X-Band Photonic Bandgap (PBG) Structure Breakdown Experiment

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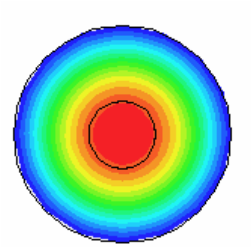
Outline

- Photonic Bandgap (PBG) modes
- SLAC single cell test stand
- PBG structure
- Breakdown testing results
- Autopsy surface imaging
- Hypothesis for results

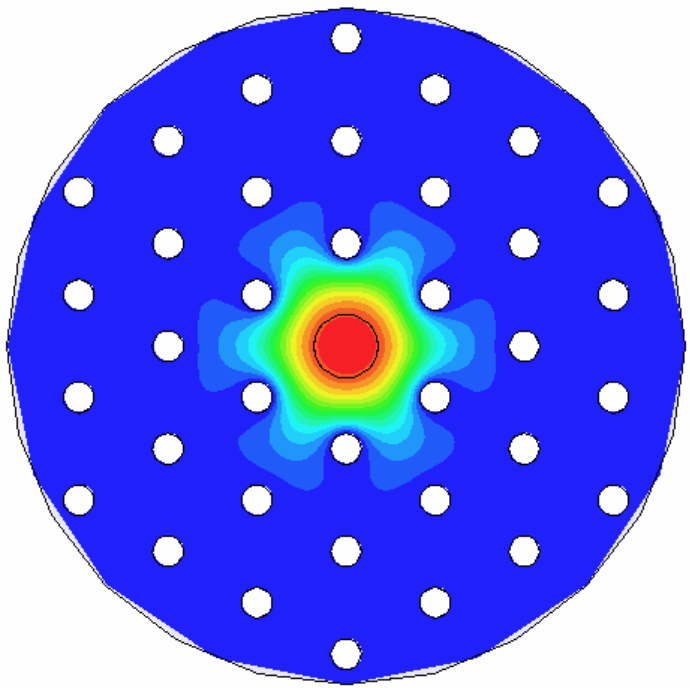
Operating Modes

- TM_{01} on-axis electric field for acceleration
- Pillbox walls confine fields
- Rods confine mode because its frequency is in the global band gap of the lattice

Pillbox



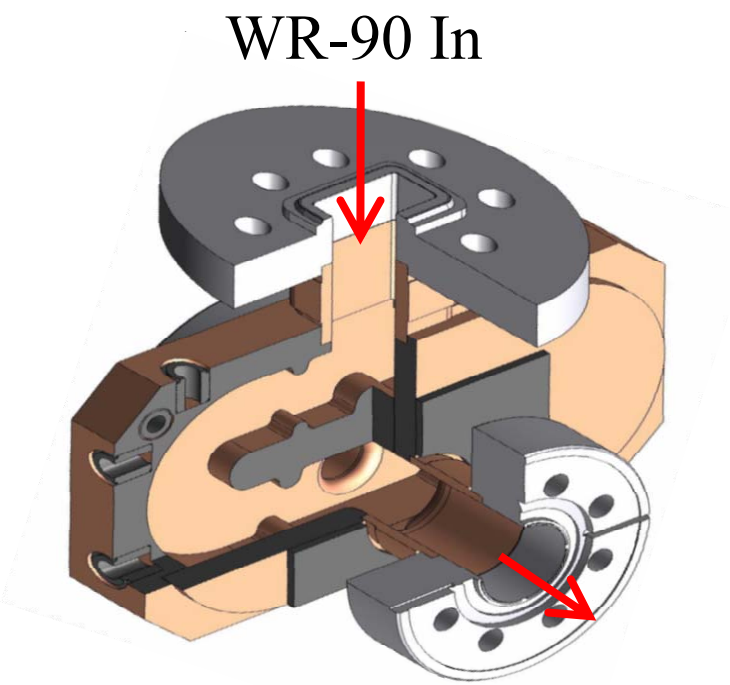
PBG



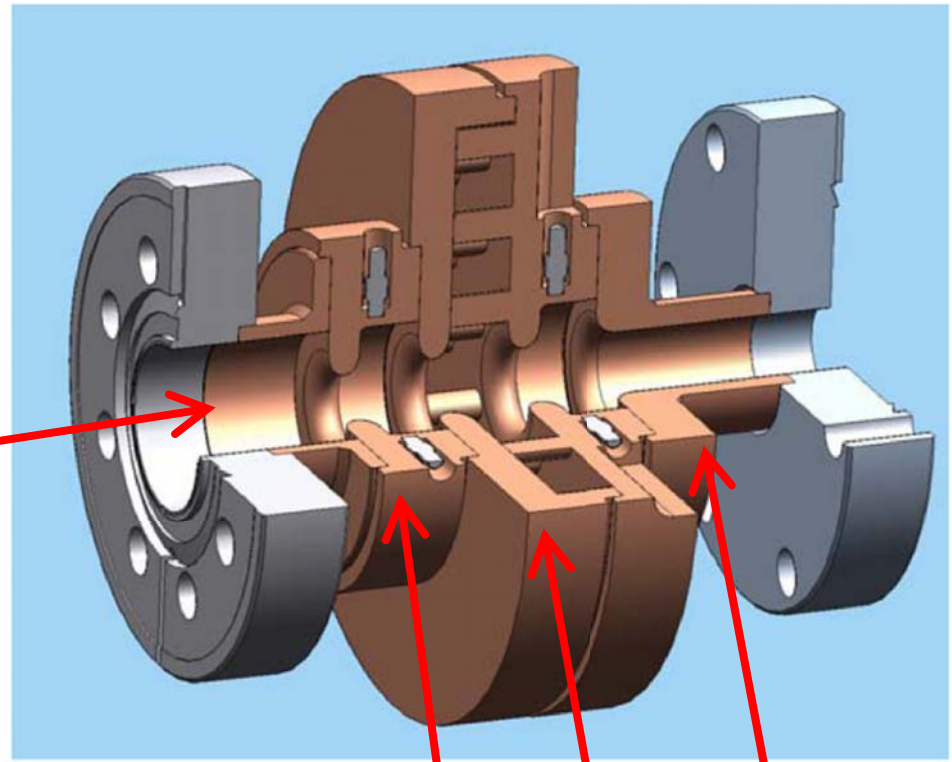
Parameter	Value
Rod Radius	2.176 mm
Rod Spacing	12.087 mm
Frequency	11.424 GHz

