# C-Band RF Cavity Development for Photocathode Testing and for HOM Absorber Testing

Haoran Xu, Petr M. Anisimov, Dongsung Kim, and Evgenya I. Simakov, Los Alamos National Laboratory, Los Alamos, NM 87545, USA

## 5.712-GHz Photoinjector Design Overview

### GOAL

- Room-temperature cathode field exceeding 100 MV/m.
- Equal surface peak electric field in individual cells.
- 180-deg RF phase difference between individual cells.
- Critical coupling at room temperature.

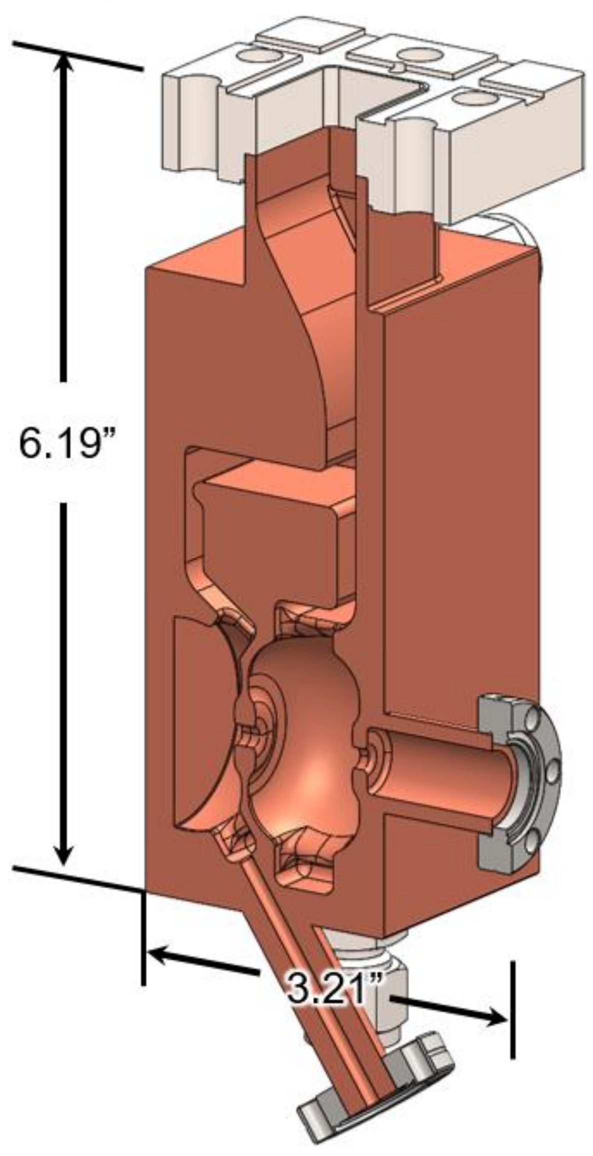
### INDIVIDUAL CELL PROFILE

- Designs of the individual cell profiles and the coupling slots to the cells were provided by SLAC and UCLA.

