

High-temperature superconducting magnet system for the next-generation helical device

N. Yanagi^{1,2}, T. Mito¹, J. Miyazawa^{1,2}, S. Matsunaga², Y. Onodera¹, N. Hirano¹,
Y. Narushima^{1,2}, S. Ito³, H. Tamura¹, S. Hamaguchi¹, H. Hashizume³, K. Takahata^{1,2}

¹National Institute for Fusion Science, ²SOKENDAI, ³Tohoku University,
yanagi@nifs.ac.jp

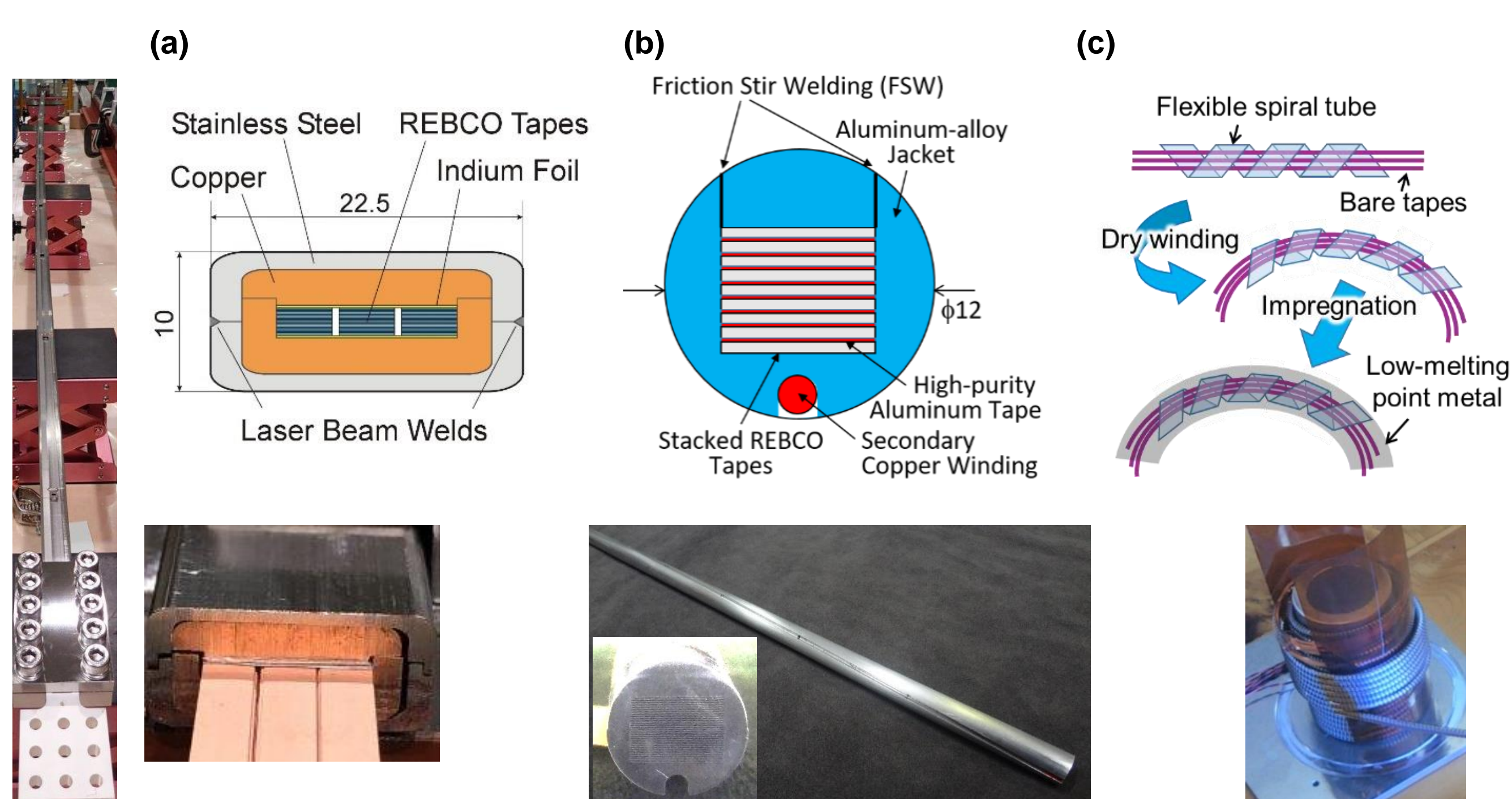
Abstract

The High-Temperature Superconducting (HTS) magnet is being considered to apply to the next-generation helical experimental device. Three types of large-current (6-18 kA) HTS conductors are being developed. One of the crucial requirements is to secure the high current density of 80 A/mm² at a 20 K temperature and 10 T magnetic field. In the first phase of the development, short samples of each conductor have been fabricated and tested in liquid nitrogen at 77 K with no external magnetic field. The critical current was observed and compared with expectation. The fabrication methods have been improved to satisfy the magnet requirement. The winding method and quench protection are also crucial requirements to use the conductor in the magnet, which are being examined with different scenarios for the three conductor options.

