A New Method to Measure the Thermal Response of Superconducting Cable Stacks Cooled by Superfluid Helium to Pulse Heat Loads

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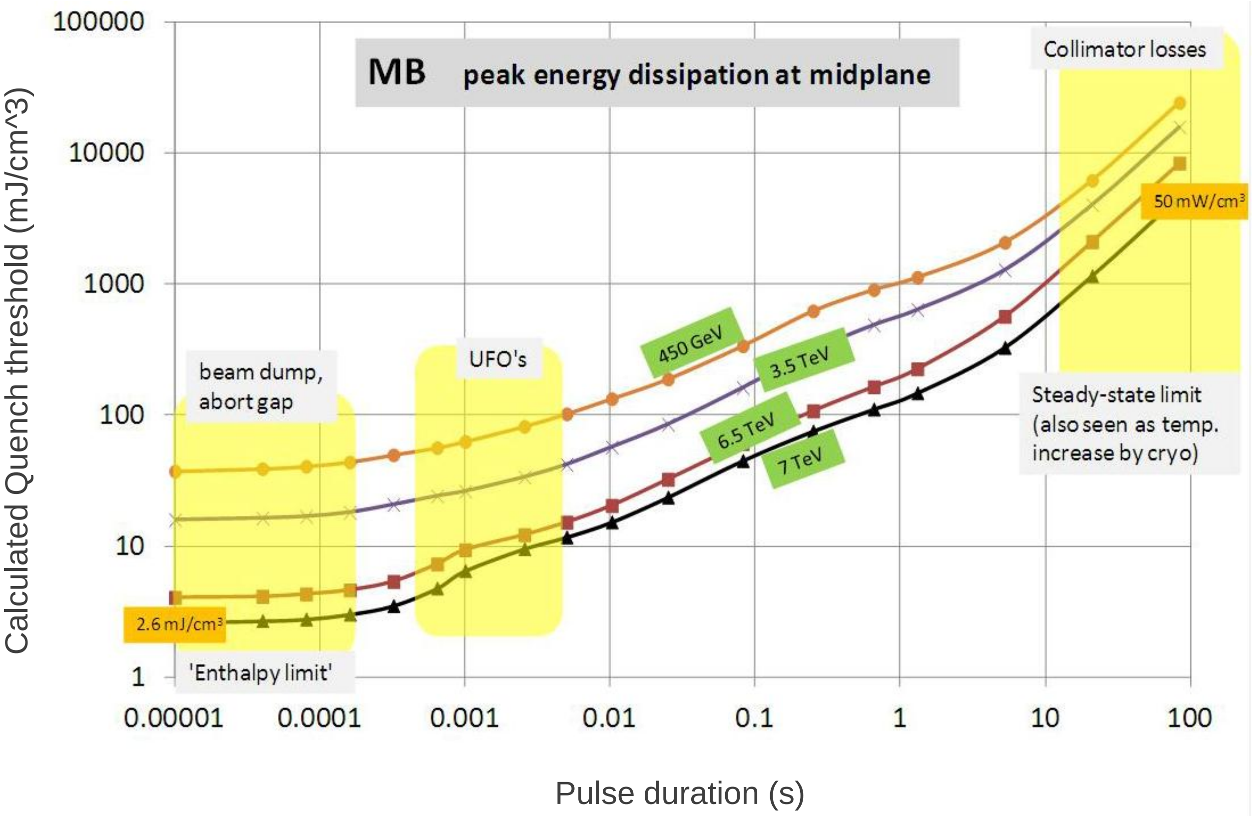
Motivation

During operation of an accelerator different heat loads occur.

