Designing a System to Locate a Defect in an Accelerating Cavity

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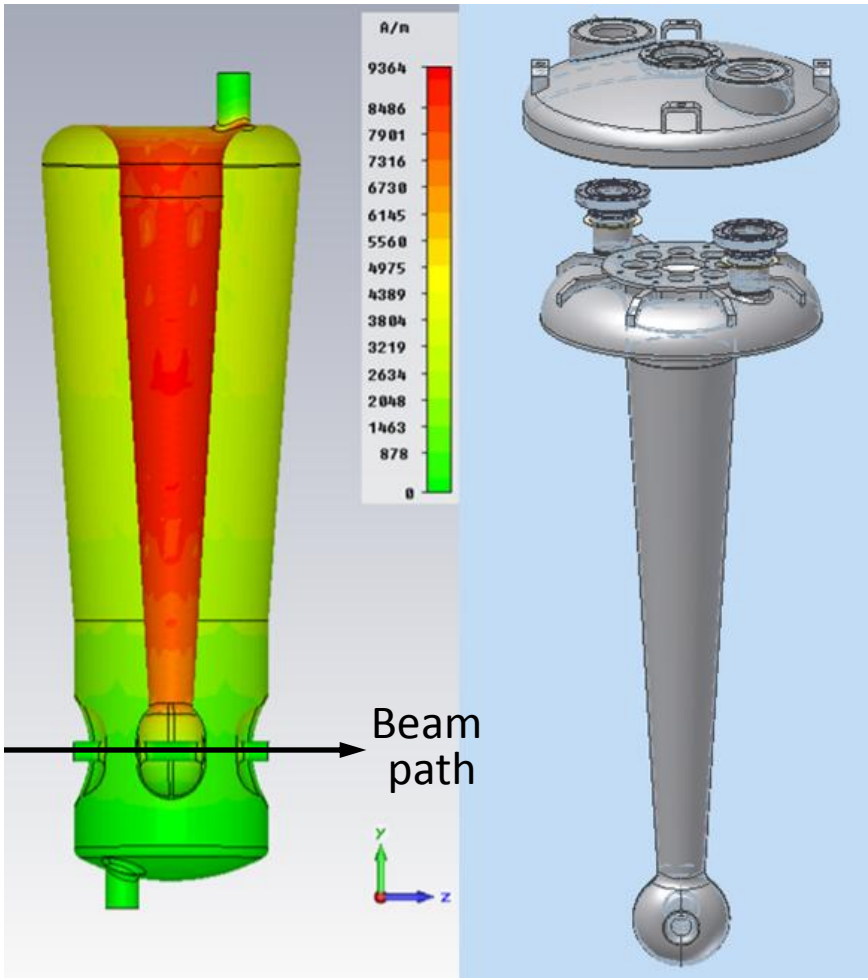
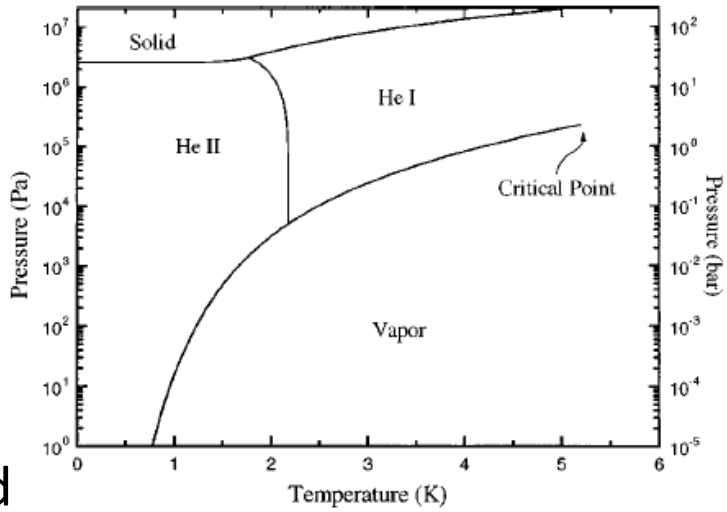
Superconducting RF Cavities

