High-Gradient Metallic Photonic Band-Gap (PBG) Structure Breakdown Testing At 17 GHz

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Outline

- Motivation
- Introduction to Photonic Band-Gap (PBG) Structures
- Structure Testing at 11 GHz at SLAC
- Structure Testing at 17 GHz at MIT Accelerator Laboratory
- Conclusions

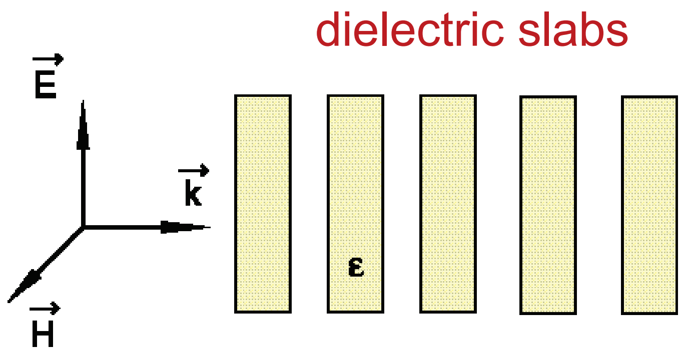
Motivation

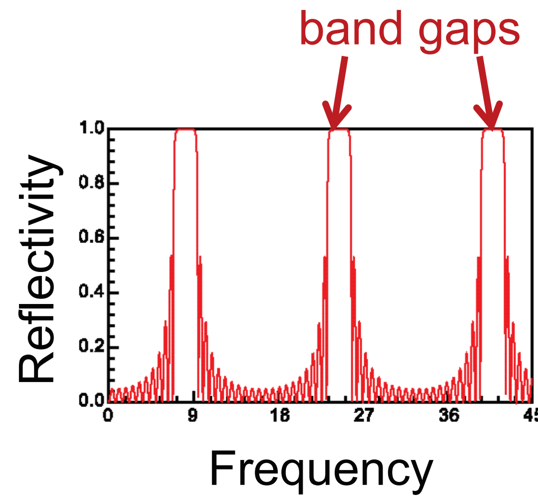
- Future linear collider structures will require wakefield damping
- Photonic Band-Gap (PBG) accelerating structures provide damping across the entire wakefield spectrum
  - Very promising for linear collider applications
- MIT also has a mandate to investigate vacuum breakdown physics
  - PBG structures explore a different regime of breakdown than conventional disc-loaded waveguide (DLWG) structures

Frequency Selective PBG Lattice

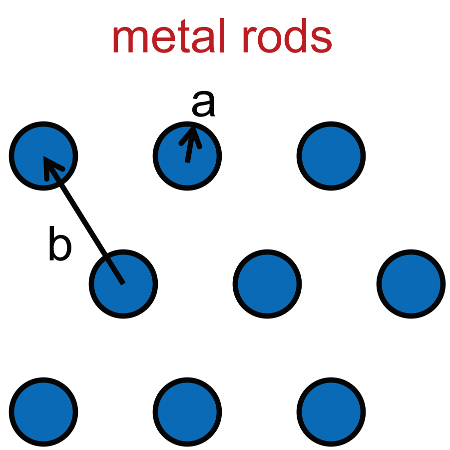
- Wave propagation is disallowed at certain frequency ranges (**Photonic Band Gap - PBG**) in a periodic lattice.

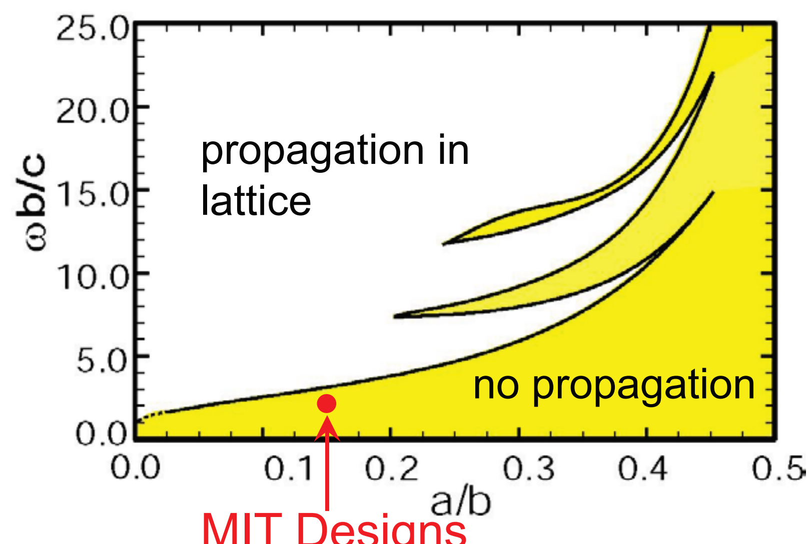
1D lattice:





2D lattice:





