Development of flexible HTS CORC® wires and terminations for high-field magnet applications

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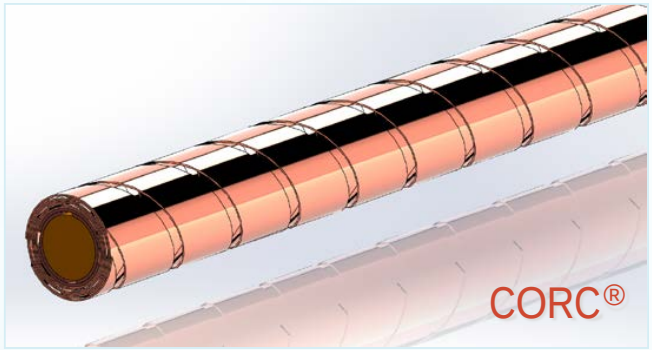
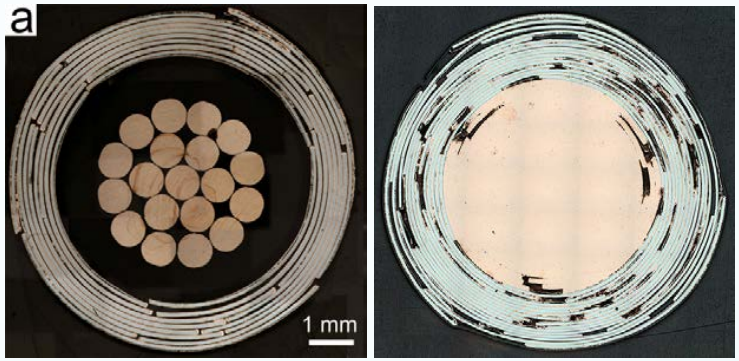
Conductor on Round Core (CORC®) cables

CORC® cable principle
Winding many high-temperature superconducting YBCO coated conductors in a helical fashion with the YBCO under compression around a small former.





Benefits

- The most flexible HTS cable available
- Very high currents and current densities
- Mechanically very strong
- Partially transposed
- Current sharing between tapes

Programs at Advanced Conductor Technologies

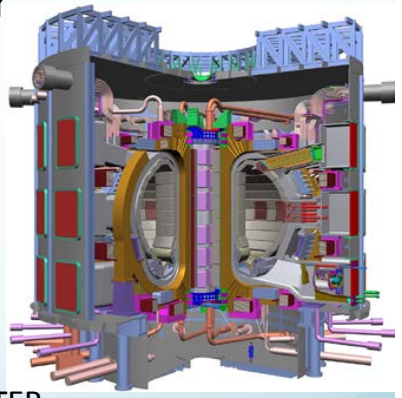
1. Department of Energy – Office of High Energy Physics (DOE-HEP)

CORC® cables for accelerator magnets including Canted Cosine Theta magnets

LHC at CERN

2. Department of Energy – Office of Fusion Energy Sciences (DOE-OFES)

CORC® cable for fusion magnets, cable joints, and terminations for fusion magnets



ITER

3. Navy

CORC® power transmission, fault current limiting cables, and Dielectrics for CORC® power transmission

NAVSEA
WARFARE CENTERS
Philadelphia

LCS 4 USS Coronado

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What makes the CORC® wire topology special?

Strain management.

