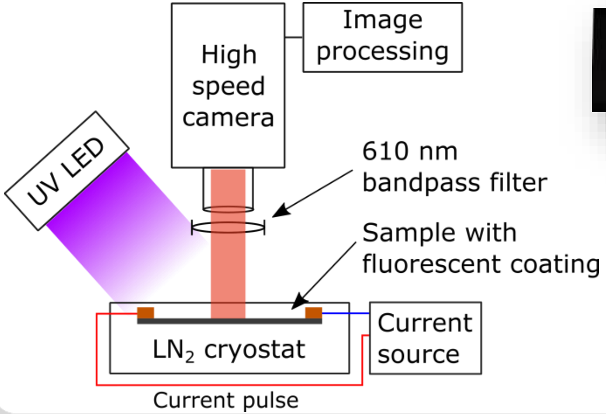
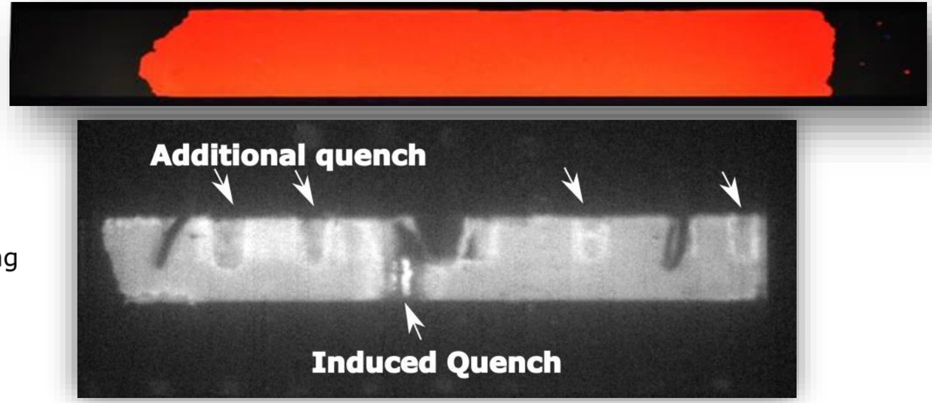
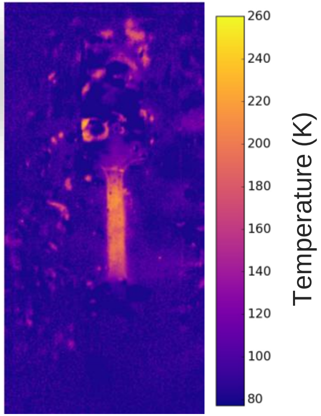
Normal zone propagation velocity and surface temperature mapping in HTS coated conductors during quench