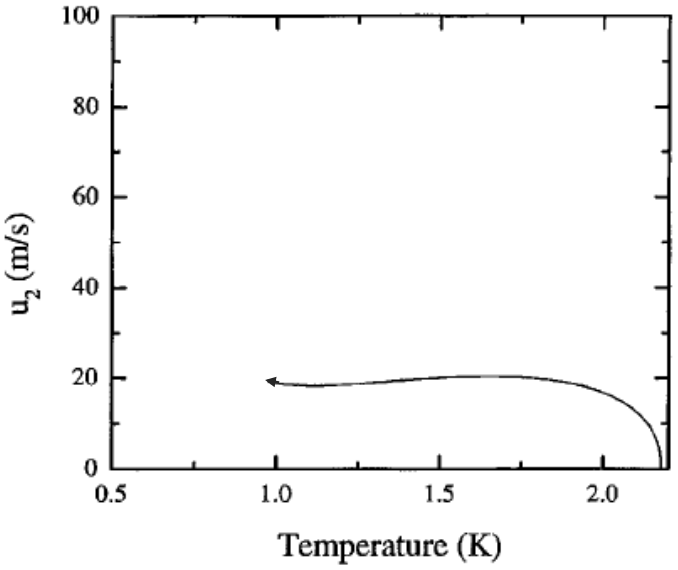
- Superconducting cavities are used to accelerate particles.
- A cavity defect may enhance localized power losses and produce a quench, which limits the accelerating gradient.
  - Quench = localized breakdown of superconductivity into normal conductivity
- Locating and mitigating defects are one way of improving the accelerating gradient.
- Cavities with a higher accelerating gradient = shorter, cheaper particle accelerators.



Superfluid Helium and Second Sound

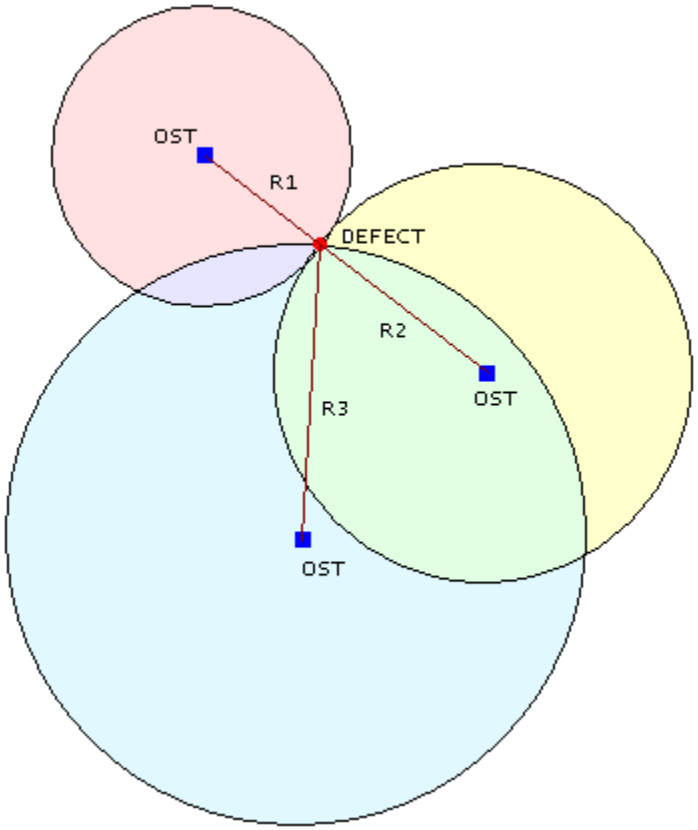
- Liquid He displays unique properties below the Lambda point (T=2.17 K).
  - Partly normal fluid, partly superfluid
  - Fountain effect, vertical creeping, high heat conduction, zero viscosity
- 2nd sound = temperature–entropy waves
  - Heat transfer in Helium II
- 1st sound = pressure–density waves
- Speed of 2nd sound < $^1/_{10}$ speed of 1st sound
  - Allows for more accurate position readings (2mm error, vs. 22mm error).
  - 2^{nd} sound velocity = $u_2 \approx 20$m/s
    1^{st} sound velocity = $u_1 \approx 220$m/s
    Detector error ≈ ± 0.1ms
    $\Delta x_{2nd\ sound} = u_2 t \pm 2mm$, $\Delta x_{1st\ sound} = u_1 t \pm 22mm$
- Superconducting RF cavities are immersed in liquid Helium bath.
- Defect dissipates more energy upon cavity quenching, becoming a source of large amplitude 2nd sound waves.





