Locating Quenches With Second Sound

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Outline & Collaborators

- Second Sound Quench-Spot Location
- A Brief History
- OST Based Results
- Summary and Conclusions

Collaborators:

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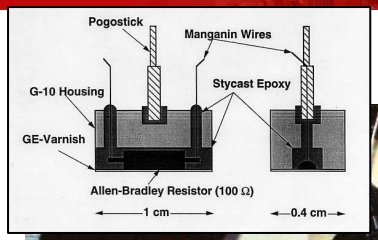
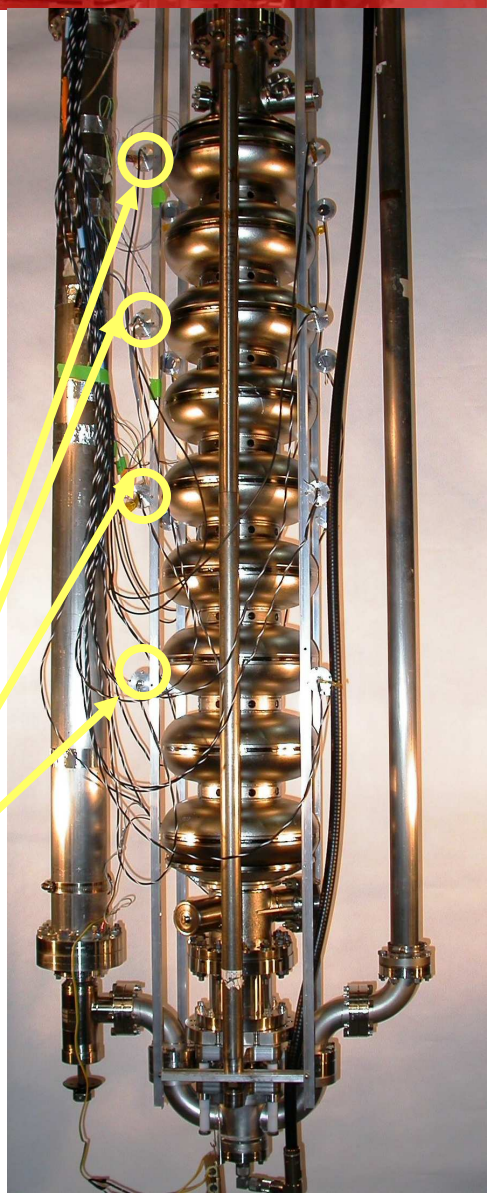
Second Sound Quench-Spot Location

- **Thermometry**
  - Full temperature map of the cavity at various field levels
  - Required for a detailed understanding of the cavity performance
  - Requires thousands of transducers



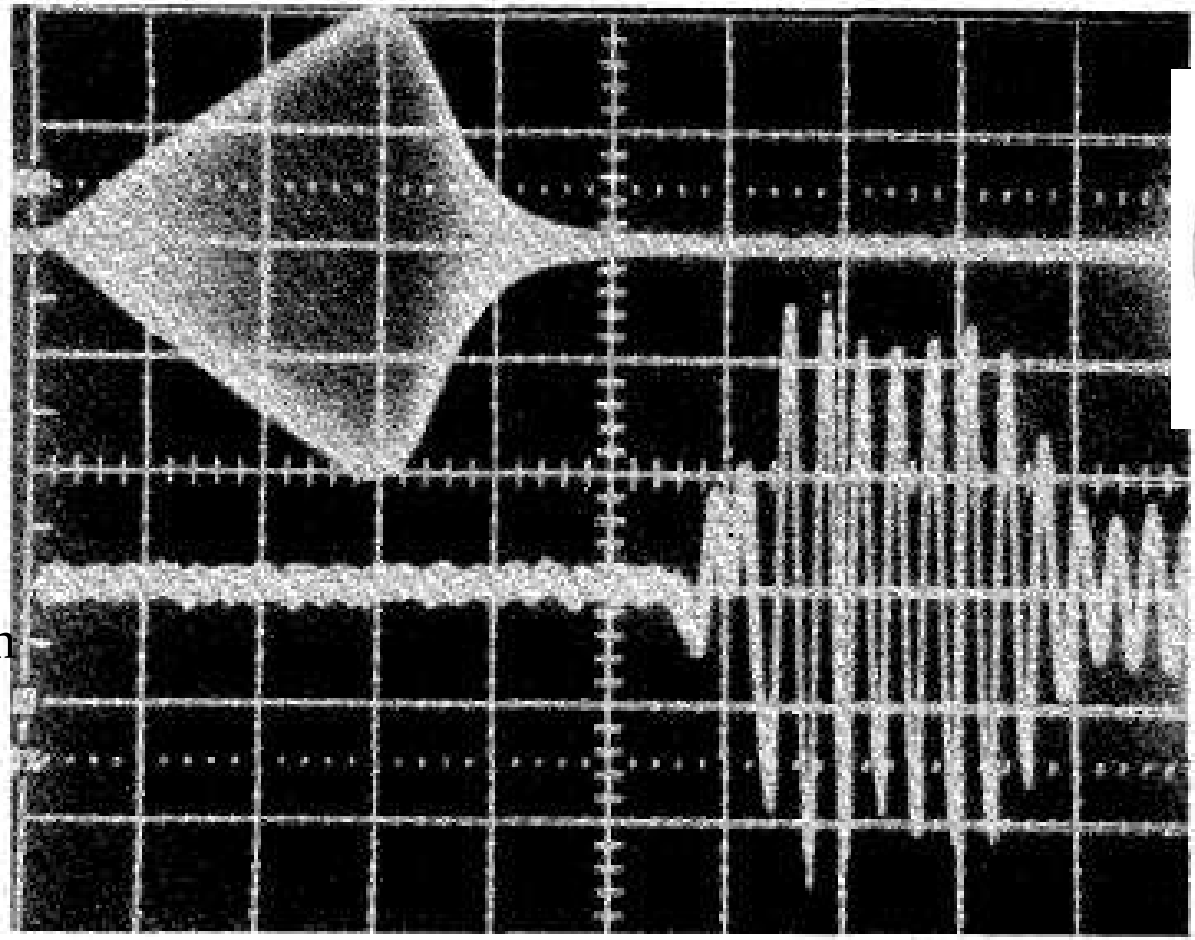
- **Second Sound**
  - Requires a few transducers (e.g. 8)
  - Simple
  - Fast
  - Accurate
  - Only locates the quench-spot
  - Convenient for the rapid testing/repair of cavities

