High flux three dimensional heat transport in superfluid helium and its application to a trilateration algorithm for quench localization with OSTs

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Abstract

Oscillating superleak transducers of second sound can be used to localize quench spots on superconducting cavities by trilateration. However propagation speeds faster than the velocity of second sound are usually observed impeding the localization. Dedicated experiments show that the fast propagation cannot be correlated to the dependence of the velocity on the heat flux density, but rather to boiling effects in the vicinity of the hot spot. 17 OSTs were used to detect quenches on a 704 MHz one-cell elliptical cavity. Two different algorithms for quench localization have been tested and implemented in a computer program enabling direct crosschecks. The new algorithm gives more consistent results for different OST signals analyzed for the same quench spot.

Motivation

Quench positions on cavities can be obtained with OSTs by trilateration, however

- Spheres do sometimes not overlap or even reach the surface
  - What is the origin of this faster than second sound?
  - Is there additional information in the OST signal that can be used to localize the quench?
- DESY has developed a software with an algorithm using a restriction on the surface
  - Works well for elliptical cavities if the quench spots are close to the equator
  - Application to non-elliptical cavities is not obvious

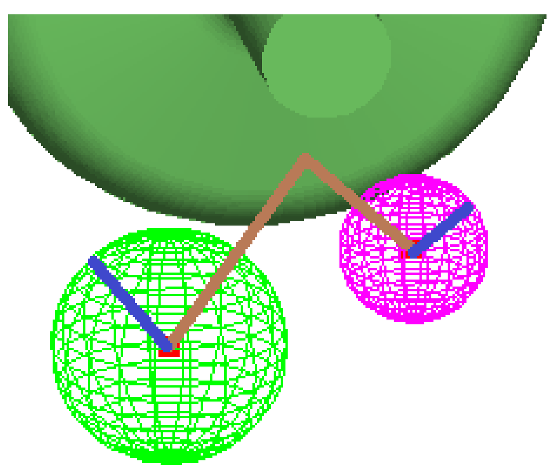


Figure 1: Quench measurement with two OSTs on an elliptical single cell cavity. The red points show the detector positions. Spheres are calculated from literature values of second sound. Note that the spheres do neither intersect nor touch the cavity surface. Desy uses an algorithm that minimizes the distance from the spheres to the cavity surface to find the quench spot (brown lines)

Dependence of the second sound velocity on the heat flux density in the two and three dimensions

- Measurements with constant heat flux in channels show that the speed of second sound v_2 depends on the heat flux density (Fig. 2)
- At 1.873 K v_2 is independent of the heat flux density
- In the three dimensional setup we see that v_2 is always above $v_{2,0}$ (Fig. 3)
- → Other effects like boiling, faster heat transport inside the niobium must be the reason for the fast heat transport observed for cavity quenches

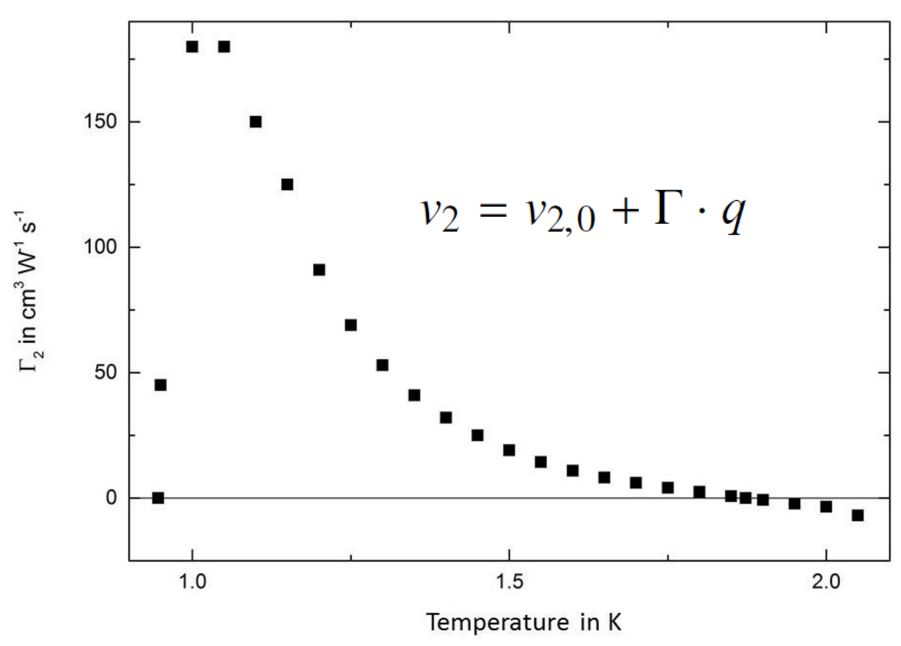


Figure 2: Plot of measurement data of the heat flux amplitude factor Γ by Dessler and Fairbank. Important temperature for our investigation is the change in sign at T=1.873 K

