Study of the Field Properties of Helmholtz Coil Pair Geometry

A COMSOL Investigation

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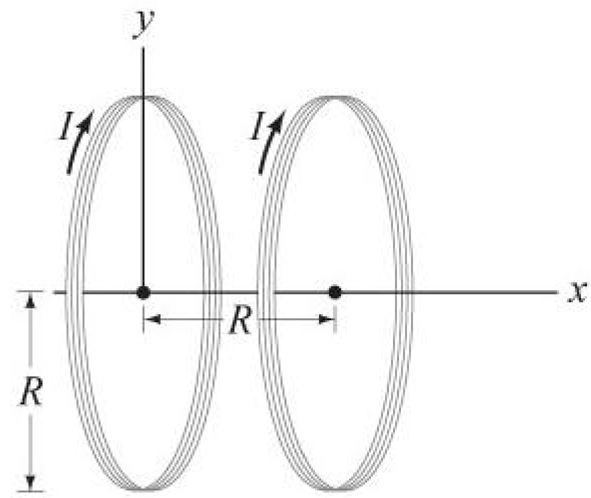
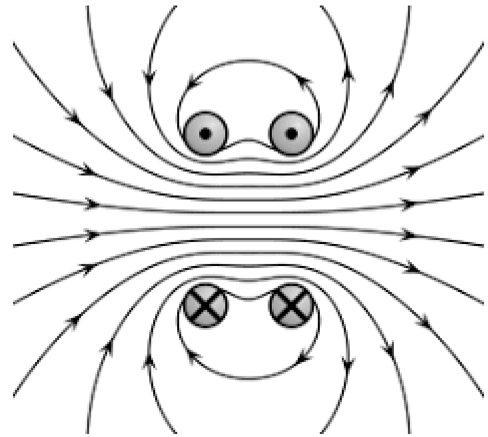
Updates

- An Introduction to Microwave Simulations with COMSOL Multiphysics (has been posted as note: CLAS12-2017-009)
- A more complete study (in a note) on holding field coils and microwave simulations in progress
- Note and material making and crystallization can be found here UVA-SPTG website:
- TechNotes/SPTG-TechNote-17002.pdf
- TechNotes/SPTG-TechNote-17003.pdf

Holding coils update

Introduction



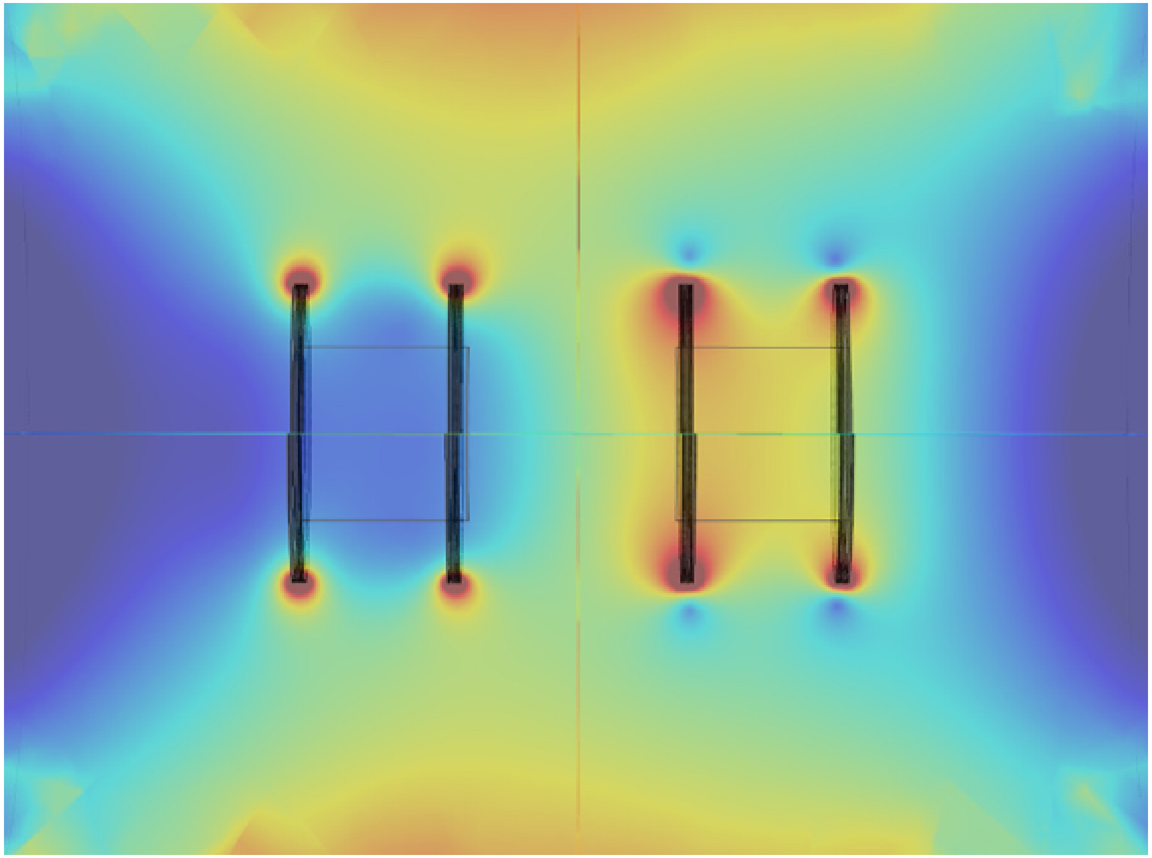


The objective of this study is to investigate how best to induce polarization in each of the target cells for two distinct resonant frequencies by changing the holding field rather than microwave frequency. The purpose of each coil system is to create a smaller additive or subtractive magnetic field inside of a 5 T background field. These smaller fields would surround each target so as to create the correct environment to induce resonance in the target material using a single microwave frequency produced at the waveguide opening.