- Steady state
- Transient
- Intermediate regime



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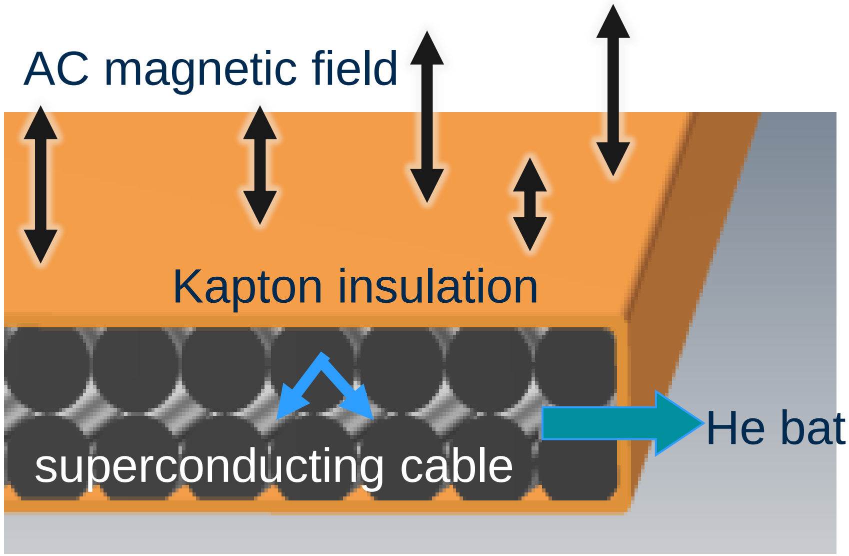
Motivation – Heat Transfer

- Heat transfer knowledge relies heavily on simulations
- Experimental qualification of simulations has been done for steady-state cooling conditions and on mock-up cables
- For transient cooling conditions experiments have been done with resistive cables, or with superconducting cables with spot heating
- Measurements on superconducting cables / stacks in transient conditions in a liquid helium bath need to be done

Measurement Idea

- Measurement with a superconducting cable stack
- Measurement in transient cooling conditions
- Use an external AC magnetic field to generate losses on the stack cooled by a liquid helium bath

