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25 K performance of conduction-cooled solenoids wound from exfoliated filament YBCO cables

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Slowa Solovyov, Zachary Mendleson, and Paul Farrell

Brookhaven Technology Group Inc., Stony Brook, NY 11794

www.brookhaventech.com

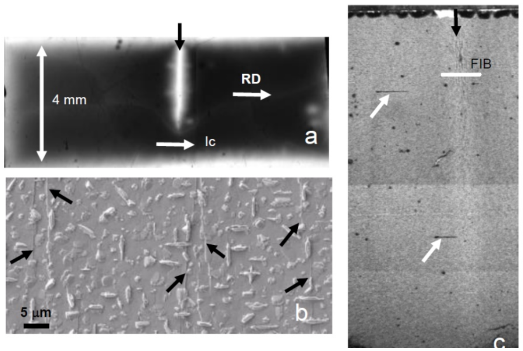
Brookhaven Technology Group

Outline

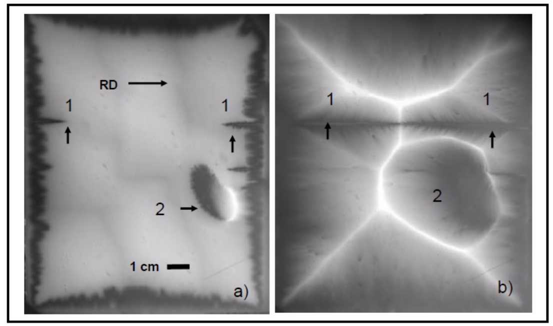
- Introduction to ExoCable technology
- Mini coil test results: 77 K and 25 K
- Flux dynamics at 25 K and effect of temperature gradients
- Conclusion and future work

Motivation: we need defect tolerant cable

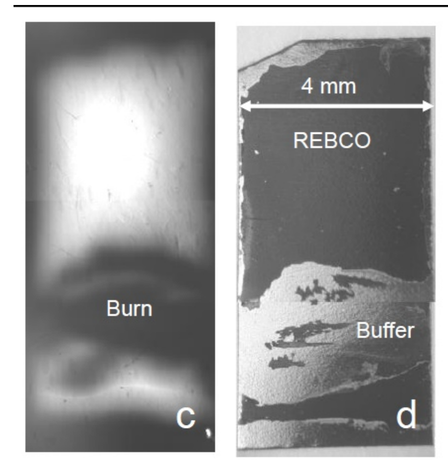
Across-tape defects



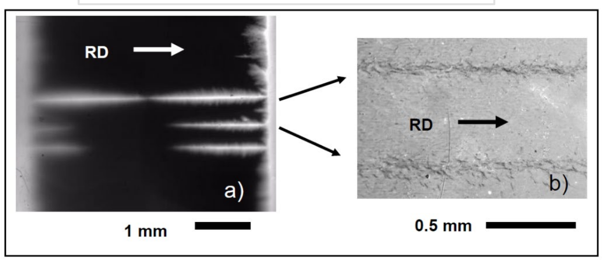
Deposition malfunction



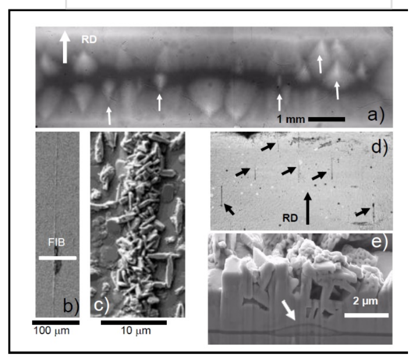
Some defects emerge during coil operation



Along-tape defects



Epitaxy failure



Courtesy of Anatolii Polyanskii
NHMFL

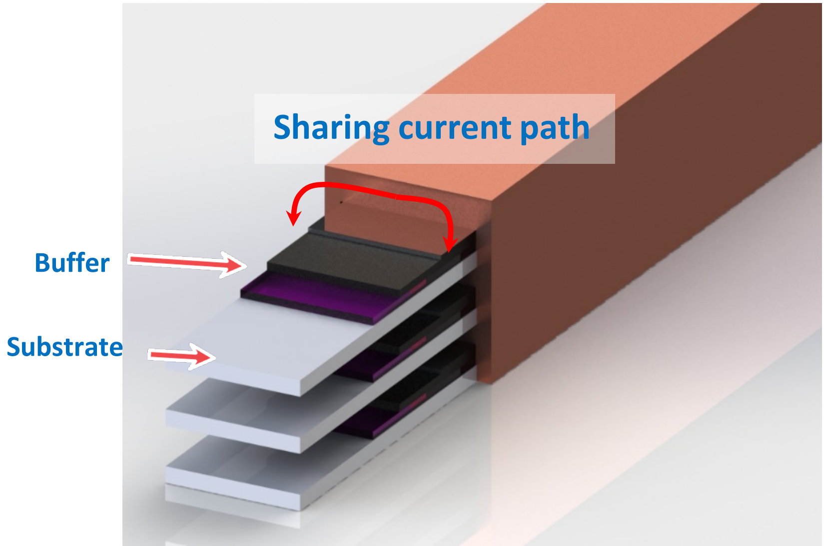
- ✓ Avoiding defects in YBCO layers is difficult
- ✓ Some defects are hidden, get revealed only after coil tests