R. Gyuráki[1], F. Sirois[2], F. Grilli[1]

[1] KIT, Germany [2] Polytechnique Montréal, Canada

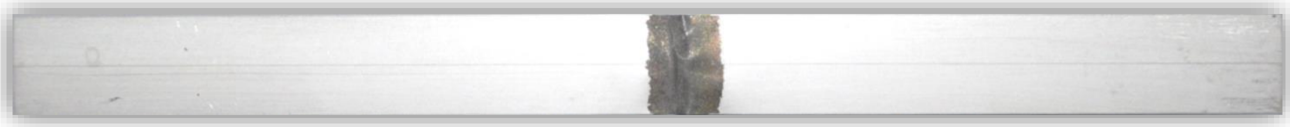






Quench challenge with HTS Tapes

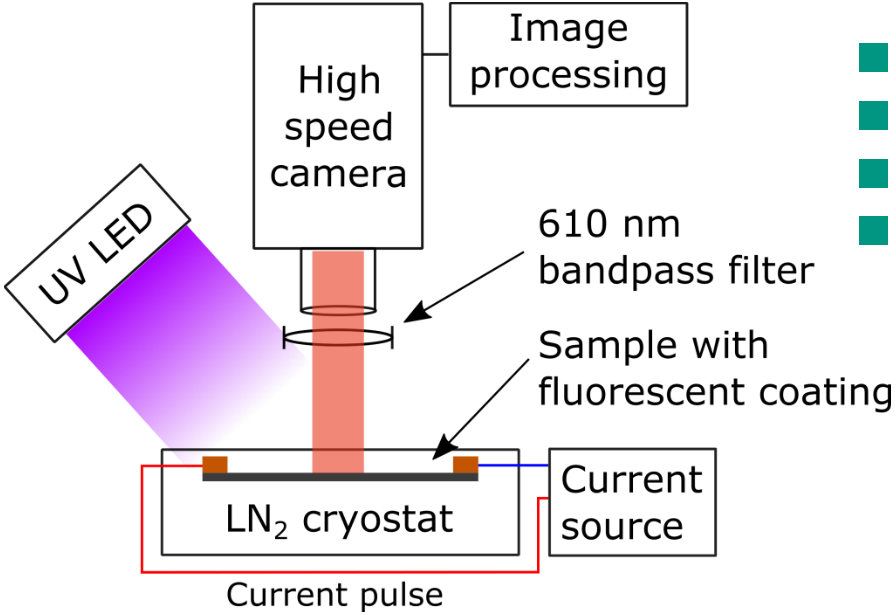
- **Quench** needs further studying
- **Normal Zone Propagation Velocity** is slow in HTS
  ➔ Can lead to the destruction of tapes, cables and devices



Burned HTS tape

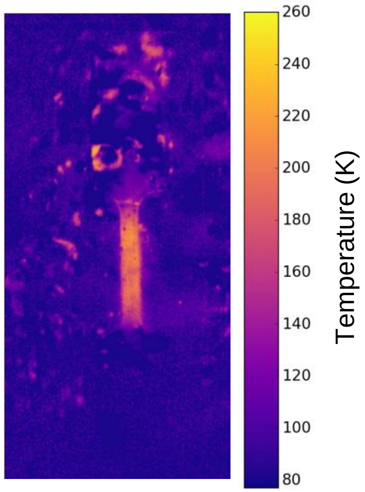
- **New optical measurement method**
  - Thermal zone development
  - Determine temperatures during quench

Measurement Principle



High-speed thermal imaging

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

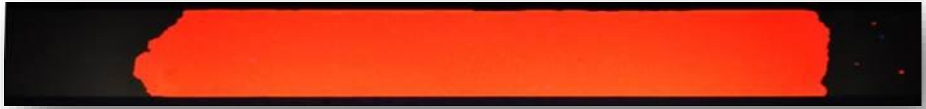


Fluorescent coating: **Europium, "EuTFC"**
Europium tris[3-(trifluoromethylhydroxymethylene)-(+)–camphorate]

