

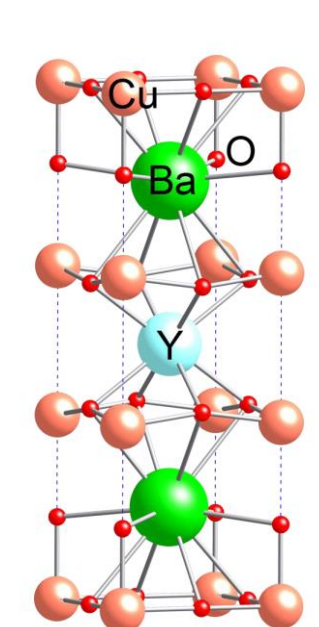
Quench Propagation On Rare-Earth Barium Copper Oxide (REBCO) Tape

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Introduction

Rare Earth Barium Copper Oxide (REBCO) is a high-temperature superconducting material that has zero electrical resistance. A quench occurs when a section of the superconductor suddenly transitions to a resistive state after exceeding its critical current. This localized loss of superconductivity generates a voltage rise, serving as an essential signal for quench detection and protection. [1] [2]

While capable of carrying extremely high currents, REBCO is mechanically brittle and has slow quench propagation which makes voltage change difficult to detect [1] [2]



Rare-earth elements in REBCO are Yttrium, Gadolinium, Lanthanum

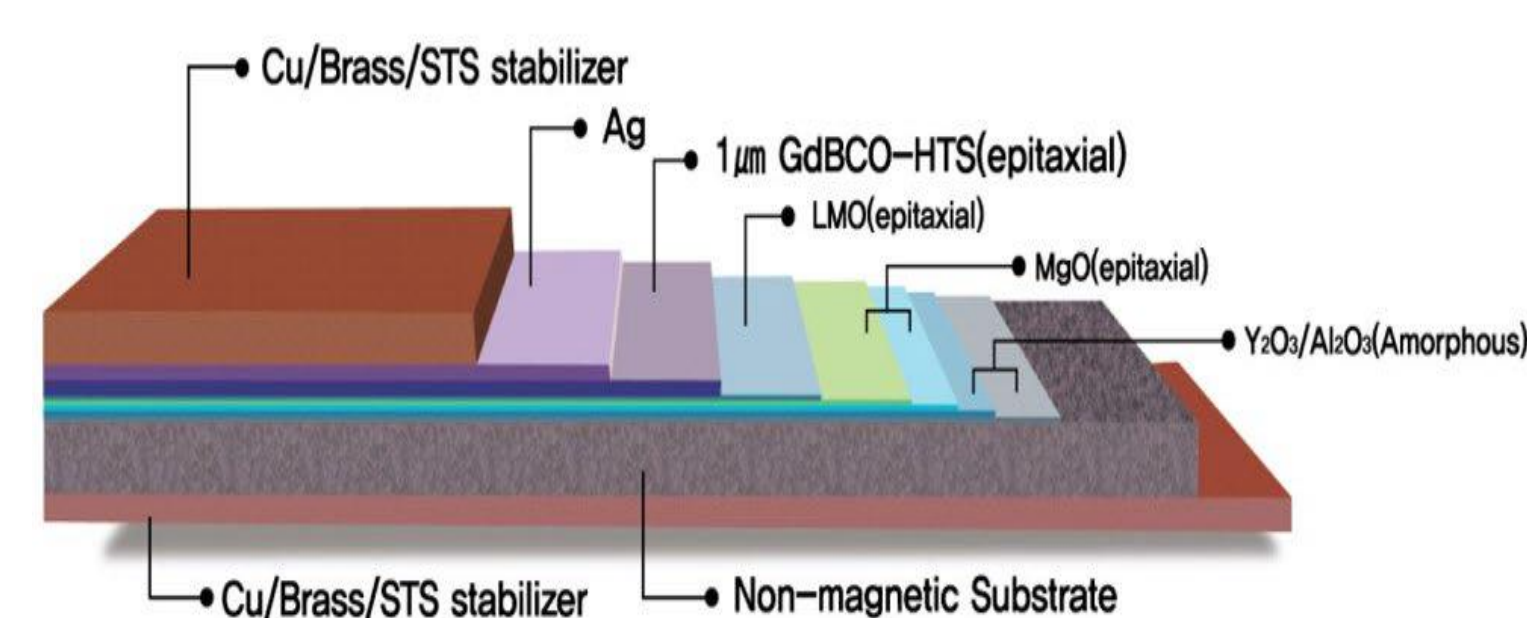


Figure 1: Structure of REBCO tape

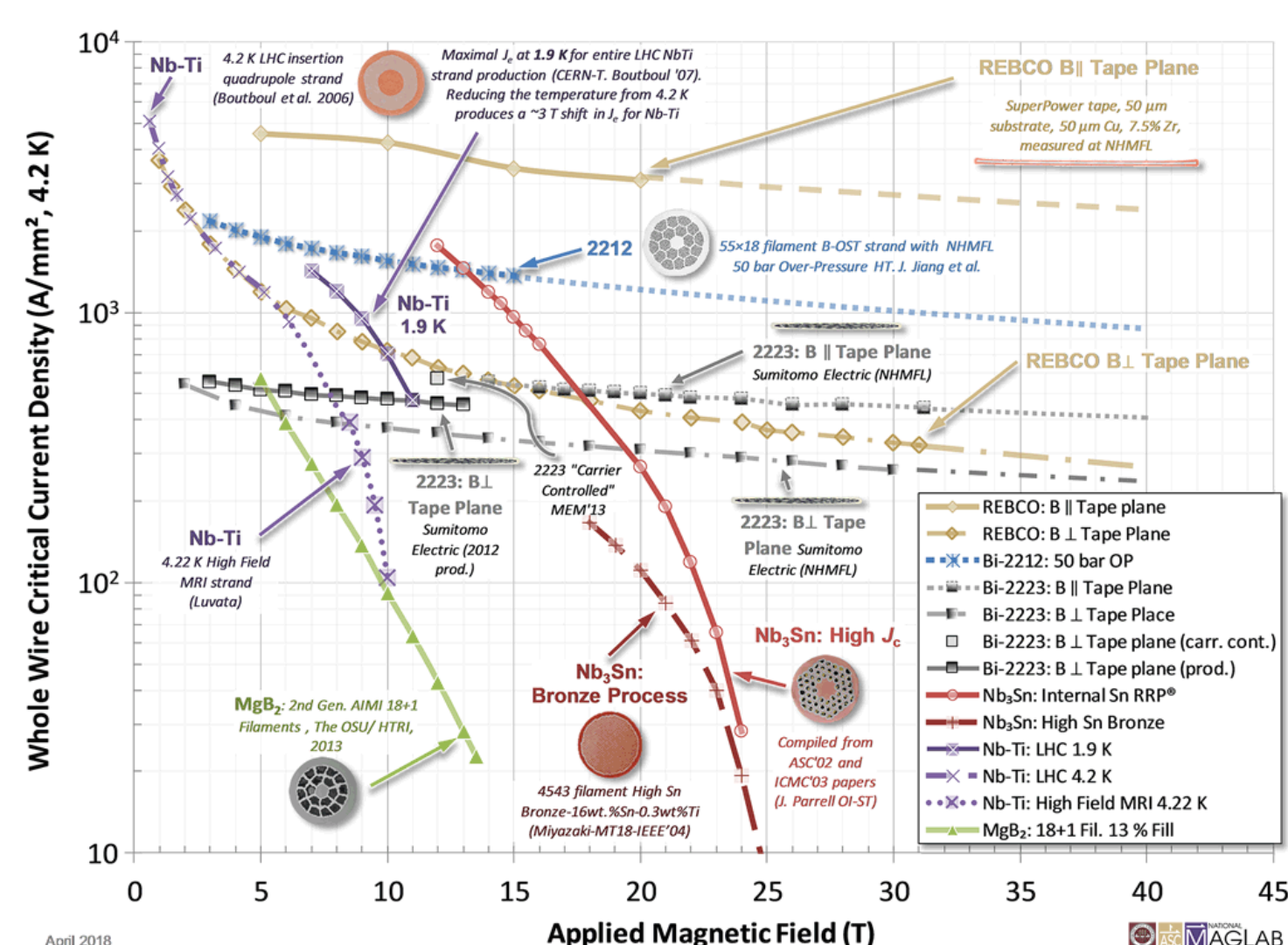


Figure 2: Graph of current density vs temperature for superconductors

REBCO Coated Conductor is the most performative superconductors available. In Figure 2, it shows that REBCO is the only conductor with a current density that can guarantee the magnetic field at 20K.

Research Goal

To analyze how fast the quench propagates by observing voltage change and increase in resistance between the voltage taps.