SLAC Setup

TM_{01} Mode Launcher

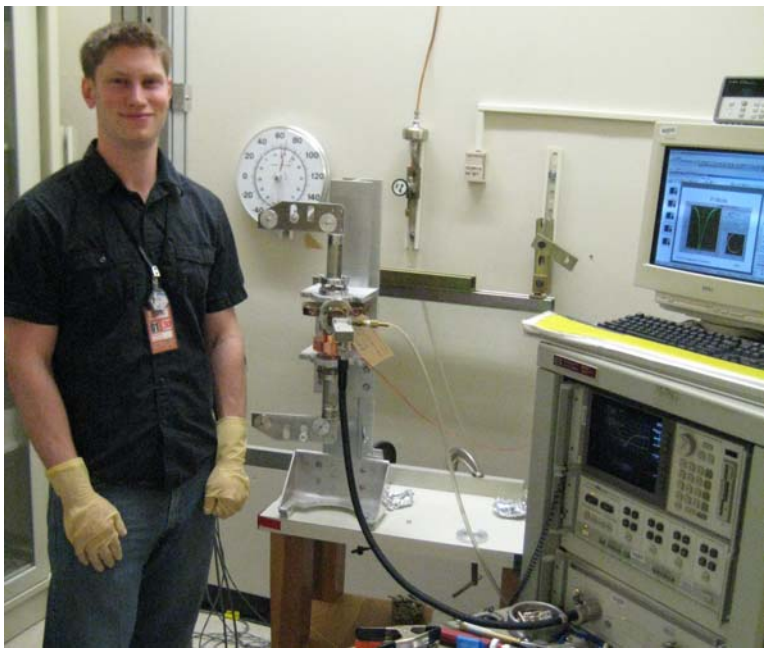


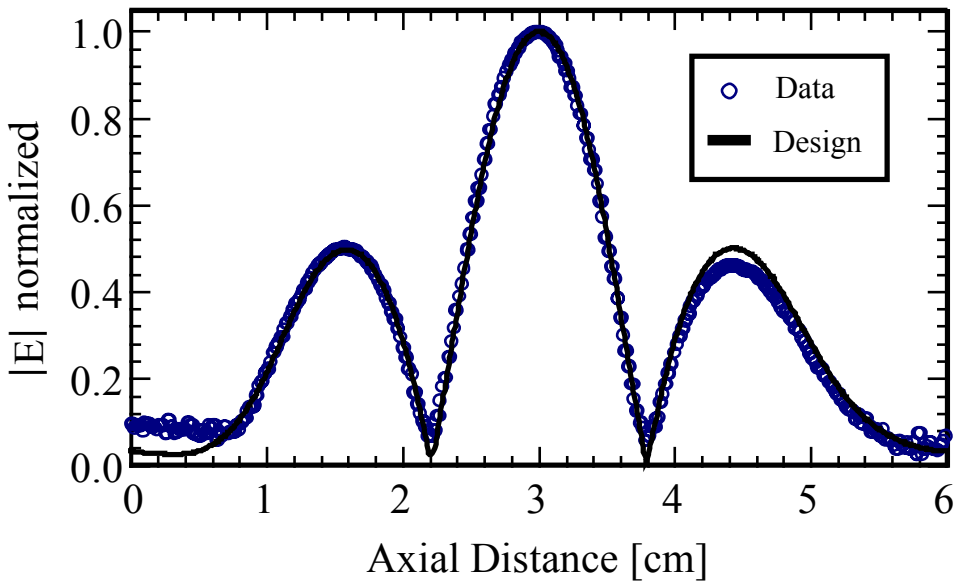
Single cell standing wave PBG structure



PBG Structure Cold Test

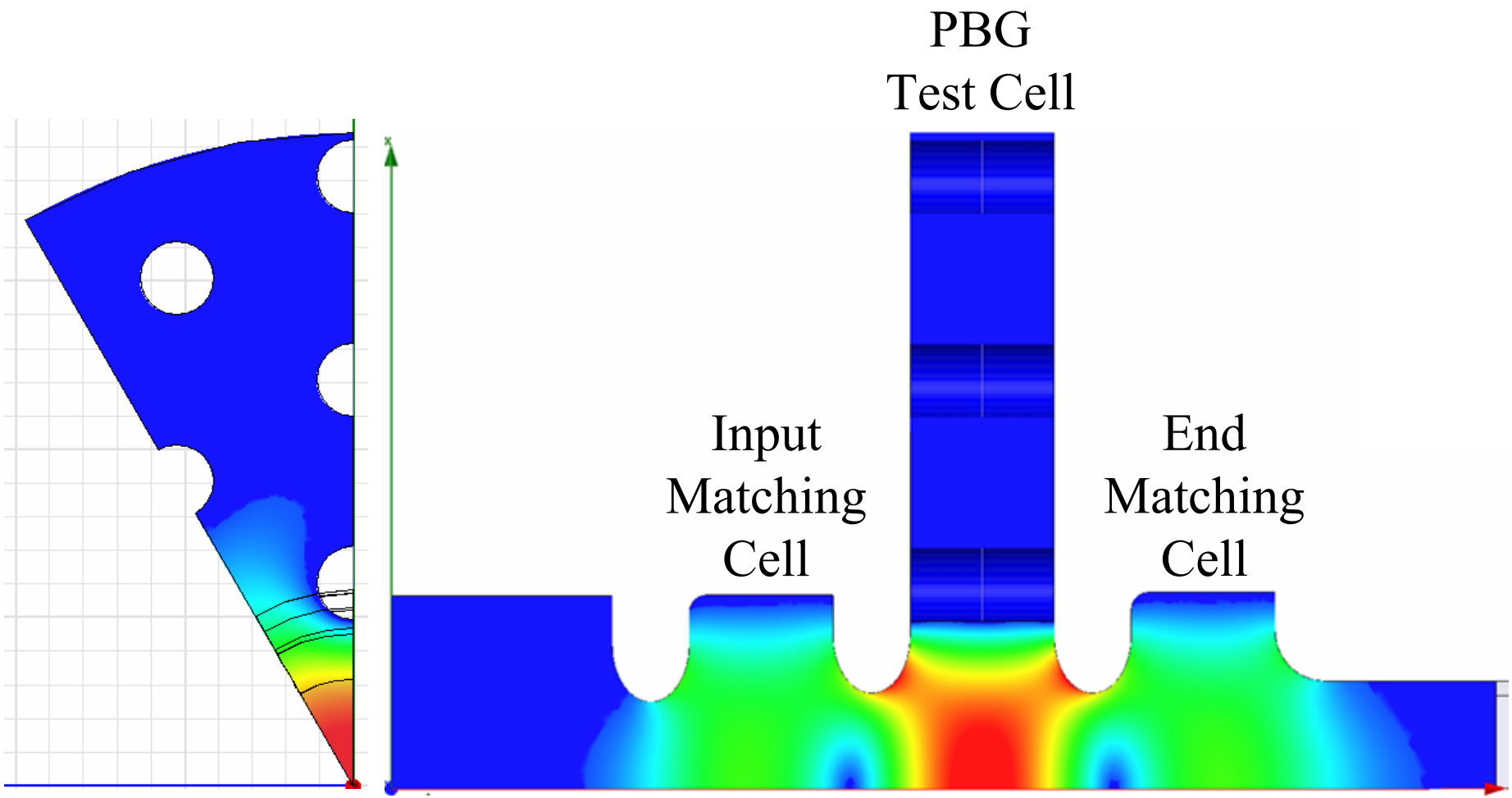
- Frequency: 11.424 GHz
- Field: ½ field in coupling cells, full field in test cell
- Coupling: near critical





