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Diagnostics system for SPL cavities & 2nd sound measurement @ Cryolab

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Diagnostics system for SPL cavities & the 2nd sound measurement @ Cryolab

ISSUE

Solution

I. Introduction

II. 2nd sound ★

III. Temperature monitor

IV. X ray

V. Bubble formation

VI. Summary

Introduction

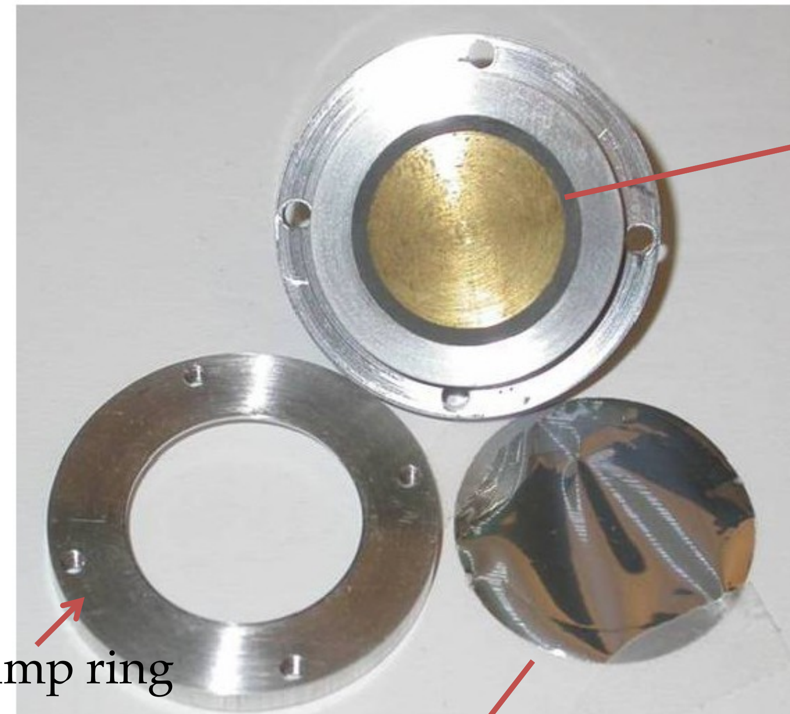
1. Thermal breakdown due to defects
2. Emission of electrons from high E field absorbs the power of the cavity

	Temperature maps	2nd sound	bubbles	X ray
Thermal breakdown due to defects (quench)	✓	✓	✓	
Field emission	✓			✓

2nd sound

- What is 'second sound'?
  - ✓ quantum mechanical phenomenon seen in superfluids
  - ✓ heat is transferred in a wave-like motion
  - ✓ heat : 2nd sound || pressure : 1st sound
- How to generate the second sound?
  - ✓ Heat source **initiates**
  - ✓ the counterflow of the superfluid (no entropy) and normal component (entropy)