Procedure

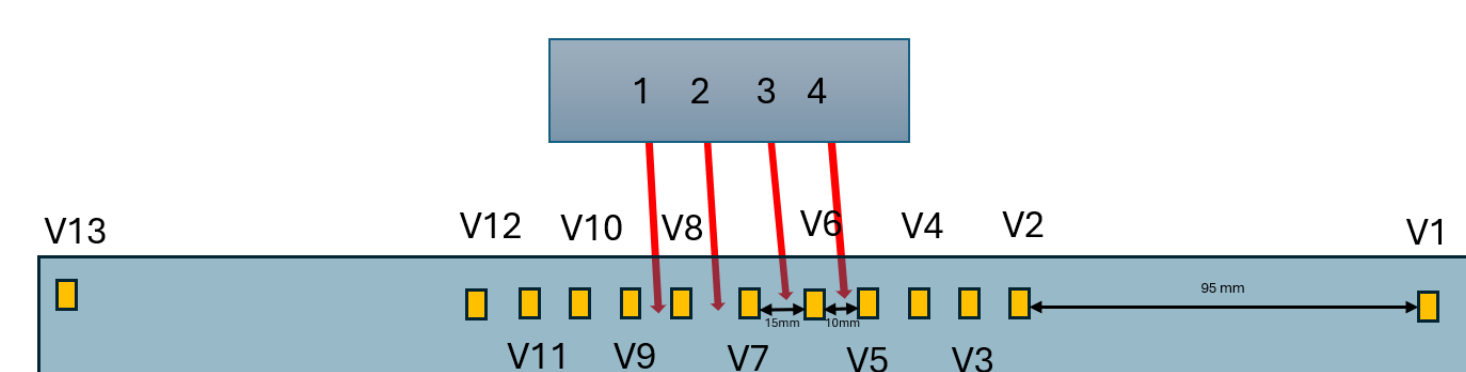


Figure 3: Schematic of the overall arrangement on PCB

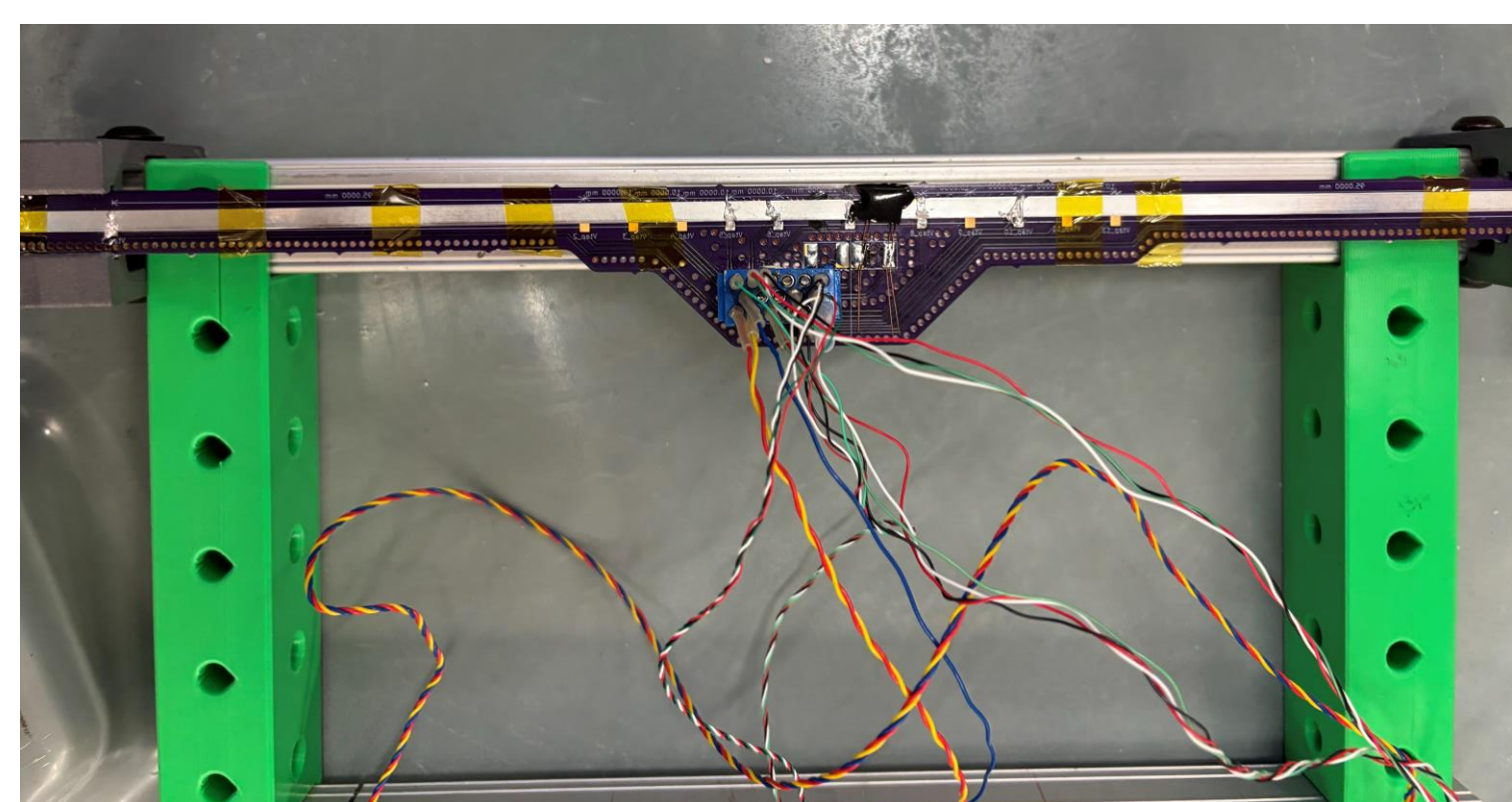


Figure 4: Test set up

A REBCO tape strip is soldered on a PCB, and wires are soldered to the connector into the Data Acquisition System (DAQ). Voltage taps are divided into segments of VT1-VT13, VT6-VT7, VT6-VT5, VT7-VT8, VT8-VT9 along the PCB to detect voltage change.

The PCB assembly is mounted onto the test fixture and attached to copper clamps at the ends for current input from the power supply. Four temperature sensors are placed from voltage taps 5 to 9 for monitoring thermal rise during quench. Then the entire setup is submerged in liquid Nitrogen (77 K) to achieve superconductivity. [3] Voltage and temperature are then measured in each test.