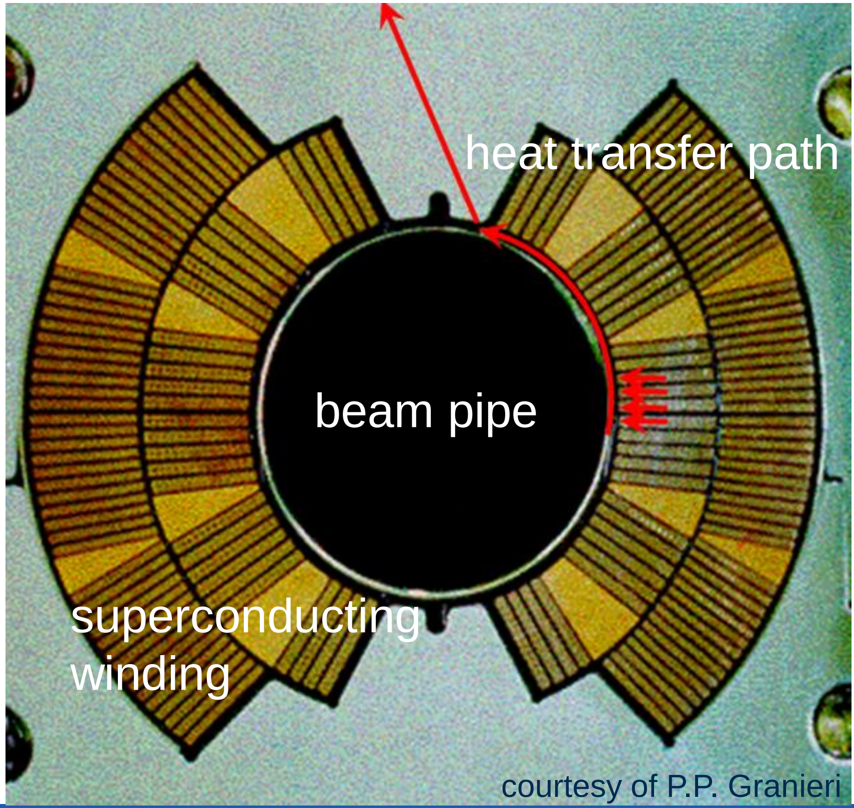

AC magnetic field

Kapton insulation

superconducting cable

He bath

towards heat exchanger


heat transfer path

beam pipe

superconducting winding

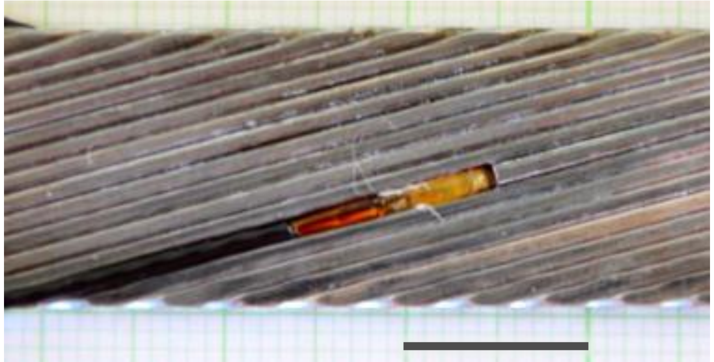
courtesy of P.P. Granieri

Experimental Set-up

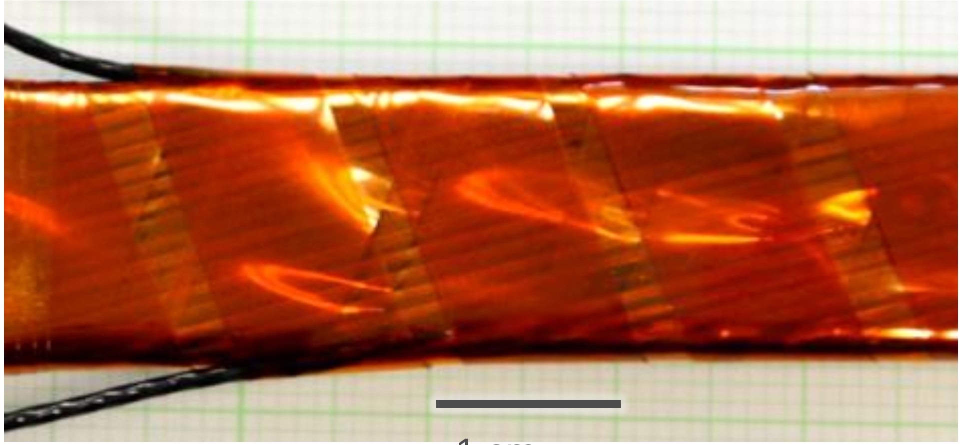
One cable is instrumented with Cernox® temperature sensors