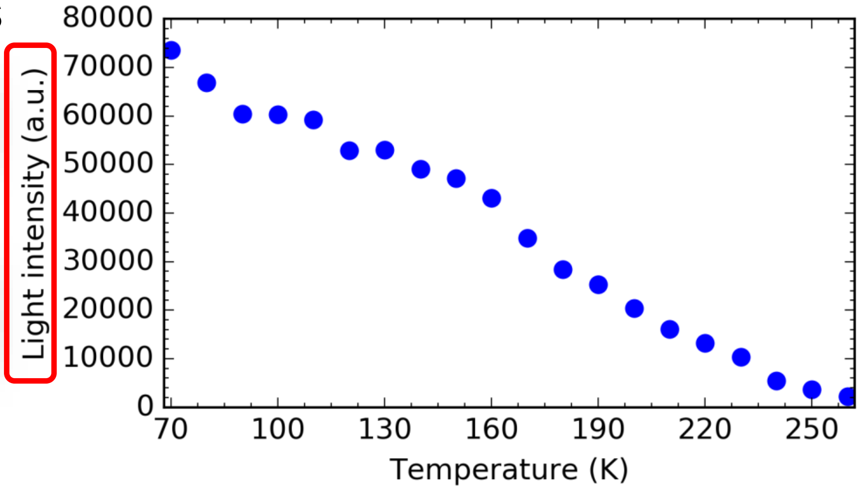
Fluorescent Thermal Imaging Concept

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

HTS Tape coated with fluorescent dye



HTS Tape excited with UV light



Measured with Marius Jakoby, IMT, KIT

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

Temperature Calibration

Karlsruhe Institute of Technology

- What the camera records

$$S(x,y) = I(x,y) \cdot \eta(x,y) \cdot r(x,y) \cdot Q\big(T(x,y)\big)$$

Recorded light intensity

Excitation intensity

Optical collection efficiency

Reflectivity

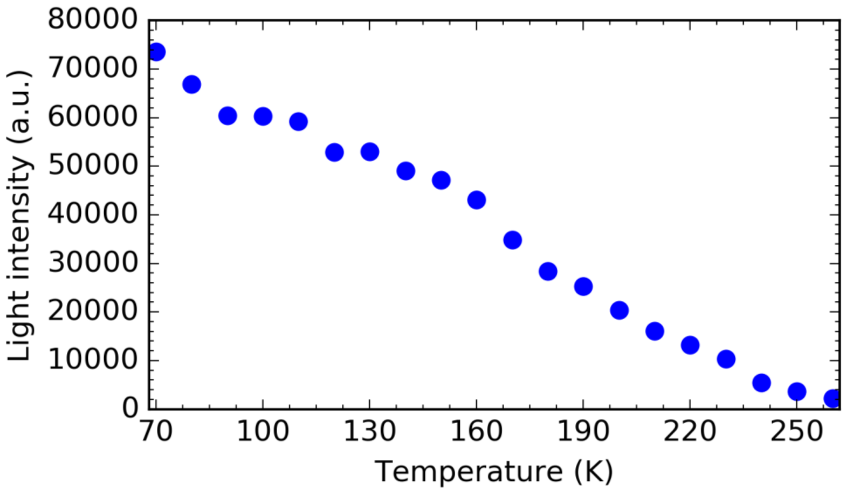
Quantum efficiency

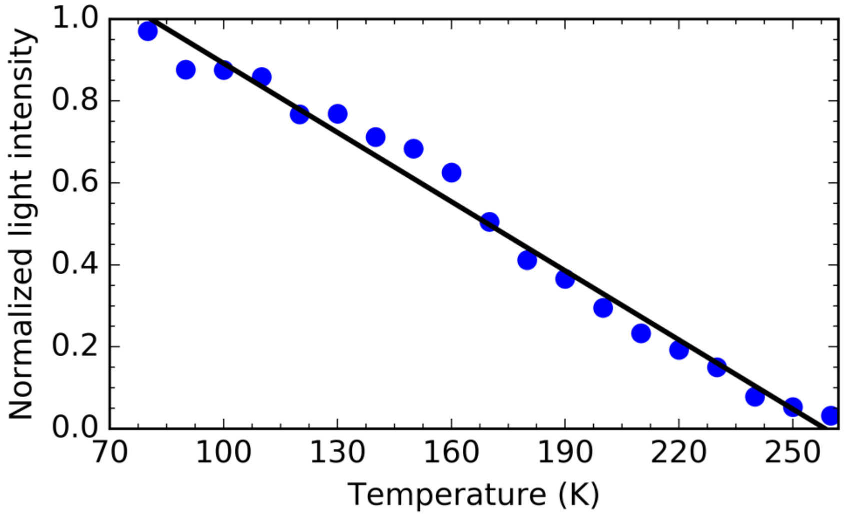
$$Q = \frac{photons\ emitted}{photons\ absorbed}$$

