Development of a High-Sensitivity RF Resonant Cavity for TASEH

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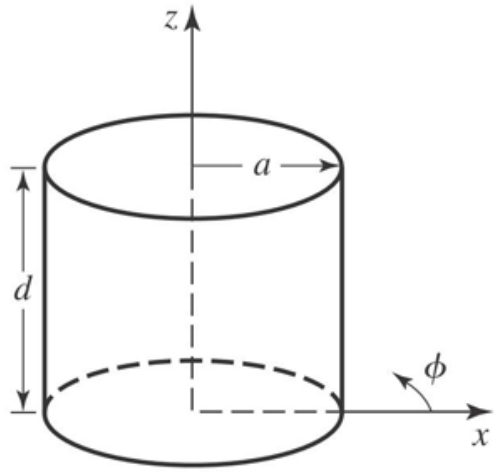
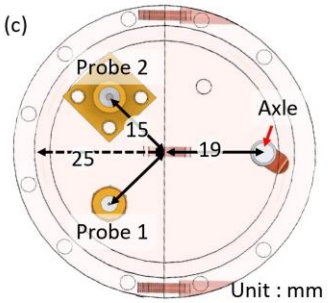
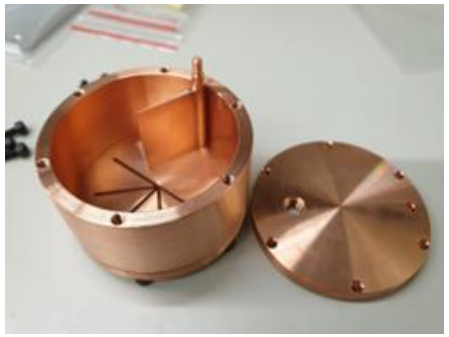
Outline

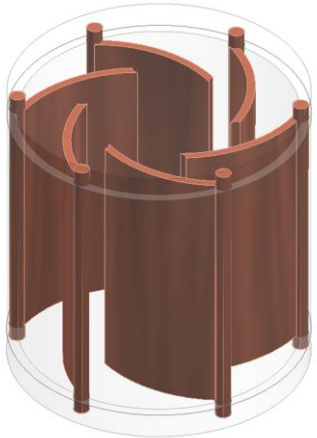
- Resonant Cavity Design Evolution
- Prototype of cone shell cavity
- Design of cone shell cavity
- E-field measurement of the cavity
- Material selection issues for cavity fabrication
- Gearbox Design and Manufacturing

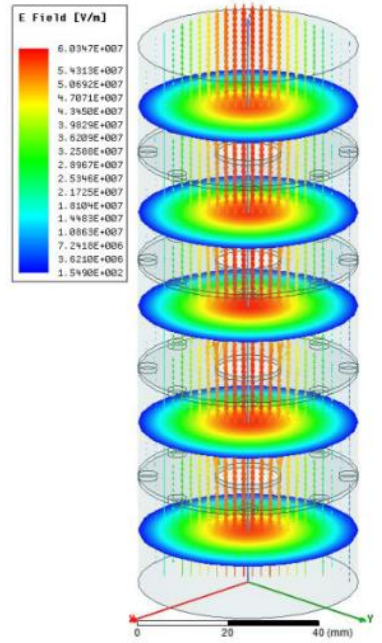
Resonant cavity design evolution





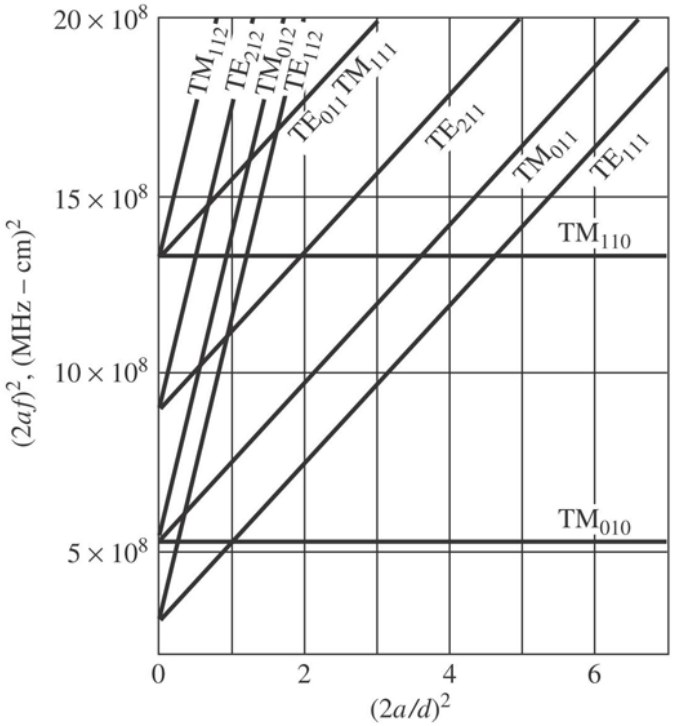




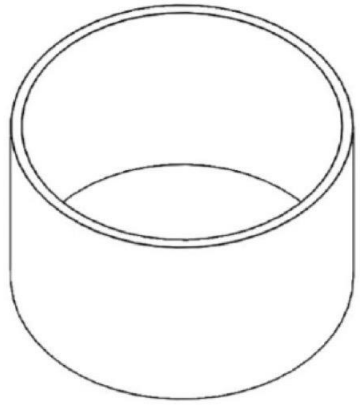


Fundamental mode : TM010

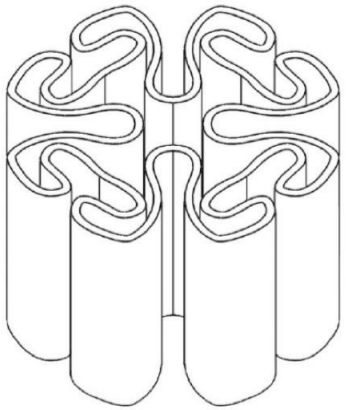
Multi-cell cavity



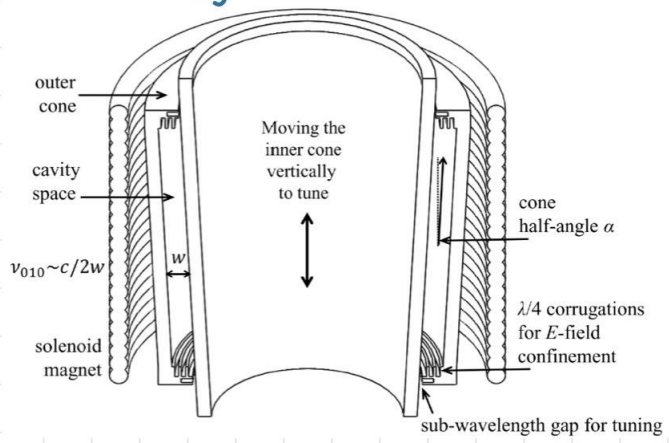
Shell Cavity

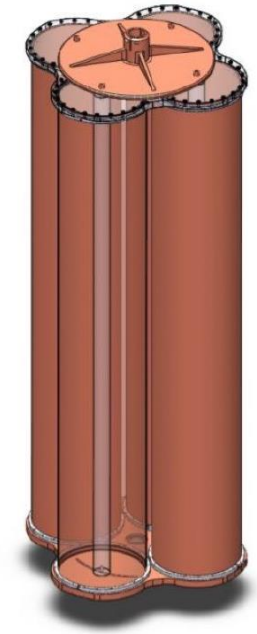


Brain Cavity

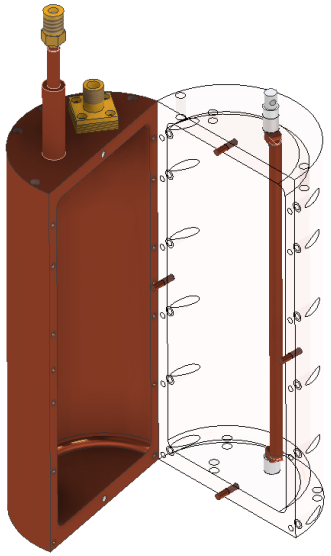


Conic Cavity

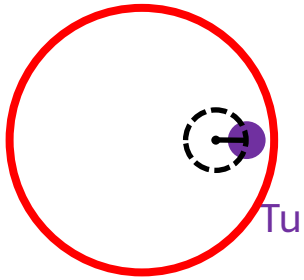




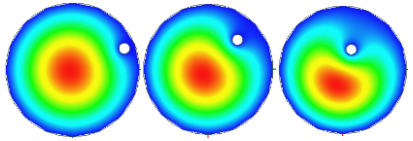
Resonant cavity design evolution



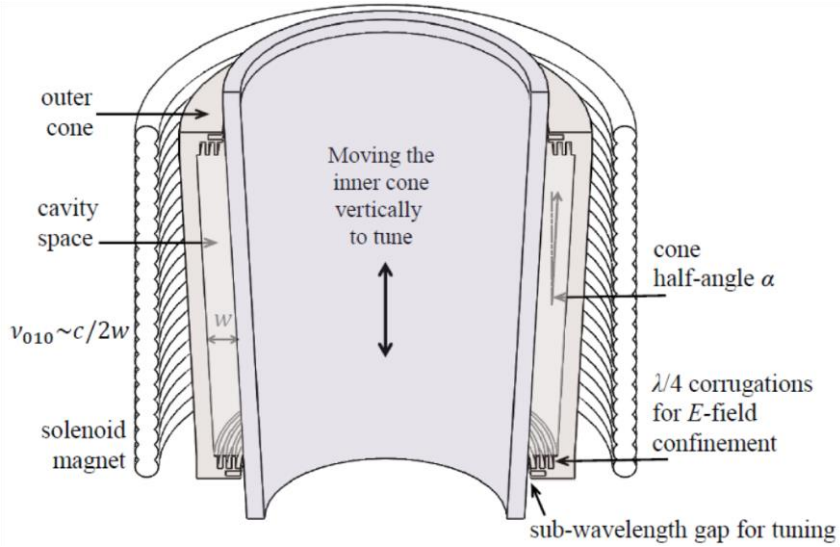
$$f_{nml} = \frac{c}{2\pi\sqrt{\epsilon_r \mu_r}} \sqrt{(\frac{p_{nm}}{r})^2 + (\frac{l\pi}{h})^2}$$



TM_{010} mode pattern

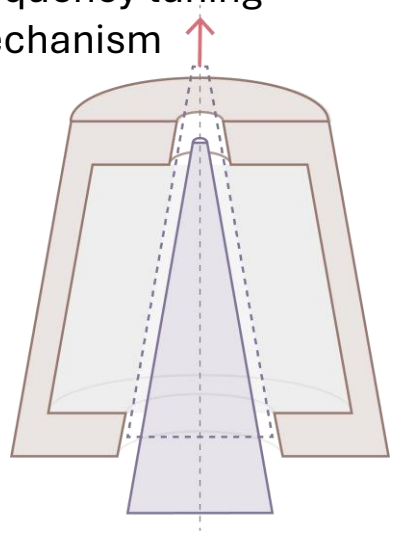


TASEH collaboration, *RSI* **93**, 084501 (2022)