Individually Kapton® insulated NbTi Rutherford cables are used

The change of the geometry of the cable is only necessary for instrumentation



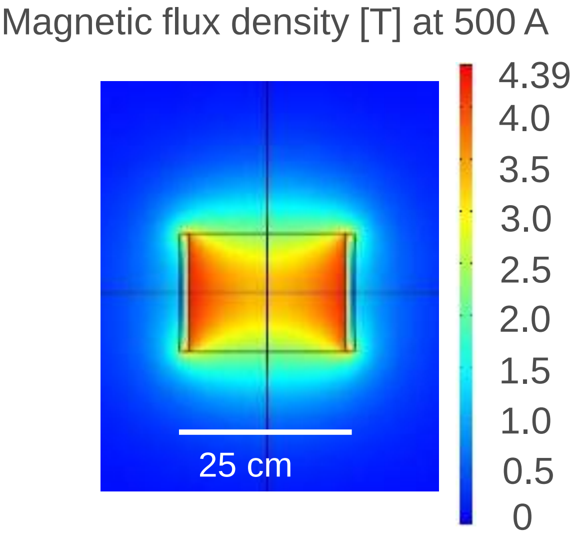
1 cm

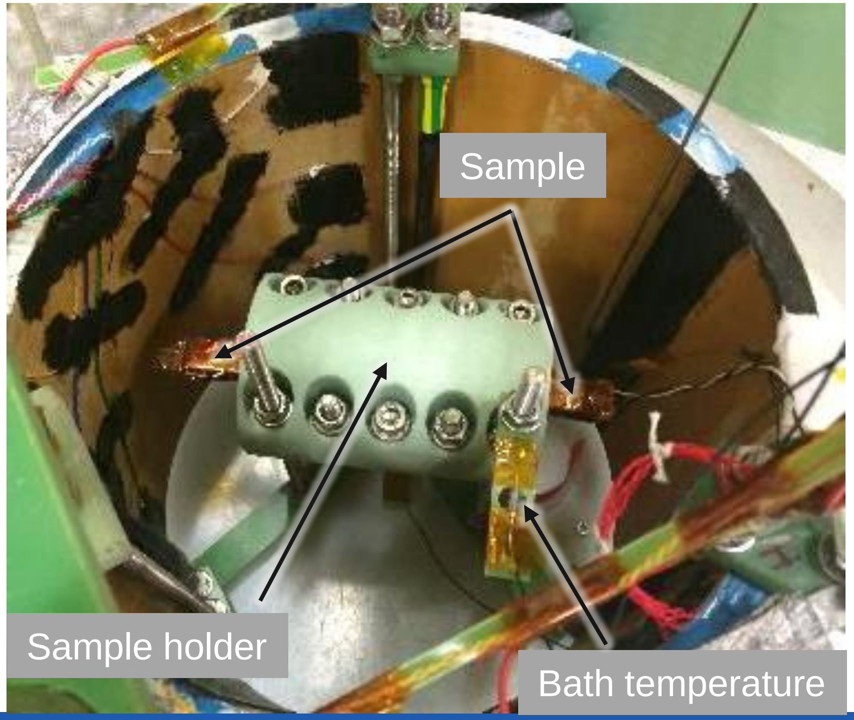


1 cm

Experimental Set-up 2

- Cable stack is kept under mechanical pressure equivalent to magnet operating conditions
- Use of external AC magnetic field to induce AC losses in superconducting cable stack