Smirnova et al. , J. Appl. Phys., 2002

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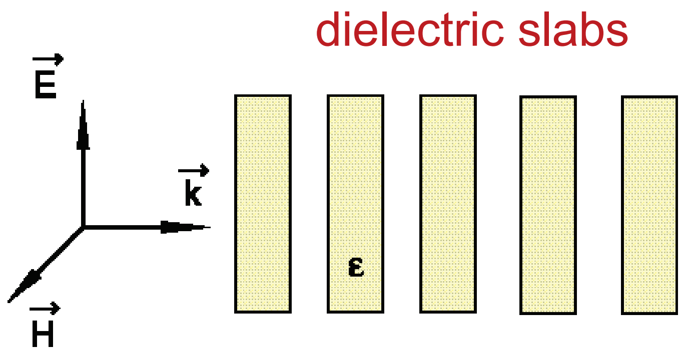
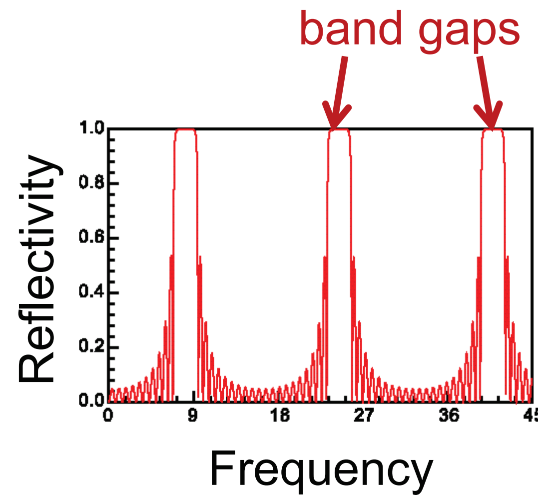
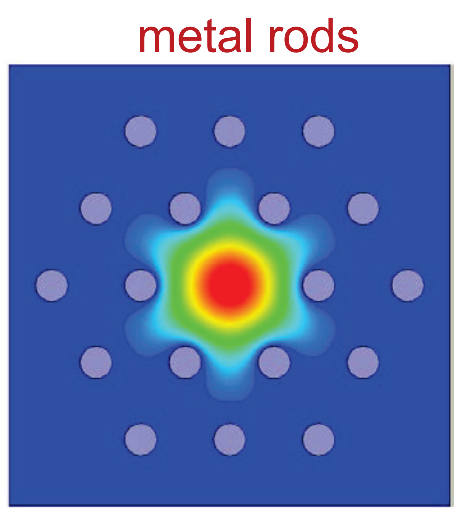
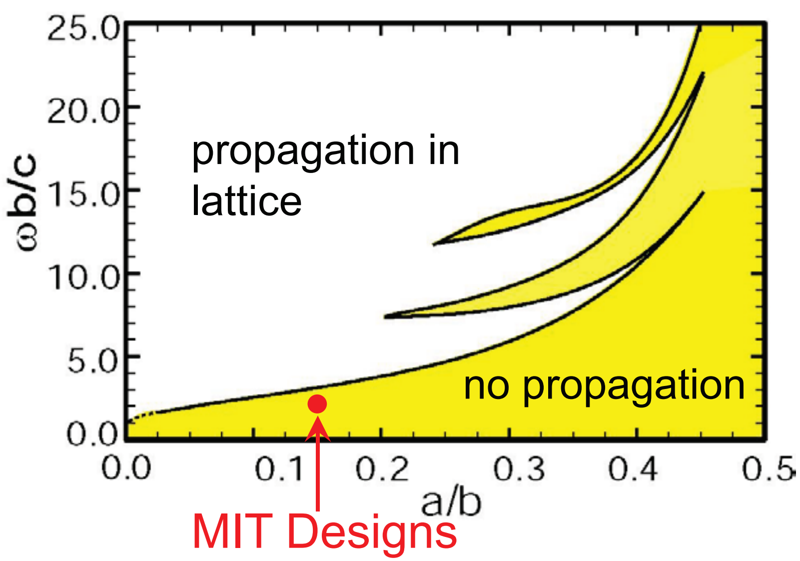




2D lattice:





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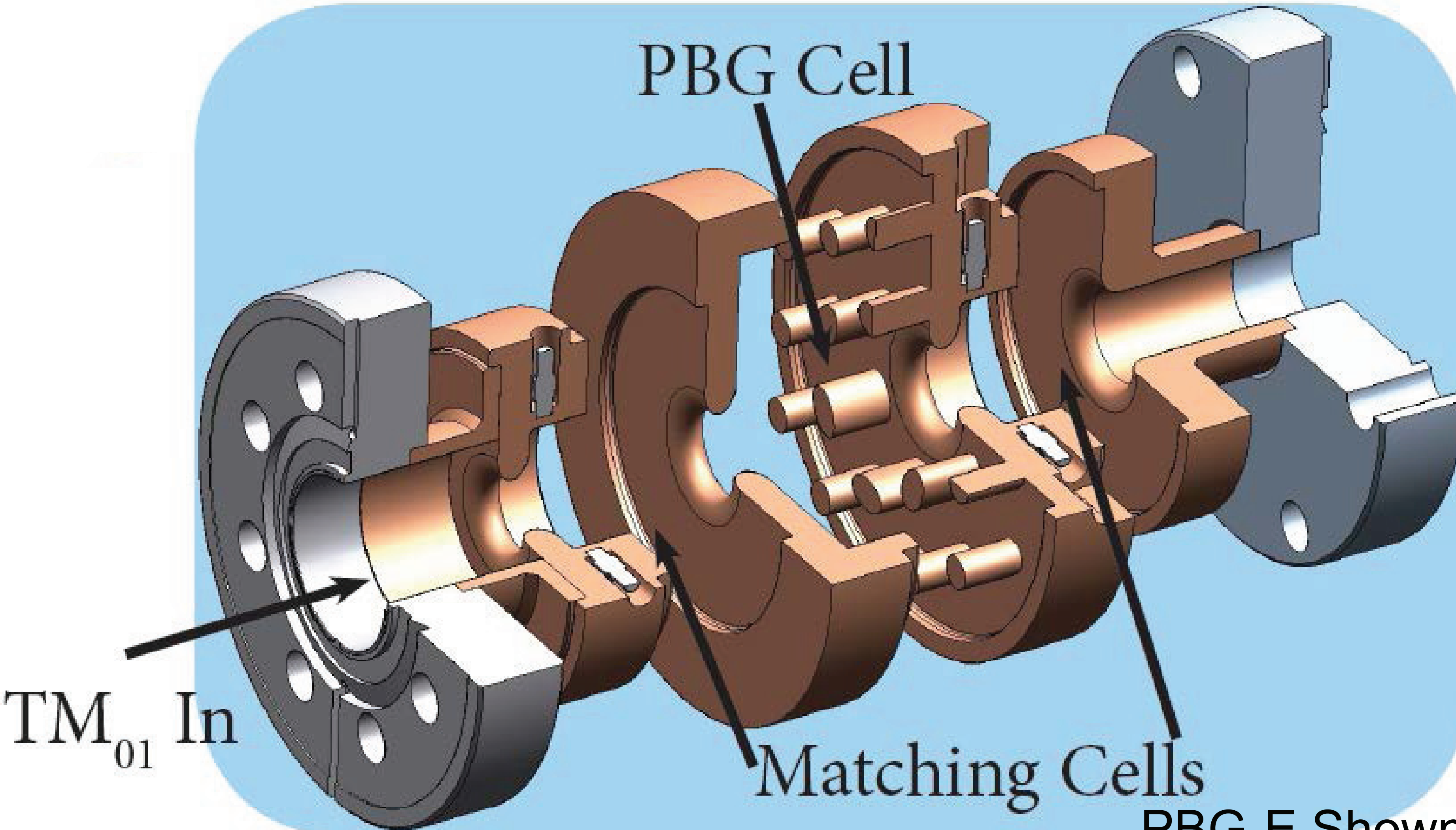
PBG Structure Testing at SLAC