### DESIGN TOOLS

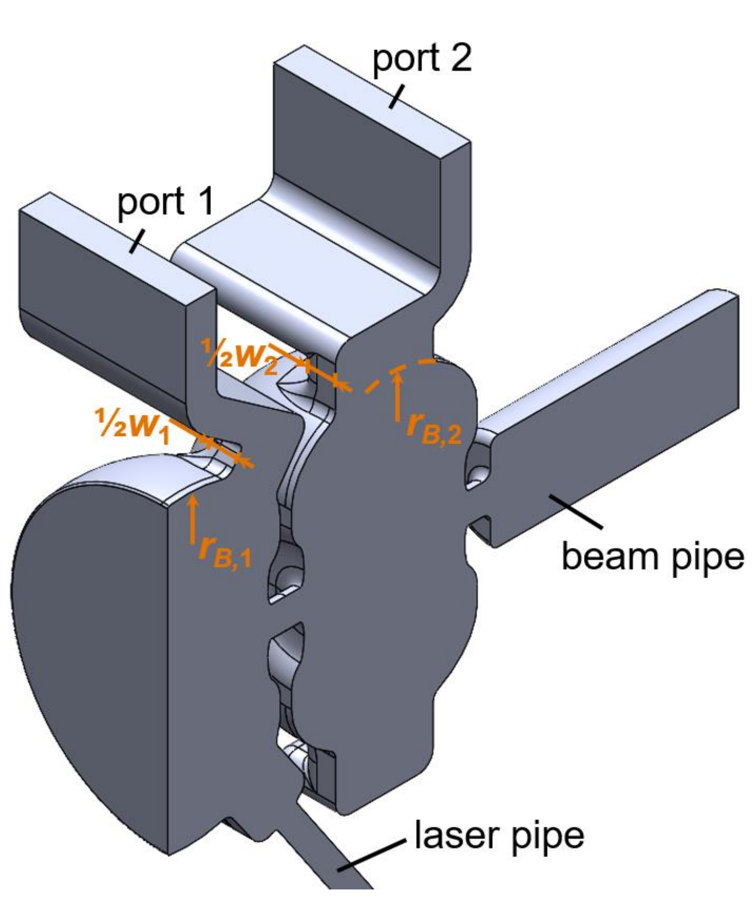
- CST Frequency Domain Solver.
- SOLIDWORKS

| Design parameters | |
|---|---|
| Operating frequency $f_0$ | 5.712 GHz |
| Cathode cell length $l_{cath}$ / ½$\lambda_0$ | 0.6 |
| Full cell length $l_{full}$ / ½$\lambda_0$ | 1.0 |
| Full cell shunt impedance $R_{sh}$ ($r_{sh}$) | 3.09 MΩ (118 MΩ/m) |
| Cathode cell unloaded quality factor $Q_{0,cath}$ | 14695 |
| Full cell unloaded quality factor $Q_{0,full}$ | 13603 |
| Entire-cavity unloaded quality factor $Q_{0,cav}$ | 14170 |
| Cavity coupling factor $\beta$ | 1.00 |
| RF power for 100-MV/m cathode field | 1.4 MW |
| RF power for 240-MV/m cathode field | 8.0 MW |