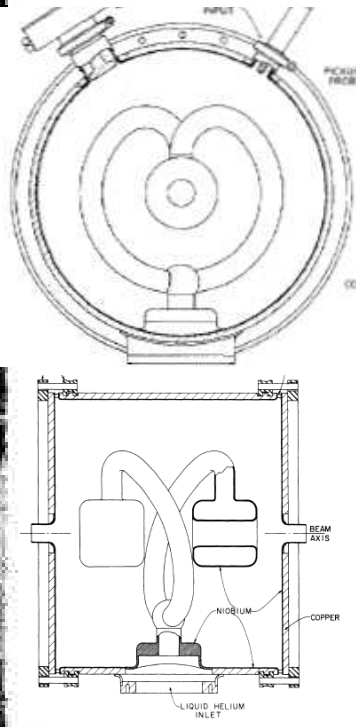


A Brief History

Cavity Field

Second-Sound
Wave Detection





16” (40.6 cm)

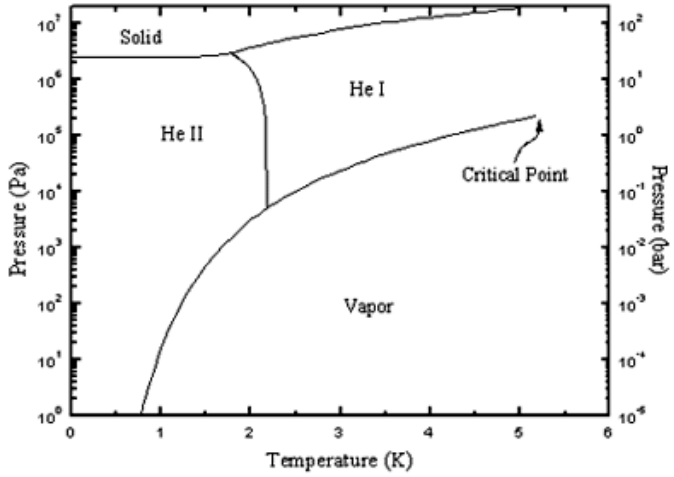
1.9 K (v_s = 18.8 m/s), Vertical Scale = 10 ms/div

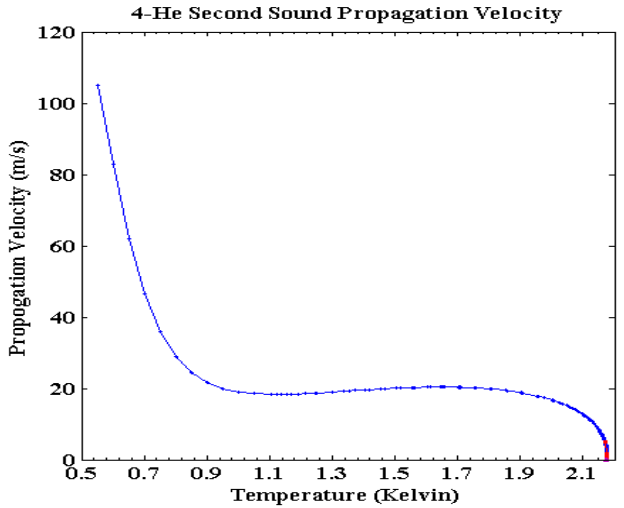
K.W. Shepard et. al, IEEE Trans. Mag, Vol. mag-15, no.1, January 1979, Pg. 666

