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# Advances and perspectives in REBCO coated conductor production at SuperPower

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2025 Coated Conductor for Applications Workshop  
CERN  
March 11, 2025

CCA2025

International Workshop on Coated Conductors for Applications

CERN | March 11-13, 2025



SuperPower Inc. is a subsidiary of Furukawa Electric Co. Ltd.

# Acknowledgements

## Thanks to the members at *SuperPower*

Amir Afshar, James Cameron, Gene Carota, Brian Davis, Iole Falorio, Hiroyuki Fukushima, Takao Hirai, Lance Hope, Hiday Ikeda, Sergey Repnoy, Hisaki Sakamoto, Travis Walion, Adam Weiner, Shinya Yasunaga, Karol Zdun.....

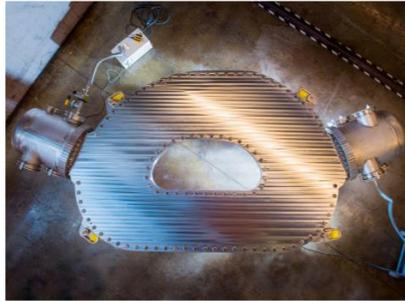
# Topics

- Currently focused applications
- Status of REBCO coated conductor manufacturing
- Ongoing manufacturing technology development efforts

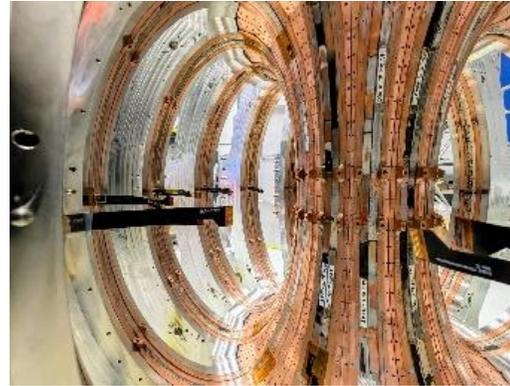
## Currently focused applications

- Fusion reactor magnets
- High-field NMR magnets
- High-field scientific research magnets
- High-field accelerator magnets
- Electric machines magnets