**Presentation: May 17, at 14:40**
**53/3-3002 – Almanor (SLAC)**

## Tuning of individual cells

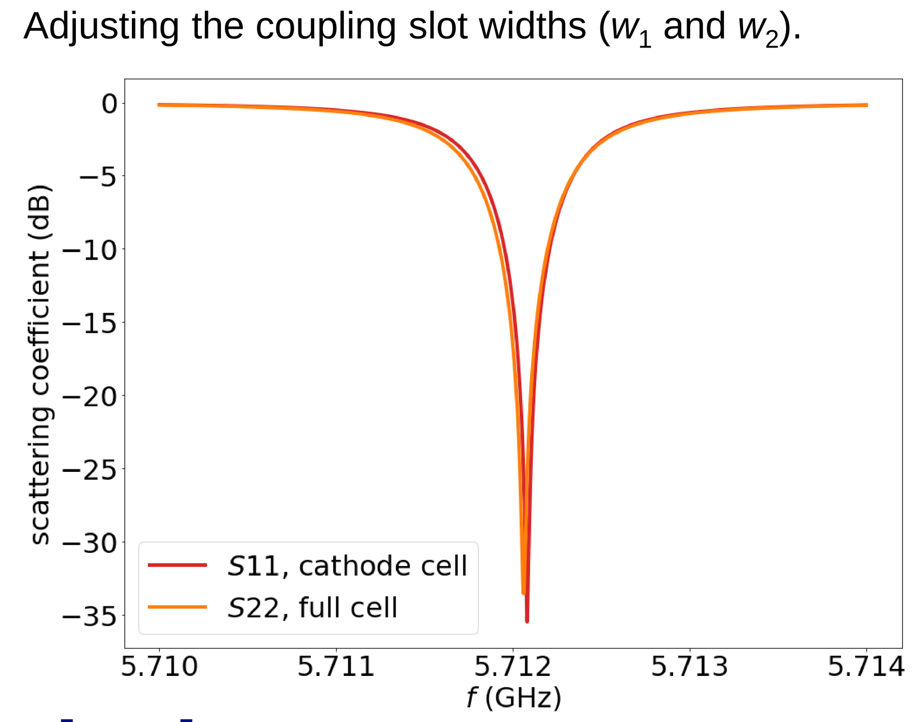



### FREQUENCY TUNING

Adjusting the minor radius of the sidewall profile in each cell ($r_{B,1}$ and $r_{B,2}$).

### COUPLING FACTOR TUNING

Adjusting the coupling slot widths ($w_1$ and $w_2$).




## Waveguide splitter design

### POWER DIVIDING

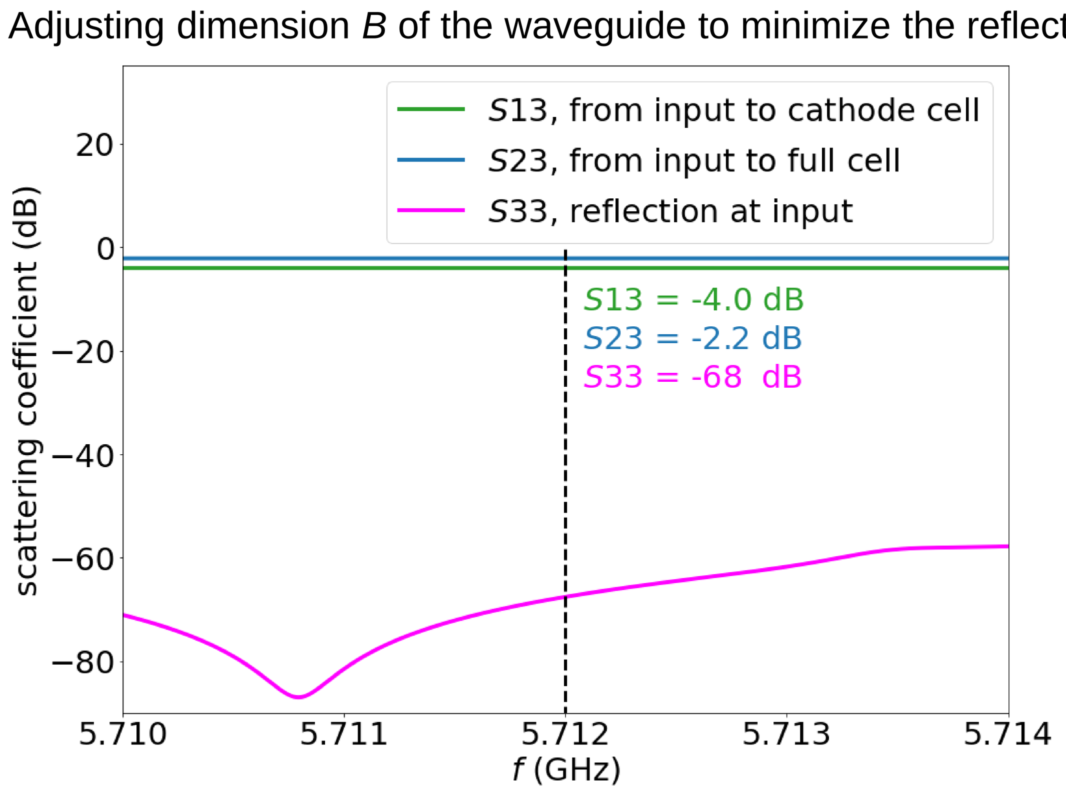
Adjusting "choke" size $c$. Smaller choke size limits the power going into the cathode cell.

