MT25
25th International Conference on Magnet Technology
RAI - Amsterdam
August 27 - September 1, 2017



Advanced tube type Nb_3Sn conductor and its applications in Hyper Tech

X. Peng[1], M. Rindfleisch[1], **M. Tomsic[1]**, X. Xu[2] , M. D. Sumption[3]

[1]Hyper Tech Research, Columbus, OH, 43228, U.S.A.
[2]Fermi National Accelerator Laboratory
[3]Ohio State University-CSMM, Columbus, OH, 43210, U.S.A.

Acknowledgement: Funded by the US Department of Energy, Division of High energy Physics, SBIR Phase II Grant No. DE-SC0013849.

Hyper Tech

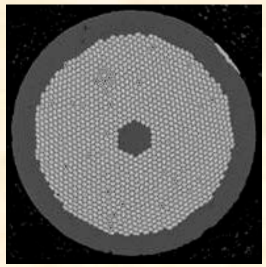
539 Industrial Mile Rd.,
Columbus, OH, 43228,
United States
Tel: 1-614-481-8050
Fax: 1-614-481-4080

Hyper Tech was founded in 2001 and has become a leading manufacturer of magnesium diboride (MgB_2), and niobium-tin (Nb_3Sn) superconductor wires. Hyper Tech Engineers have considerable experience designing and manufacturing superconducting coils and cryogenic systems for customers using MgB_2, Nb_3Sn, and YBCO superconductor wires and tapes. This enables us to recommend to customers the right superconductor for the desired applications.

Manufacturing Experience

Experience in conductor manufacturing, coil fabrication or both:

- BSCCO
- MgB_2
- Nb_3Al
- Nb_3Sn
- NbTi
- Pnictides
- YBCO
- Other non-ferrous non-superconducting



Processing equipment:

- Wire drawing equipment and furnaces for R & D conductor development
- Welded seam CTFF process for mono and multi-filament wire (one shift 10,000 km/yr capacity)
- Large capacity twisting
- Wire-in-channel soldering
- Insulation braiding
- Coil winding capacity designed for strain-sensitive wire

Low AC loss MgB2 wire and applications

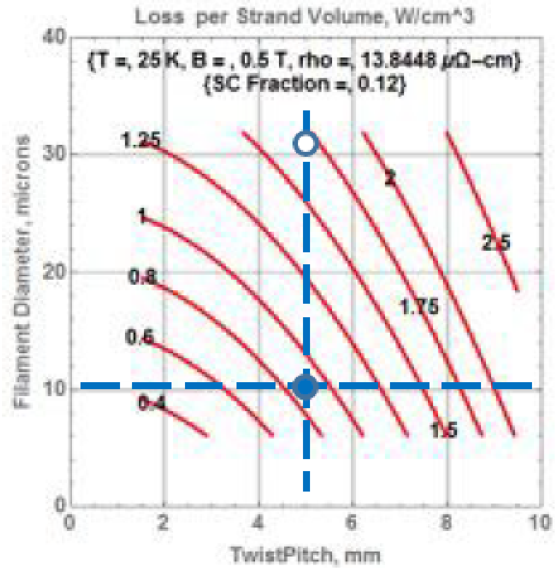
Reducing Losses in AC Stator Requires Litz-like Wire

SC wire development driven by calculated (theoretical) AC losses

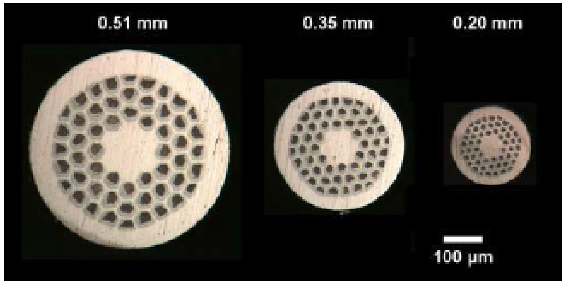
Solution is fine, tightly twisted filaments

↓Hysteresis Loss, need fine filaments
↓Coupling Loss, need tight twist
↓Transport Loss, usually negligible