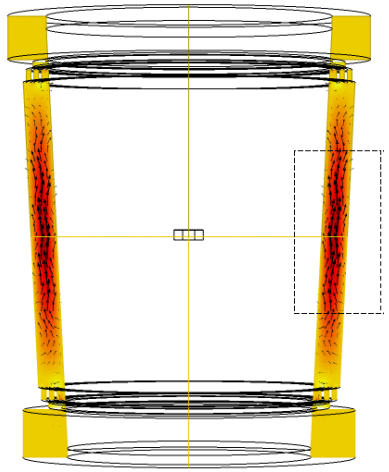


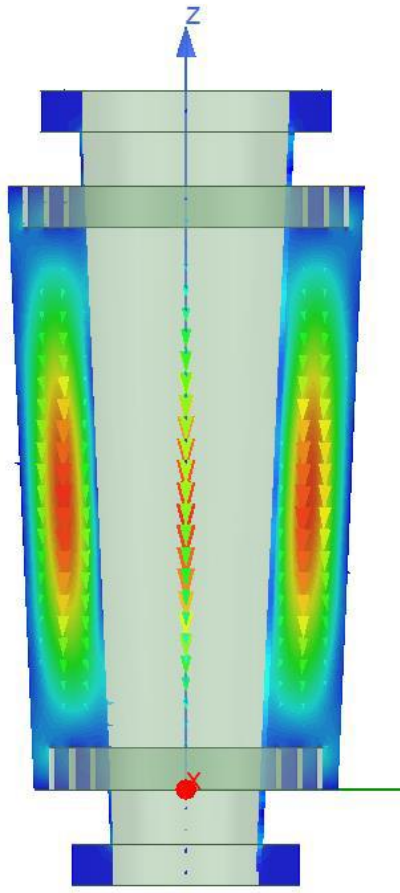
$$f_{lmn} = \frac{c}{2\pi\sqrt{\epsilon_r \mu_r}} \sqrt{(\frac{l\pi}{L})^2 + (\frac{m\pi}{w})^2 + (\frac{n\pi}{h})^2}$$

Frequency tuning mechanism



TM_{010} mode pattern





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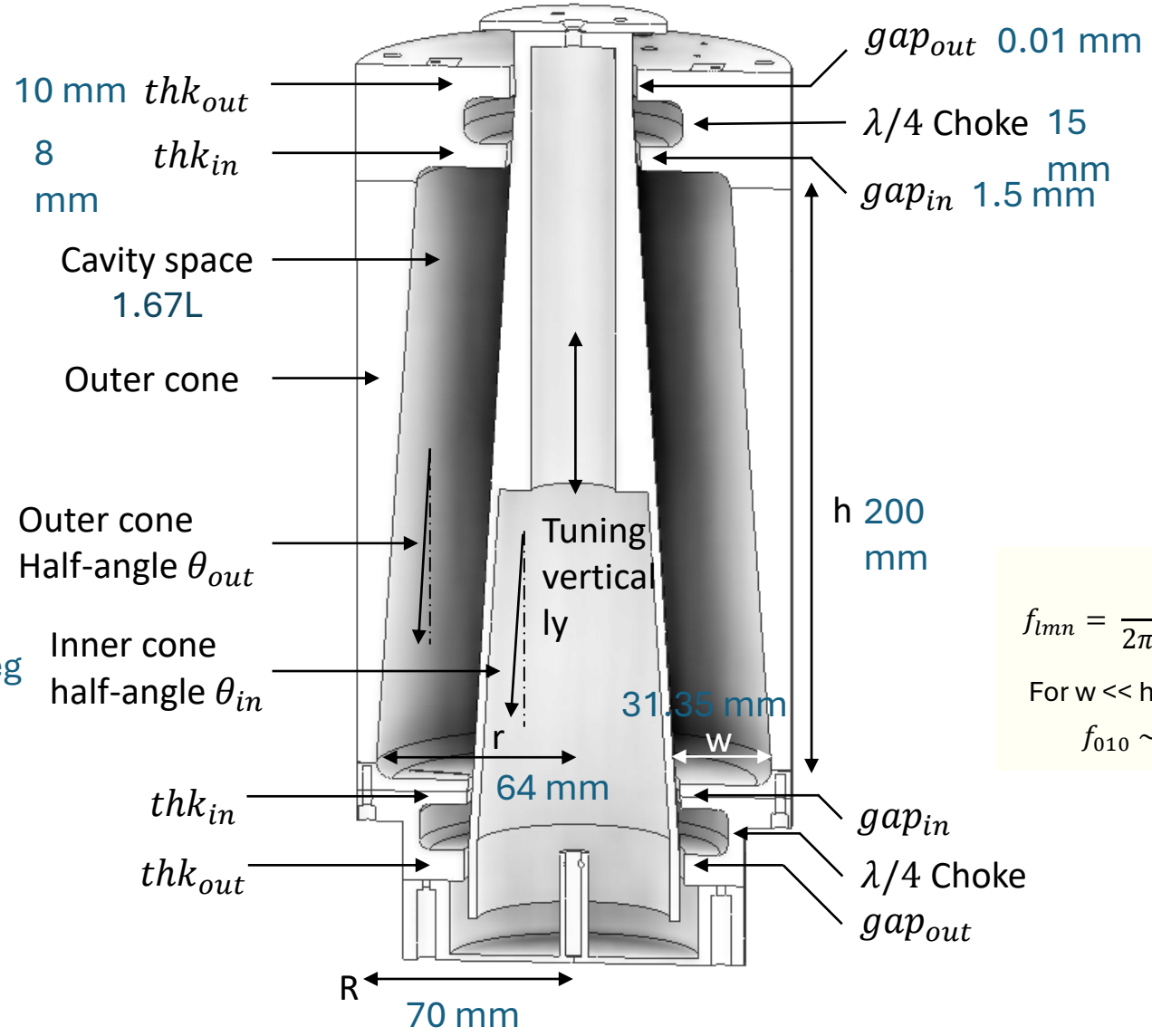
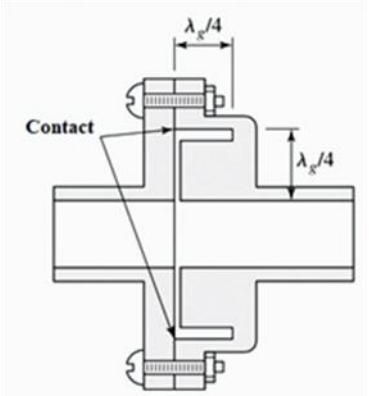
Prototype of cone shell cavity





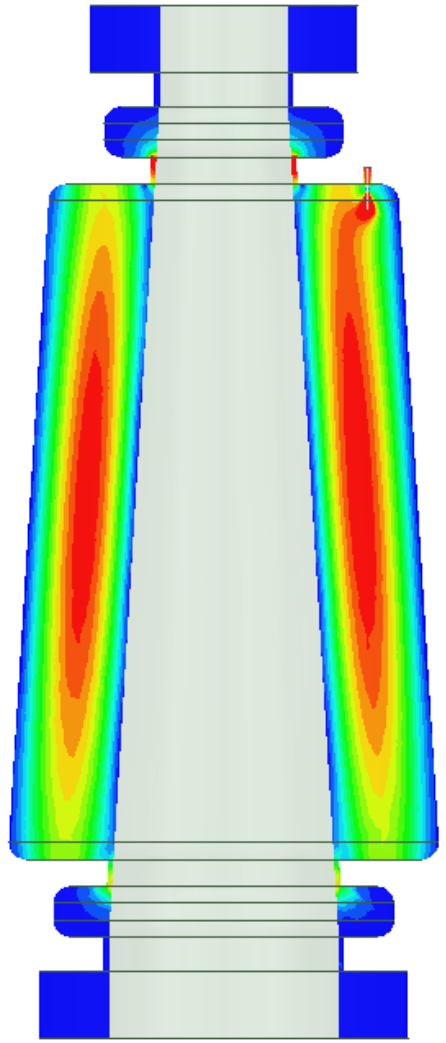
RF choke

$$f_{lmn} = \frac{c}{2\pi\sqrt{\epsilon_r \mu_r}} \sqrt{(\frac{l\pi}{L})^2 + (\frac{m\pi}{w})^2 + (\frac{n\pi}{h})^2}$$

