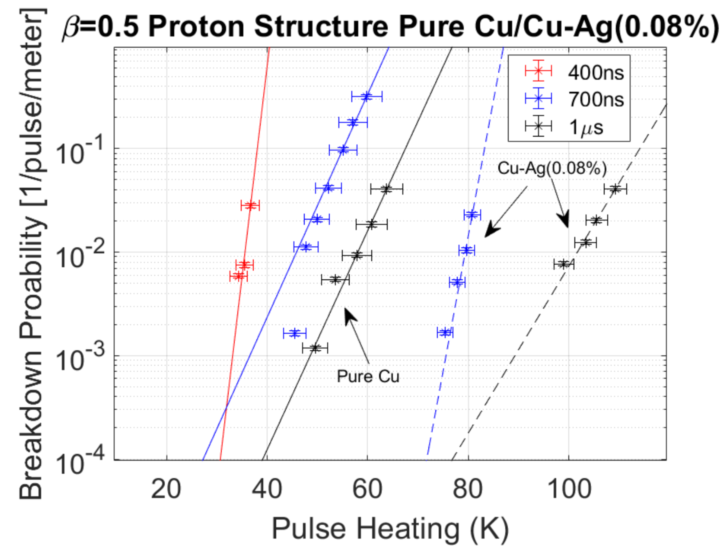


Peak surface electric fields in excess of 300 MV/m demonstrated in high gradient tests

Breakdown probabilities were recorded for three different pulse lengths for copper and copper-silver cavities.







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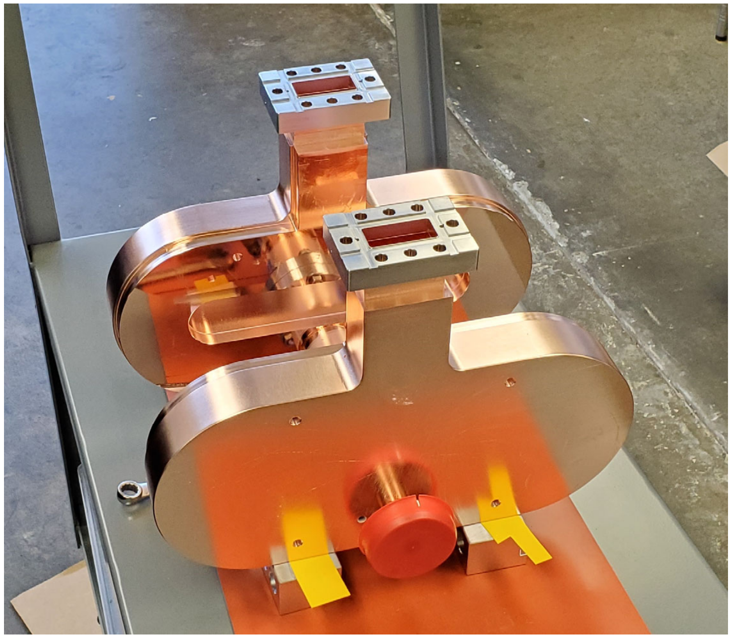
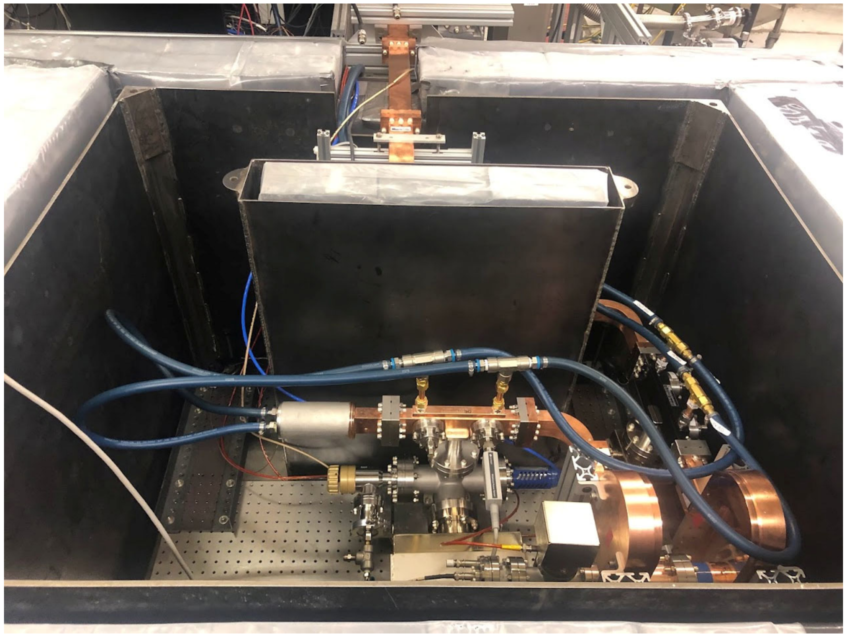
We designed and fabricated a mode-launcher for on-axis coupling with decreased surface magnetic fields

The mode launchers are conditioned up to 20 MW of input power.



