COMSOL Modeling Results and Tutorial

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Models

- Noise from the Bulk Thermal Modes of the End Mirrors
- Ability to change the Radius of Curvature of a Filter Cavity Mirror
- Ability to correct for Astigmatism and other Higher Order Modes due to Coating Stress in the End Mirrors

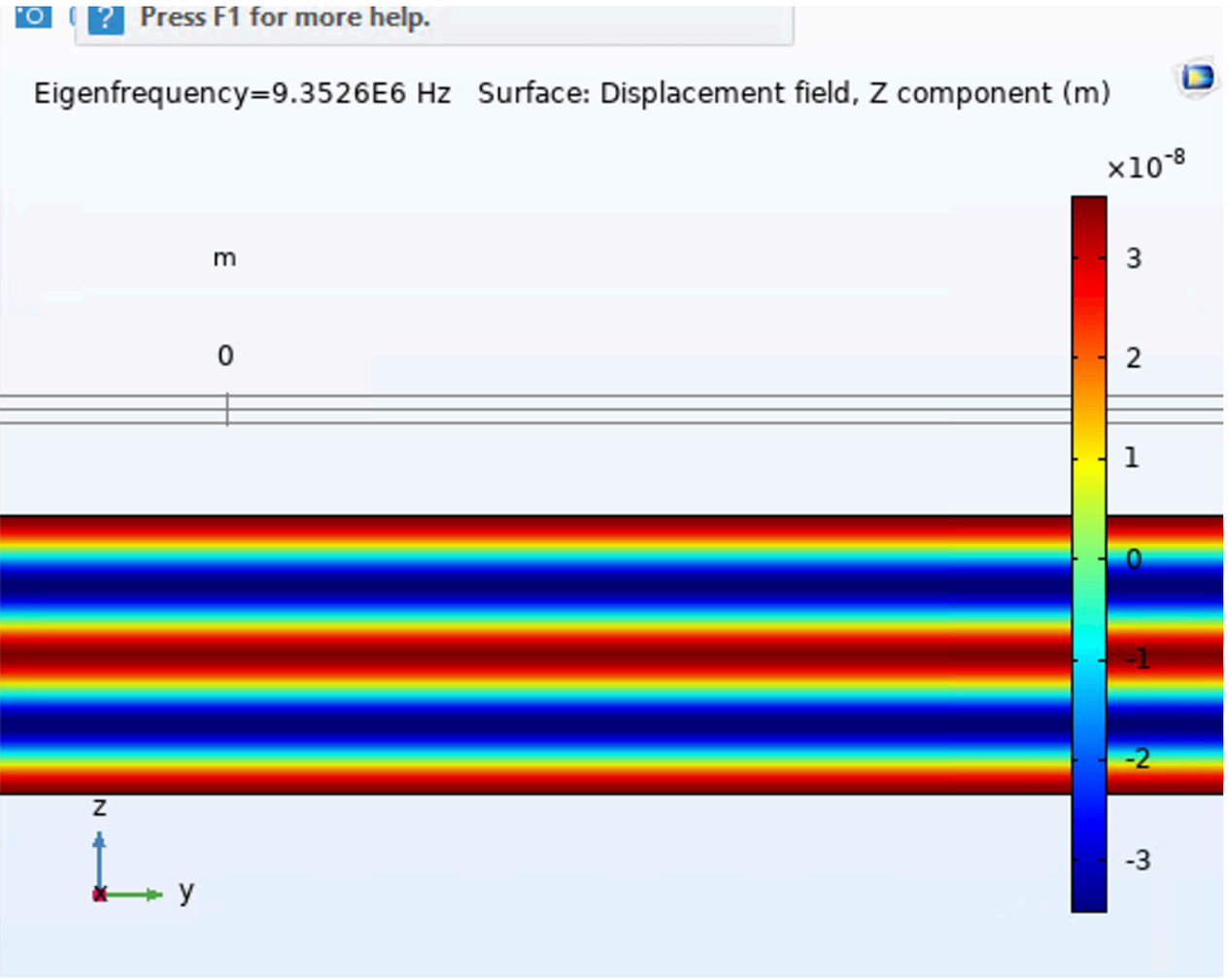
Bulk Thermal Noise Starting Point

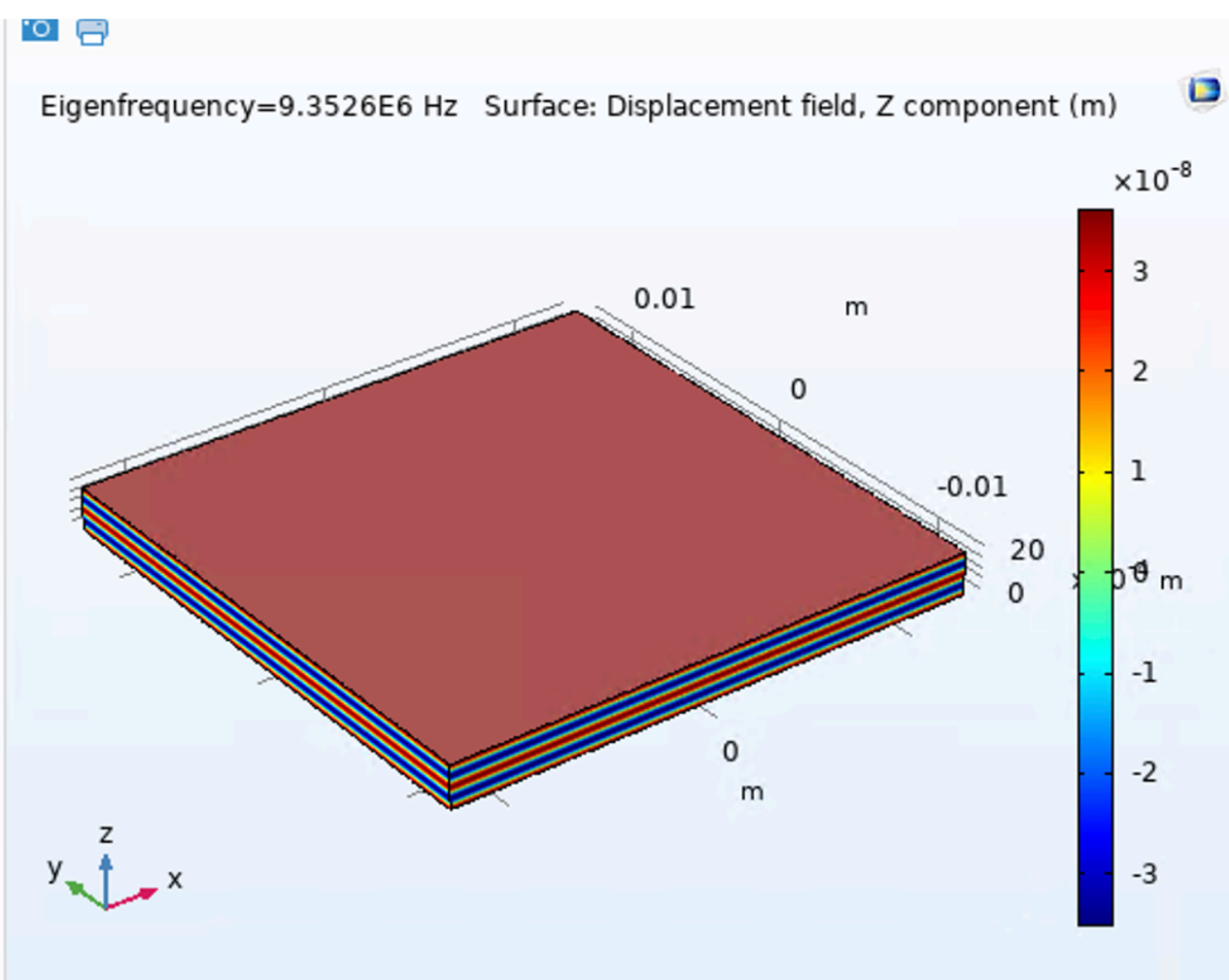
- Have an Approximate Analytic Model
  - Assumptions:
    - Mirror is Rectangular Prism
    - Orthogonality Assumption of Bulk Modes
    - Low Q bath doesn't couple into Mirror
- Most Worried about how Acoustic Longitudinal Etalon Bulk Modes of the Mirror Couple into the Rest of the Modes Between hem