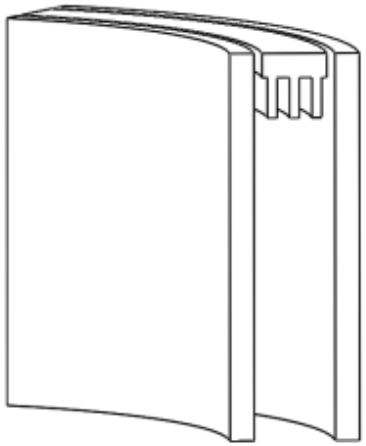
For w << h,

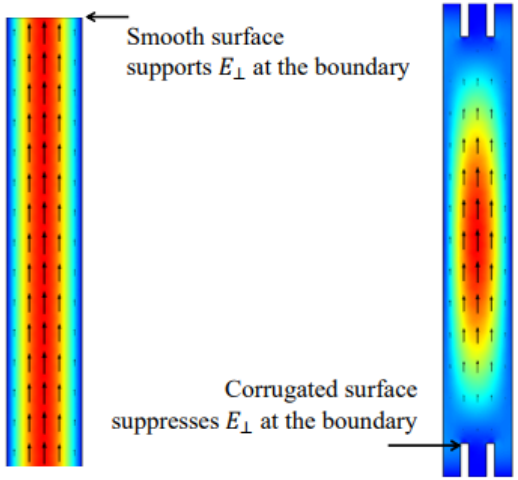
$$f_{010} \sim c/2w$$

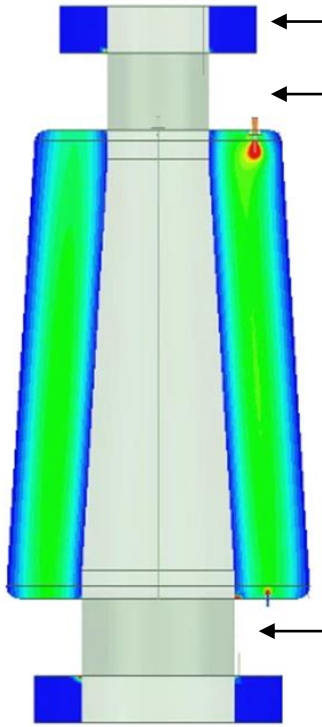
E-field distribution TM_{010}



Design of RF leakage prevention mechanism







Field leak out through the gap

$Q_0 = 508$

$Q_0 = 10602$

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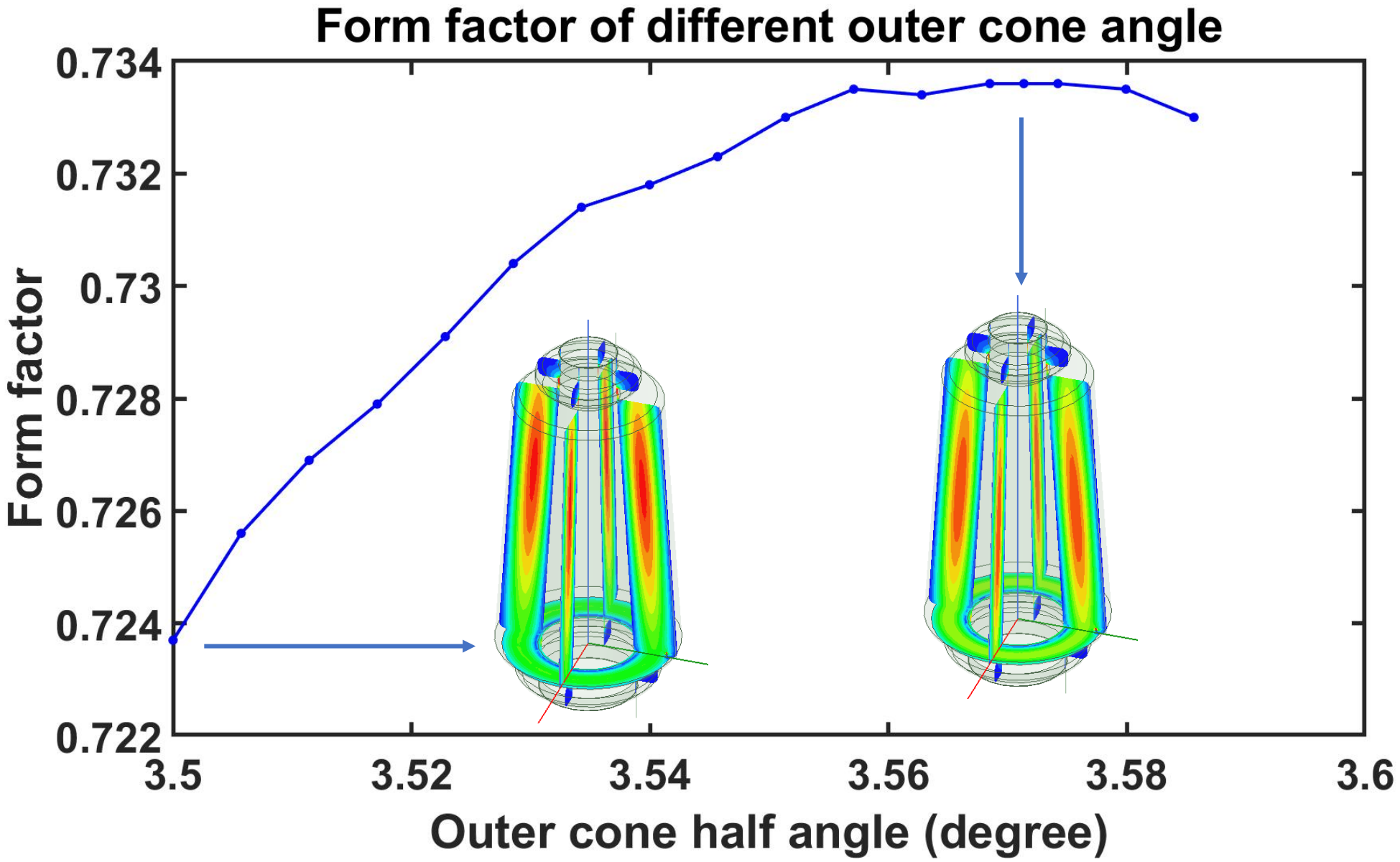
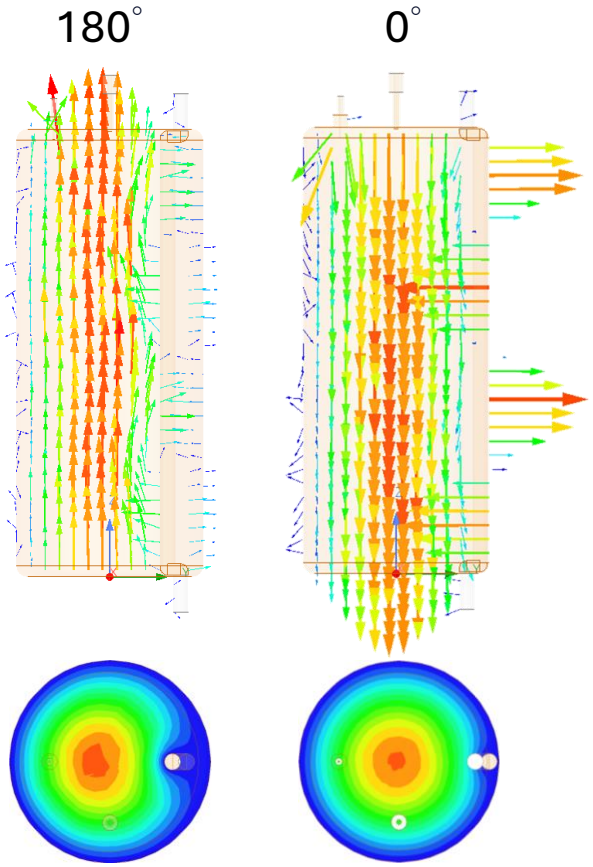
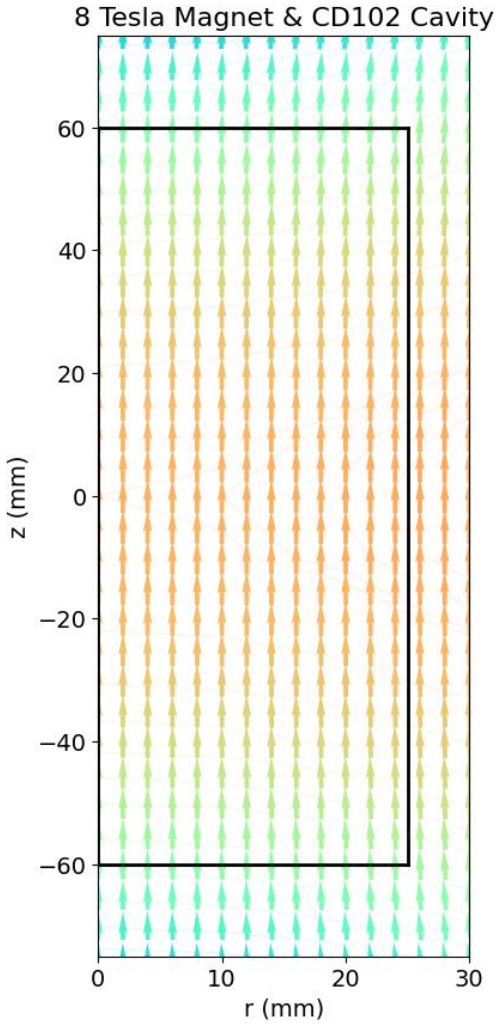
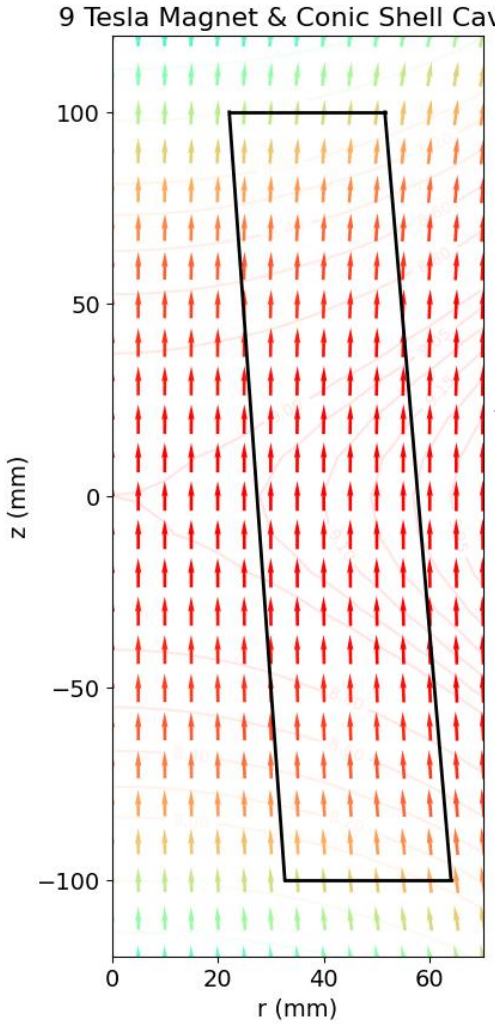
Outer cone angle optimization