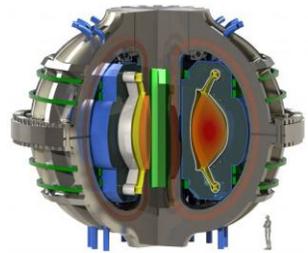
# REBCO CC for fusion reactor magnets



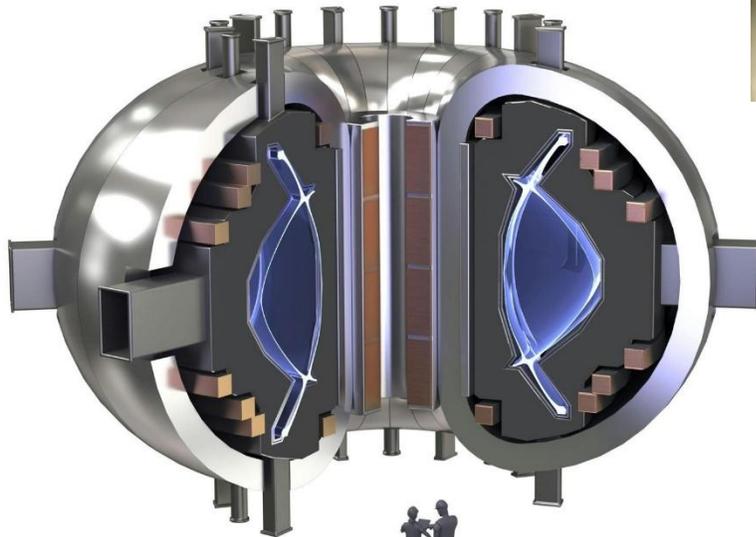
TFMC



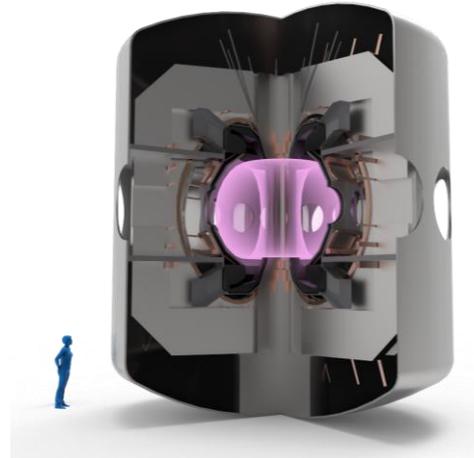
Demo4



SPARC



ARC

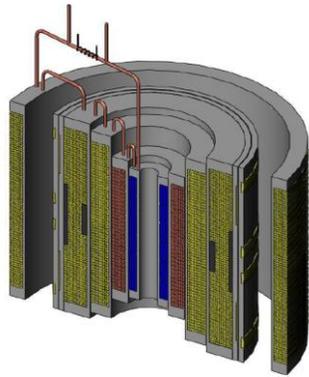


STX

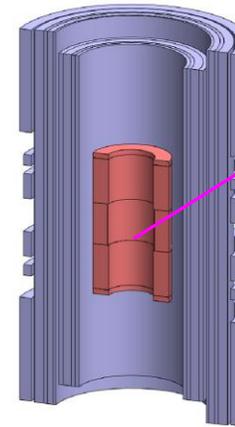


STEP

# REBCO CC for high-field NMR magnets



High-field magnets for commercial NMR system



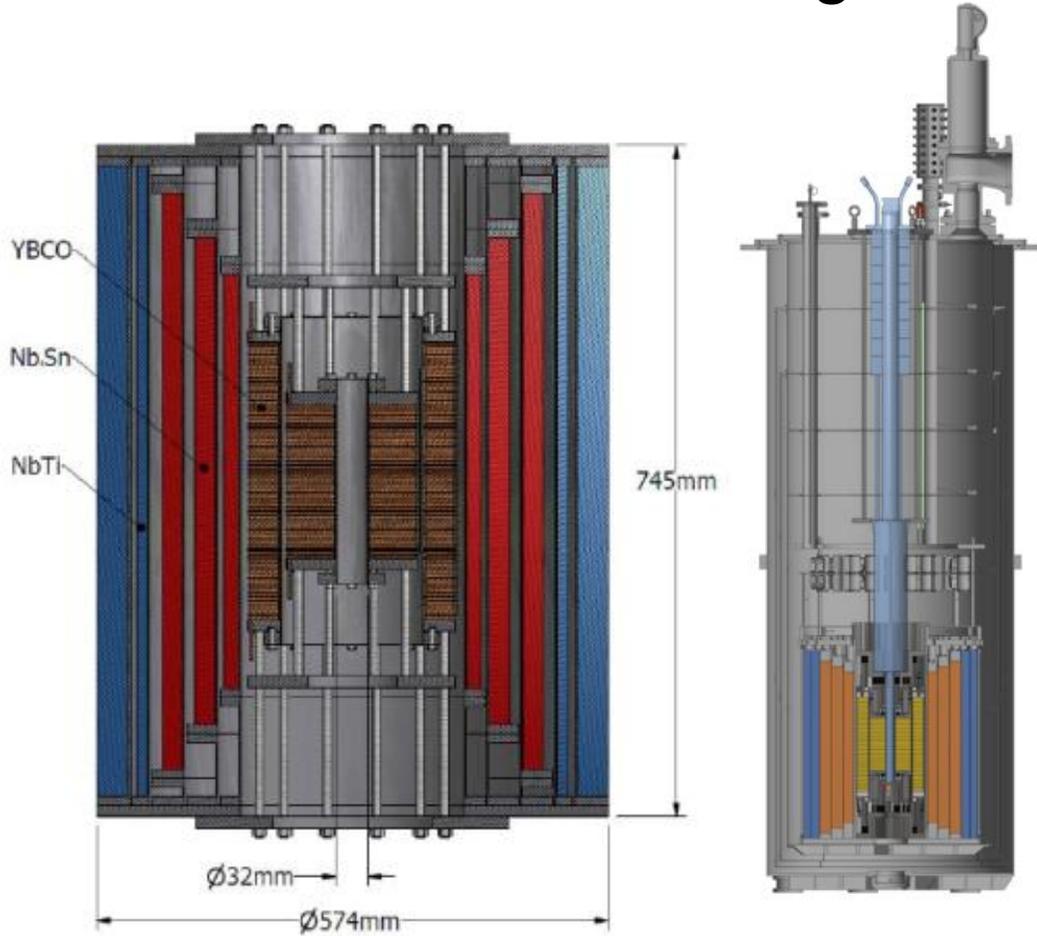
H835



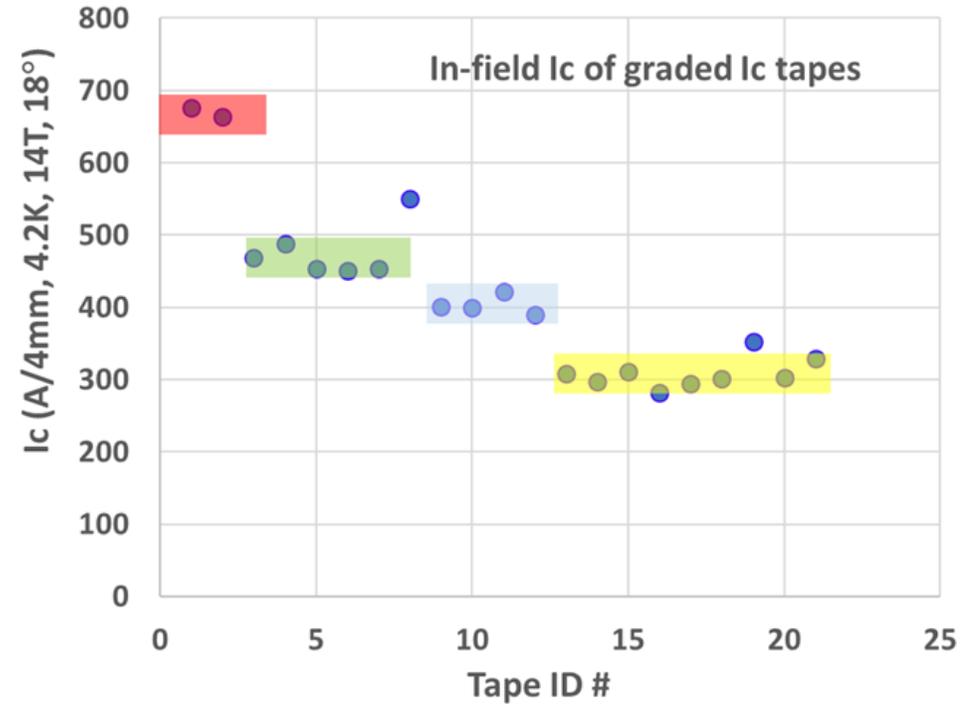
1.3GHz NMR underdevelopment

High-field all-superconductor magnets for NMR

# REBCO CC for high-field scientific research magnets



32T user magnet with 17T HTS insert and 15T LTS outsert



Graded Ic REBCO CC for the ongoing 40T magnet project

# REBCO CC production at SuperPower

## Core manufacturing technologies:

- Ion Beam Assisted Deposition (**IBAD**) to create texture
- Metal Organic Chemical Vapor Deposition (**MOCVD**) with artificial pinning centers (APCs)

