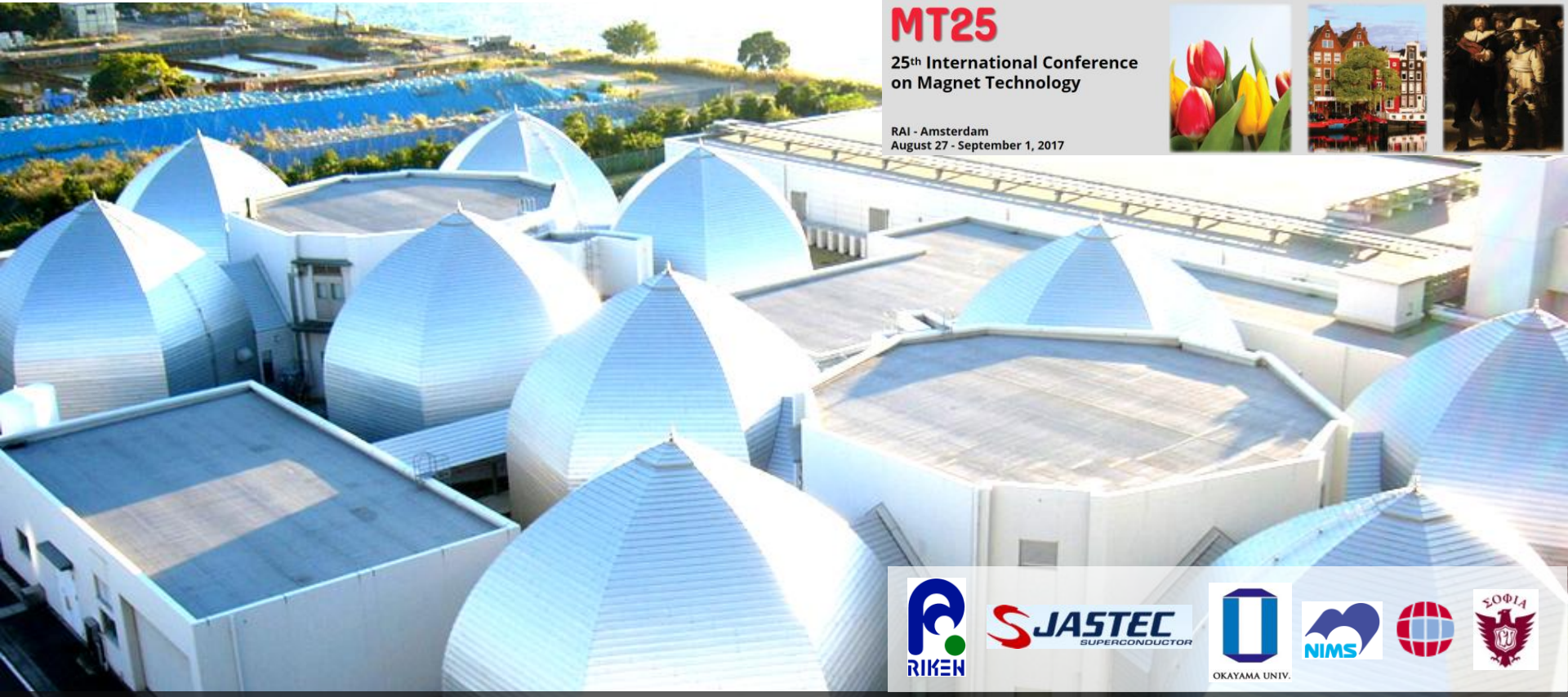
This work was supported in part by the MEXT and in part by the Japan Science and Technology Agency (JST) under the Strategic Promotion of Innovative Research and Development Program.



