A Coupon Tester for Normal Conducting High-Gradient Materials

MOPAB371

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Outline

- What is a coupon tester?
- Why not use a TM_{010}-mode cavity?
- Design Considerations
- Candidate Geometries
- Conceptual Assembly
- Conclusions and Timeline

A few notes up front…

This work is supported by the Los Alamos LDRD program.

It is part of an effort to develop theoretical models of the breakdown process, to *ab initio* design new materials for high-gradient operation, and to test those materials in a C-band test stand at Los Alamos.

What is a coupon tester?

- Higher fields (E, H, modified Poynting vector) are associated with higher breakdown rates, all else equal.

- A coupon tester is a specially designed RF structure to:
  - Allow high RF field gradients (electric and magnetic, in our case) to be applied to a removable part of the structure;
  - Have the highest fields in the structure, be on that removable part.

- So, a coupon tester lets us explore the behavior of candidate materials for high-gradient structures, at high fields, without having to build a complete structure
  - Faster to prepare to test a new material
  - Less expensive
  - Allows easy "post-mortem" examination of the surface post-testing

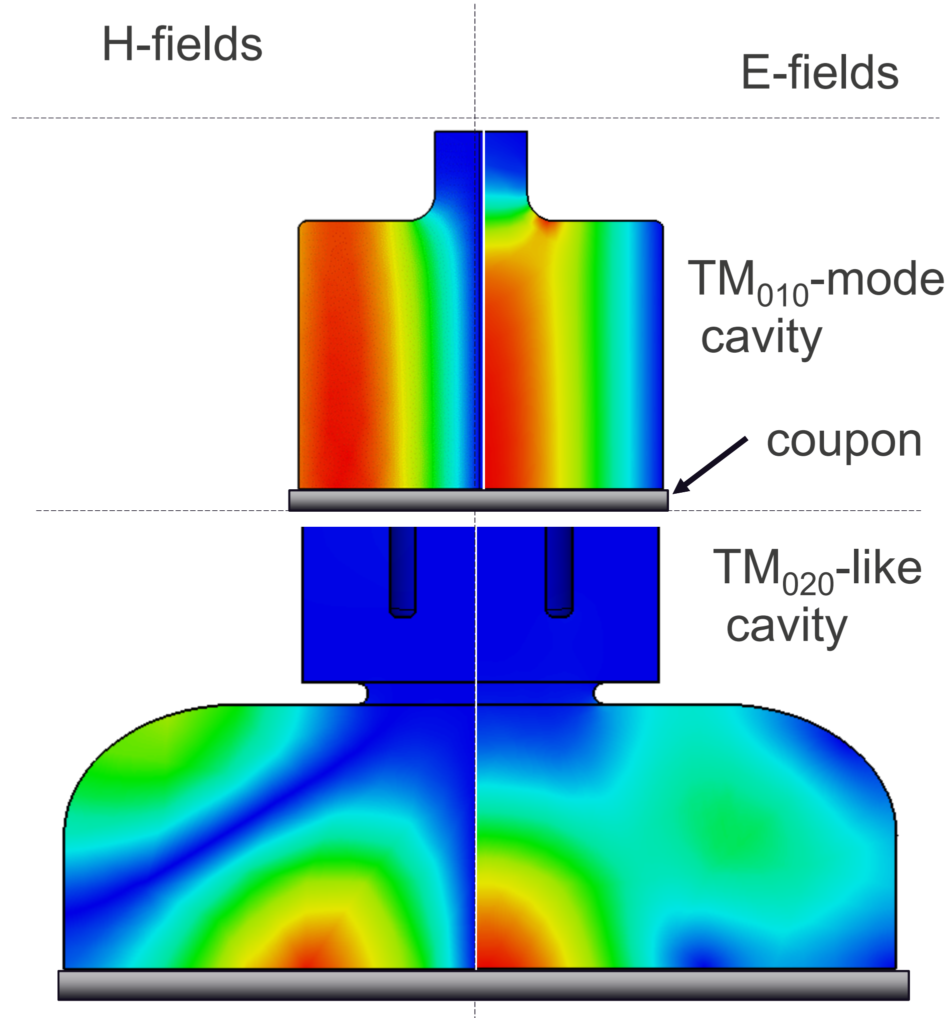
Why not use a TM_{010}-mode cavity with a removable back wall, like the SLAC/BNL/UCLA RF guns?