### REBCO formulation

- **AP** – for applications at various conditions
- **HM** – for applications at lower temperatures and higher fields

### Dimensions

- Width = 2, 3, 4, 6, 12 mm
- Piece length = typically ~300 m, and up to 900 m depending on specification

### Non-superconducting layer thickness

- Substrate thickness = 30 or 50  $\mu\text{m}$
- Total Ag thickness = 3~5  $\mu\text{m}$
- Total Cu stabilizer thickness = 10~120  $\mu\text{m}$

### Critical Current

- $I_c(77\text{K, s.f.})/4\text{mm} = 120\sim 160$  A (AP tapes)
- $I_c(4.2\text{K, 15T//c})/4\text{mm} = 400\sim 500$  A (HM tapes)
- $I_c(20\text{K, 20T//c})/4\text{mm} = 160\sim 200$  A (HM tapes)

### Customization

- Polyimide insulation (currently by wrapping, polyimide coating coming)
- Soldered lap joints ( $\leq 100$  n $\Omega$ -cm<sup>2</sup>)
- Solder coating (SnPb solder, typically 10  $\mu\text{m}$  total)
- Filamentization (down to 200  $\mu\text{m}$  in filament width)
- AgAu coating instead of pure Ag (for current leads)

# REBCO CC production at SuperPower

- Phase 1 capacity expansion completed in 2023
- Production capacity doubled from ~ 120 km/yr to ~ **240** km/yr (12 mm-w)



IBAD system IBAD2



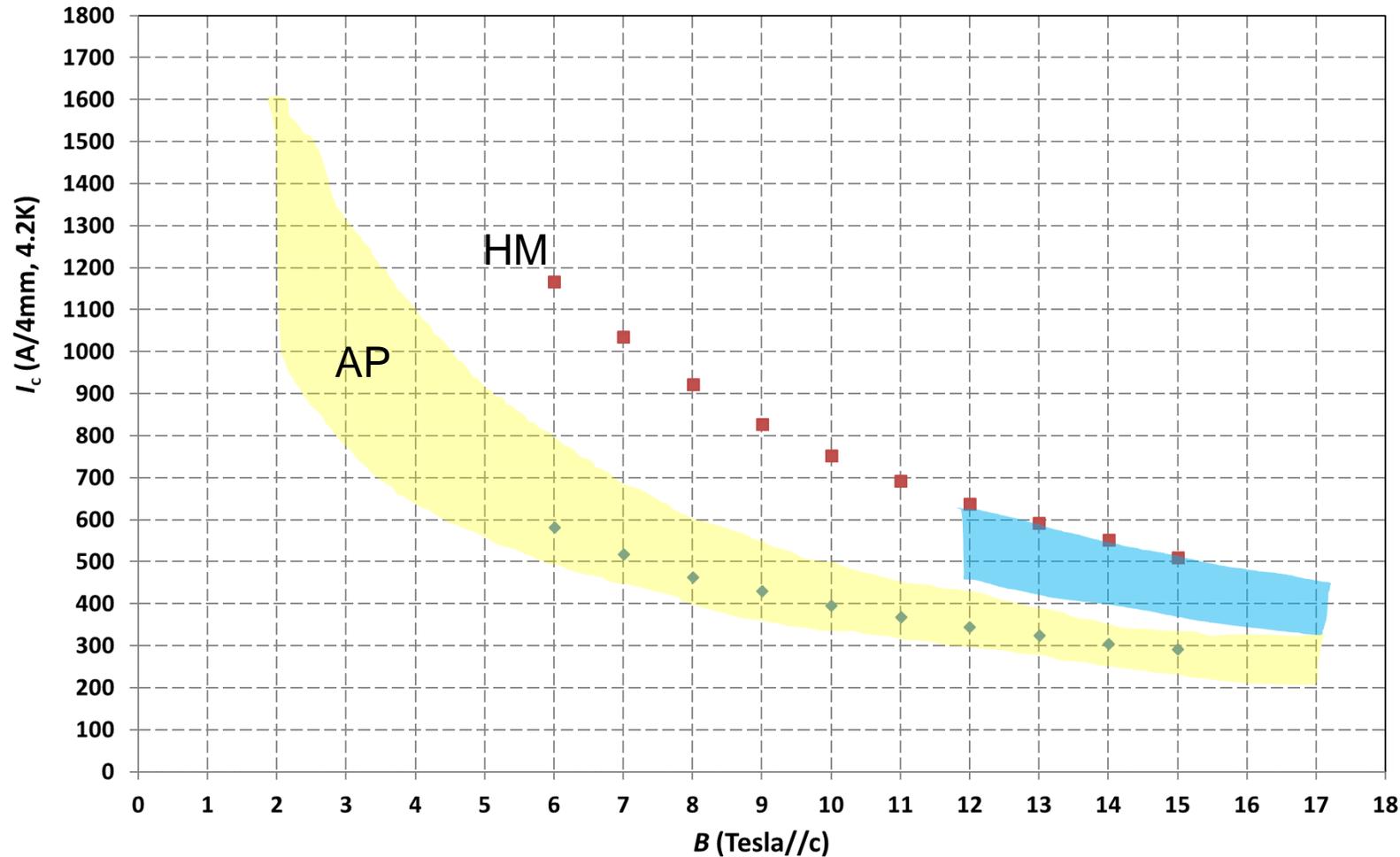
MOCVD system M6



MOCVD system M7

Manufacturing equipment added in Phase 1 capacity expansion

# In-field $I_c$ of REBCO CC made with new MOCVD systems



Shaded areas – old machines  
Data points – new machine (M6)