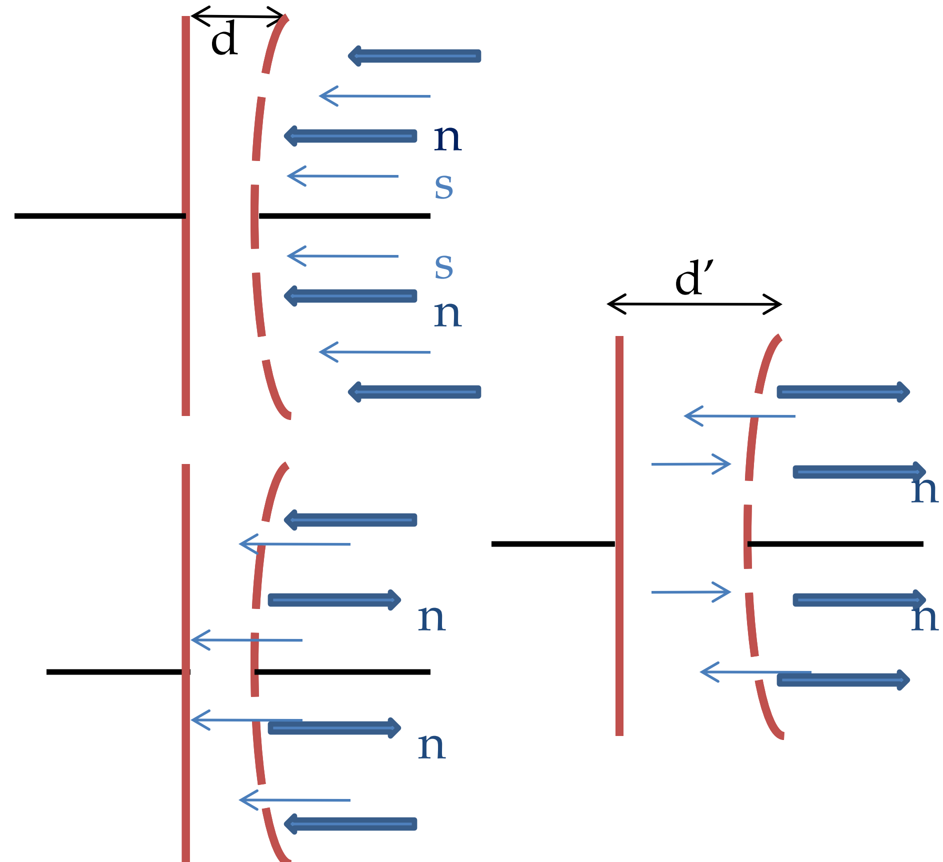
Oscillating superleak transducer



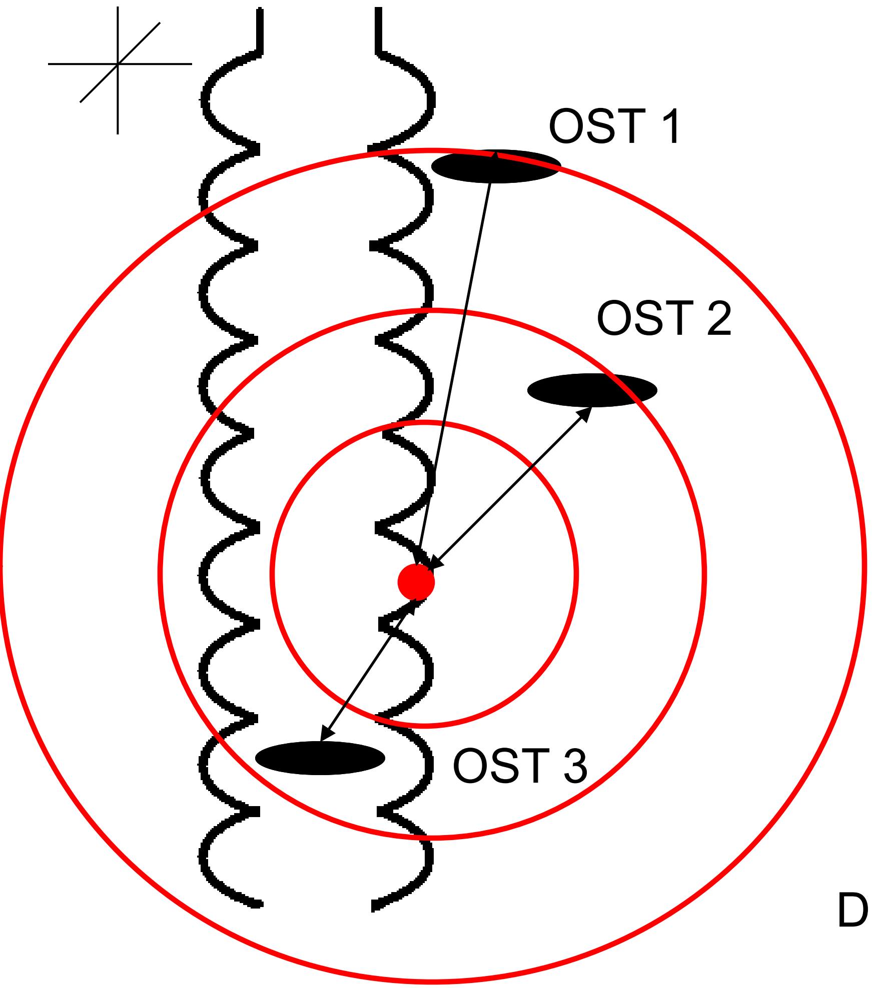
clamp ring

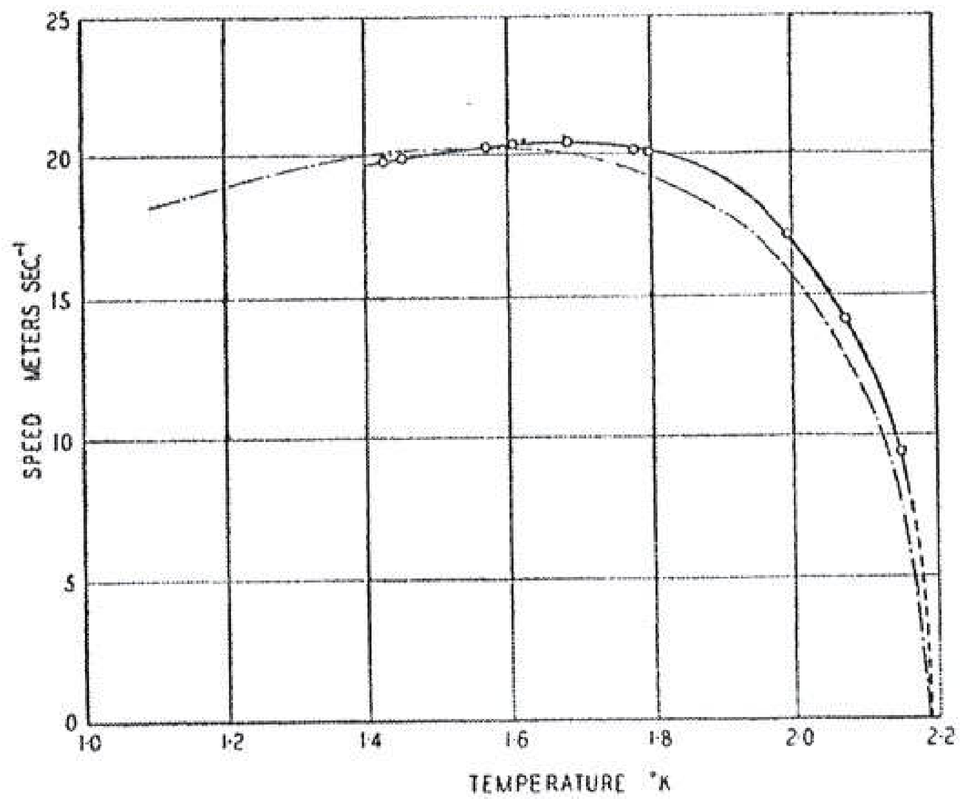
Porous filter membrane (flexible)