SBIR work by Hyper Tech Research

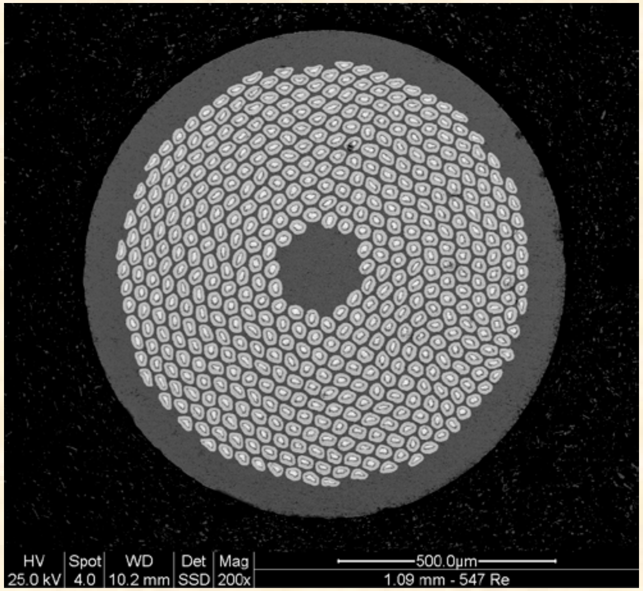


Hyper Tech Research wire configuration options developed under SBIR

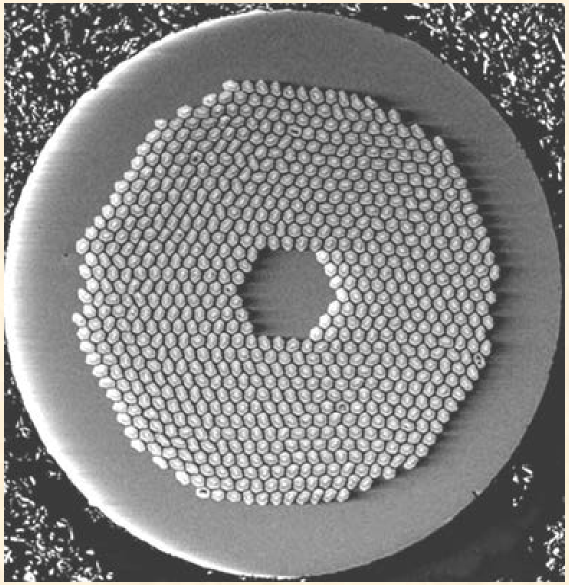


Nb_3Sn Conductor Manufacture at Hyper Tech

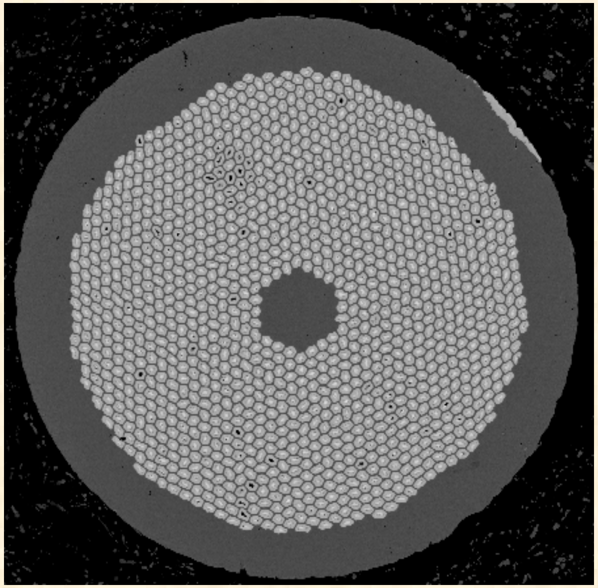
High Count Restack Tube Type Strands