Exploring Inner Coil Turn Number

Starting with a configuration of 10 inner coil turns and 10 outer coil turns for each couple, the inner turn number was increased by 5 for each simulation

Introduction



- Import CLAS background field (map from Geant of detector package ~5T)
- Want at least a difference 140.150-140.700 GHz (15 mT)
- Try for ~0.5 A in one coil and 0.491 in others coil in opposite directions
- Starting Geometry: ~2.59 cm Major Radius, 0.01 cm Minor Radius, Axial Pitch 0.05 cm

Results of study

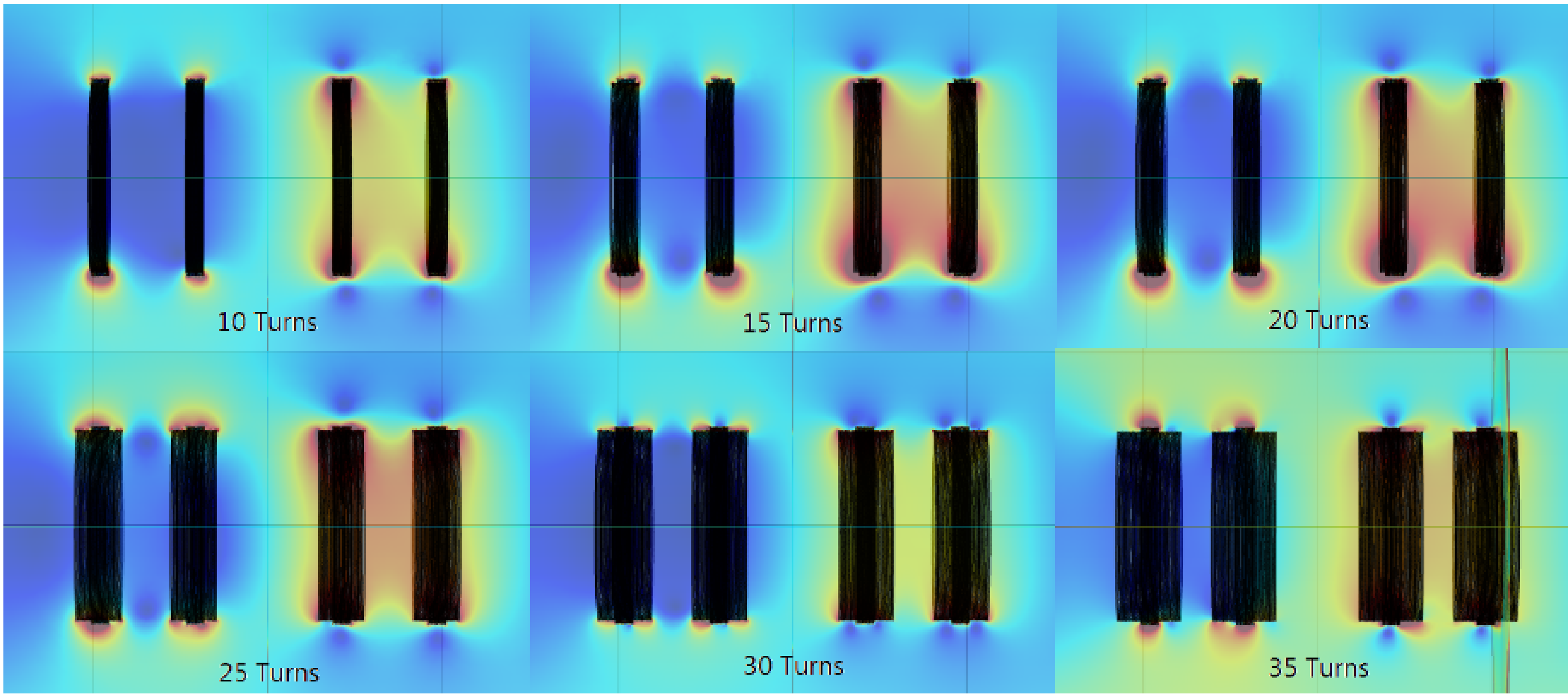


Figure: Visualization of coil geometry variation.

Field Homogeneity vs. Radial Position (cm)

