Study of High T_c Superconducting MgB_2 Thin-Film Coated RF Cavities

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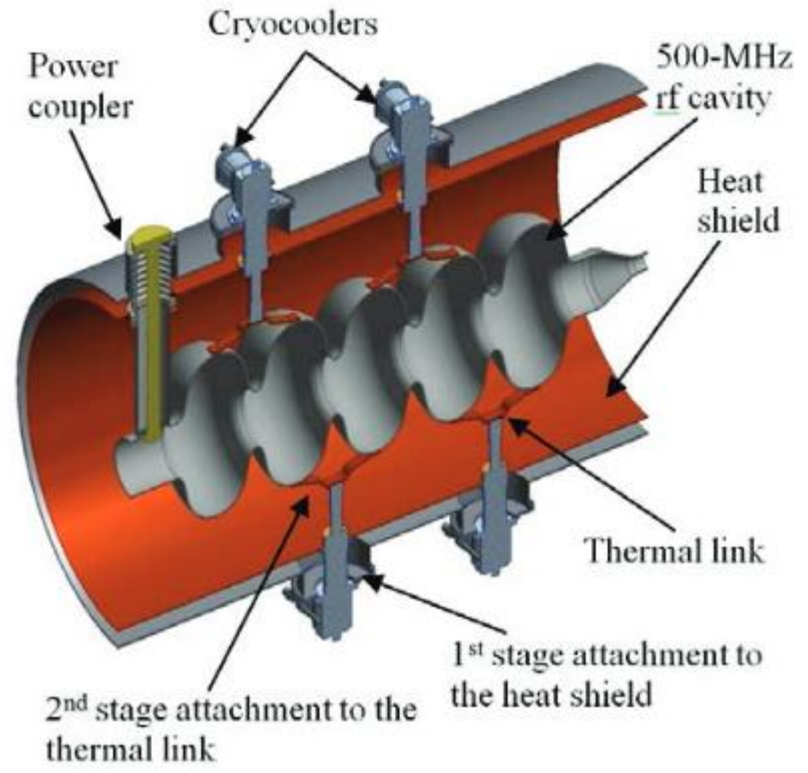
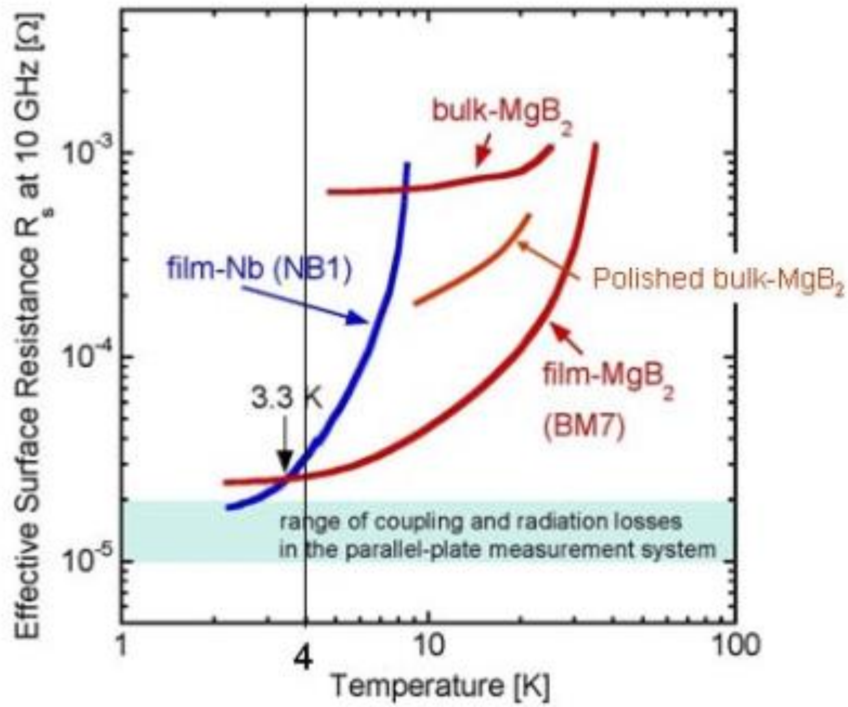
Introduction

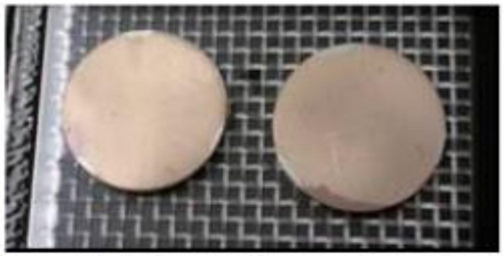
- Magnesium diboride shows promise for use in cryogen-free RF systems
- Simplifies cavity
- Performance of the cavity is limited by impurities in coating
- Need to develop a cost effective way for testing quality