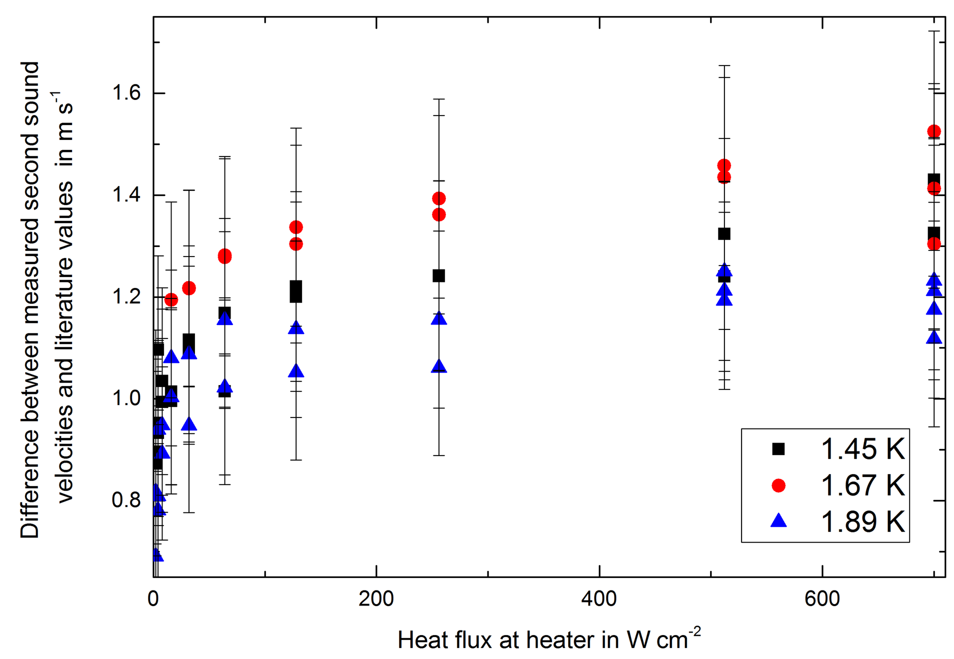


Figure 3: Difference between the measured second sound velocity and the literature data versus applied heating flux densities. Data are shown for one OST at 5 cm distance directly facing the heat source.

Angular dependence of the second sound signal

- The angle between OST and heat source is directly related to the slope *dV/dt* of the obtained signal
- Can be used as a crosscheck for quench data