- Test 1: Ramp current until spontaneous quench to determine quench current.
- Test 2: Ramp current to 300A with voltage threshold at 5mV, quench is manually induced by pulse of 0.195A at 10 ms by applying reduced current to the strain gauge which acts as a 'spot heater' placed near VT7.

Results

Test 1

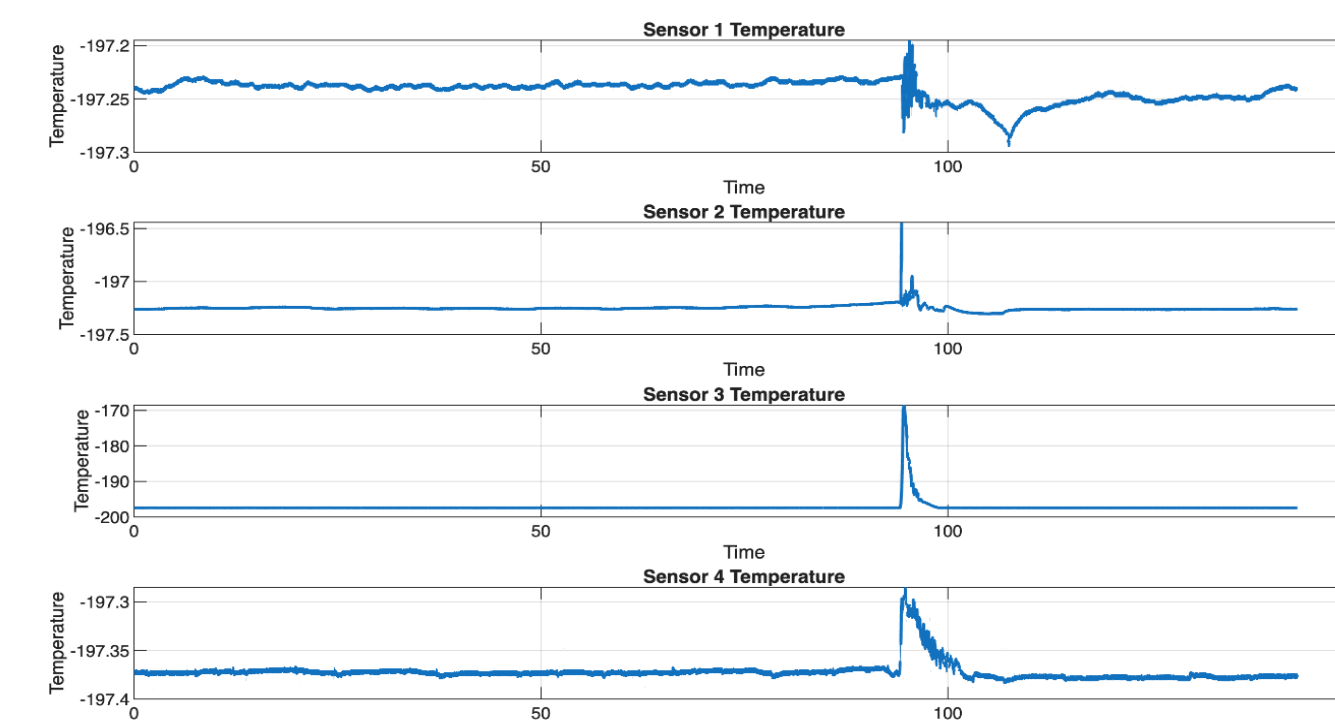


Figure 5: Graph of temperature vs time for each sensor

Sensor 3 shows the most significant spike in temperature on $-168.496\text{ }^{\circ}\text{C}$ (104.65 K).

Power supplied to the burnt area at the time of burn was 84.9 W/cm^2 which falls within the range of 500 to $1000\text{ }^{\circ}\text{K}$.

This indicates that the heat produced was beyond the simultaneous cooling of the liquid nitrogen, thus, melting the sample.