Design and technical development of a high-resolution 1.3 GHz NMR magnet

Mon-Af-Or5-01

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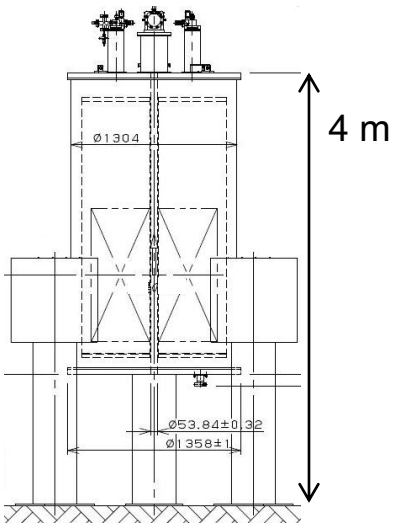
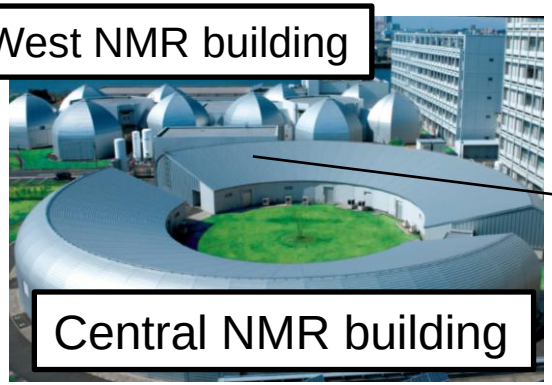
Contents

Requirements for a 1.3 GHz NMR magnet

- ***1.3 GHz (30.5 T) high-resolution NMR applicable to amyloid protein analysis to cope with Alzheimer's disease***
- ***Compact magnet and less stray field (5 G line: <8 m)***
- ***No helium consumption, by using cryocoolers***
- ***Operated in the driven mode or if possible in the persistent current mode***



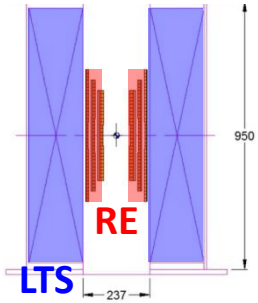


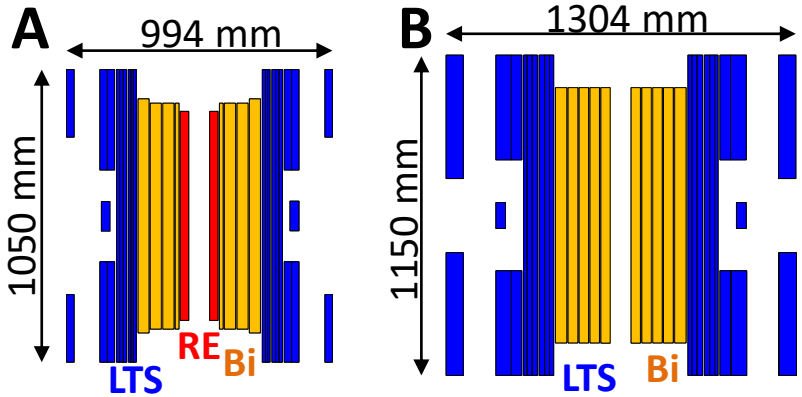
RIKEN Yokohama Campus

Concept and first design options

1. ***High HTS field contribution*** *(>23 T) for compactness*
2. ***Bi-2223 dominant design*** *with a REBCO innermost coil*
3. ***LAYER-WOUND COILS*** *for homogeneous magnetic field and future opportunity of persistent current operation*

Iwasa et al.
IEEE TAS **25**
(2015)
4301205





	MIT 1.3 GHz	Present work (Bi-2223 dominant)
HTS coil	REBCO (18.8 T)	**A:** Bi-2223 (16.9 T) + REBCO (7.6T) **B:** Bi-2223 (23.0 T)
Winding	NI double-pancake	Layer-wound

- **Smaller screening current-induced field and opportunities of a persistent current operation**
- **Larger magnet**

