Normal zone propagation velocity and surface temperature mapping in HTS coated conductors during quench

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Quench challenge with HTS Tapes

- **Quench** needs further studying
- **Normal Zone Propagation Velocity** is slow in HTS
  - Can lead to the destruction of tapes, cables and devices

![Burned HTS tape]

- **New optical measurement method**
  - Thermal zone development
  - Determine temperatures during quench
Measurement Principle

High-speed thermal imaging
- Not traditional thermal imaging
- Temperature dependency of fluorescence
- Record dynamic events
- High speed (2500 images / second)

Fluorescent coating: Europium, “EuTFC”
Europium tris[3-(trifluoromethylhydroxymethylene)-(+)–camphorate]
Fluorescent Thermal Imaging Concept

- **Absorption** and **re-emission** of photons

HTS Tape coated with fluorescent dye

HTS Tape excited with UV light

- Fluorescence **decays with increasing temperature**
- **Light intensity** is crucial (not the colour)
- Cannot interpolate directly on the measurement curve

Measured with Marius Jakoby, IMT, KIT
Temperature Calibration

What the camera records

\[ S(x, y) = I(x, y) \cdot \eta(x, y) \cdot r(x, y) \cdot Q(T(x, y)) \]

- Recorded light intensity
- Excitation intensity
- Optical collection efficiency
- Reflectivity

To remove all artefacts from images, take the ratio of 2 images

\[ S_R(x, y) = \frac{S_{Hot}(x, y)}{S_{Cold}(x, y)} = \frac{I(x, y) \cdot \eta(x, y) \cdot r(x, y) \cdot Q(T_{Hot}(x, y))}{I(x, y) \cdot \eta(x, y) \cdot r(x, y) \cdot Q(T_{Cold}(x, y))} = \frac{Q(T_{Hot}(x, y))}{Q(T_{Cold}(x, y))} \]

Quantum efficiency

\[ Q = \frac{\text{photons emitted}}{\text{photons absorbed}} \]
Temperature Calibration

![Graph showing the relationship between temperature and light intensity. The graph indicates a decreasing trend in light intensity as the temperature increases.]
Measurement: Sample Preparation

- Mixture
  - Europium
  - PMMA
  - Acetone

- Droplet coating

- Heat treatment
  (30 min at 175 °C)

HTS Tape coated with fluorescent dye

Current lead
Boiling diverter
Current lead
Surface Temperature Mapping

Mitigated optical artefacts
- Non-uniform coating thickness
- Boiling $N_2$ bubble diverter

Non-mitigated optical artefacts
- Boiling
Copper Stabilized Tape

SuperPower, 20 µm copper
12 mm x 15 cm
3 mm x 3 cm middle section

Applied current pulse
Copper Stabilized Tape

0 ms | 40 ms | 60 ms | 80 ms | 100 ms
---|---|---|---|---
Reference | Heating starts | Quench starts | Normal area | Limit exceeded

Temperature (K)

Heating starts

Quench starts

Normal area

Limit exceeded
Non-stabilized Tape

SuperOx, non-stabilized
12 mm x 15 cm
2 filaments, Magnetic defect

Applied current pulse

Recorded image

Normalized image
Non-stabilized Tape

General observation
- Non stabilized tapes heat up “instantly”
- Little to no temperature information

- NZPV can be obtained
- 0.25 cm in 19.2 ms \( \Rightarrow \) 13 cm/s
Conclusions and Outlook

- Observe heating profile
- Optical NZPV calculation
- Temperatures can be extracted

- Filamentary HTS tapes
- Cables, e.g. ROEBEL

Anna Kario, KIT, EuCARD2