Self-Protected High-Temperature Superconducting Demonstrator Magnets for Particle Detectors

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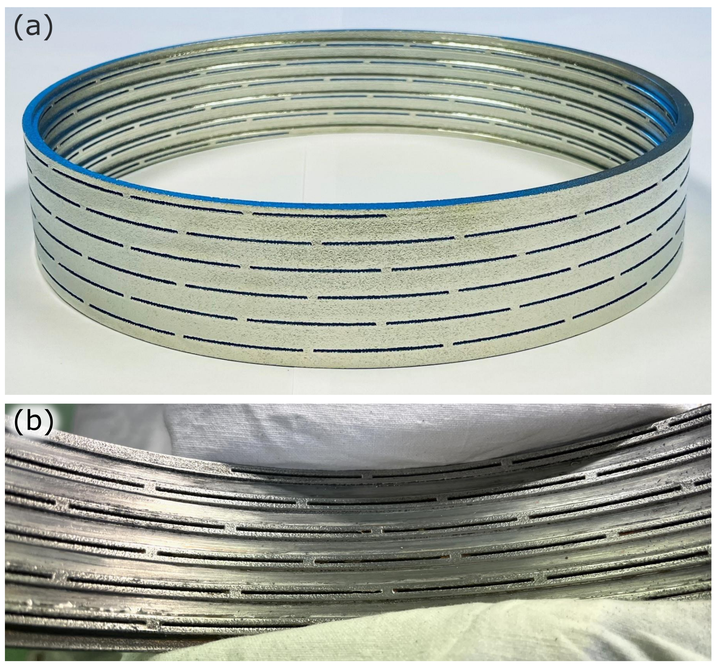

Fig. 1 Demonstrator 1: Frontal - top view of the coated cylinder before soldering (a) and inside view of the coil after soldering of the HTS tapes (b).

Introduction

- Developed two "**self-protected**" light-weight ReBCO coils.
- Ultra-thin **radiation transparent** and radiation transparent
- Supports development of HTS coil for space-borne AMS-100 particle detector [1].
- Coated 3D-printed support structure acts as:
  1. Aluminium stabilisation
  2. Passive quench protection **(partial insulation**)
  3. Mechanical support.
- Both coils are fully superconducting at 4.5 kA in LHe.
- Quench behaviour of Demonstrator 1 measured and simulated.

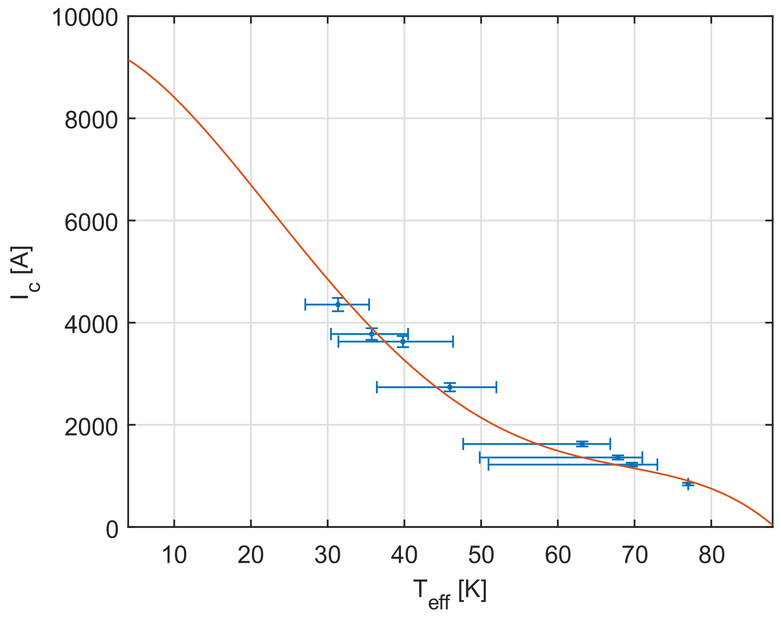

Fig. 2 Critical current as function of temperature measured for Demonstrator 1 and the corresponding trendline.