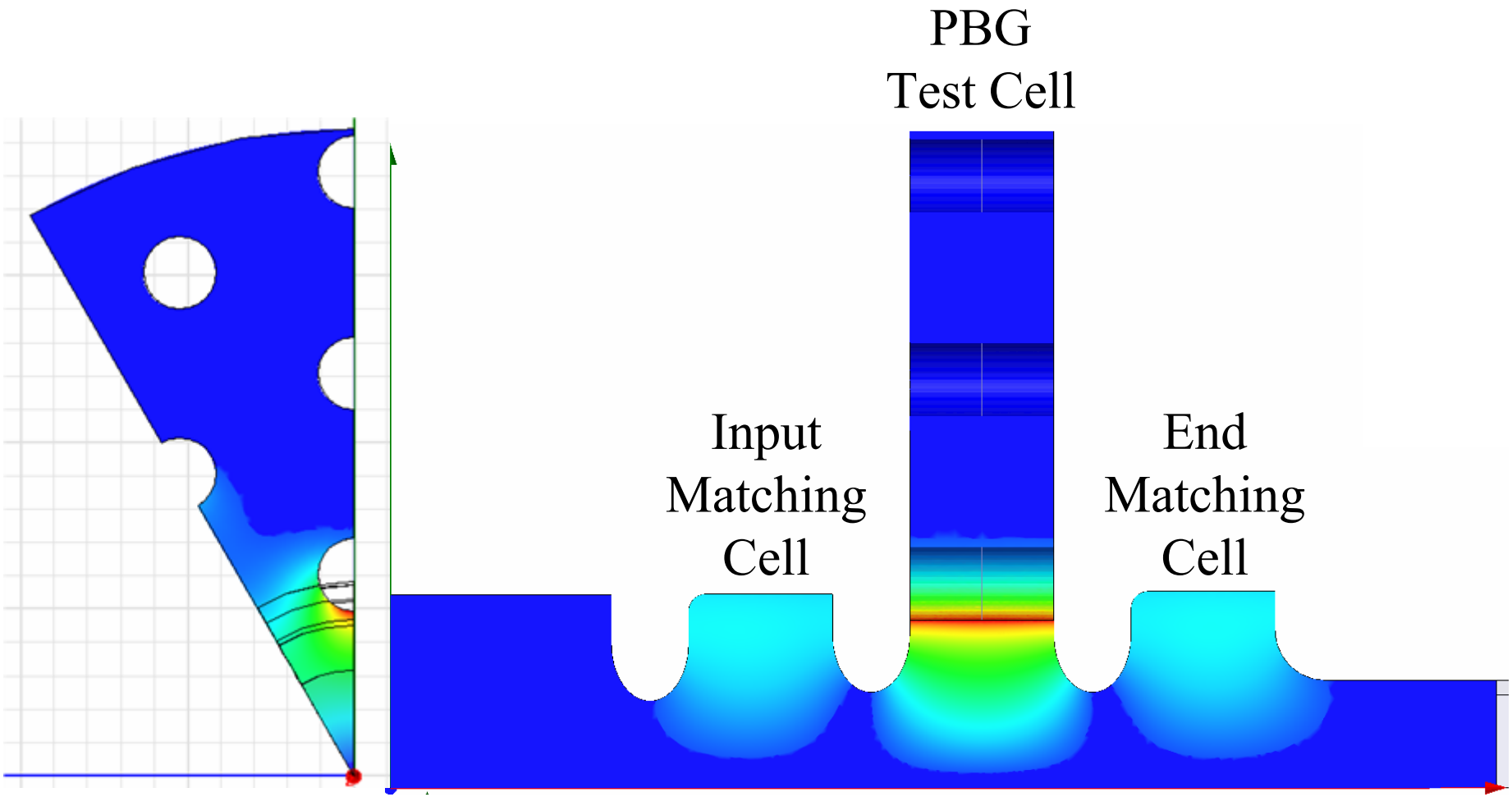
PBG *HFSS* Electric Field

- For 5.9 MW of power, 100 MV/m gradient = 208 MV/m surface field on iris

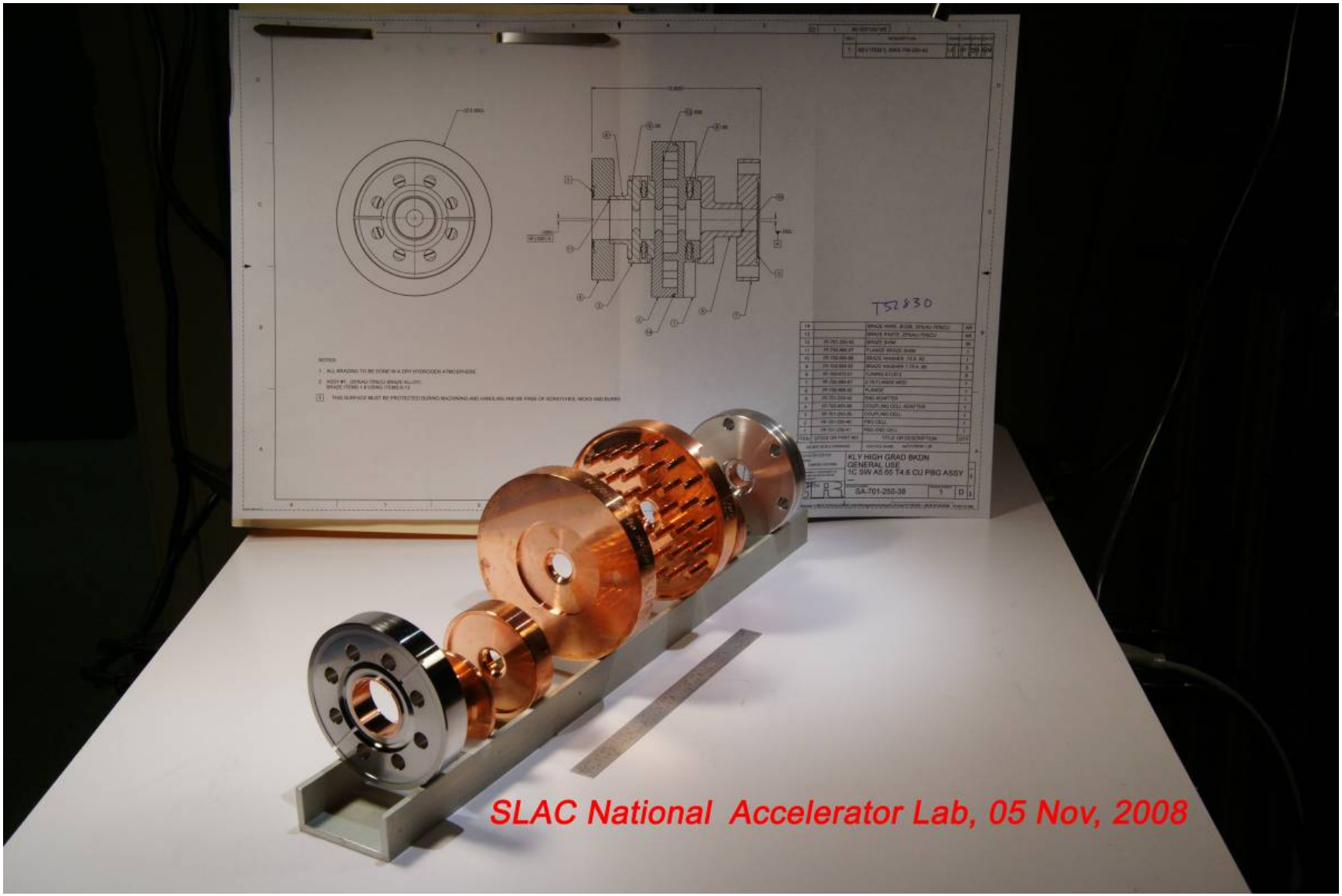


PBG *HFSS* Magnetic Field

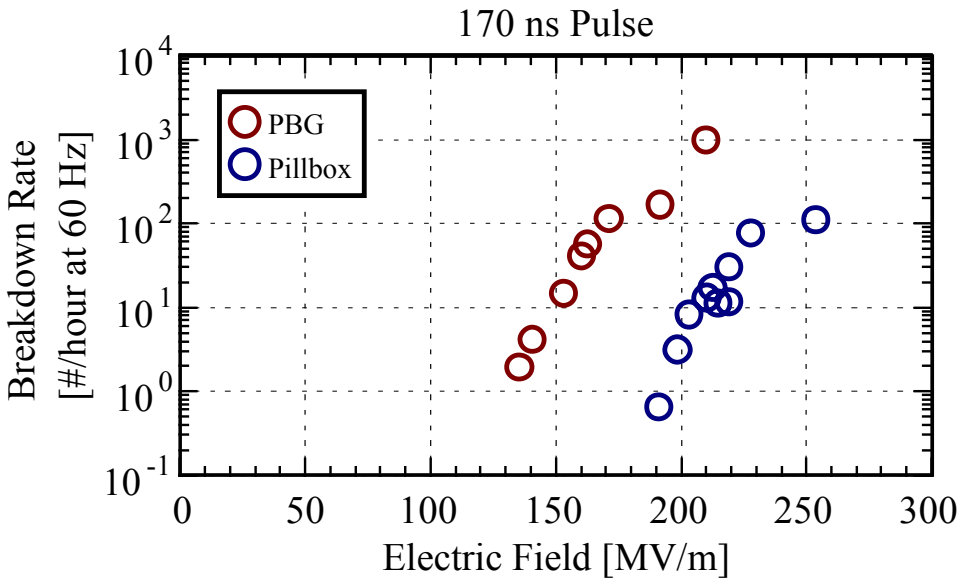
- For 5.9 MW of power, 100 MV/m gradient = 890 kA/m surface field on inner rod