Technical issues on the designs

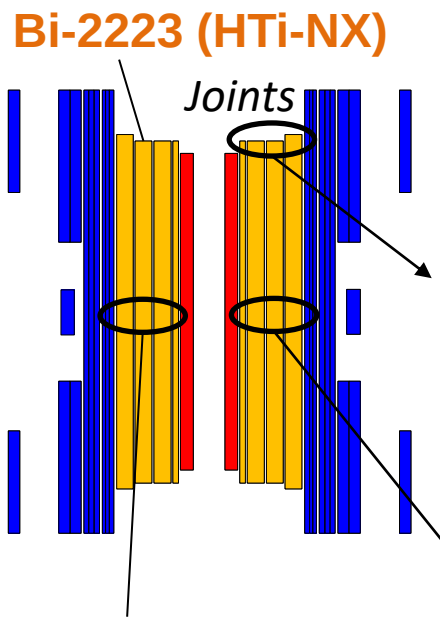
- **Bi-2223**: *Easy to control, without unexpected degradation*
  => **MECHANINCAL STRESS MANAGEMENT**

- **REBCO**: *Hard to control, due to a large screening current-induced field and degradation*
  => **PREDICTION OF SCREENING CURRENT** and **PROTECTION**

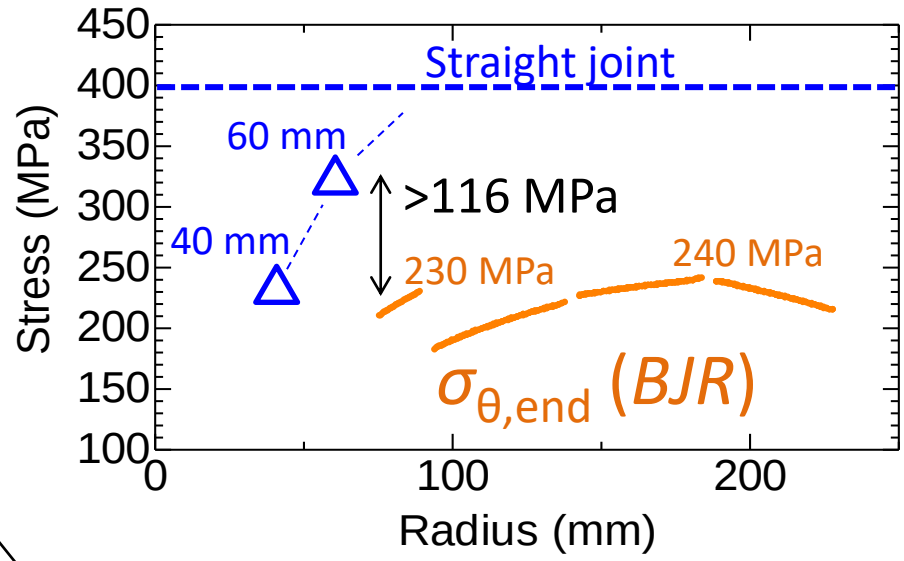
- Persistent current operation
  => **SUPERCONDUCTING JOINTS**
  (Wednesday morning plenary)