Test 2

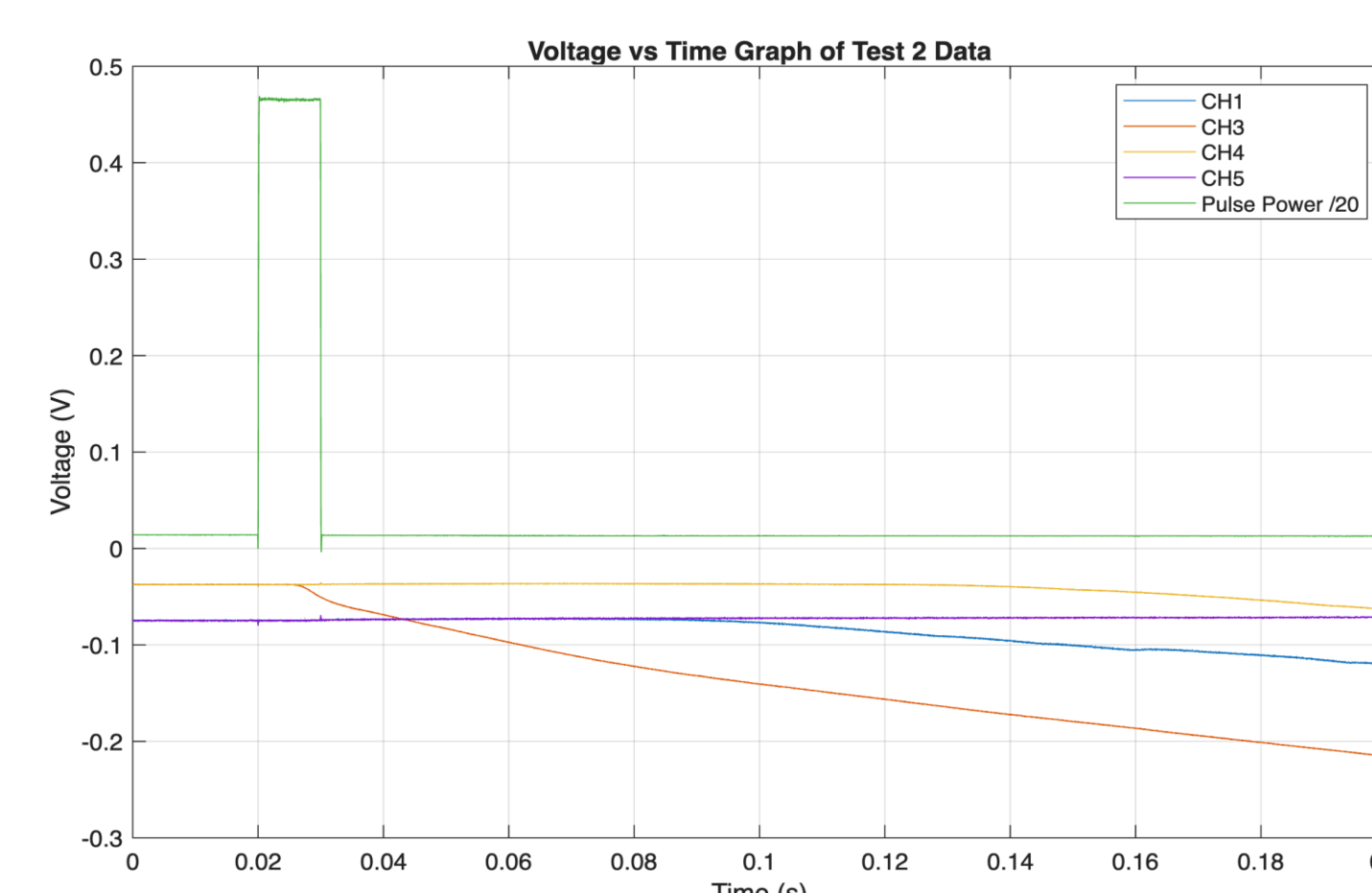


Figure 8: Voltage vs Time graph of channels and pulse power scaled to 20

Resultantly, it can be denoted that from VT7 where the spot heater was placed, the quench propagated along both directions of the REBCO tape.