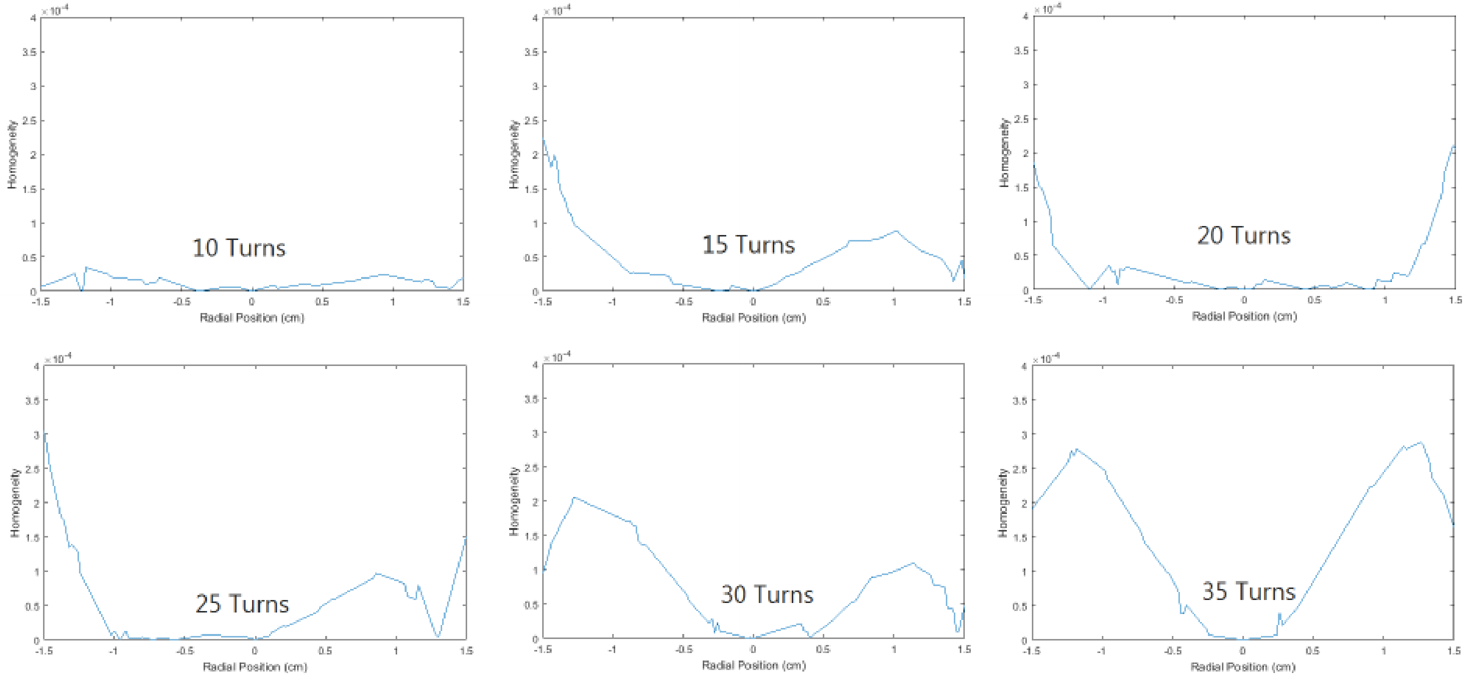


Figure: Field Homogeneity vs. Radial position.

150 measurements were taken radially inside the coils along -1.5 cm to 1.5 cm as an approximation for cup size. Field homogeneity $\frac{dB}{B}$ was measured by using the field at R=0 as reference.

Variation Results

N_{inner}	Mean dB/B
10	1.277e-5
15	4.844e-5
20	3.100e-5
25	4.989e-5
30	7.943e-5
35	1.470e-4

Table: Radial field homogeneity of coil configurations.

Field Homogeneity vs. Z-Position

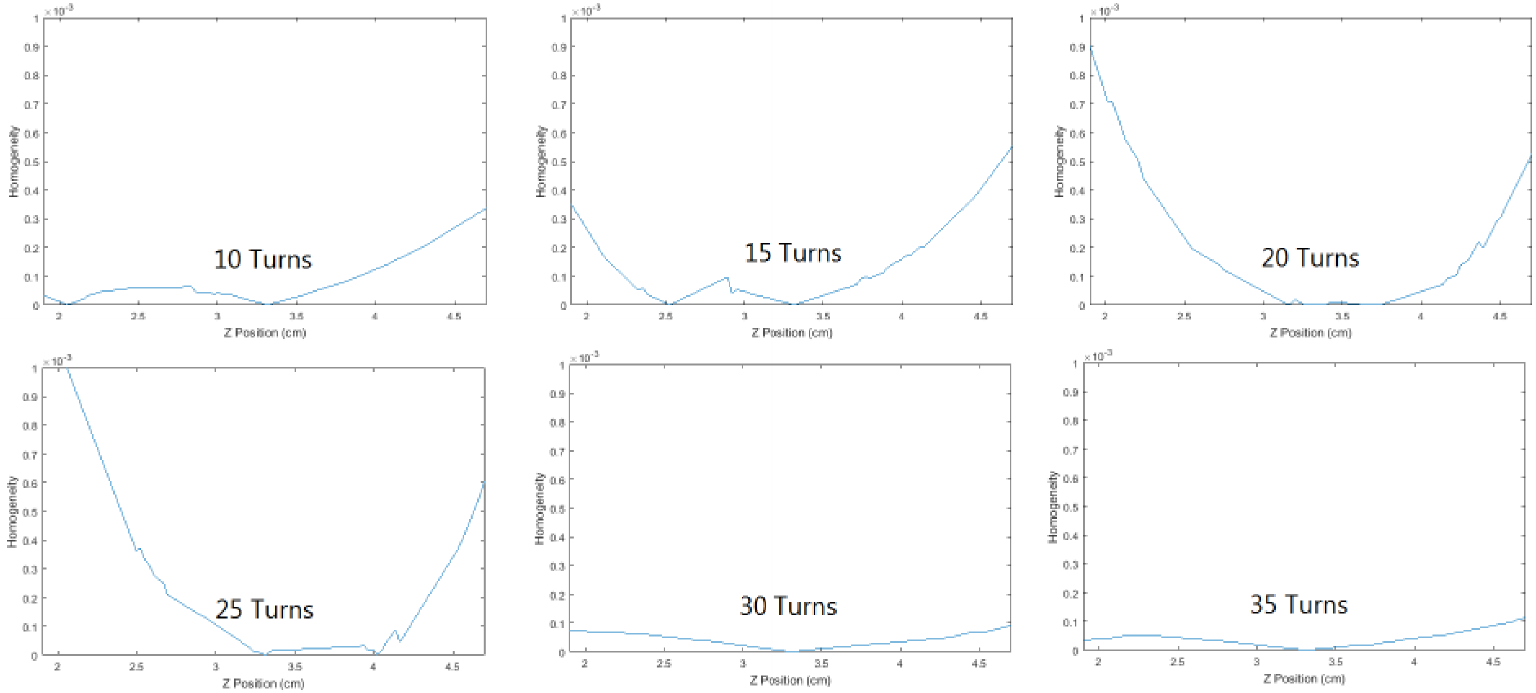


Figure: Field Homogeneity vs. Z position.