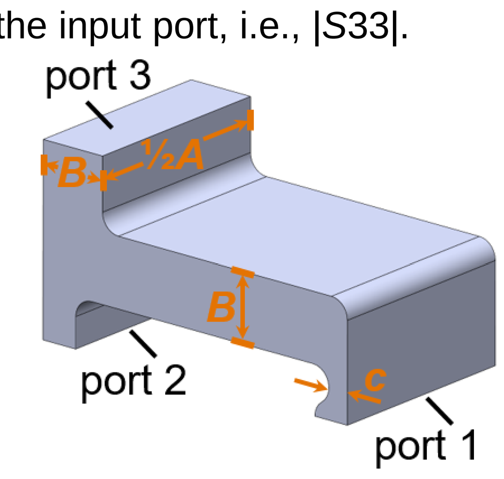
### PHASE DIFFERENCE

Adjusting dimension $A$ of the waveguide. Greater dimension $A$ increases the phase difference.

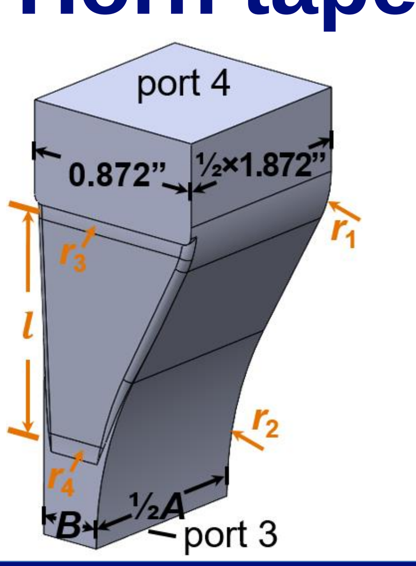
### REFLECTION MINIMIZATION

Adjusting dimension $B$ of the waveguide to minimize the reflection at the input port, i.e., |$S33$|.




## Horn taper optimization




### PORT 4

The input port has the dimensions of the standard WR187 waveguide.

### PORT 3

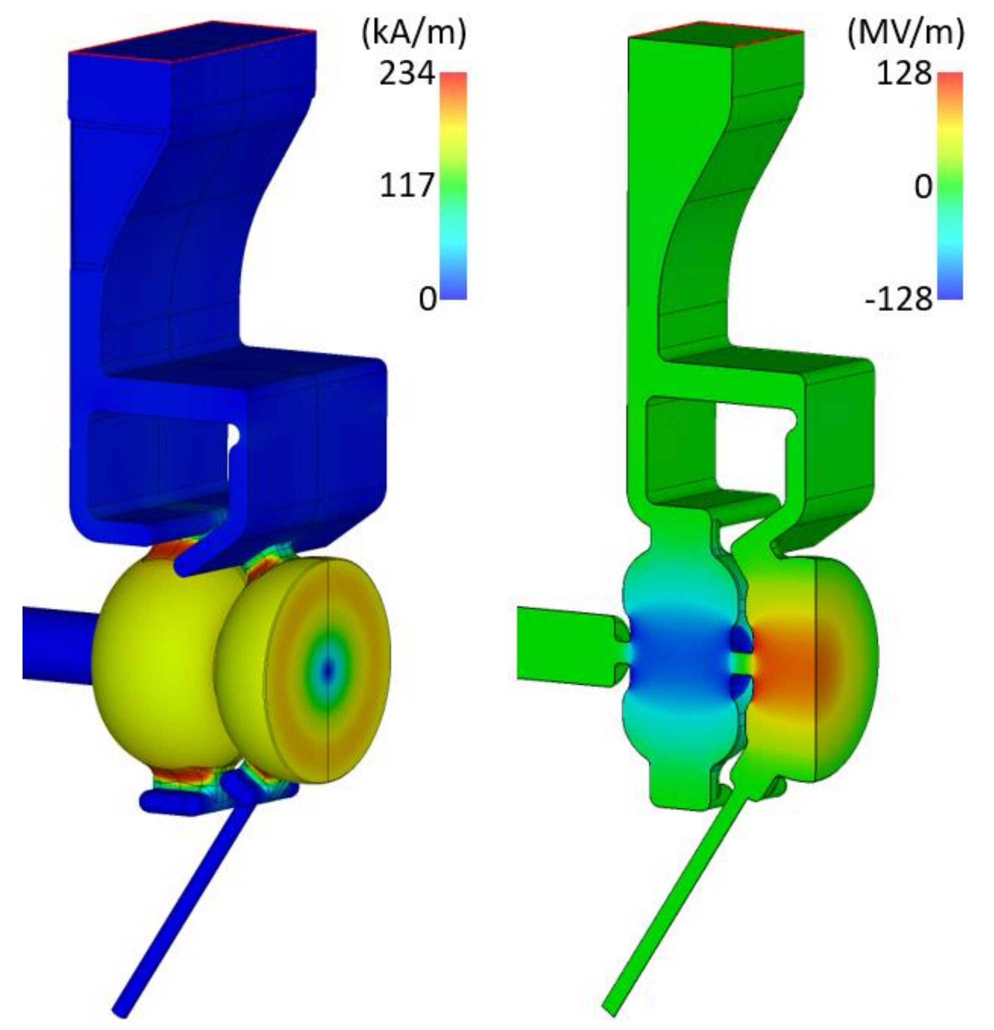
The output port matched the waveguide splitter design.