## Major ongoing manufacturing technology development efforts

- Increasing yield, throughput, and consistency
- Establishment of QMS compliant with ISO 9001
- Design of next generation MOCVD system
- Development of new REBCO formula specifically for fusion
- Extending in-field  $I_c$  testing capability
- Filamentized REBCO CC via laser striation
- Polyimide coating for insulation
- Improvement of slit edge quality by hybrid slitting

# Transition from small-scale to large-scale production

- **Small-scale production**

- Low throughput and low yield
- Low material usage efficiency
- Lack of in-line monitoring and control
- Longer machine downtime for maintenance and repair
- High production cost

## Transition



- **Large-scale production**

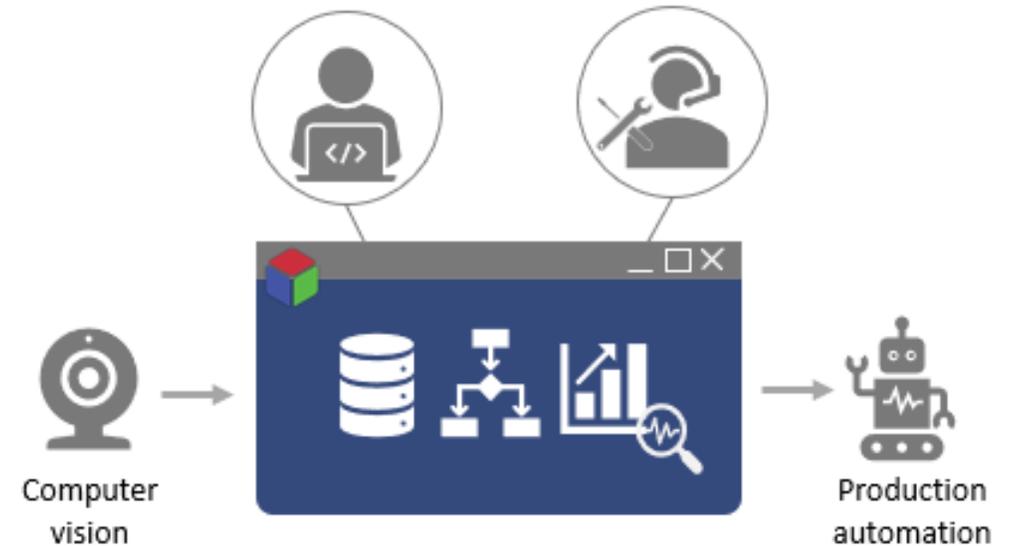
- High throughput and high yield
- Higher material usage efficiency
- Improved operation stability with in-line monitoring, closed-loop control
- Reduced machine downtime (planned and unplanned)
- Reduced production cost

## Next generation MOCVD system under design

# CTQT (Continuous Tape Quality Tracking) system



- **CTQT** is a Data Warehouse platform
- It includes the data acquisition, analysis and reporting tools,
- On the platform the process and measurement data is stored in an organized manner,
- Engineers, technicians, managers and researchers could access the data anywhere from the intranet (or externally by using a VPN) and visualize it to gain insight into the manufacturing processes.