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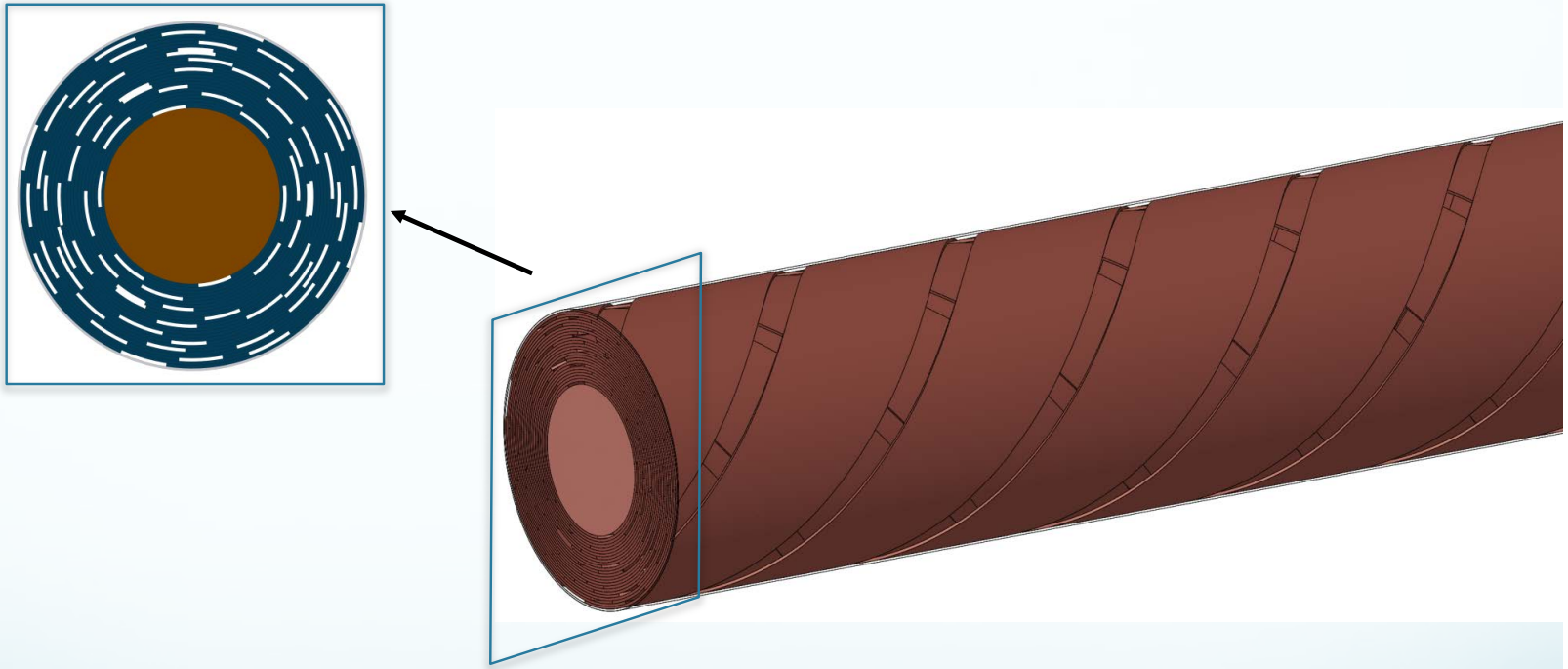
Looking at strain in a CORC® conductor