### REFLECTION MINIMIZATION

- Adjusting the fillet sizes $r_1$, $r_2$, $r_3$, and $r_4$, and the taper section length $l$, to minimize the reflection at the WR187 waveguide port.
- Minimized reflection achieved below -60 dB.

## Finalized cavity design

- Local peak electric field normalized to the peak electric field on the beam axis, $E_m$.
- Local peak magnetic field normalized to ($E_m$ / $Z_0$), where $Z_0$ = 377 Ω.




| Electric field local peak values | |
|---|---|
| Cathode cell overall | 1.20 |
| Cathode plane | 0.94 |
| Cathode cell coupling slot | 0.48 |
| Full cell overall | 1.20 |
| Full cell coupling slot | 0.30 |
| Choke | 0.059 |

| Magnetic field local peak values | |
|---|---|
| Cathode plane | 0.55 |
| Cathode cell coupling slot | 0.69 |
| Full cell coupling slot | 0.66 |
| Choke | 0.035 |

## Fabrication

- Cavity profile with significant complexity.
- Copper cavity machined in halves, and then brazed together with the flanges.
- One pair of tuners used for the cathode cell and the full cell, respectively, on the opposite sides, in the horizontal direction.
- Beam pipe diameter expanded for accommodating the electron beam transverse size variation over the course of the initial transport.