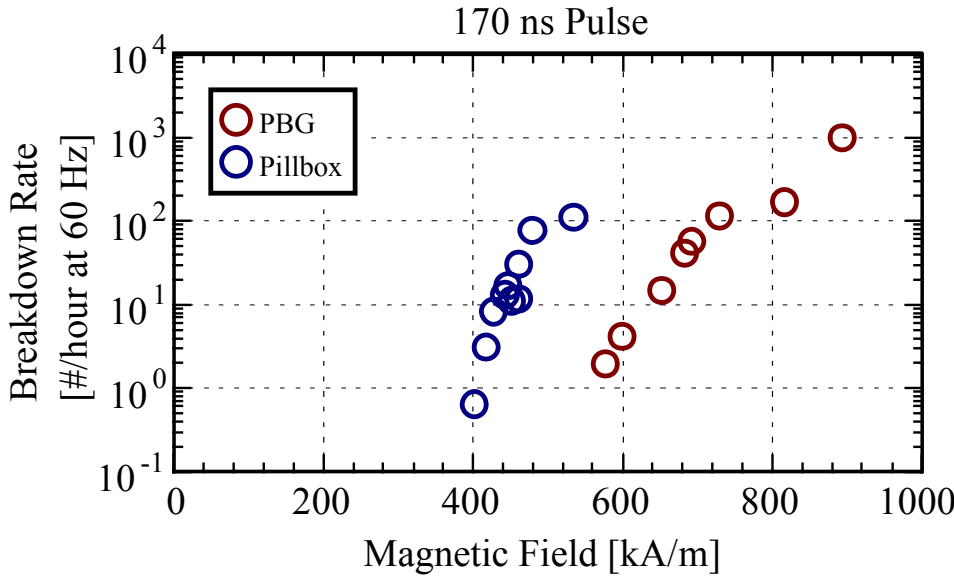


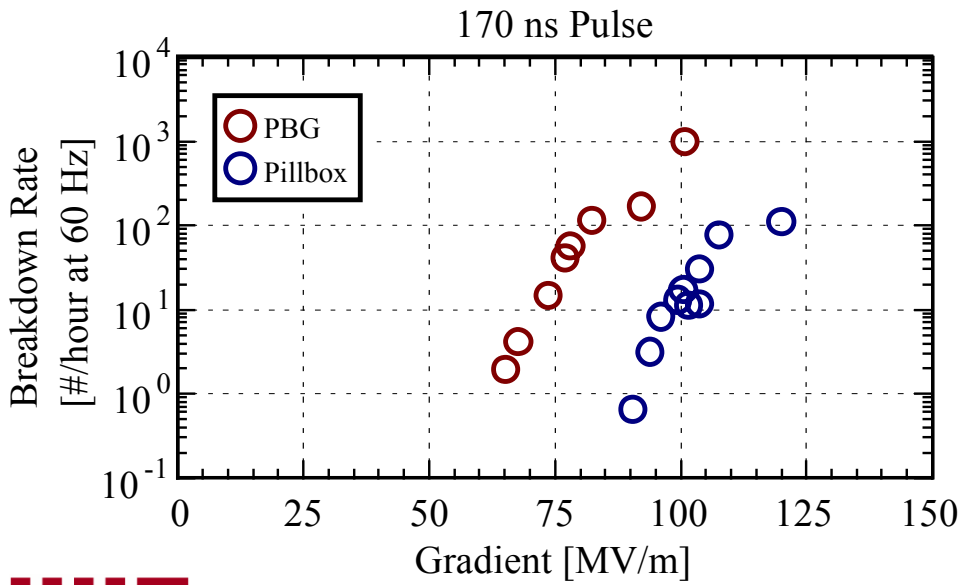
PBG Structure Fabricated at SLAC

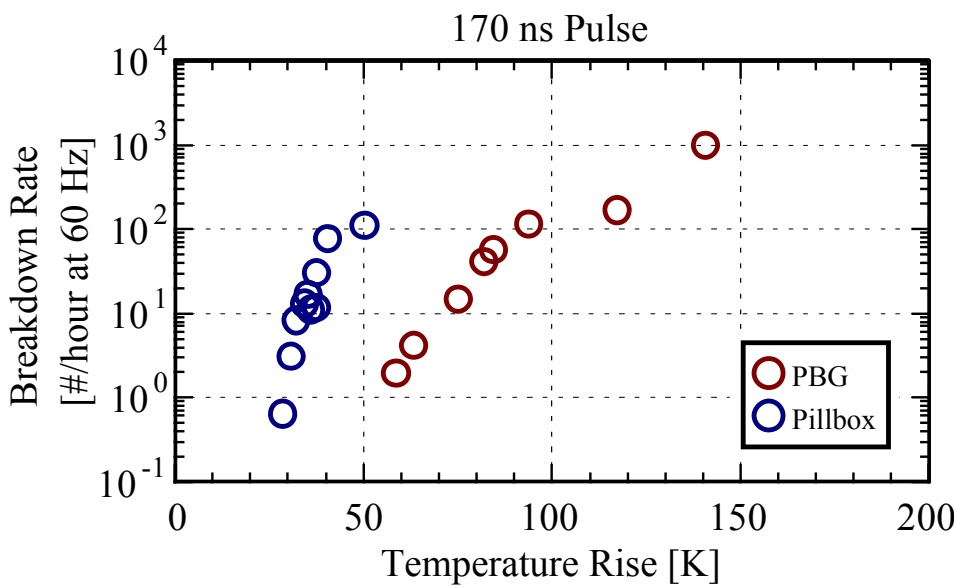


Breakdown Data





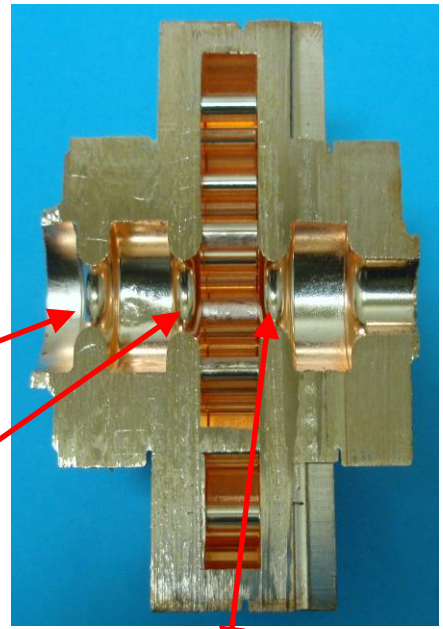


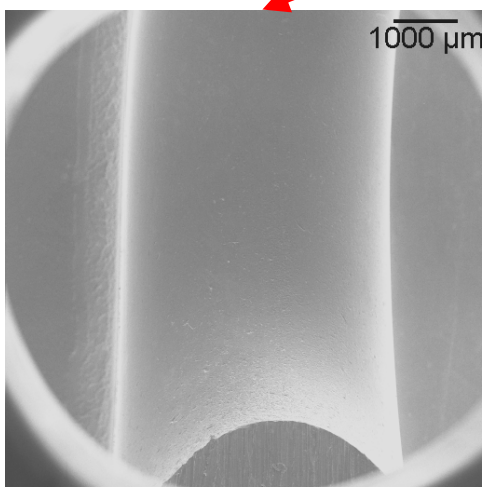


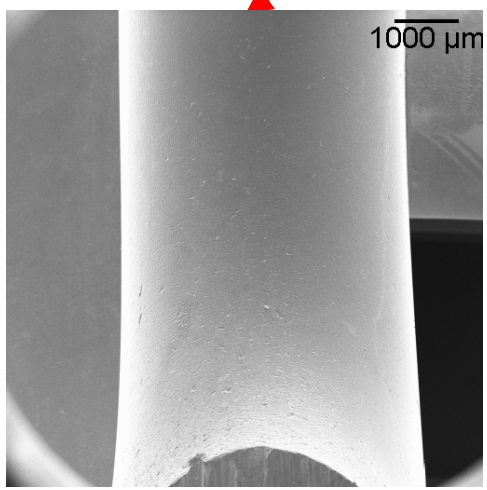
PBG SEM Damage