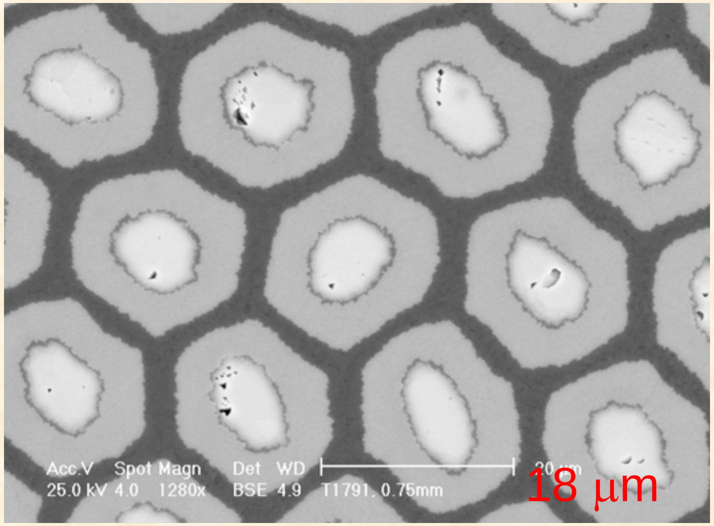
21 µm, 547

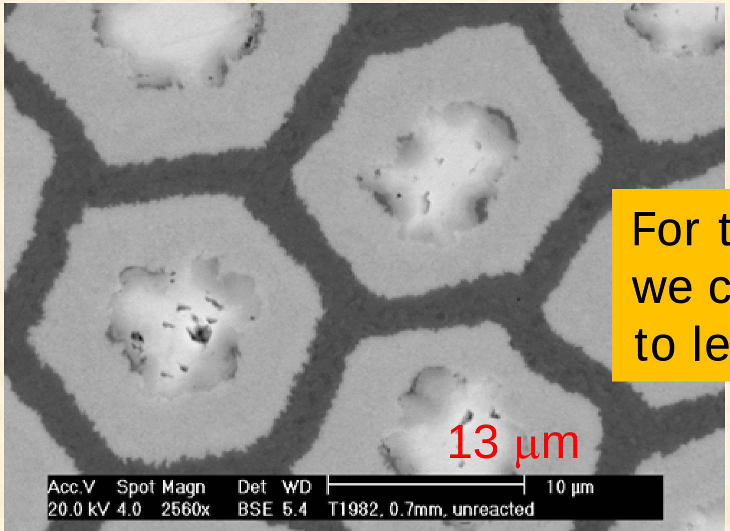


18 µm, 744



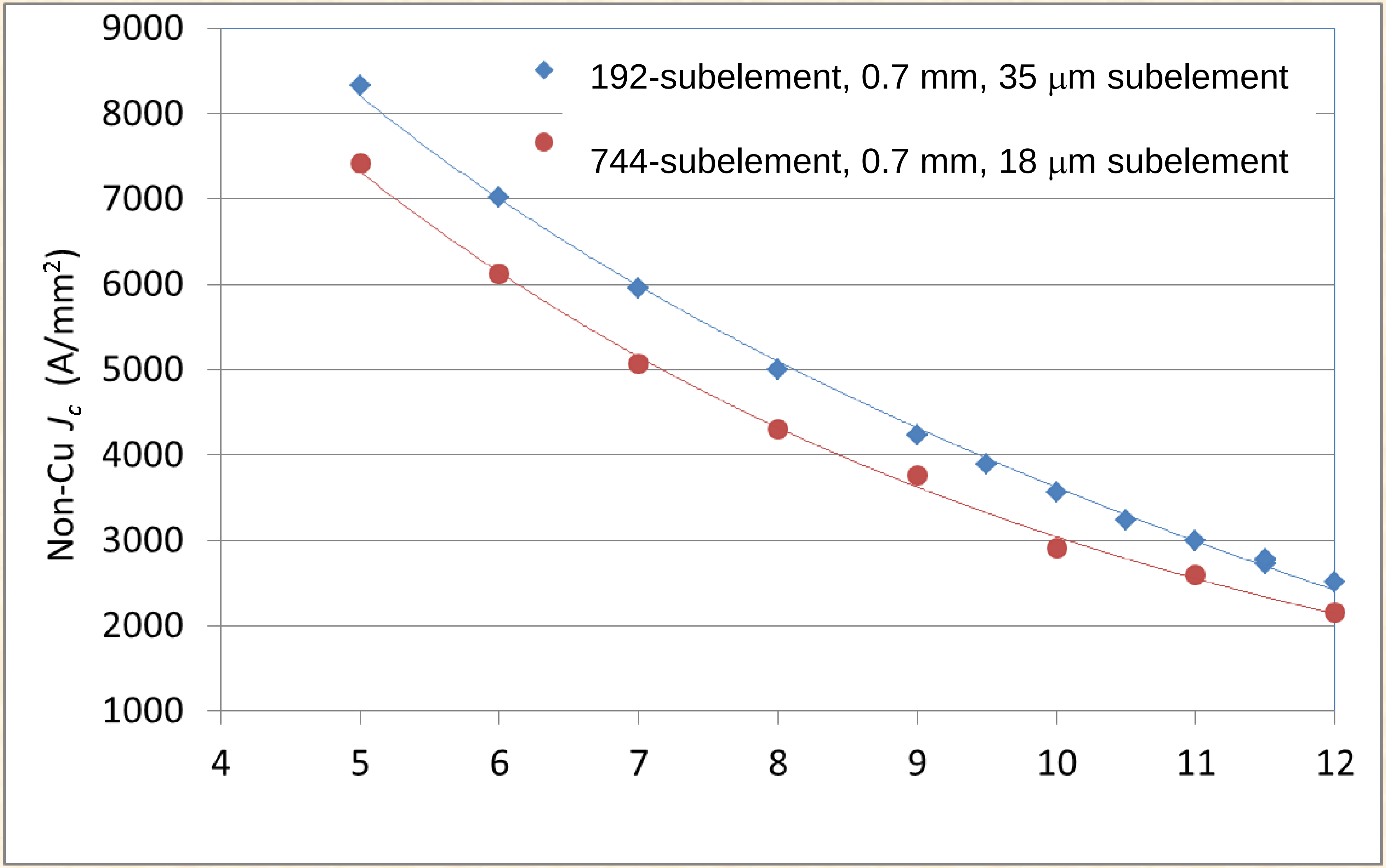
13 µm, 1248



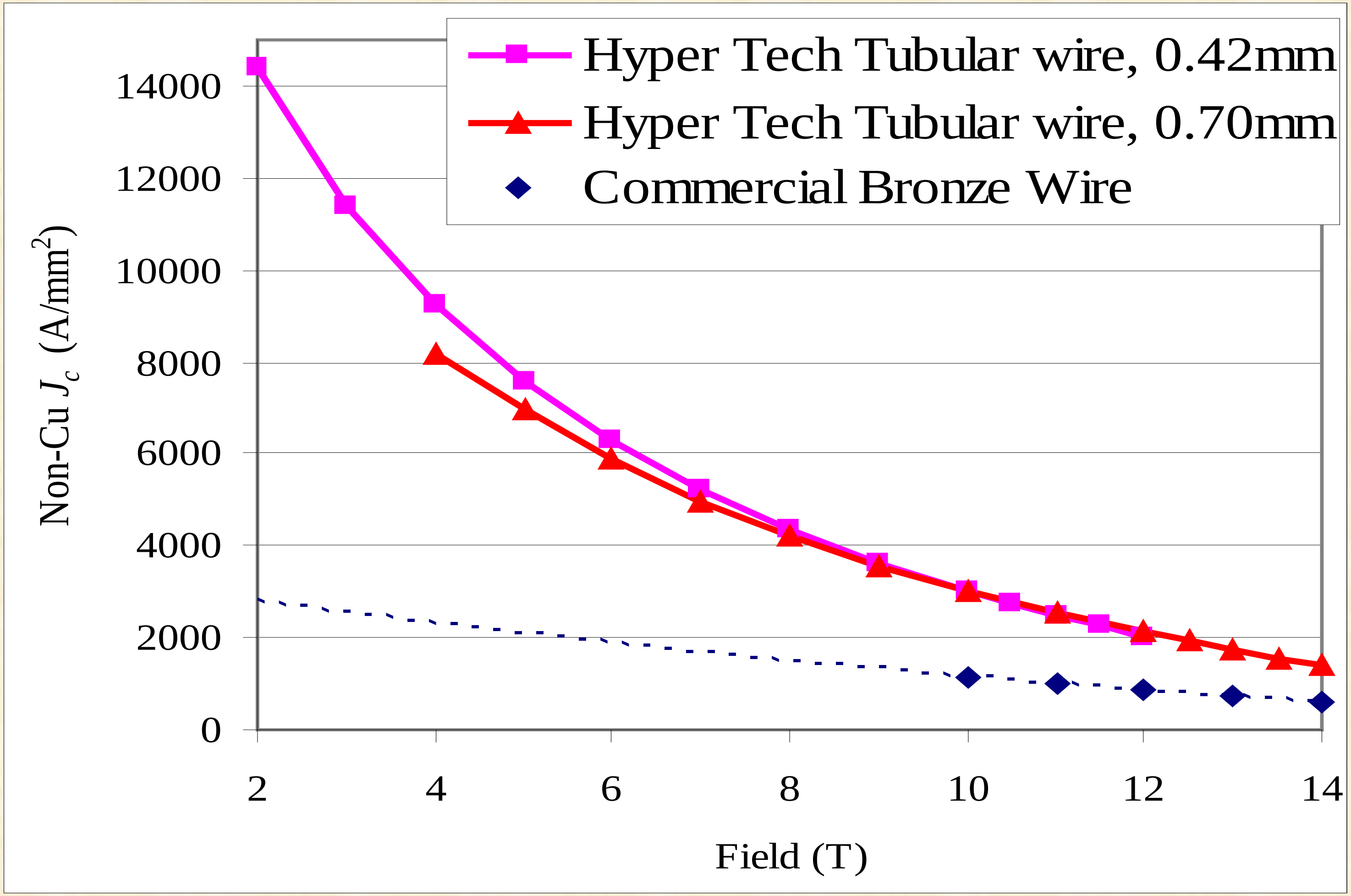


For tube type strands, we can get D_{eff} down to less than 20 µm.