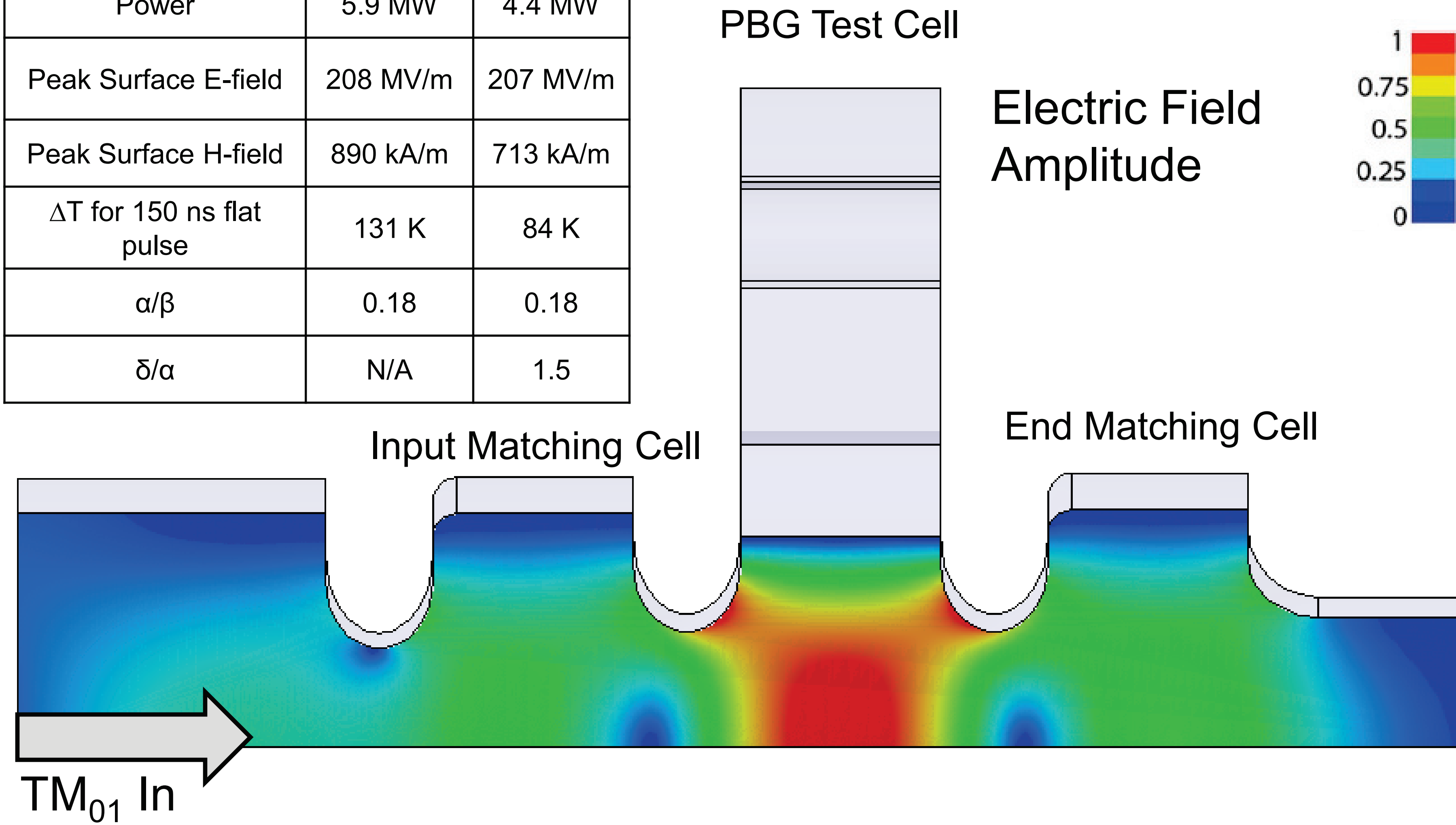
- Standing-wave structures with peak field in PBG cell