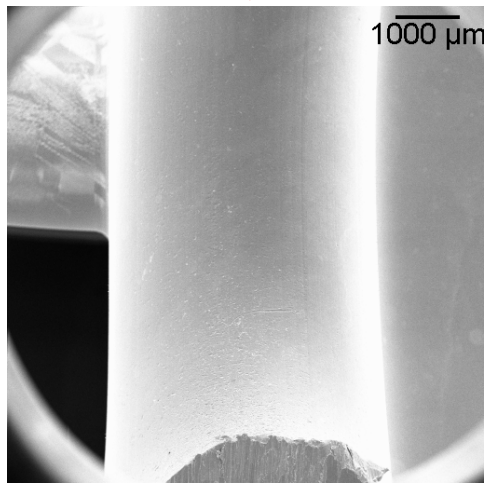
- After High Power testing
- Cut the structure in half
- Scanning Electron Microscopy

- Irises undamaged





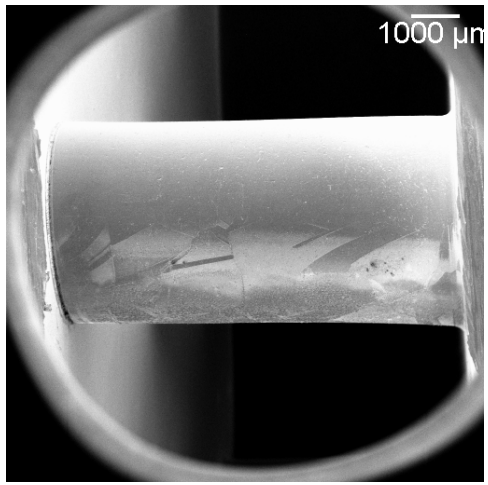


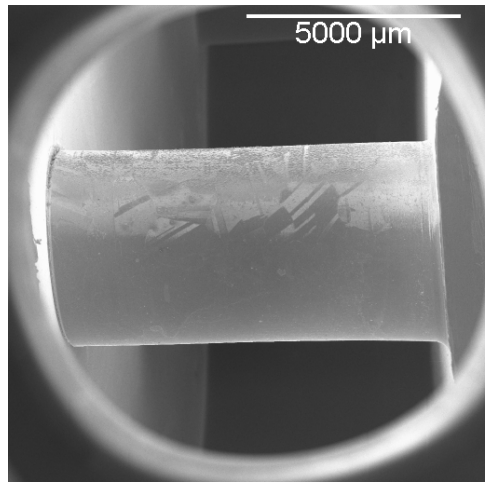


PBG SEM Damage

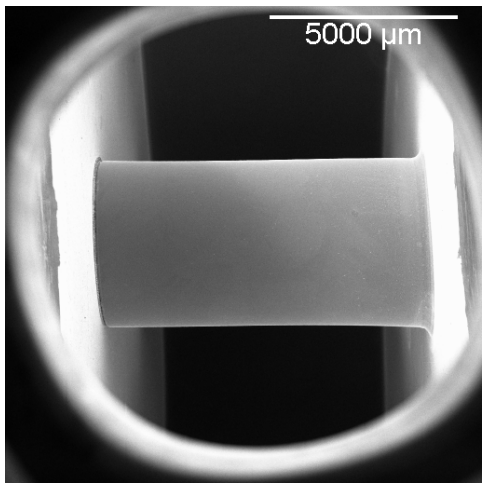
- Inner Rods damaged, Outer Rods undamaged