Evaporated gold layer on the end plate (fixed plate)



OST to track the quench spot





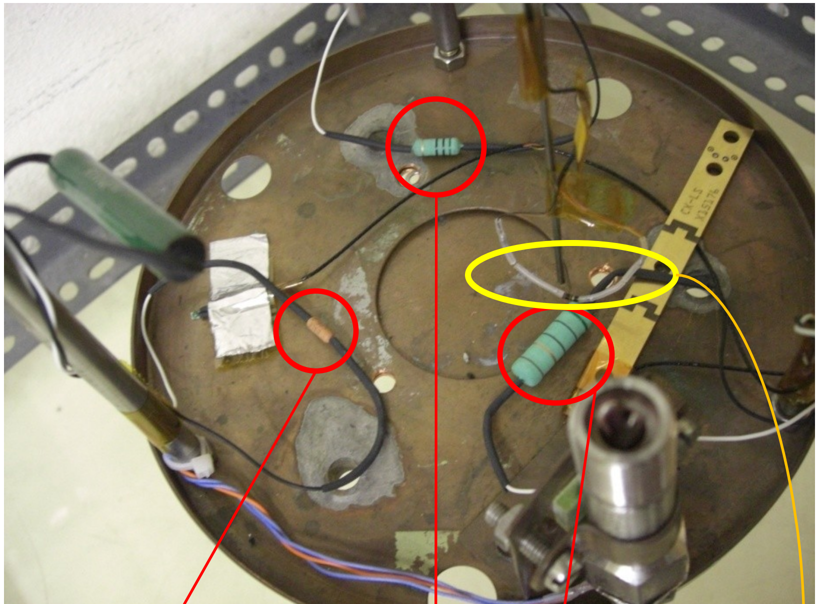
Source: Fairbank, Phys. rev. vol. 71, nr. 9, 1947