Solution: electrically coupled cable

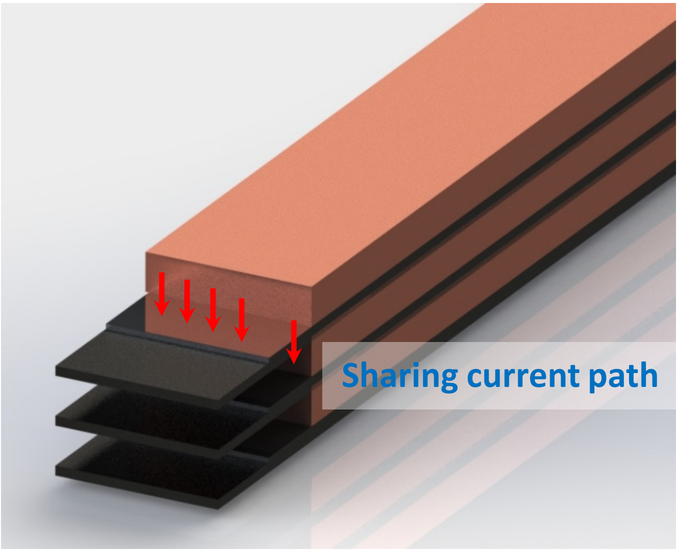
We are solving the following problems:

- Single-filament magnets proven difficult to protect against burnout
- Substrate prevents efficient current sharing
- Multifilamentary cable is far more expensive than a single tape
- Not compatible with epoxy impregnation

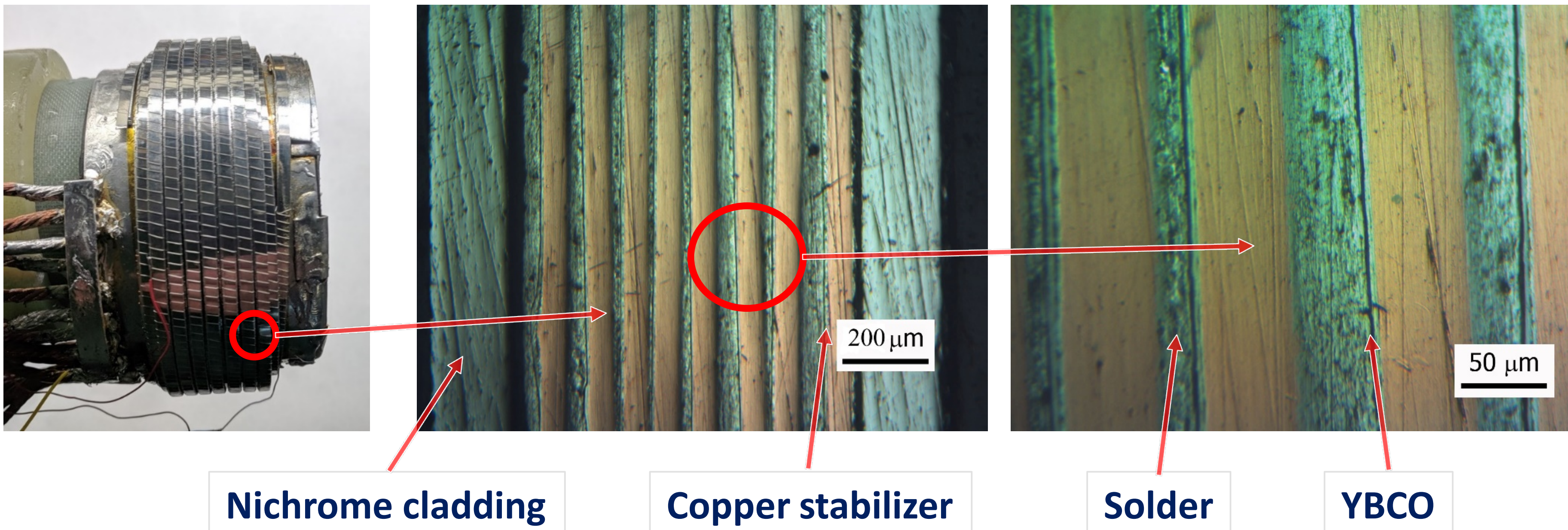
2G wire stack



BTG exfoliated filament stack



Multi-filamentary cable architecture



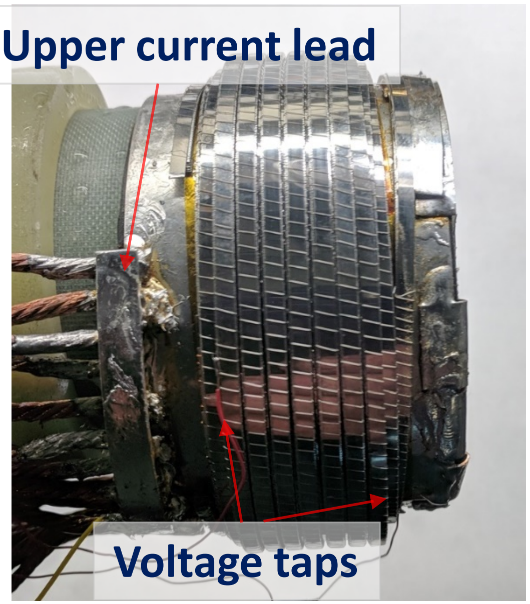
✓ **Electrically connected filaments are the key element**

