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Construction and Persistent-Mode Operation of MgB_2 Coils in the Range 10 - 15 K

for a 0.5-T/240-mm Cold Bore MRI Magnet

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Outline

- Project overview
- Coil design
- Joint: key issues; test results
- PCS: open/close; dump
- 3 Coils & 3-coil assembly: persistent-mode operation & discussion
- Next step
- Conclusions

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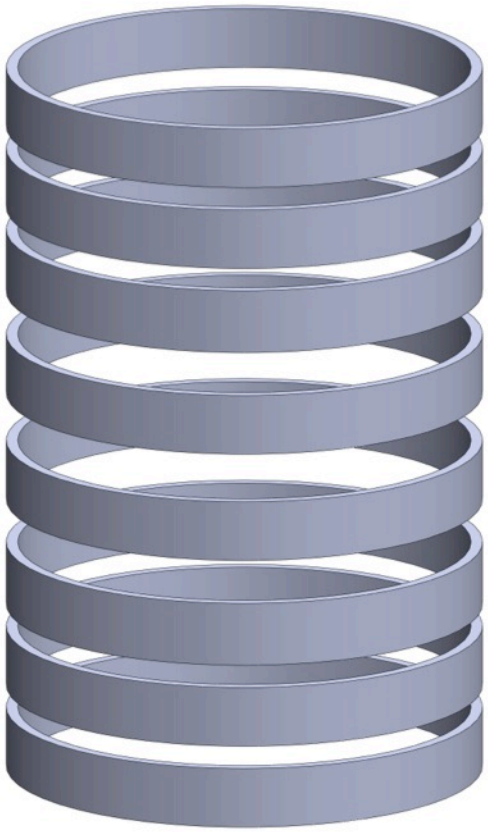
Project Overview



Parameters [Unit]	Values
I.D. [mm]	276
O.D. [mm]	290
Total Height [mm]	460
Operating Current [A]	102
Center Field @ 102 A [T]	0.5
Overall Current Density [kA/cm^2]	11.3
Total Conductor Length [km]	2.1

- Wind-and-react
- Module coils, each with a PCS and joint
- Wound with monofilament wire
- Persistent operation in the range 10-15 K

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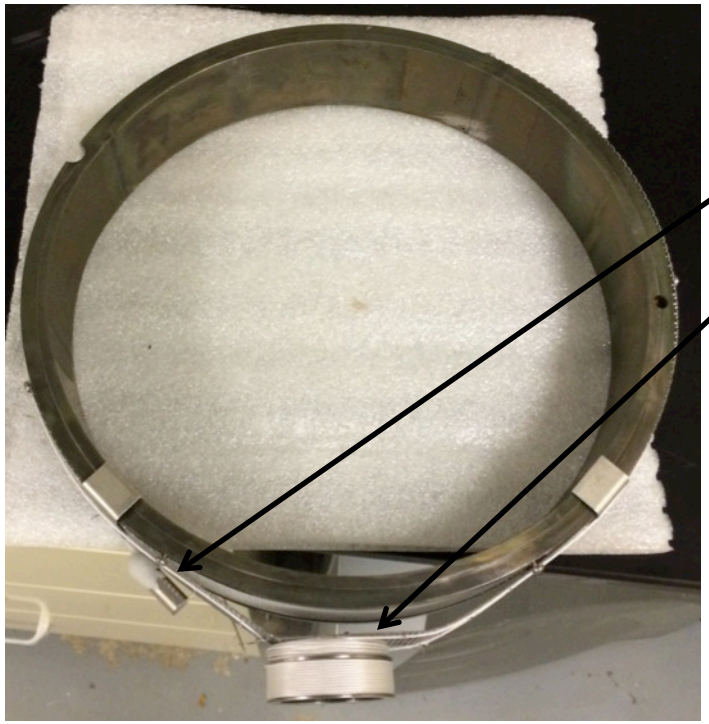
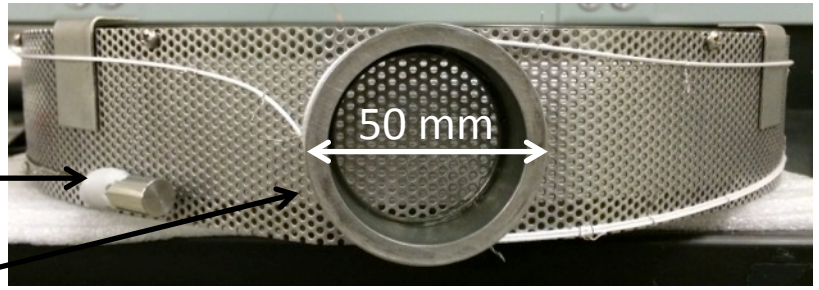
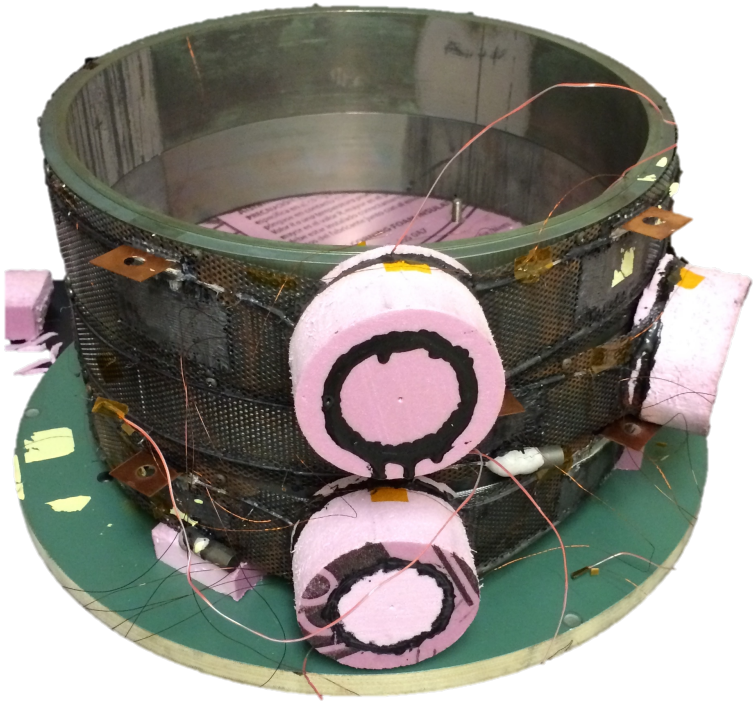
Coil Design