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

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

Temperature Calibration

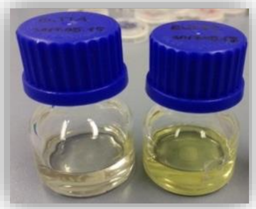




Measurement: Sample Preparation

- Mixture

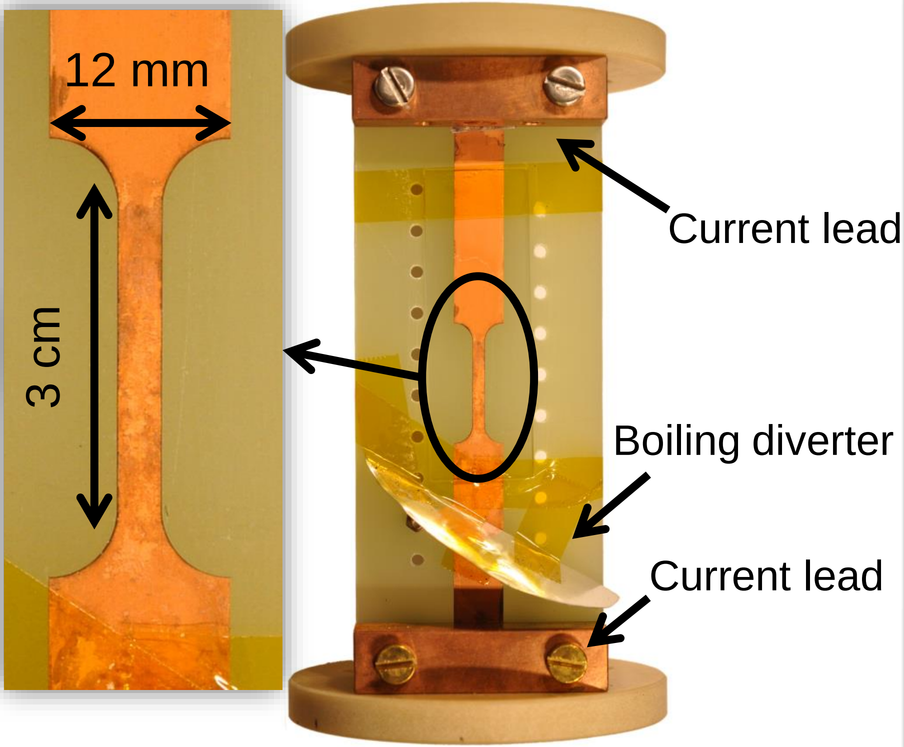
Europium
PMMA
Acetone



- Droplet coating

HTS Tape coated with fluorescent dye

- Heat treatment
(30 min at 175 °C)