Relevant Properties of Liquid Helium

- Wave Propagation in LHe
  - Normal P-ρ wave = 1st Sound, with velocity = ~ 220 m/s
  - Below the lambda point a T-S wave can propagate = 2nd Sound, with velocity = ~ 20 m/s
  - Superfluid ρ-T wave = 4th Sound, with velocity = ~ 200 m/s

- The detector response time can be around 0.1 msec or less which implies a spatial uncertainty of 2 to 4 mm if the start time (initiation of cavity RF field collapse) can be determined to the same timing uncertainty





Russel J. Donnelly and Carlo F. Barenghi, "The Observed Properties of Liquid Helium at the Saturated Vapor Pressure." J. of Phys. Chem. Ref. Data, vol. 7, Issue 6, Pg. 1217 (1998).

Second Sound Quench-Spot Location

- Simple defect localization schemes can be implemented by exploiting the properties of superfluid He, e.g. second sound waves.
- When a cavity quenches, typically several joules of thermal energy are transferred to the helium bath in a few microseconds.
- If the cavity is operated at $T < 2.17K$, the helium bath is a superfluid and a second sound wave propagates away from the heated region of the cavity.
- By locating several transducers in the helium bath around the cavity, the second sound wave front can be observed. The time of arrival of the second sound wave at a given transducer is determined by the time of flight from the heated region, which is centered on the defect causing quench.
- Measuring the time of flight to 3 or more uniquely located transducers, unambiguously determines the defect location.

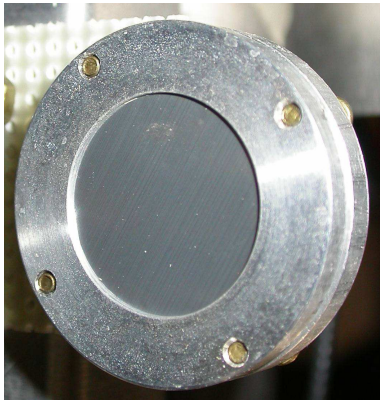
Second Sound Quench-Spot Location

- Any resistor with a large temperature coefficient can be used
  - Germanium (ANL, M. Kelly TUPPO032)
  - Cernox
  - Graphite

RTD

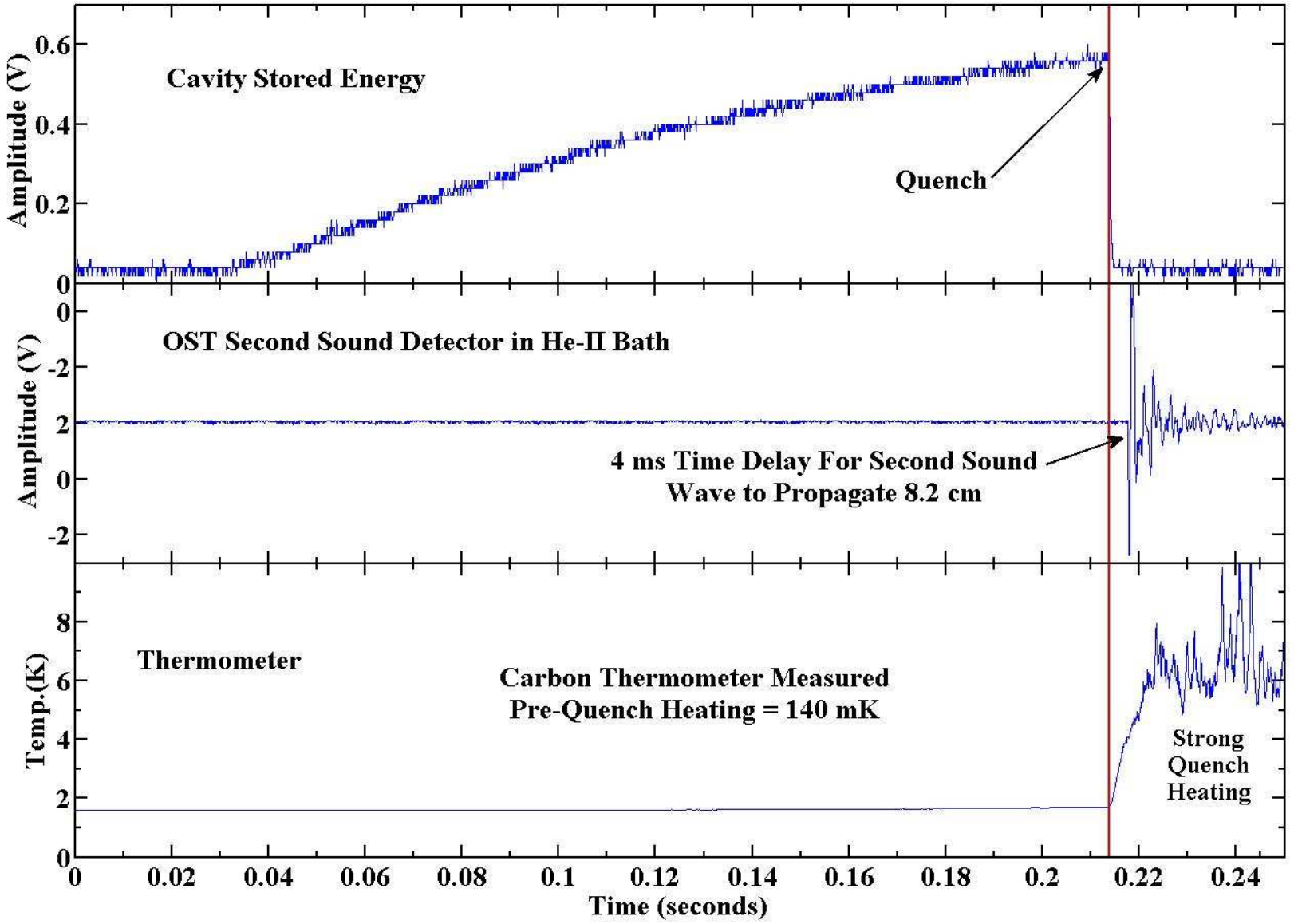
0.39” (1mm)