Along the Z direction, the 35 turn configuration was found to be the most homogeneous.

Variation Results

N_{inner}	Mean dB/B
10	9.066e-5
15	1.430e-4
20	2.000e-4
25	2.850e-4
30	4.146e-5
35	3.937e-5

Table: Z field homogeneity of coil configurations.

Varying Individual Currents

Since the background magnetic field decreases as the magnitude of Z increases, supplying different currents to the front and back couples can make the field more homogeneous.

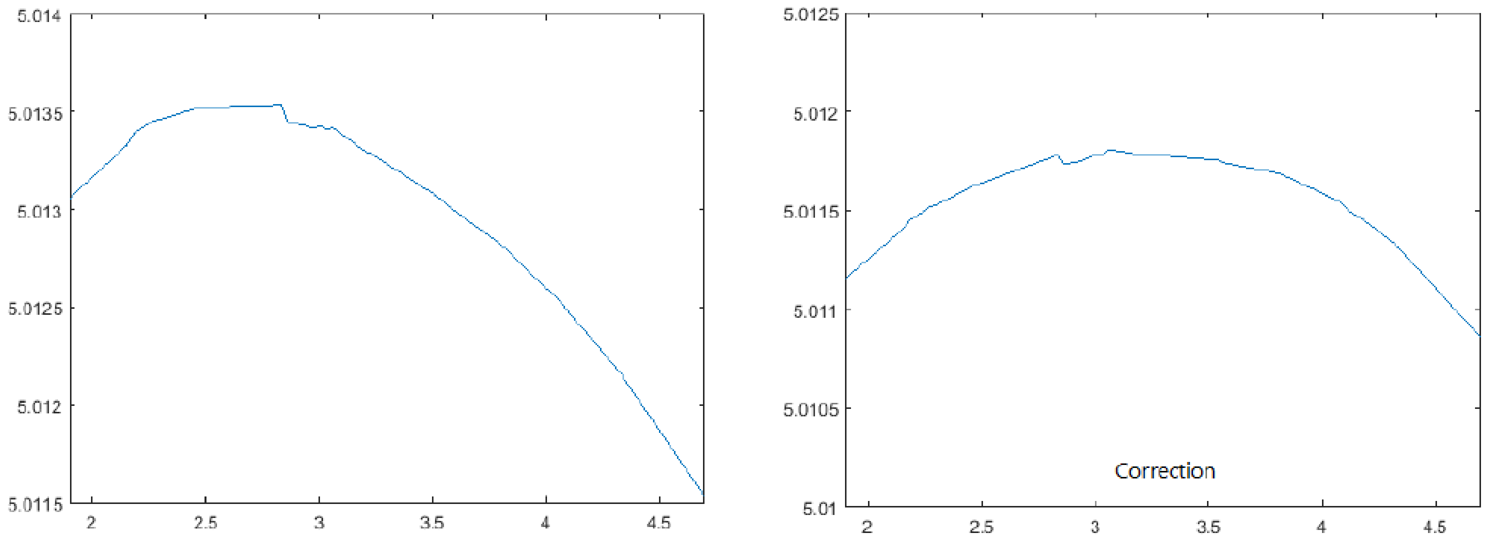


Figure: 10-10 coil configuration. Comparison of magnetic field along the Z direction. The graphic on the left represents a configuration where the currents supplied to both coil couples are equal. The graphic on the right represents a configuration where twice the current is supplied to the right couple as the left.

Current Variation Results

- For 30-10 coil configuration
- Superposition for three configurations with varied inner and outer currents
- Supplying different currents to the inner and outer coil leads to variation on the order of $0.5X10^{-4}$ In homogeneity
- A more specialized simulation is possible to answer specific concerns

Present coil status conclusions

- It was found that varying the currents in the front and back couples can work to restore symmetry to an asymmetric field thereby increasing the field homogeneity
- Variations of the currents on the range studies has only a small change in each case to the homogeneity
- Seems to be enough flexibility for finding an optimal homogeneity given a certain geometry constraint
- More details to come in second note

Microwave Simulations Status

- We are still exploring what COMSOL can do

  - what it is most useful for in cavity studies

  - what is it strengths in microwave simulations

  - weaknesses and work-arounds

- Best way forward for irradiating two cells simultaneously with close to equal irradiation