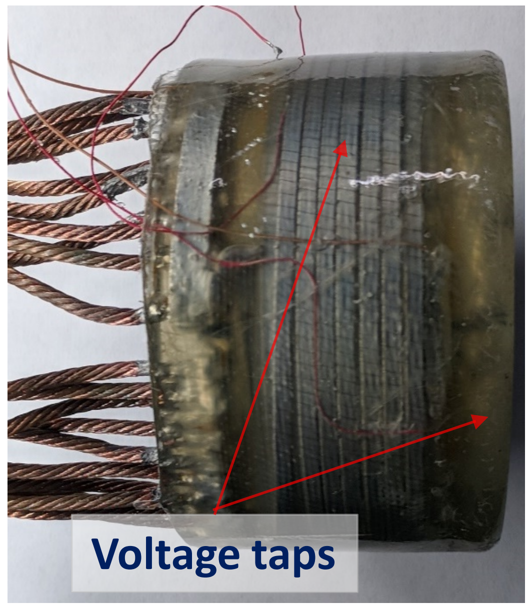
Test coil manufacturing process

Dry wound

Vacuum impregnation, Stycast 1266

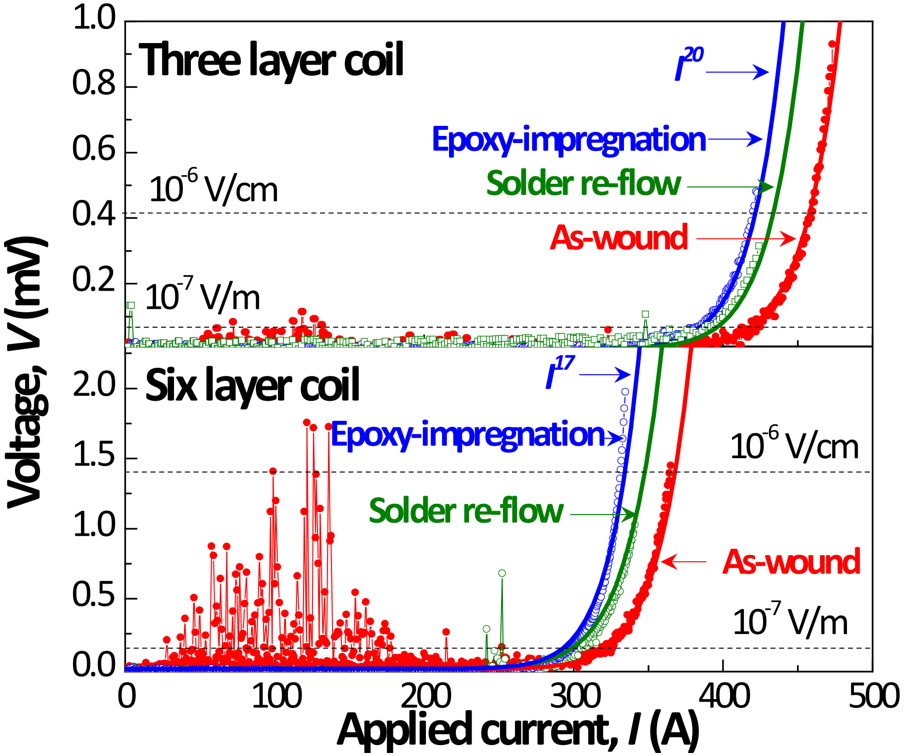
Cooling collar attached