- Perforated sheet for securing PCS and joint
- Copper connectors
- Stycast after heat treatment
- Styrofoam to insulate PCS
- Staggered PCS position to avoid interference

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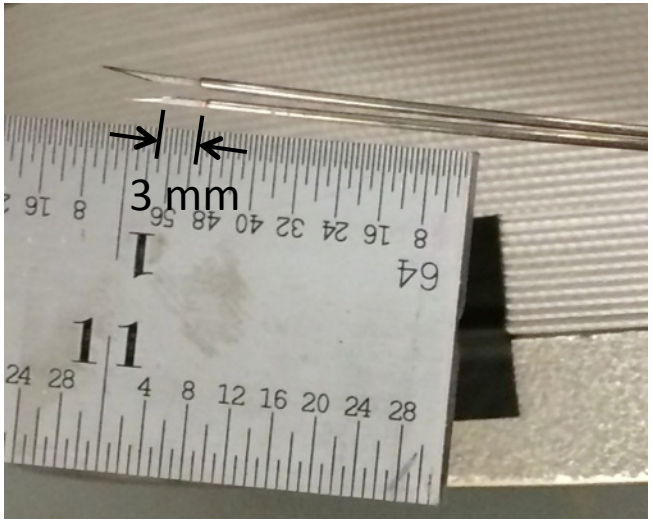
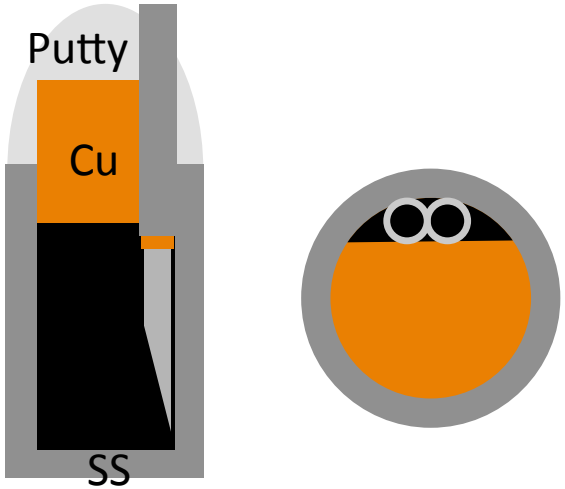
MgB_2 Monofilament Unreacted Joints

- Effect of potential copper contamination
- Compress powder, but not necessarily with extremely high pressure (300 MPa)
- High ambient pressure (35 kPa) during heat-treatment
- Argon environment, no moisture