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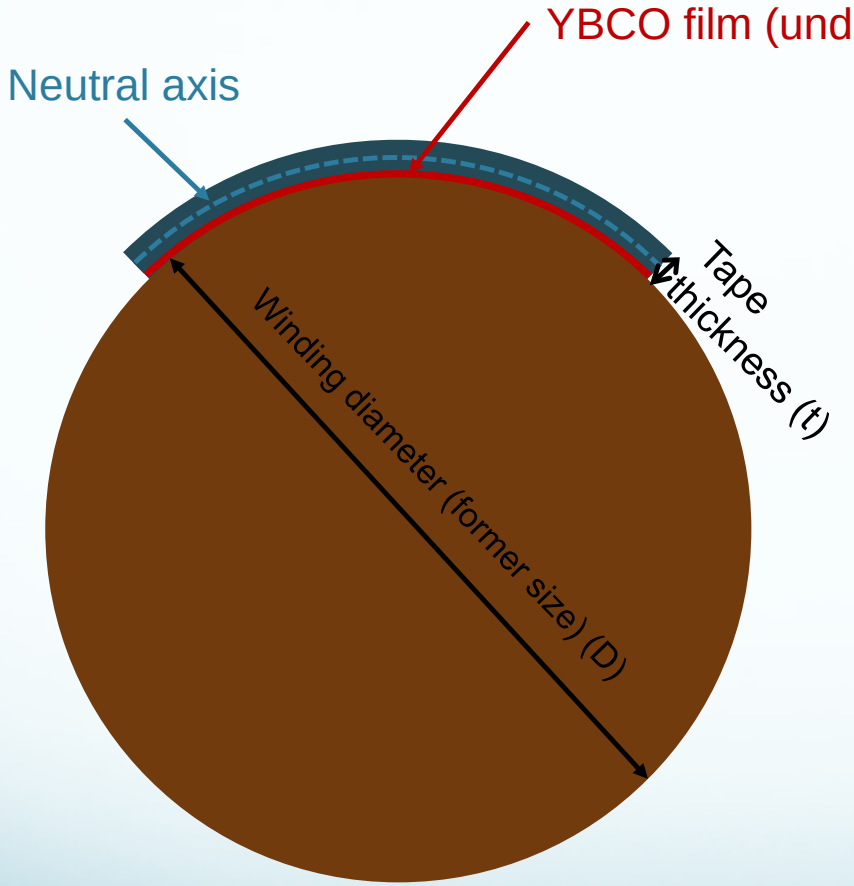
Looking at strain in a CORC® conductor



Strain on the YBCO

$$\varepsilon \propto \frac{-t}{D+t}$$

Two routes to drastically increase J_e:

1. Decrease tape thickness (t)
   - Intrinsically improves J_e of tape
   - Also, allows for smaller formers (D) i.e. larger tape filling fraction in a CORC wire
2. Increase tape's maximum compressive strain tolerance

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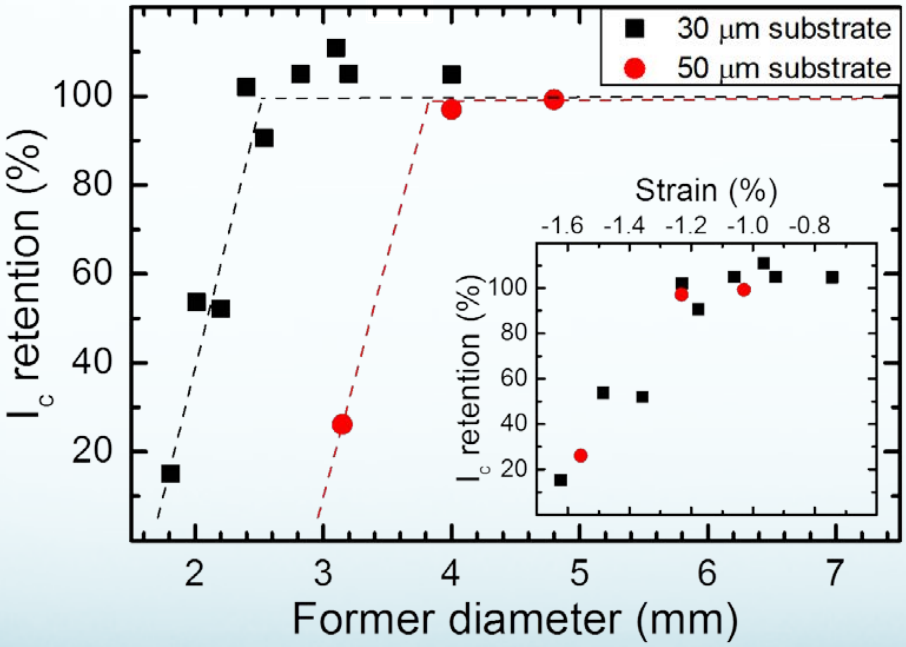
Looking at strain in a CORC® conductor

Moving from 50 micron to 30 micron substrates allowed us to use a former with a smaller diameter, incorporating more than a dozen additional tapes into the CORC cross section

- Notice that I_c degrades around -1.2 % strain.



