COMMISSIONING CORNELL OSTS FOR SRF CAVITY QUENCH IDENTIFICATION AT JLAB*

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Abstract

Understanding the current quench limitations in SRF cavities is a topic essential for any SRF accelerator that requires high fields. This understanding crucially depends on quench localization. Second sound quench detection in superfluid liquid helium with oscillating superleak transducers (OSTs) is a technique recently applied at Cornell University as a fast and versatile method for quench localization in SRF cavities [1]. Having adopted Cornell design, we report in this contribution on our experience with OSTs for quench localization in different cavities at JLab.

INTRODUCTION

The International Linear Collider (ILC) reference design report specifies $Q_0 = 8 \cdot 10^9$ at $E_{acc} = 35$ MV/m as the acceptance criterion in the vertical acceptance tests of 9-cell ILC cavities. This specification is the current state of art in superconducting RF and presents a challenge to cavity vendors. Many of the produced cavities fail to meet this specification because of quenches. Understanding of the quench limitation is a scientific challenge pursued by many SRF groups, which rely heavily on thermometry for quench localization on the cavity surface and thermal characterization of lossy regions.

Recently, detection of second sound wave from quench with oscillating superleak transducers was put forward at Cornell University as another tool for quench localization. Unlike thermometry, second sound time-of-flight measurements do not provide information on heat distribution and preheating field dependence in the quench region, however, second sound detection also is not limited to a particular cavity shape and can be used for virtually any cavity testing in superfluid helium. Many SRF laboratories around the world adopted this technique. In this contribution we discuss our experience with OSTs.

EXPERIMENTAL SETUP

For the second sound detection system we have adopted Cornell design. Dr. Zachary Conway kindly provided us with 16 OSTs built at Cornell University. For standard ILC tests we attach 8 OSTs onto the standard JLab cage around the cavity, Fig. 1. The OSTs are connected with RG-174 cable to a 120 volts-biased amplifier outside the dewar. The amplified signal is then fed into TDS2024B oscilloscopes. For quench location determination after the test we use the

Figure 1: For the standard ILC RF test 8 OSTS are attached to the standard JLab cage around the cavity. Two more OSTs are behind the cavity and cannot be seen on this picture.

Cornell ”wire” method: second sound time-of-flight measurement is determined for each OST trace, the distance to the quench origin is calculated from time-of-flight and second sound velocity for each OST, then wires are cut to the corresponding length and attached to respective OSTs, finally, the point where all wires converge is the quench origin [2].

RESULTS AND DISCUSSION

Second sound system was routinely used for SRF testing of 9-cell cavities since September 2010. OSTs were used at JLab to locate quenches in TB9RI019, TB9RI027,

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TB9NR001, Jlab LG-1, PKU2, Seamless DESY 9-cell as well as in ICHIRO-07, MHI-08, and IHEP-01 where our 2-cell thermometry cannot be attached. We also used OSTs during 3.5 cell gun cavity and the crab cavity. In several cases we found and marked all limiting defects for all pass-bands in one RF test. In Fig. 2 second sound detection data for π-mode quench in DESY Seamless 9-cell is plotted for some of the OSTs. In general, OST signals converged to an

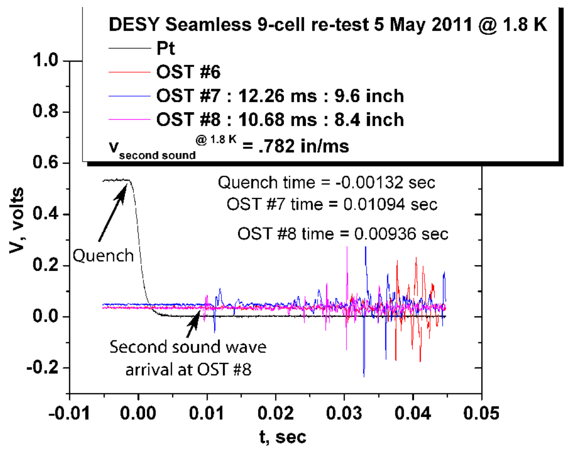

Figure 2: π-mode quench OST data in DESY Seamless 9-cell. Black line is the transmitted power trace. Red, blue, and magenta lines are the OST data.

area of about 1 inch in ILC cavity tests, however, in some cases the convergence was worse spanning area of a few inches.

Although OST system is not limited to a particular cavity shape, analysis of the results for cavities other than ILC-like proved to be difficult. In Fig. 3 we plot OST results for crab cavity measurements [3]. Only one of the four detectors put around the cavity showed a reproducible signal, which is indicated in the picture. We believe that we've seen only one signal barely above noise floor on only one of the OSTs, because the stored energy dissipated during quench in this test was only 0.1 J, which more than two orders of magnitude lower than tens of Joules, typically measured in ILC-shape cavities. The trace on the oscilloscope was identified as the time of second sound wave front arrival at OST. Following the standard procedure, from the time-of-flight and the second sound velocity, we calculated the distance from the OST to the quench origin. The cavity was inspected after the test and we tried to find possible quench origin locations on the cavity. It turned out that the only location that satisfied calculated distance from OST to quench origin was the edge of one of the cavity flanges. Although we have never done thermometry on this region, the field is very low there, therefore, it is unlikely to be the source of the quench.