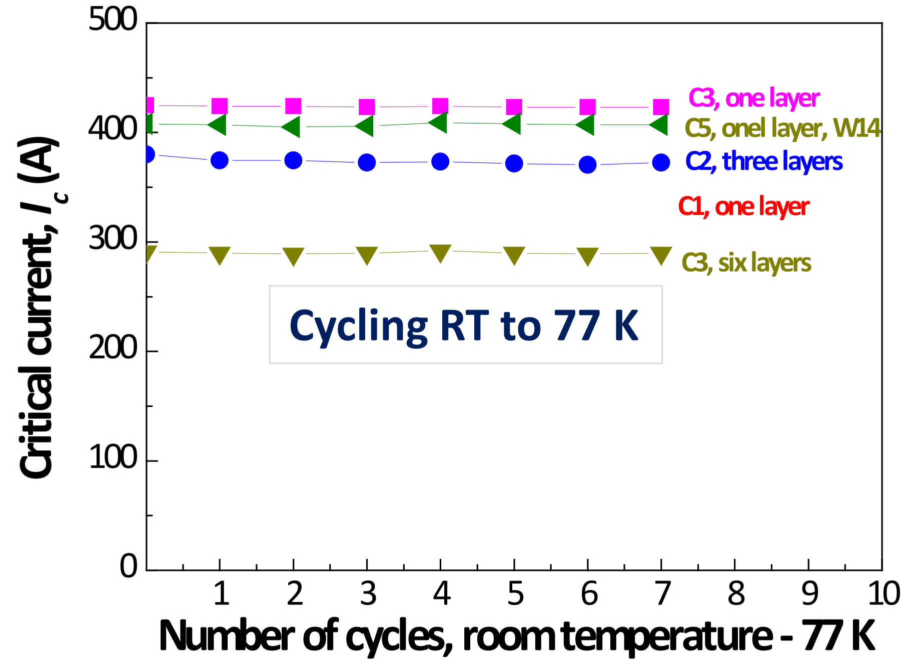




12 coils, over 100 meters of cable tested

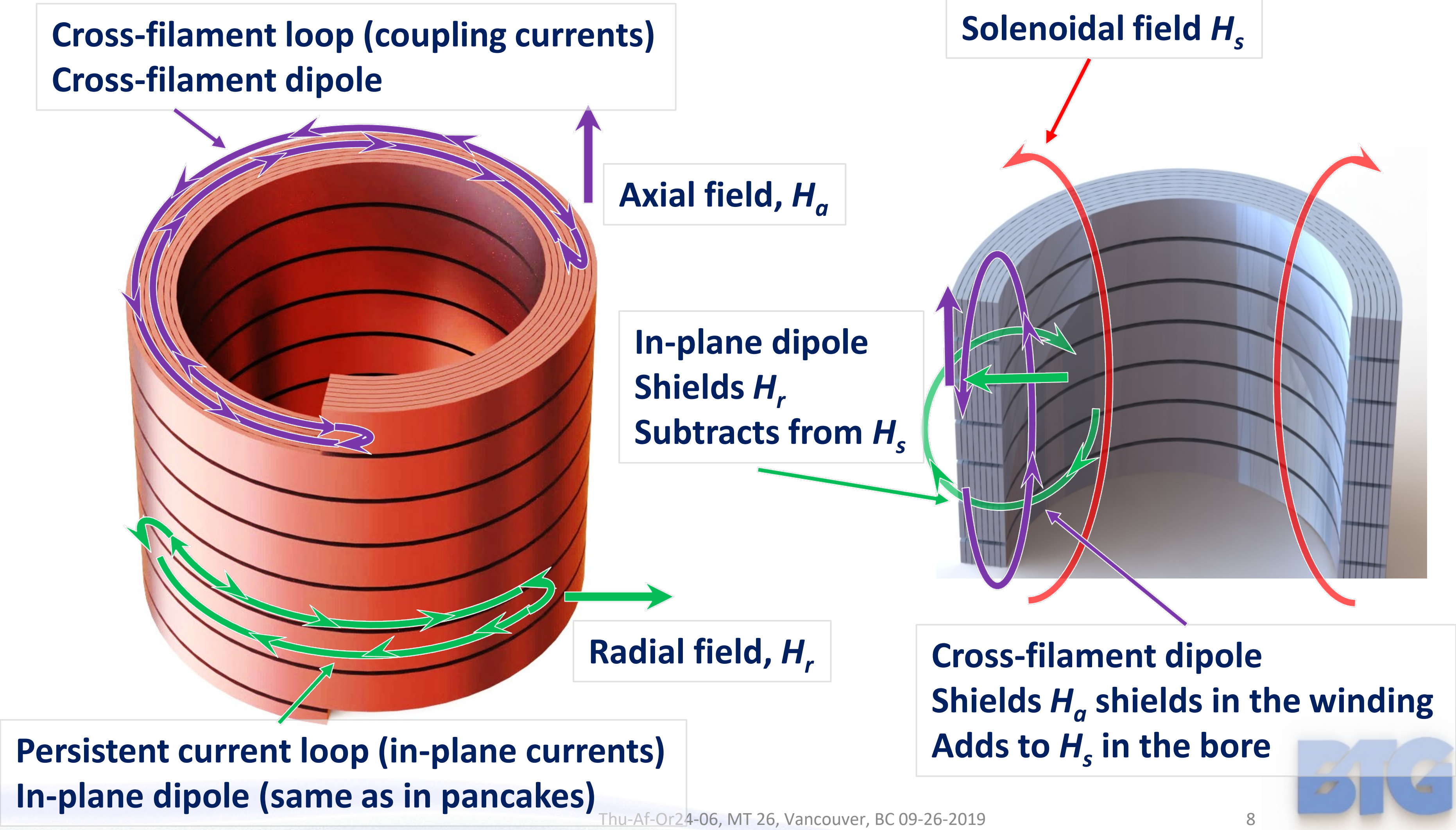
77 K performance after re-flow and impregnation