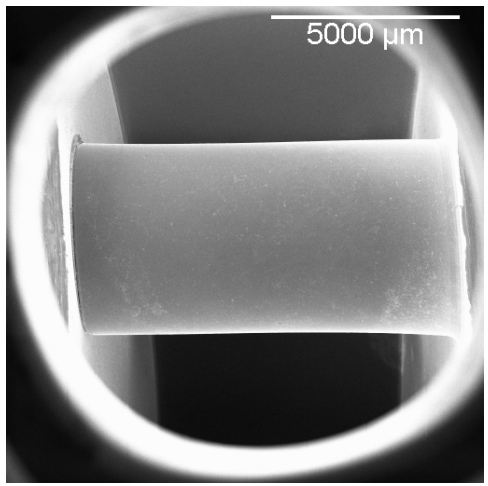
Inner Rods

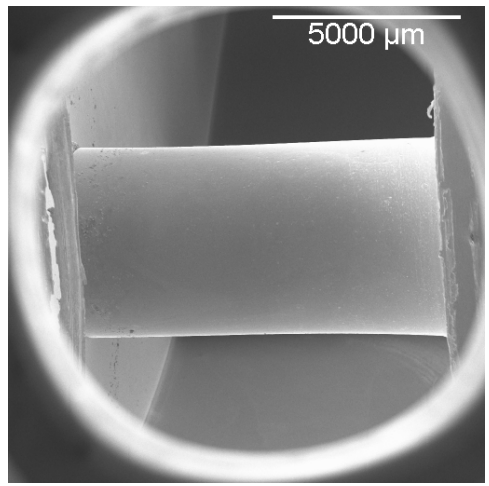




Outer Rods

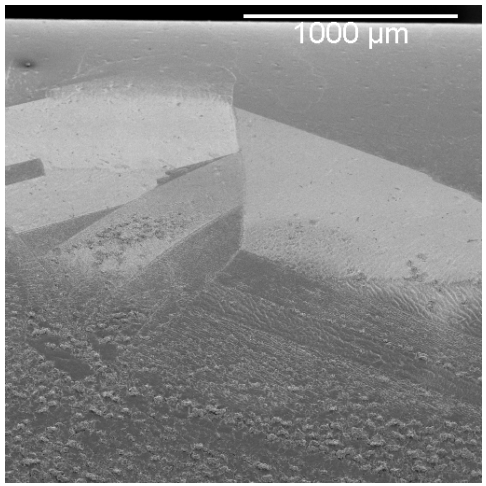


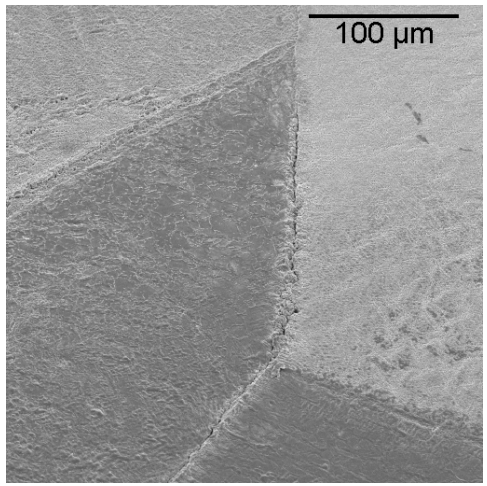


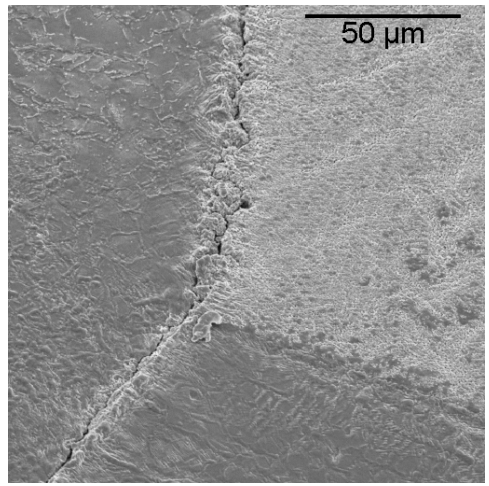


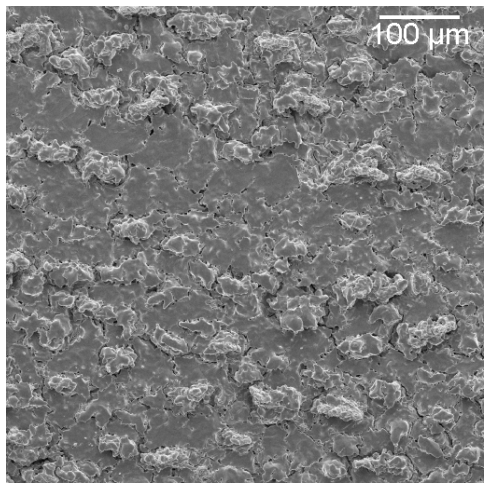
PBG SEM Damage

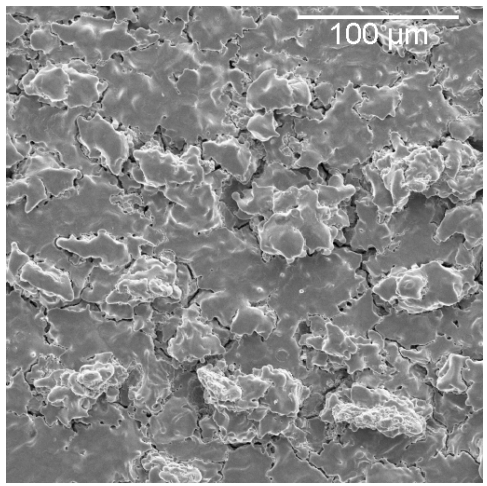
- Pulsed Heating damage on Rods, detail





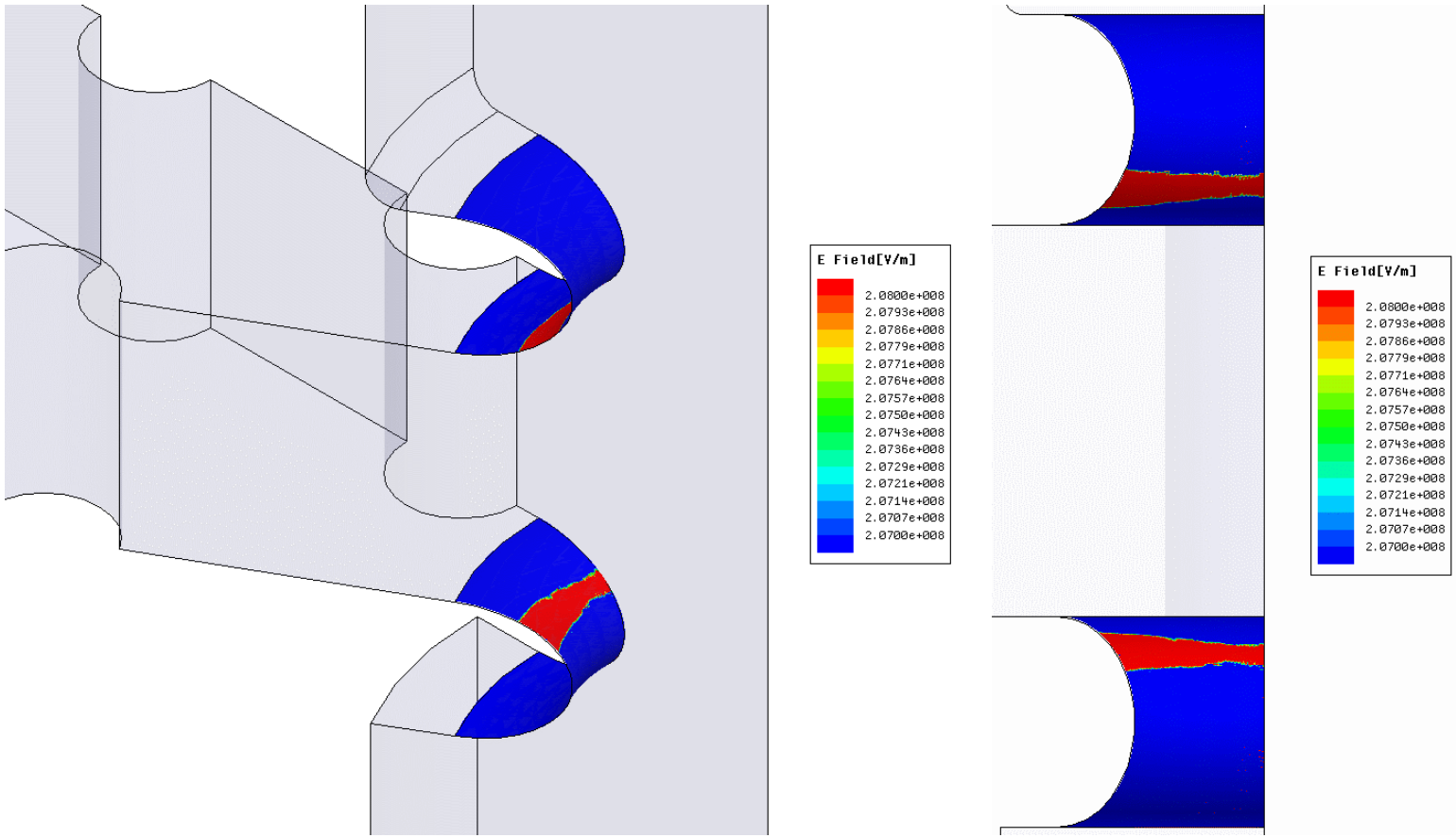






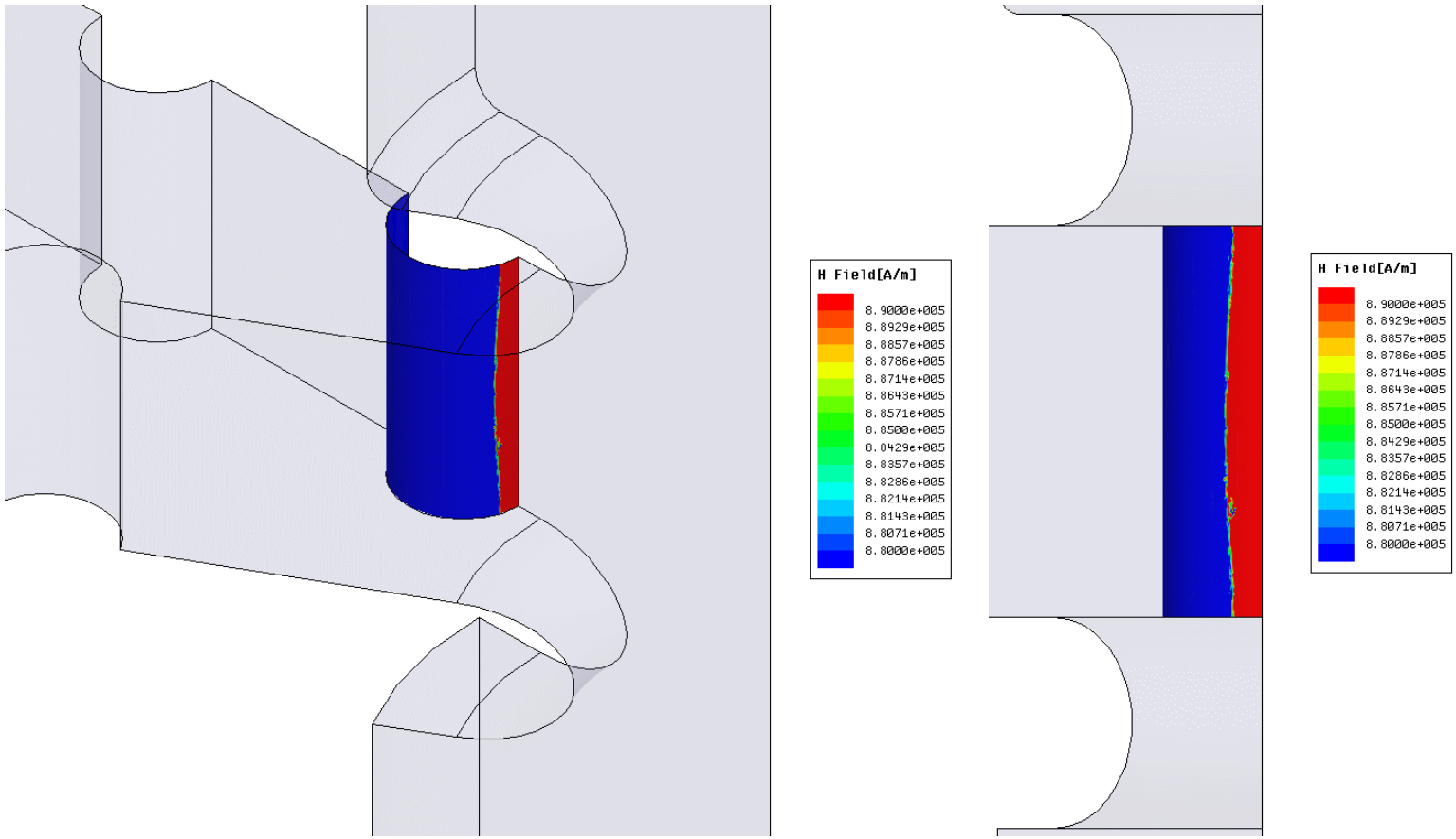
PBG Maximum Electric Fields

- High Electric field regions
- 208 MV/m



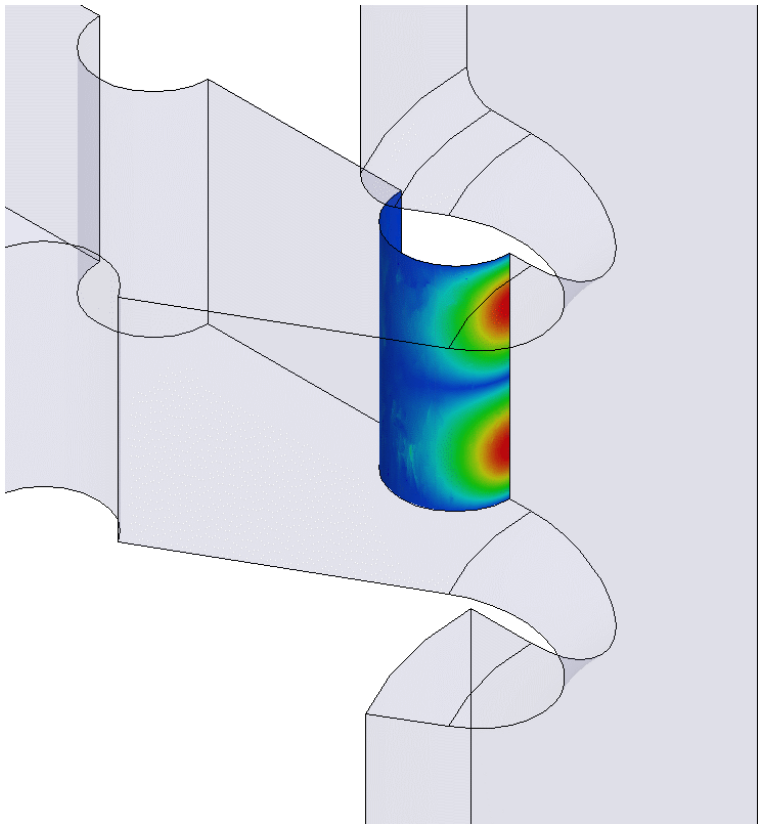
PBG Maximum Magnetic Fields

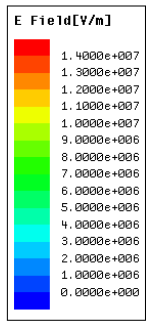
- High Magnetic field regions
- 890 kA/m

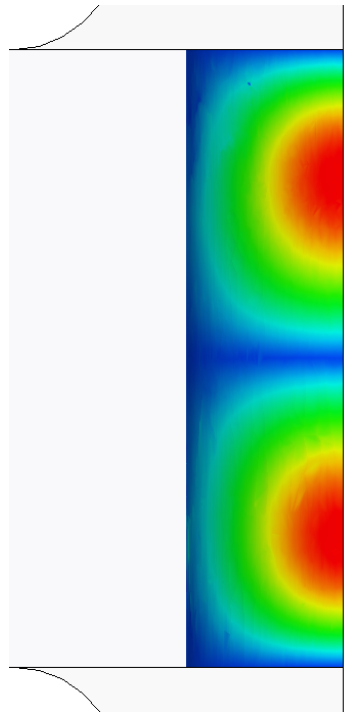


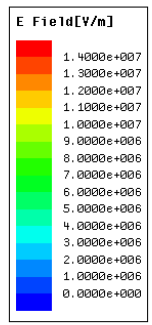
PBG Breakdown Hypothesis

- Electric field on rod: 14 MV/m