PBG-E Shown

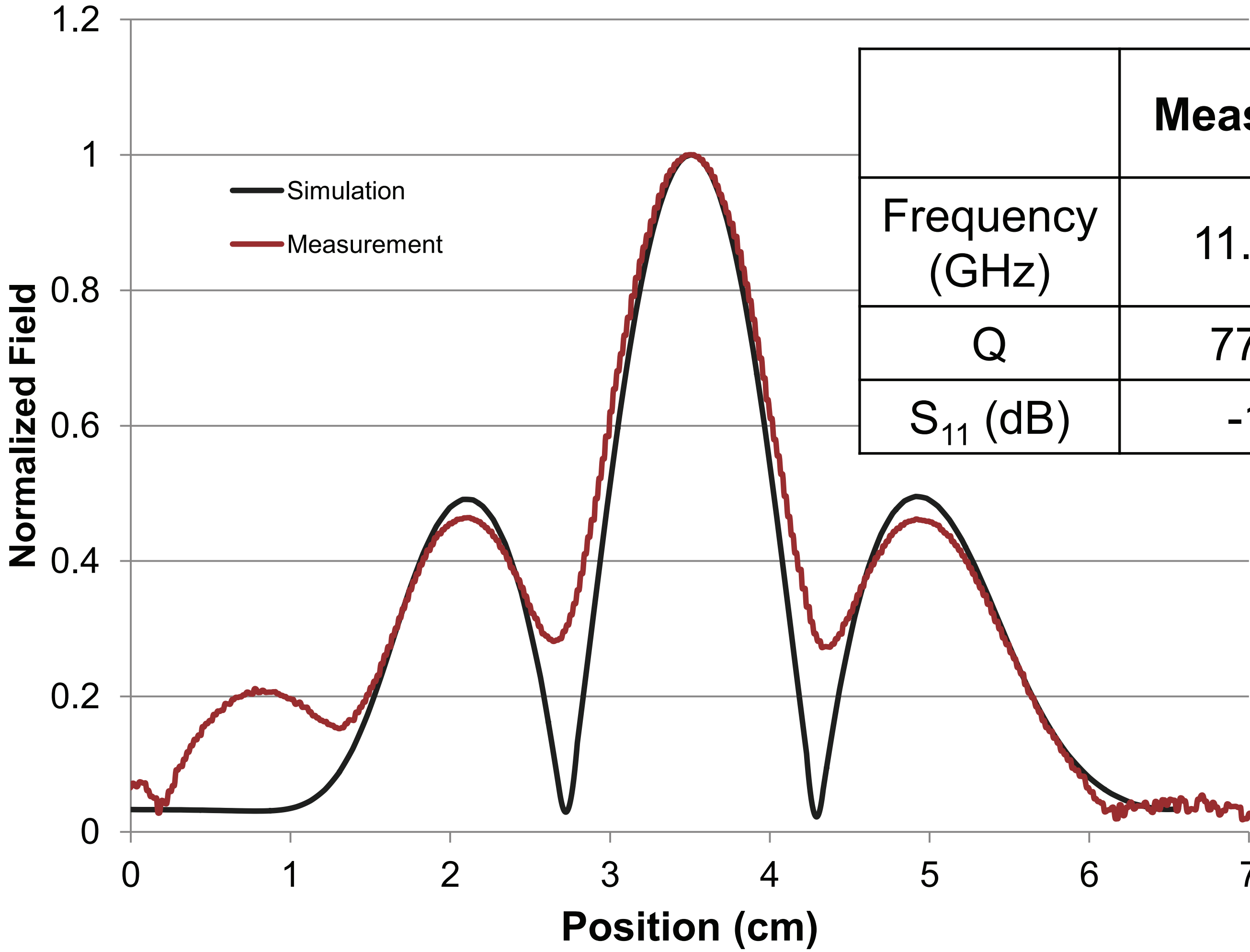
PBG Structure Testing at SLAC

Performance @ 100 MV/m Gradient	PBG-R	PBG-E
Power	5.9 MW	4.4 MW
Peak Surface E-field	208 MV/m	207 MV/m
Peak Surface H-field	890 kA/m	713 kA/m
ΔT for 150 ns flat pulse	131 K	84 K
α/β	0.18	0.18
δ/α	N/A	1.5