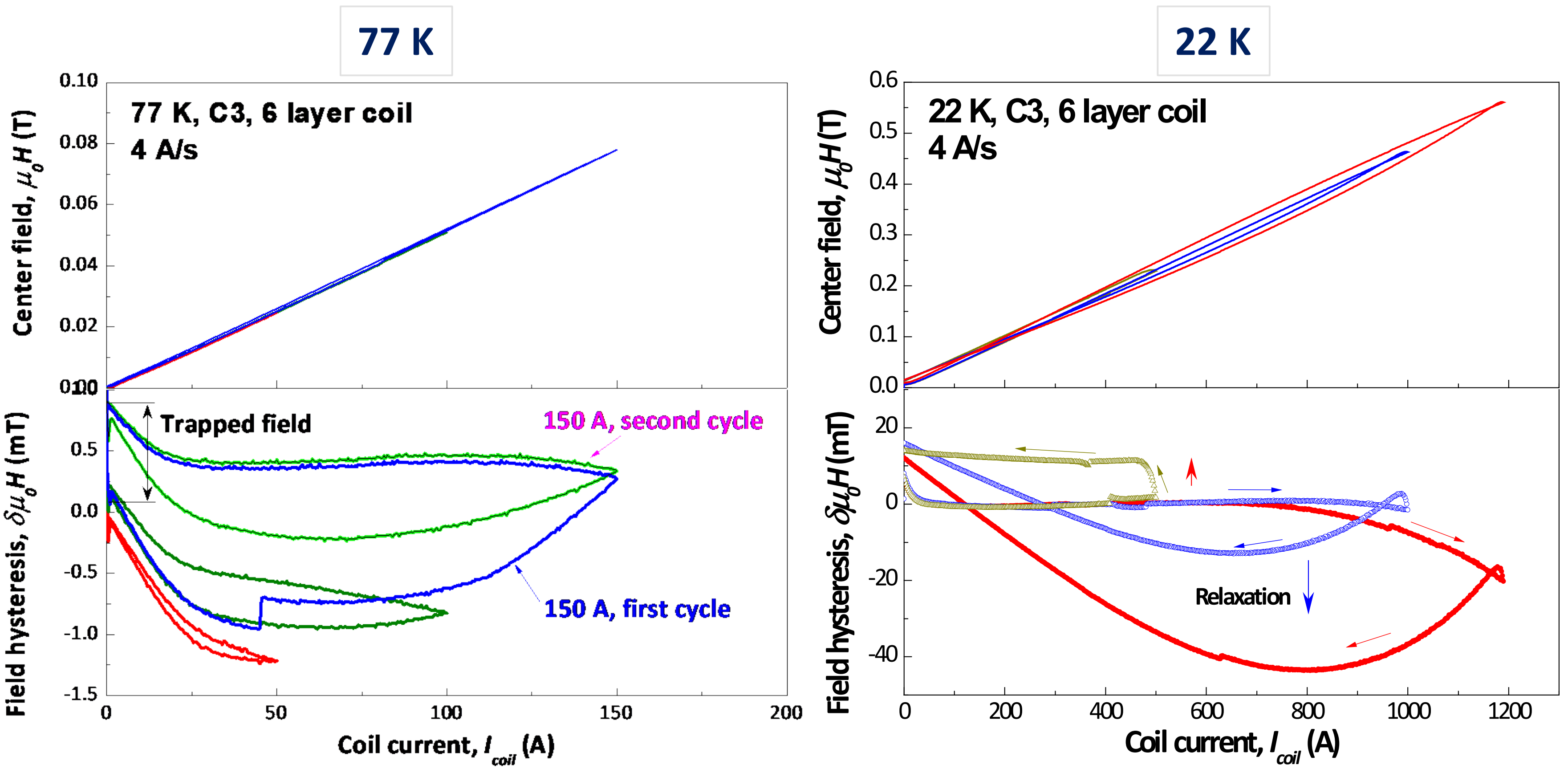


- ✓ No Ic and n-value degradation after multiple rapid cool-downs to 77 K
- ✓ Solder reflow significantly reduces the winding noise, but reduces I_c by 8%

Winding magnetization: flux penetration model into a coupled cable, highly anisotropic filament



Central field hysteresis at 77 and 25 K

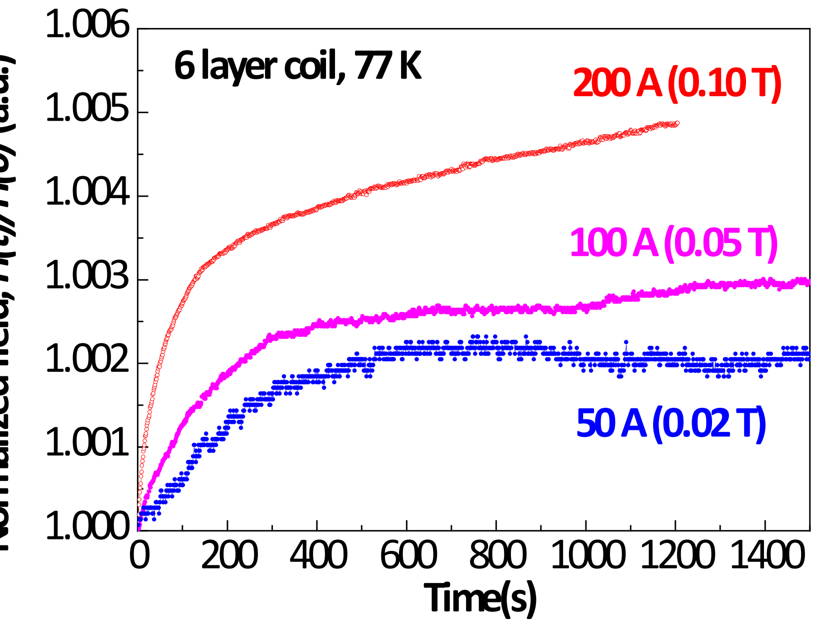


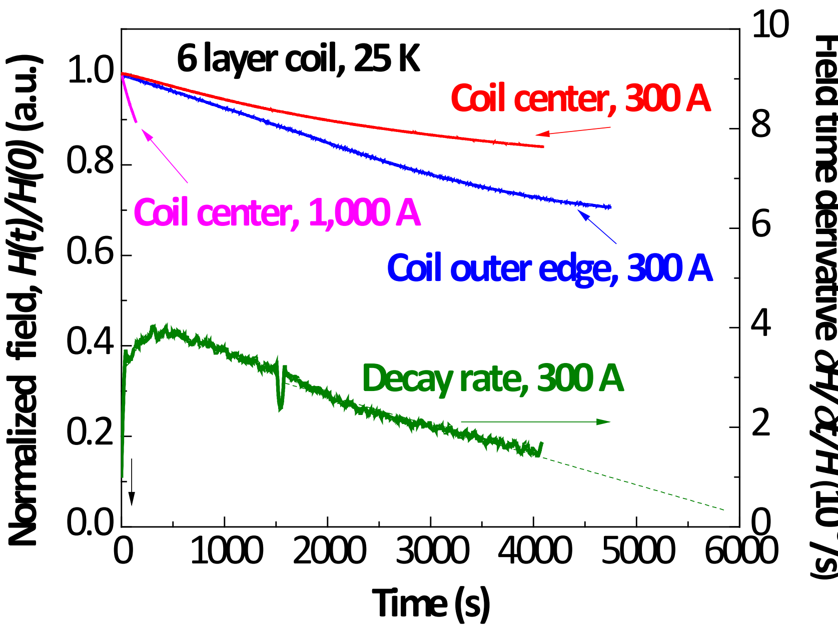
✓At 22 K field dynamics is defined by relaxation at high currents