- Oscillating Superleak Transducers (OST)
  - Sense only second sound
  - Provide a much more sensitive and selective detector in noisy environments (see R.A. Sherlock and D.O. Edwards, “Oscillating Superleak Second Sound Transducers,” Rev. Sci. Instrum. 41, Pg. 1603 (1970).
  - OST operation is analogous to a Helmholtz resonator.

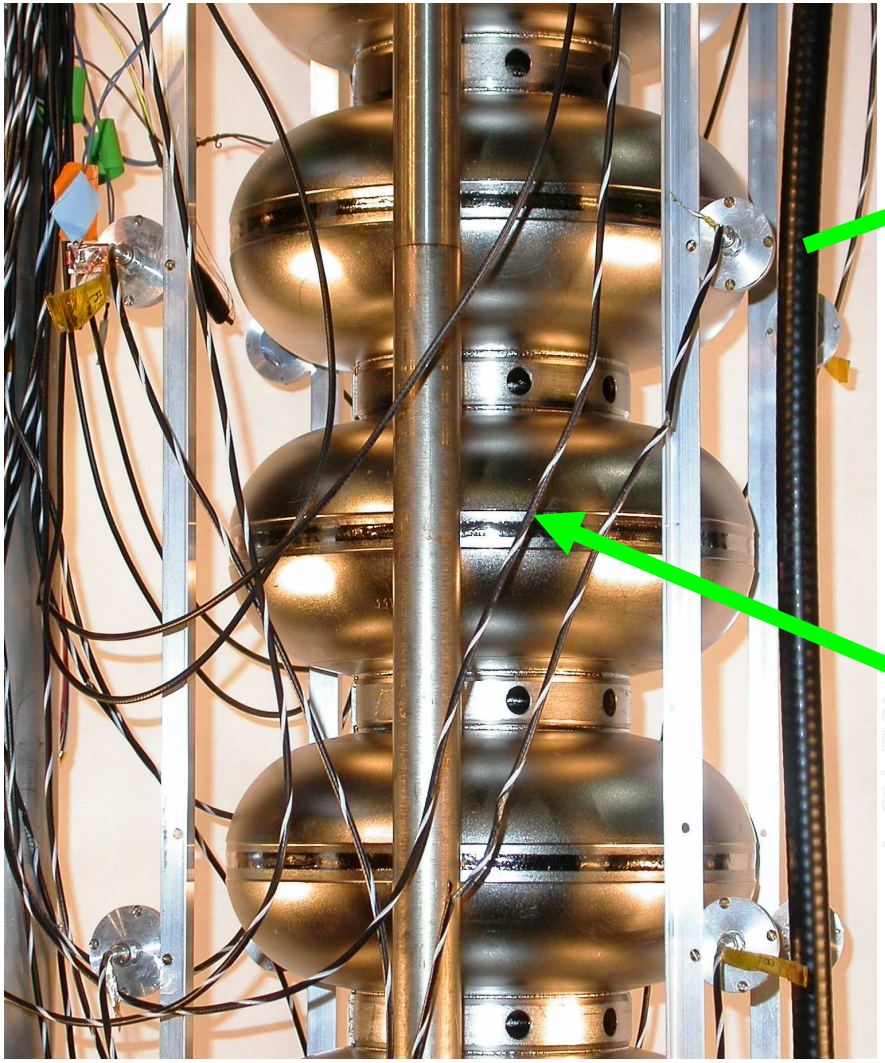


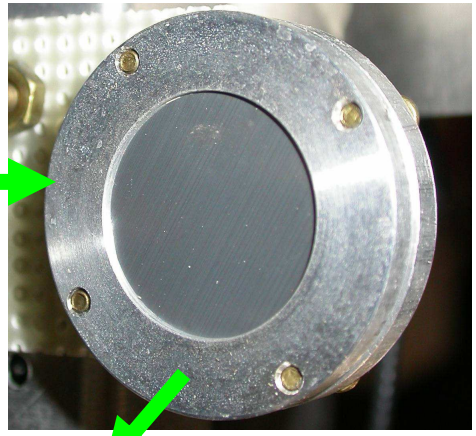
1” (2.5 cm)
(smaller version
in development)