  - optimized nose cavity

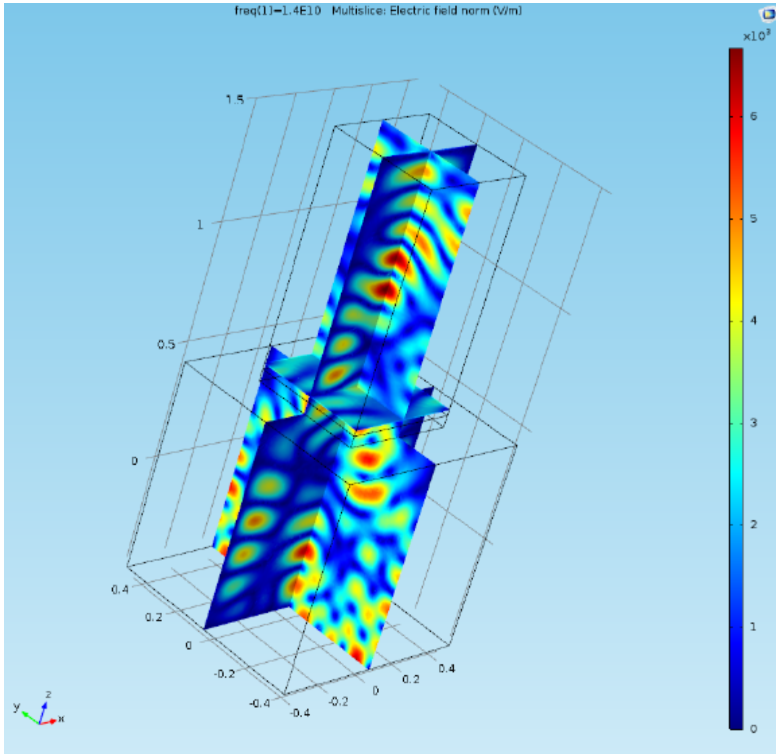
  - wedge reflector

  - slotted waveguide

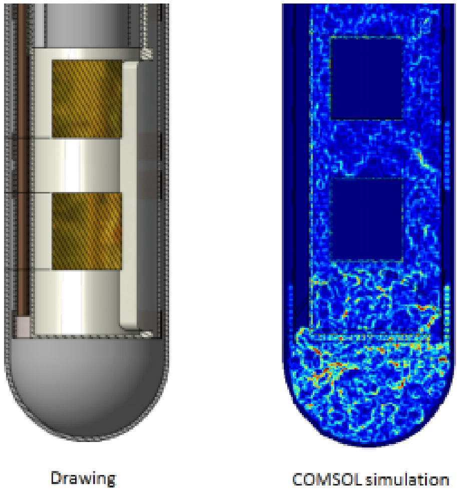
What we know now

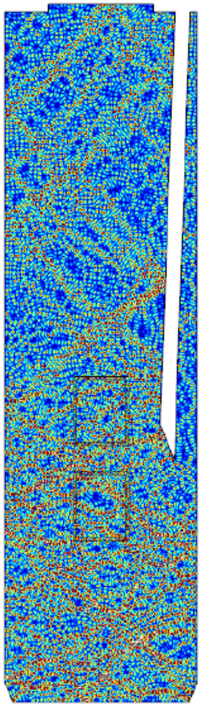
- 3D-COMSOL only possible with dimensions on the order of 1mm for the frequency of interest
- 2D-COMSOL must make strategic slices in order to do anything (that may or may not tell you what you want to know)
- 2D-Axial symmetric: simulation of a 3D geometry, perfect for microwave horn, waveguide, nose with horn in the center
- 2D-Rectangular slice: Cross section view in xy-plane with The flow at the boundaries is given per unit length along the third dimension (but you can change that length). So only gives you a view of a thin slice of the geometry that you describe to analysis the solution space.