Distance= velocity * travel time
= 20 m/s * t

2nd sound setup @ Cryolab

3 heaters 1 adjustable thermometer, 1 fixed

1 adjustable OST, 3 fixed

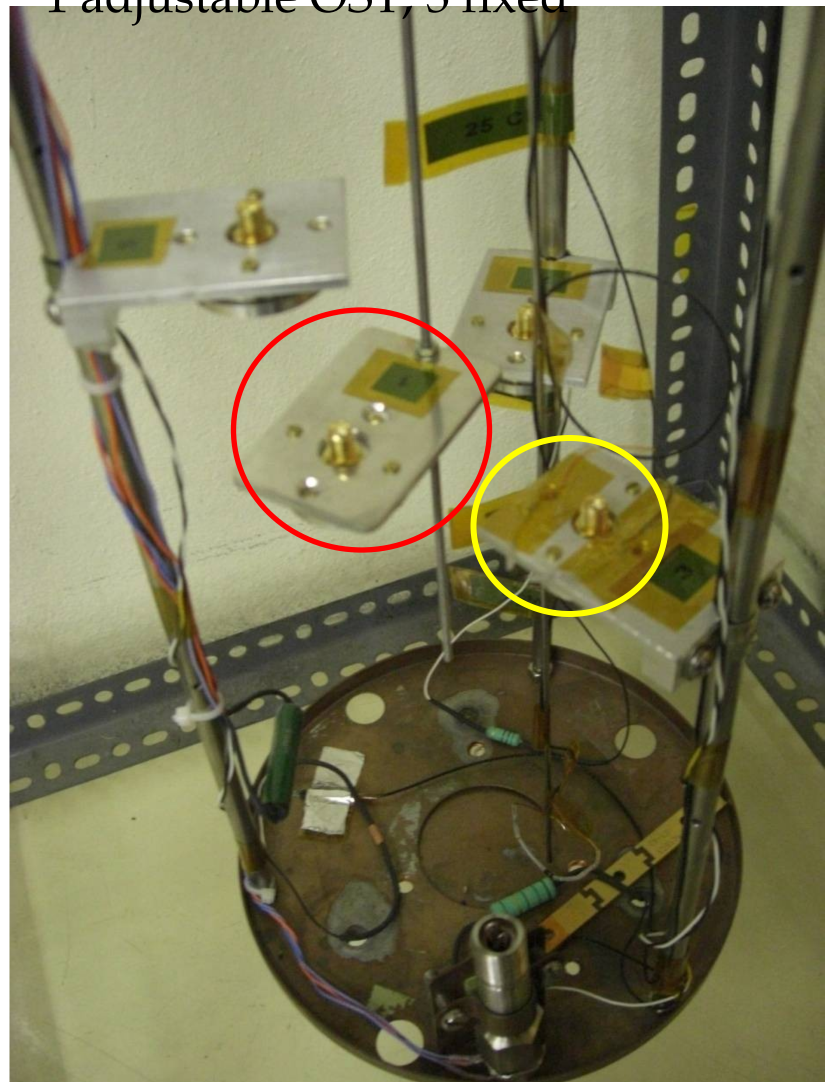


Metal film, 2W

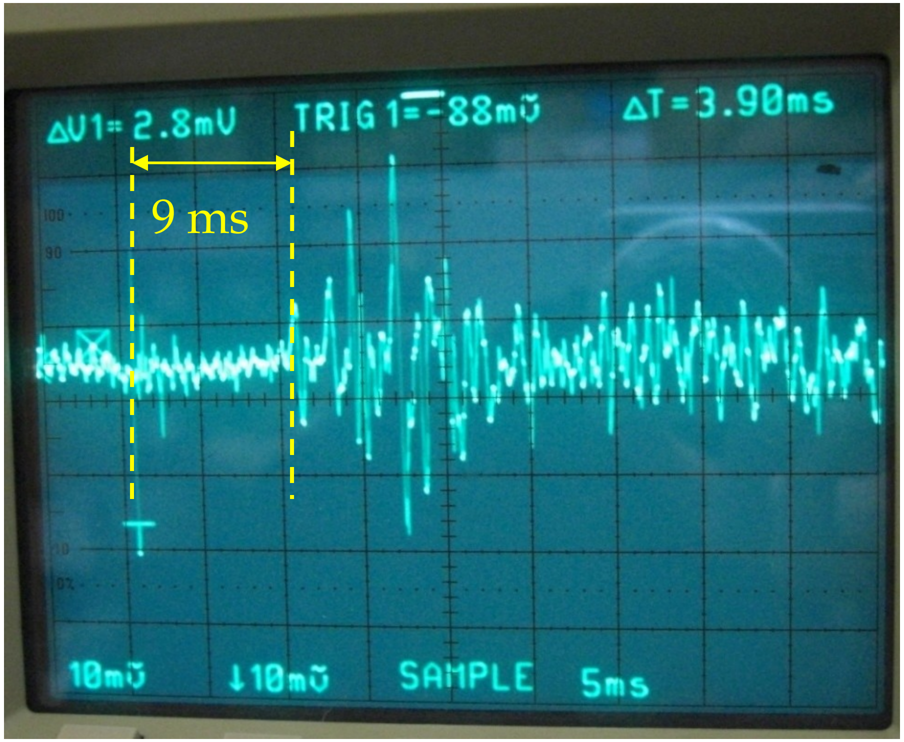
Wirewound, 3W

Wirewound, 7W

(A.B) carbon resistor 100 Ω, 1/8W



2nd sound signal

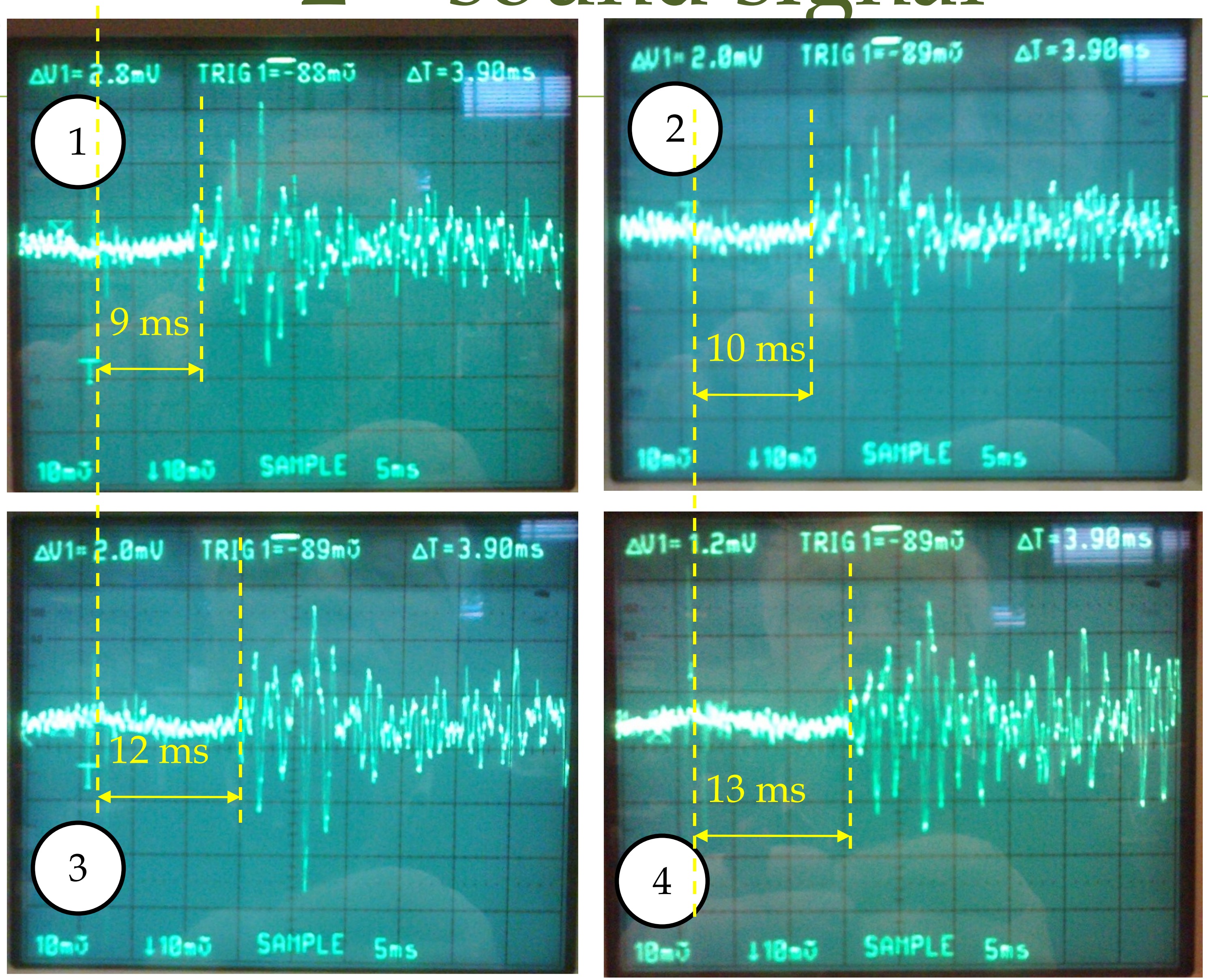


OST 1: 70pF , *f=12kHz* (R.T)
OST 2: 63.5pF, *f=6.5kHz* (R.T)
Suppress common mode hum (50Hz)

OST 1 (20 cm) - OST2 (20cm)

V= D/ Δt
=20cm/9ms
=22.2 m/s

2nd sound signal



Photos taken by Wolfgang Weingarten

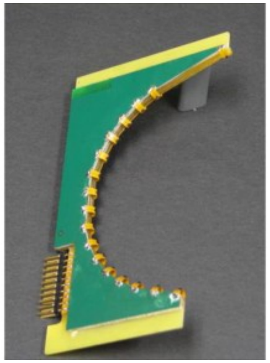
Temperature maps

Field emission	quench	Precursor	Residual (loss)distribution
✓	✓	✓	✓

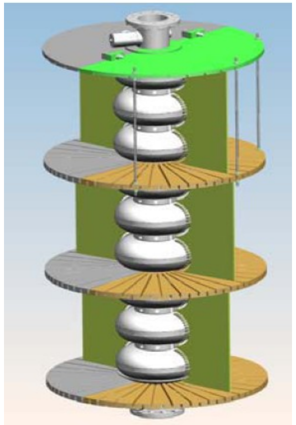
Methods:

1. Fixed

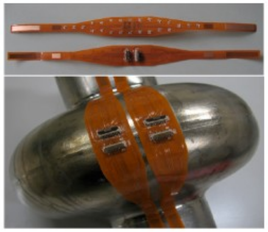
2. Rotating