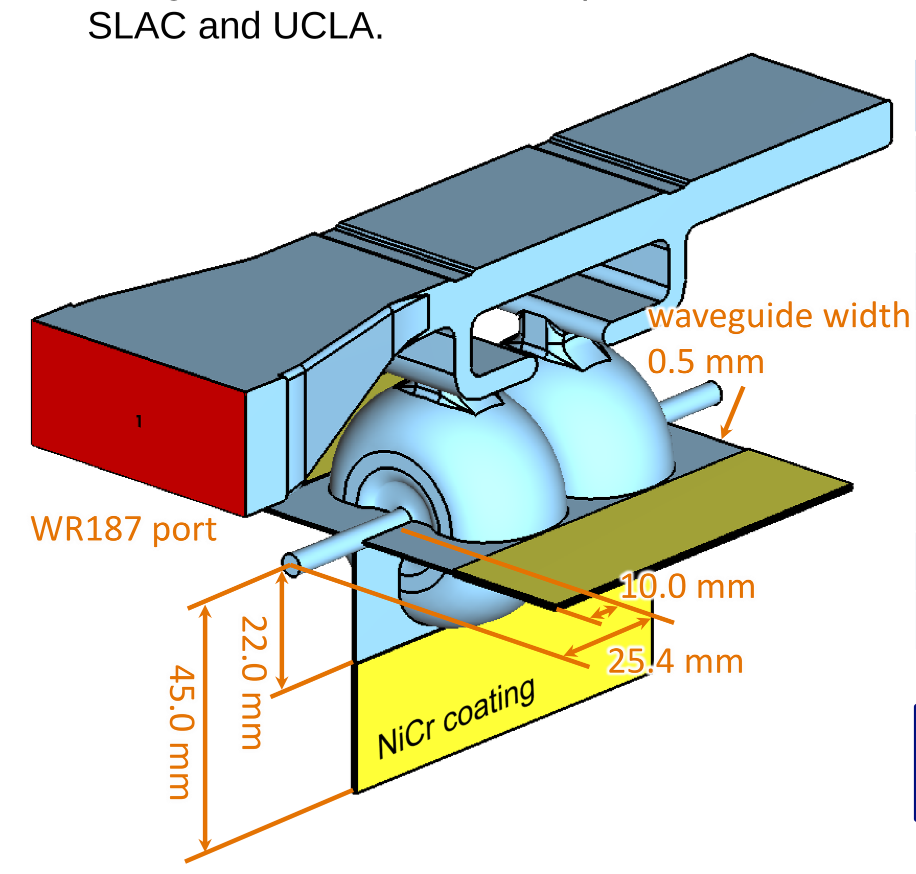
## 5.712-GHz two-cell cavity with HOM absorber

### GOAL

- Performance of the HOM absorber coating, i.e., NiCr, vs. high-gradient breakdowns.
- High-gradient testing of the RF design.
- Critical coupling, π-mode.

### INDIVIDUAL CELL PROFILE

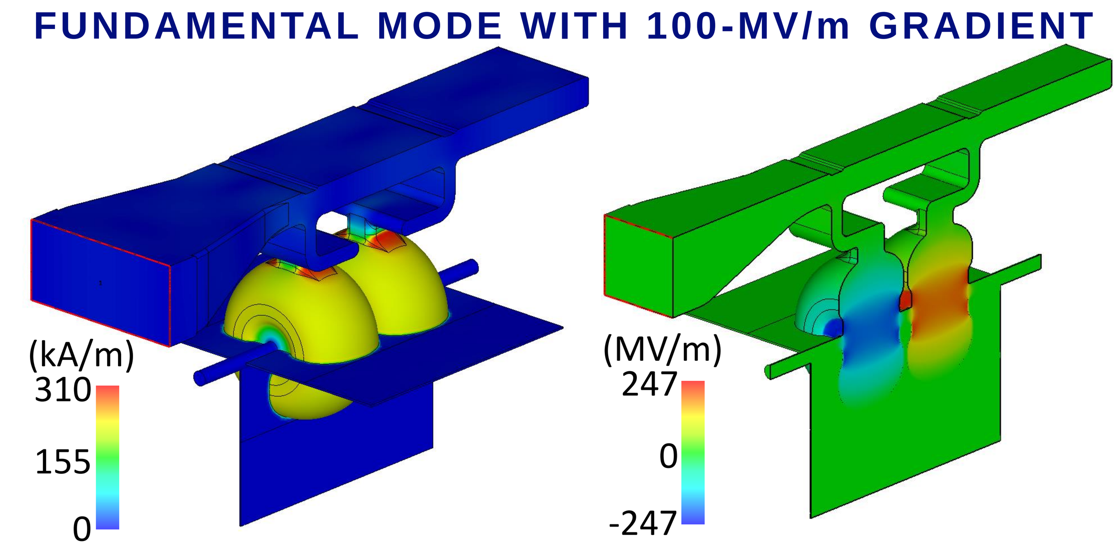
- Designs of the individual cell profiles and the coupling slots to the cells were provided by SLAC and UCLA.