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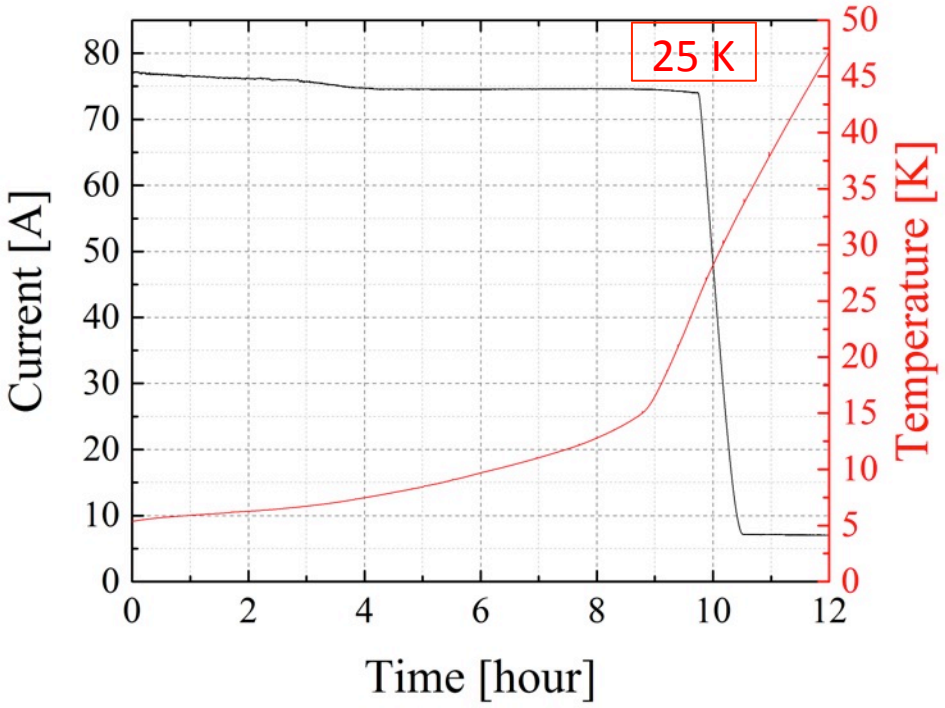
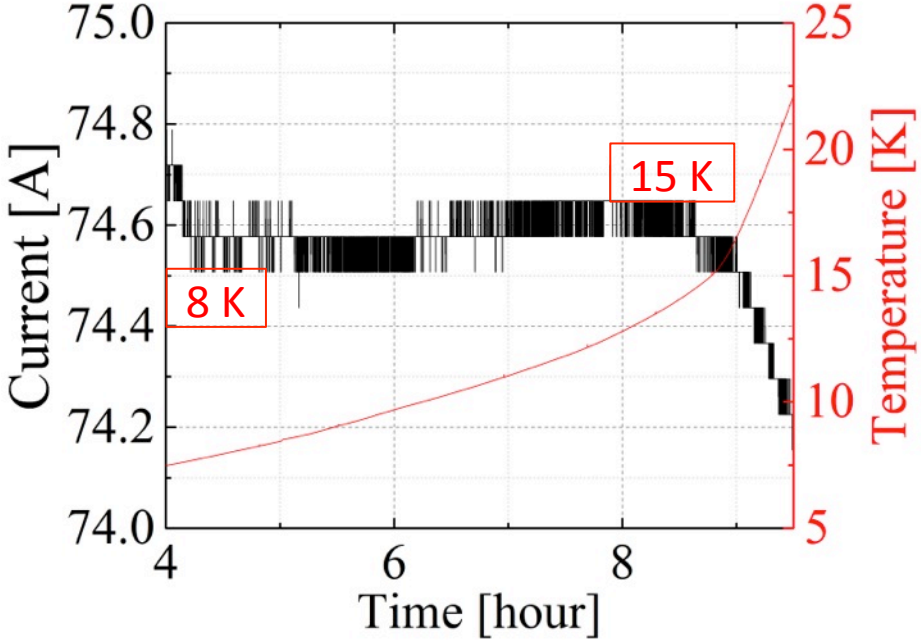
Small-Loop Test at 75 A





- Initial decay possibly due to niobium
- No observable decay 8-15 K for 4.5 hours
- Loop inductance ≈ 3×10^{-5} H
- Loop resistance < 3×10^{-12} Ω

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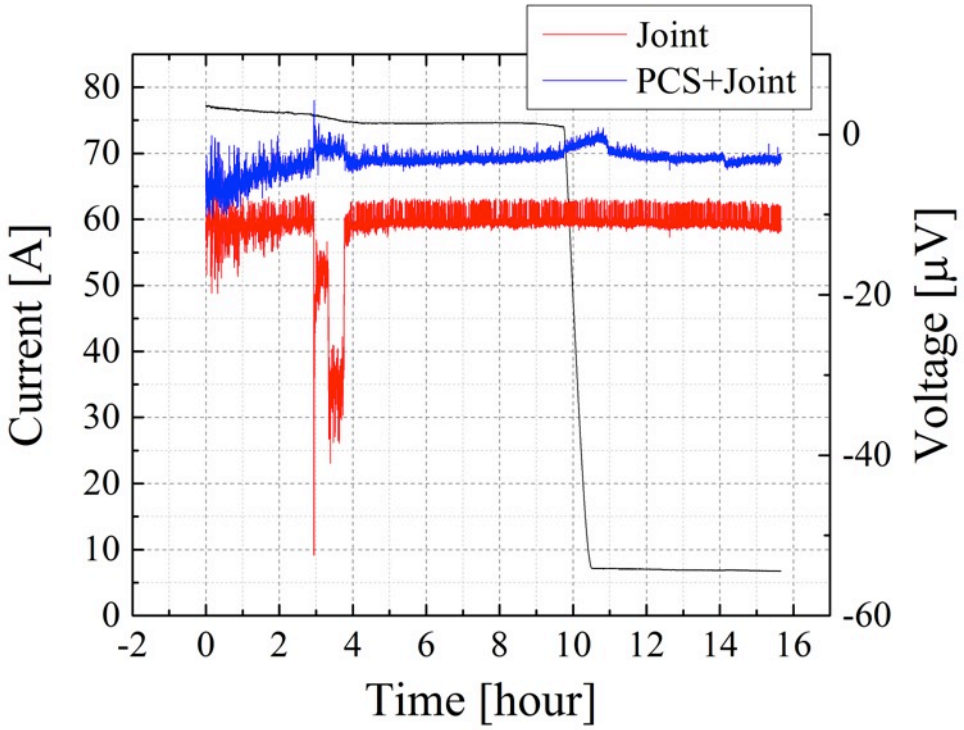
Small-Loop Test at 75 A (Cont.)