Table 1. Characteristics of the two demonstrator magnets at 4.5 kA

Demonstrator	1	2
Number of windings	5	15
Open bore diameter	230 mm	390 mm
HTS layers	4	4
Length of the HTS tape stack	4 m	19 m
Central B-field at 4.5 kA	0.1	0.2
Peak B-field on conductor at 4.5 kA	1.2 T	1.3 T
Inductance	0.01 mH	0.12 mH
Time constant: measured (expected)	6 s (6 s)	83 s (90 s)
Stored energy at 4.5 kA	0.1 kJ	1.3 kJ
Junction resistance of the connectors at 4 K	0.15 μΩ	0.05 μΩ

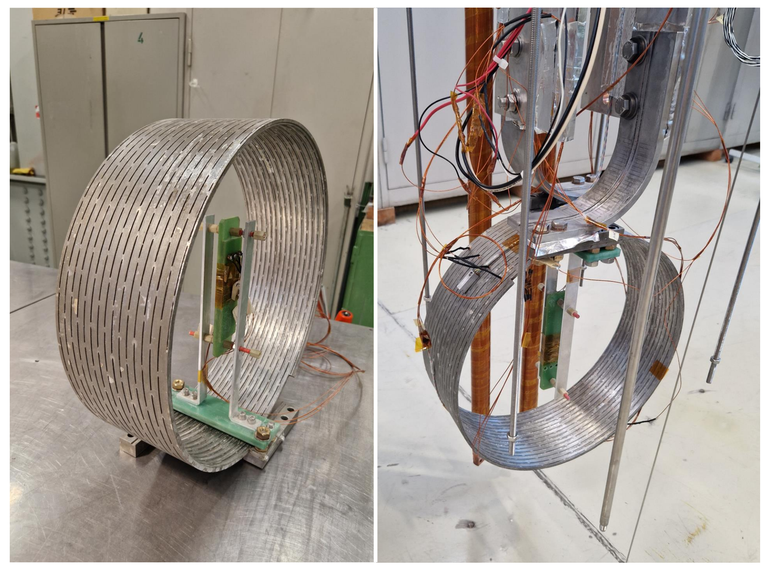

Fig. 3 Demonstrator 2 with a 390 mm diameter bore (a) and the magnet assembled in the cryostat insert (b).

Main results

- Developed **new method for stabilising ReBCO with Al10SiMg** (aluminium alloy), forming a coil.
- **Critical current** measured for Demonstrator 1 as a function of temperature (Fig. 2) [2].
- **Current-to-magnetic** and **electric field response** measured for Demonstrator 2 (Fig. 3).
- No degradation in Demonstrator 1 after **thermal cycling** and locally quenching the coil despite **voids** in the solder joints.
- Developed and verified **numerical model** for simulating the **transient behaviour** of partially insulated coils [3].
- Measured and simulated magnetic (a) and electric field (b) responses to heating pulses are shown in Figs. 4 and 5.

Fig. 4 Current-to-magnetic and electric field responses of Demonstrator 2.

Transient behaviour during a local quench (80 W/cm² heater)