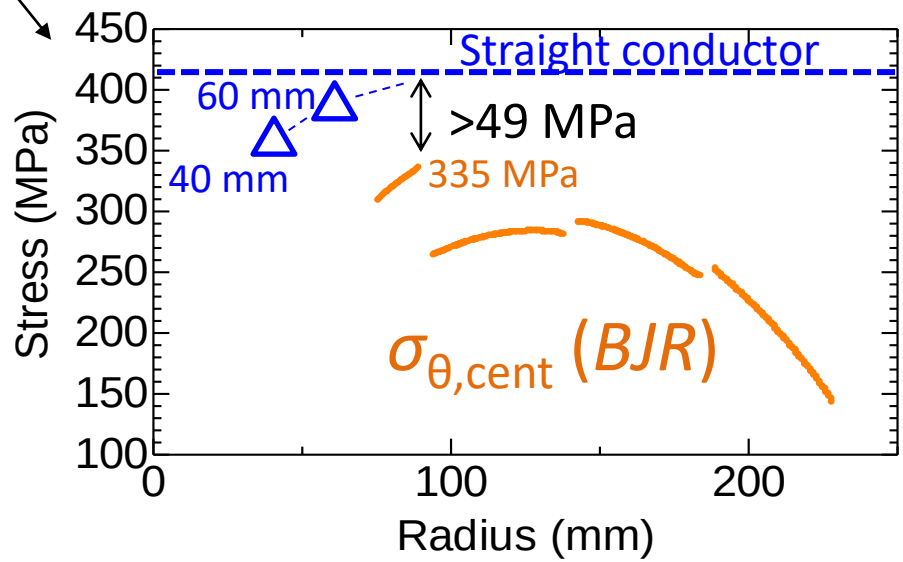
Contents

Hoop stress tolerance under bending strain



σ_z = -50 MPa

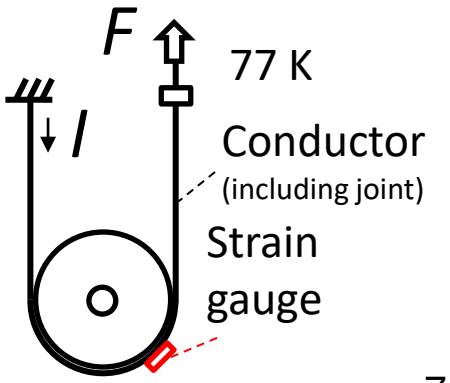




99% I_c recovery stress (reversible stress) measured at 77 K

Joint resistance:

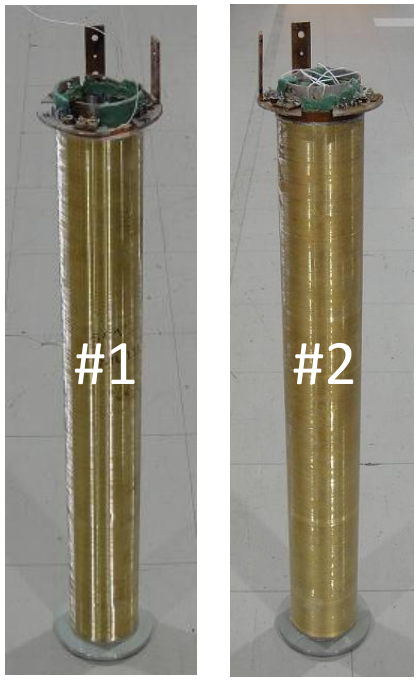
- ~50 nΩ/joint at 77 K
- Sufficiently small for driven mode operation



Axial compressive stress tolerance

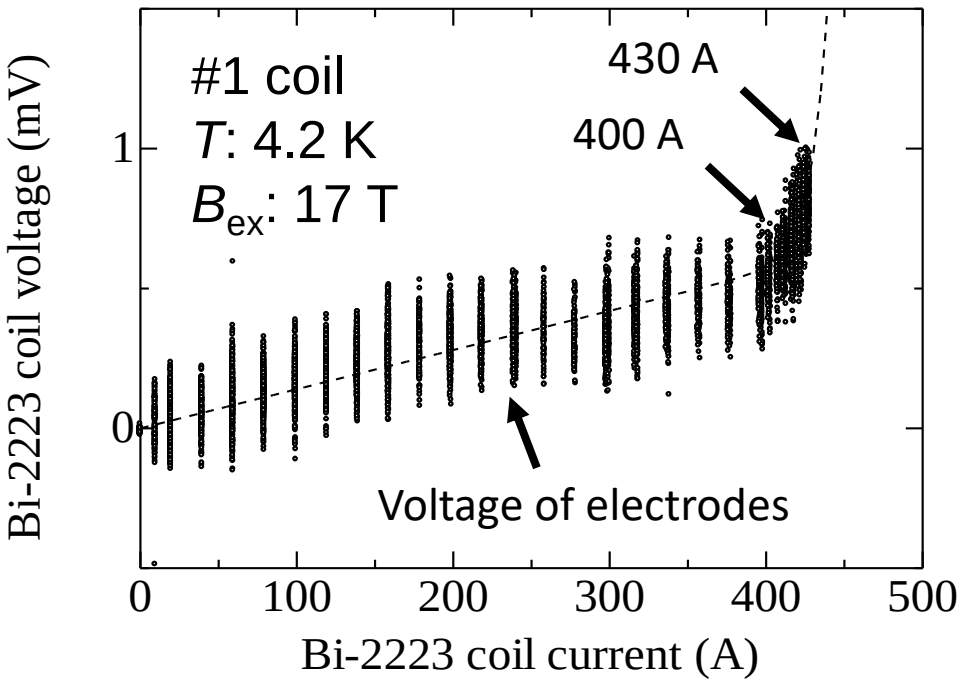
Bi-2223 conductor (Type HTi-NX)