- Magnetic field → Pulsed Heating Damage → Increased β → Increased Electric Field → Breakdown









Summary

- Breakdown testing of an 11.424 GHz PBG structure at SLAC at high power (>5MW), rep rate (60Hz), and gradient (>100MV/m)
- First breakdown testing of a PBG structure
- No damage observed on peak electric field regions (>200MV/m)
- Identified rf magnetic field as a major issue affecting breakdown

Future Plans and Other Work

- Next Structure possibilities
  - Redo first PBG design with lower pulsed heating
  - Elliptical rod PBG for lower pulsed heating
  - 5 Rod PBG (under investigation)

- Other papers at PAC 2009
  - Roark Marsh: **WE6RFP081**
  - Brian Munroe: **WE6RFP082**

Acknowledgements

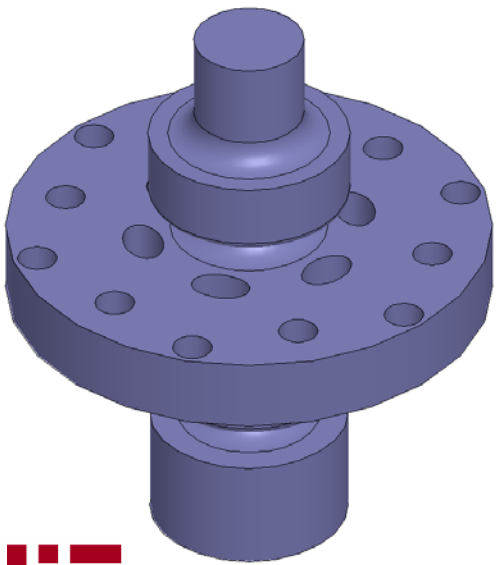
- Funding: Department of Energy, High Energy Physics, under contracts DE-FG02-91ER40648 and DE-AC02-76-SF00515

