Quench studies for ILC cavities

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ABSTRACT: Quench limits accelerating gradient in SRF cavities to a gradient lower than theoretically expected for superconducting niobium. Identification of the quenching site with thermometry and OST, optical inspection, and replica of the culprit is an ongoing effort at Jefferson Lab aimed at better understanding of this limiting phenomenon. In this poster we summarize experiments that have been and are being developed at JLab for quench studies and highlight some of our findings with several SRF cavities that were limited by quench.

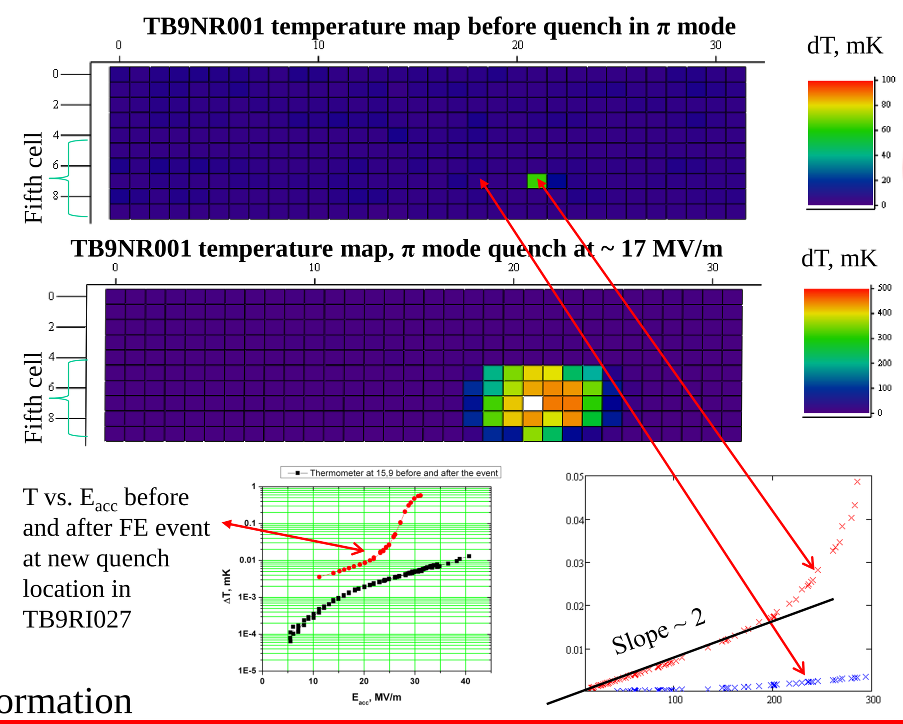
Quench localization

Thermometry

We routinely use 2-cell thermometry for quench localization and pre-heating characterization:

- Quench location was identified in TB9RI027 and quench location move to a different location after field emission event was recorded. The change in temperature rise vs. field was also measured before and after the event, which led us to believe that niobium surface modification may be involved into the field emission event.
- Twin defect was identified in TB9NR001 on the equator weld, and the preheating data shows deviation from quadratic behavior starting from about 14 MV/m with quench at about 17 MV/m
- Quench location were identified in TB9RI019 and JLab LG-1

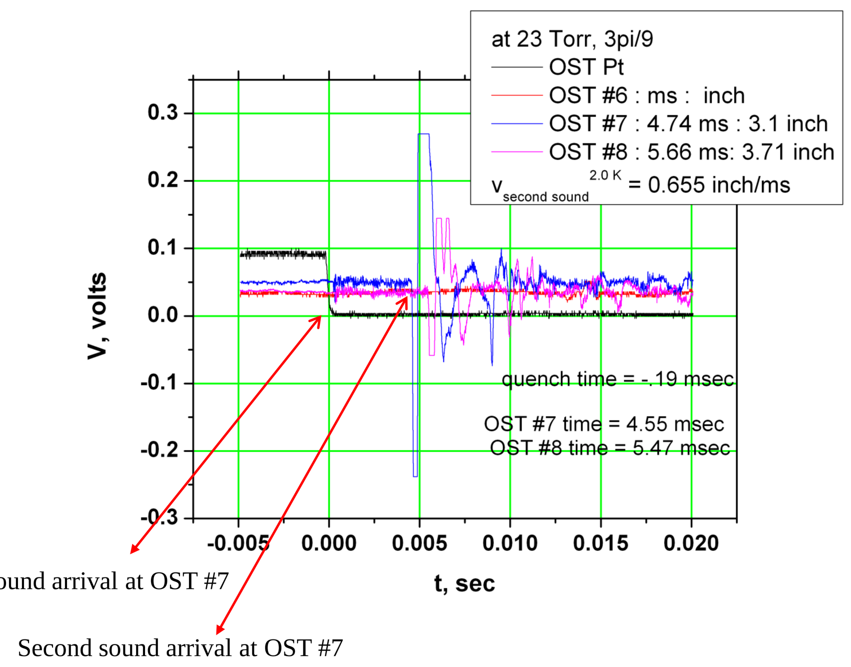
Please, see our poster THPO005 for more information