$$\chi^2(\omega) = \frac{4k_B T k \phi(\omega)}{\omega[((k - m\omega^2)^2 + k^2\phi^2(\omega)]}$$

Acoustic Longitudinal Etalon Bulk Modes

- 4th Acoustic Longitudinal Etalon Bulk Mode shown
- Full Coupling into the laser

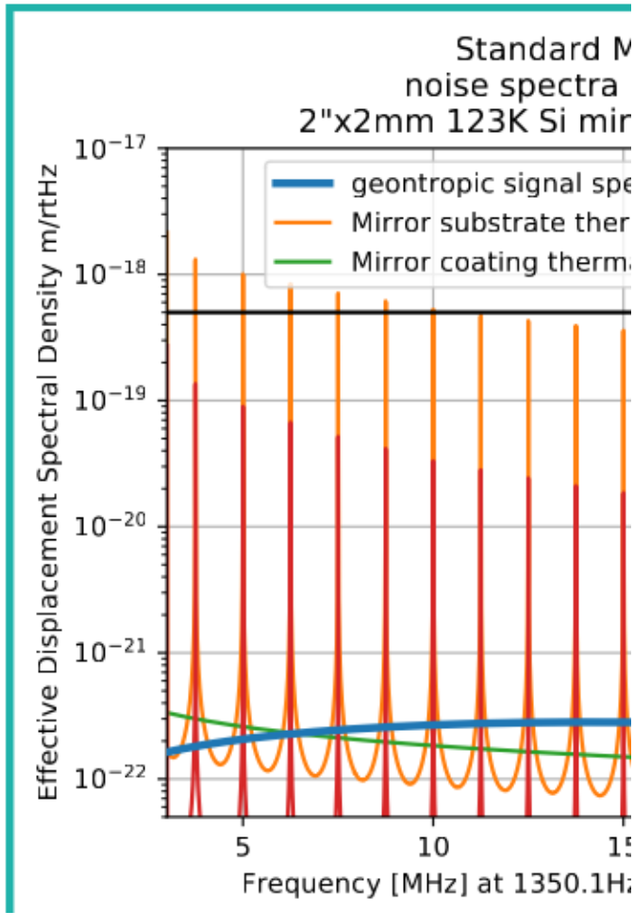




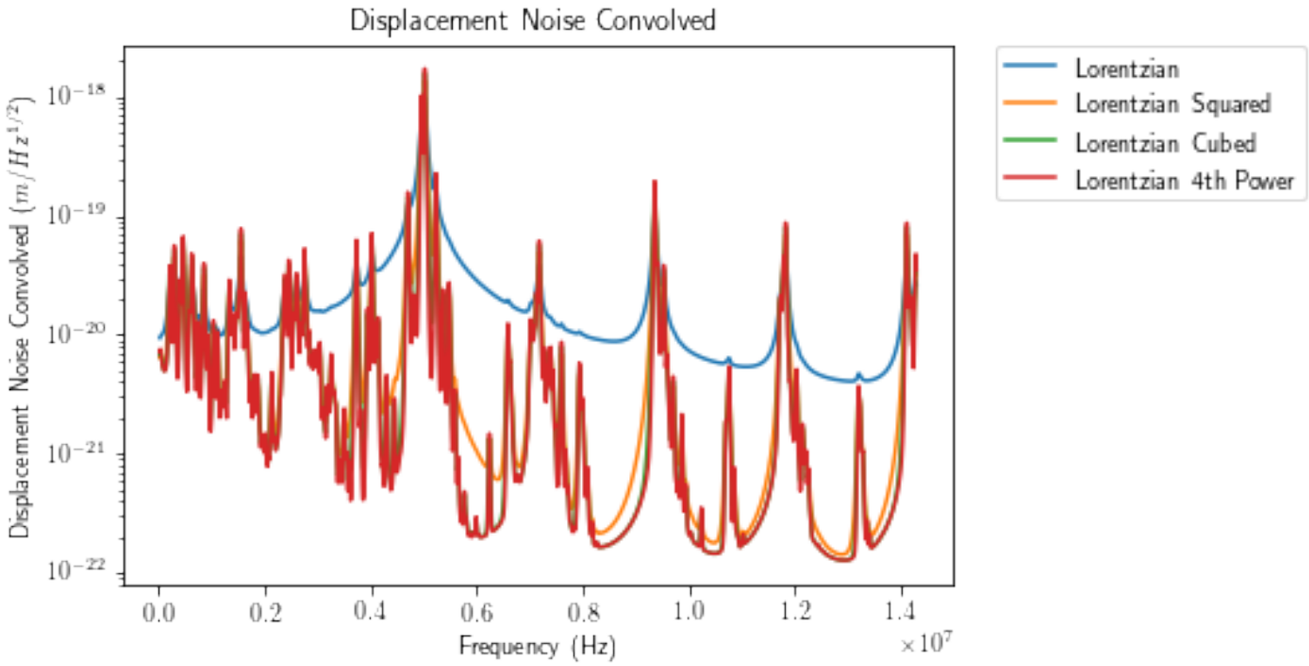
How to get spectrum

- Eigenmode Decomposition
  - Direct
  - Can apply different laser parameters with one simulation
  - Takes too long in the MHz band, even with LIGO server
    - Requires every mode
- Susceptibility
  - More indirect
  - Each Simulation only useful for Single Laser Parameter Set
  - But ultimately able to be computed in a reasonable time