JASTEC



4 K

B_{ex}: 17 T



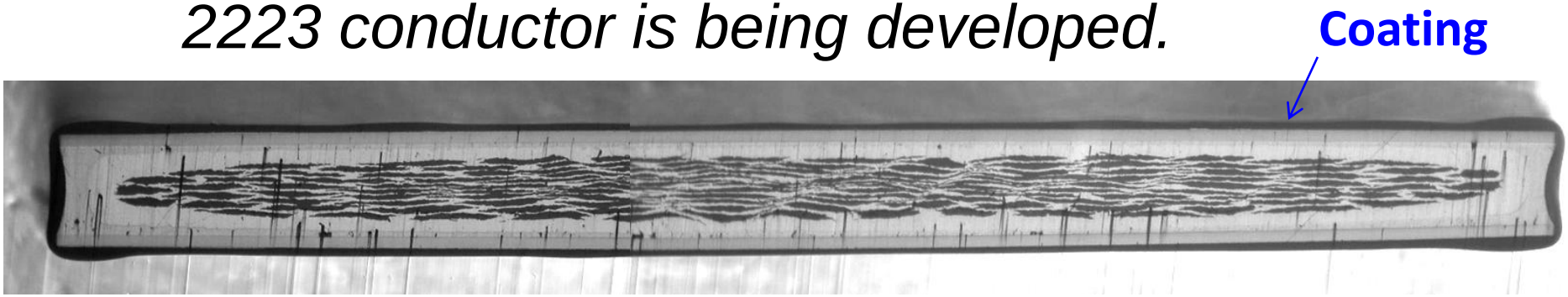
I_c = 455 A (0.1 μV/cm), n = 40

- No degradation under σ_z = -68 MPa at 400 A
- Much higher than -50 MPa of the 1.3 GHz magnet designs

Short summary

- *Bi-2223 coils are unexpected-degradation-free and are "DESIGNABLE" with mechanical stress management.*

- *To avoid a short circuit due to strong electromagnetic forces, coating insulated Bi-2223 conductor is being developed.*