This result could be understood if what was identified as the second sound wave front arrival was not the wave front arrival. In Fig. 2 one clearly see second sound wave front arrival, however, one can also notice that the first arrival is

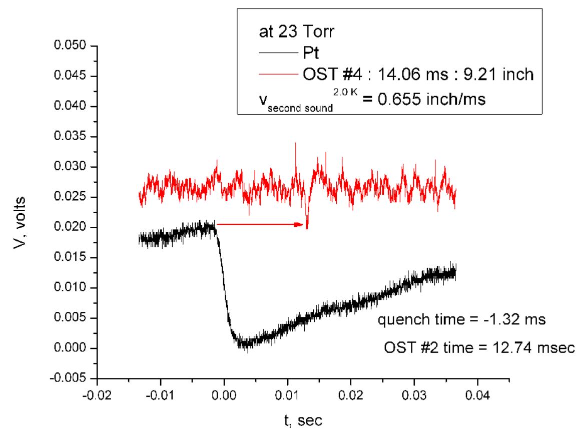

Figure 3: OST results for crab cavity measurements. Black line is the transmitted power trace. Red line is the OST data.

not the strongest signal: upon wave arrival at $\tau \cong 10$ msec the voltage across OST #8 drops from about 30 mV to -14 mV, but it is not the strongest signal, about 20 msec later at $\tau \cong 30$ msec the OST #8 register voltage below -130 mV. Since one would expect the signal to dissipate and lose energy as the wave expands, this stronger signal is hard to explain as the product of the original wave after reflections of different surfaces. With this data in mind we speculate that the signal barely above noise floor that we saw during the crab cavity measurements was not the second sound wave front arrival, but the second sound wave front arrival was hidden by the background noise.

Our experience with crab cavity suggest that OST detection technique need to be improved and better understood to give reliable results with non-ILC-like cavities. In our experiments we noticed that we get a better signal-to-noise ratio by reducing the temperature from the standard for ILC testing $T_{LHe\ bath}$ = 2.0 K to 1.8 K. In Fig. 4 we plot comparison of $T_{LHe\ bath}$ = 2.0 and 1.8 K measurement for the same quench in MHI #8. By going to a lower temperature signal is improved by a factor of two. But experience with crab cavity suggests that factor of two is not enough and rather an order of magnitude improvement is needed, if one wants resolve low energy quenches. Therefore, one possible future directions is modification of OST sensor to improve sensitivity. The other is simulation of second wave propagation from quench origin to OST sensor.

CONCLUSION

Having adopted Cornell design, we commissioned OST system for ILC cavity testing at Jefferson Lab. OSTs were used to locate quenches in π mode and other pass-band modes in TB9RI019, TB9RI027, TB9NR001, Jlab LG-1, PKU2, Seamless DESY 9-cell as well as in ICHIRO-07, MHI-08, and IHEP-01, where our 2-cell thermometry cannot be attached. We also used OSTs during 3.5 cell gun cavity and the crab cavity, however, interpretation of the

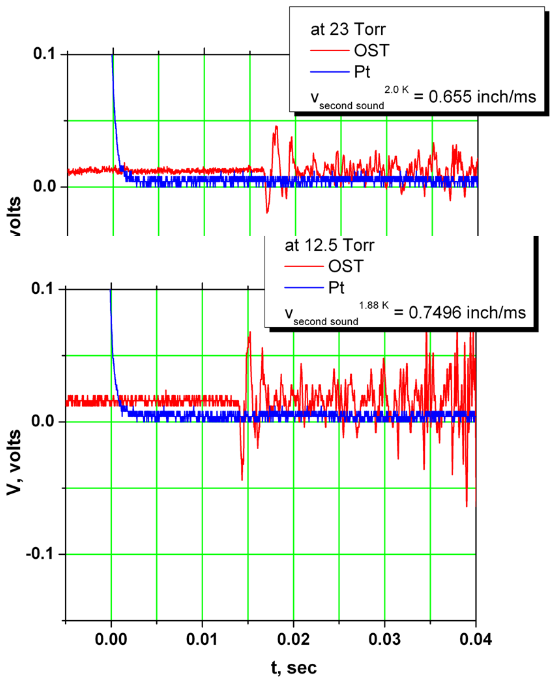

Figure 4: Comparison 2.0 and 1.8 K data for the same quench. In the top plot the red line is data captured with OST during MHI #8 quench at 2.0 K, the signal is about 55 mV top to bottom. In the bottom the same quench captured by the same OST at 1.8 K, the signal is 110 mV top to bottom.

measurements in these cavities proved to be difficult. Possible future directions are modification of OST sensor to improve sensitivity and simulation of second wave propagation from quench origin to OST sensor to improve resolution.

ACKNOWLEDGEMENT

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[1] Dr. Zachary Conway is now at Argonne National Laboratory