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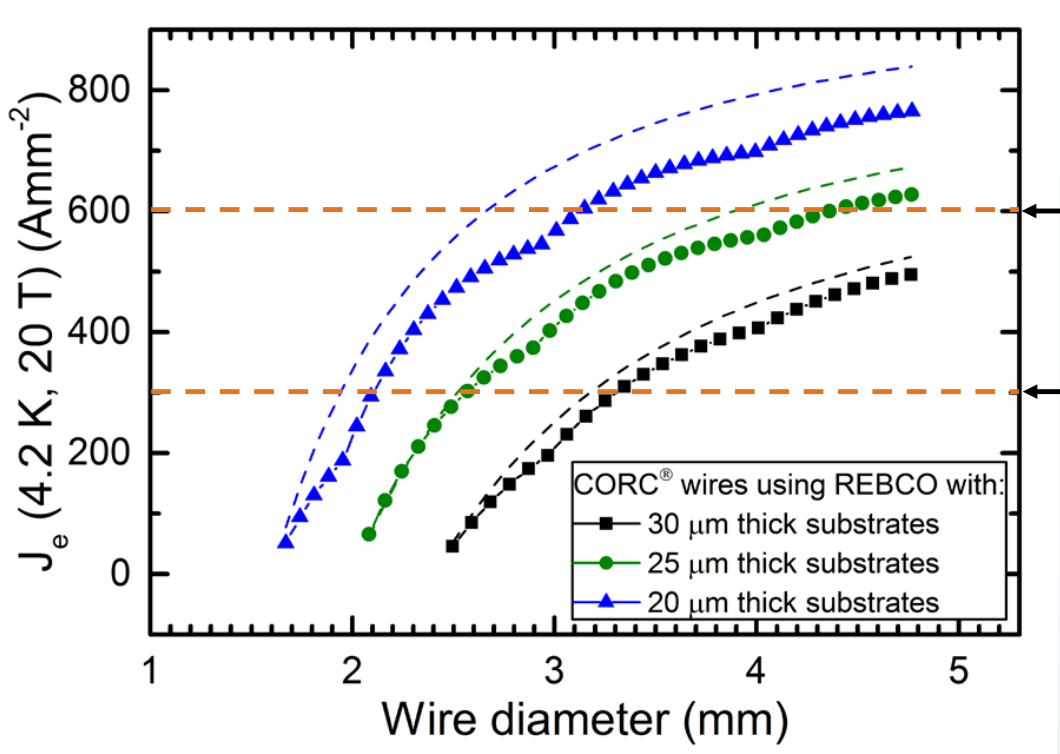
Decreasing tape thickness to increase CORC® J_e



As you add layers to the CORC conductor, conductor J_e increases towards the tape J_e

Value desired for accelerator magnets such as CCT dipoles

Value desired for many research magnets (recently obtained in a CORC® conductor)