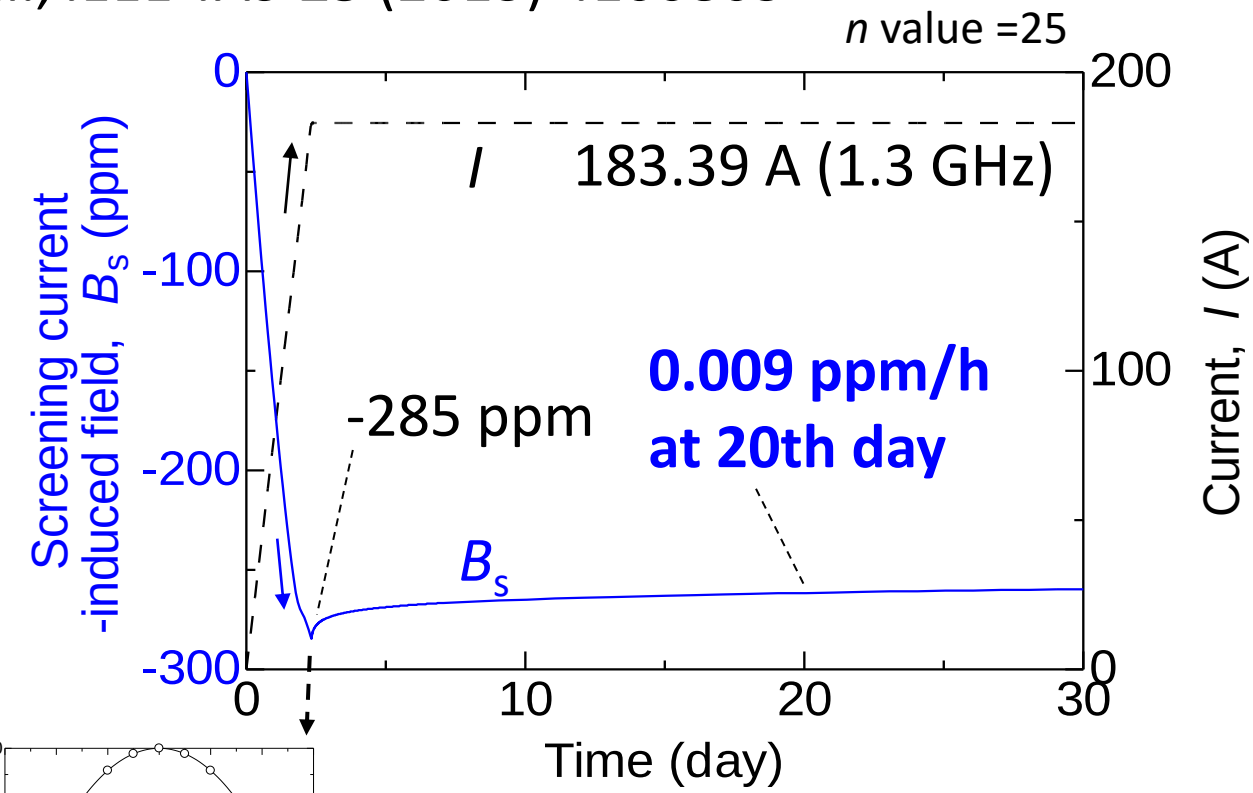


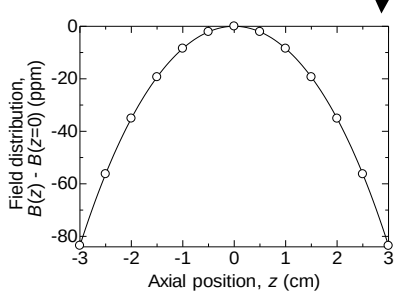
Contents

Simulated screening current-induced field of the REBCO innermost coil

3D FEM with the fast multipole method

Ueda et al., *IEEE TAS* **23** (2013) 4100805





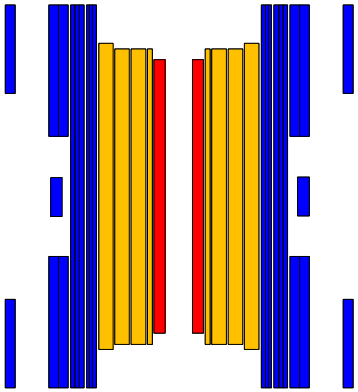
Z2 harmonic:

-8.4 ppm/cm^2

Short summary

- *The magnitude of screening current effects from the REBCO innermost coil is not so large.*

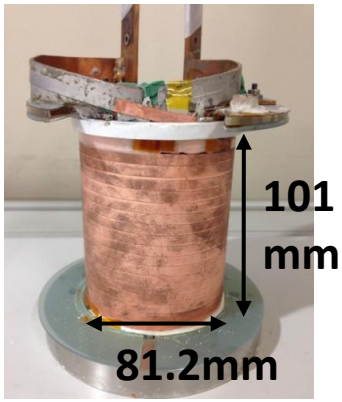
- *We will also simulate screening current-induced field from the large volume of the Bi-2223 coils.*

