Arrival Time of He-II Second Sound Waves for Quench Detection in Superconducting Cavities.

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Abstract

Currently improvement of the superconducting cavities is essential for the development of new and more powerful accelerators. Tracking the quench induced in niobium surfaces its fundamental in order to achieve a gradient exceeding 30MV/m. Automate the detection process becomes an important task as the XFEL foreseen to need 800 cavities. Also this are the cavities of choice for the ILC. A program to get the arrival times of second sound waves caused for the gradient of temperature is presented here.

1 Motivation

To date the main obstacle in achieving a gradient exceeding 30MV/m is the quench induced in surface structures in the niobium.

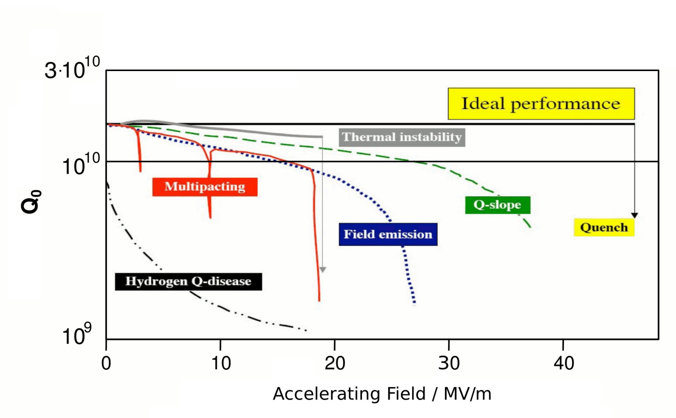

Figure 1: Limitations for the accelerating field.

Most of the limitations that one can found are understood and solvable (figure 1), either on the cavity processing or while booting the accelerator. But the local thermal instability produced by a quench is still under investigation.

The current method to localize the origin of a quench is rather cumbersome and slow. The occurrence of a quench is evident as the operating properties of the cavity change radically. But the actual tracking of the origin involve 116 carbon resistors mounted on the cavity surface, this resistors can be rotated 360° azimuthally around the cavity. This resistors make an exhaustive temperature mapping at the 9 cells of the surface cavity simultaneously.

This procedure takes a considerably amount of time, first mounting the resistors (and afterwards unmounting) for each cavity. Consequently the profiling measurements with the rotating temperature mapping system takes about an hour and a half per mode.

While with second sound waves one must set-up the OST once and the test only takes some minutes. One can achieve a resolution of about 1mm, a big improvement over the temperature mapping.

2 Second sound waves in He-II and experimental setup

The flow of He-II acts as if it were a mixture of two fluids. The superfluid, has no viscosity or entropy and can flow without dissipation through extremely narrow channels. The normal fluid has a finite viscosity and carries all the entropy.

The superfluid is viewed as a background fluid that is, in effect, at absolute zero. The normal fluid is the sum of elementary excitations, or quasiparticles, which are excited from the superfluid in increasing number as the temperature is increased from absolute zero. Second sound can be generated by any means that separates the motion of normal fluid and superfluid.

First sound is ordinary sound, which consists of fluctuations in total density. It's velocity is only weakly dependent on temperature. Second sound has a velocity that is a strong function of temperature, becoming zero at the lambda point. Second sound consists of fluctuations in entropy or temperature, and is carried by the normal fluid. One important thing to notice is that in first sound the proportion between normal and superfluid particles doesn't change, and that the two components move in phase with each other while in second sound the components are out of phase.

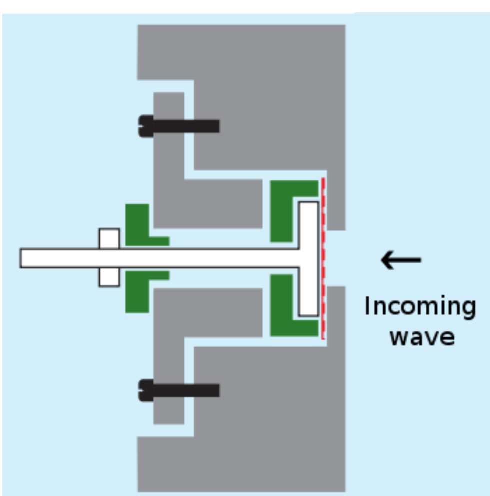

Figure 2: Side view of a OST, filter in red, frame in gray, insulators in green and a fix rod and button in white.

The Oscillating Superleak Transducers (figure 2) consists of filter, a plastic film with micron-size holes created by fission fragments in a reactor. The filter (red) is plated with gold on one side to make a capacitor "loudspeaker". The frame (gray) is connected to a bias voltage and connected to ground by a large capacitor, the rod and button (white) are insulated electrically (green) and connected to an oscillator, and the whole apparatus is immersed in a bath of He-II.

The normal fluid cannot pass through the film's holes, but the superfluid can, so upon arrival of a second sound wave the superfluid will go trough the filter hence making the membrane to bend and start oscillating as a result of the flowing He-II, this causes changes in the capacity. So the transducer can act as a detector for second sound.

One uses a set of eight OST (figure 3) to cover the surface of the superconducting cavity, at least three signals and a surface constraint are needed to track the source of the wave.