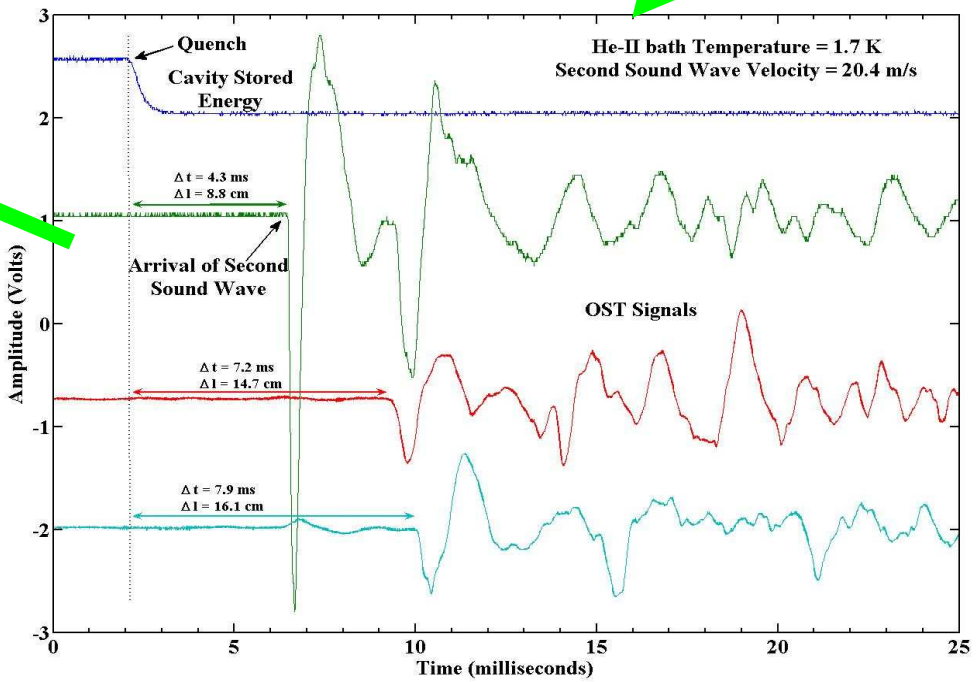
Second Sound Quench-Spot Location



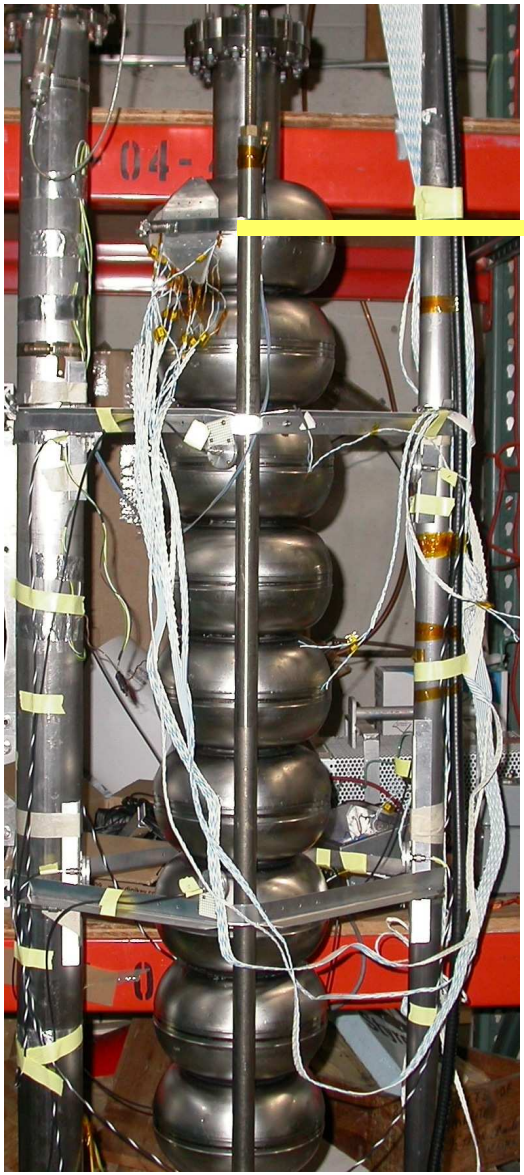
Results

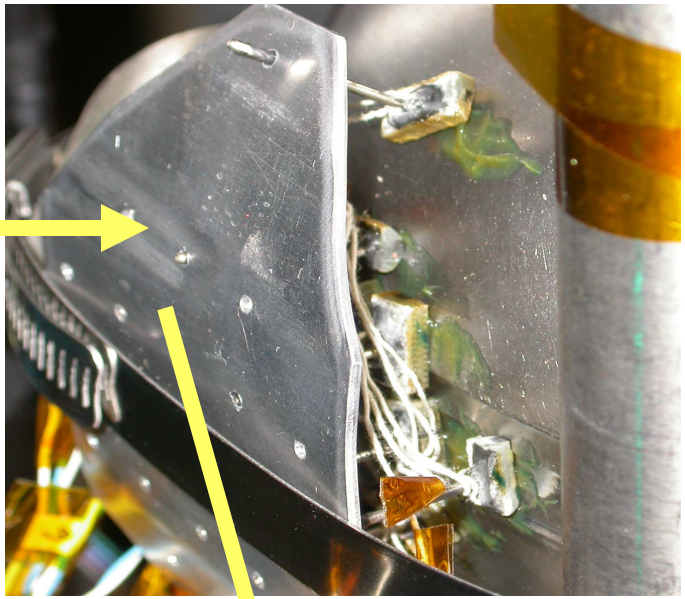




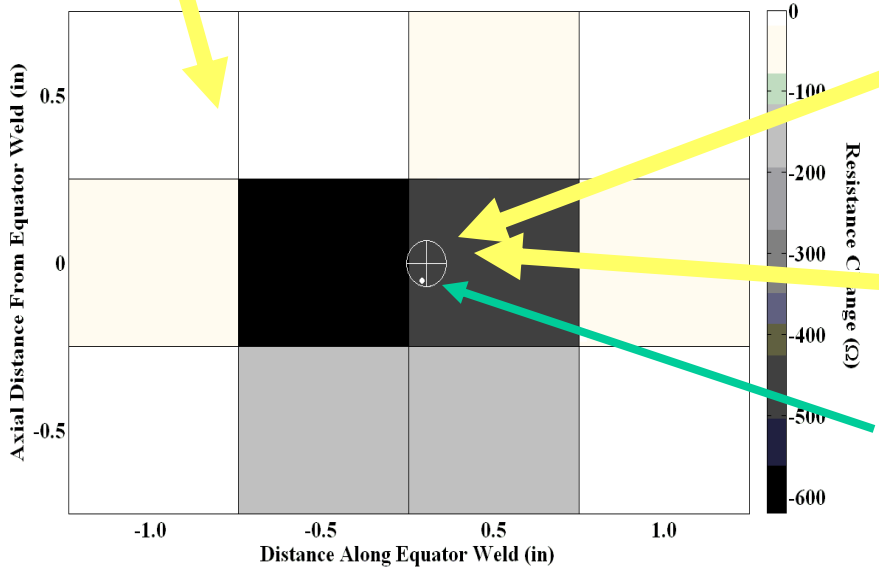

Quench
Cavity Stored Energy
He-II bath Temperature = 1.7 K
Second Sound Wave Velocity = 20.4 m/s
Δt = 4.3 ms
Δl = 8.8 cm
Arrival of Second Sound Wave
OST Signals
Δt = 7.2 ms
Δl = 14.7 cm
Δt = 7.9 ms
Δl = 16.1 cm
Amplitude (Volts)
Time (milliseconds)
3
2
1
0
-1
-2
-3
0
5
10
15
20
25

Results Making Sure This Works





Comparison of fixed thermometer heating, 2nd sound location and Optical location. Defect heating is about 50 mK at 8 MV/m