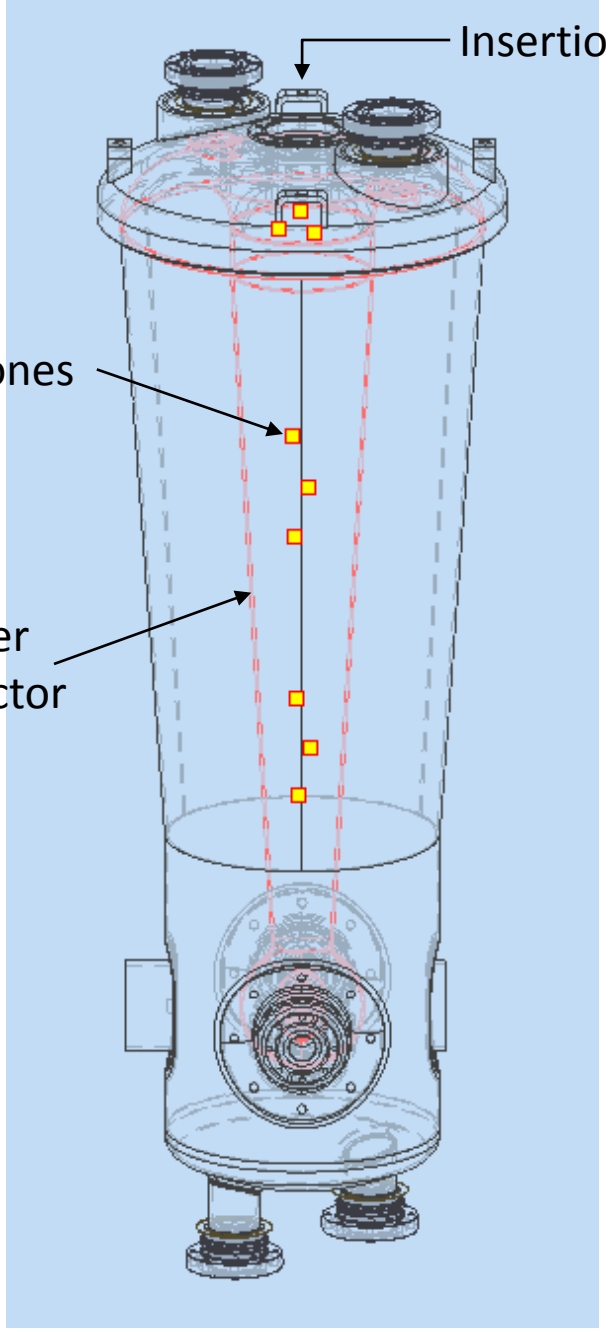
Transducers (OST) and Trilateration

- Oscillating Superleak Transducer = 2nd sound microphone
- 9 fixed microphones inside the cavity listen for second sound.
- Second sound large amplitude waves --> cavity quench
- Second sound detection --> change in capacitance
- $v = {}^{d}/_{t}$
  - Distance between defect and microphone can be calculated from velocity of 2nd sound and time elapsed between quench and detection.
- These distances can be used to locate the defect on the cavity, using 3D trilateration.