Superconducting Material: Magnesium Diboride

- Magnesium diboride versus niobium
  - Higher critical temperature (39 K vs. 9 K)
  - Little increase in surface resistance with higher surface magnetic fields
  - Lower surface resistance at 4 K
  - Same surface resistance at 8 – 12 K as Nb at 4 K
  - Increase in accelerating gradient past the limit imposed by the quench field of Nb



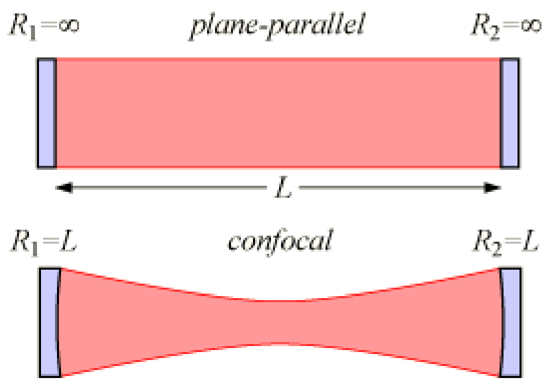


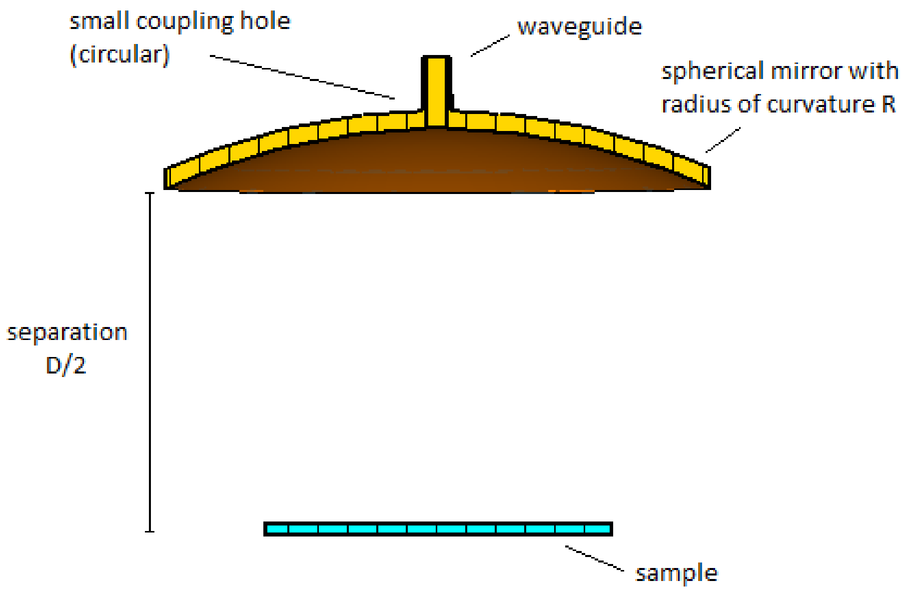
Magnesium diboride coated coupons

Fabry-Perot Open Resonator

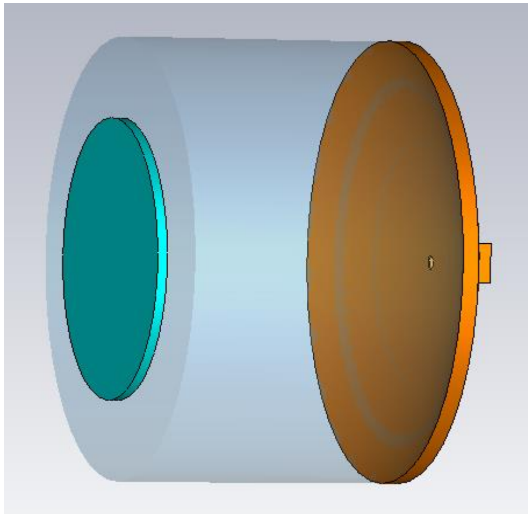
- Simple structure, insensitivity of experimental design to frequency, high quality factors are obtainable
- Optical cavity with parallel mirrors
- Half confocal: no second mirror, magnetic field is maximum at sample
- The $TEM_{0,0,q}$ modes induce magnetic fields onto the sample. Results in measurable heat loads on the sample which can be used to test the quality of the coating.