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Introduction of CORC® wires

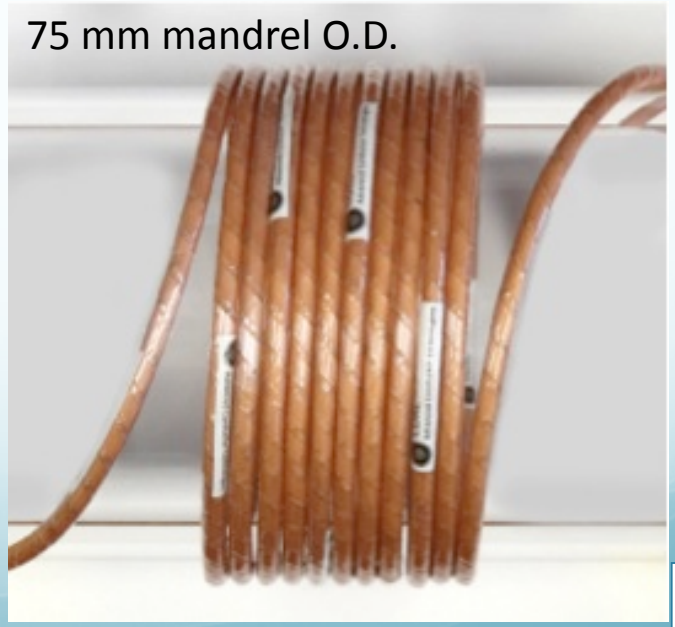
CORC® cables

- tapes with 50 μm substrate
- O.D.: 5 – 10 mm
- tapes of 3 mm and 4 mm width

CORC® wires

- tapes with 30 μm substrate
- O.D.: 2.5 – 5 mm
- tapes of 2 mm and 3 mm width

First round, isotropic YBCO wire!



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What benefit does a wire have over a cable?

Flexibility

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Improved flexibility of CORC® wires

Bending tests shows > 80% Ic retention after bending to 3.5 cm diameter.

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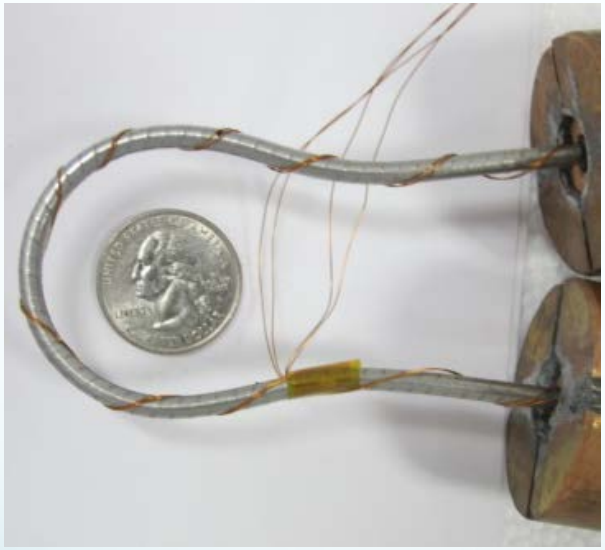