Field decay or coil quench not caused by the joint

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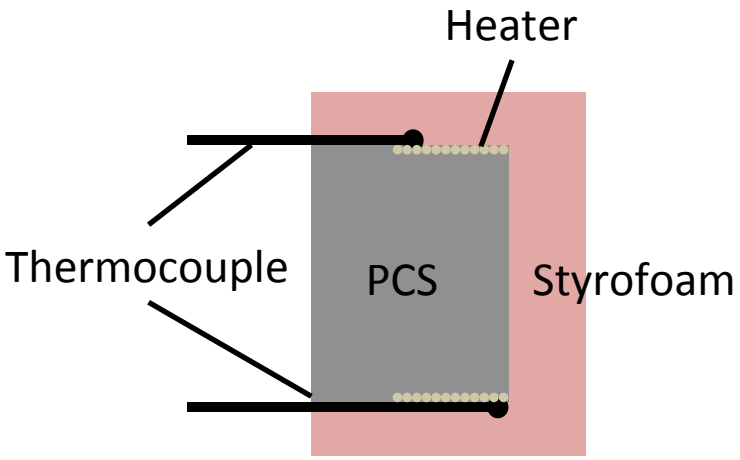
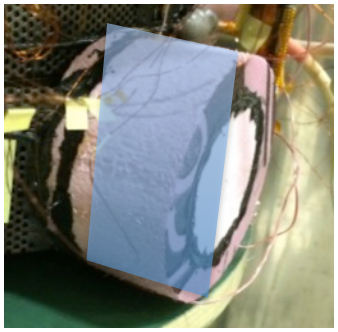
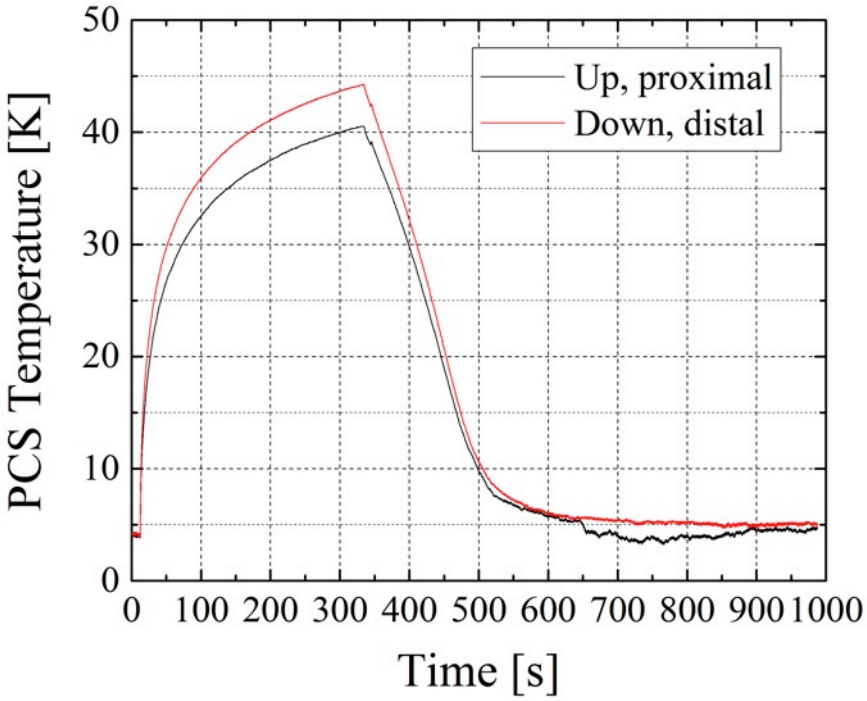
PCS Open/Close



Side view of an insulated PCS

- Opens in 3 min. with 1 W
- Closes in 3 min. in gas helium
- Less than 1 W to maintain 40 K in gas helium at 5 K





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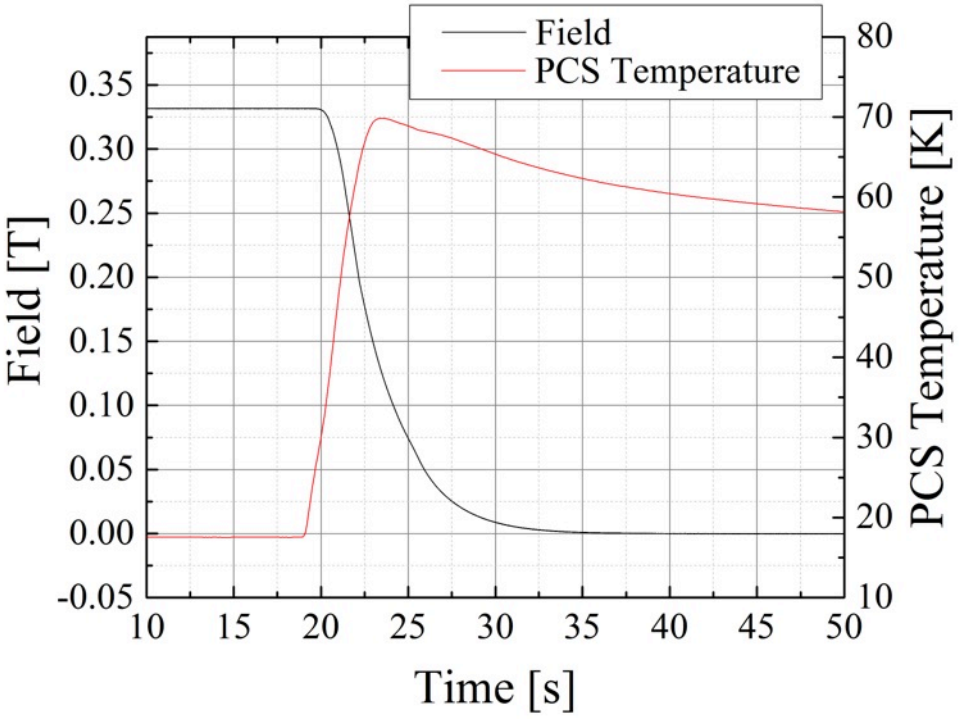
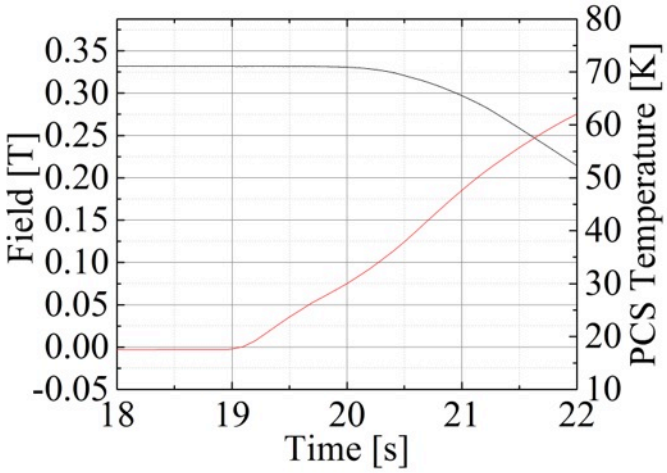
PCS Dump Test