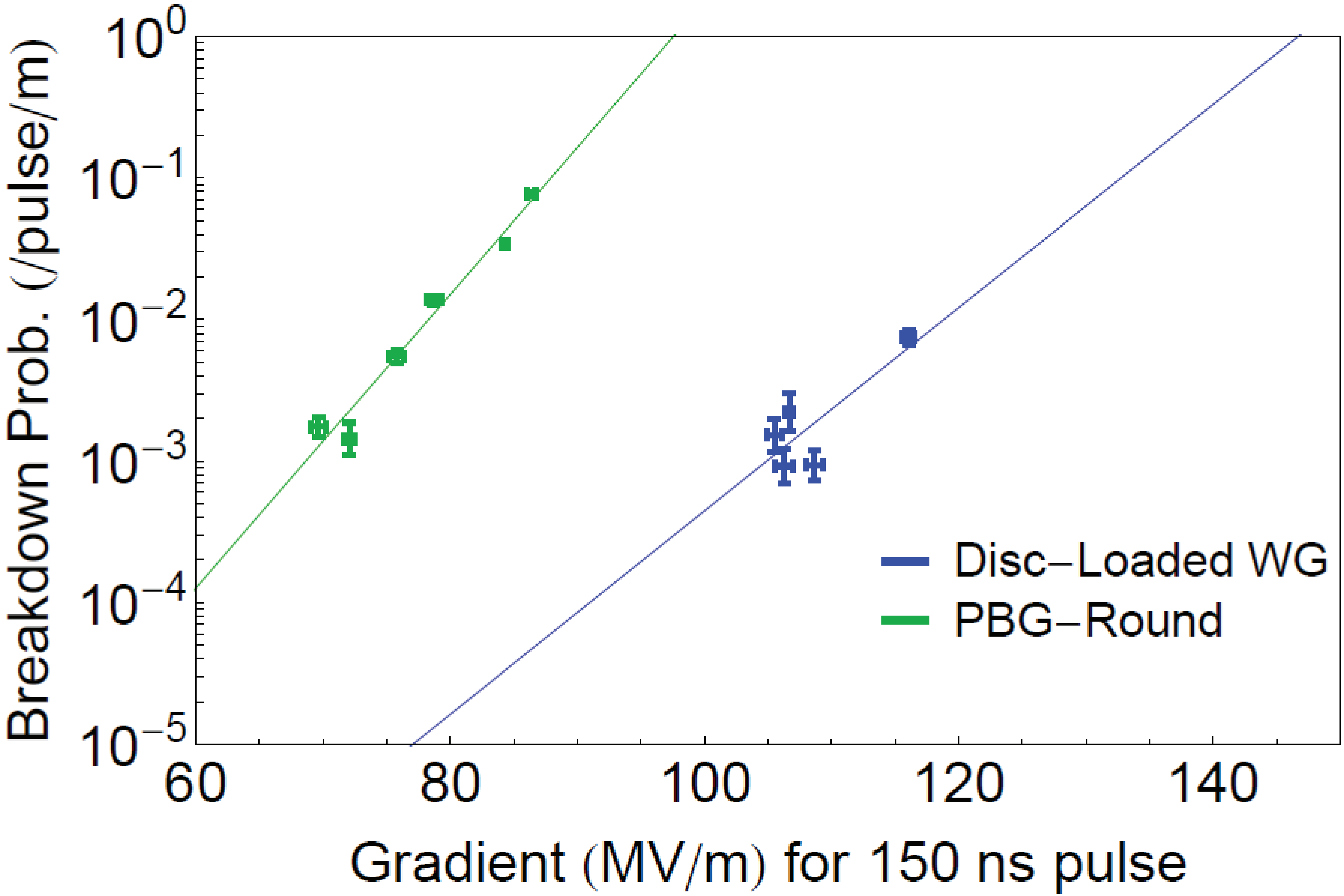
Cold Test of Elliptical-Rod PBG

- Non-resonant bead pull used to determine field profile

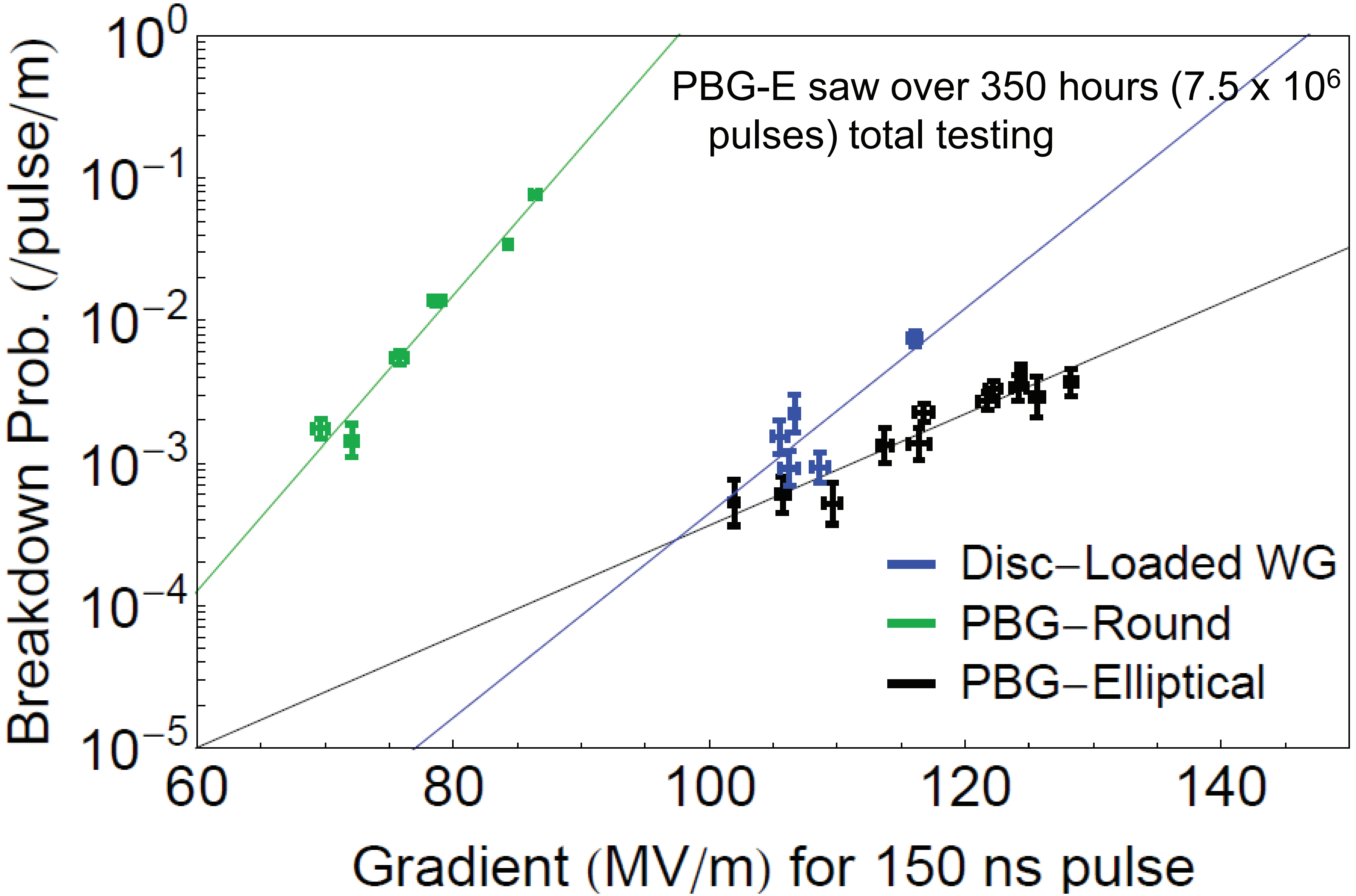


	Measured	Design Value
Frequency (GHz)	11.440	11.427
Q	7792	8304
S_{11} (dB)	-18	-50