**CTQT** is under development by **FETI**, our sister company in Budapest, Hungary

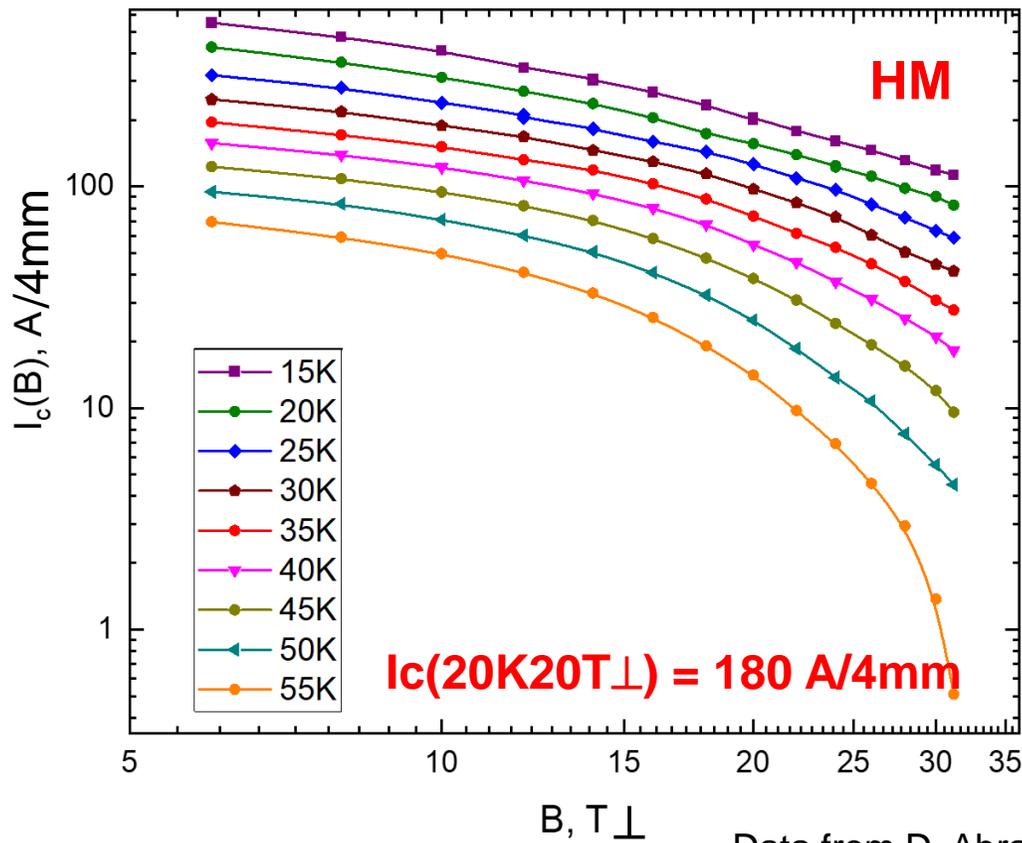
## Implementation of ISO 9001:2015

- SuperPower has more than 10 years experiences with key customers in meeting requirements from ISO 9001:2015 (5 times second-party QMS audits)
- Decision has been made to move forward to become a certified company
- Quality team formed and resources put in place
- Gap audit to be carried out by an FEC sister company before having registration audit
- Currently focusing on QMS documentation, employee training, establishing and implementing SOPs and WINs

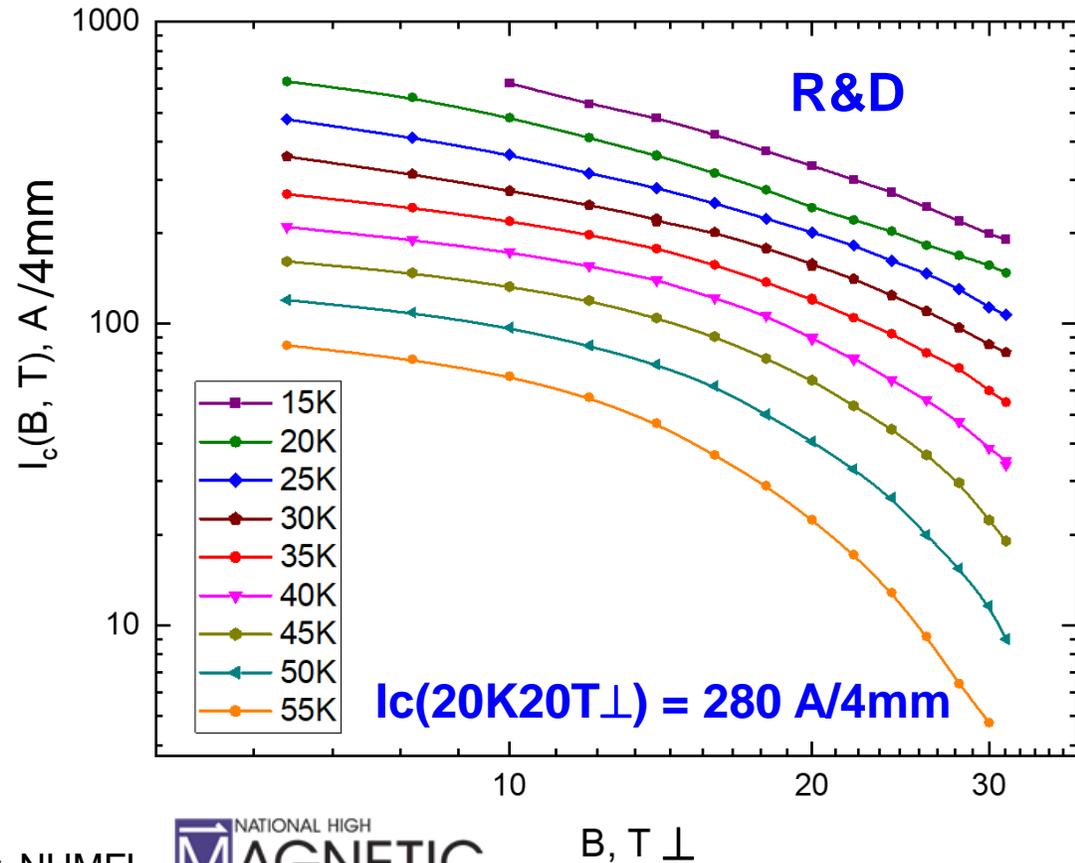


# Development of new REBCO formula for fusion

- Further improvement in in-field performance around 20K20T where fusion magnets operate
- New REBCO formula named **FM**, to be launched to the market in 2026