Source: Moeller et al. Proc. of SRF09



Source: Canabal et al. Proc. of IPAC '07



Source: Tongu et al. Proc. of IPAC '10

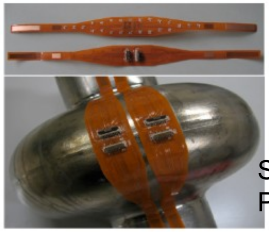
Source: Reschke, Proc. of LINAC08

Sensor selection for temperature mappings

	Differential accuracy	Absolute precision (reproducibility)	Dimensionless sensitivity	Price per unit
Carbon resistor	☺	😐	☺	☺☺
Silicon diode	☺	😐	☺	☹
Cernox	☺	☺	☺	☹
Germanium resistor	☺	☺	☺	☹
Ruthenium Oxide	☺	😐	☺	☹

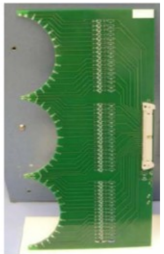
Temperature mapping proposal

- 1 cell test & (fast real time multiple cell measurement):



Source: Tongu et al. Proc. of IPAC '10

✓ fixed scheme
✓ Sensor strips for attachment onto the cavity walls
✓ 32 *32= 1024 sensors per cell
✓ ~5000 sensors for 5 cell, fixed board



Source: Canabal et al. Proc. of IPAC '07

- Multiple cell test (patience needed)