Breakdown Probability vs. Gradient, PBG-R



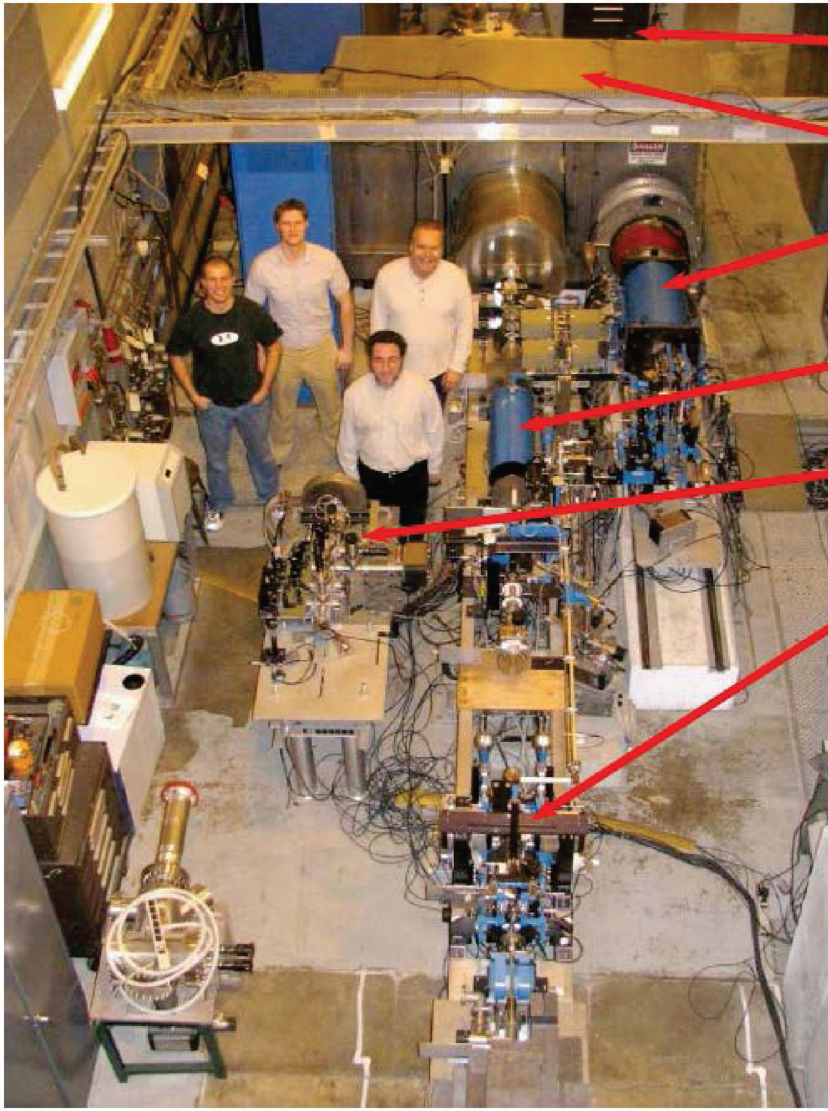
Breakdown Probability vs. Gradient, 3 Structures



MIT Accelerator and Test Stand

- Highest frequency stand-alone accelerator currently operational

MIT Accelerator Parameters	
Modulator Voltage	700 kV
Modulator Pulsed Power	500 MW
Klystron Power	25 MW
RF Frequency	17.14 GHz
Linac Energy	25 MeV
Linac Length	0.5 m, 94 cells
SW Test Stand Power	2-3 MW



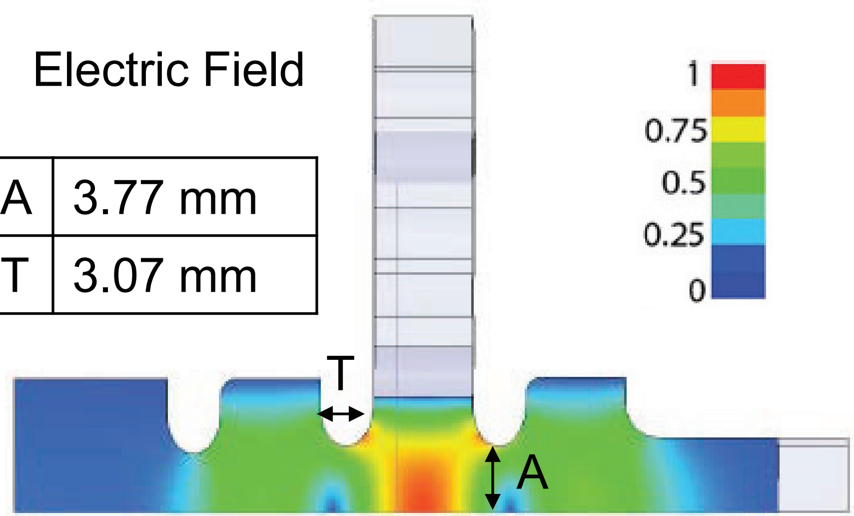
Single-Cell Structure Testing At MIT

- First structure for Ku-band high-gradient testing scaled from PBG-R structure tested at SLAC, designed in HFSS
- High temperature rise at 17 for investigating breakdowns

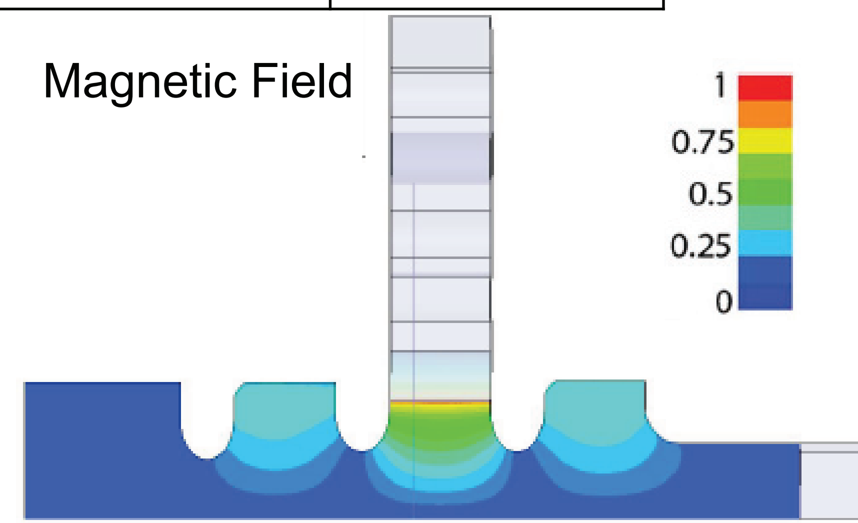
Performance at 100 MV/m	**17 GHz**	**11 GHz**
Power	2.4 MW	5.9 MW
Peak Surface Electric Field	200 MV/m	208 MV/m
Peak Surface Magnetic Field	900 kA/m	890 kA/m
Pulsed heating for 150 ns flat pulse	163 K	131 K