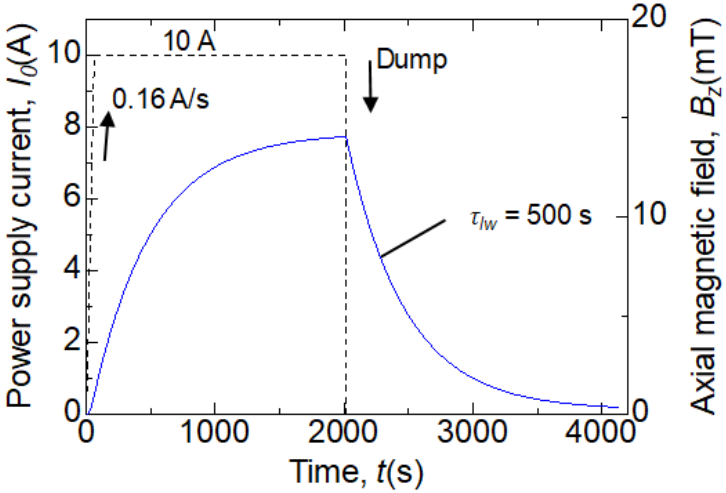


Contents

Layer-wound coil has never received the benefit of NI…

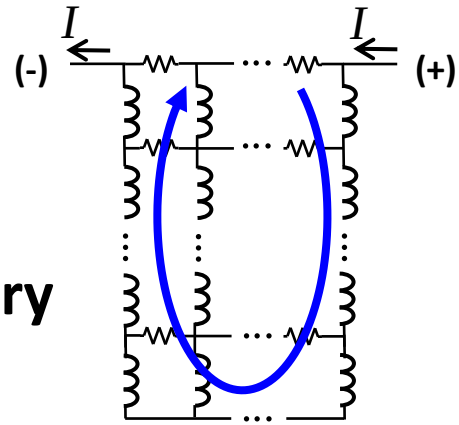
Extremely long field delay

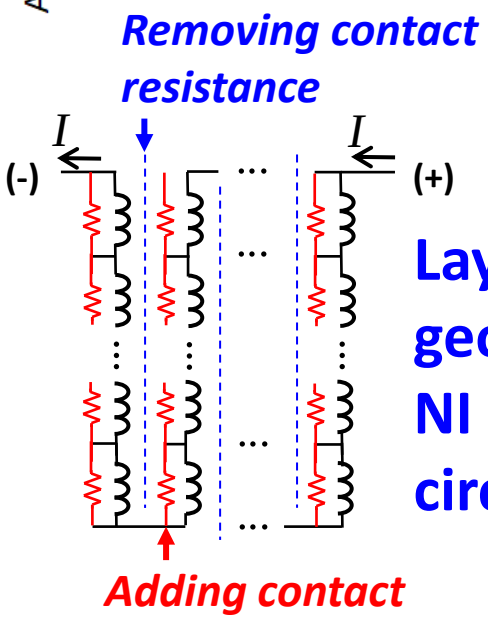




Suetomi et al.
SuST **29** (2016) 105002

Magnetic diffusion in a large secondary circuit



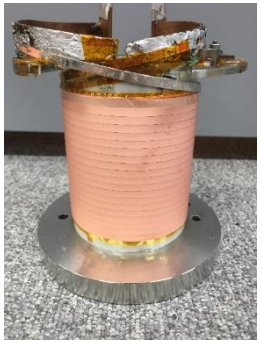


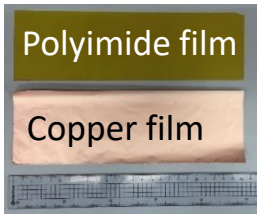
Suetomi et al.
in preparation

Layer-wound geometry with NI pancake circuit

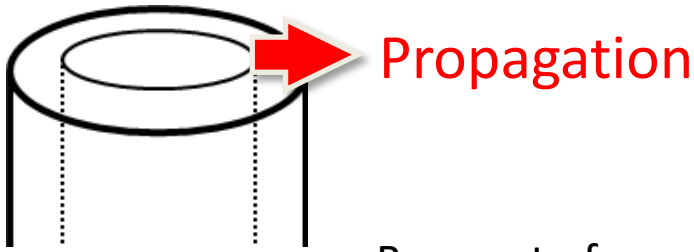
Compatibility of a SHORT FIELD DELAY and SELF-PROTECTION in a layer-wound coil