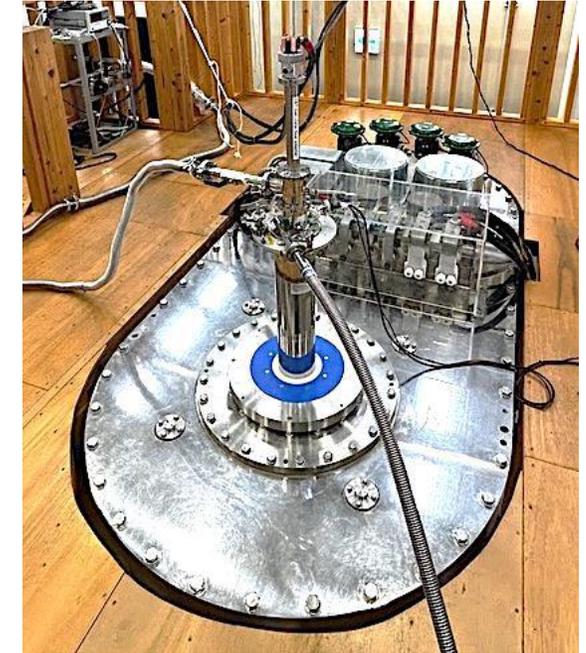
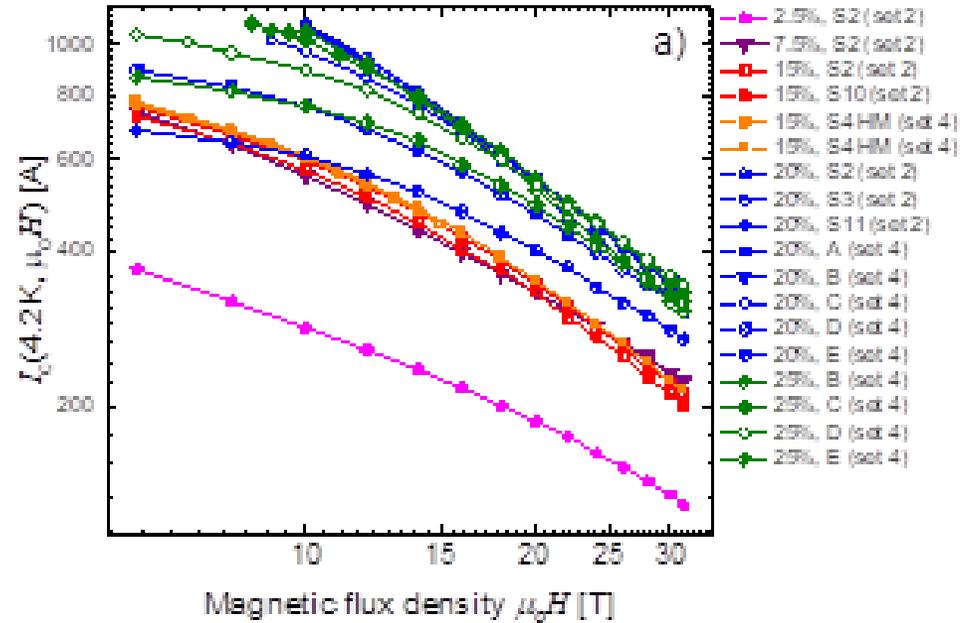


Data from D. Abraimov, NHMFL



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**MAGNETIC**  
FIELD LABORATORY