✓ rotating scheme
✓ motor to drive the wiring arms, multiplexing circuit

- Sensors:

 1. Allen Bradley Carbon resistors

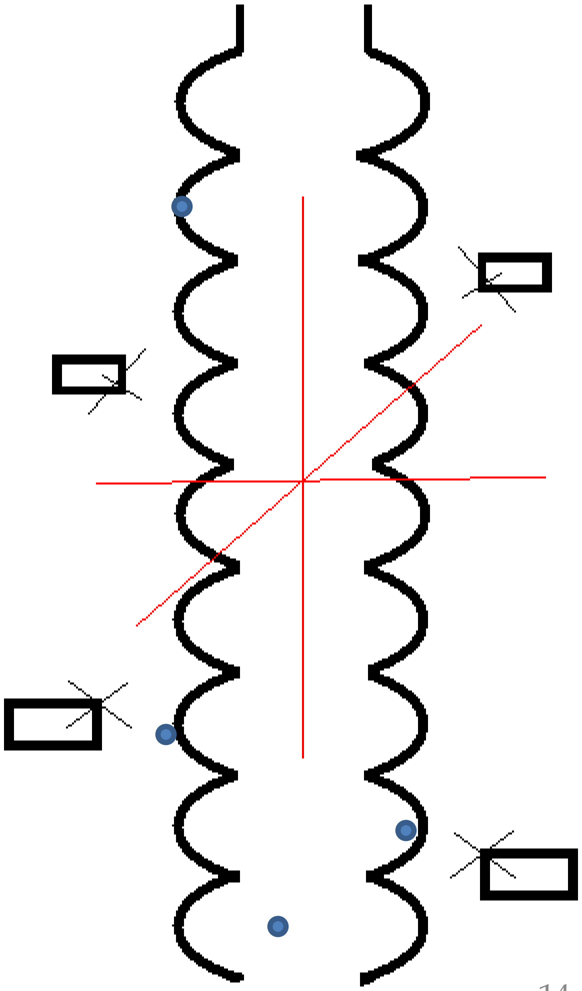
X ray detection

- At high E fields, the field emitted electrons collide with the cavity wall →produce bremstrahlung.
- Photodiodes (silicon) implemented along with the temperature sensors and an amplifier circuit for integration
- Enable discrimination between defects and electron impact spots.
- Used under all helium conditions

→Measurement of the spatial X-ray distribution : location & distribution of electron emission

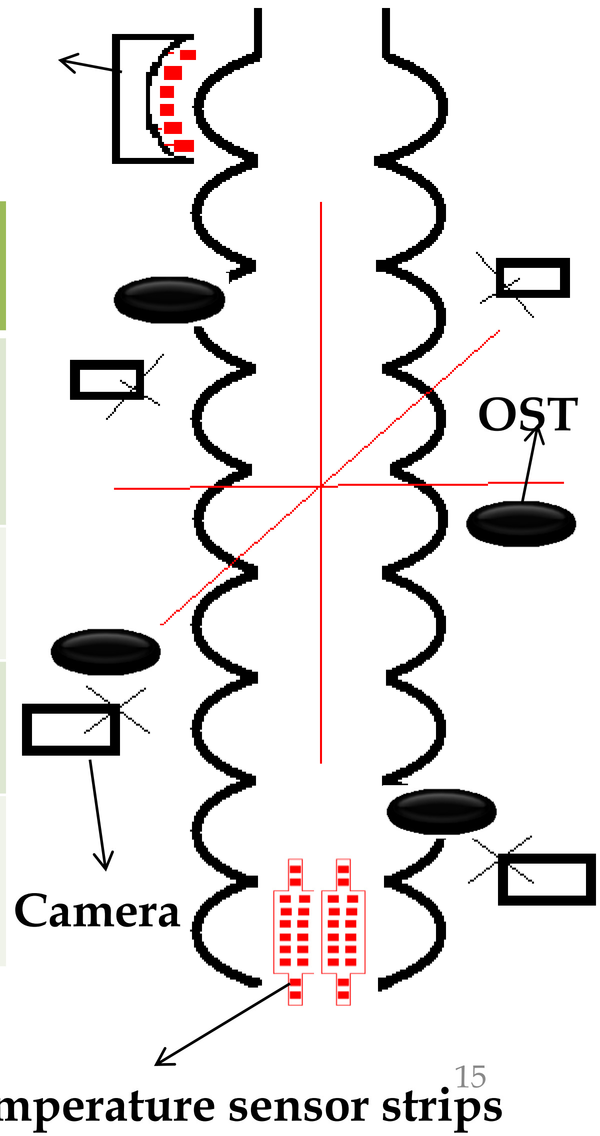
Bubble formation (nucleate boiling)

- around the heater area: heat accumulation→ boiling
- 4 Intensified charged-coupled device (CCD chip) (Extremely high sensitivity, used in night vision devices, for cryogenic use, in normal boiling He)
- 90 degree spacing



Summary

Signal	2nd sound	Temperature maps	X ray	Bubble formation
Equipment	OST	Fixed/ carbon resistors	Fixed/ photodiodes	ICCD camera
Thermal breakdown	✓	✓		✓
Field emission		✓	✓	
Helium needs	Superfluid	Subcooled (better sensitivity)	All He	Normal boiling He



Acknowledgements

- OSTs by Prof. Georg Hoffstätter, Dr. Zack Conway at Cornell University, Ithaca, N.Y. , USA
- TE-CRG/Cryolab: Johan Bremer and his team
- Supervisor: Dr. Wolfgang Weingarten
- Colleagues and former colleagues of BE-RF group

Q & A

Thank you very much!