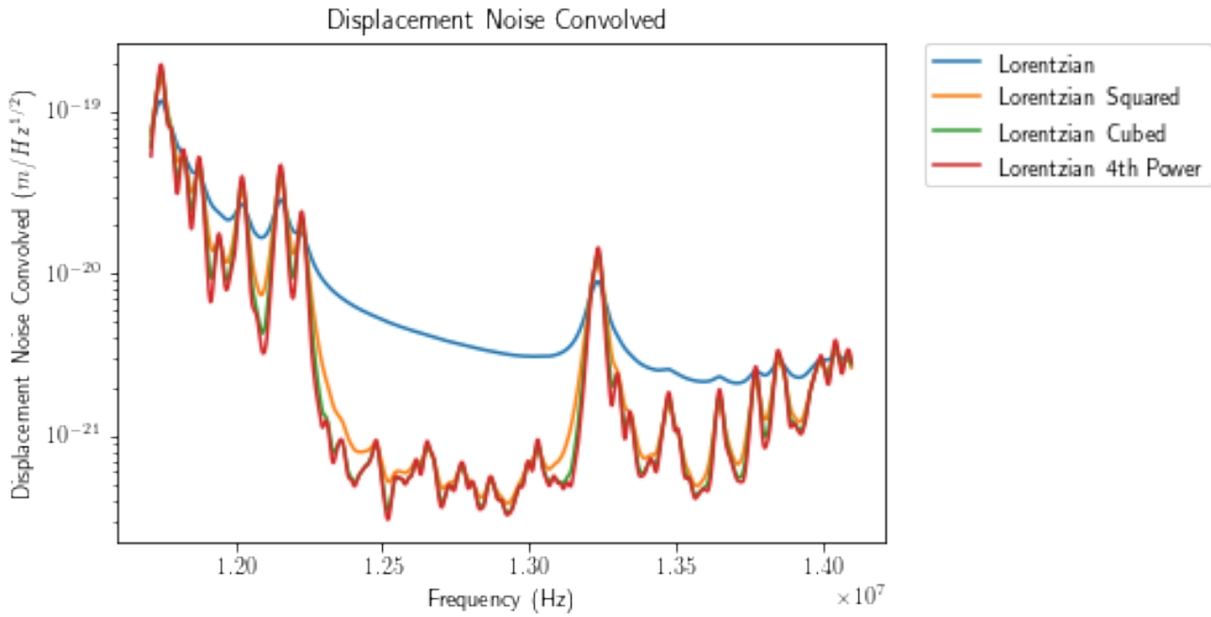
Results



Square Mirror Analytic

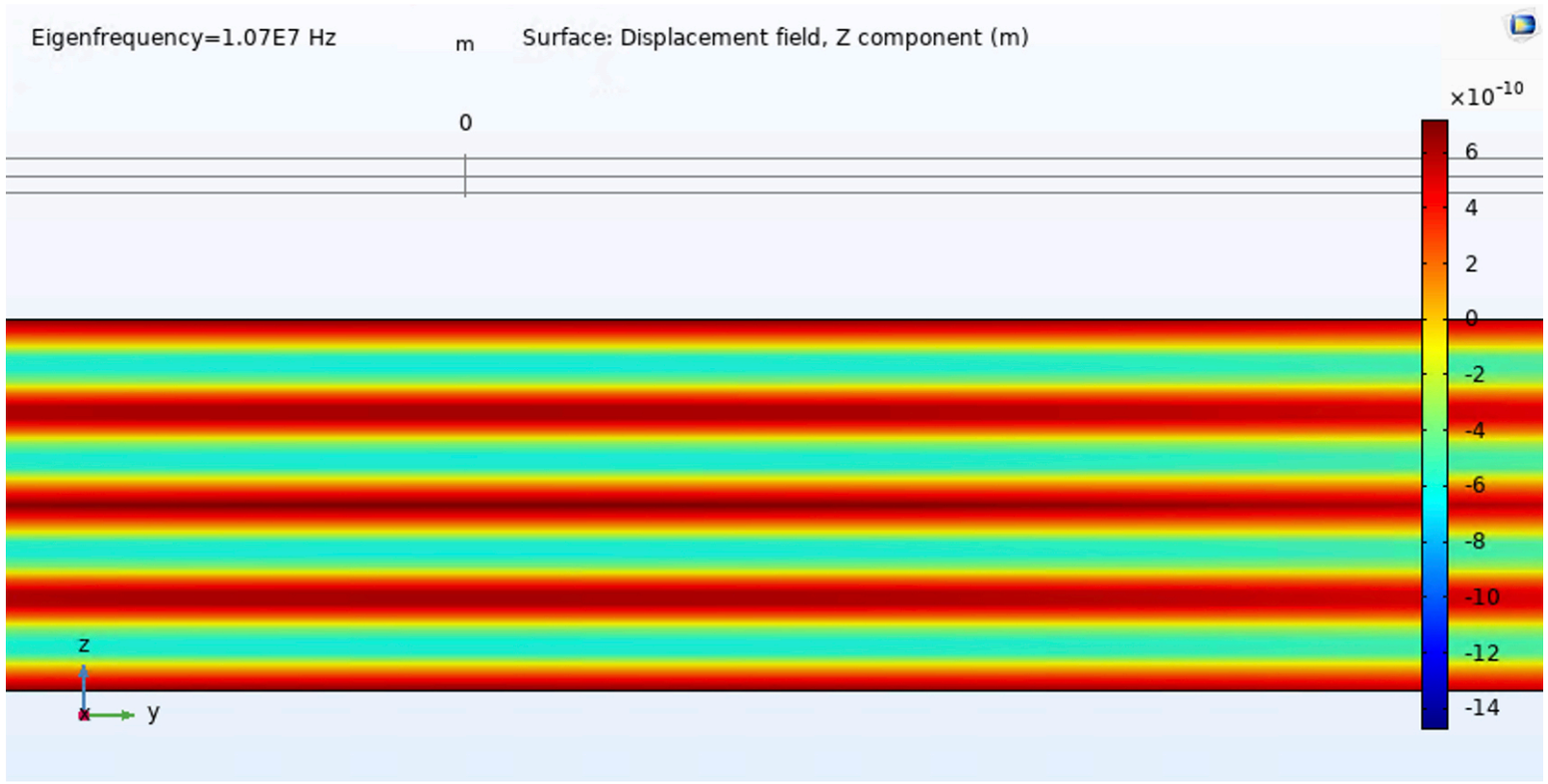


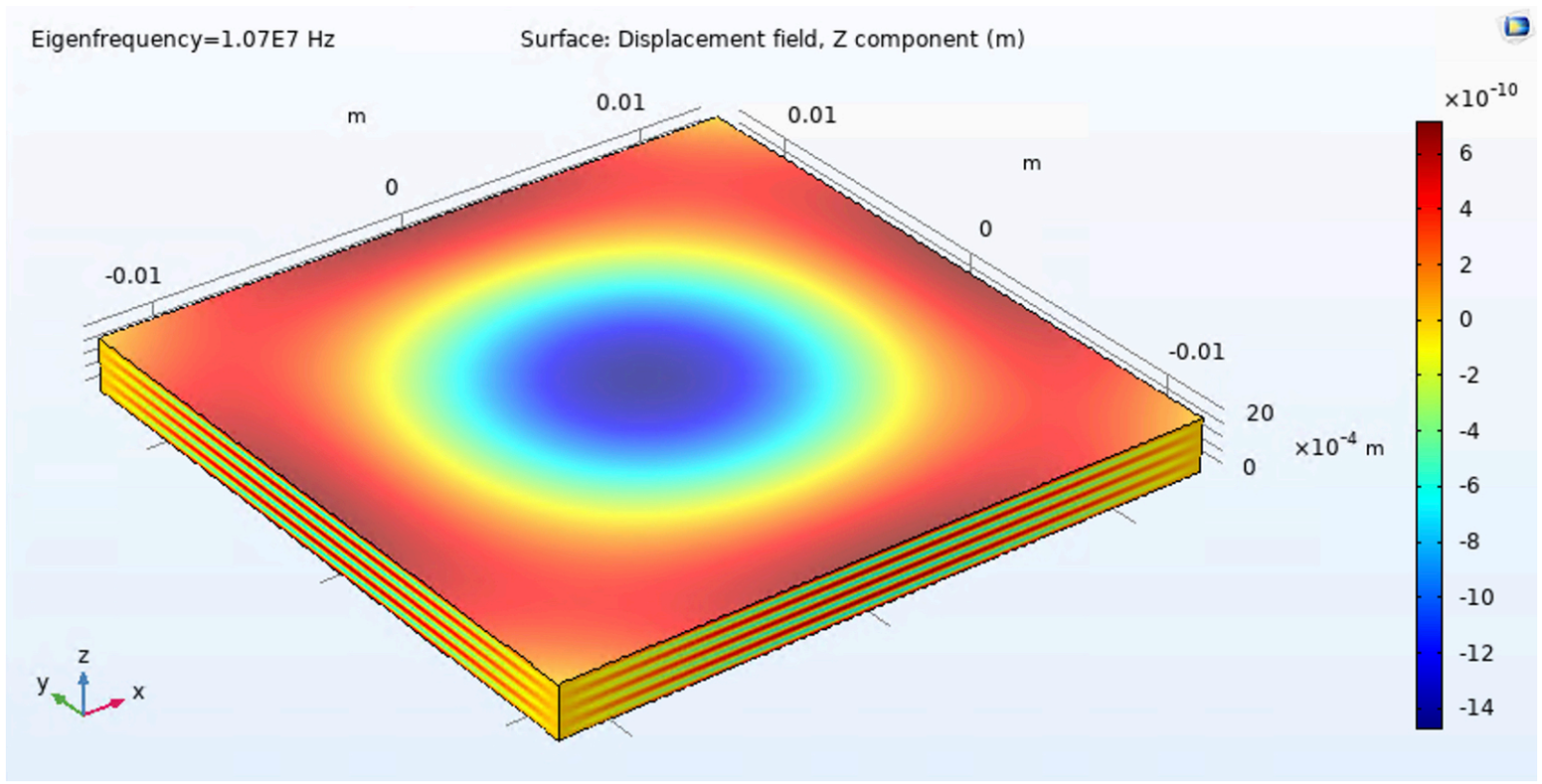
Square Mirror COMSOL