- Dump initiated in 1 s with 0.4-A current; faster with a capacitor
- Dump time constant ~ 3 s
- Highest temperature in PCS < 70 K

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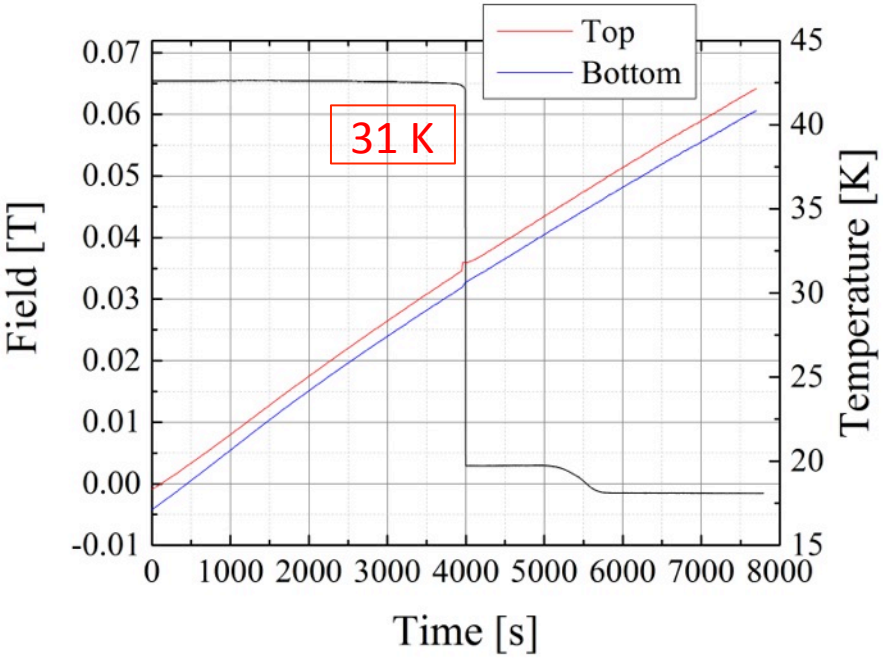
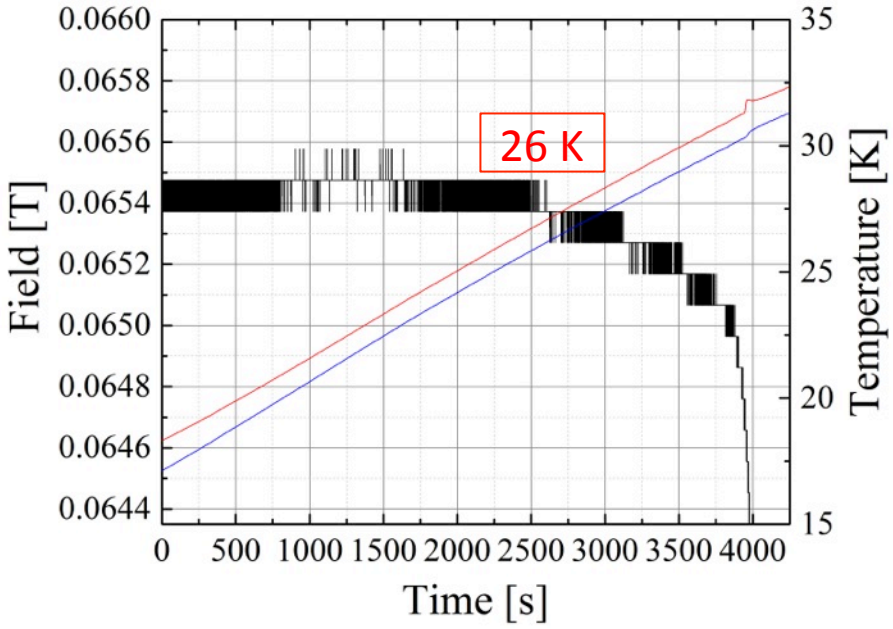
Single Coil Persistent Mode at 50 A