OST

Second sound quench detection in superfluid helium with superleak oscillating transducers (OSTs) was recently introduced by the SRF group at Cornell University. OSTs offer unique advantage compared to the conventional thermometry that they are not limited to a particular cavity shape and can be used for virtually any cavity testing in superfluid helium.

- OSTs were used to locate quenches in TB9RI019, TB9RI027, TB9NR001, Jlab LG-1, PKU2, Seamless DESY 9-cell as well as in ICHIRO-07 and MHI-08 where our 2-cell thermometry cannot be attached. We also attempted to locate quenches in 3.5 cell cavity and crab cavity.
- When detectors were close to quench location we also observed first sound arrival.



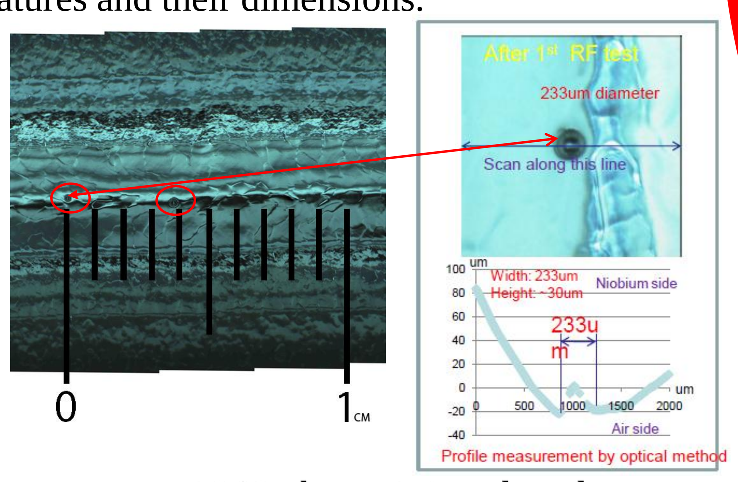
Please, see our poster THPO0029 for more information

Quench characterization

Optical inspection

Part of the defect identification and characterization is optical inspection. Many defects that cause quench are visible geometrical features on the inner surface that can be resolved with optical inspection systems. These systems provide information on the location of the features and their dimensions.

Twin cat-eye feature in TB9NR001 was found with the optical inspection system at the predicted quench location



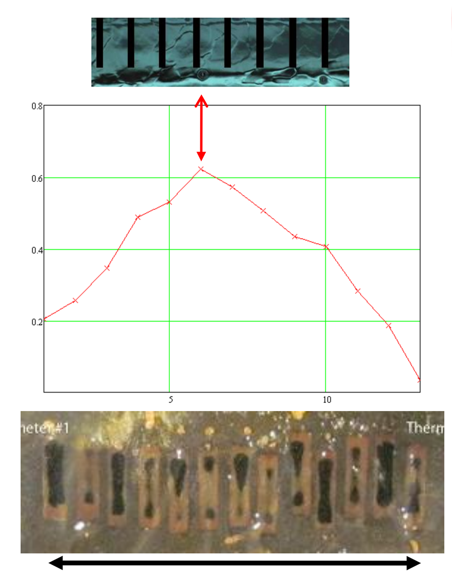
Please, see the posters THPO027 by J. Dai et al. and THPO036 by R. L. Geng et al. for more information

High resolution thermometry

2-cell ILC shape conventional thermometry as well as newly-built high resolution thermometry has been used to characterize quenches and quench preheating:

- Preheating before and after high field FE event in TB9RI027 has been recorded with the 2-cell thermometry;
- Heating distribution and field dependence at the artificial geometrical defect in C1-3 cavity was measured with high resolution thermometry;
- Larger pit of twin cat-eye feature in TB9NR001 was identified as the culprit causing quench at 17 MV/m in π mode and pre-heating field dependence for both pits was measured