Test 1 determined the quench current of the F2F BEBCO Tape on PCB Board. Theoretically, each REBCO surface carries about 180A and results confirmed that the quench current occurred around 360 A. Prominent burn occurred at quench current near VT9 and destroyed the sample. Therefore, voltage rise could not be detected thus not measured due to this rapid spike in quench.

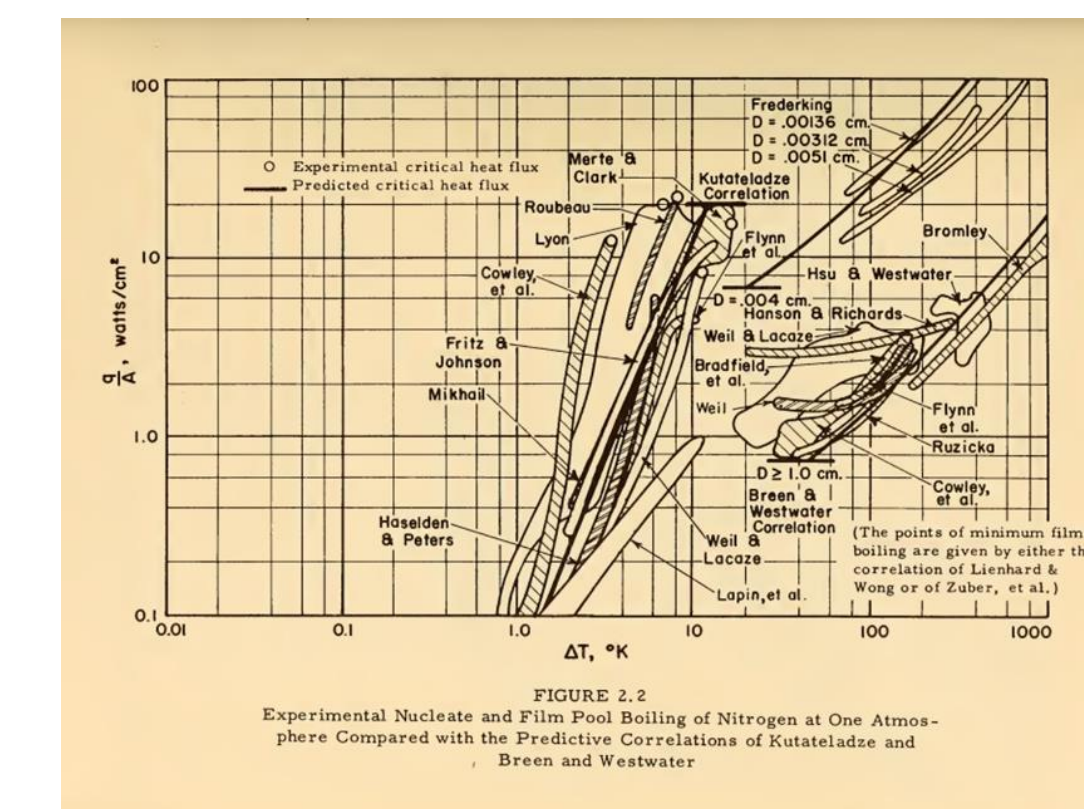


Figure 7: Graph of nitrogen boiling point



Figure 6: Resultant burn on sample

As soon as pulse begins, channel 3 spikes in voltage, implying that it has quenched. Voltage rise is seen across all the channels except Channel 5 (VT1-VT13) which showed no change as it was open, so the quench protection connected to this channel for current to be automatically shut down if voltages go above threshold (5mV), did not work in this test, therefore, burning the sample.

The quench uniform start time is about 0.026 s where the voltage spike happens in channel 3. At 0.092 s, it propagated in channel 1 over 15 mm by 226 mm/s. At 0.148 s, it propagated in channel 4 by 164 mm/s over 20 mm.