Magnetic flux density [T] at 500 A



Experimental Set-up 3

The magnet has an inductance of $0.5\ \mathrm{H}$ and is powered with

$$230\ \mathrm{V_{eff}},\ 50\ \mathrm{Hz}$$

resulting in

$$I_{max} = 2.1\ \mathrm{A}$$

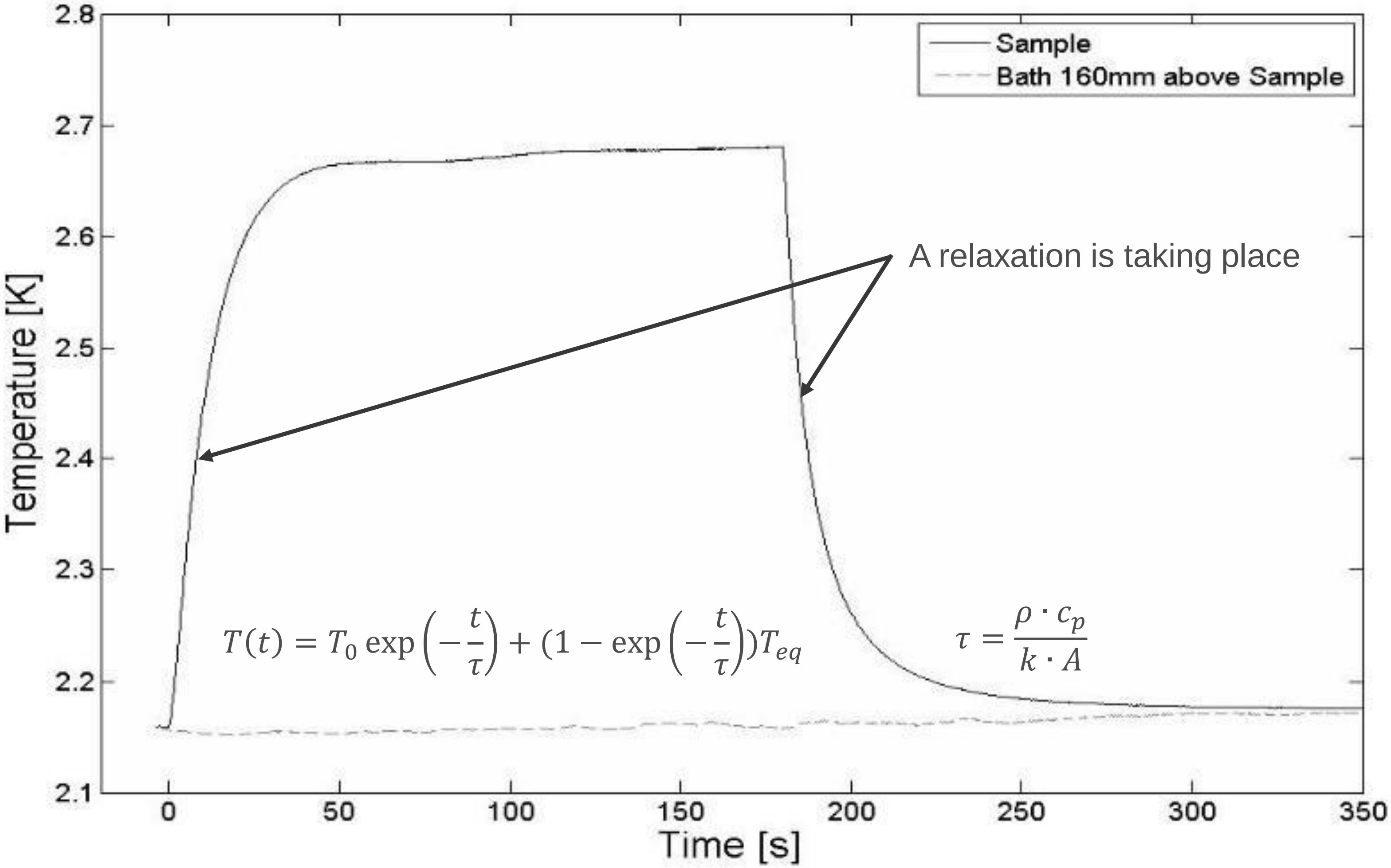
This gives a peak to peak current change of

$$\frac{dI}{dt} = 1300\ \mathrm{A/s}$$

And results in a peak to peak magnetic field change of

$$\frac{dB}{dt} = 8\ \mathrm{T/s}$$

Measurement Result



A relaxation is taking place

$$T(t) = T_0 \exp\left(-\frac{t}{\tau}\right) + (1 - \exp\left(-\frac{t}{\tau}\right))T_{eq}$$

$$\tau = \frac{\rho \cdot c_p}{k \cdot A}$$

Measurement Result 2

Using the aforementioned function and τ as fitting parameter one finds values for τ between

$$9.7\ \mathrm{sec}\ \pm 0.3\ \mathrm{sec}\,.$$

From the steady-state temperature difference the heating power Q can be deduced with the equation