Flux dynamics at 77 and 25 K

77 K

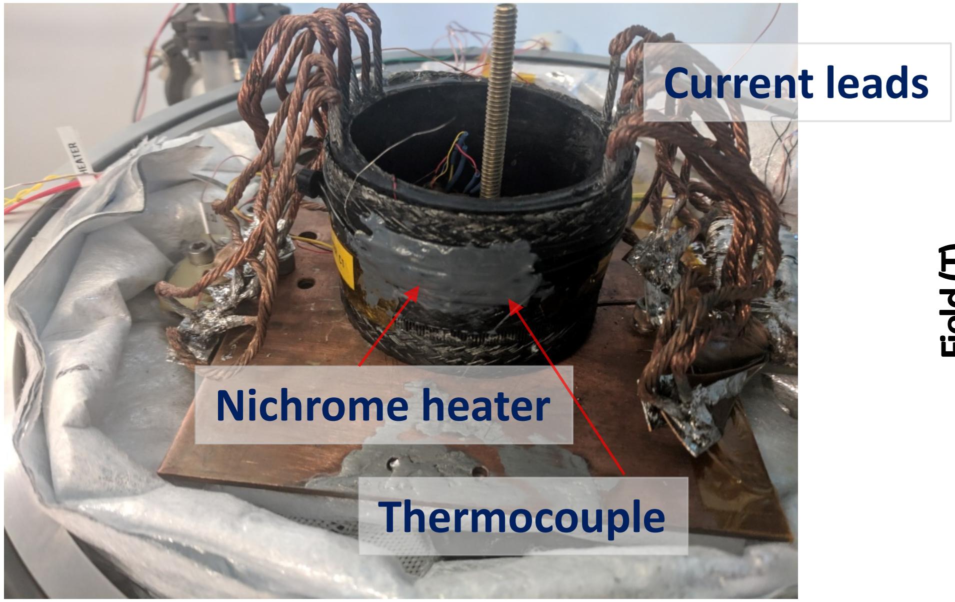
25 K

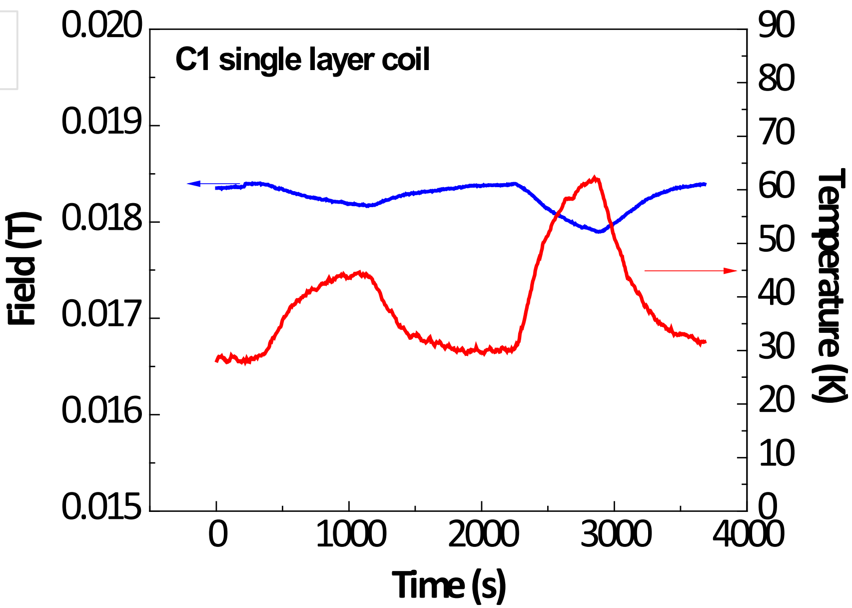




✓ **Completely different field settling profile at 77 and 25 K.**

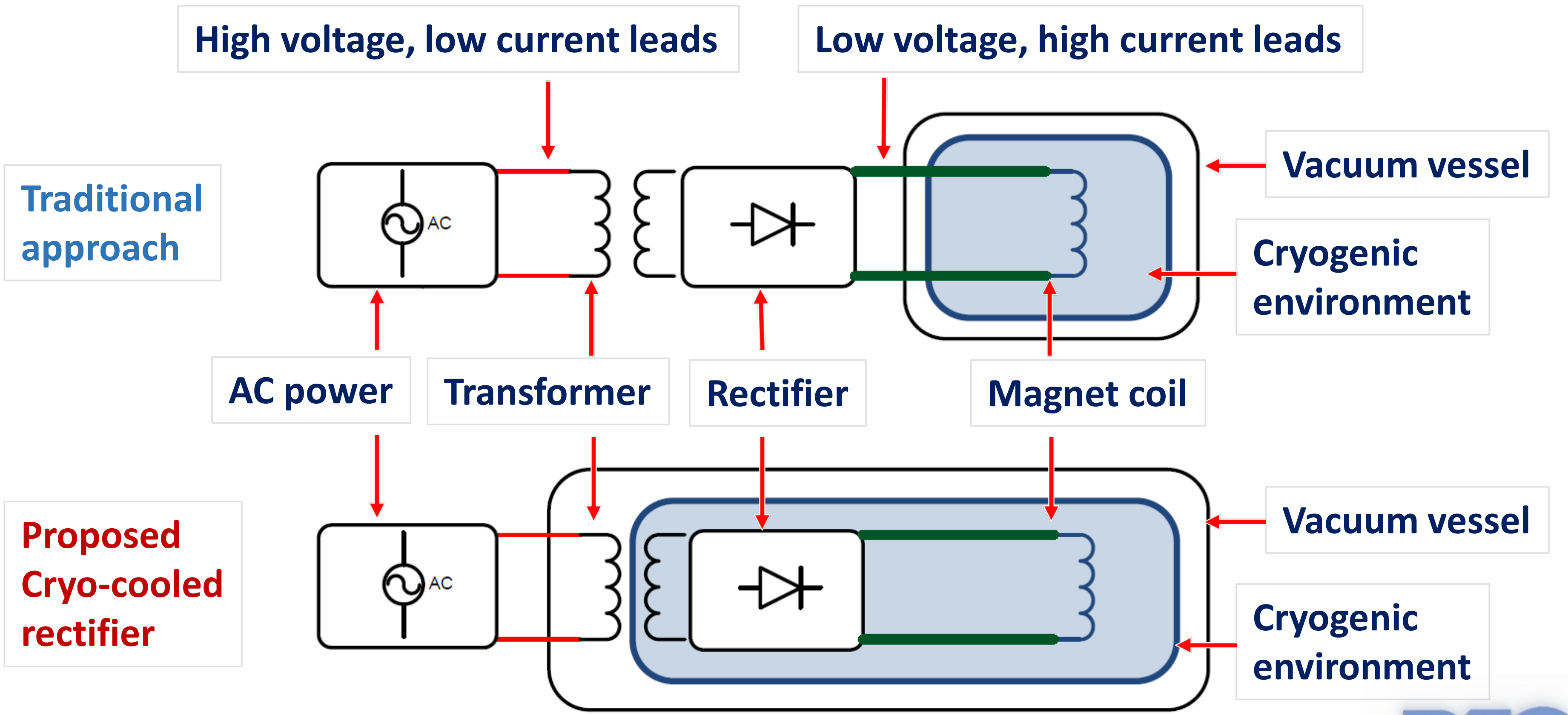
Heat migration from the current leads and effect on the field quality