J_cs Results

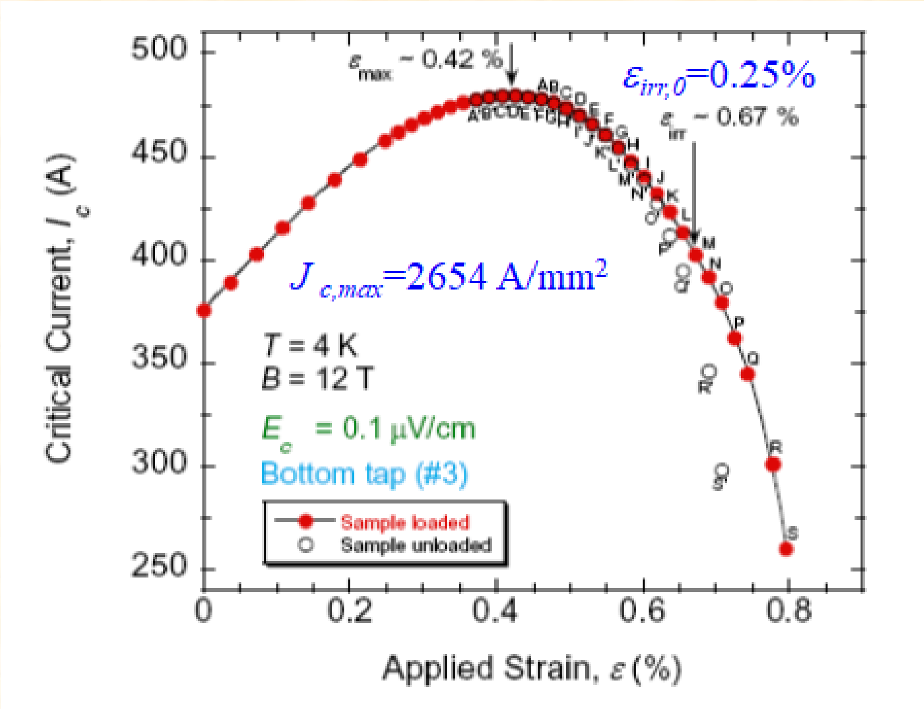

192-subelement, 0.7 mm, 35 μm subelement
744-subelement, 0.7 mm, 18 μm subelement
Non-Cu J_c (A/mm^2)
9000
8000
7000
6000
5000
4000
3000
2000
1000
4
5
6
7
8
9
10
11
12

J_cs Results of 744 restack strands

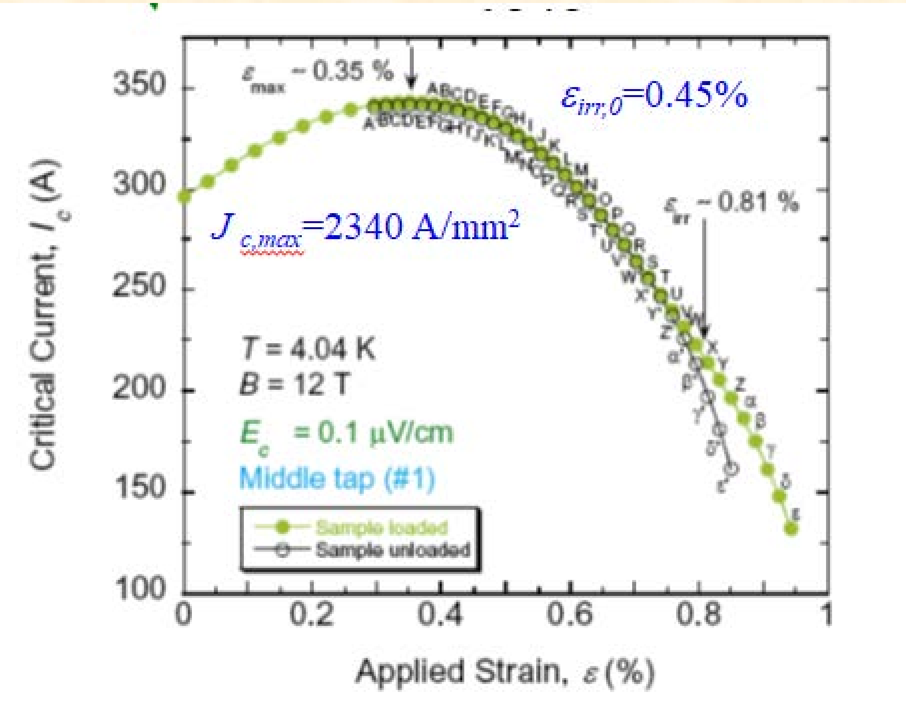


Strain Sensitivity (12 T)