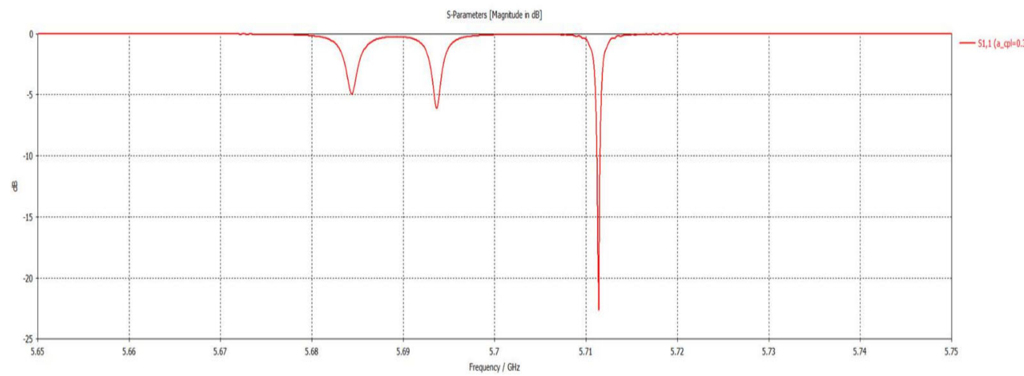


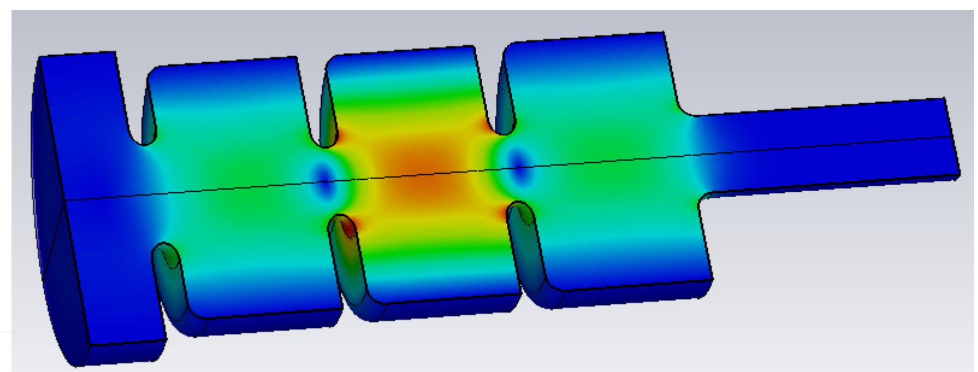
Tests of a benchmark cavity will allow us to establish gradient limitations at C-band as compared to other frequencies

Several cavities will be tested in FY22:

- Copper + brazed (fabricated)
- Copper + welded (in fabrication)
- Copper-silver, 0.085% silver (in fabrication)
- Copper-silver, 2% silver (in fabrication)

Frequency	5.712 GHz
Cell length	1.034 in
a/λ	0.105
Iris radius	0.217 in
Q(copper, RT)	12700
Power for 200 MV/m surface field	5.3 MW





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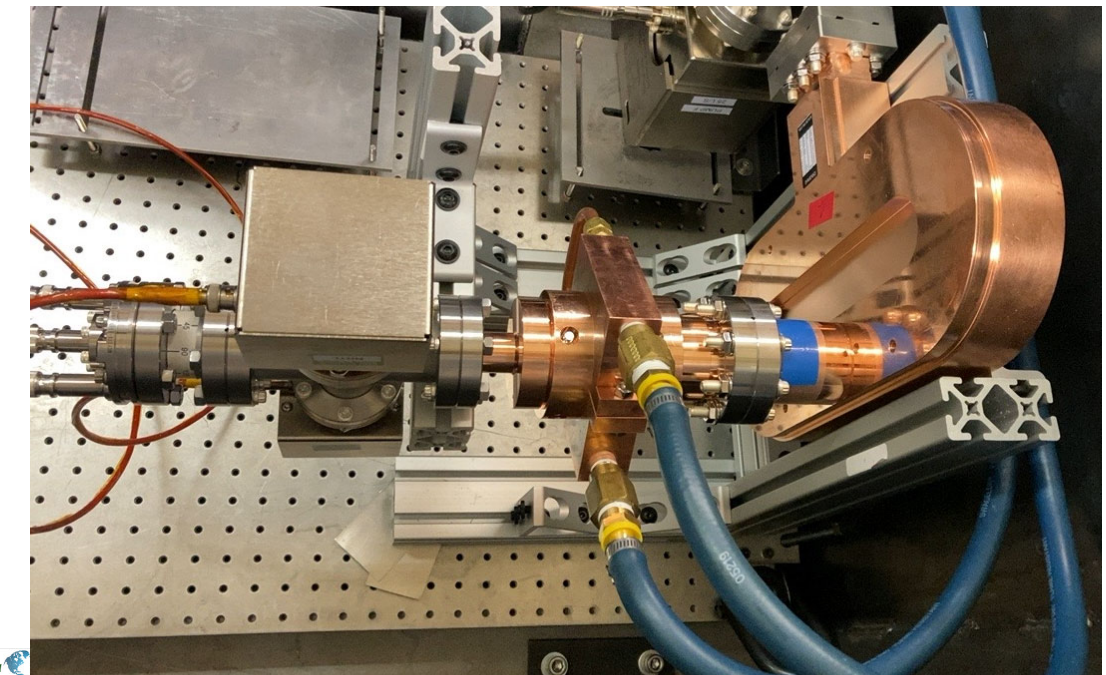
The first a/λ=0.105 cavity is fabricated and currently undergoing high gradient testing

The cavity is currently being conditioned at 400 ns pulse length.



Summary and near term test plans

LANL C-band high gradient test stand is currently operational

- Testing of the SLAC copper beta=0.5 cavities is finished.
- In FY22 we plan to test multiple a/λ = 0.105 cavities made with different methods.

<u>The test stand is open to collaborators.</u>

We consider adding the capability to cool cavities under test to cryogenic temperatures.

LANL has plans for further developing its C-band accelerator capabilities

- We aim to develop a C-band accelerator test facility for advanced cathode, accelerator, and material studies.
- A location was identified on LANSCE mesa that can accommodate a 20 kW electron beam.
- Director Initiative money were allocated in FY22 to jump start this facility.
- 5-year goal: build operational C-band cryo-cooled copper accelerator.
- Ultimate goal: provide 43 keV photon bursts for material studies