Please, see the posters THPO019 by A. D. Palczewski et al. for more information

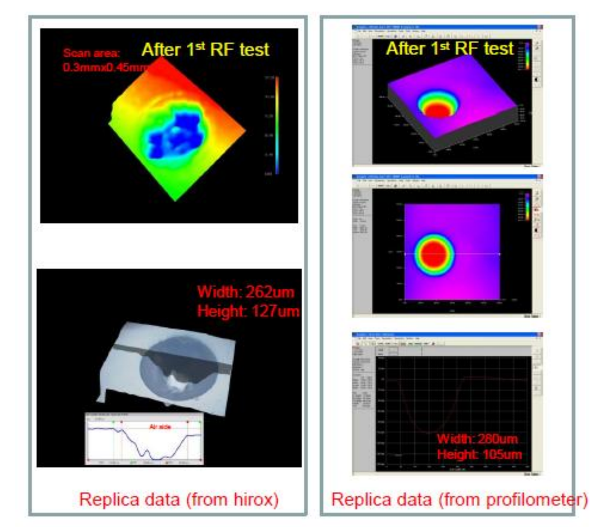


13 A-B resistors in 16 mm

Replica

Using the replica material kindly provided to us by Dr. Furuta from KEK* we characterized several topological features:

- Twin cat-eye defect in TB9NR001 was replicated and measured with profilometer;
- Several defects in PKU2 were measured;



Please, see the posters THPO027 by J. Dai et al. for more information

*Dr. Furuta is now with SRF group at Cornell University

Quench understanding

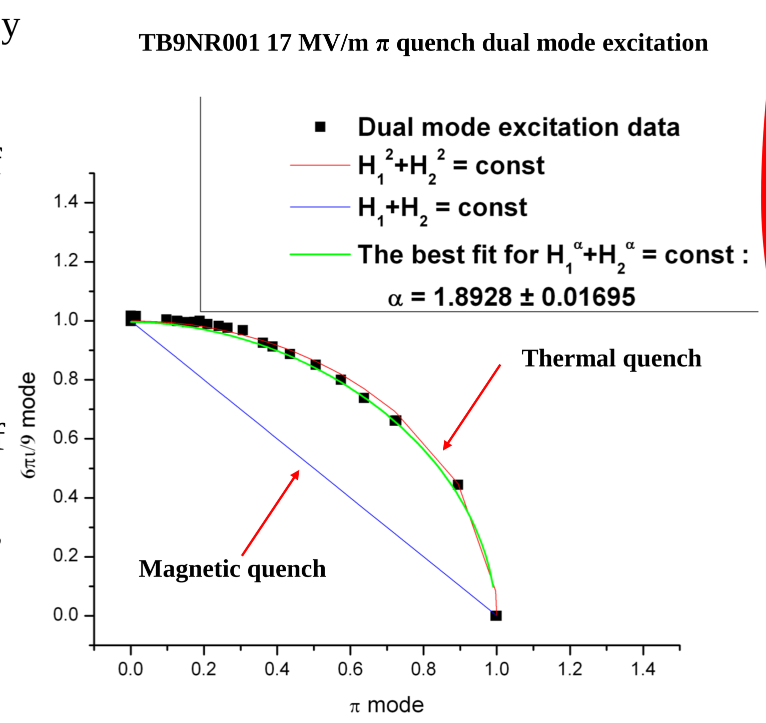
Dual mode excitation

The idea is to excite two modes in the 9-cell cavity limited by the same quench. Depending on the nature of the quench we expect two scenarios:

1. If it is a thermal quench, then the limitation during excitation of two modes will be $H_1^2 + H_2^2$, where H_1 and H_2 are fields in each mode;
2. If it is a magnetic quench, then the scaling will be $H_1 + H_2$.

- Total 7 defects were measured with this technique in PKU2, Jlab LG-1, and TB9NR001;
- Quench in Jlab LG-1 in 8pi/9 mode at 40.5 MV/m has exponent of 1.50 ± 0.04, indicating that it is not a magnetic quench;
- π mode limiting defect in TB9NR001 has exponent of 1.91 ± 0.03, which is the closest to thermal quench exponent we’ve measured so far.