50 A Persistent Mode: field degraded at 26 K; coil quenched at 31 K

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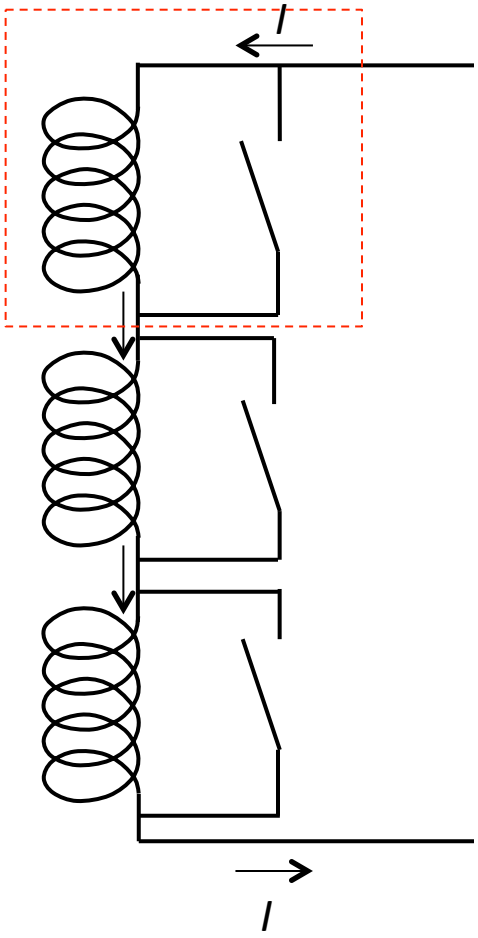
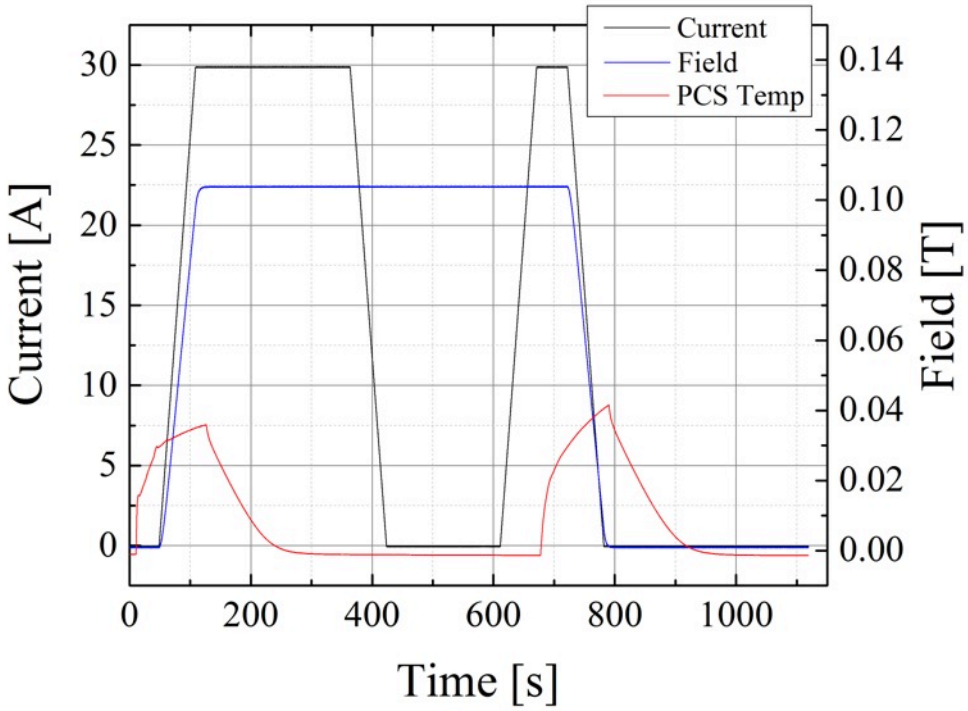
Charge/Discharge 3-Coil Assembly in Persistent Mode





Each coil charge/discharge when PCS's open/close simultaneously

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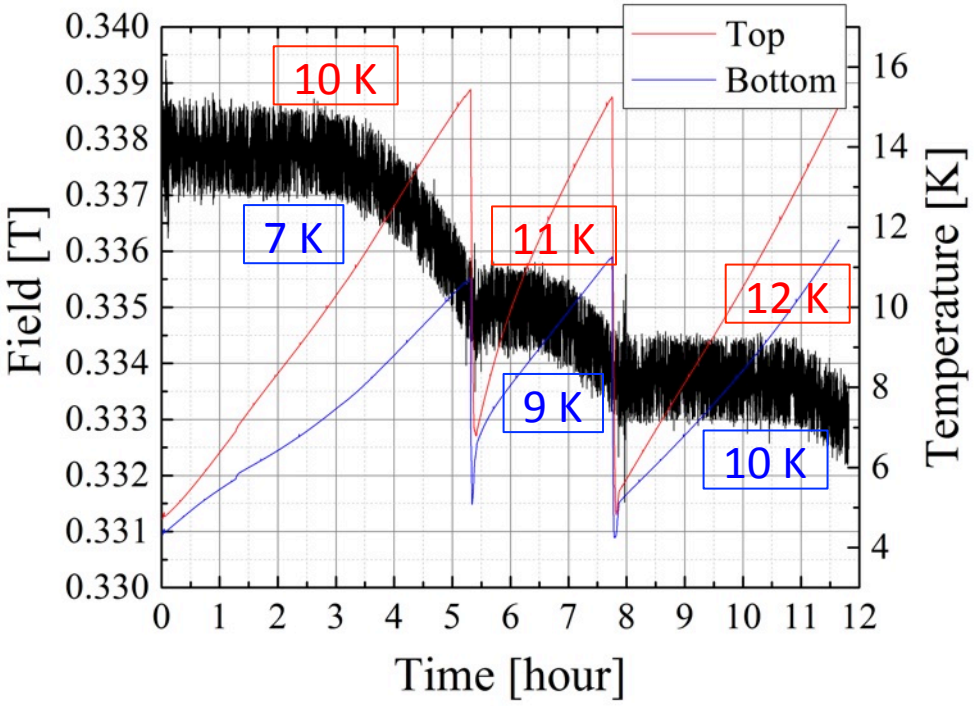
3-Coil Assembly Persistent-Mode at 100 A