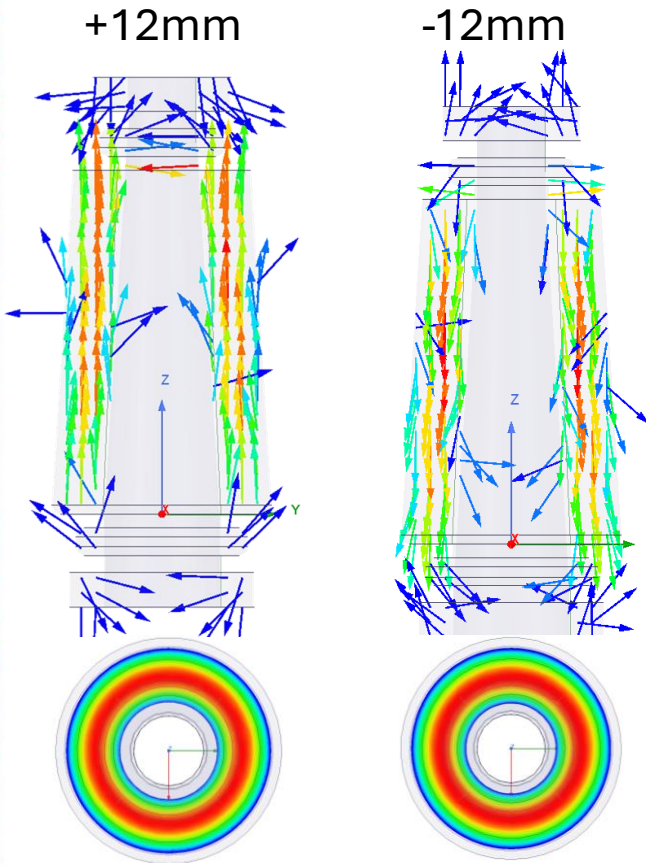


Comparison of 2 Cavities





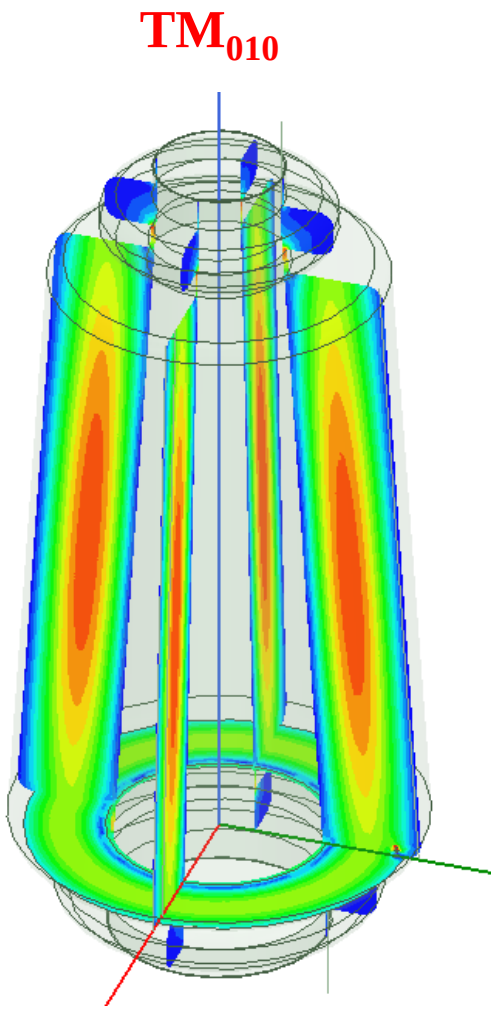


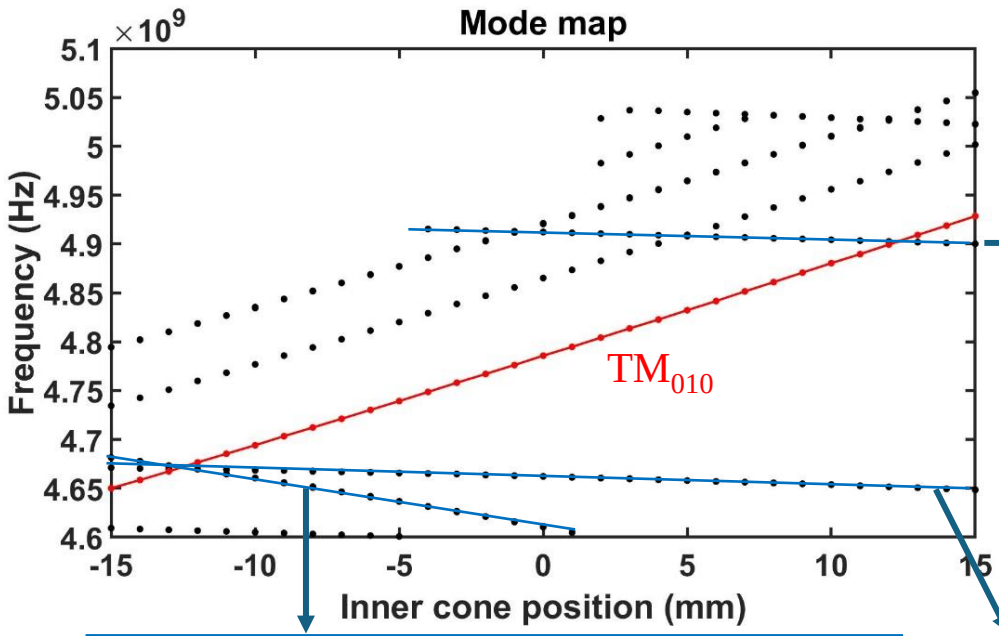


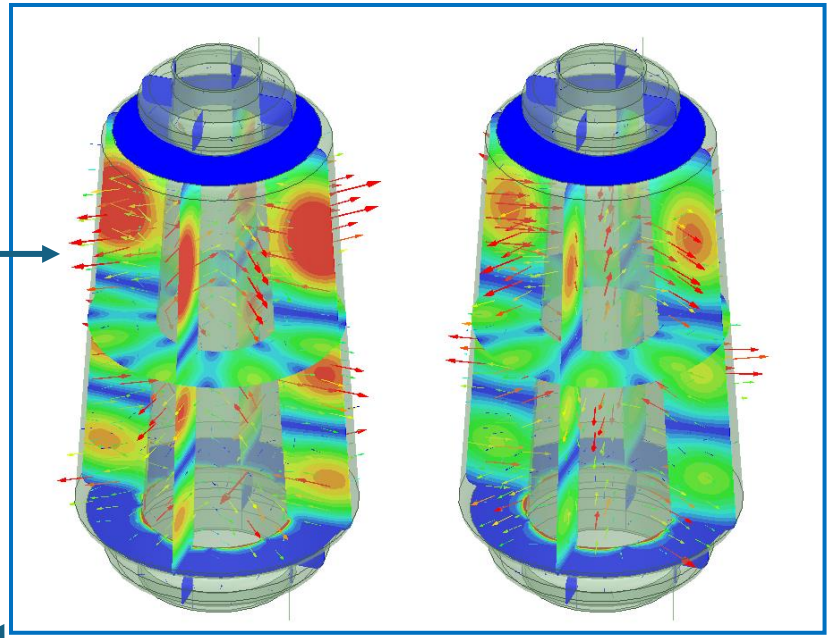
Cavity type	Q	C	V	$\sqrt{VC\sqrt{Q_0}}$
CD102	18000	0.62	0.234L	4.41
Conic-shell	11000	0.73	1.67L	11.3