192-subelement, 0.7 mm

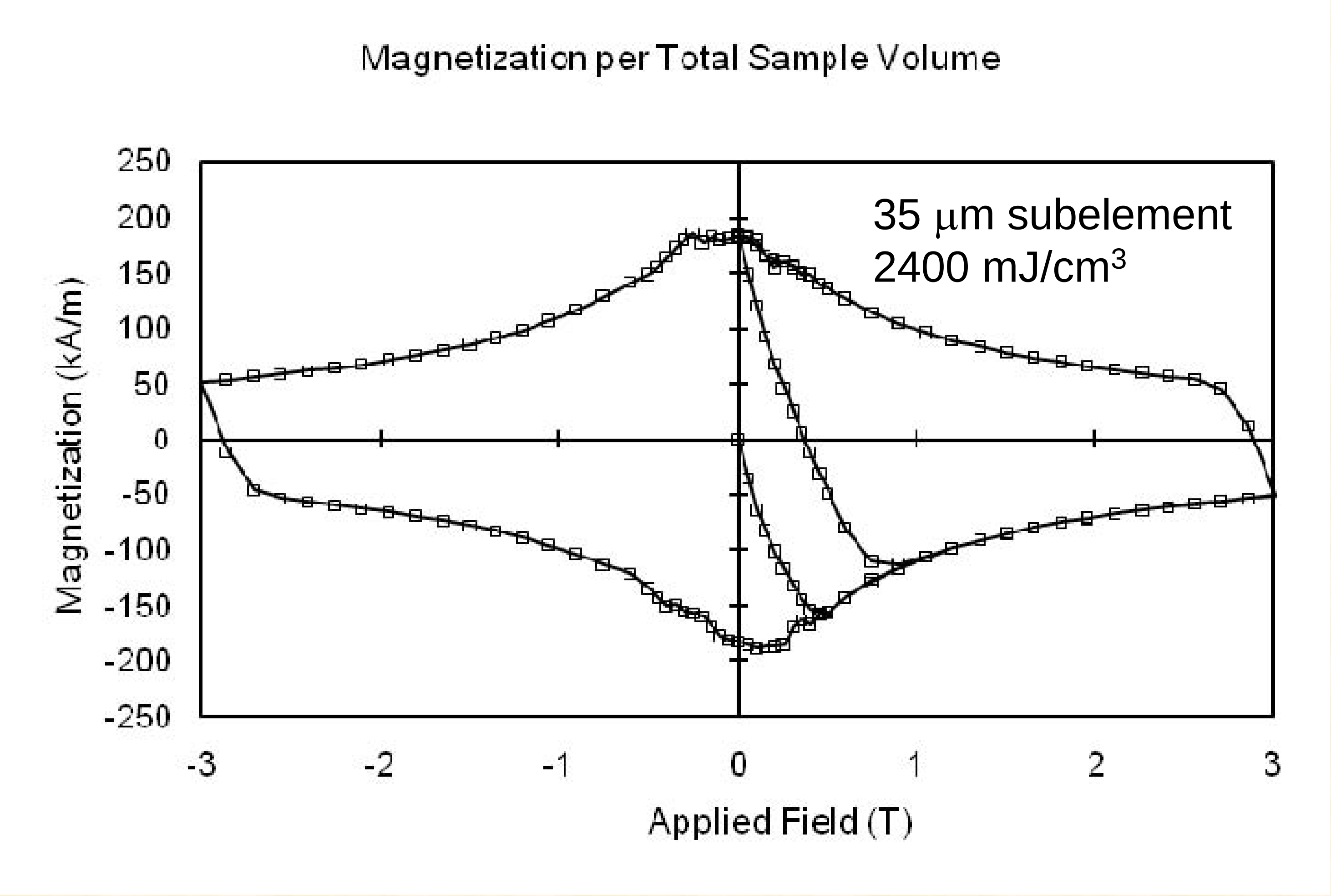


744-subelement, 0.7 mm

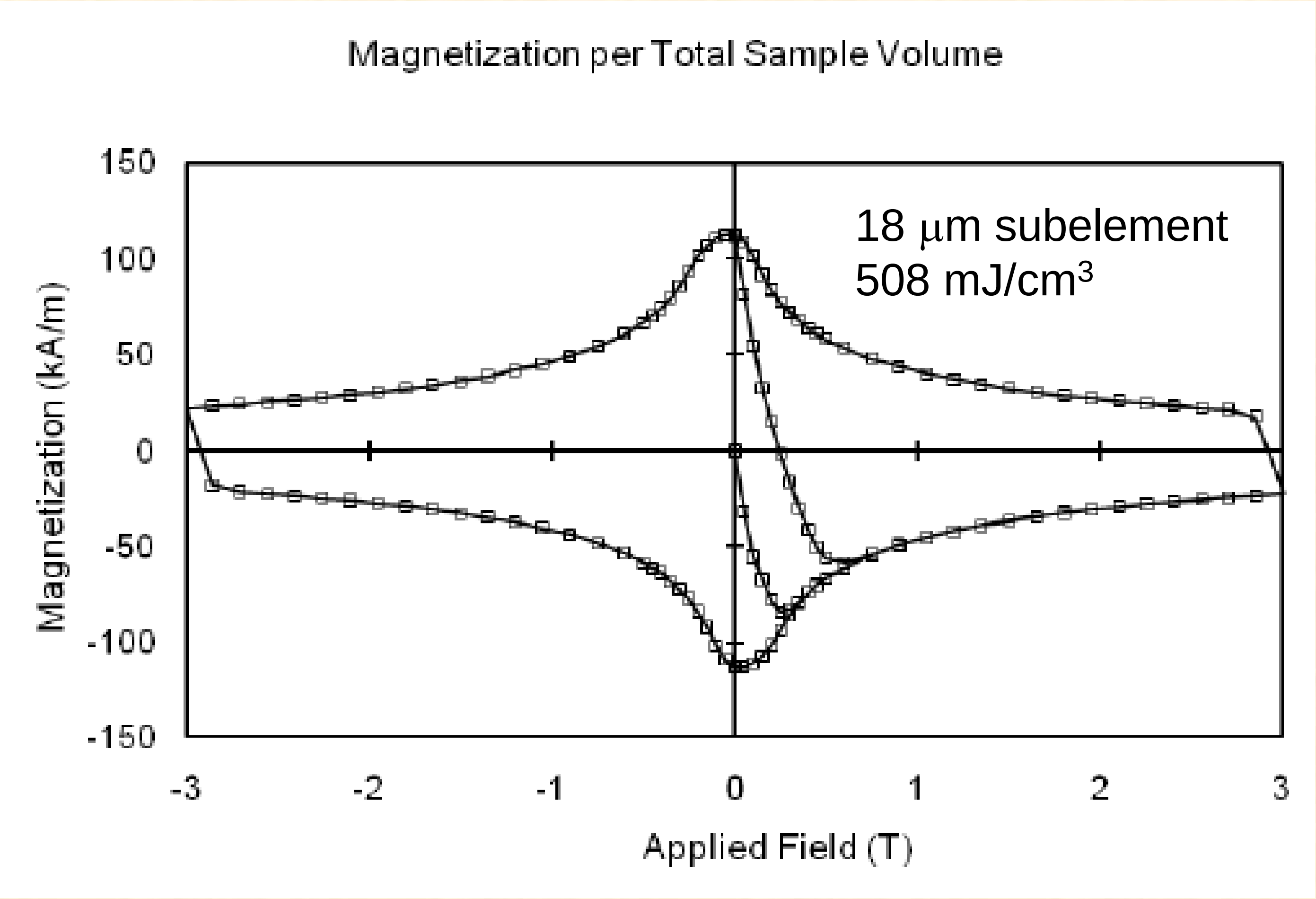


Tested by NIST

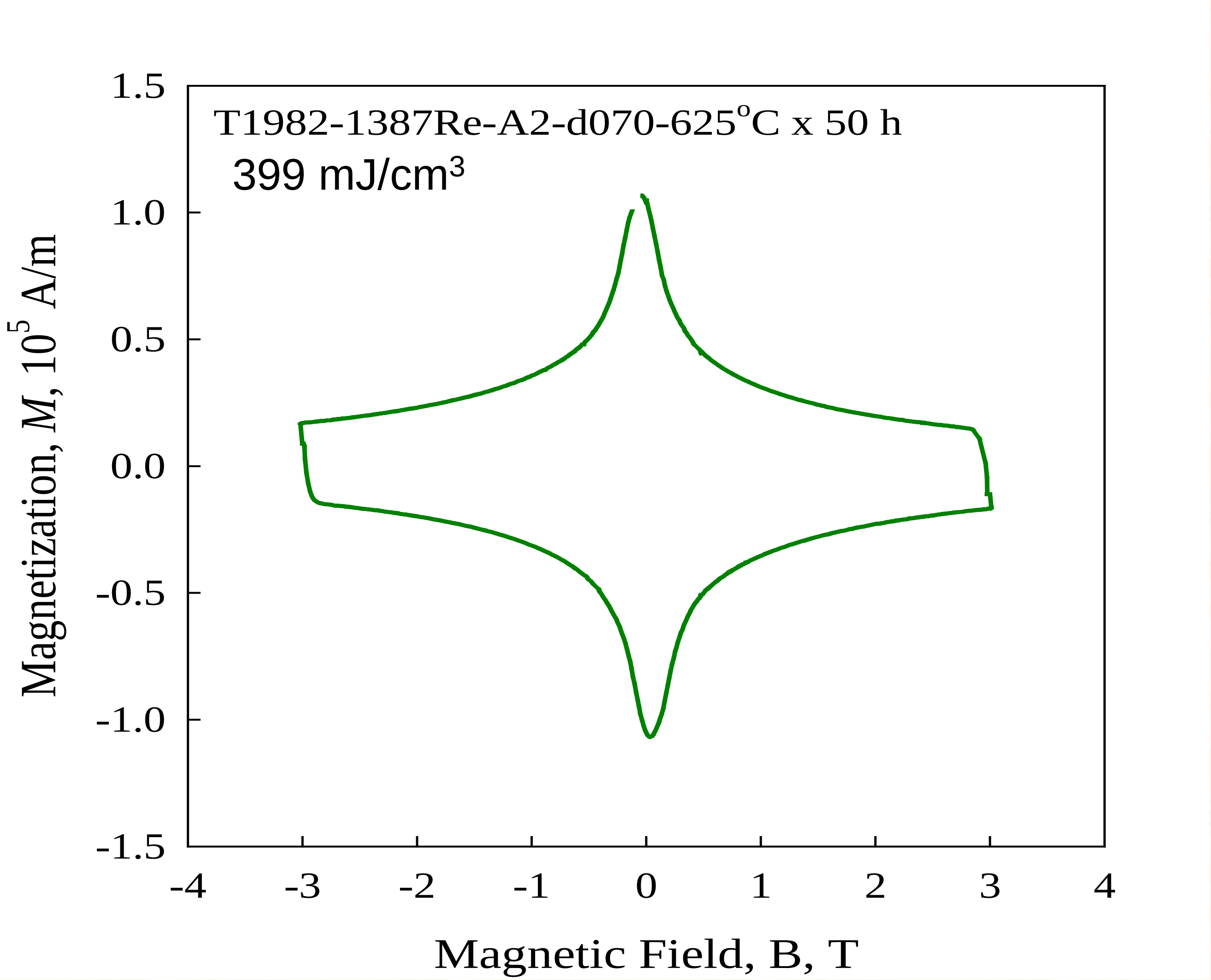
Magnetization Data of the 192-subelement Wire (0.7 mm)



Magnetization Data of the 744-subelement Wire (0.7 mm)



Magnetization Data of the 1248-subelement Wire (0.7 mm)