The TM_{010}-mode "pillbox" cavity has:

- High current at the edge of the back wall, relative to the peak cavity fields ~1.4 A/mm / (MV/m)
- High ratios of E and H fields on the cavity surface, to the coupon surface

A purpose-designed coupon tester cavity has:

- Low current at the coupon/cavity boundary, relative to the peak cavity fields, ~0.07 A/mm / (MV/m)
- Definitively higher E and H fields on the coupon, than on the cavity surface



Design considerations

RF

- Defining $E_{c(s)}$ as the peak E-field on the surface of the coupon (cavity excluding the coupon), and $H_{c(s)}$ as the corresponding H-field, maximize E_c / E_s, and H_c / H_s.
- Keep the surface current across the cavity / coupon joint as low as possible
- Good separation from neighboring modes
- Low fields on the coupler, esp. coax tip

Mechanical

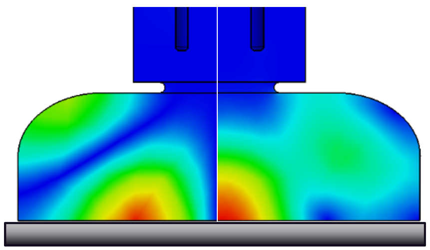
- Keep the coupon as simple as possible – easy to machine, etc.
- Provide a means of temperature stabilizing the coupon
- Separate the RF and vacuum seal functions at the coupon / cavity boundary

Desirable Diagnostics (beyond reflected power)

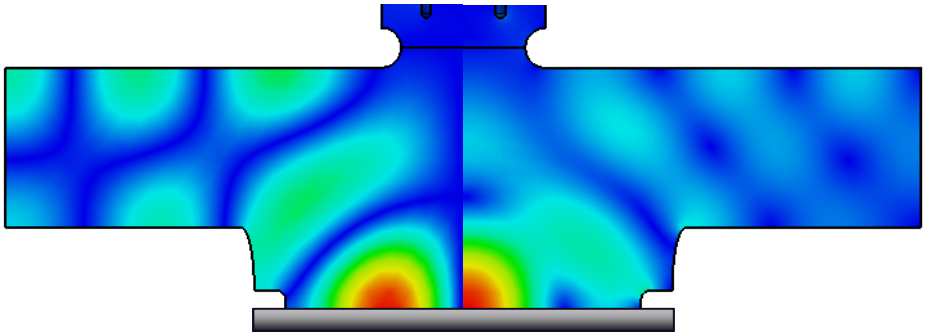
- An on-axis port to measure field emission and breakdown current
- Cavity field probe
- Optical ports to view coupon