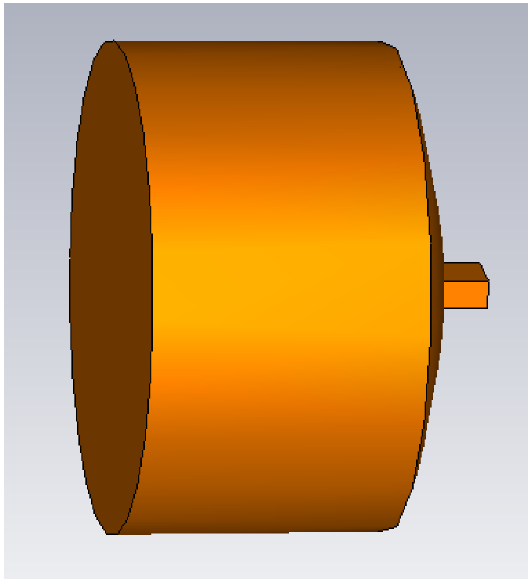
$$f_{0,0,q} = \frac{c}{2D}\left[q + 1 + \frac{1}{\pi}\cos^{-1}\left(1 - \frac{D}{R}\right)\right]$$





Simulations





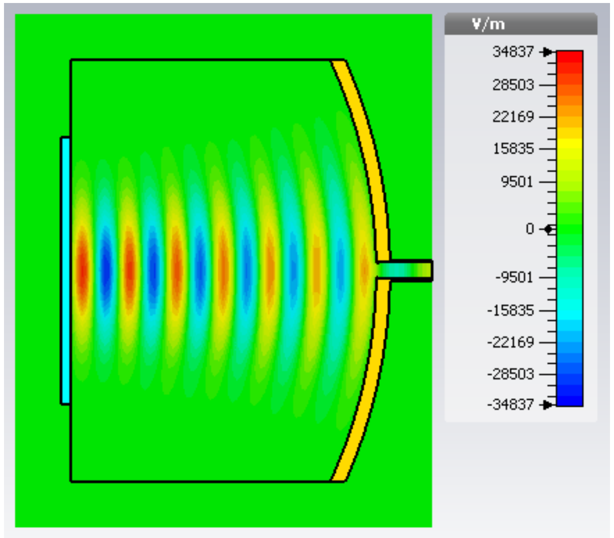
- Scaled from a paper by Martens[1]
- Previously tried 8 GHz but sample size was too small
- Frequency: 30 GHz because of commercially available amplifiers
- CST Microwave Studio used to optimize resonator
- Closed resonator used to show how much power was escaping confinement in the open resonator

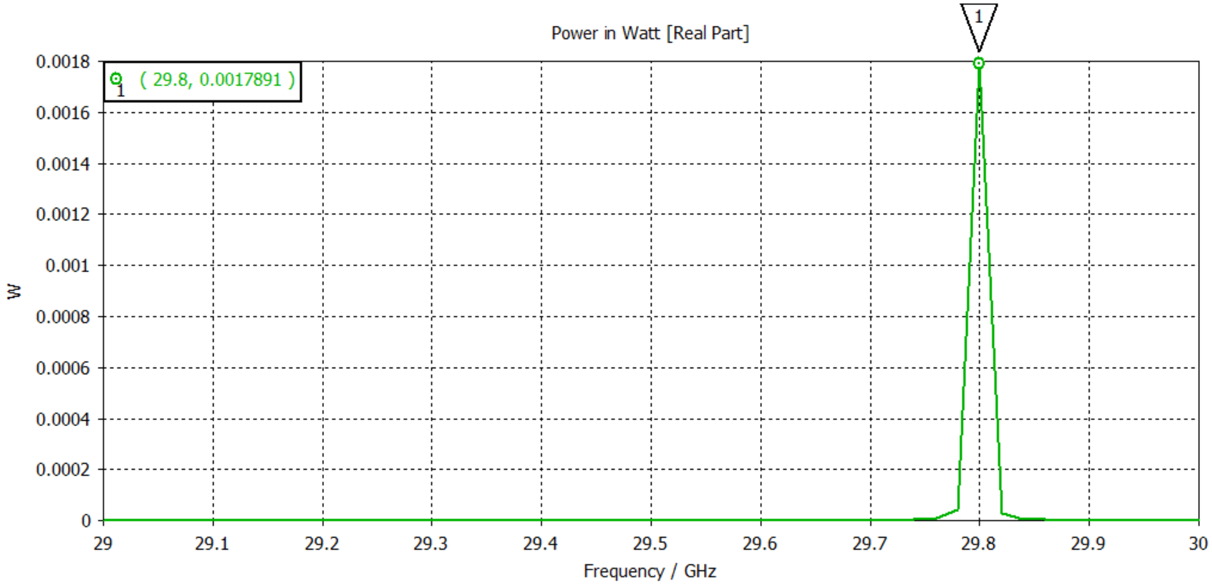
Description	Scaled Value	Ideal Value
Frequency	30.11 GHz	29.80/29.78 GHz
Radius of mirror	110 mm	110 mm
Height of curvature	45.72 mm	45.72 mm
Coupler Radius	1.50 mm	1.77 mm
Separation	66.00 mm	66.00 mm
Radius of sample	25.40 mm	29.05 mm

[1]Martens, J.S., et al. 1991. "Confocal Resonators for Measuring the Surface Resistance of High Temperature Superconducting Films." Appl Phys Lett 58 (22): 2543-2545.