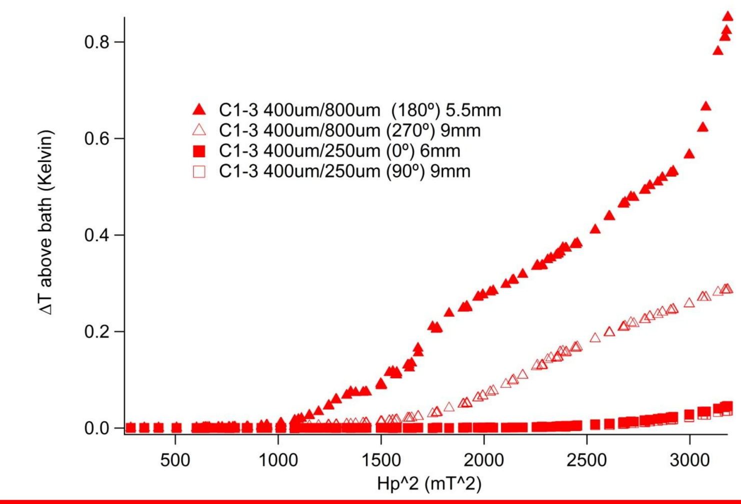
Please, see our poster THPO017 for more information



Artificial defects

Contamination, surface features, local field enhancement, etc., can lead to suppressed superconductivity that will limit the achievable gradient. In order to gain insight into contribution to quench from topological features four pits with well-defined geometry were created on the inner surface of a 1.5 GHz CEBAF-shaped cavity.

- The cavity was limited at 13 MV/m by a deeper pit in the high magnetic field region;
- Field dependence of quality factor, local heating with conventional thermometry as well as local heating around limiting defect with high resolution thermometry were measured and compared to calculations.



Please, see the poster THPO020 by J. Dai et al. for more information.

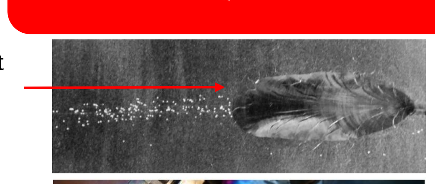
Quench mitigation

EB re-melting

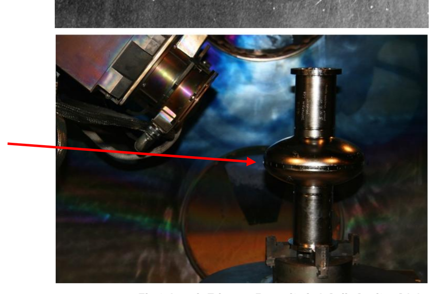
Type-I quench location often coincides with a single topological feature on the inside surface of 9-cell ILC cavities. Electron beam re-melting at the identified quench location is an ongoing effort at Jefferson lab.

- Several 1-cell cavities with known defect having repaired using this technique resulting in Q_0 and accelerating gradient improvement.
- The accelerating gradient in C1-1 cavity after EB repair and 5 µm BCP has improved from 17 MV/m to 27 MV/m.
- We also collaborate with KEK and Femilab on local grinding mechanical repair and centrifugal barrel polishing, respectively.

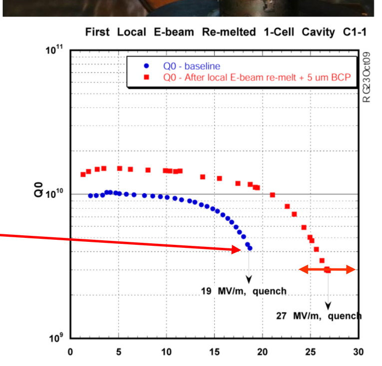
EB re-melting test on a sample showing pit removal



Single cell EB re-melting setup



After EB re-melting the quench field improved from 19 MV/m to 27 MV/m



Please, check the contribution TUPO029 by R. L. Geng et al. for more information.

Centrifugal barrel polishing

Often the number of features revealed by the visual inspection on the surface is too many for a local mechanical grinding. In such cases centrifugal barrel polishing can produced mirror-like surface over the whole surface area, as was recently demonstrated at Fermilab. We are working towards turning existing JLab centrifugal barrel polishing machine into a convenient tool for resetting surface of problematic cavities.

- Preliminary studies have been done on samples to measure the residual contamination and roughness of the surface following Fermilab’s recipe;
- 6 new 1-cell cavities are being made for CBP optimization as a part of ICP development at JLab.

MFI CBP machine at JLab

Sample holder SS cavity made by P. Kneisel

Please, see the poster THPO071 by A. D. Palczewski et al. for more information.

CONCLUSION: In this contribution we summarized experiments that have been and are being developed at JLab for quench studies. Quench identification with thermometry and second sound, quench characterization with optical inspection, thermometry, and replica are standard processes at JLab aimed at understanding quenches. Recently developed high resolution thermometry was specifically created for quench region heat evolution and high resolution quench spot characterization. Dual mode excitation and artificial pits measurements were designed to probe the nature of quench and experimentally evaluate contribution from topology to quench. Studies under way to develop quench mitigation techniques, such as electron beam remelting and centrifugal barrel polishing.

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