Example Solutions



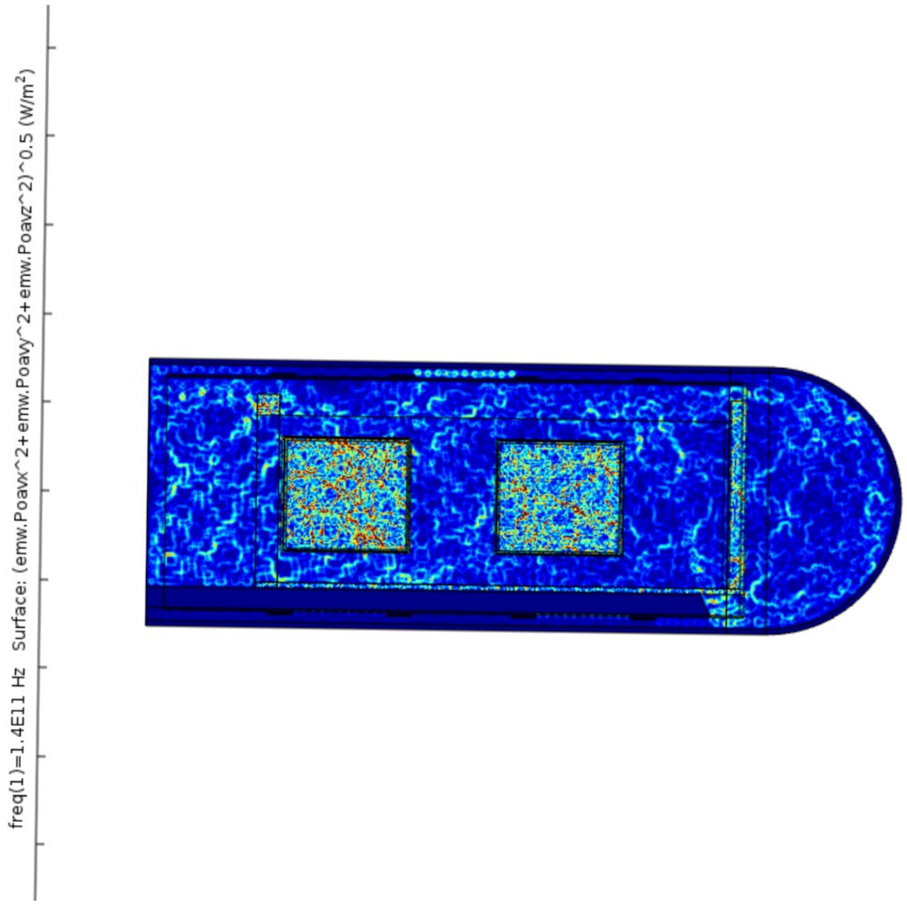
3D-Multislice

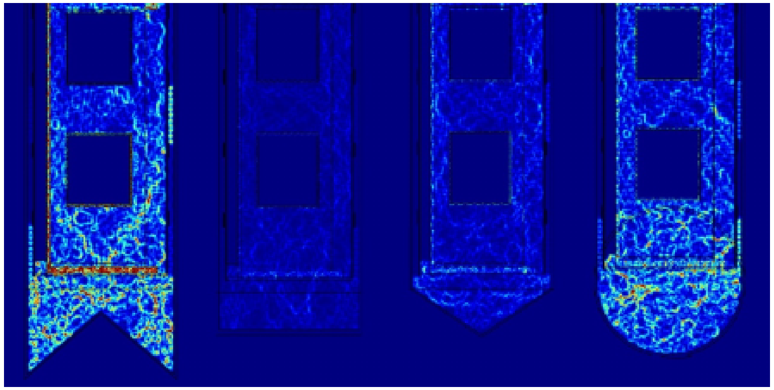


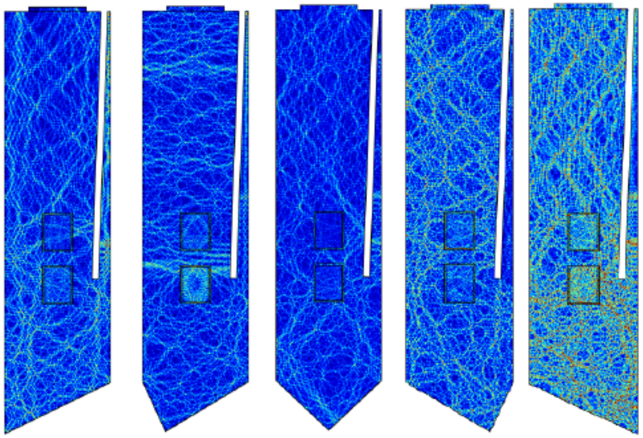


2D-Rectangular

Interpretation of slices



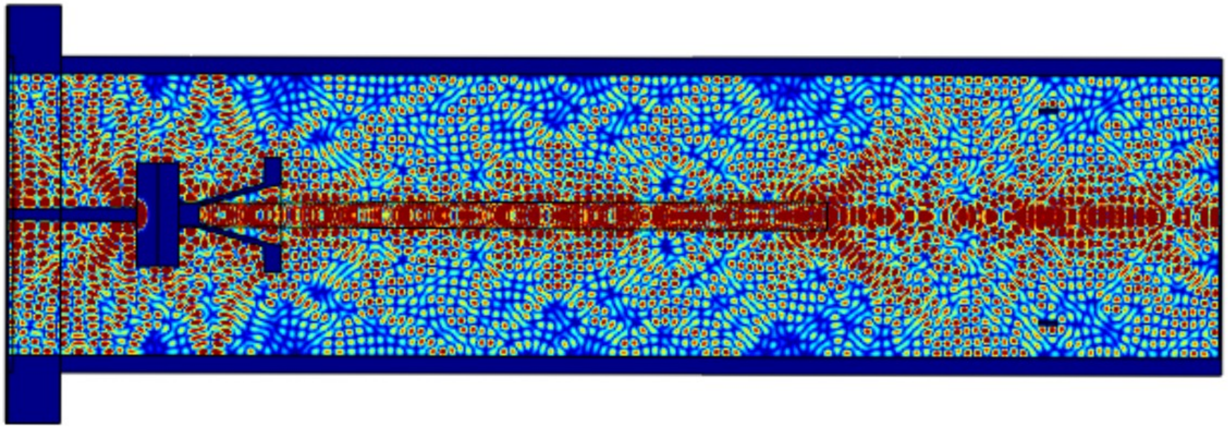




- We previously shown that it is possible to optimize geometry to get more even irradiation at each cell location (but we need to know how reliable these 2D-Rectangular slices are in understanding a 3D situation that is not symmetric)

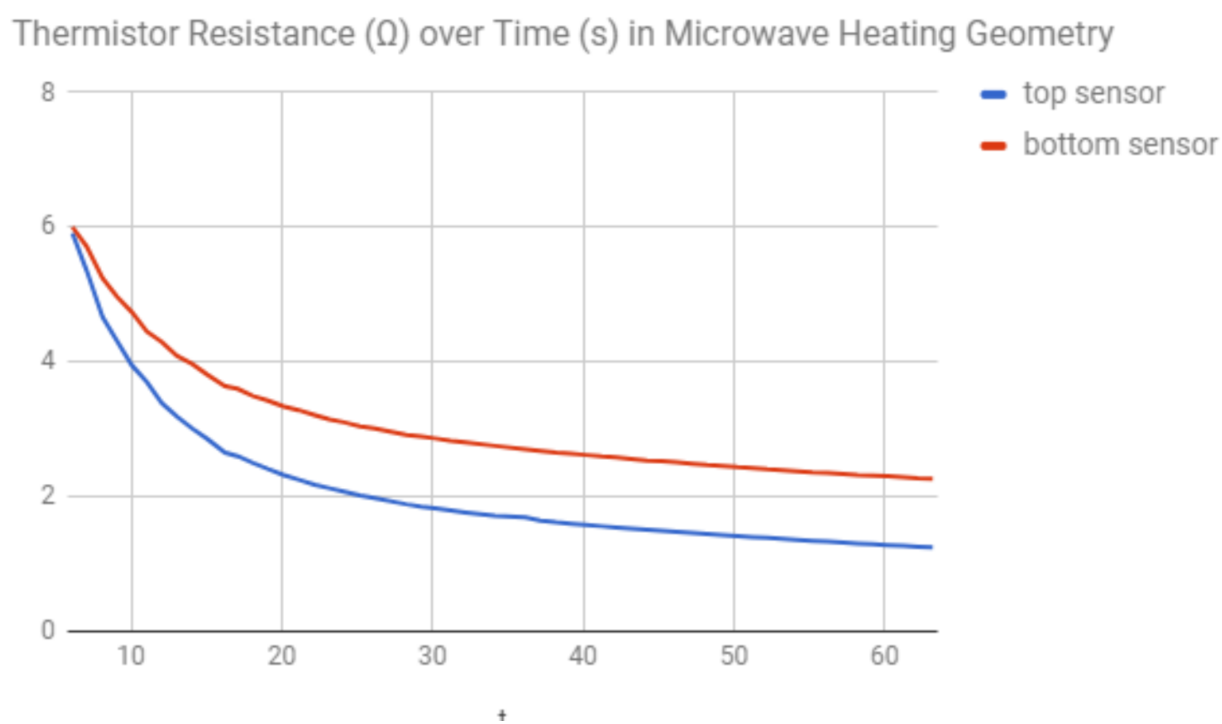
Interpretation of slices

- 2D-Axial symmetric (a 2D slice of a real 3D axial symmetric geometry)