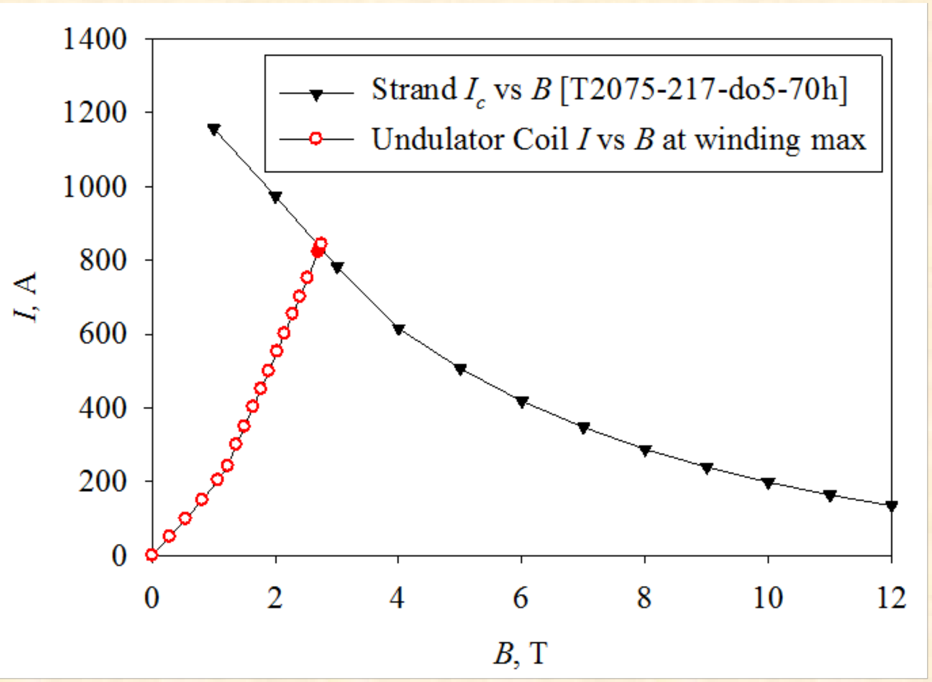


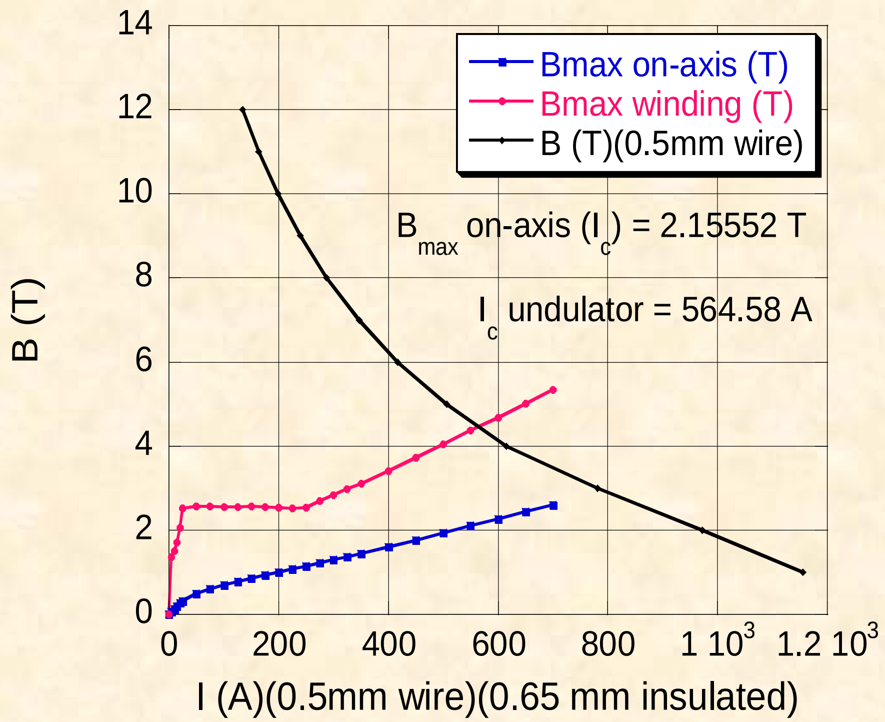
Potential Applications

Strand	D_{eff}	Non-Cu Jc at 12 T, A/mm^2	I_c of 0.7mm strands, A	$\varepsilon_{irr,0}$, %	AC loss, mJ/cm^3
744-subelement	18 µm	1900-2200	300-350	0.43-0.48	600
1248-subelement	12 µm	1600-2200	250-350		400

This high count restack wire could be used for Future Advanced Fusion Projects

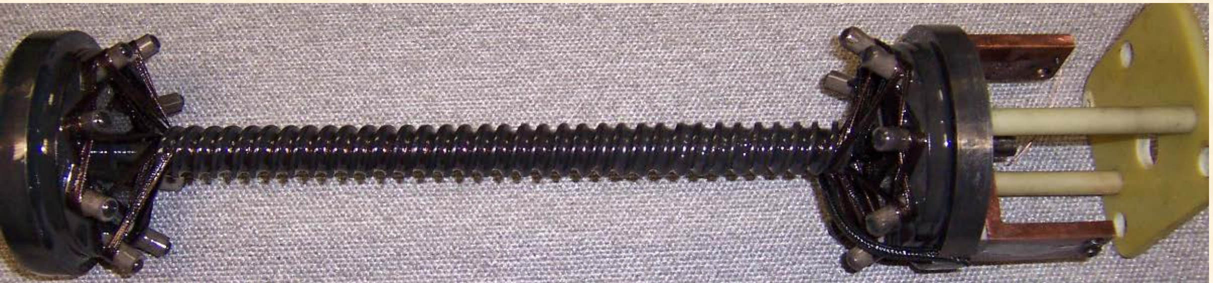
Applications on Short Period Helical Undulators