HTS Conductors

Three types of HTS conductors are being developed:

- **STARS** (Stacked Tapes Assembled in Rigid Structure)
 - Simple stacking of REBCO tapes
 - Copper stabilizer and stainless-steel jacket (laser beam welding)
 - Joint-winding with a bridge-type mechanical lap joint
- **FAIR** (Friction Stir Welding, Aluminum-alloy jacket, Indirect cooling, REBCO)
 - Stacking of REBCO tapes and twisting
 - Aluminum-alloy jacket (Friction Stir Welding)
 - Continuous winding and hardening by heat treatment
- **WISE** (Wound and Impregnated Stacked Elastic tapes)
 - Stacking of REBCO tapes in a flexible metal tube
 - Impregnation by low-melting temperature metal after winding
 - Non-insulation winding

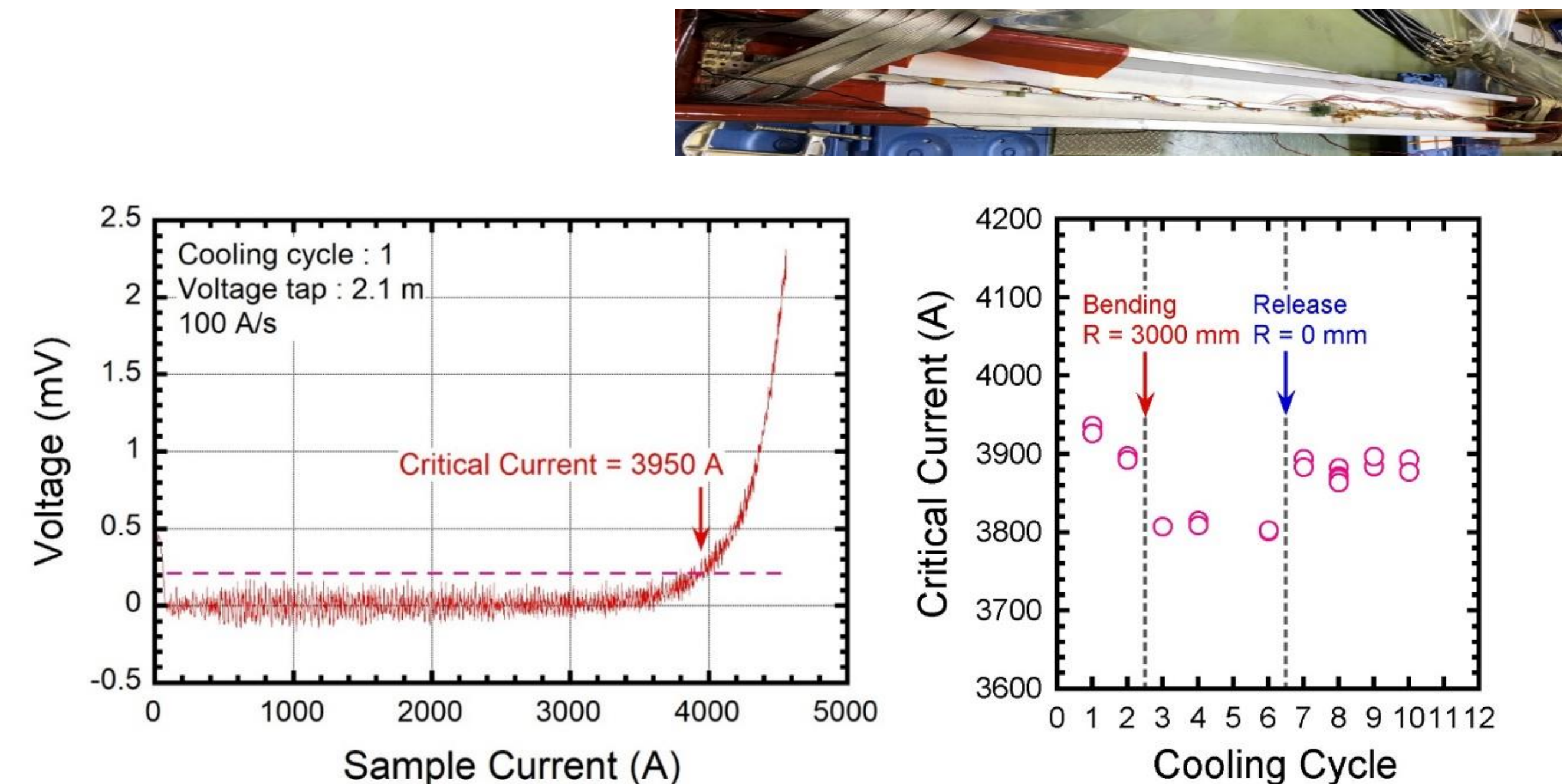


	STARS	FAIR	WISE
Size (w/o. insulation)	10 mm × 22.5 mm	φ12 mm	7.2 mm × 7.2 mm
Current @10 T, 20 K	18 kA	12.5 kA	4 kA
Current density	80 A/mm ²	110 A/mm ²	80 A/mm ²
HTS material	REBCO	REBCO	REBCO / Bi-2223
Twisting	none	2 rotations / m	none
Stabilizer	Cu	Al-alloy	U-Alloy78
Reinforcement	SS	Al-alloy	SS (partially)
Welding	LBW	FSW	none
Electrical Insulator	internal	external	none (NI)
Impregnation	none	Epoxy	U-Alloy78
Joint	Mechanical	Solder	U-Alloy78
Quench protection	Resistive dump	Resistive dump w/ secondary circuit	Self-protection by NI winding
Helical coil winding	Joint-winding	Continuous winding	Continuous winding