# Extending low-temperature high-field $I_c$ testing capability

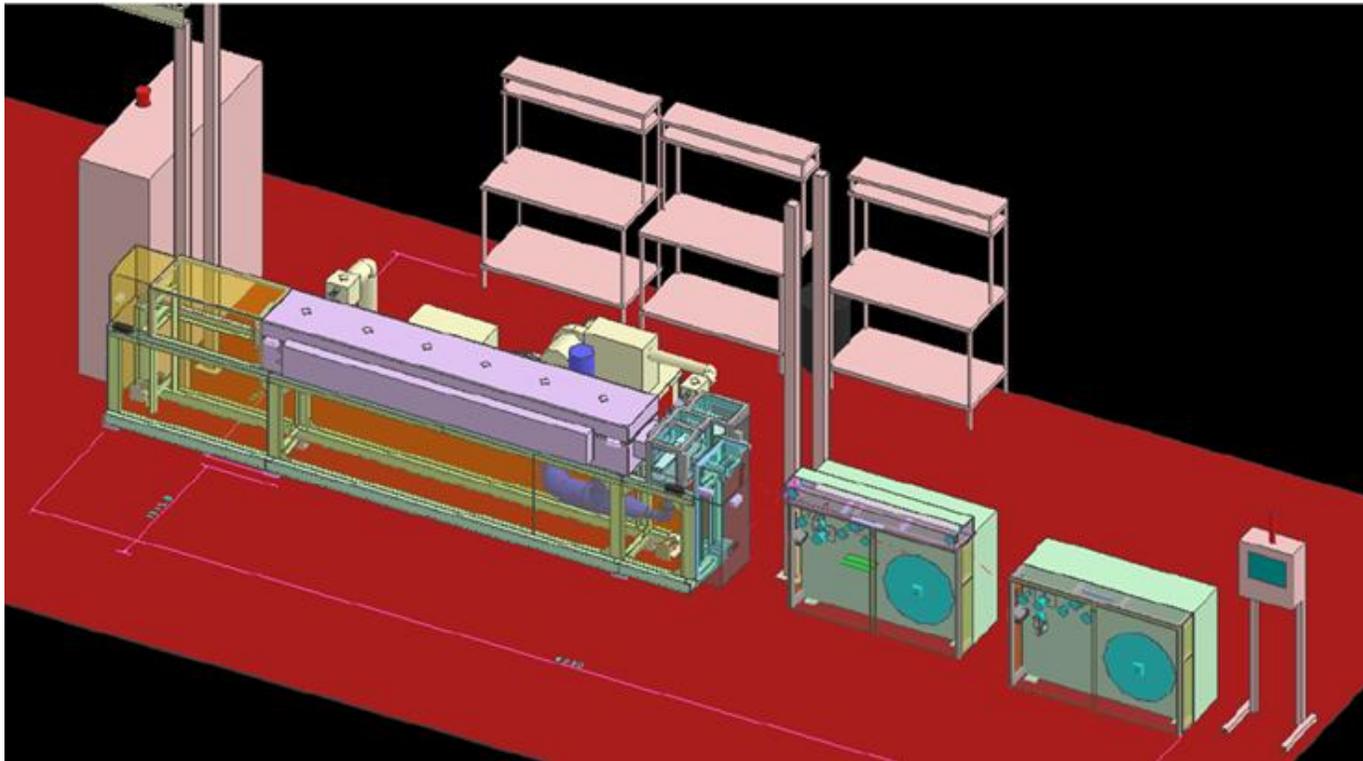


4.1K, 8T and 17T  
Nikko, Japan

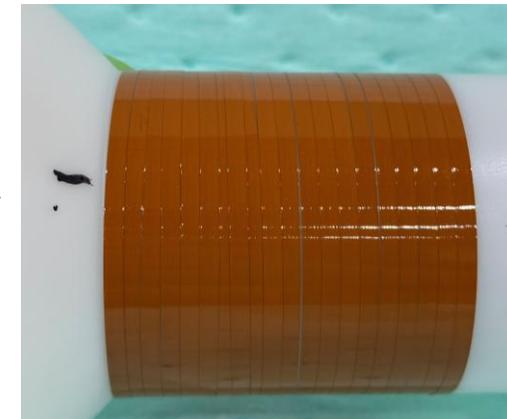
D. Abraimov *et al*, manuscript  
accepted IEEE-TASC

Up to 25 T at various temperatures  
Pulsed current up to 5kA  
Y. Tsuchiya *et al*, IEEE-TASC  
10.1109/TASC.2025.3543148

# Reel-to-reel polyimide coating system to apply insulation



Currently, insulation is applied by Kapton tape wrapping

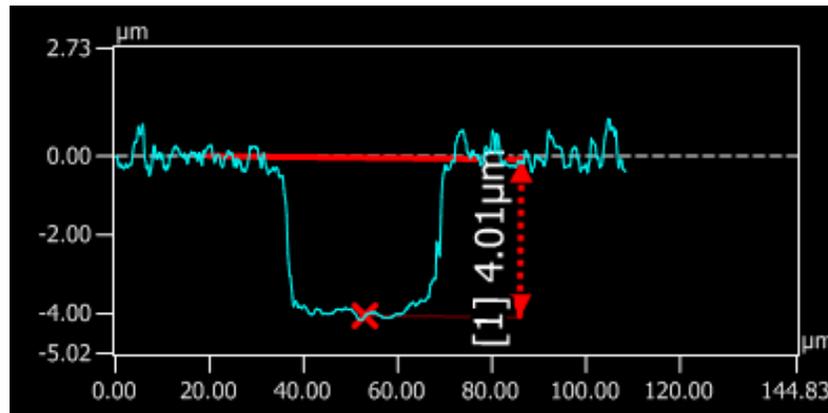
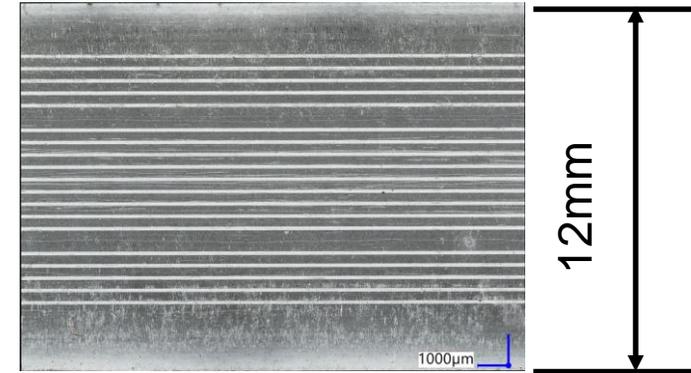


Experimental insulated tape made with PI coating system

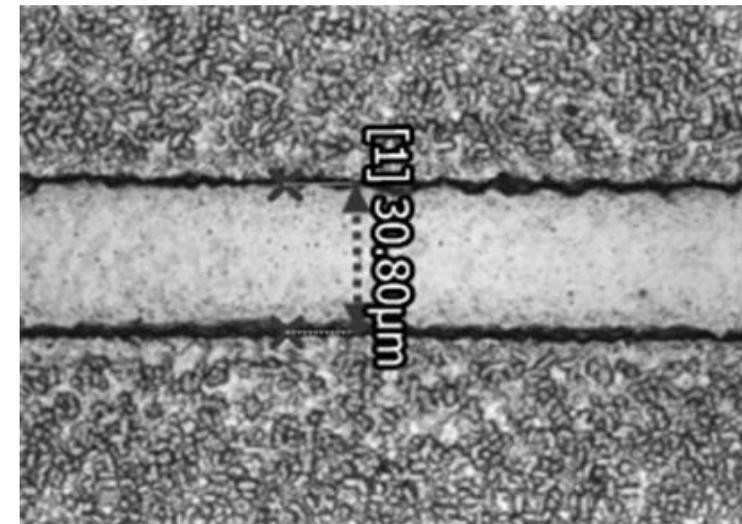
R2R Polyimide coating system to be installed in April 2025

# Filamentized REBCO CC via laser striation

- Filamentization performed by laser striation for reduction of AC losses and mitigation of screening current
- Specific striation dimension/geometry, maximizing  $I_c$  retention
- Development on capability for long-length processing, compatibility with post-striation processes