LAYER NO-INSULATION (LNI)
REBCO coil

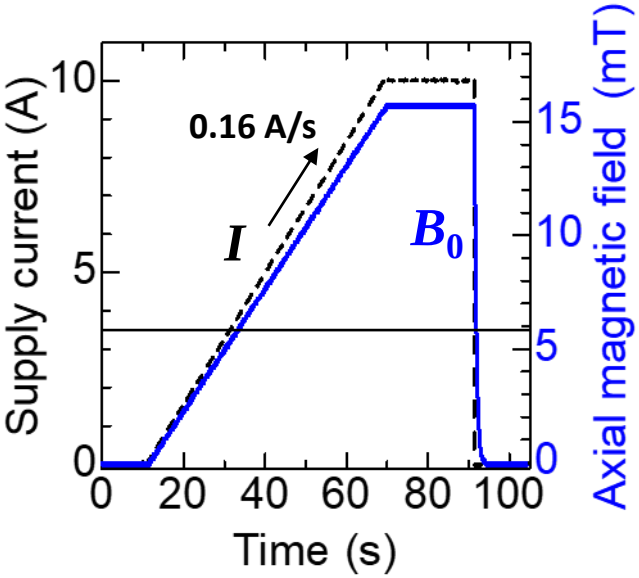




Suetomi et al.
in preparation



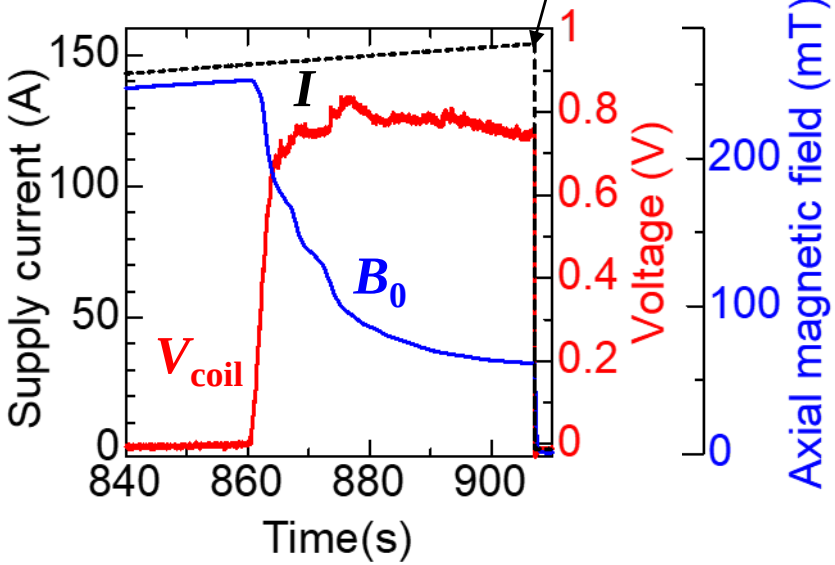
Field delay



Short field delay:
τ = 0.5 s

Over current

Burn out of a terminal conductor



Self-protect from thermal runaway

Conclusions

Conclusions

- *Bi-2223:*
  - *Designable with mechanical stress management*
  - *Avoiding short circuit due to strong electromagnetic forces*

- *REBCO:*
  - *LNI (layer no-insulation) method for the combination of self-protection, homogeneous field and persistent current operation.*

Further viewpoint: REBCO or Bi-2223 ?

	REBCO-dominant design	Bi-2223-dominant design
Unexpected degradation and thermal runaway	Frequent	Rare
Field stability and homogeneity	Low	Better
Magnet size	Very compact (higher J)	Compact
Superconducting joint	Yes	Not yet

- **For a high-resolution 1.3 GHz NMR, we prefer a Bi-2223 dominant design with taking advantage of a REBCO innermost coil.**
- **Towards 1.5 GHz (35 T), more REBCO is required.**