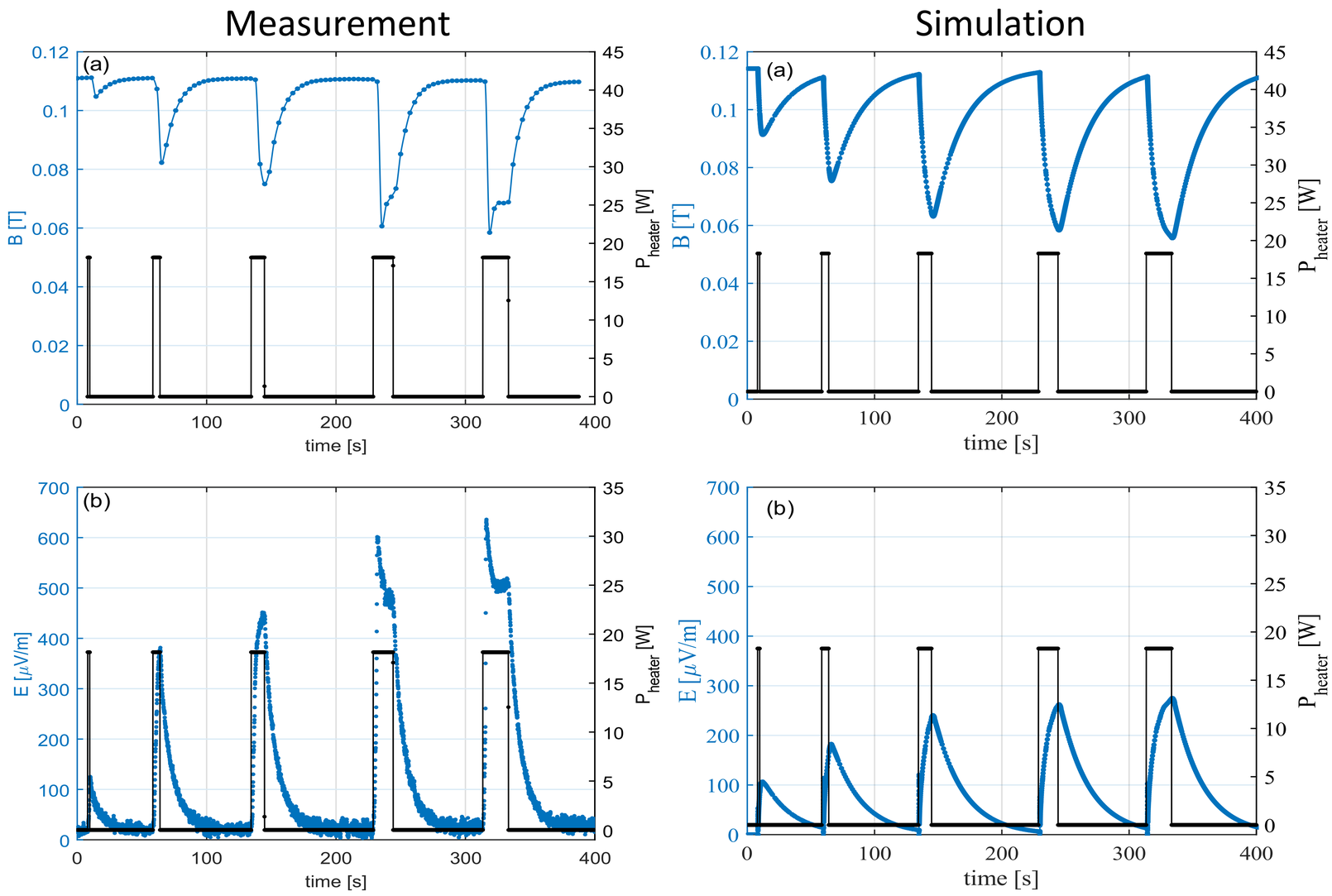

Fig. 5 Measured magnetic (a) and electric field (b) response to heating pulses.

Fig. 6 Modelled magnetic (a) and electric field (b) response to heating pulses.

Conclusions

- ReBCO tapes can be soldered to electrochemically coated 3D-printed aluminium without observable degradation.
- It is promising that this technology works in spite of an imperfect soldering quality.
- The shown stability during a local quench proves that aluminium alloys are a good candidate for stabilising HTS-based detector magnets when combined with partial insulation quench protection.

EUCAS2023
Bologna, Italy
3rd-7th September

References

[1] Schael, S. *et al.,* "AMS-100: The next generation magnetic spectrometer in space – An international science platform for physics and astrophysics at Lagrange point 2," *Nuclear Instruments and Methods Phys. Res. A* **944**, 162561 (2019).
[2] Van den Eijnden, J. L. *et al.,* "Self-Protected High-Temperature Superconducting Magnet for Particle Detectors" (submitted to *Superconductor Science and Technology)*.
[3] Van den Eijnden, J. L., Vaskuri, A., and Mentink, M. ReBCO Partially Insulated Solenoid Simulation [Computer software v1.0 2023]. https://github.com/JoepVdE/RePISoSi

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