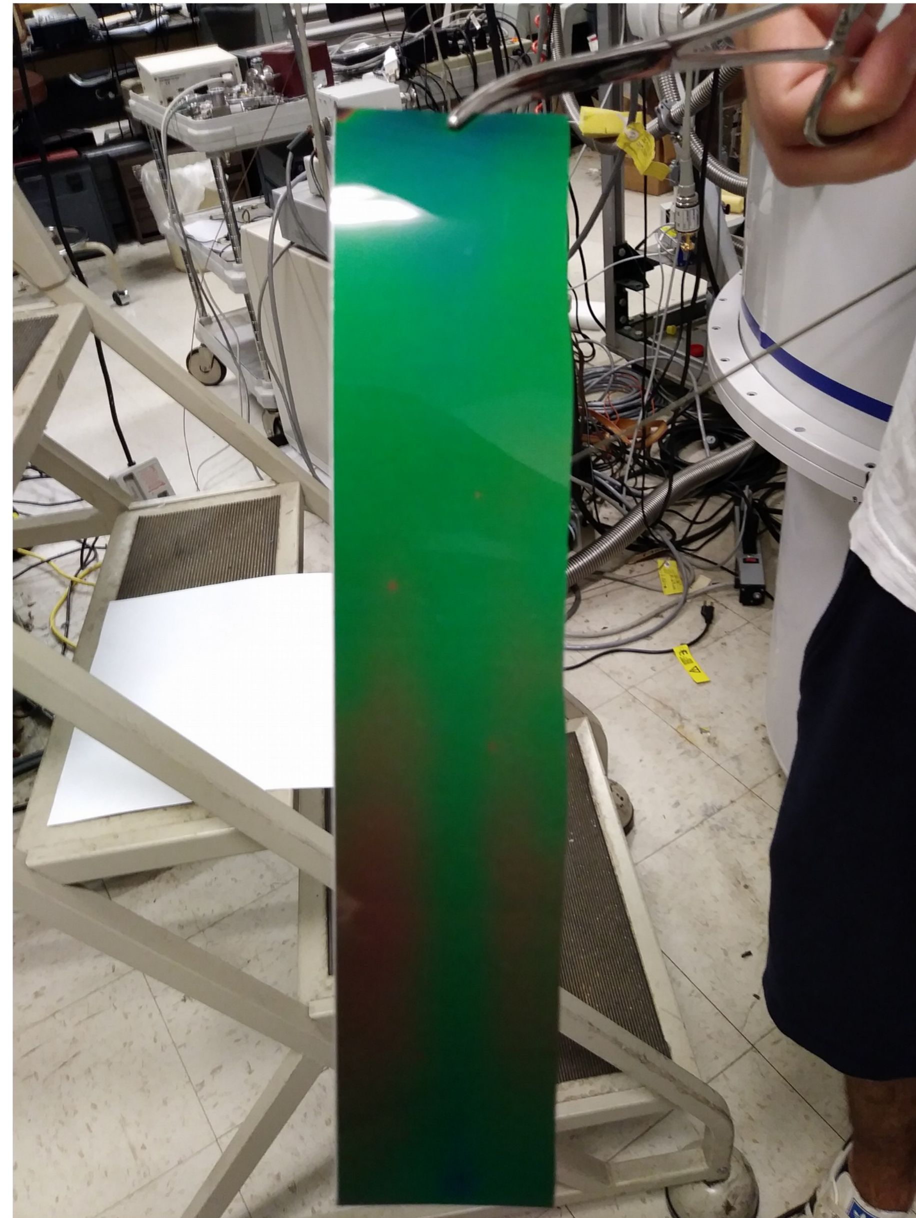


Present Status

- Working on comparison and empirical testing using liquid crystal film and physical nose cavity with thermistors

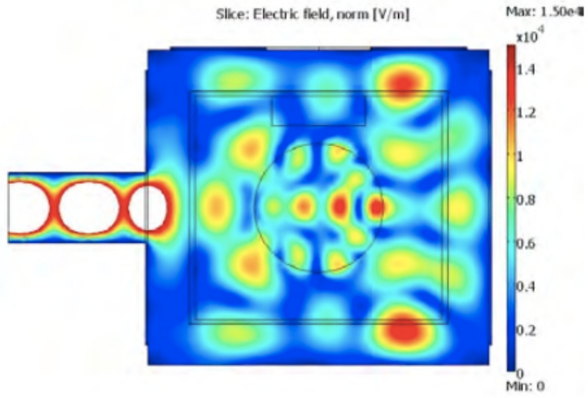


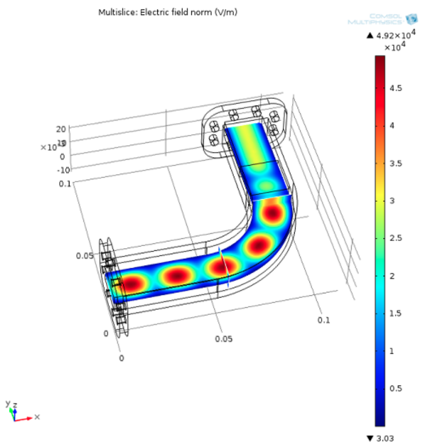

NESLAB



What we know so far

- Rectangular slices are not ideal for what we want to study
- For small geometries: design for waveguides and horns COMSOL is really useful for optimization
- COMSOL has a large parameter space and can be compared to real experimental tests, but it is difficult





Conclusions on Microwave SIMs

- We have previously pointed out the COMSOL studies suggest that strategic nose cavity design can optimize the irradiation to both cells (this is suggested using 2D-Rect)
- This also suggested by 3D-low frequency tests
- We are presently comparing both 2D-Axial, and 2D-Rect with experimental tests
- What is useful? What are geometry options?