Electric Field

A	3.77 mm
T	3.07 mm



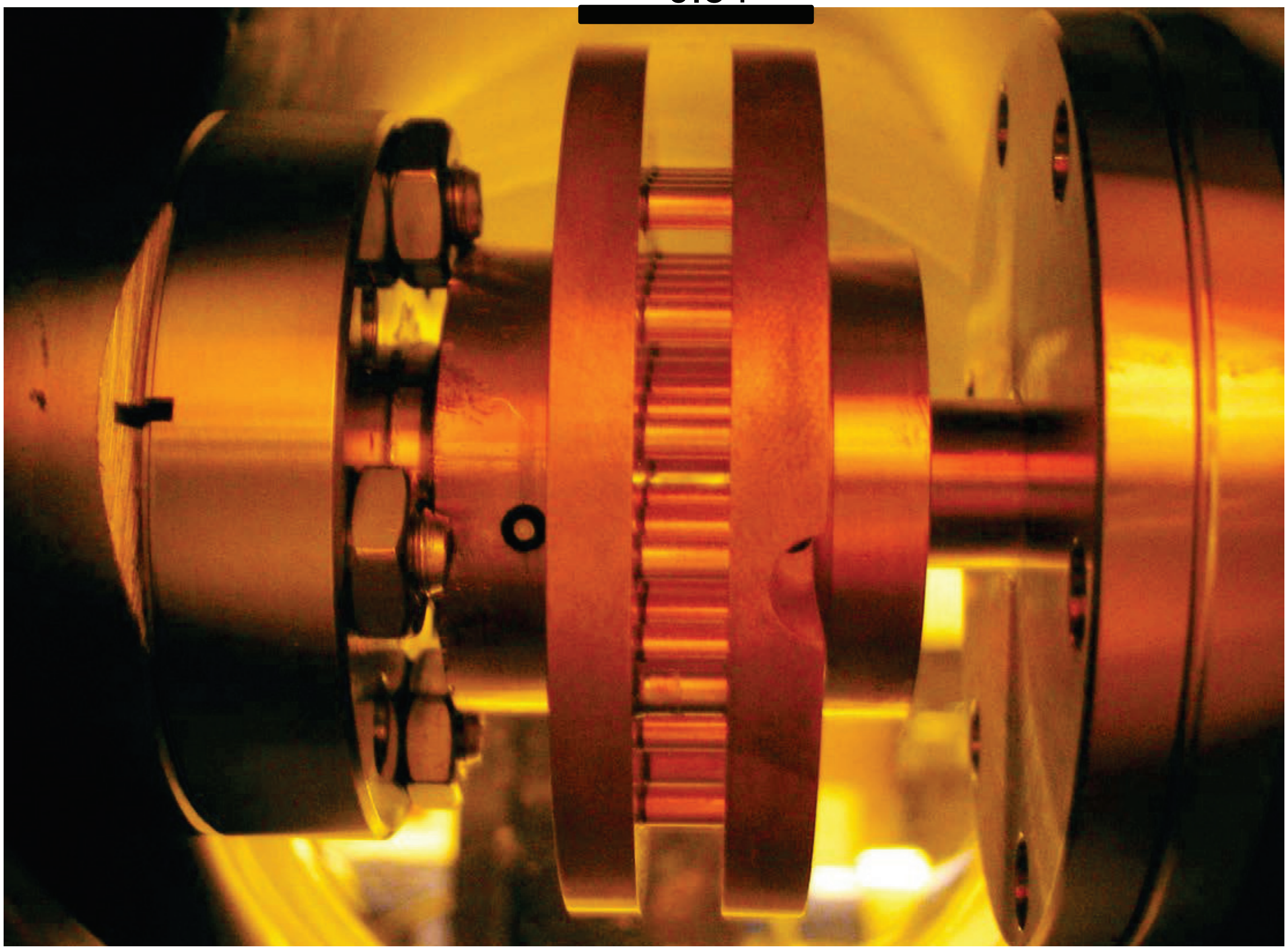
Magnetic Field



Single-Cell Structure Testing At MIT

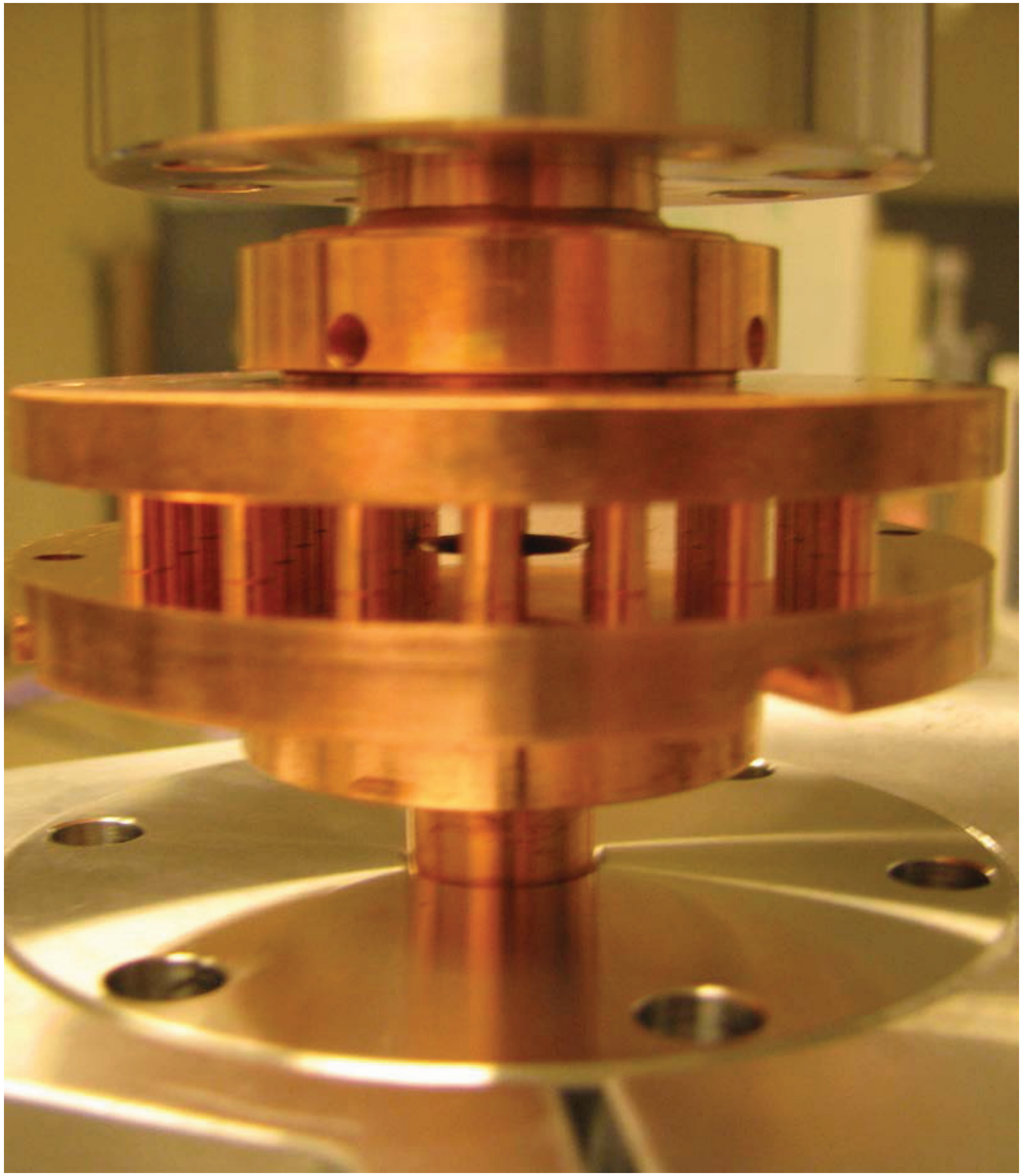
- Preliminary version of structure installed in test stand