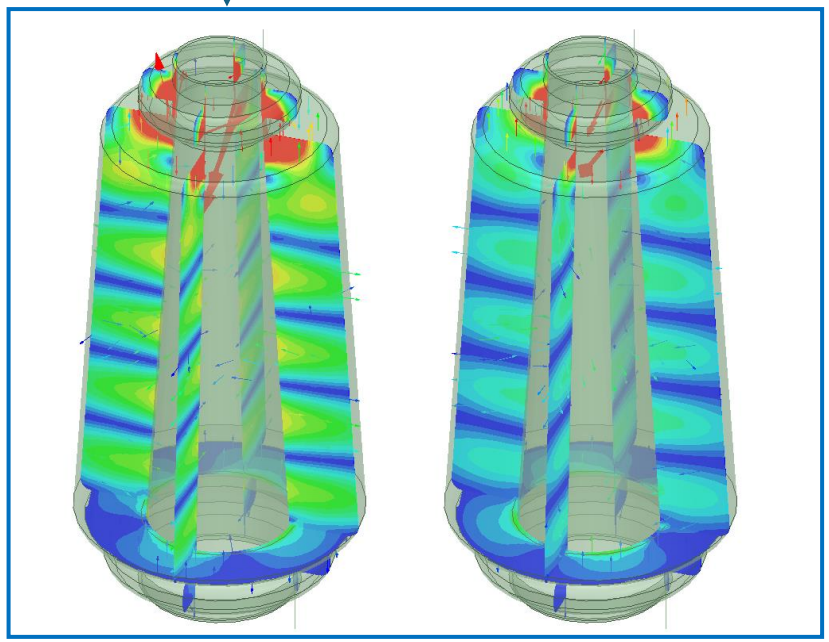
2.56 times improvement

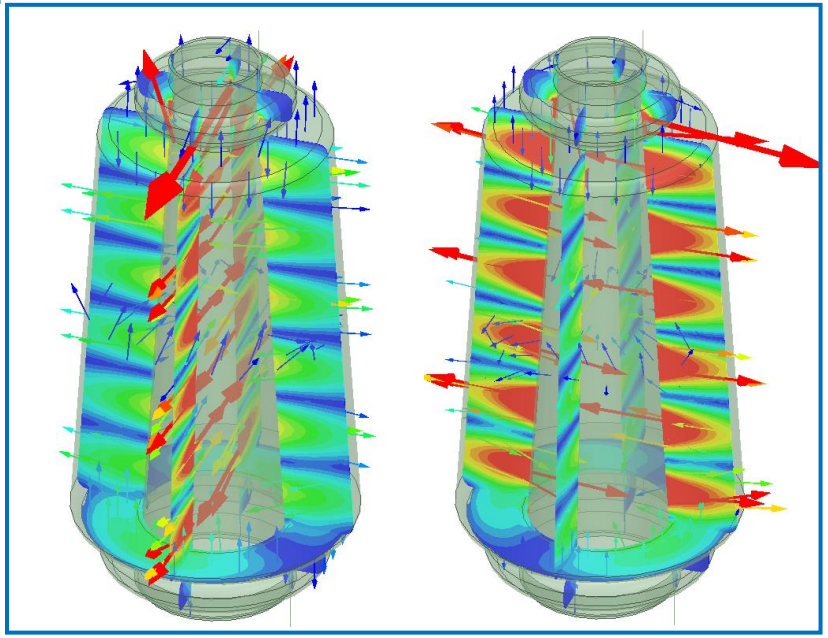
Mode crossing of cone shell cavity



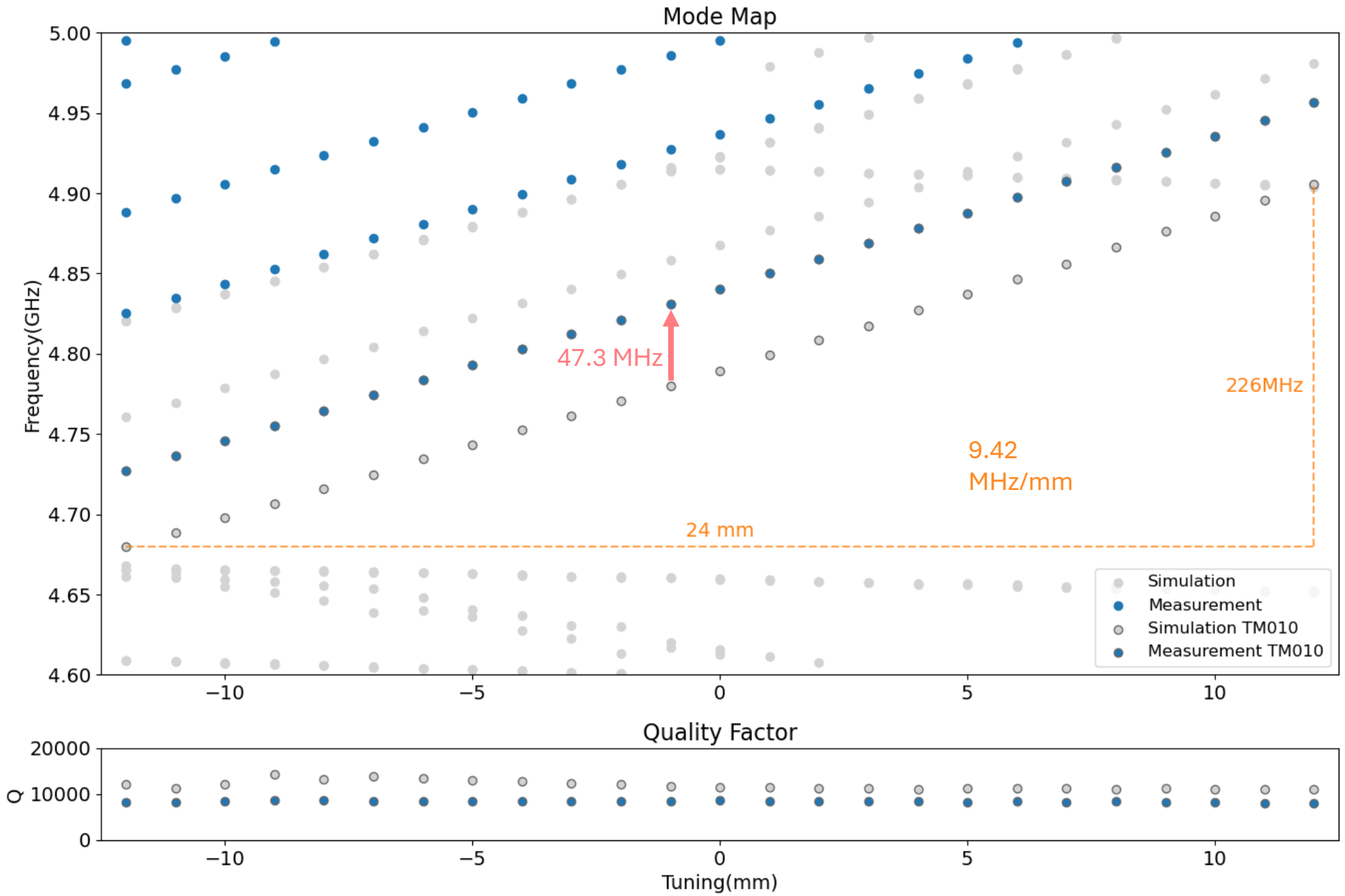




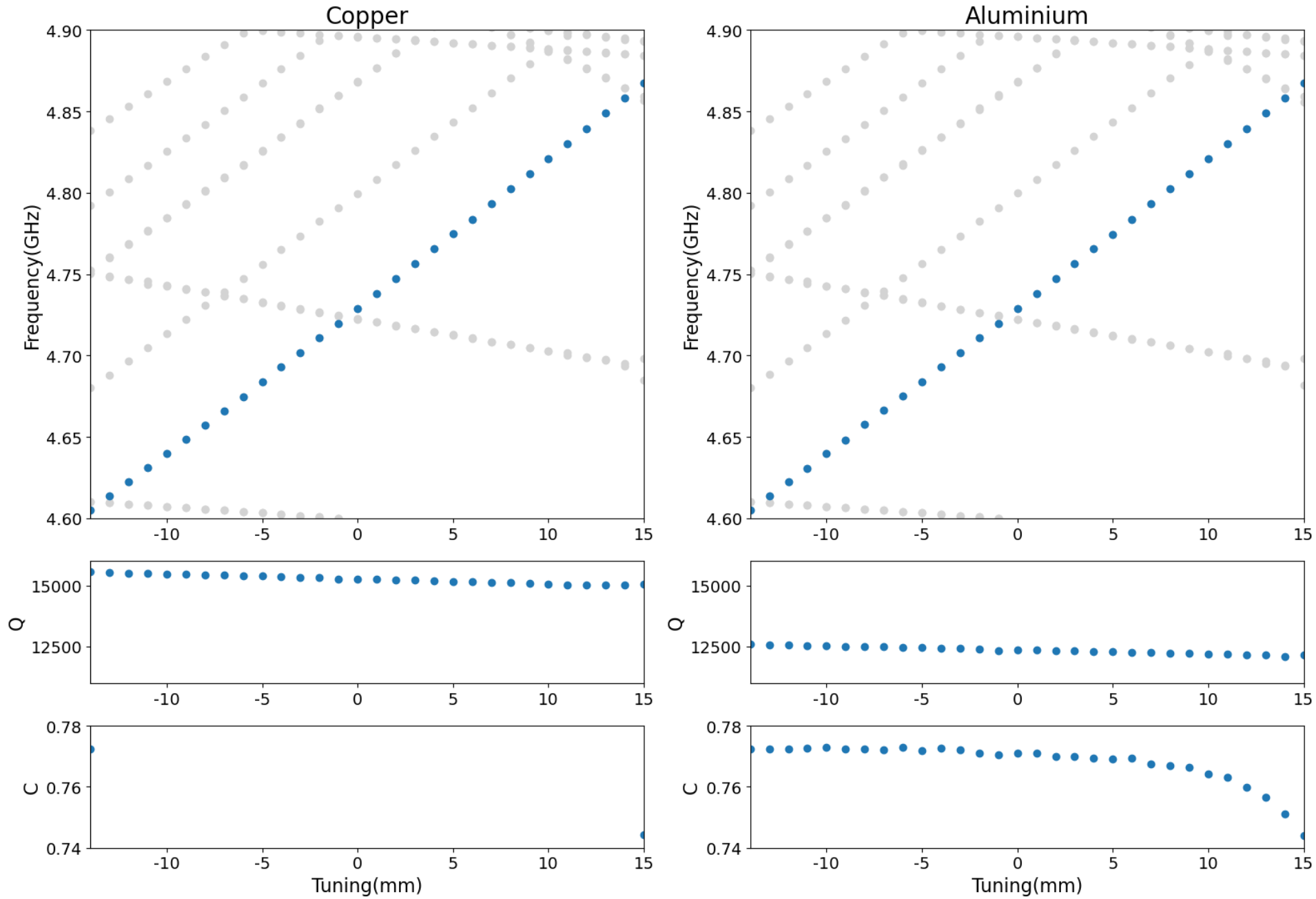




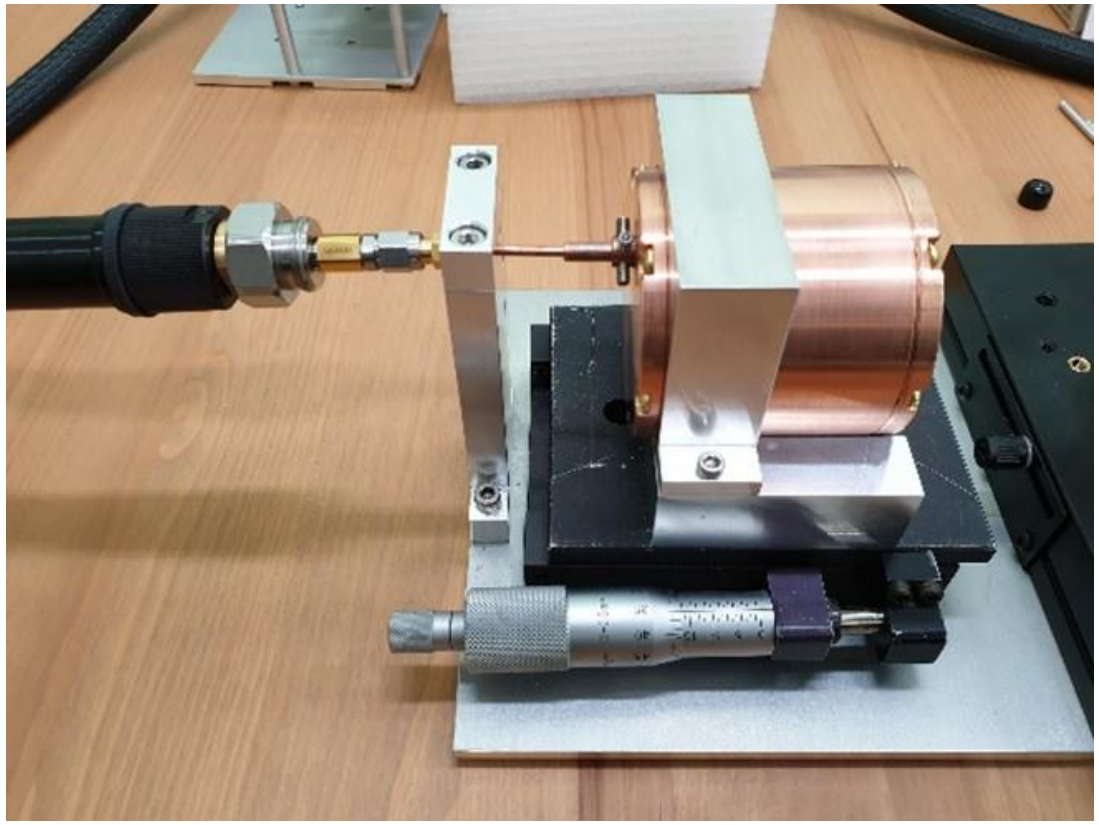
Comparison between simulation and measurement



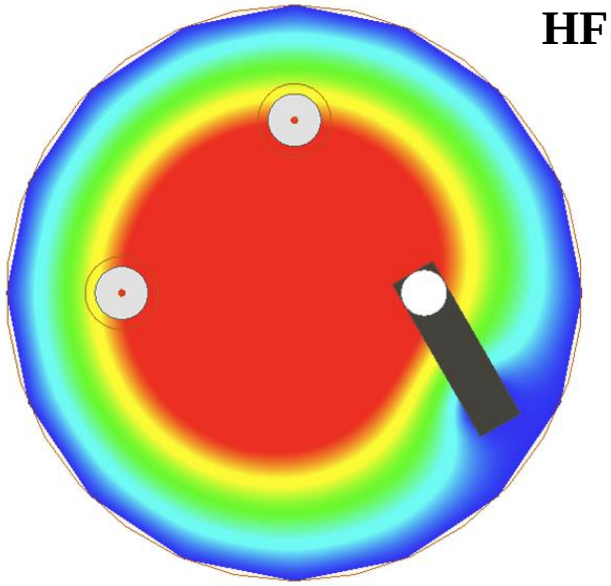
Eigenmode of Cone Shell Cavity



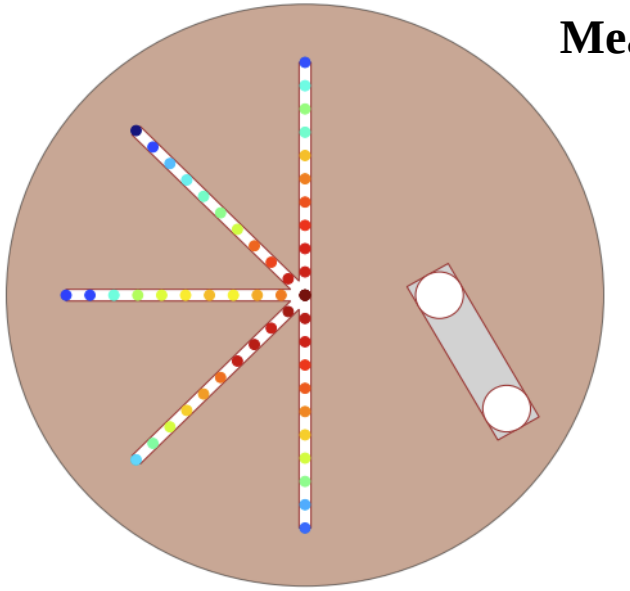
E-field measurement - Coaxial Cable Coupling Measurement