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Back up slides

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Second sound extra

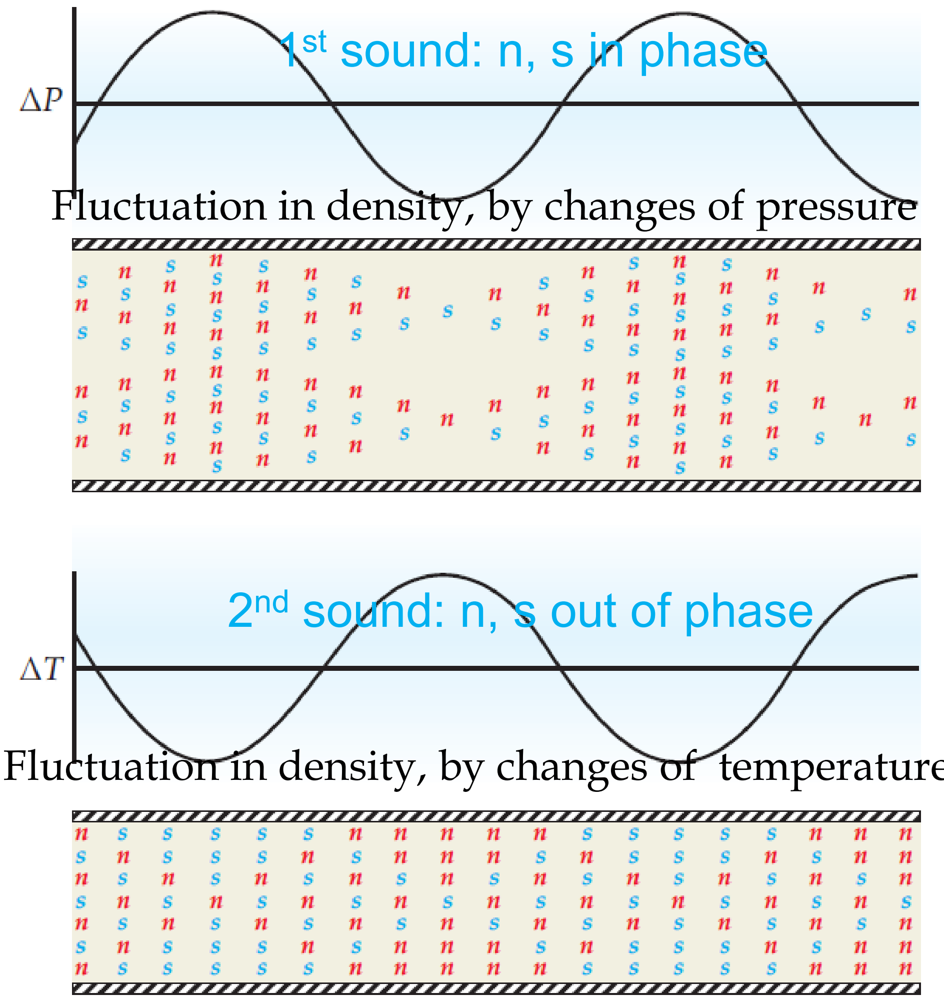
- Helium →Lambda point 2.17K → superfluid He
- 2 fluid model