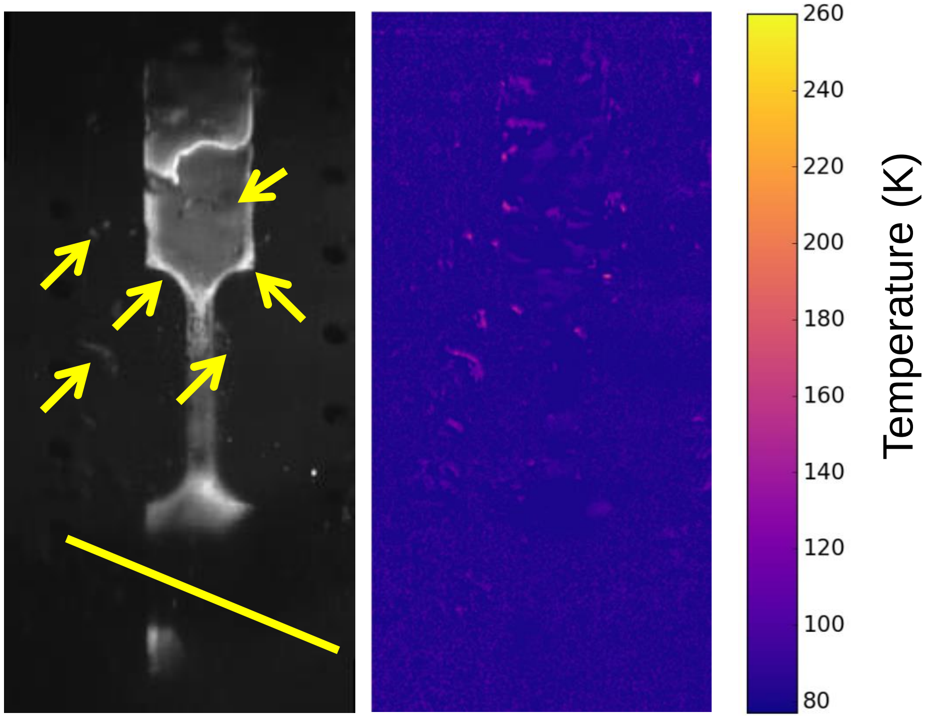
Surface Temperature Mapping

Mitigated optical artefacts

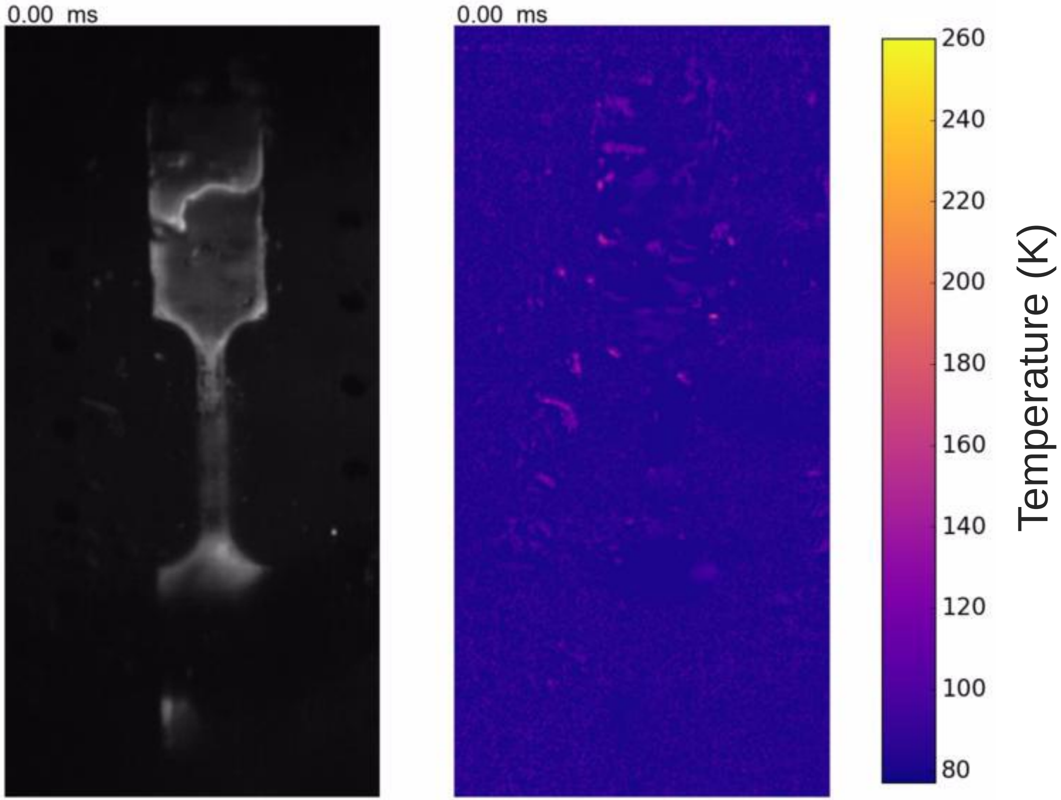
- Non-uniform coating thickness
- Boiling N_2 bubble diverter