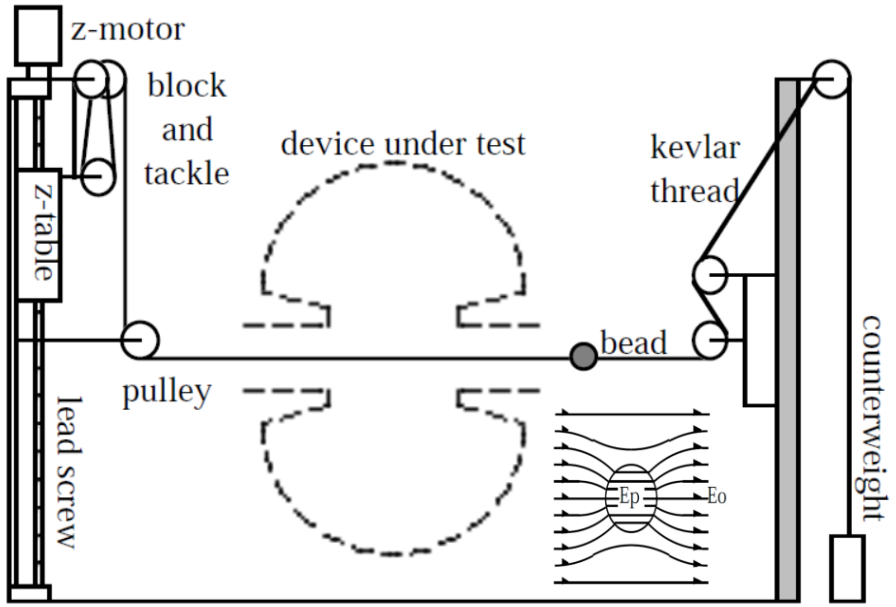
HFSS simulation results

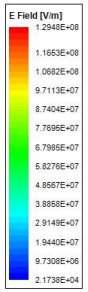


Measurement results



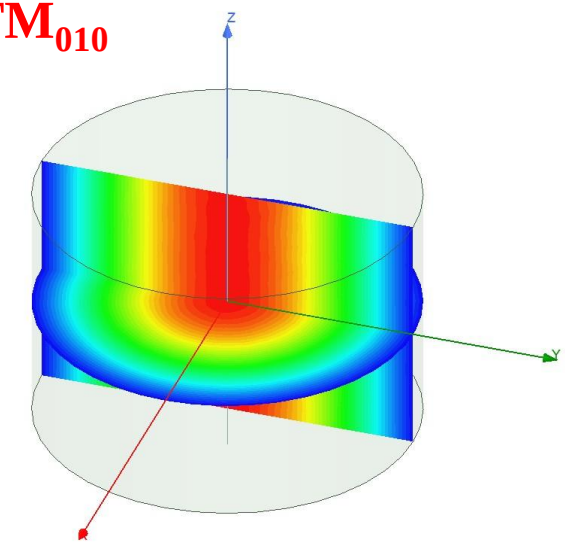
Bead-pull Measurement

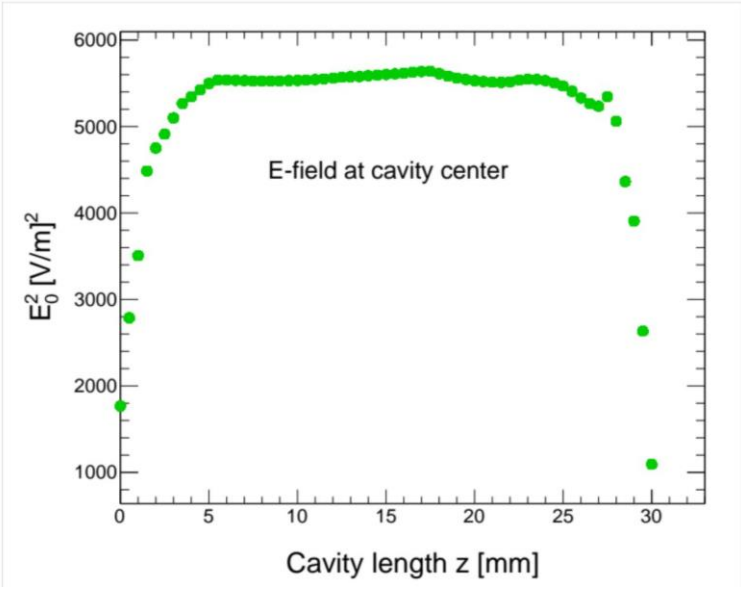


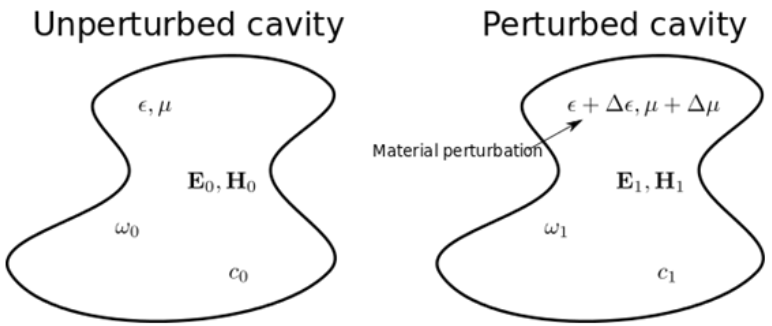


HFSS simulation results

TM_{010}

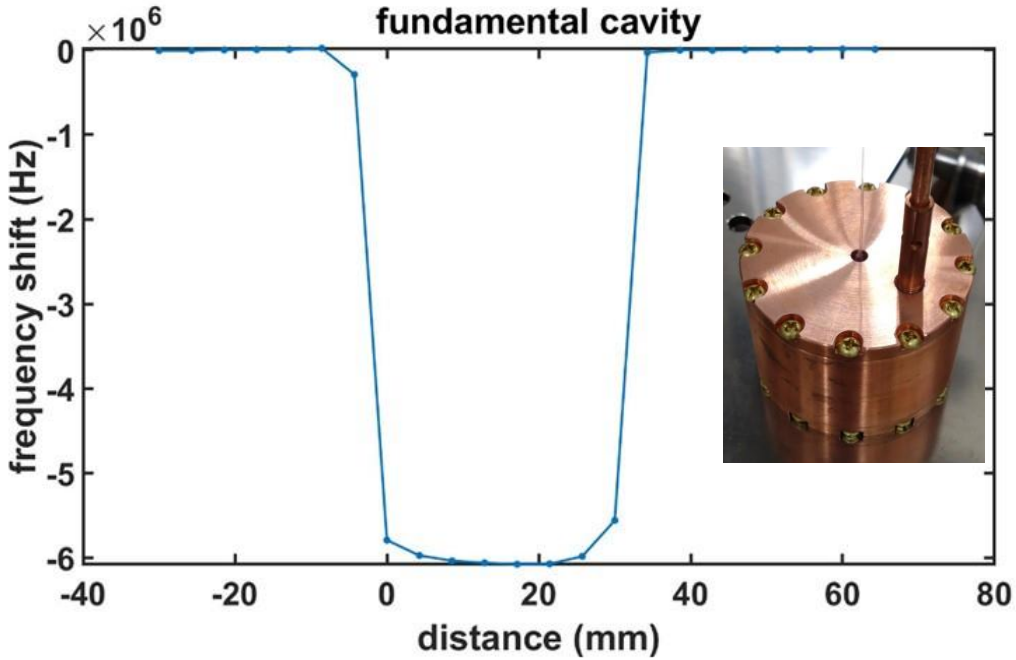






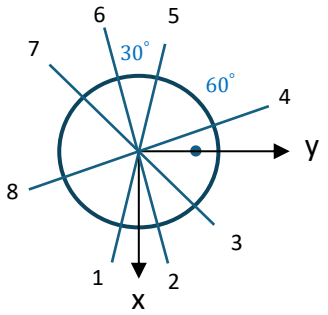
$$\frac{\Delta\omega}{\omega_0} \approx -\frac{\int(\Delta\epsilon|E_0|^2)\,d\Delta V}{\int(\epsilon|E_0|^2+\mu|H_0|^2)\,dV} \propto |E_0|^2$$