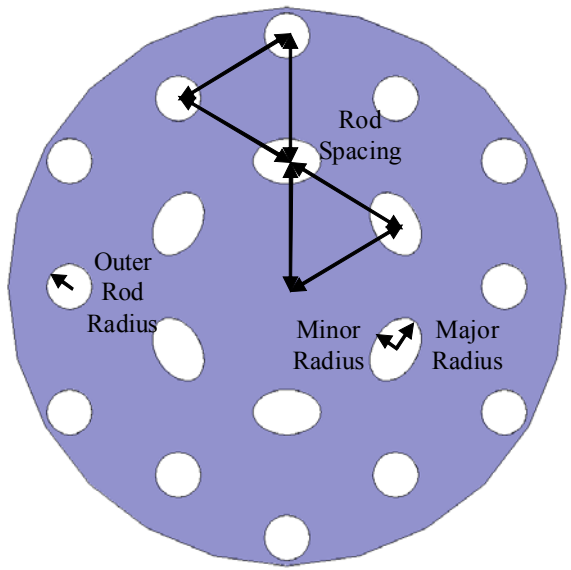
- SLAC National Accelerator Laboratory: David Martin (mechanical design), Jim Lewandowski (cold test), Dian Yeremian (hot test), Lisa Laurent (SEM micrographs)

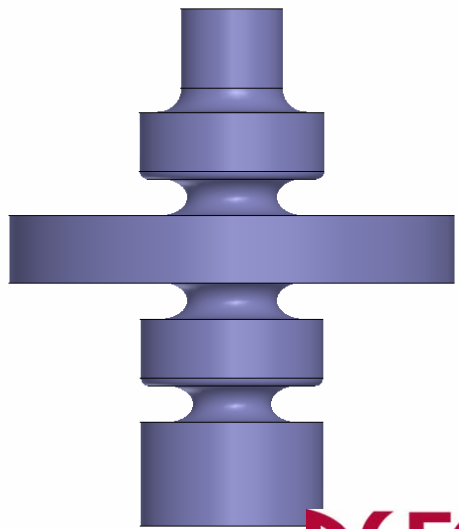
PBG Structures, *The Next Generation*

- Elliptical rod design with less pulsed heating
- 100 MV/m, 100 ns, 48 K temperature rise on rods, compared with 78 K for first PBG structure

Parameter	Value
Major Radius	3.399 mm
Minor radius	2.266 mm
Rod Spacing	12.588 mm
Outer Rod Radius	2.266 mm







Pillbox Breakdown Results

- 17 Structures tested to date
- Various pillbox geometries can be compared
- Gradient is a two-dimensional problem: rate vs gradient, or other field parameters
- Data collapses when looking at magnetic field?