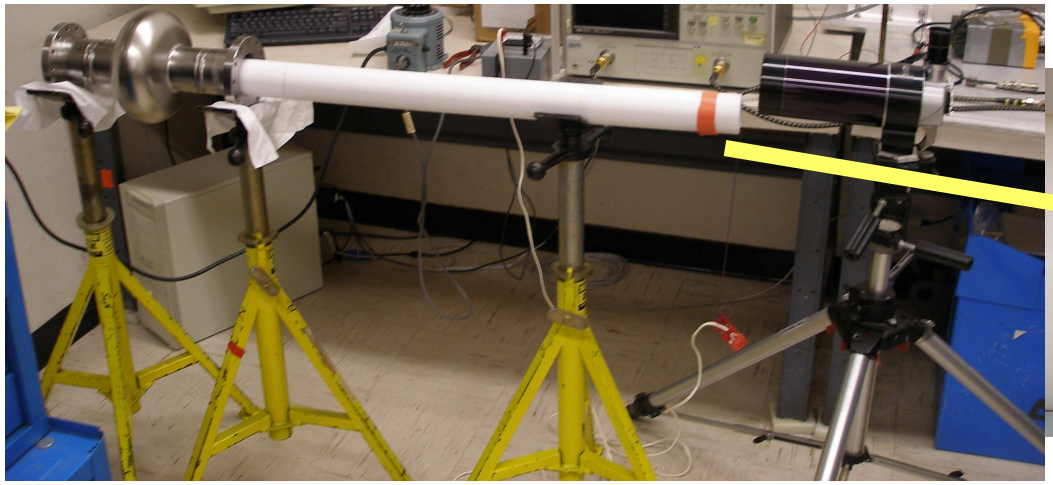


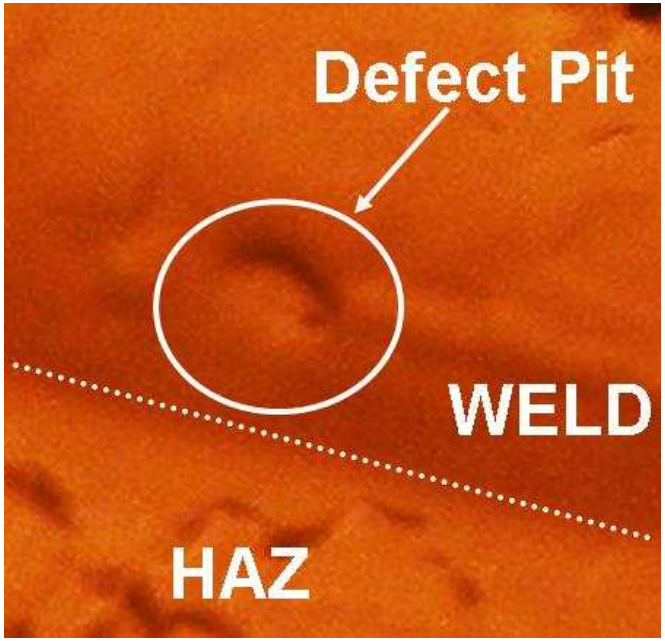
2nd Sound Defect Location

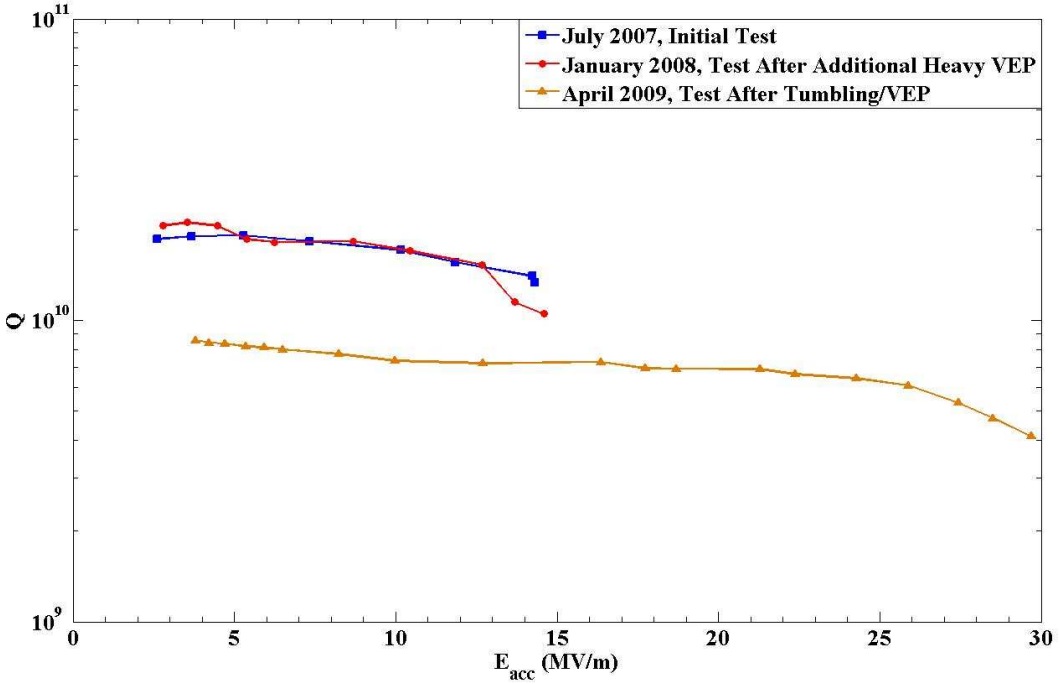
3mm radius circle around 2nd sound result