Future Work

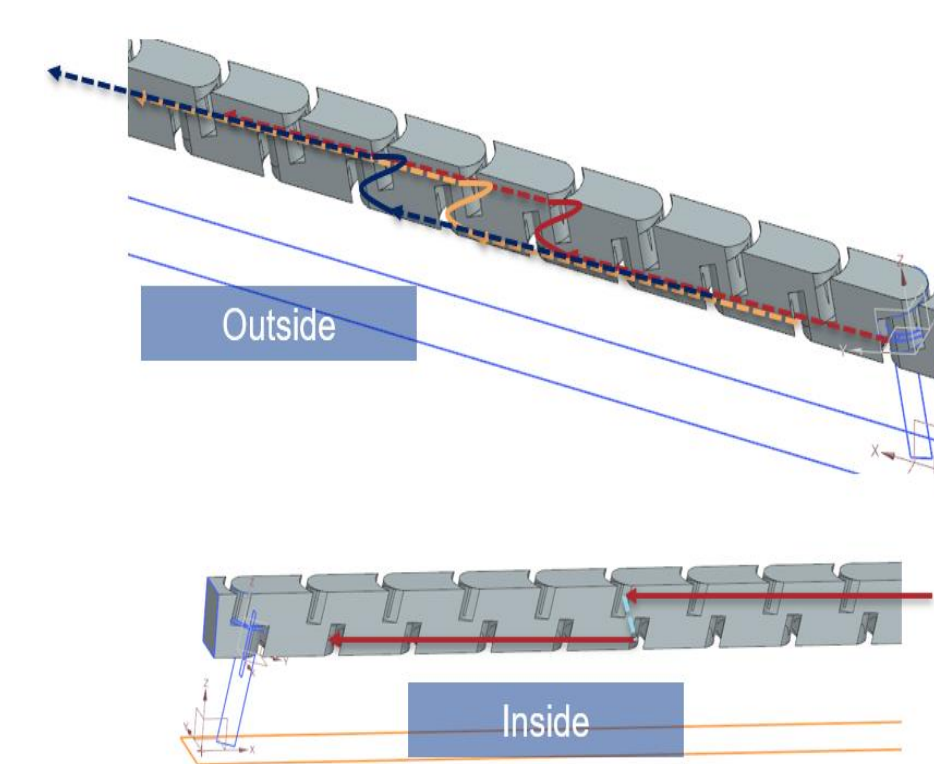


Figure 9: Arrangement of REBCO in Rutherford-like Cable



A cable with new geometry, featuring full transposition similar to Rutherford cable is being designed to aim at more uniform current distribution and higher transposition in order to minimize magnetic field and reduce AC loss along the REBCO tape.

Tape-shaped conductors like REBCO can only bend easily in one direction and bending them aggressively causes damaging strain.

Referring to Rutherford cables, a helical wrap is introduced by treating each tape like a ruled surface and repeating this angled transition so that adjacent tapes switch positions where inner becomes outer, and outer becomes inner.

References

- [1] Panda, S. S. G. (2025). Mechanical characterization and quench propagation study on REBCO tape stack (Master's thesis, Northern Illinois University)
- [2] L. Bottura. (2014). Magnet Quench 101. ArXiv (Cornell University), 1-9.
- [3] Imbasciati, L. (2003). Studies of quench protection in Nb_3Sn superconducting magnets for future particle accelerators (Doctoral dissertation, Vienna University of Technology).
- [4] M. De Stasio et al., "Measurements of Quench Propagation Velocity in HTS Cable for Fusion Applications Using Optical Fiber Sensors," in IEEE Transactions on Applied Superconductivity, vol. 36, no. 5, pp. 1-5, Aug. 2026, Art no. 4605605, doi: 10.1109/TASC.2026.3664056