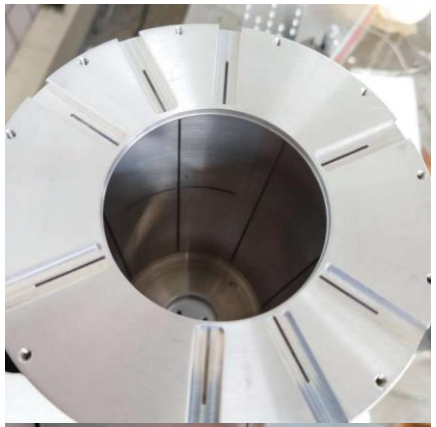
Measurement results

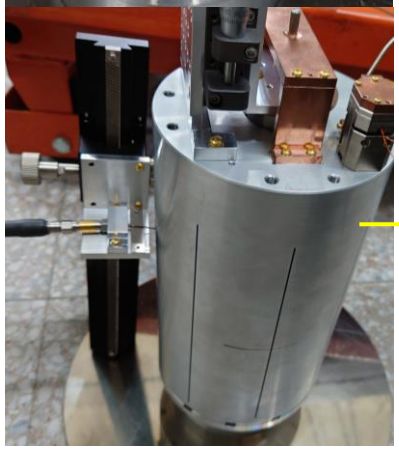


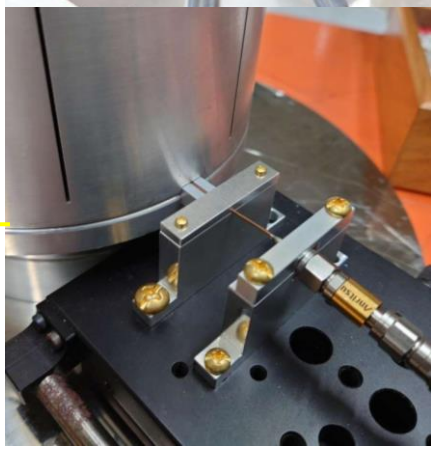
E-field Measurement

Probe Measurement

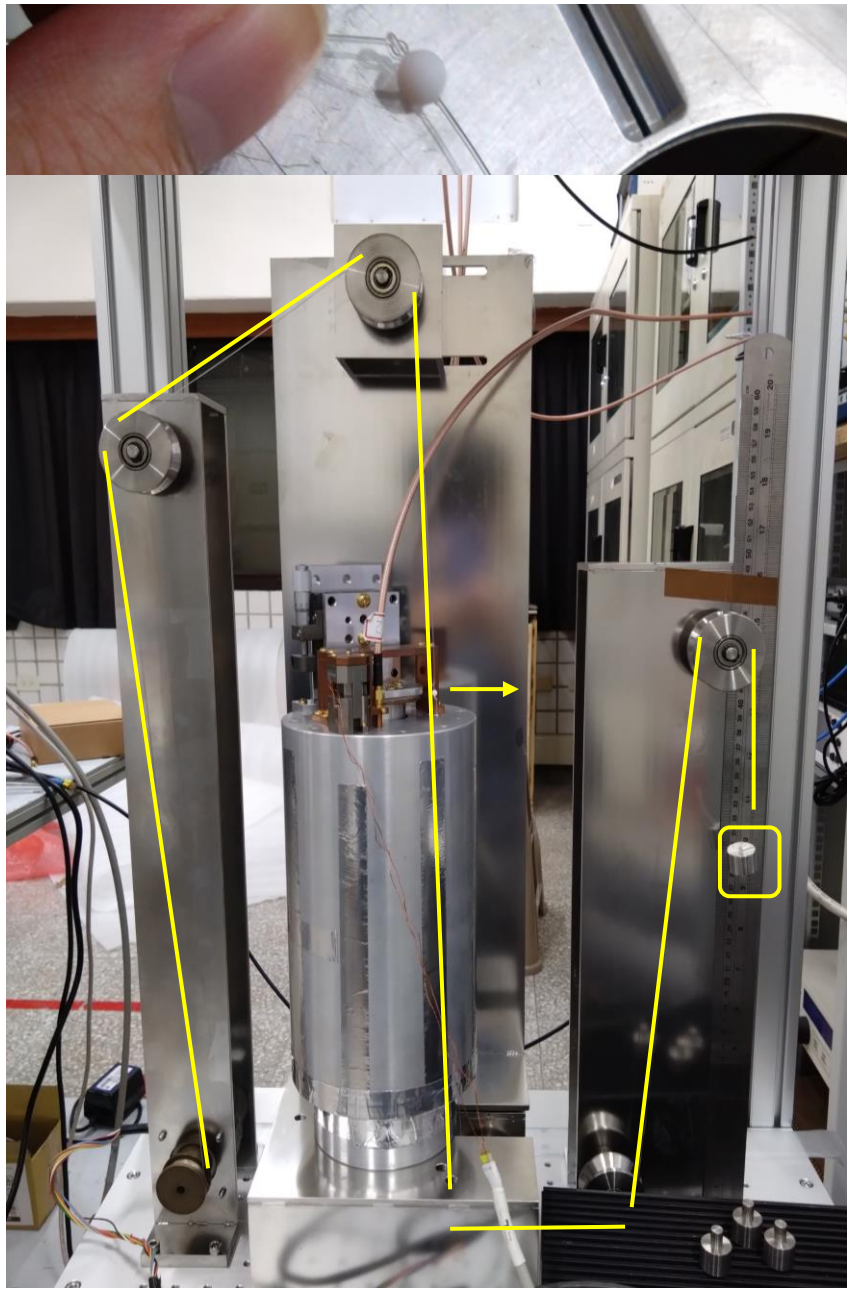




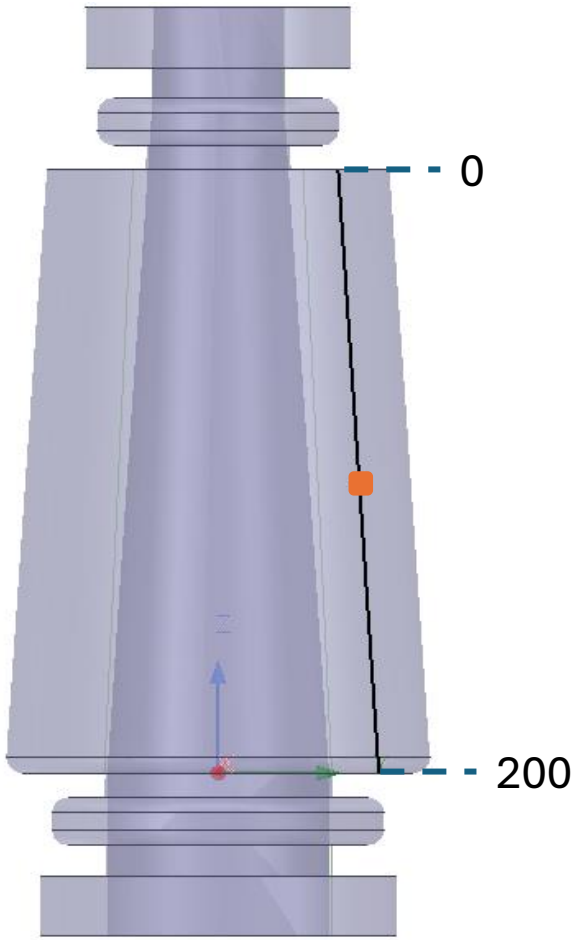


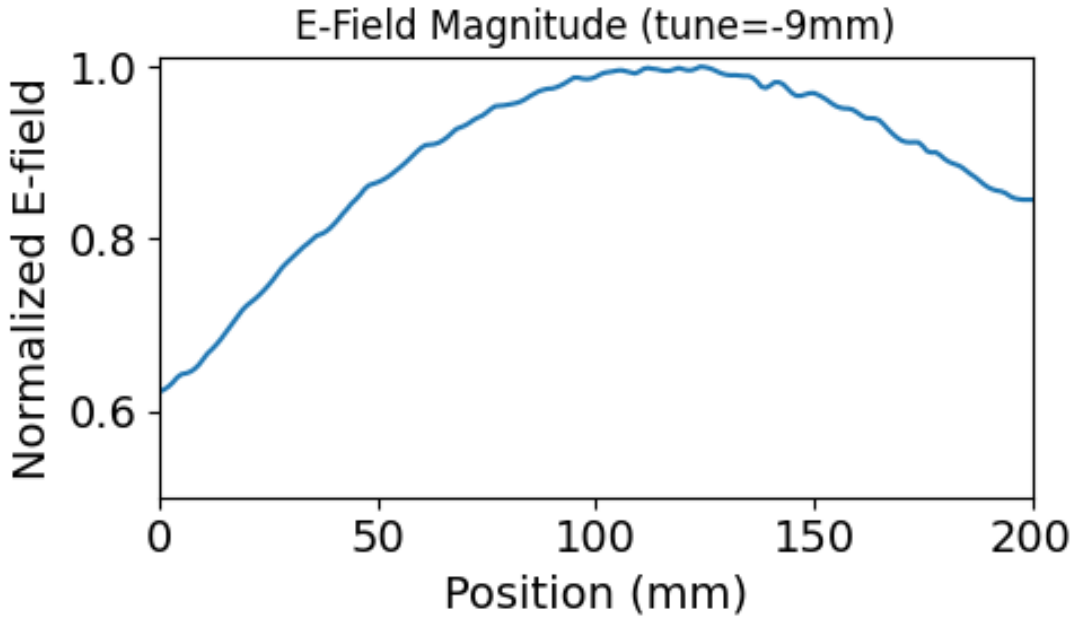


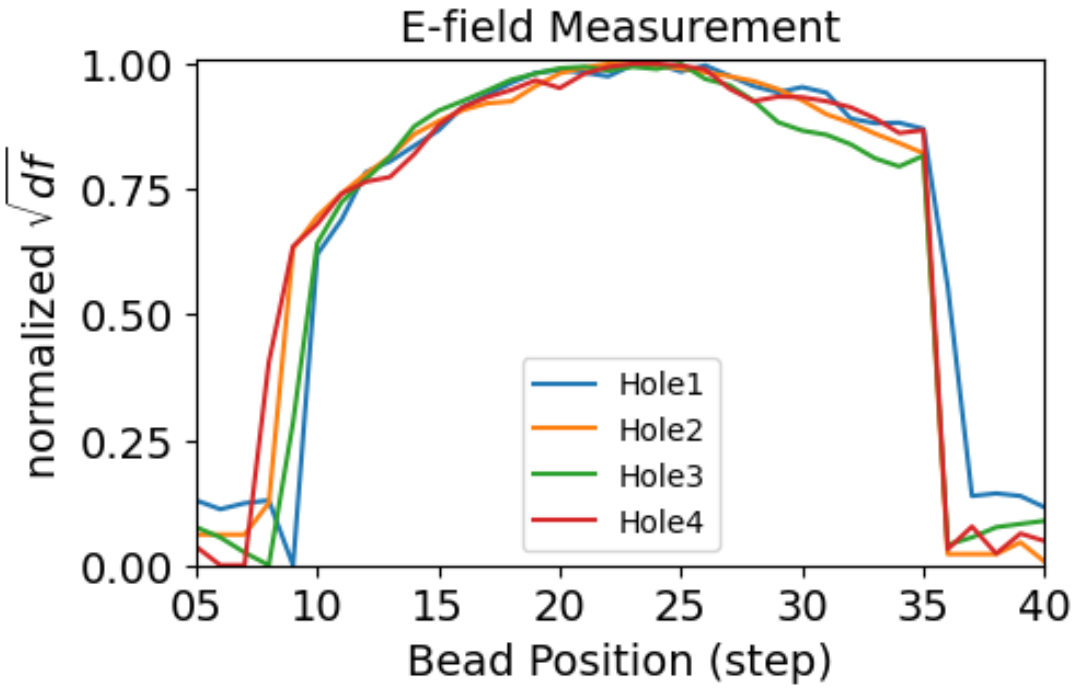
Bead-pull Measurement



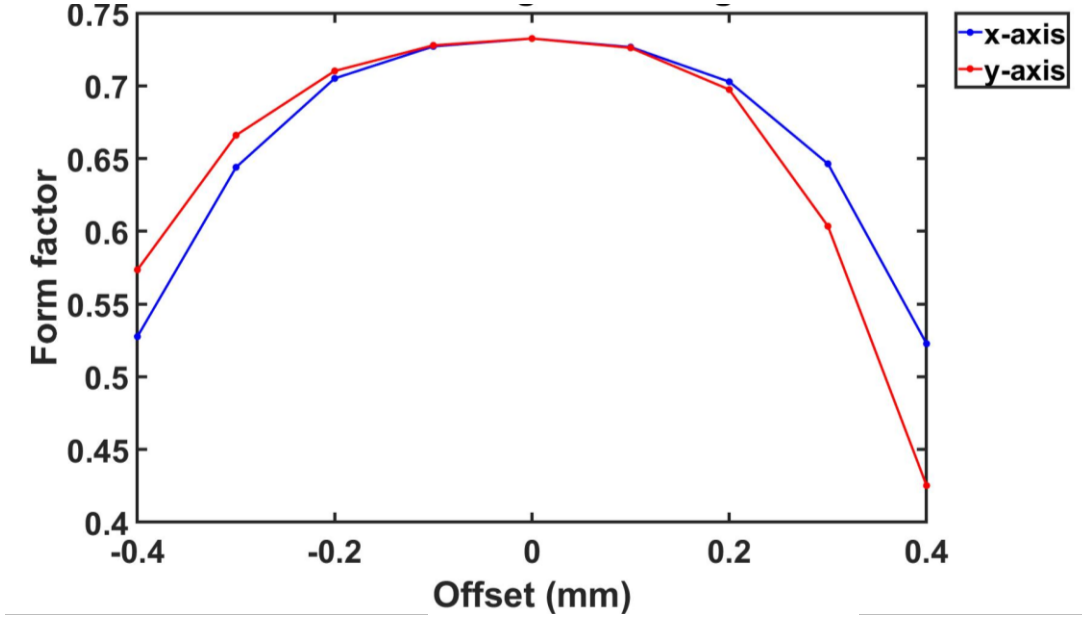
Bead-pull Measurement



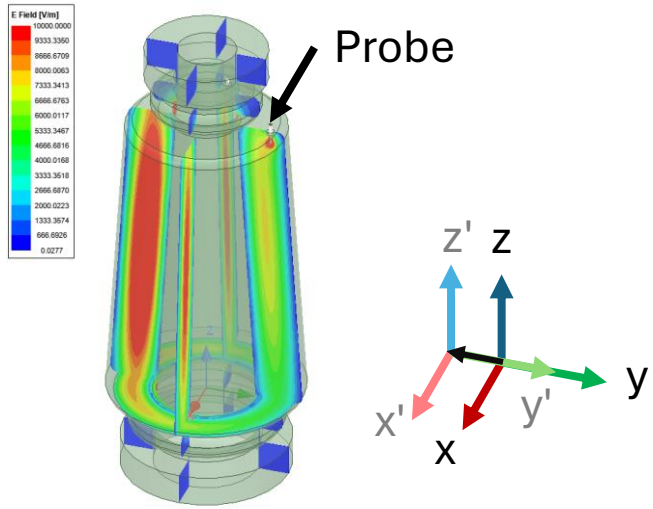


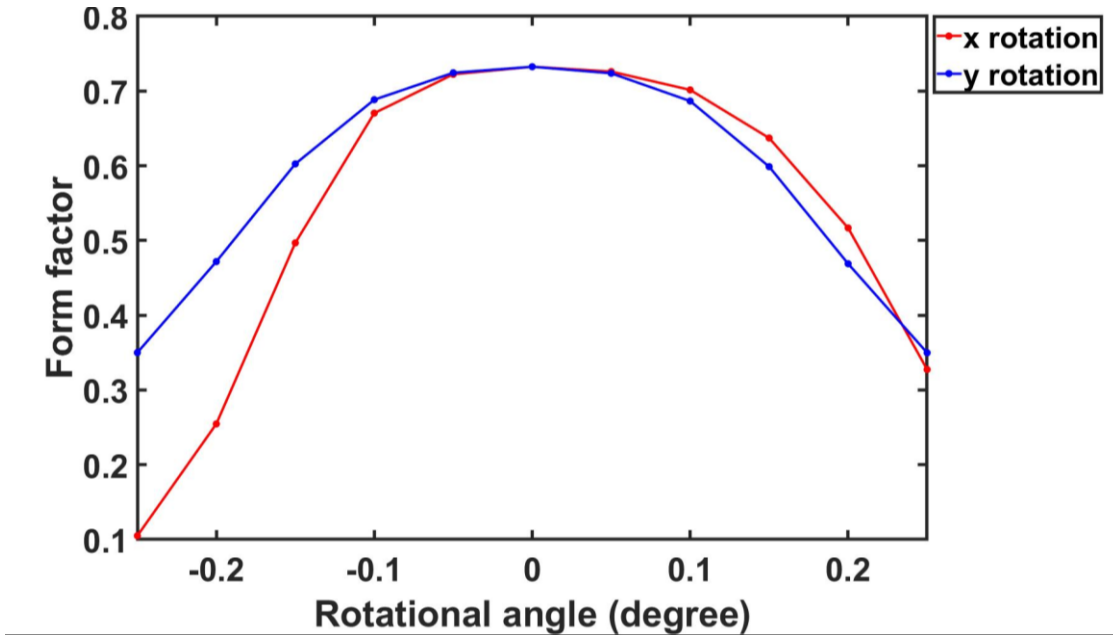


Inner & outer cone misalignment

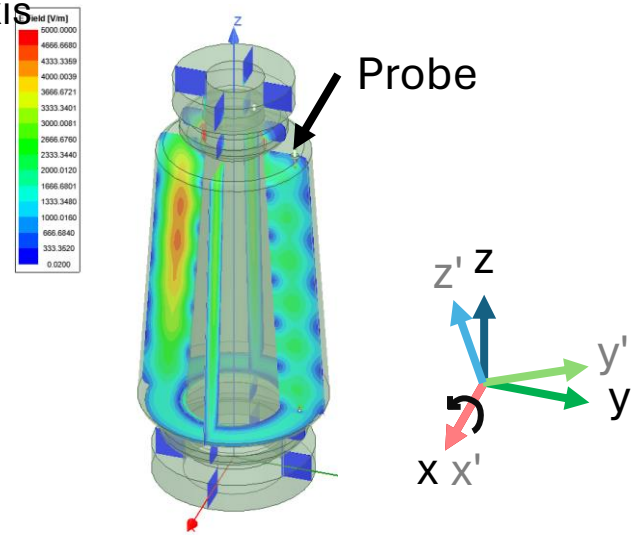


- Inner cone shift of 0.2 mm along y





- Inner cone rotation of 0.2 degree around x-axis



Material selection issues for cavity fabrication

Eddy currents generated during superconducting magnet quenching cause RD damage

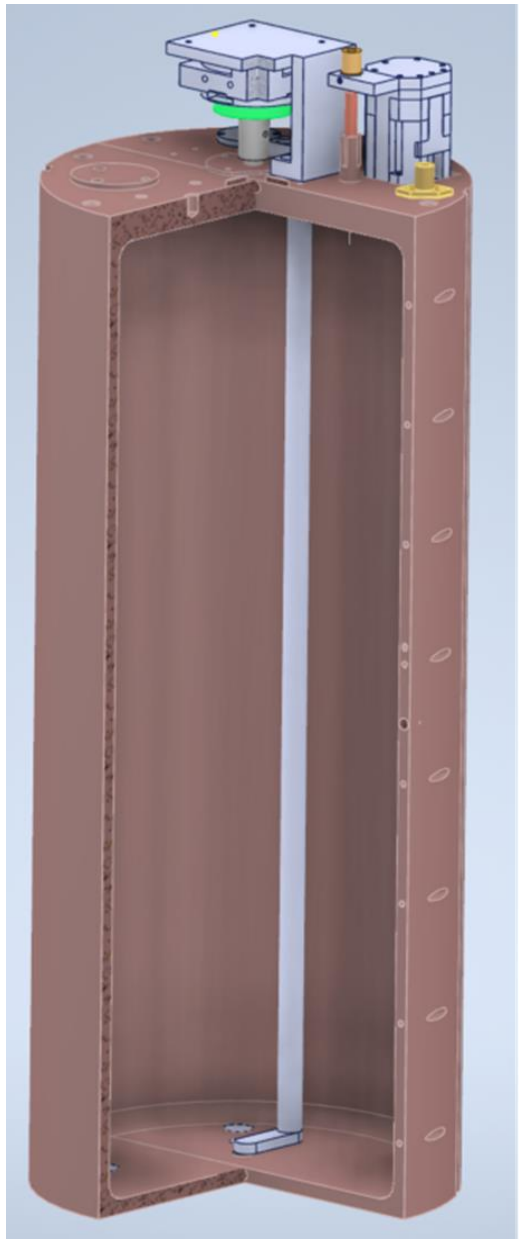