Optically Located Defect

Results

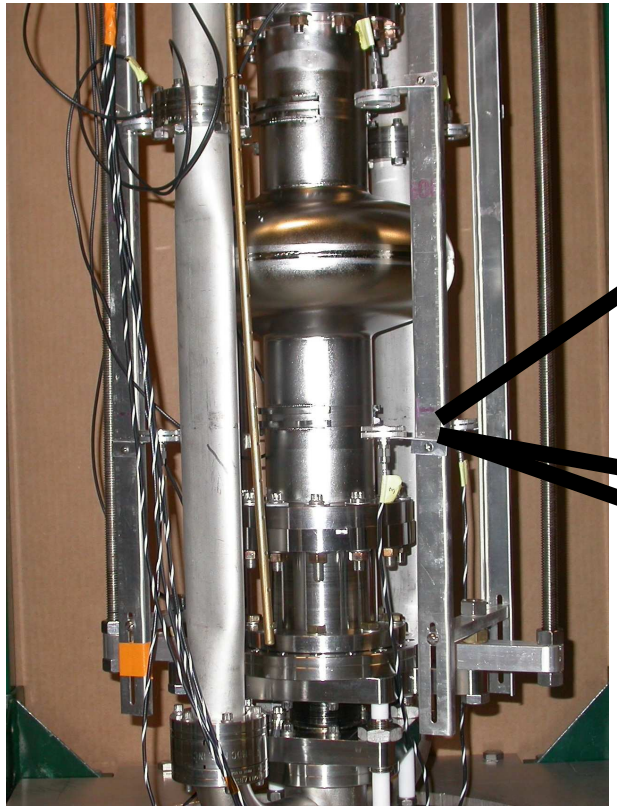


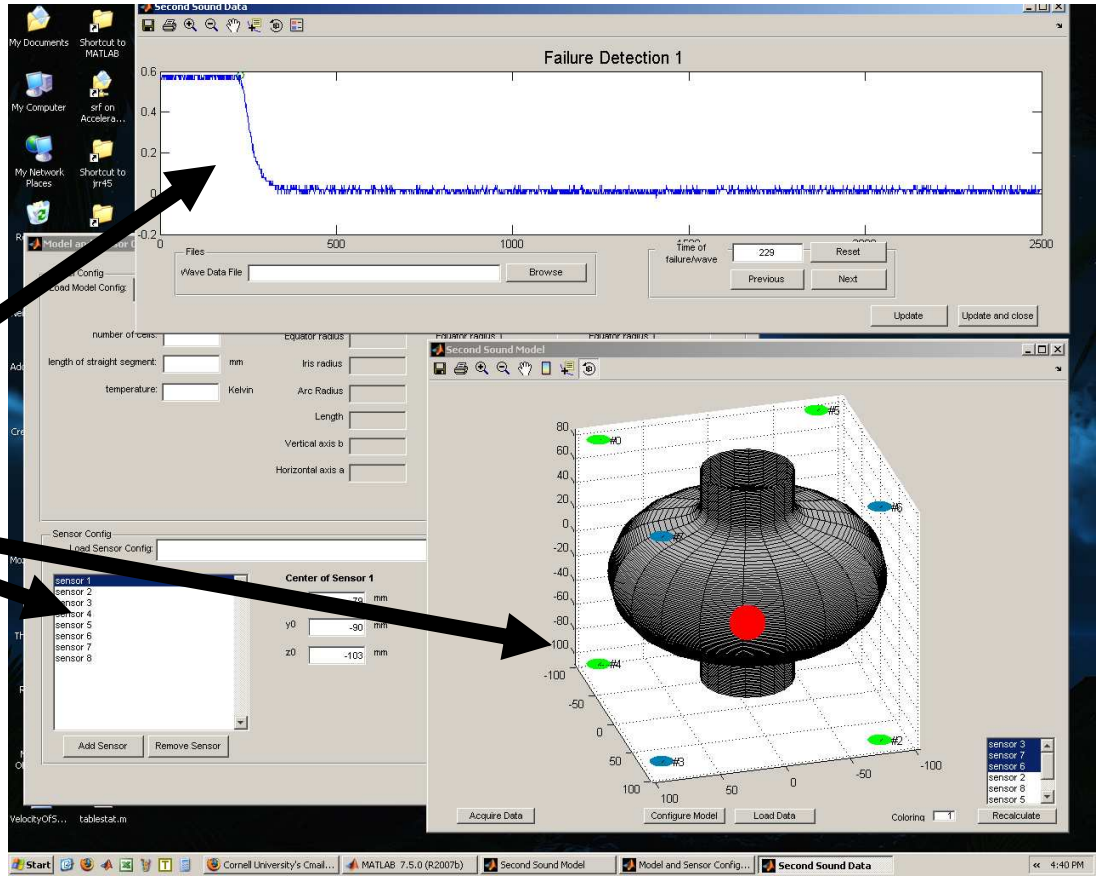

Defect Pit
WELD
HAZ


July 2007, Initial Test
January 2008, Test After Additional Heavy VEP
April 2009, Test After Tumbling/VEP
Q
10^{11}
10^{10}
10^{9}
0
5
10
15
20
25
30
E_{acc} (MV/m)

Future Plans

- Future Plans
  - Reduce OST Size (e.g. To fit into a cavity helium jacket)
  - Detect Pre-Quench Heating (Quench Protection)
  - Computer modeling





Summary

- 2nd sound quench location provides a simple, efficient, and reliable method of determining the location of quench-spots.
- 6-8 sensors per cavity test are employed versus thousands of resistors. This saves time, money, and frustration.
- The second sound quench-spot location technique would benefit any SCRF institutions which wants to rapidly test/repair cavities.