Circular Mirror COMSOL

Problematic Half Acoustic Mode



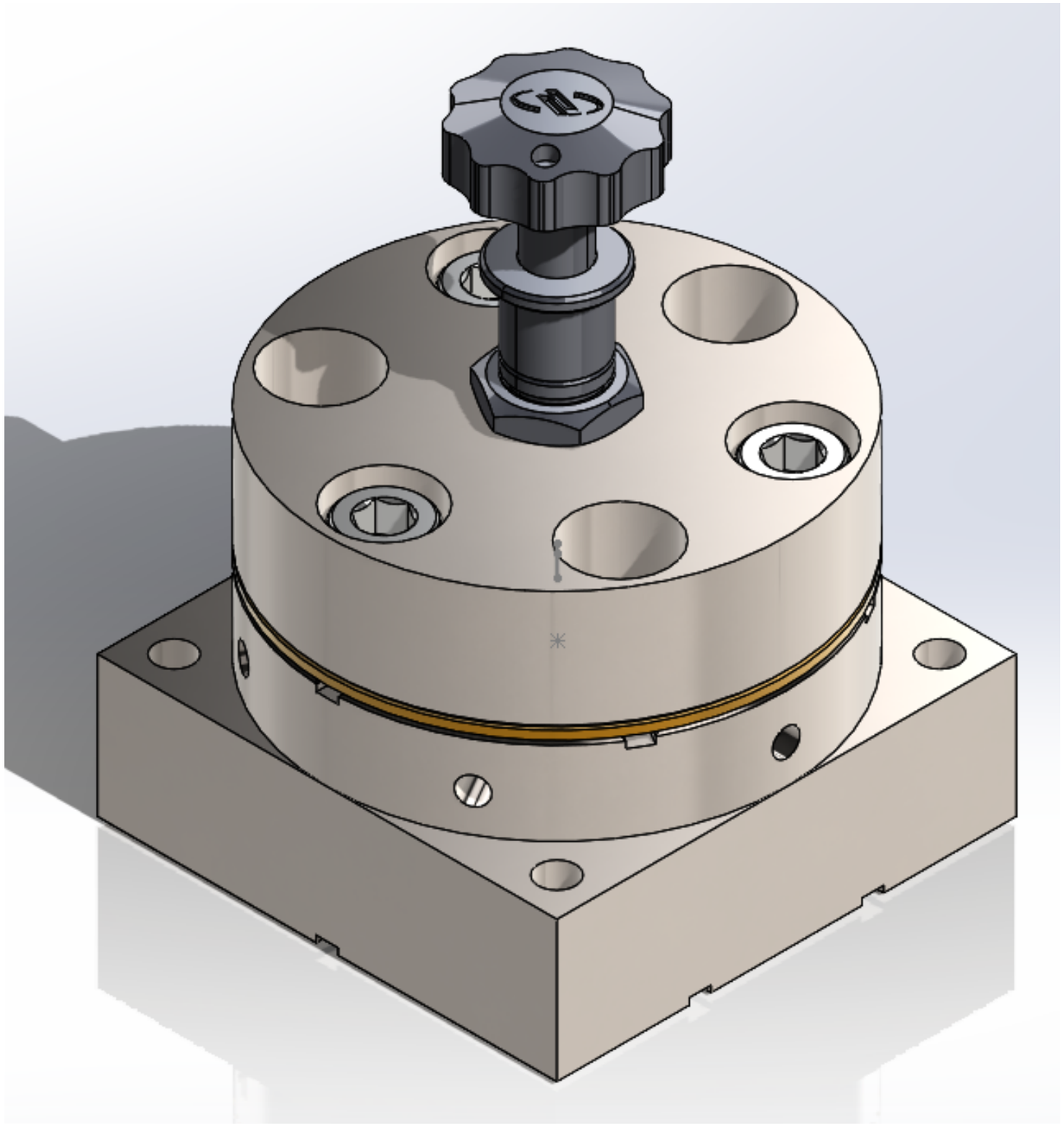


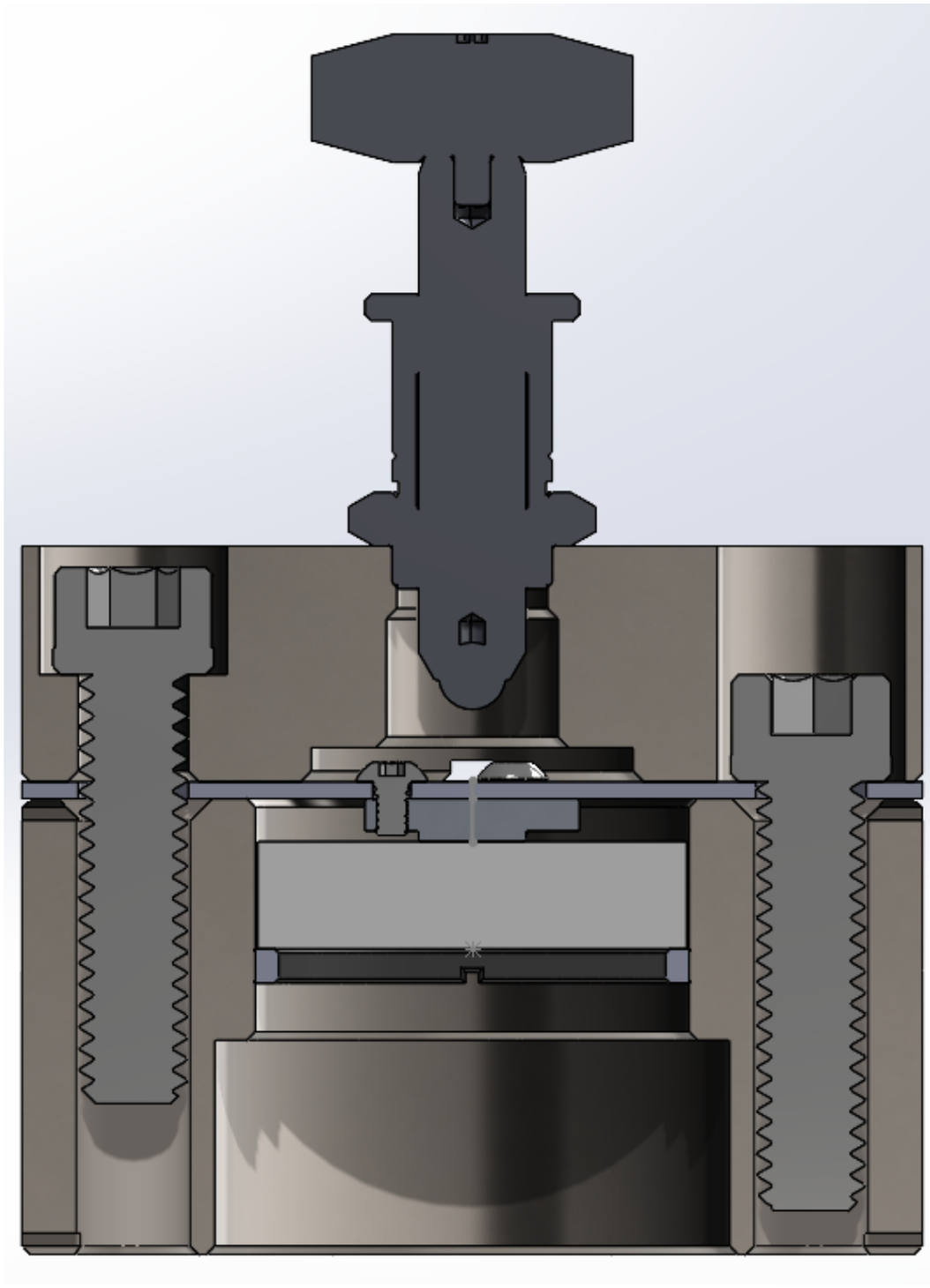
Radius of Curvature Pusher

“The CRUSHER”