~0.54"



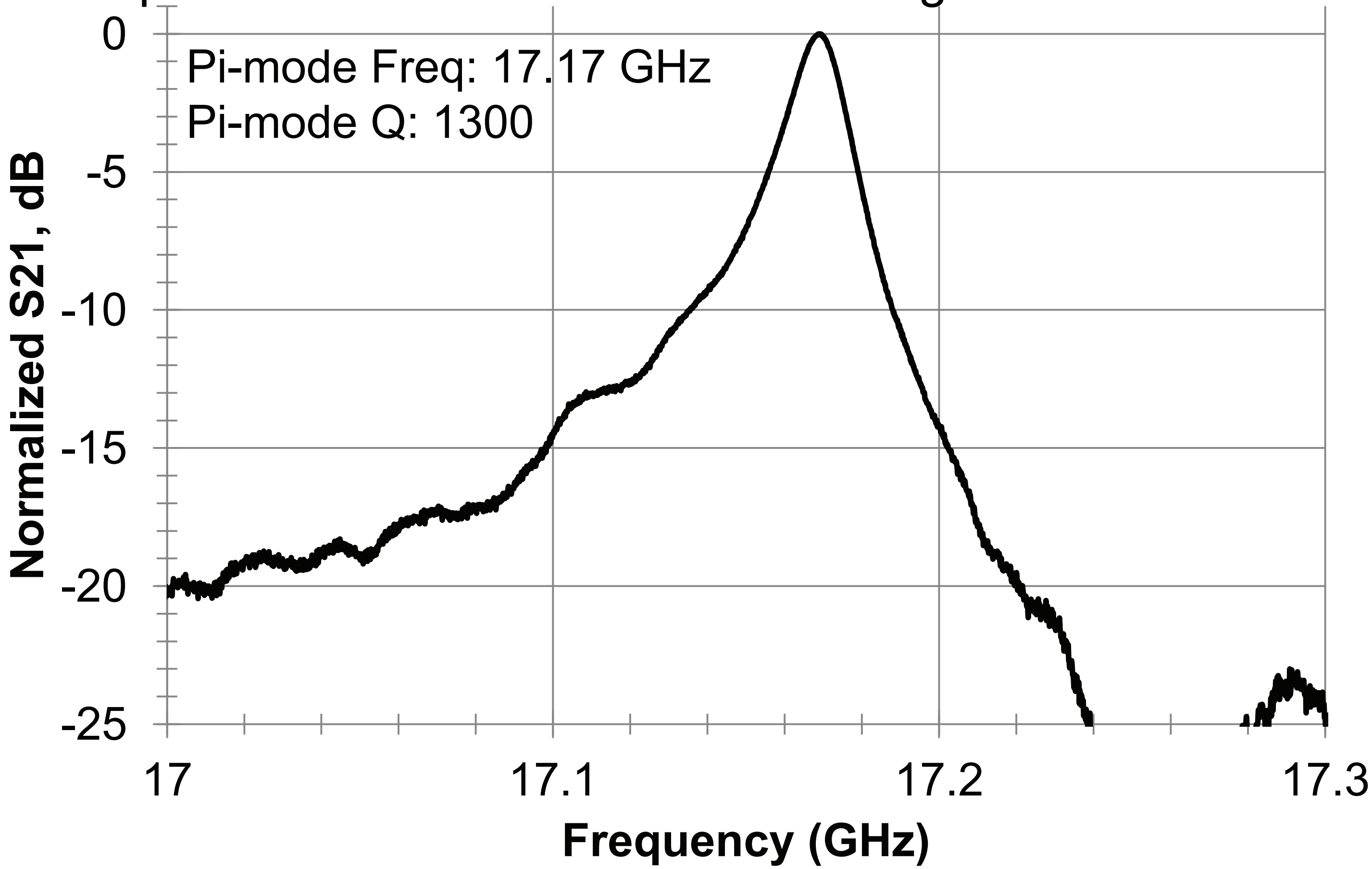
Single-Cell Structure Testing At MIT

- Finals structure under fabrication



Single-Cell Structure Testing At MIT

- Final structure under fabrication
  - Pre-braze testing shows improved coupling, Q (from S_{21})
  - Field profile to be measured after brazing



Conclusions

- Structure testing at SLAC showed PBG-E significantly improved performance vs. PBG-R
  - Almost 2 times higher gradient at the same breakdown probability
  - Peak Gradient: 128 MV/m at $3.6 * 10^{-3}$ /pulse/m
  - Lowest breakdown probability: $5.2 * 10^{-4}$ /pulse/m at 109 MV/m
- Future experiments at 17 GHz will further investigate breakdown behavior
  - Changes of breakdown probability with frequency
  - Change in temperature rise relative to fields in structure
  - Novel diagnostics, monitor changes in surface during testing

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