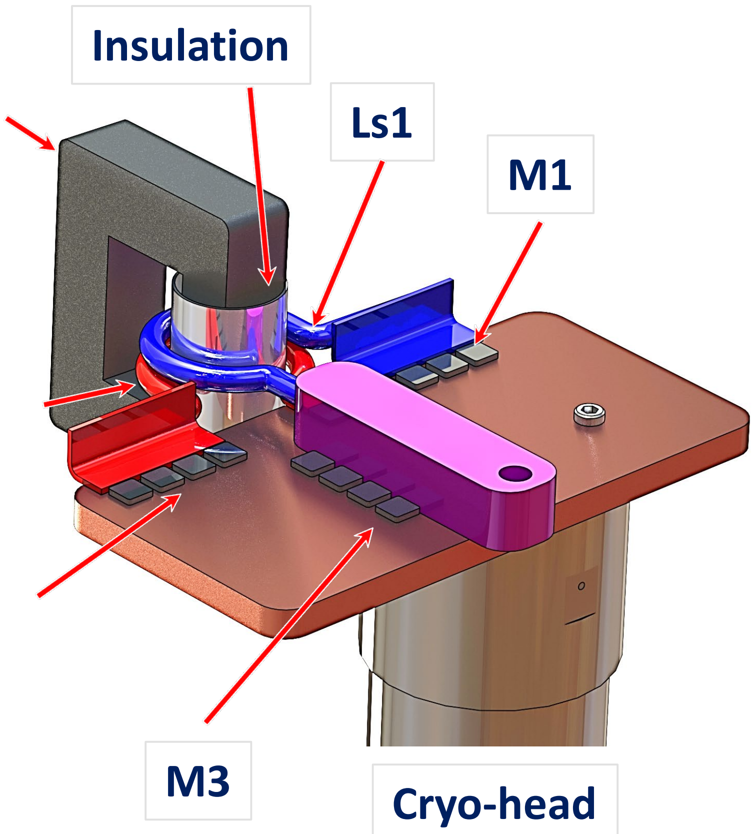


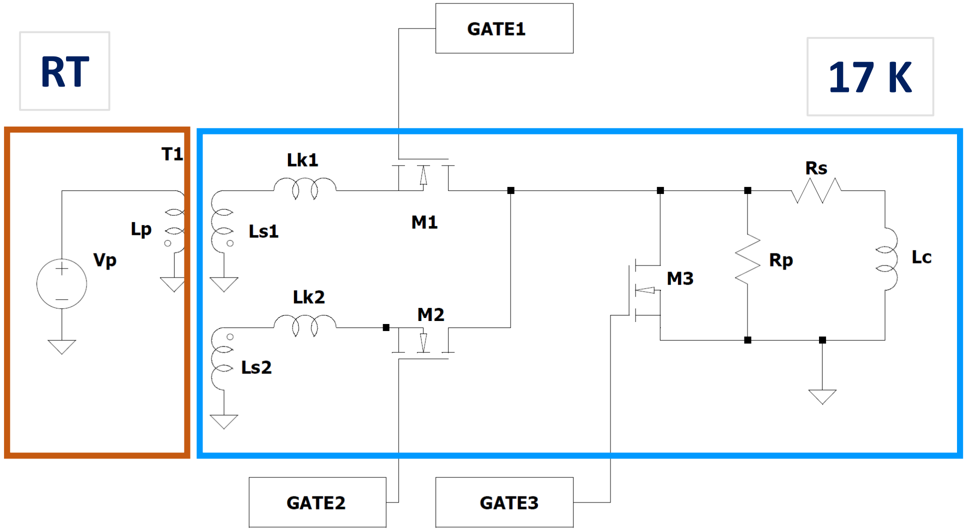
✓Winding temperature gradient are responsible for the field decay