Normal fluid Entropy, viscocity

- normal component + superfluid component

Bose-Einstein condensate

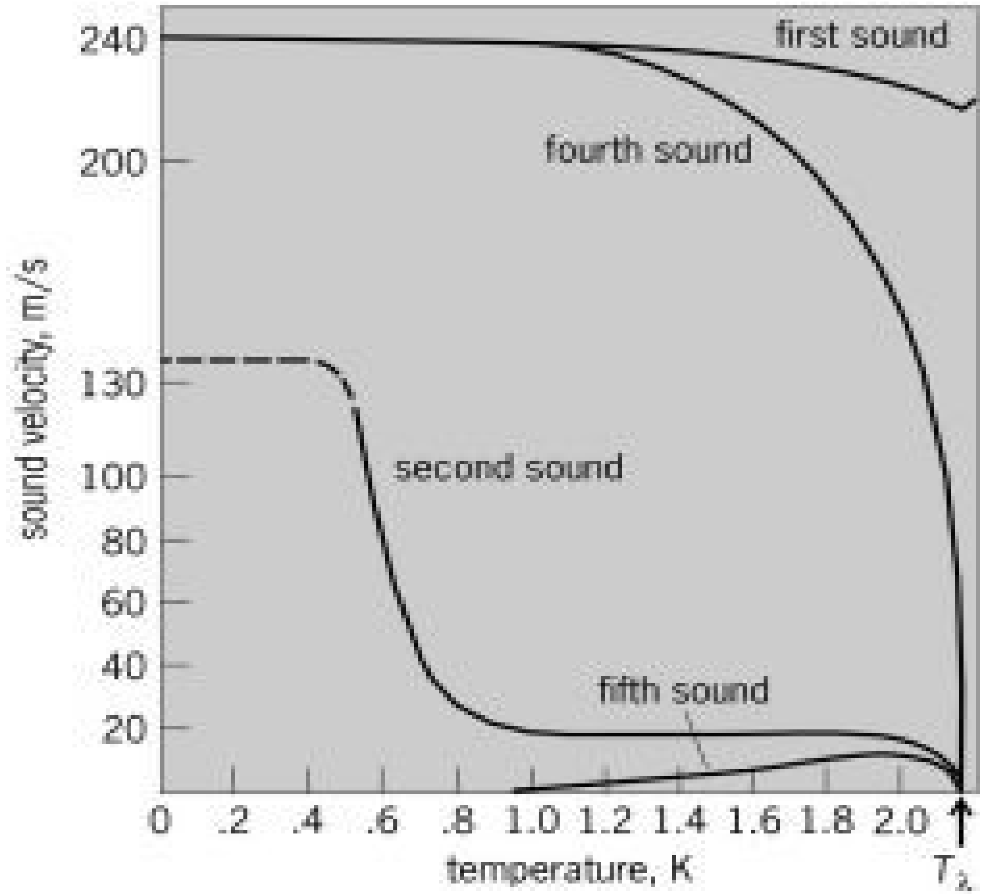
With no entropy, no viscosity

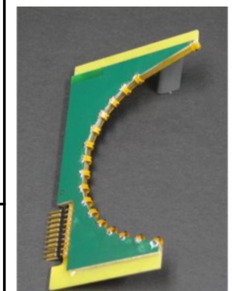
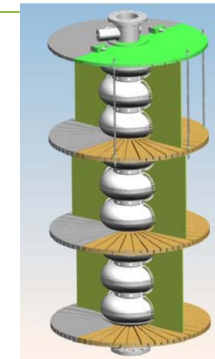
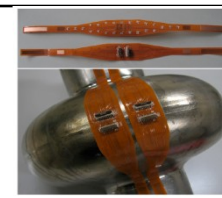
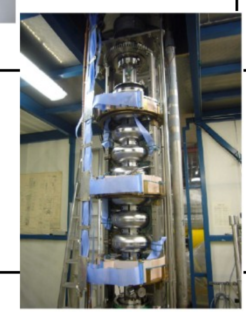


Source: R. Donnelly. Physics today 2009

Second sound and first sound below the lambda point

1. First sound- pressure wave
2. Second sound- entropy (temperature) wave
3. Third sound- wave travels in very thin films of helium in which the thickness of the film varies.
4. Fourth sound- pressure wave travels in superfluid helium. When its confined in a porous material.
5. Fifth sound- temperature wave that propagates in helium confined in superleaks. (analogous to second sound)



Defects diagnostics method	Sensor type	Temperature range	Sensitivity	Performance in Magnetic field	Mechanical layout	Multiplexing
Fixed (1 cell)	Carbon (Allen-Brad.)	1K-100K	with 10mK resolution	Small M field dependence	 	No
Fixed (9 cell)	Carbon (Allen-Brad.)	1K-100K	0.186mV/mK at 2 K			Yes
Fixed	Silicon diode	1.4K-500K	Nearly constant 2.3mV/K (S_D=-0.01 at1.4K)	Fair above T>60K		Yes, but not separate
High density (fixed strips)	Ruthenium Oxide (RuO_2)	0.01K-40K	Negligible for T>40K (S_D~-0.07) S_D~-0.5 at 1.4K	Good below 4K		Yes (CMOS)
Rotating ***	Carbon resistors	1K-100K	<5mK	Small M field dependence		-many cables that move around
Fast thermometry (equator & iris)	Cernox™	0.10K-325K	S_D=-1.6 at1.4K	Excellent above 1K		No, few cables

Sensor selection for temperature mappings

	Temperature range		Accuracy	Dimensionless sensitivity dR/R x T/dT			Price per unit
	Low	High		1.4	4.2	20	
Silicon diode**	1.4K	325K	±20mK(<10K); 55mK (10K~475K)	-0.01	-0.09	-0.29	USD$ 100~300
Cernox	0.3K	420K	±5mK (4,2K)	-1.6	-0.9	-0.59	USD$ 100~300
Germanium resistor	0.1K~1.4K	40K~100K	±5mK (<10K)	-0.93~-3.9	-0.73~-2.6	-0.62~-2.4	USD$100~300
Ruthenium Oxide (for cryogenic use)	0.05K	40K	±13mK (4.2K)	-0.47	-0.25	-0.07	USD$ 100~300

Adapted from Lakeshore datasheet document