Simulation Results – Open Resonator

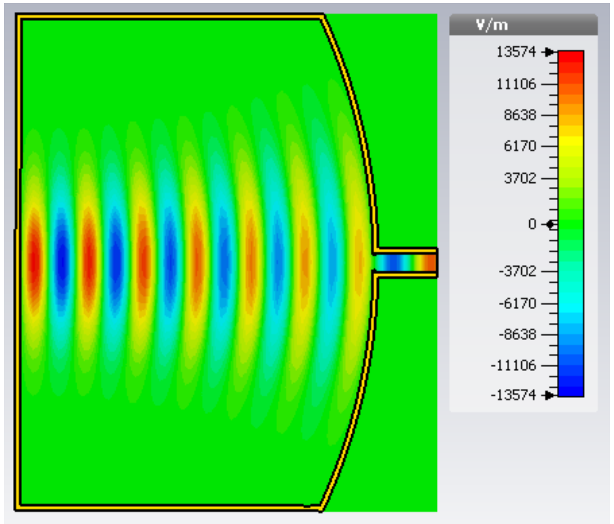
- Dimensions didn't change from scaled values
- Changing dimensions didn't greatly affect the system
  - Most of the power was dissipated out of the system
- Very small power dissipation onto the sample 0.0017891 watts (0.35% of total power)
- 99.2% of power lost from system or did not propagate according to S-parameters
- Conclusion: desired mode ($TEM_{0,0,26}$) not trapped

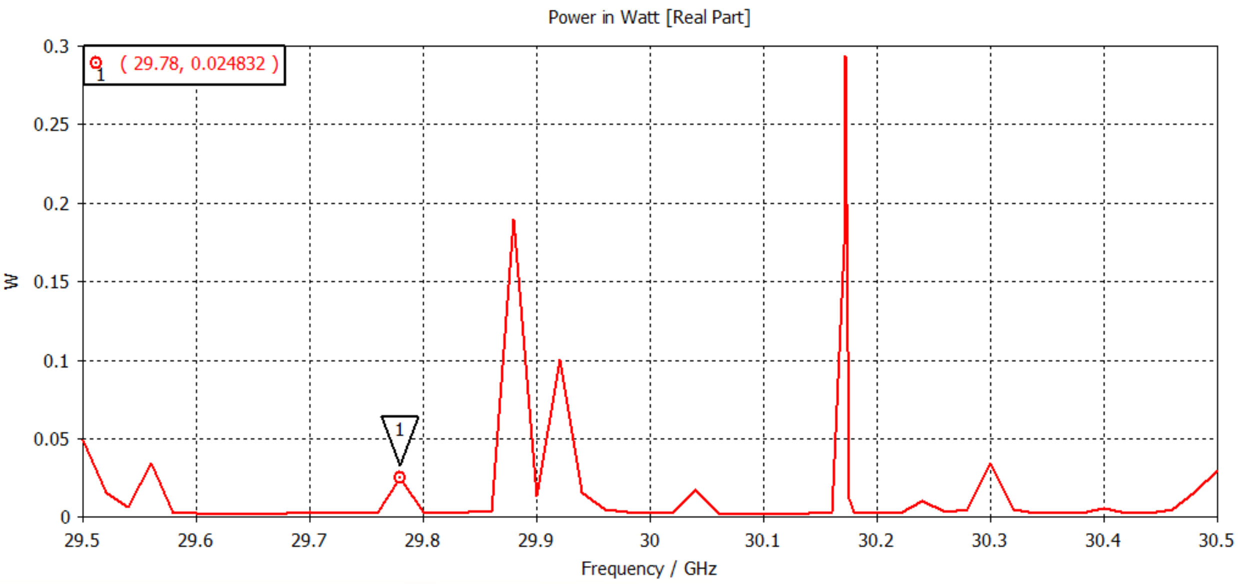




Simulation Results – Closed Resonator

- Attempt to force the mode
- Very small power dissipation onto the walls 0.024832 watts (4.97% of total power)
- 46.2% of power did not propagate according to S-parameters
- Expect the power dissipation onto the walls to approach 100%
- Unexplained shift in frequency from open resonator





Summary and Future Work

- MgB_2 would allow for simplification of RF systems
  - Operate at higher temperature and eliminate need for cryogens
- Need to develop a method to test quality of magnesium diboride coating of various deposition techniques
- Future work:
  - Design a resonator with adequate power dissipation onto sample
  - Study the closed resonator with the walls and sample separated
  - Find the reason for the differences between the open and closed resonators