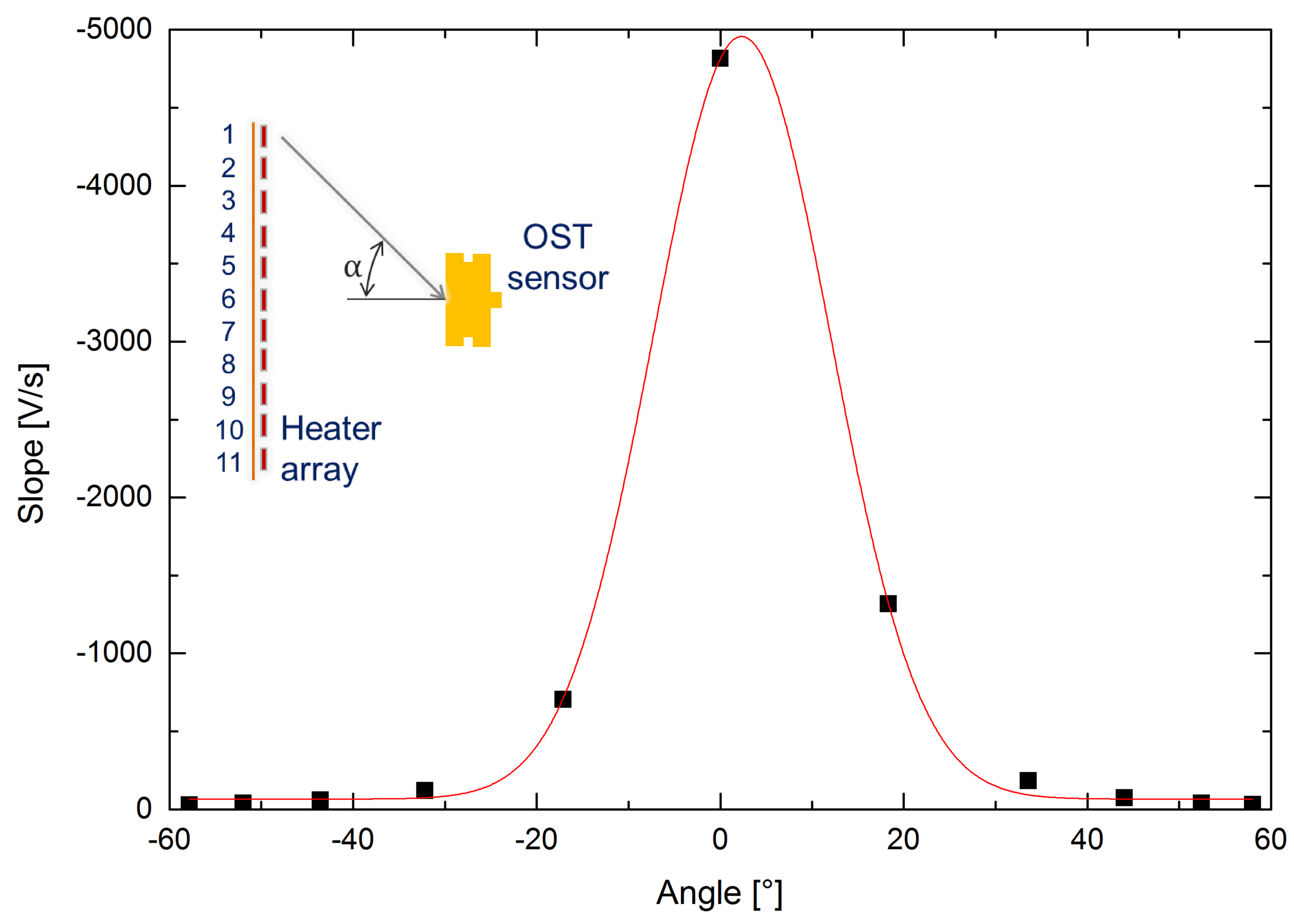


Figure 4: Measured slope of the OST signal dependent on the incident angle to the membrane of the OST. Inset: Schematic of the experimental set-up to test the influence of the inclination angle of the second sound wave on the OST membrane.

A software for quench localization for arbitrary cavity shapes

- Direct import of CAD models
- Two Algorithms for quench location implemented:
  - Algorithm I from DESY (Fig. 1)
  - Algorithm II developed at CERN (Fig. 5)

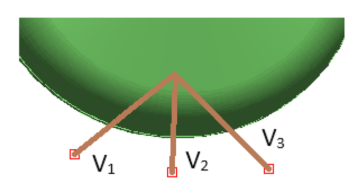
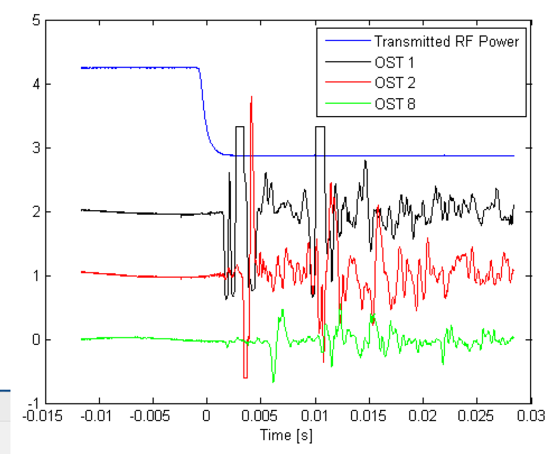


Figure 5: Algorithm II: For every detector it calculates the distance to each surface point and the velocity from the running time. Then the standard deviation (SD) of the velocities for all detectors are calculated for every point. The vertex with the smallest SD is the quench spot.