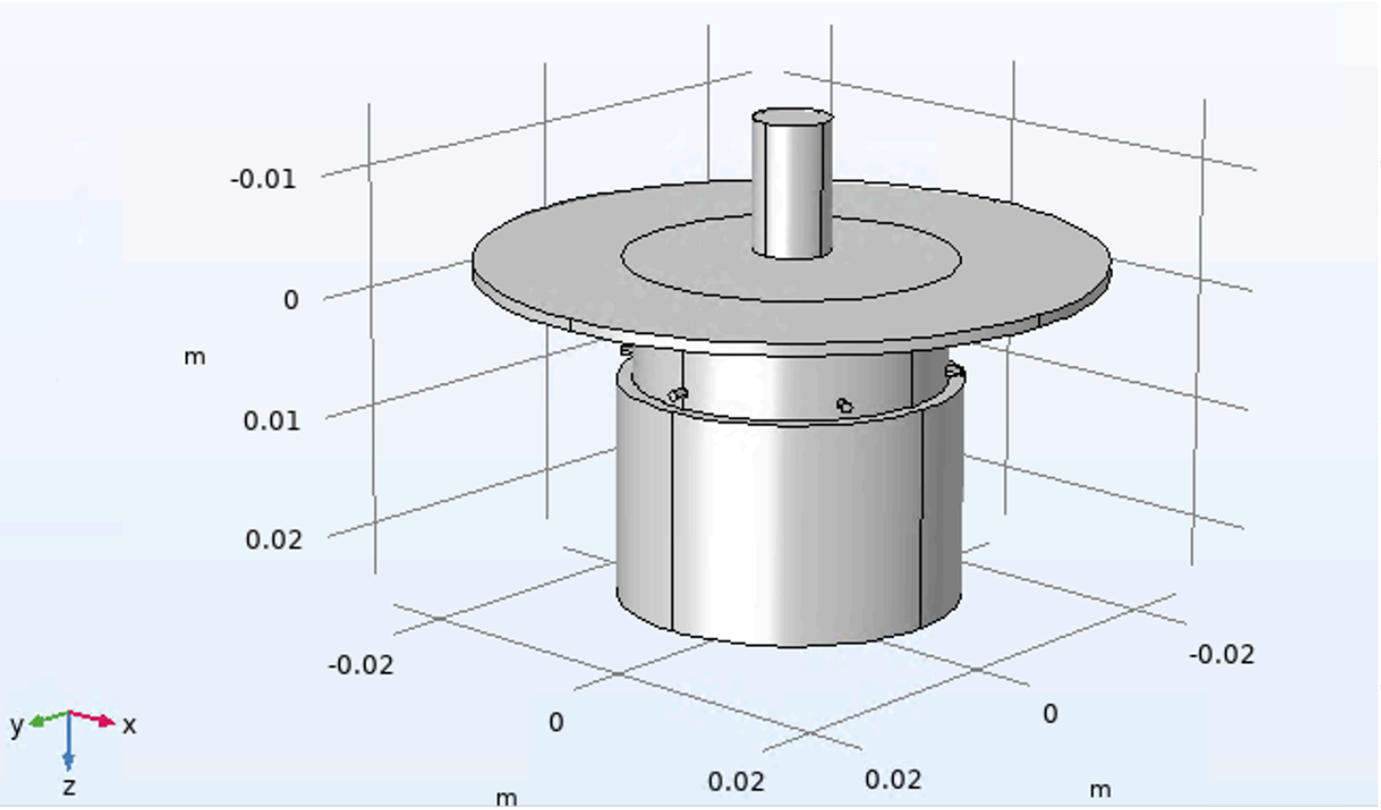
- Don’t want Higher Order Hermite-Gauss Modes of the Carrier to Leak through the Filter Cavities
- Want to Continuously Change the Gouy Phase to Prevent This