Conductor tests in liquid nitrogen

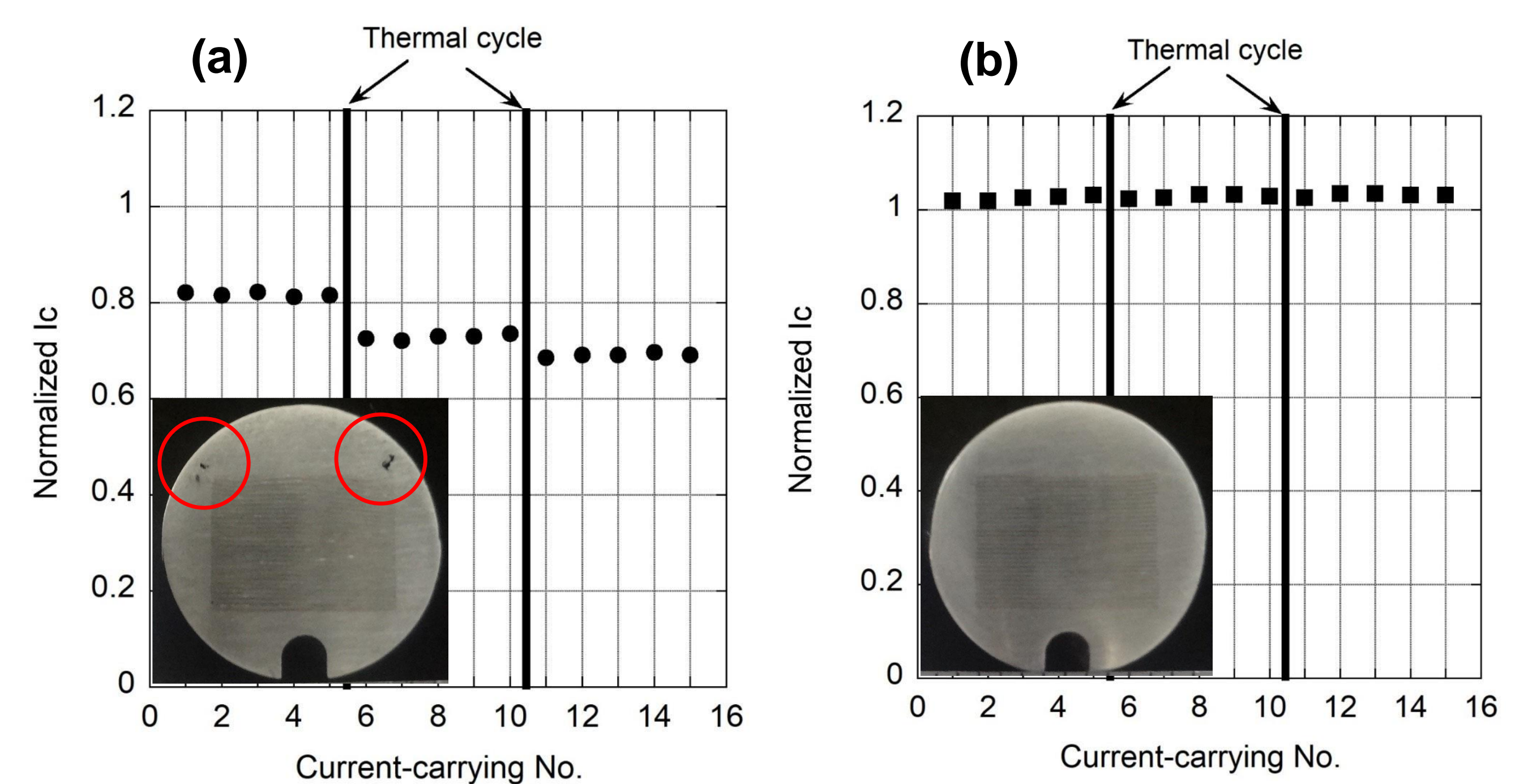
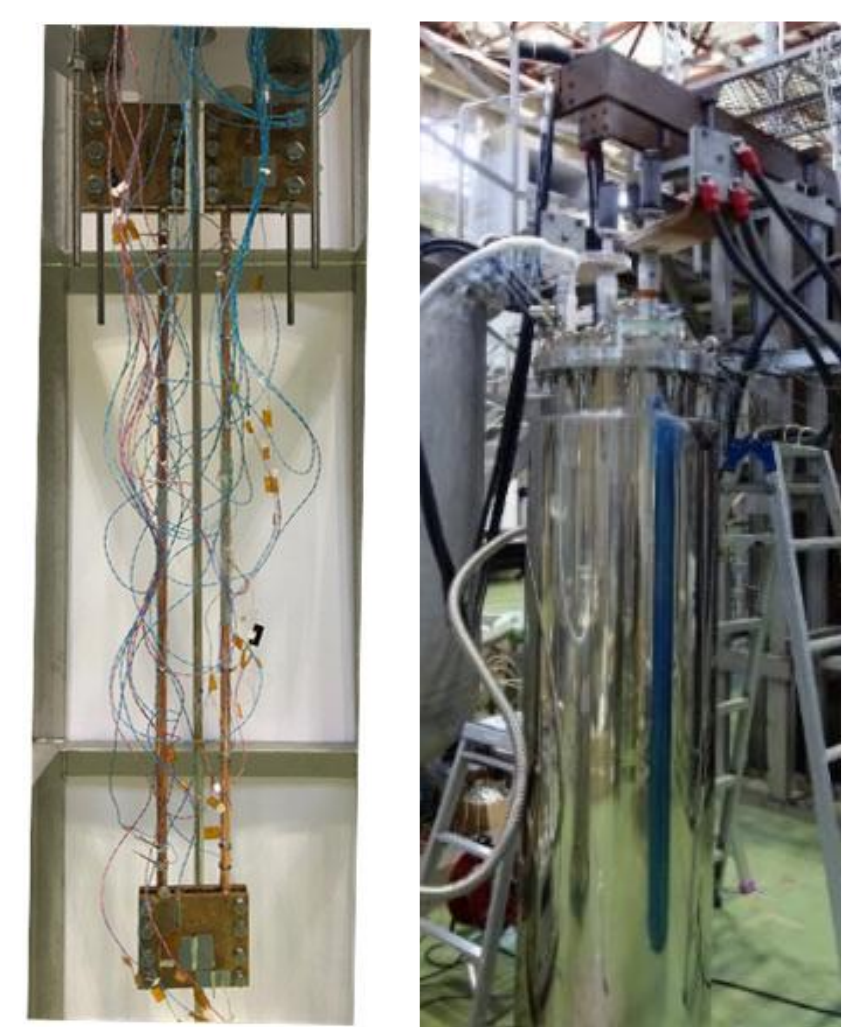
STARS Conductor

- Critical current of ~4 kA confirmed
- <1% degradation with cooling cycle
- Recovery from bending (0.1% strain)



FAIR Conductor

- A series of 1-m long FAIR conductor samples were fabricated and tested in liquid nitrogen
- Difference in the thermal contraction between Al-alloy jacket and REBCO tapes, an excessive shear strain (buckling) might be applied locally
- Adjusting the uniformity of FSW process, critical current degradation does not degrade including twisting and thermal cycling



WISE Conductor

- A series of 1-m long WISE conductor samples were fabricated and tested in liquid nitrogen
- Suppression of delamination by adding Bi-2223 layers
- A 2-m long sample will be tested in > 7 T and < 10 K