Persistent mode at 100 A to 10 K; 98 A to 12 K

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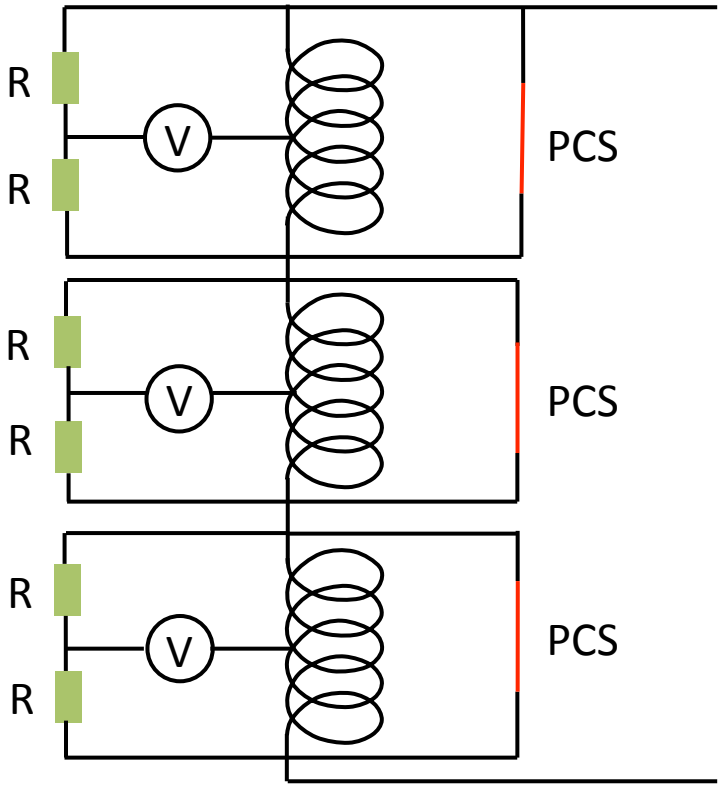
Bridge Circuit



Bridge voltage indicates resistance in the coil

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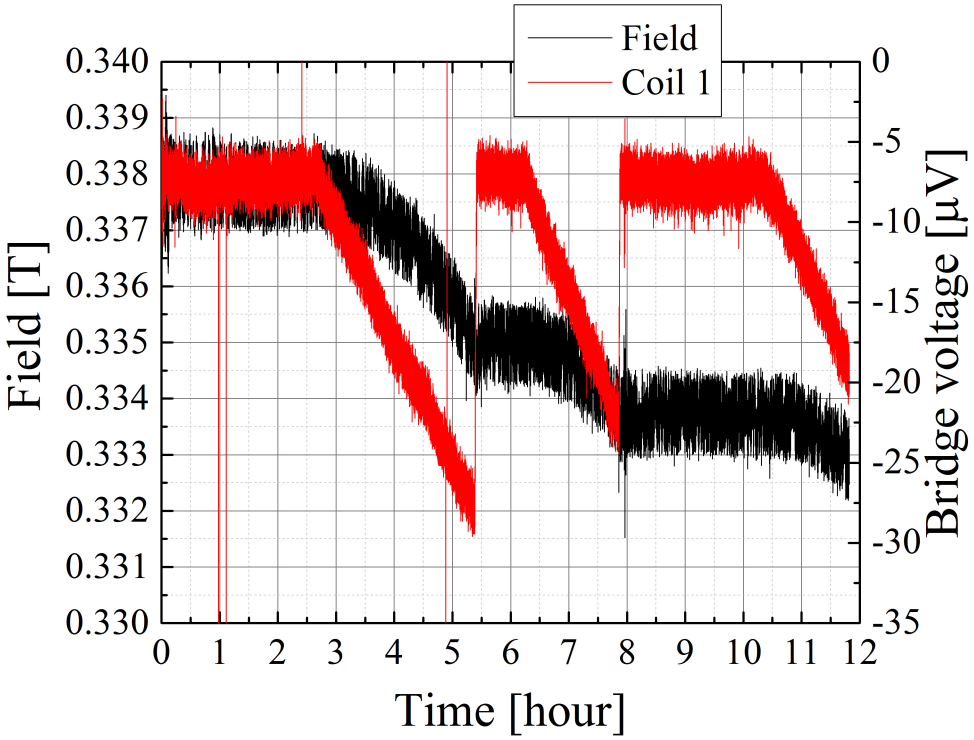
Bridge Voltage of Coil 1



Average voltage of the first decay:

$$V = \frac{1}{2}IR = \frac{1}{2}L\frac{dI}{dt} = 0.5 \times 0.2 \times \frac{1}{7200} = 1.4 \times 10^{-5}\ \mu\text{V}$$