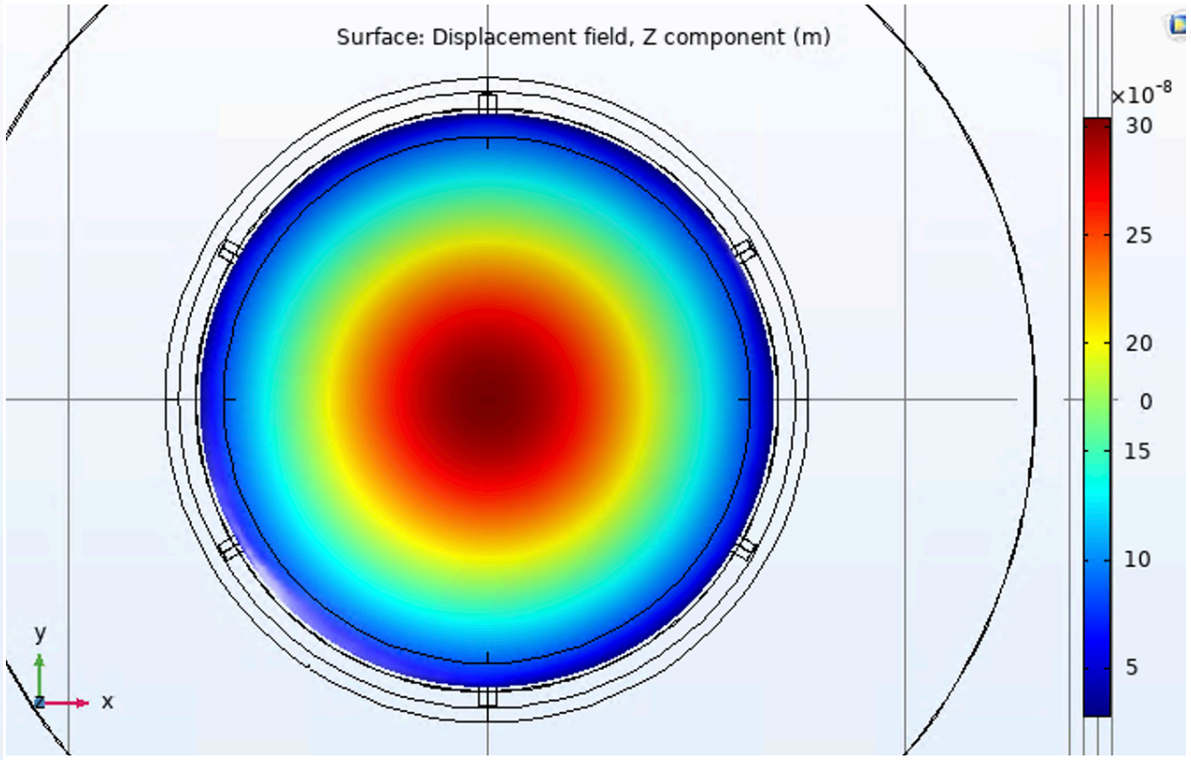
The Design





The Model


-0.01
0
0.01
0.02
m
-0.02
0
0.02
m
-0.02
0
0.02
m
y
x
z


Surface: Displacement field, Z component (m)
×10⁻⁸
30
25
20
0
15
10
5
y
x

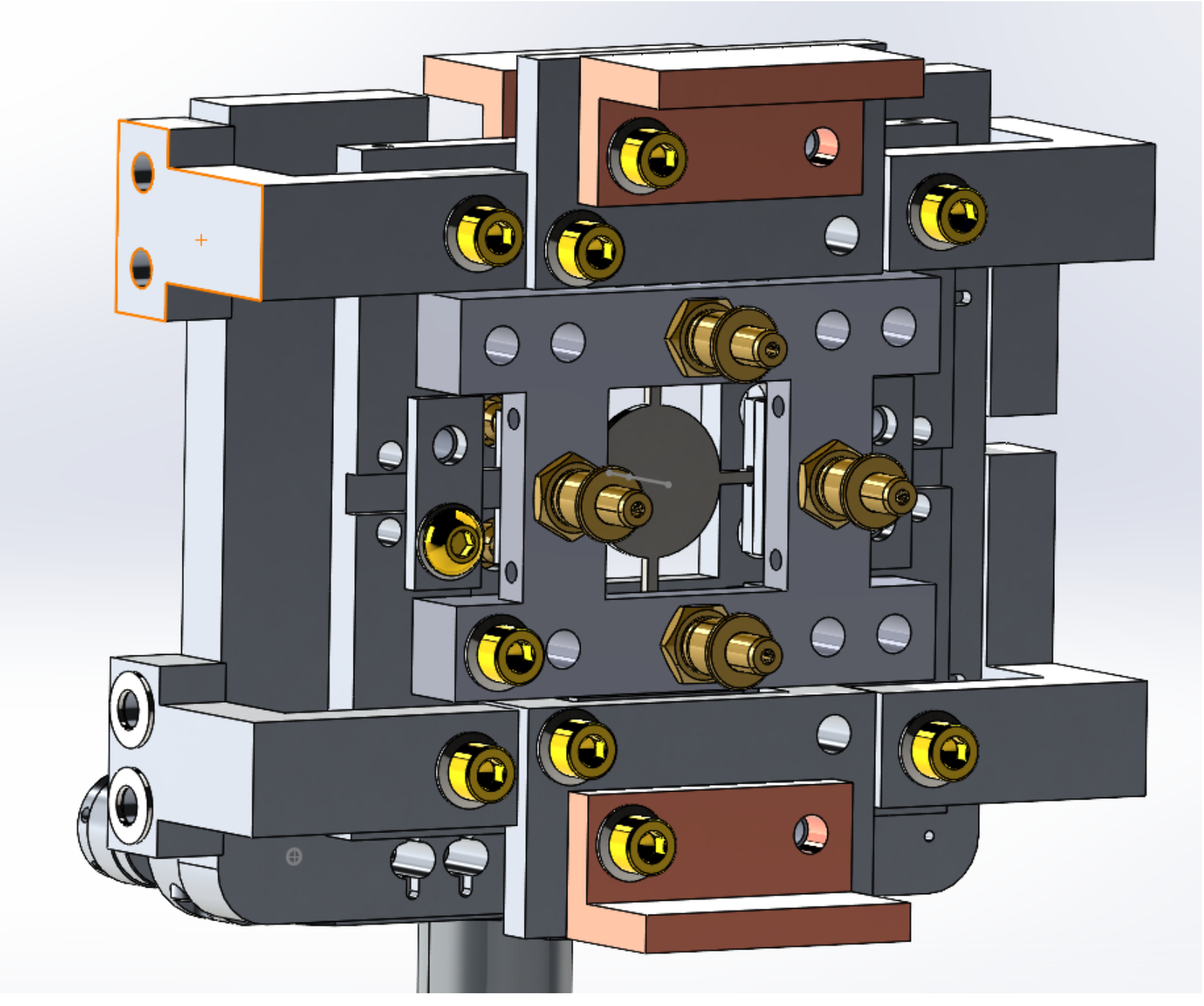
Results

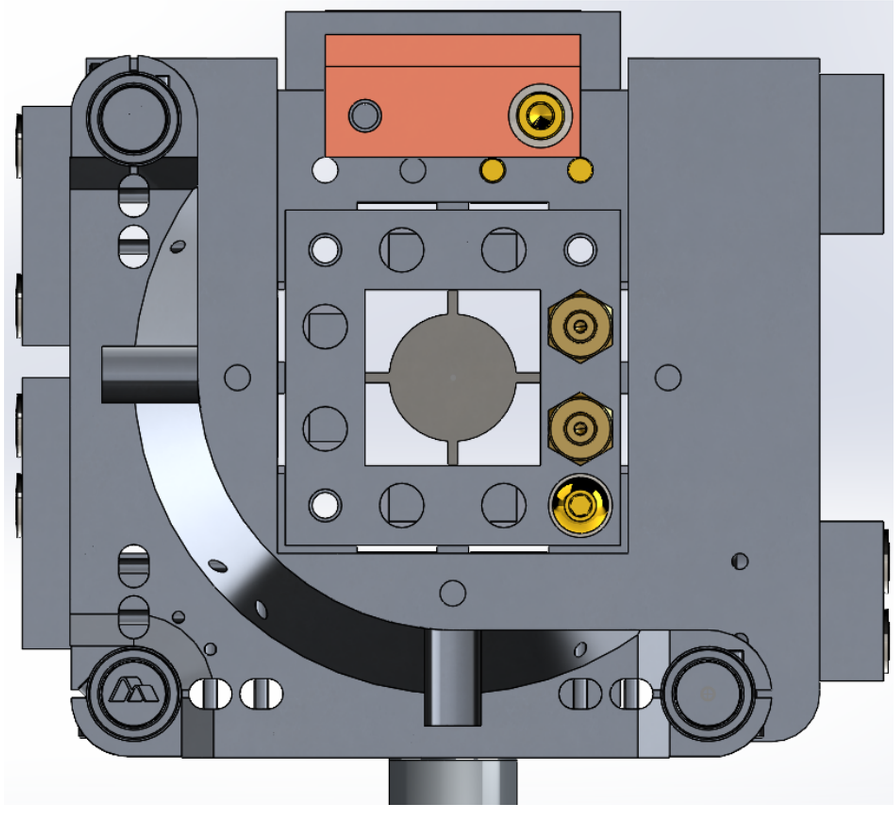
- Export Wavefront Integration as .tex for Python Code
- 55 N of force change the radius of curvature by 10 mDiopters