Proposed cryocooled rectifier

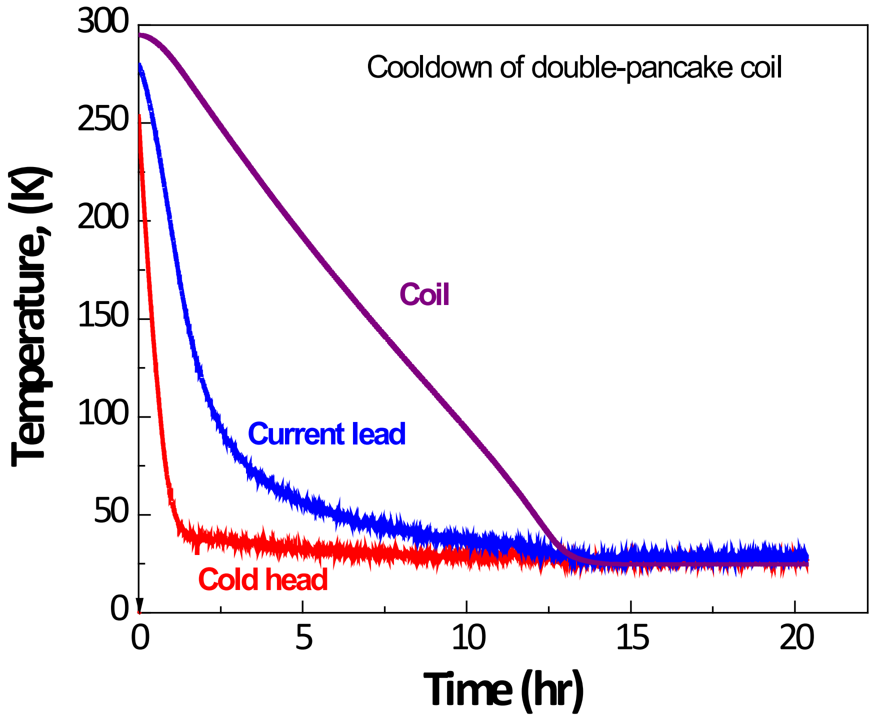


Mechanical design of the current management system



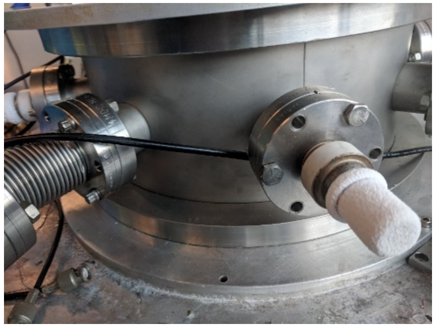


System cooldown, cryogenic current drive



Power input

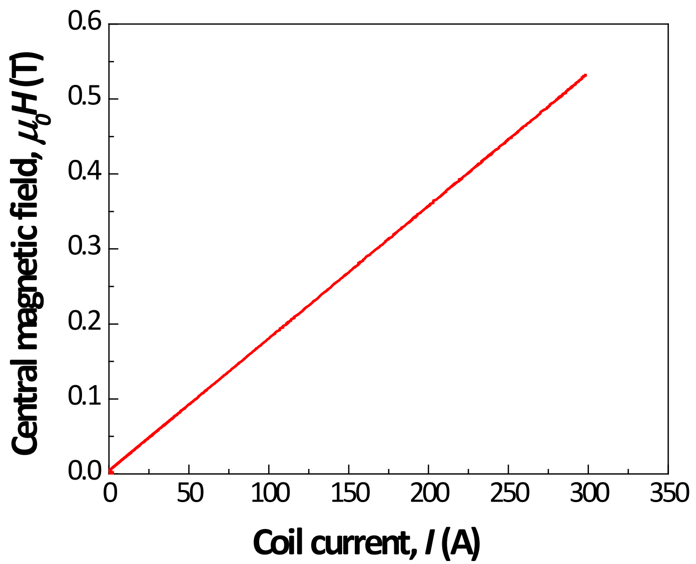
Traditional

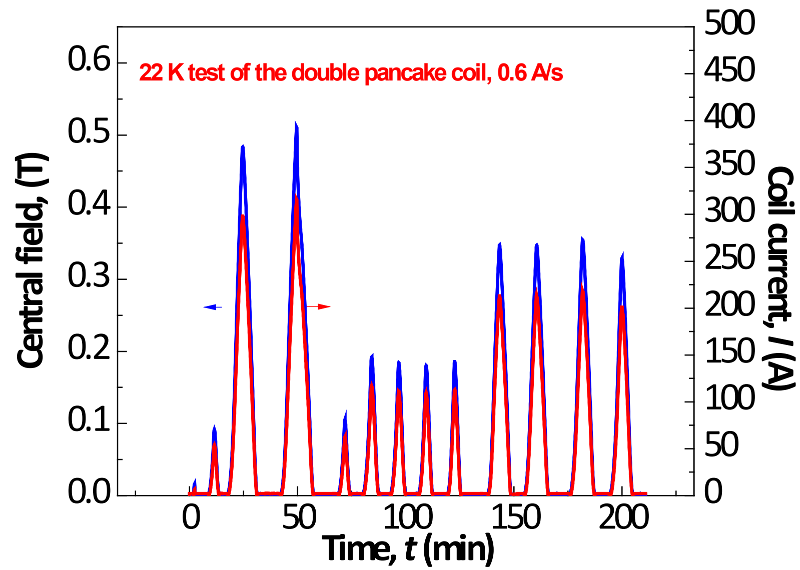


Cryogenic drive

✓**Lighter high-voltage input introduces very little conduction loss**

Powering a double-pancake coil with a cryogenic current drive





✓ **Significantly reduced hysteresis**

Conclusion and future challenges

- Conclusion:
  - Demonstrated operation of epoxy-impregnated multi-filamentary cable in conduction cooled mode
  - Winding magnetization at 25 K is strongly affected by thermal gradients, due to heat leakage trough current leads
  - Cryogenic current drive reduced hysteresis

- Future challenges
  - Scale-up of the filament handling
  - Continuous splicing
  - Designing interleaved multi-module current drive