Non-mitigated optical artefacts

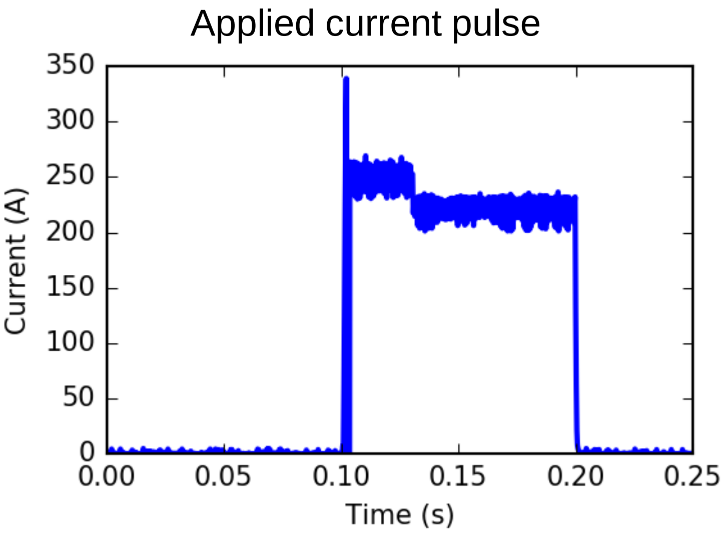
- Boiling



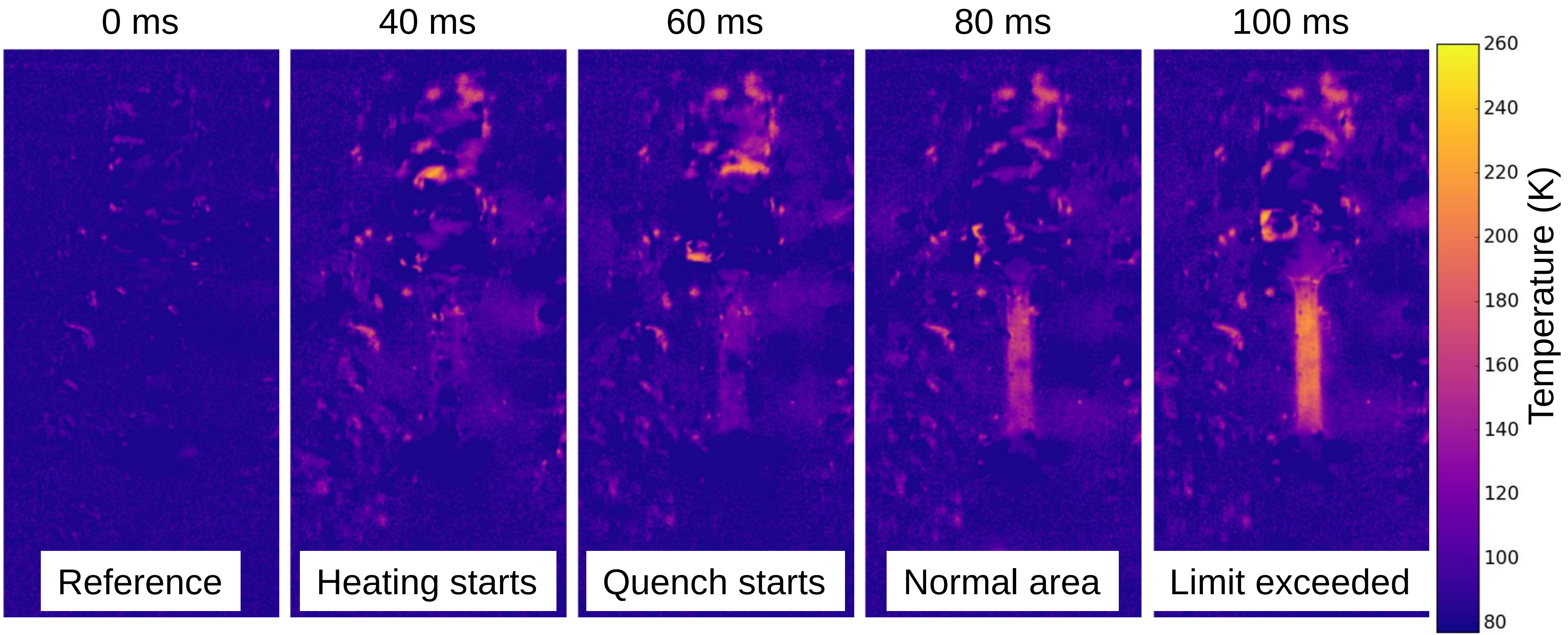
Copper Stabilized Tape



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



Copper Stabilized Tape



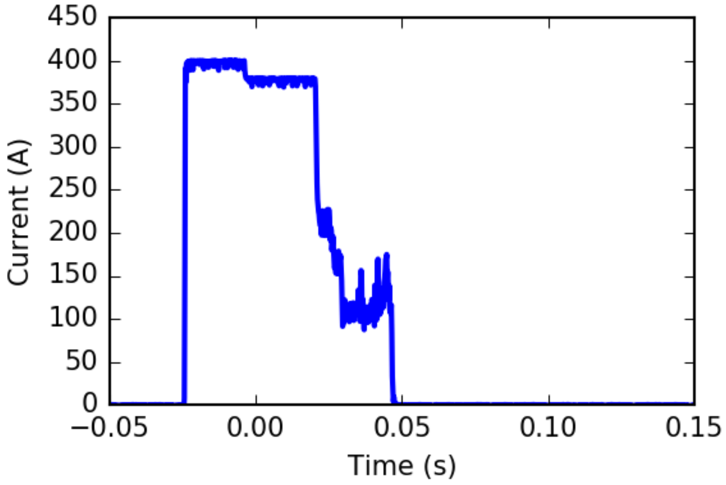
Non-stabilized Tape