- Relatively robust against misalignment

Astigmatism Correction

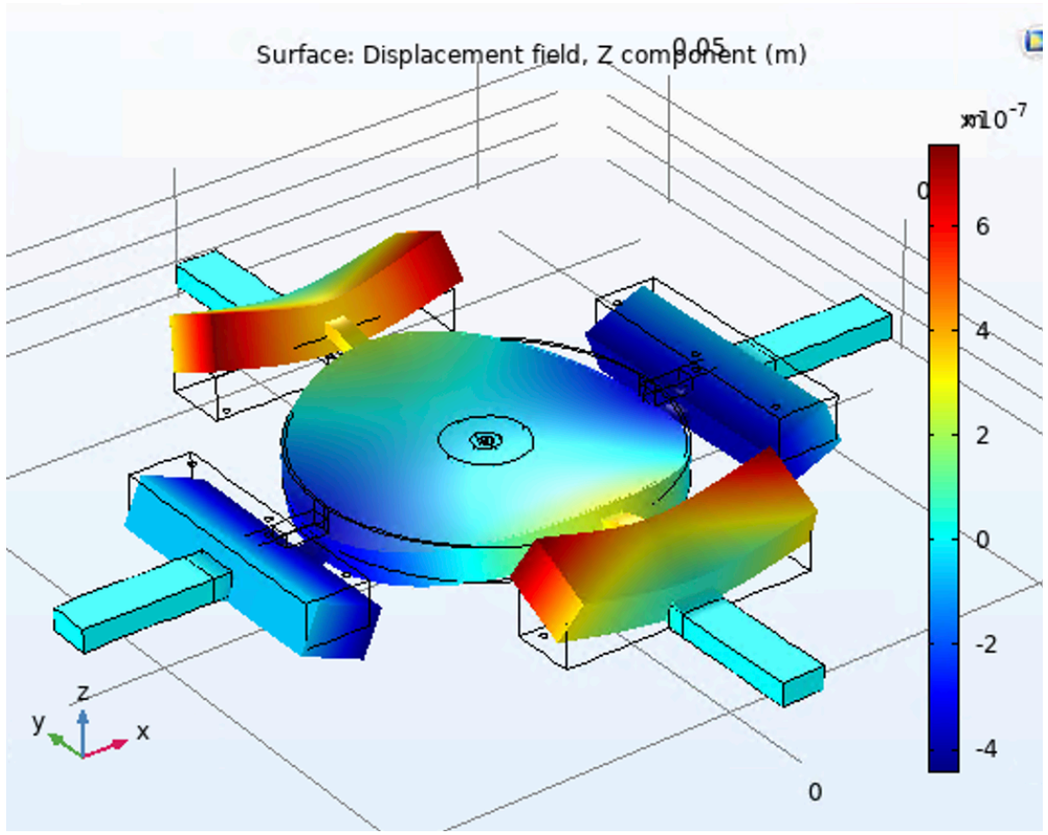
- Need Thin Optic to space out the Acoustic Longitudinal Etalon Bulk Modes
- The Optic is Less Stiff and the Wavefront gets Distorted by the Coating Stress
- Need Flat Mirror to reduce the Contrast Defect of the Interferometer to Photon Count