Candidate geometries

TM_{020}-like mode



TM_{041}-like mode

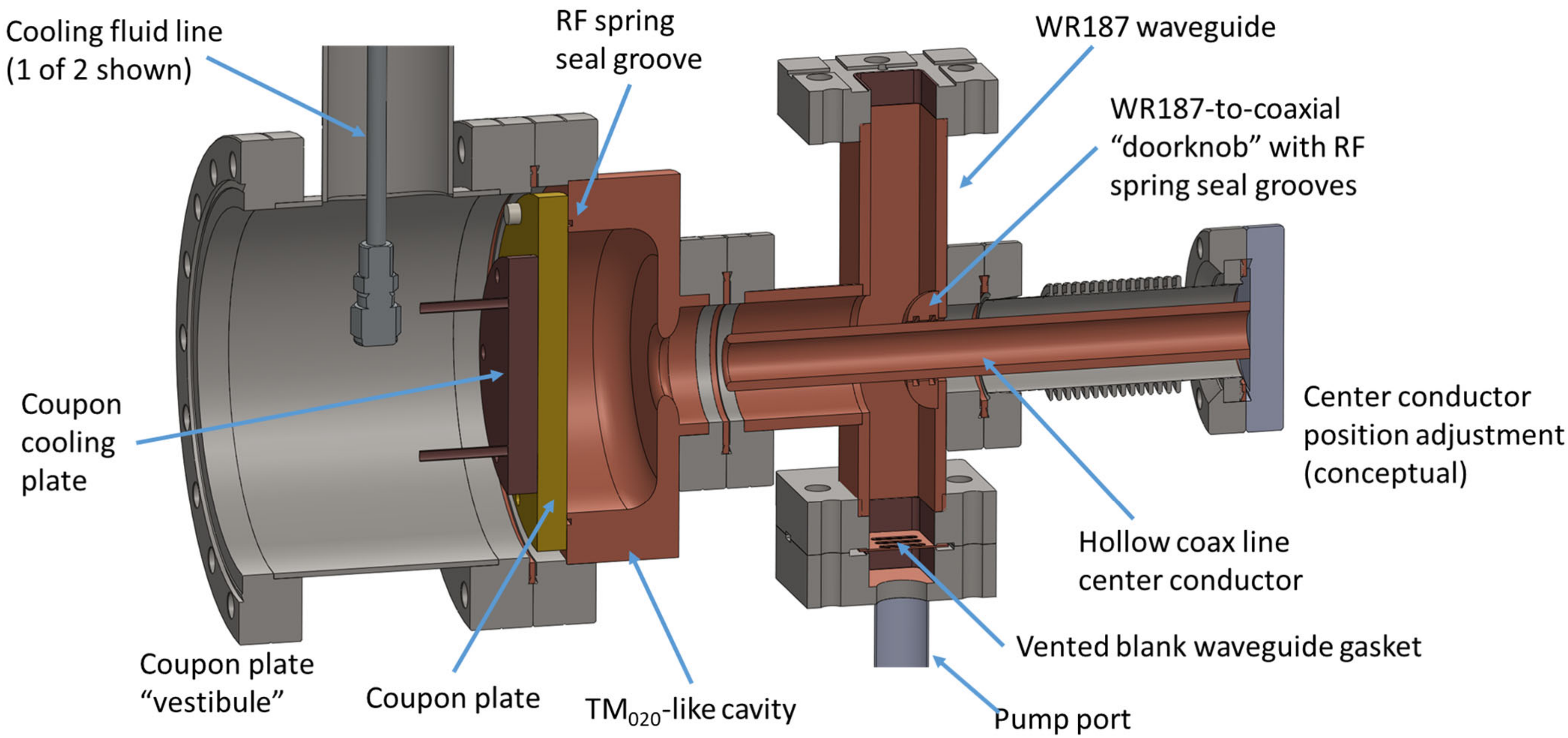


✓ Smaller, simpler construction
✓ Lower RF power needed
✗ Low H_c/H_s ratio
✗ Probe ports (optical, field) problematic

✓ More uniform field ratios
✓ Good options for probe port placement
✗ More complex fabrication
✗ Physically larger

Parameter	TM_{020}-like	TM_{041}-like
Q_0	16,800	23,500
E_c/E_s	2.89	2.33
H_c/H_s	1.42	2.33
R_e (MΩ/m²)	$5.7 \cdot 10^3$	$3.10 \cdot 10^3$

Conceptual Assembly



Conclusions and Timeline

- We have developed two coupon tester variants for normal-conducting high-gradient materials.

- Both use a rectangular-to-coaxial power coupler

- We will downselect, finalize and fabricate the preferred design, with the goal of having a coupon tester operational in early 2022.

Also at IPAC:

MOPAB146

Status of the C-Band Engineering Research Facility (CERF-NM) Test Stand Develpment at LANL, Dmitry Gorelov

MOPAB341

First C-band high gradient cavity testing results at LANL, Evgenya Simakov

MOPAB342

Design, fabrication, and commissioning of the mode launchers for high gradient C-band cavity testing at LANL, Evgenya Simakov

MOPAB362

Atomistic Modeling of the Coupling Between Electric Fields and Bulk Plastic Deformation in Rf Structures, Soumendu Bagchi

THPAB138

FEbreak: A Comprehensive Diagnostic and Automated Conditioning Interface for Breakdown Analysis and Dark Current, Mitchell Schneider