3 The program

The data retrieved from the measurements consists of a matrix of ten columns the first column is the time, then the quench and the successive contains the output of the each OST.

The program was written in *MatLab*, it consists of two parts, the first stores the variables involved and plots the data of the quench and the OST's, in order to choose which OST register a signal, not all the OST have a clear output of the wave but instead are just noise.

On the second part the respective OST must be chosen as part of the arguments of the MatLab function. The program will make the computation, store the results and make a new plot showing the points used to make the calculations.

For the OST-data the program looks for the minimum value, as that is what characterises the occurrence of a wave. After the minimum the signal will start to oscillate in a damping fashion. Later the program looks for the moment when the quench occurs, i.e. when the "step" takes place. For doing so the program starts from the last-minus-twenty data point and checks if the slope to the right is increasing, and if the slope to the left is decreasing. If so it will enter a loop that will confirm that all the points in between have the same properties. This verification is needed as the data jitters. If the point fulfills the properties it will be stored. If it finds another point this will be stored instead. On the end it will store the first point of the step.

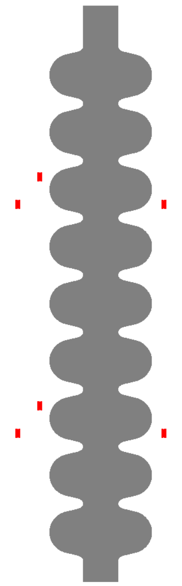

Figure 3: Scheme of a second sound setup: 9-cell cavity and 8 OST's.

A characteristic result is:

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The times for the waves to arrive, from the file
AC126_49_20100503T151022.csv are:
 micx: 0.0097
 micy: 0.0091
 micz: 0.0652
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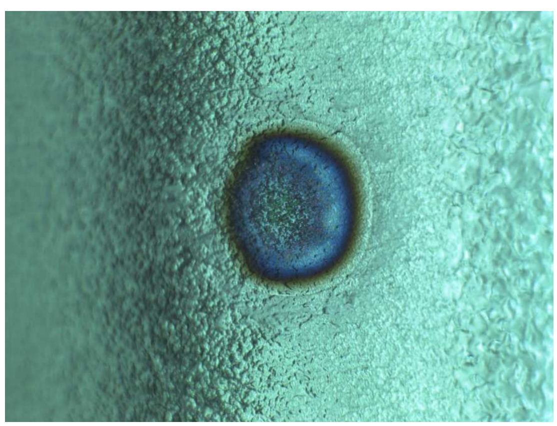
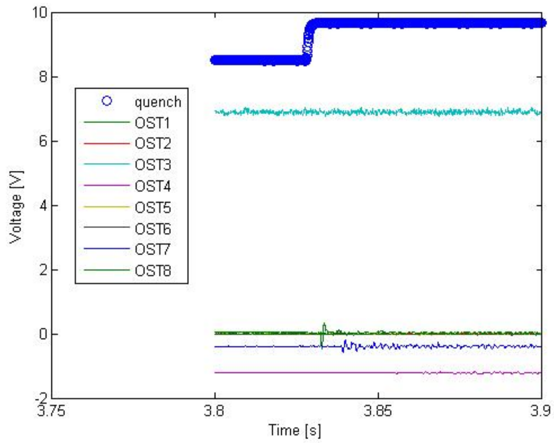
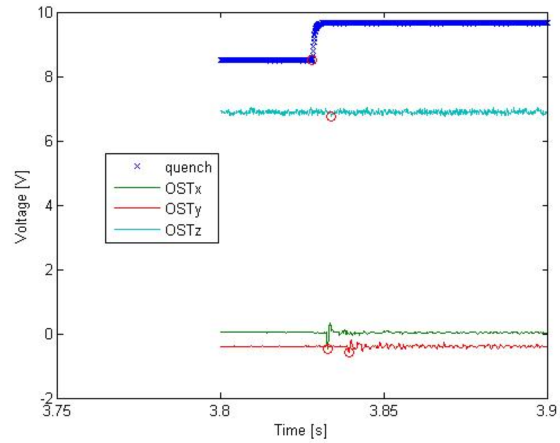


Figure 4: Photograph of a defect.



(a) First output



(b) Second output

Figure 5: Plots obtained from the program, the first to choose the correct data set and the second to show the data points used to compute the times.

4 Outlook

It's necessary to keep on researching on how to avoid, track and correct defects on the superconducting cavities as this are a main limitation for obtaining high gradient fields.

The methods for doing so must be simple, reliable, fast and economical as there will be a massive production of cavities for the XFEL. Whenever possible, the process must be automated.

References

[1] F. Schlander et al., "Progress on Diagnostic Tools for Superconducting High-Gradients Cavities", LINAC'10, Tokyo, September 10, (to be published)

[2] Z.A. Conway et al., "Oscillating Superleak Transducers for Quench Detection in Superconducting ILC Cavities cooled with He-II", LINAC '08, Vancouver, September 2008.

[3] R.J. Donnelly, "The two-fluid theory and second sound in liquid helium", American Institute of Physics, October 2009.