Calculated d*I*/d*t* matches measured values

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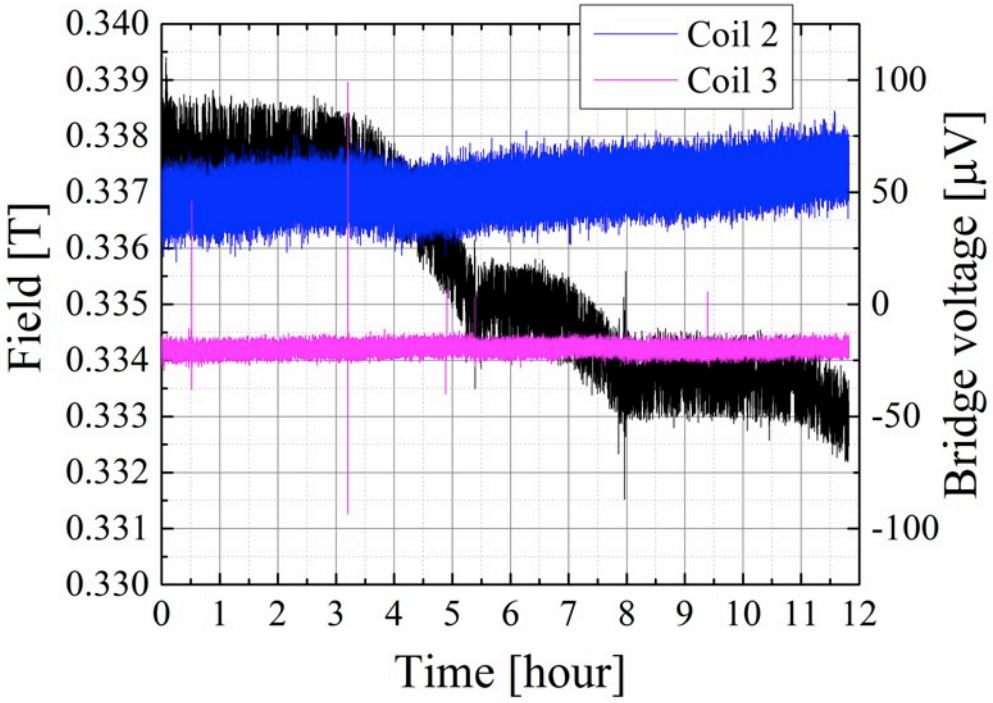
Bridge Voltages of Coil 2 & 3



Coils 2 & 3 superconducting

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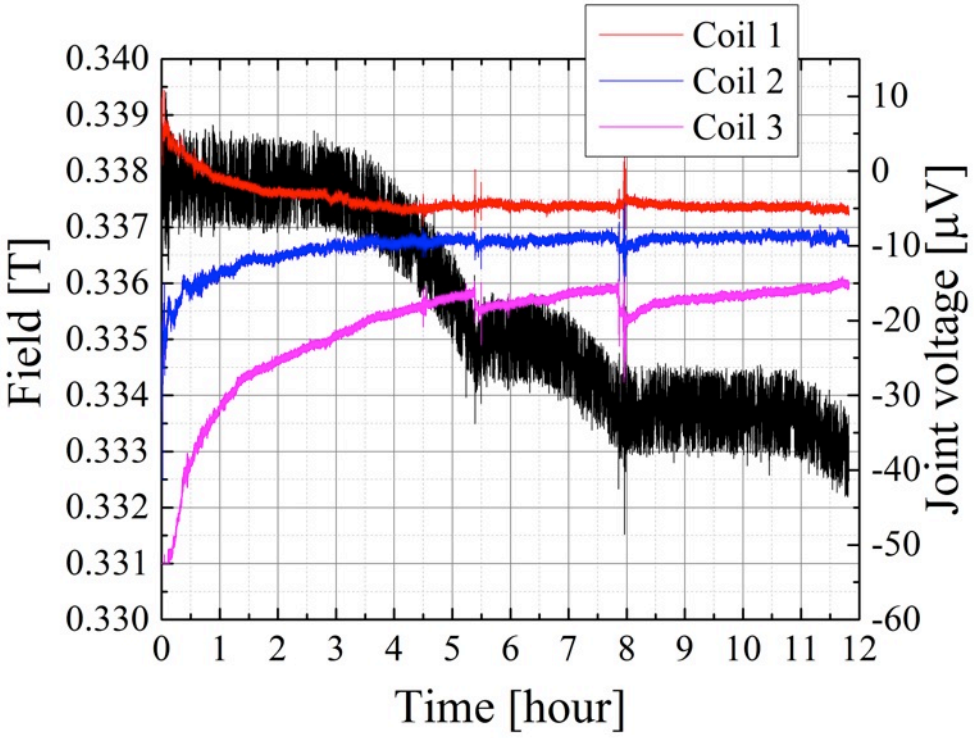
Joint Voltages of 3 Coils



Joints 1, 2, & 3 superconducting

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Potential Reasons for Coil Defect

- Winding
- Heat treatment
- Handling after heat treatment
- Thermal shock from ~ 70 K to room temperature
- Over heating during test

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Next Step

- Finish 8-coil assembly
- Coils immersed in SN2, with better temperature control for monitoring persistent-mode longer
- Room-temperature bore for field mapping

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Summary

- Built & assembled 3 coils for a 0.5-T/240-mm cold bore MgB_2 magnet, each of ~ 300 m continuous length
- First full-current operation of multiple-coil assembly in persistent-mode at > 10 K
- Confirmed successful operation of key components: 1) 276-mm ID MgB_2 coils; 2) PCS; 3) superconducting Joint; 4) protection

Thank You!