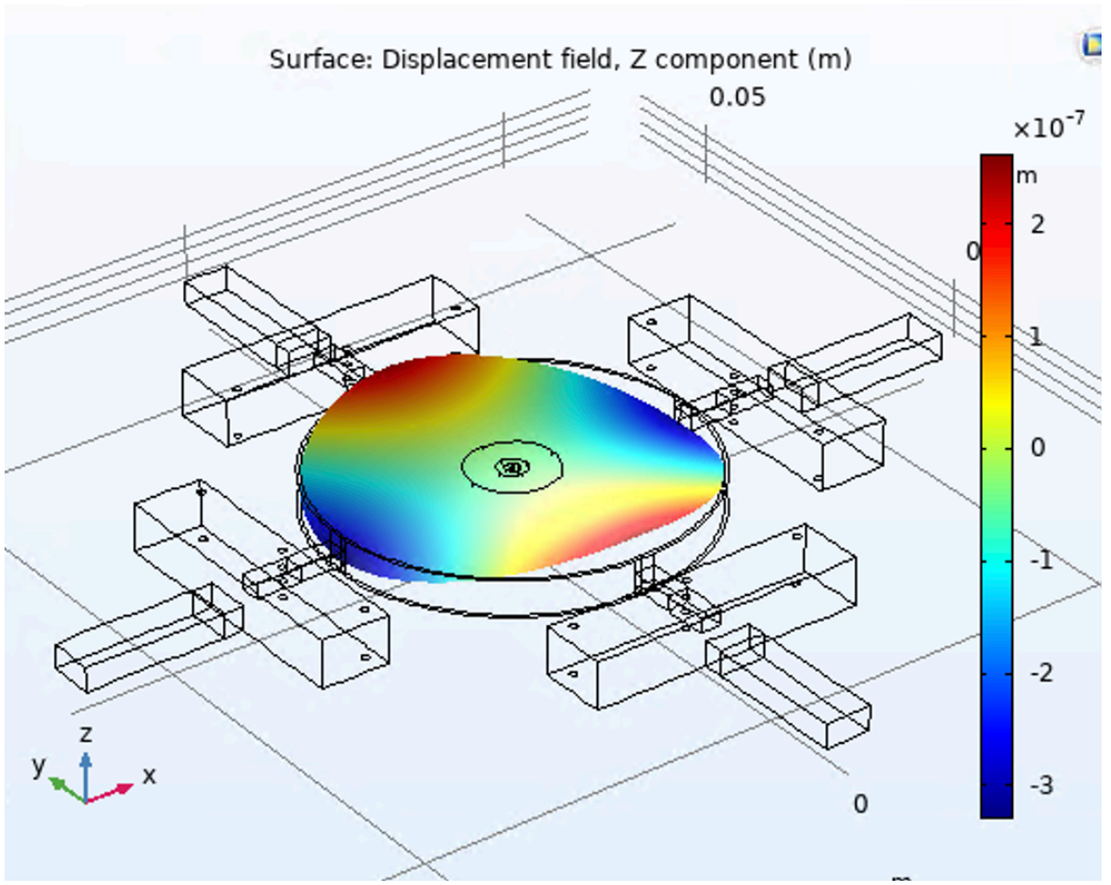
The Design

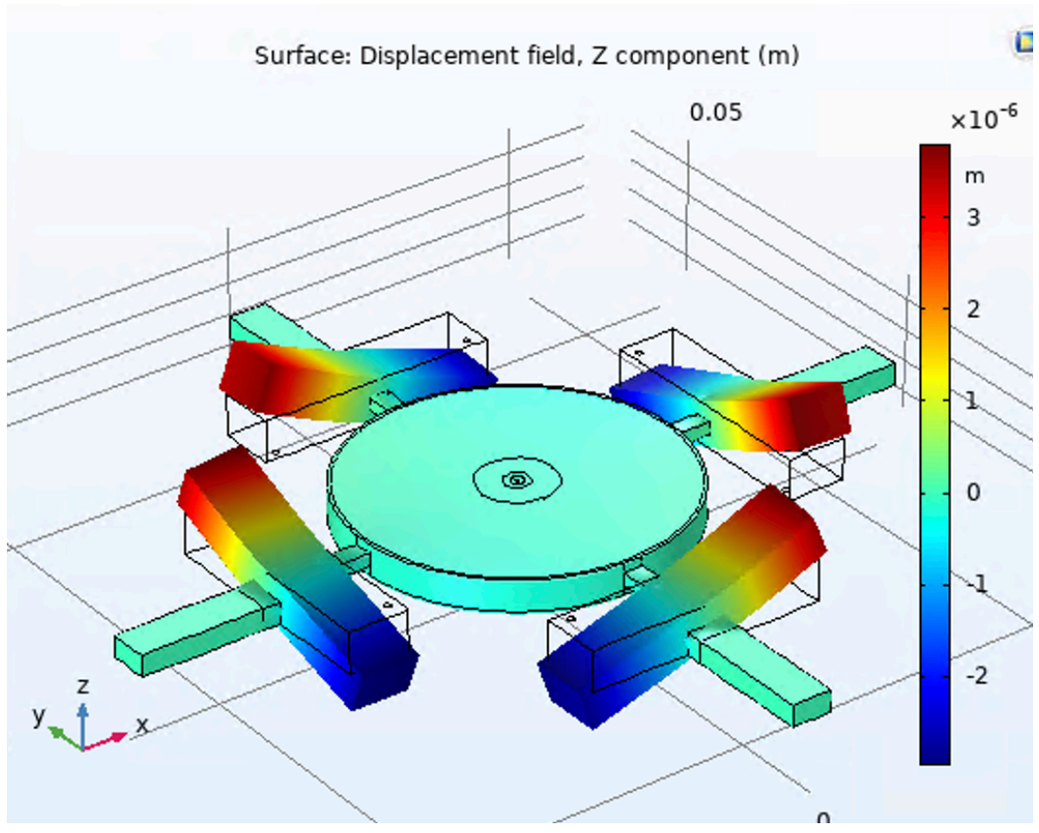


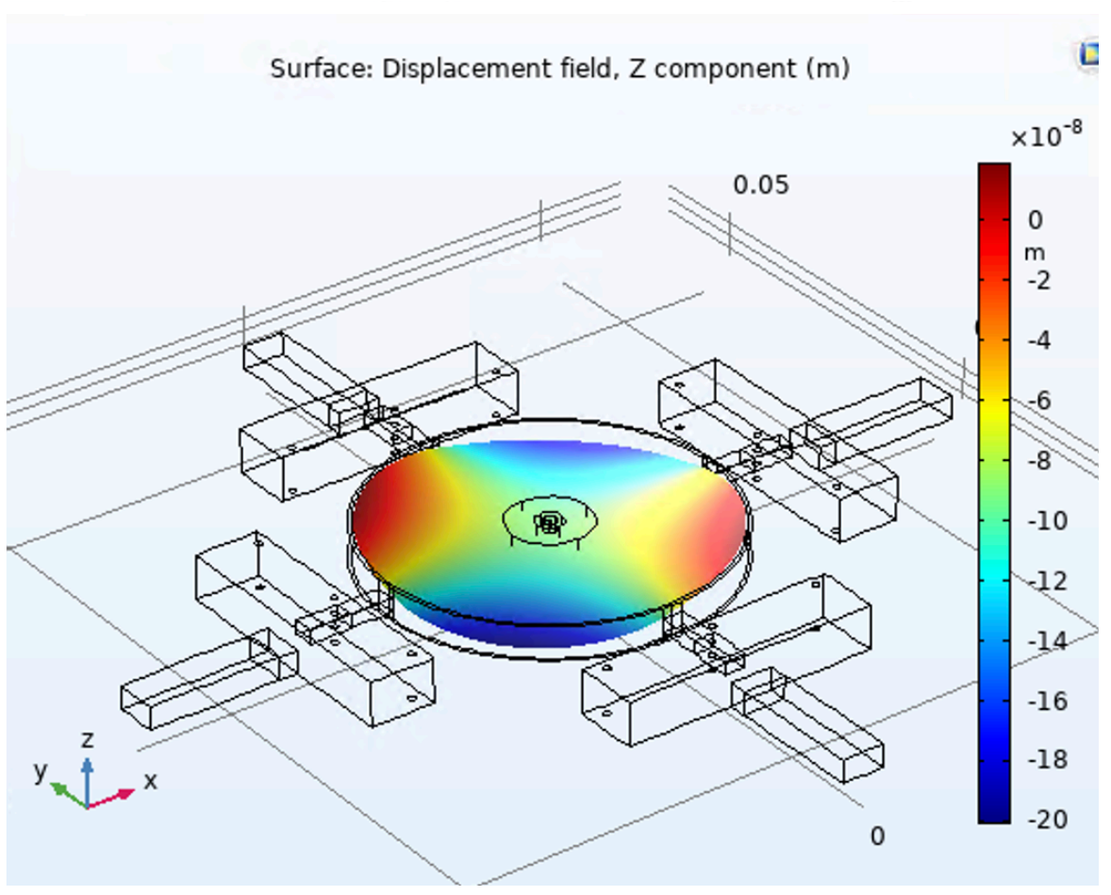


The Model


Surface: Displacement field, Z component (m)
0.05
×10⁻⁷
6
4
2
0
-2
-4
0
z
y
x


Surface: Displacement field, Z component (m)
0.05
×10⁻⁷
m
2
1
0
-1
-2
-3
0
z
y
x


Surface: Displacement field, Z component (m)
0.05
×10⁻⁶
m
3
2
1
0
-1
-2
0
z
y
x


Surface: Displacement field, Z component (m)
0.05
×10⁻⁸
0
m
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
z
y
x

Results

- Export Wavefront Integration as .tex for Python Code
- 3 Modes we care about and can Easily Address: 02 + 20, 02 -02, 11
- We hope to Address all these Modes with under 50 N of force
- Need a Better Understanding of the Coating to model the Correction Needed
- 02 + 20 mode somewhat Weakly Addressed
  - Cause for Some Concern
- Model Looked at Stress at Optical Bond Site
  - Could be Limited by Breaking the Optical Bond