| Design parameters | |
|---|---|
| Operating frequency $f_0$ | 5.712 GHz |
| unit cell shunt impedance $r_{sh}$ | 118 MΩ/m |
| unloaded quality factor $Q_0$ | 13500 |
| unloaded quality factor, without absorber $Q_{0,\text{ uncoated}}$ | 13525 |
| Cavity coupling factor $\beta$ | 1.00 |
| RF power for 100-MV/m gradient | 4.4 MW |
| NiCr loss for 100-MV/m gradient | 2.5 kW |
| NiCr electrical conductivity | 1.0×10$^6$ S/m |

**Presentation: May 17, at 11:20**
**51/3-305 - Kavli 3rd Floor (SLAC)**

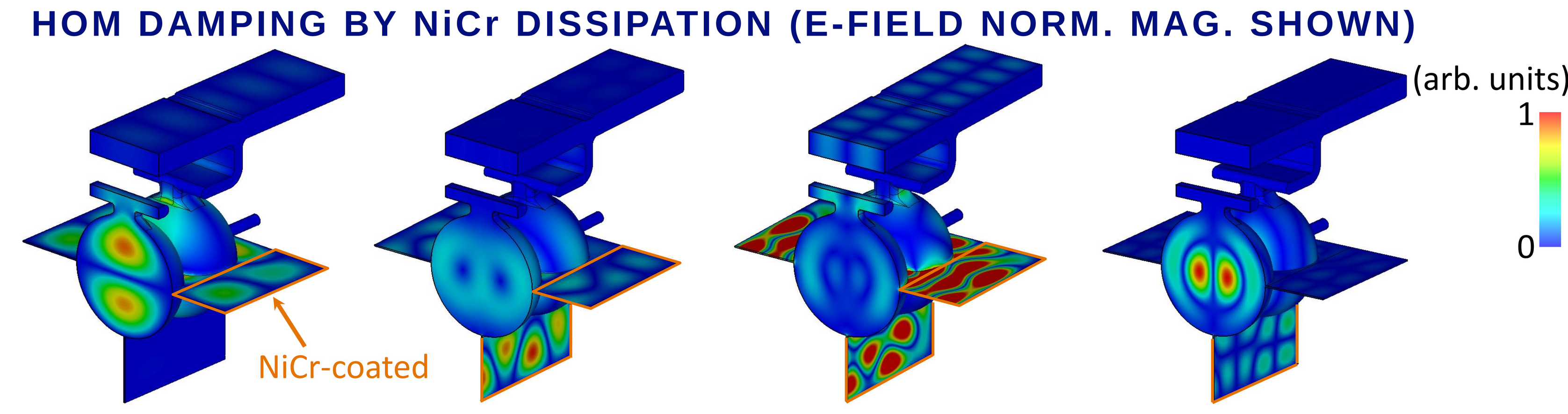
### FUNDAMENTAL MODE WITH 100-MV/m GRADIENT




| Electric field local peak values | |
|---|---|
| Cavity overall | 1.48 |
| Coupling slot | 0.28 |
| Waveguide | 0.086 |

| Magnetic field local peak values | |
|---|---|
| Coupling slot | 0.70 |
| Waveguide | 0.075 |

### HOM DAMPING BY NiCr DISSIPATION (E-FIELD NORM. MAG. SHOWN)




TM110 (9.27 GHz) TM211 (12.28 GHz) TM120 (15.67 GHz) TM121 (17.65 GHz)

## Fabrication

- Cavity profile with significant complexity.
- Copper cavity machined in quadrants, coated with NiCr layers, and then brazed.
- One tuner for each quadrant.

Managed by Triad National Security, LLC, for the U.S. Department of Energy's NNSA.

Photoinjector cavity work supported by the Laboratory Directed Research and Development program of Los Alamos National Laboratory, under project number 20230011DR.

HOM-damping cavity work supported by the U.S. Department of Energy, under Contract No. 89233218CNA000001

The 2023 International Workshop on Future Linear Colliders (LCWS2023)
SLAC, Menlo Park, CA, USA
15-19 May 2023

haoranxu@lanl.gov

LA-UR-23-24871