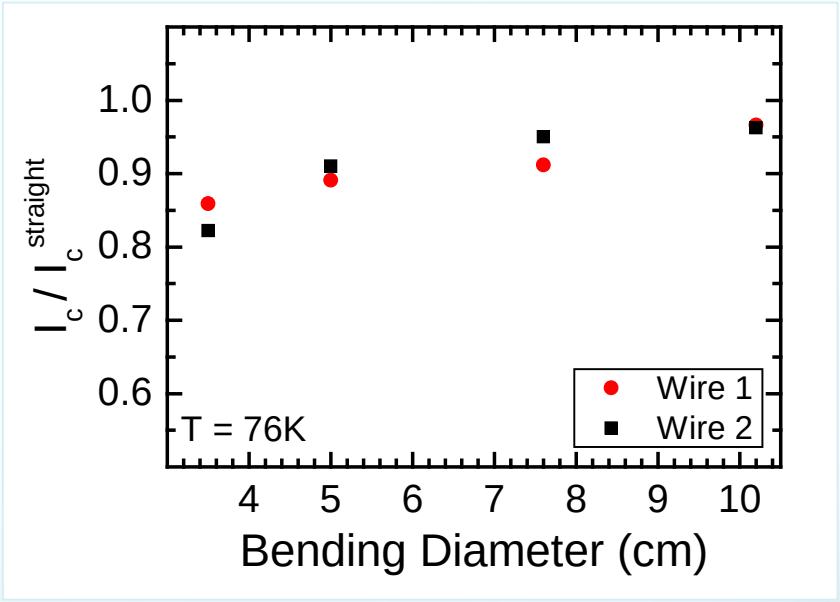

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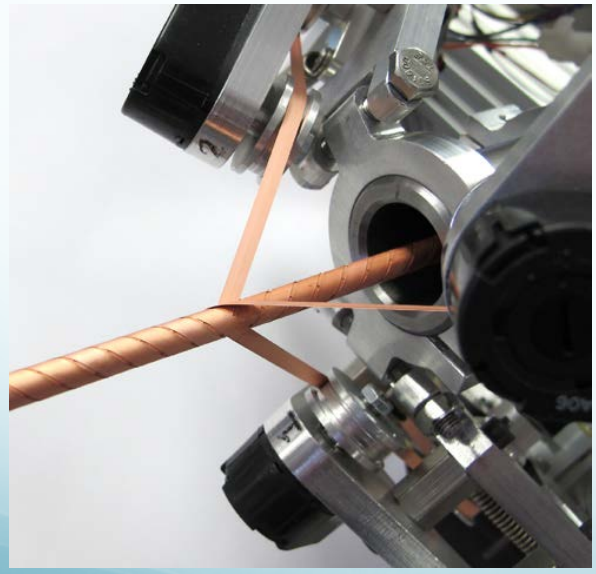
CORC® cable and wire production

Winding of long CORC® cables with custom cable machine

- Accurate control of cable layout
- Long cable lengths possible (> 100 meters)
- I_c retention after winding 95-100 %



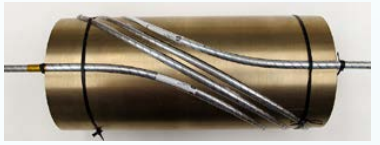
Commercial sales

CERN

- 12 meter CORC® cable (38 tapes)
- Cable for detector magnets

LBNL

- 50 meter CORC® wire (16 tapes)
- Wire for accelerator magnets



What about terminations?

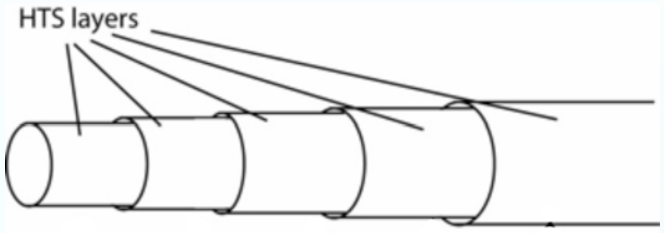
How can we terminate several dozen HTS tapes in a CORC® cable or wire?

Conical terminals

- *Easy to damage when mounting cables*
- *Not practical*

Tube terminals

- *Tapering of each layer of tape allows for more even contact resistance*
- *Terminal only slightly larger than conductor*
- *robust*



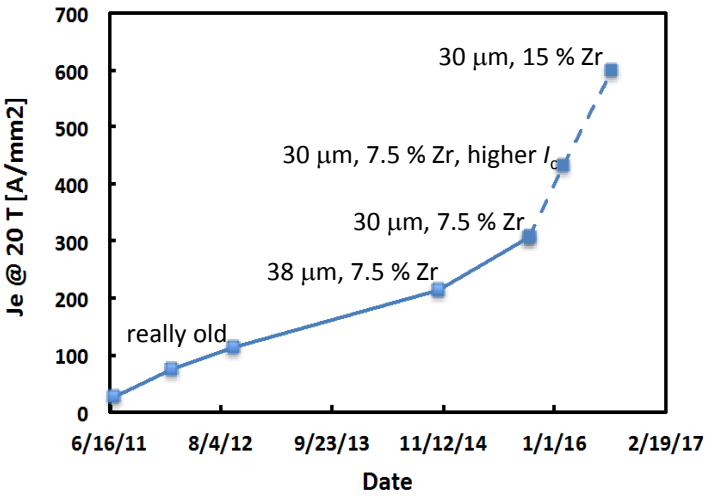
Summary

CORC® wires are now available

- Diameters of 2.5-5 mm
- Bendable to 3.5-5 cm diameter
- Robust terminations being developed

CORC® wires are practical!

- No reaction needed
- No handling of single tapes
- CORC® wires are ready for use in accelerator magnets



CORC® wire J_e on track to 600 A/mm^2 at 20 T

- Clear path to improving J_e by decreasing tape thickness, improving pinning properties and/or improving compressive strain tolerance

Many thanks to SuperPower for making the transition to 30 µm substrates!

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