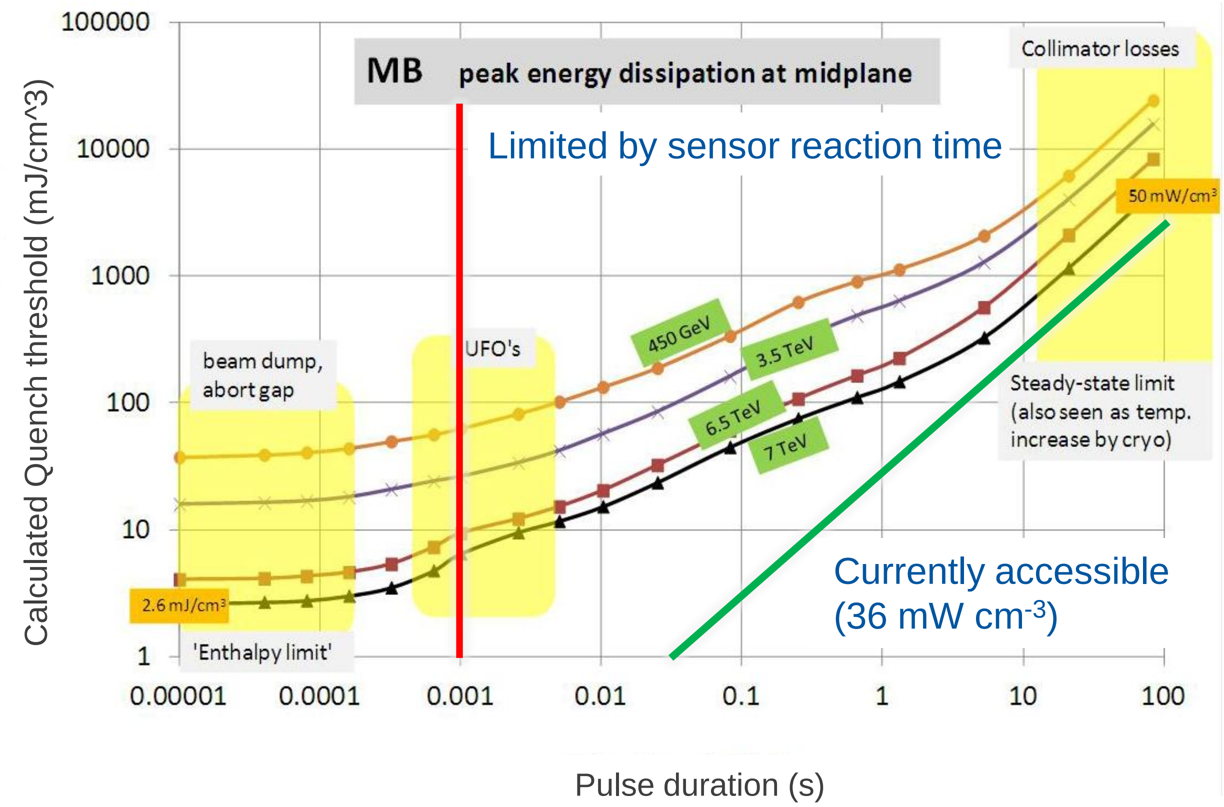
$$Q = \left(T_{eq} - T_0\right) \cdot \left(\rho \cdot c_p\right) \cdot \tau.$$

A heating power of $\mathbf{36\ mW \cdot cm^{-3}}$ is found.

Conclusion

With the presented method it is possible to do heat transfer measurements on superconducting cables without needing to implement a heater.

With the current set-up a heat deposit of $\mathbf{36\ mW \cdot cm^{-3}}$ is possible.



Limited by sensor reaction time

Currently accessible ($36\ mW\ cm^{-3}$)

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Outlook

- On bringing the sample in accordance with the insulation as build in the magnets
- Measurements at different temperatures to distinguish between the influence of the thermal link and the specific heat
- A comparison of measurements with an impregnated cable and a non-impregnated cable will give further information about the temperature gradient between the strand and the helium in the cable voids.
- A double bath cryostat will enable measurements in a pressurized liquid helium bath
- A higher excitation frequency to do faster measurements and also increases the amount of generated heat.


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