OFHC → **Stainless steel 316 + coated copper**

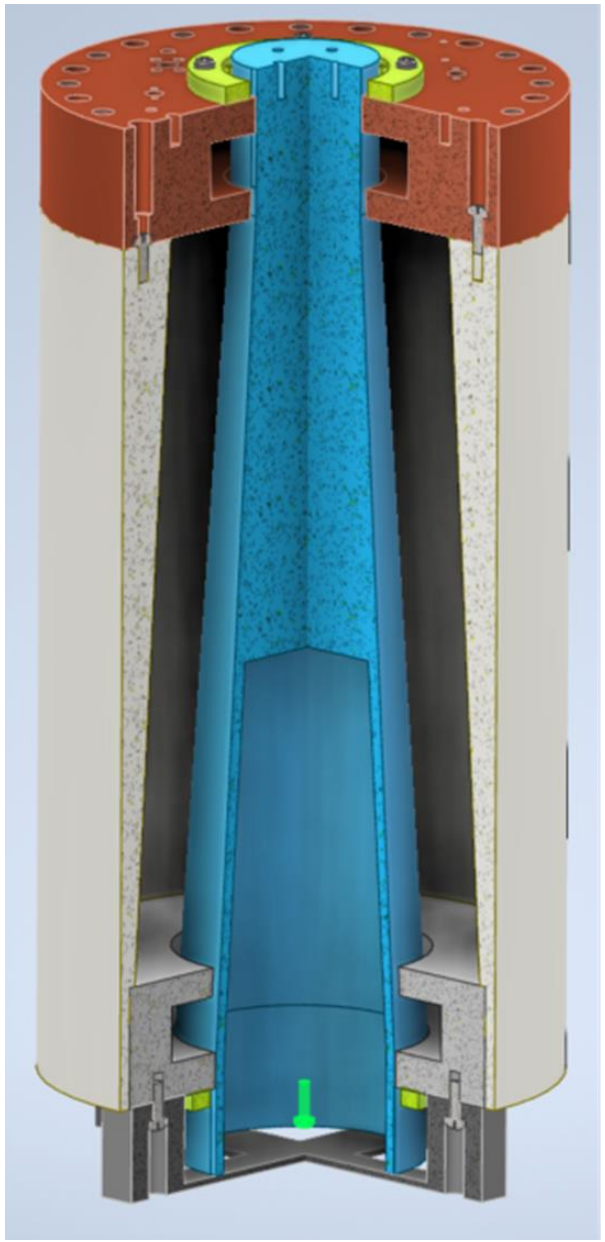
A cylindrical cavity made of stainless steel 316 and then coated with copper.

Copper Coating Methods:

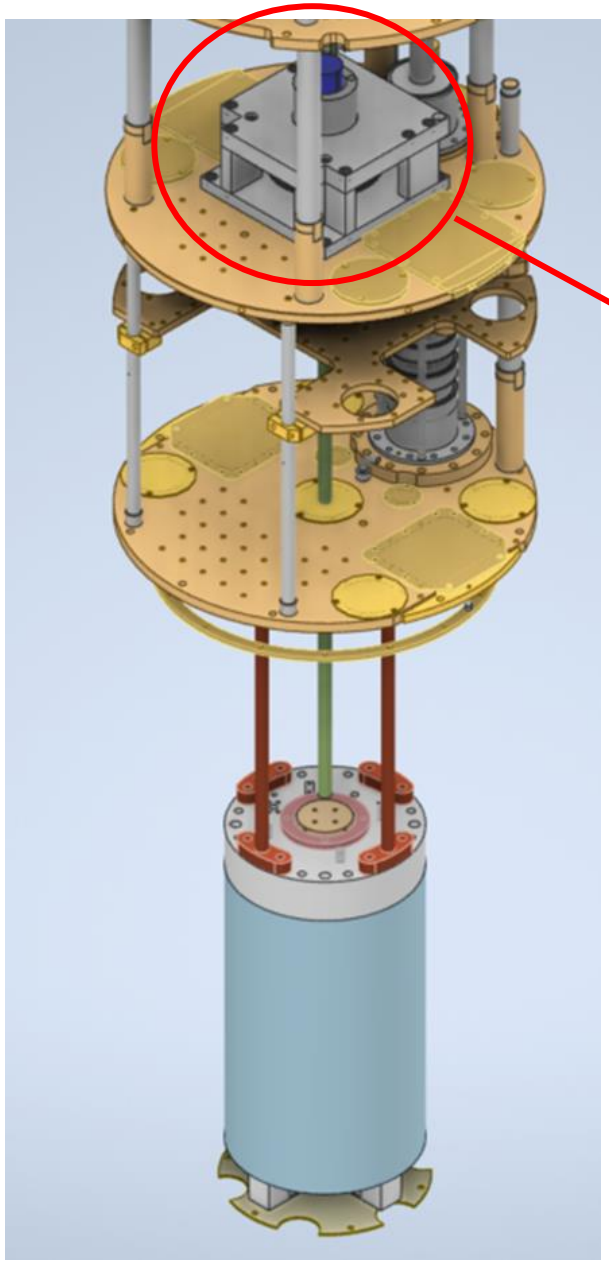
1.Traditional Electroplating
2.Cold Spray Coating
3.Cold Spray Coating + Traditional Electroplating
4.Hot Isostatic Pressing (HIP)

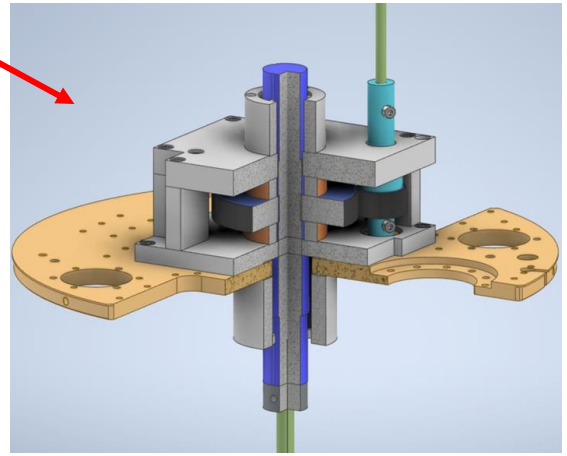
Gearbox Design and Manufacturing





Inner cone weight = 2.7 kg





Summary

- Completed the theoretical design and prototype model fabrication of the cone shell cavity, verifying its feasibility. The sensitivity is estimated to improve by a factor of 2.56.

- A complete electric field distribution measurement system has been established.

- Improved material selection and manufacturing processes for resonant cavity fabrication.

- Completed the gearbox design and initiated the production of a prototype model .