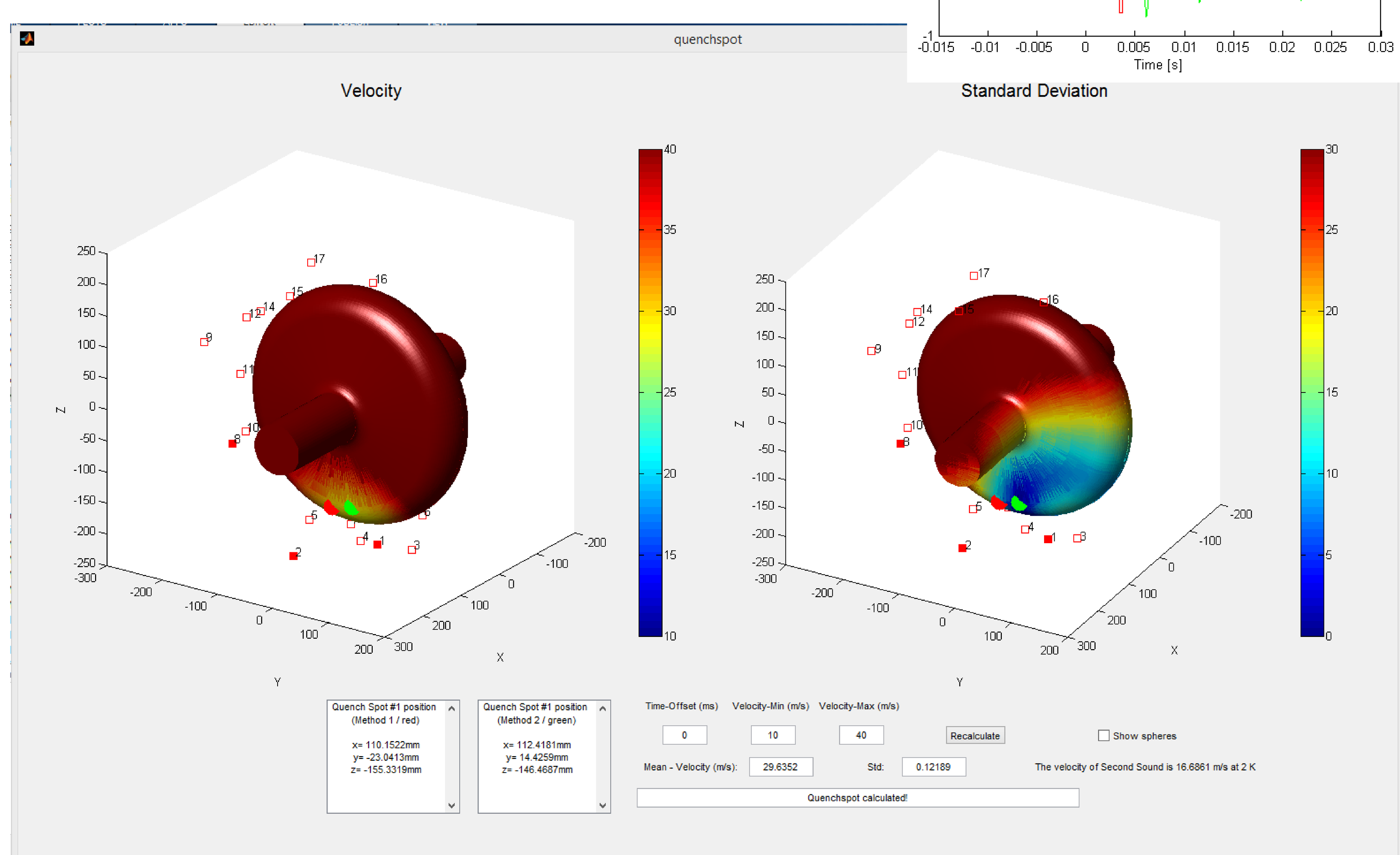


Figure 6: Output window of the quench localisation software. Red/Green dot is the quench spot as predicted by Algorithm I/II. Signals from OST 1,2 and 8 were used for localisation (closed symbols). OST data is shown in upper picture. The slope in the data is consistent with the wider angle between quench spot and detector 8.

Acknowledgement

The authors would like to thank Ricarda Laasch from DESY for providing the Matlab software on which our computer program is based.