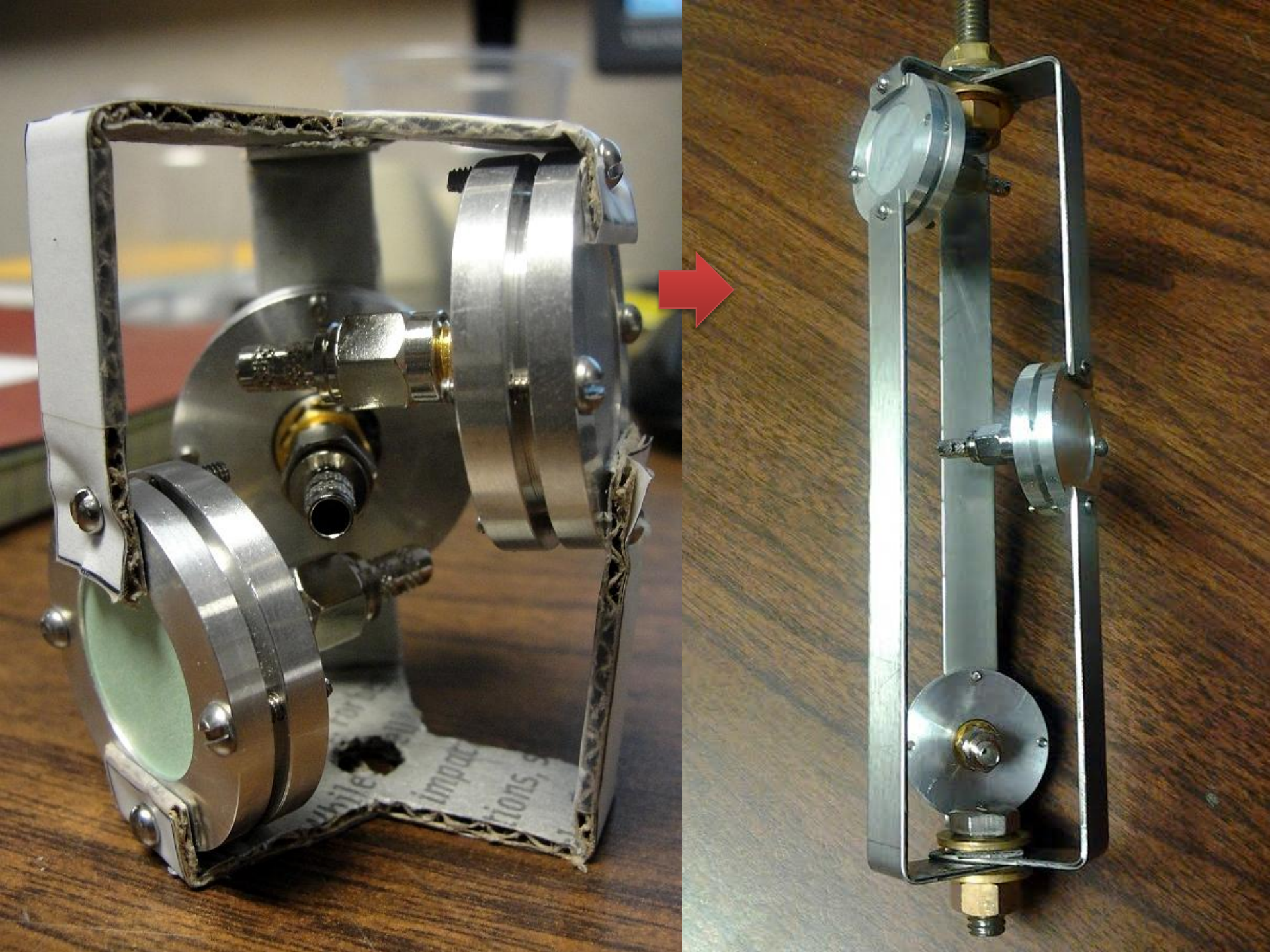


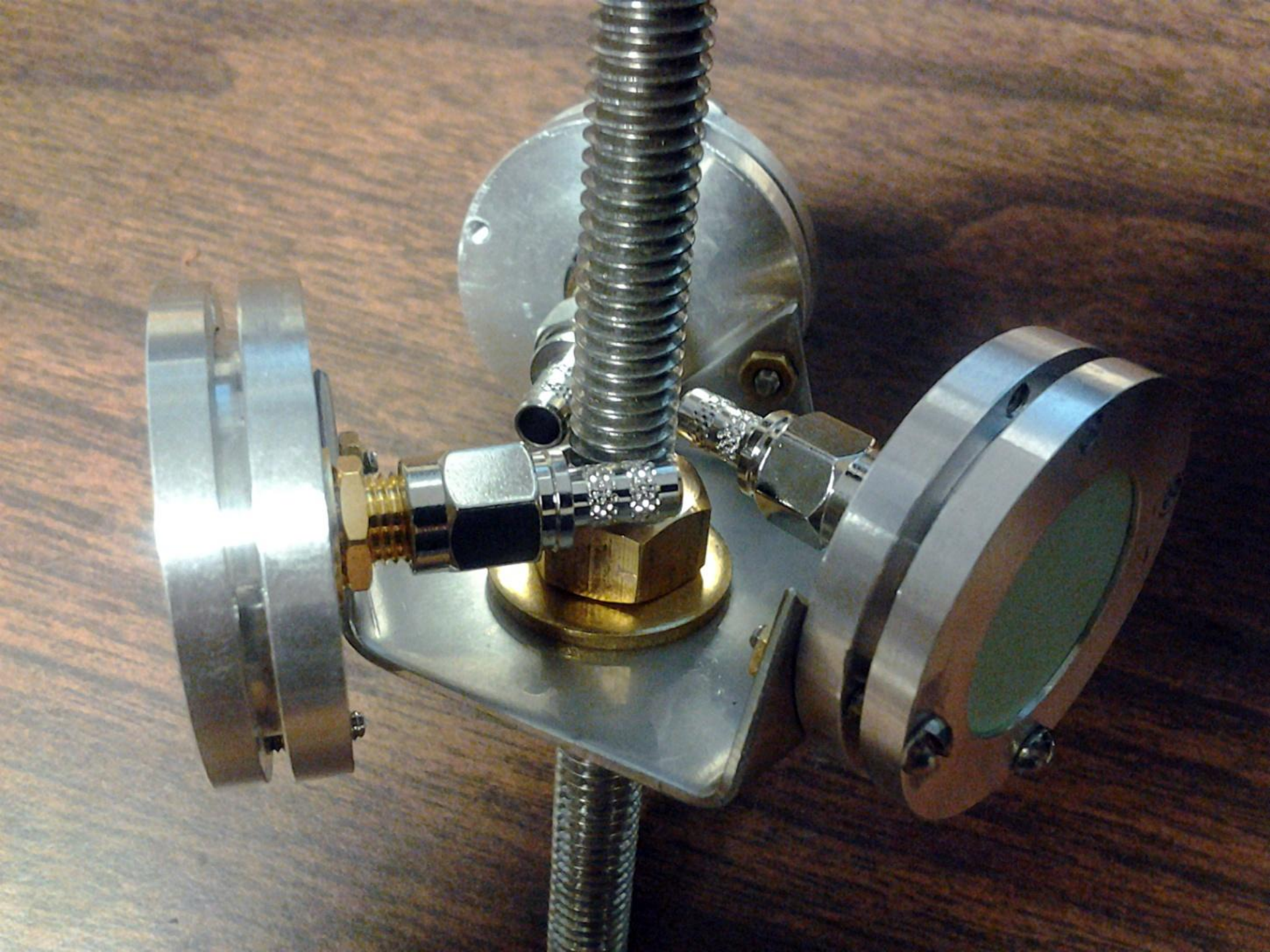
Designing the System

- A system designed for locating a defect inside a fully assembled quarter-wave cavity was drafted.
- Immersed in a liquid He bath, the design consists of a support structure positioning 9 microphones throughout the inside of the center conductor.
- Can measure in the vertical and azimuthal directions.
- The system was to fit inside the center conductor, through two small openings at the top of the cavity.
  - 3 in. and 2¼ in. diameter openings
- The system was designed to be cheap, reusable, with the ability to be quickly installed and removed in one piece.



Quarter-wave cavity





Summary

- Defects can limit the efficiency of accelerating structures.
- Detection system uses properties of liquid Helium, present in the accelerating structure, to locate a defect.
- Located defects can be alleviated, and accelerators made cheaper.

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Questions?