SuperOx, non-stabilized

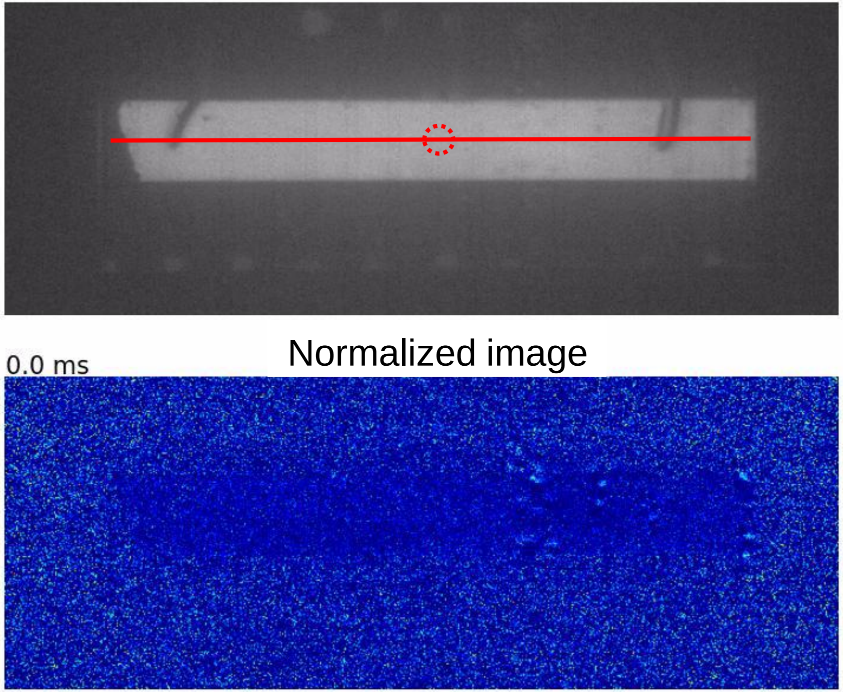
12 mm x 15 cm

2 filaments, Magnetic defect

Applied current pulse

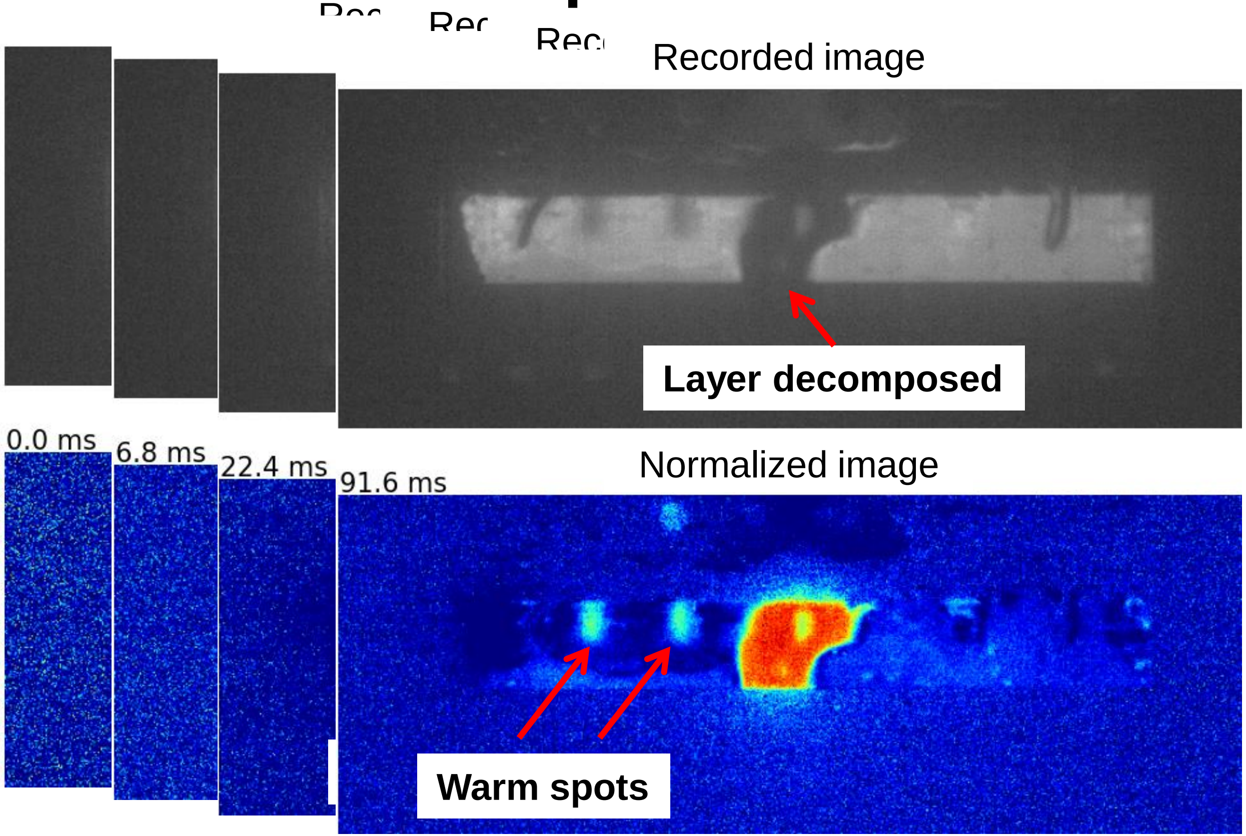


Recorded image



Normalized image

Non-stabilized Tape



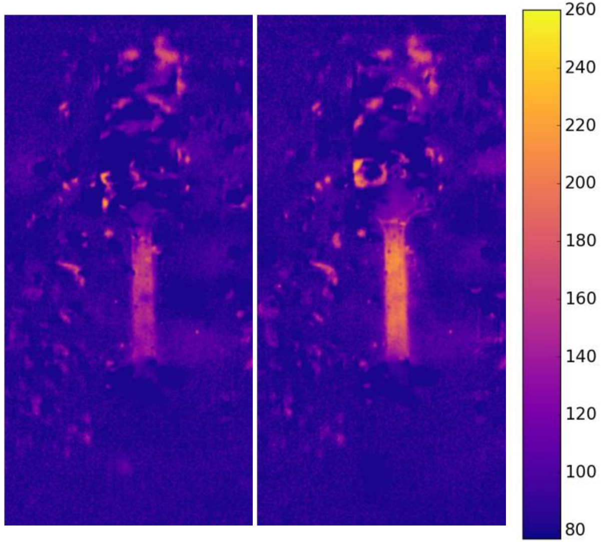
General observation

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

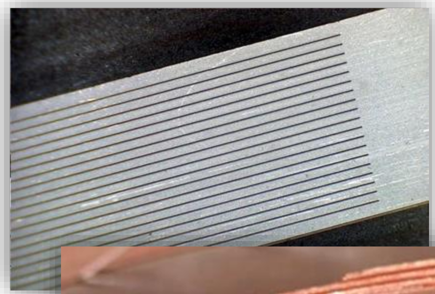
- NZPV can be obtained
- 0.25 cm in 19.2 ms ➔ 13 cm/s

Conclusions and Outlook

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



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



Anna Kario, KIT, EuCARD2