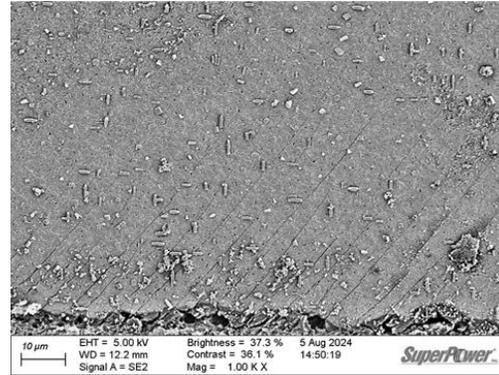
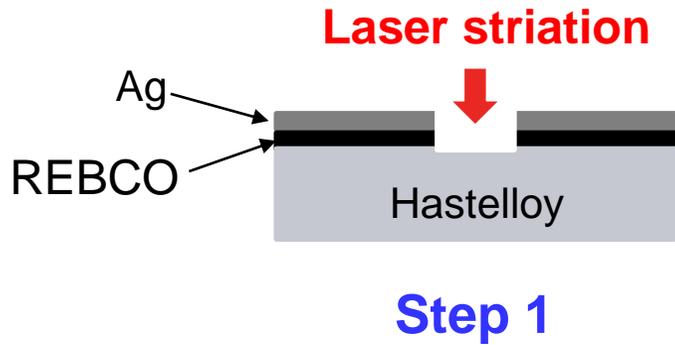
Cross-section depth profile of striation



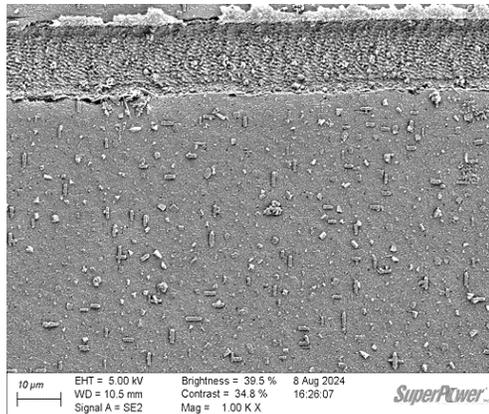
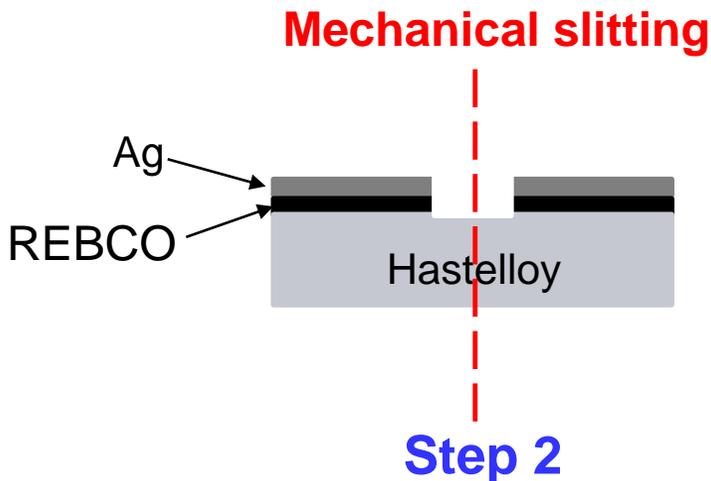
Top view of striation

# Development of hybrid slitting to improve slit edge quality

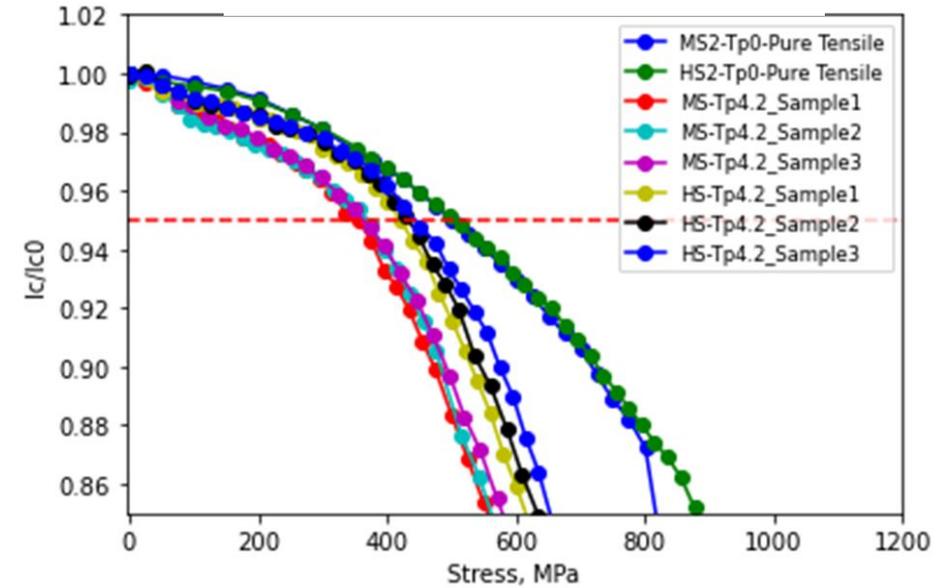
- A two-step process with laser striation prior to mechanical slitting
- Minimizing the damages to the REBCO layer at the slit edges



REBCO edge (mechanical slit)



REBCO edge (hybrid slit)



Torsion plus tension test showed about 20% increase in critical stress in hybrid slit samples versus mechanical slit samples

## Summary

- Manufacturing technology advancement for REBCO HTS wires is driven by the demand and requirements mainly from compact fusion and also from other high-field magnet applications.
- Great efforts are being made to increase yield and throughput, improve processing stability to achieve higher consistency in wire performance and quality, and reduce material cost.
- We are focusing on new REBCO formula development and the design of the next generation manufacturing systems.