Exploring Smaller Packing Fraction

- Density of material
- Less empty space in the target cell
- More material in the target

  - Try crystallized wafers

Why Crystallized?

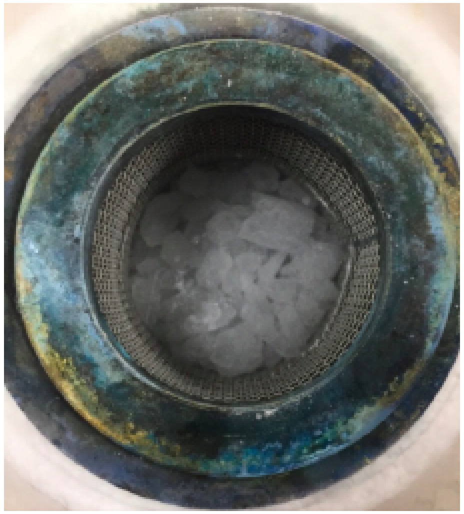
- More fissures in a glassy matrix
- More Dense
- Harder to break as thin wafers
- Polarization not much different for irradiated ammonia

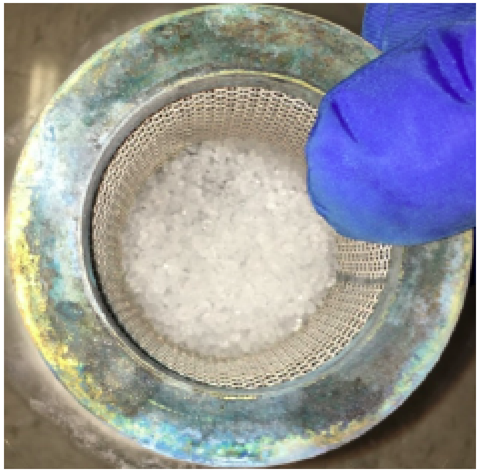
Making Crystallized Ammonia

- Very slow cooling
- Use Dry Ice and Ethanol bath
- ~13g/hour
- 6 hours to make

Results

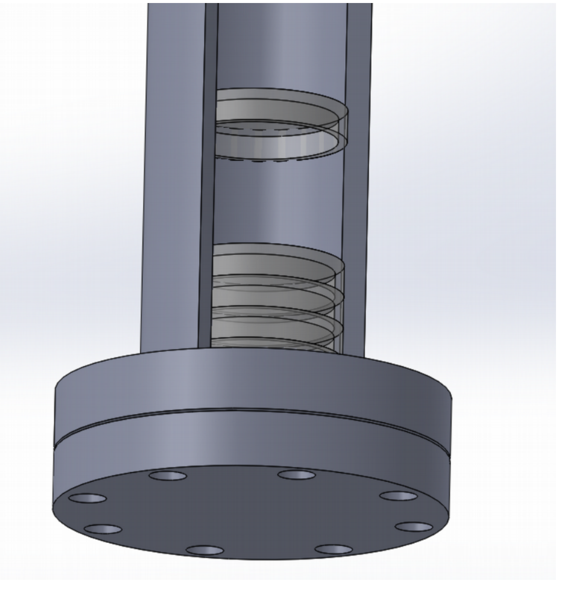
- Comes out very very hard
- Somewhat Transparent
- Very robust type of material
- Breaks up in large chunks (no scraps)

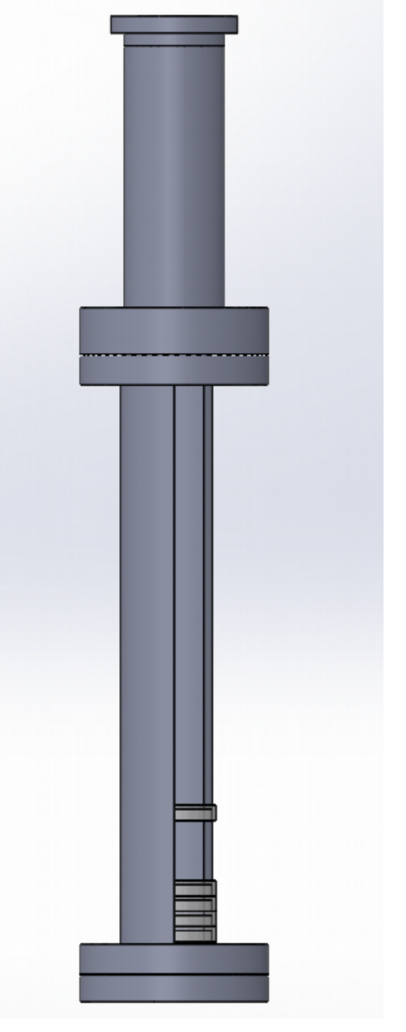




Next

- Try to make crystallized wafers
- Optimally the diameter of the target cell
- Use cups to form wafers in cylinder
- Load cell
- Irradiated
- Polarization Tests





THANKS