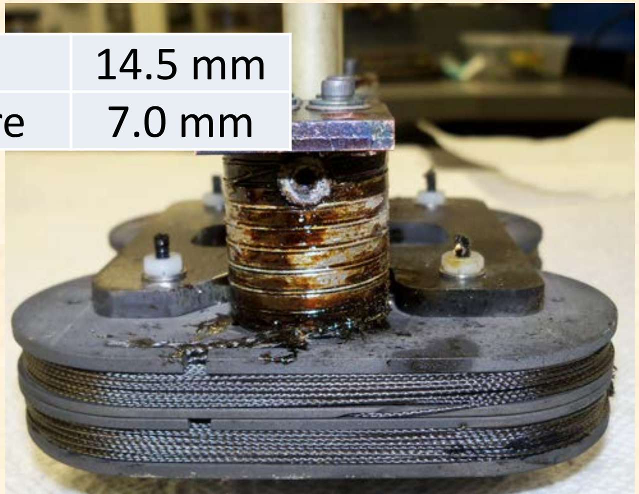




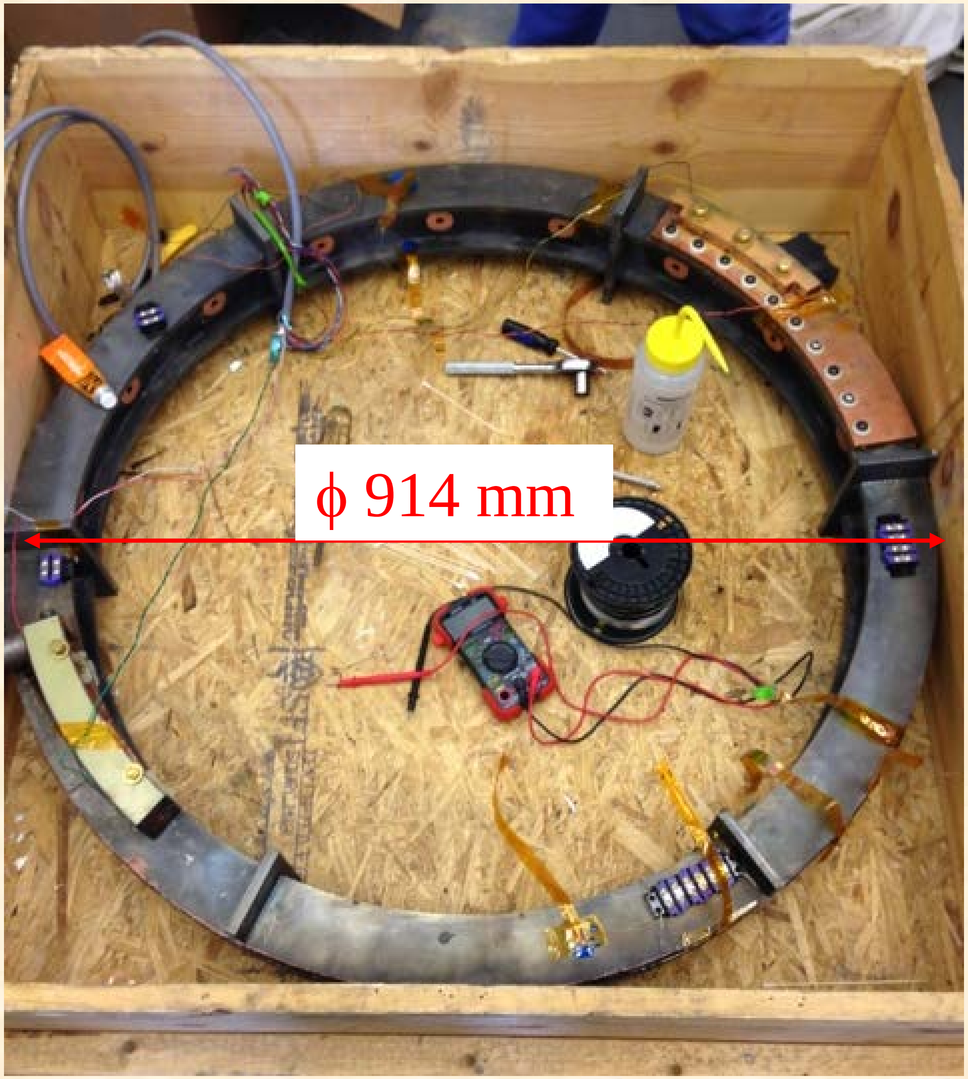
Period (λ)	14 mm
Winding bore	8.0 mm
Beam aperture	7.0 mm

Period (λ)	14.5 mm
Beam aperture	7.0 mm





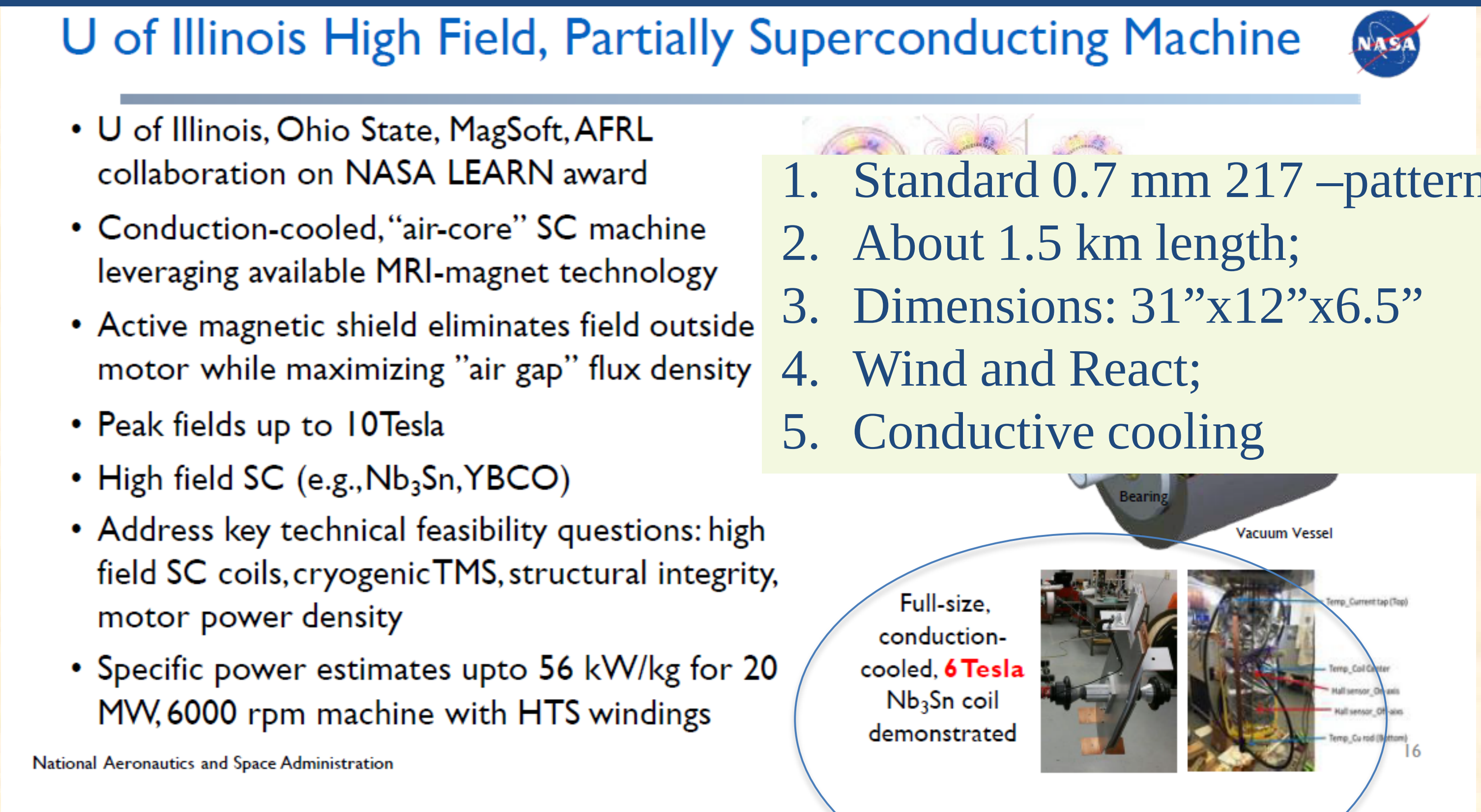
One Meter OD Coil Made for High Field MRI



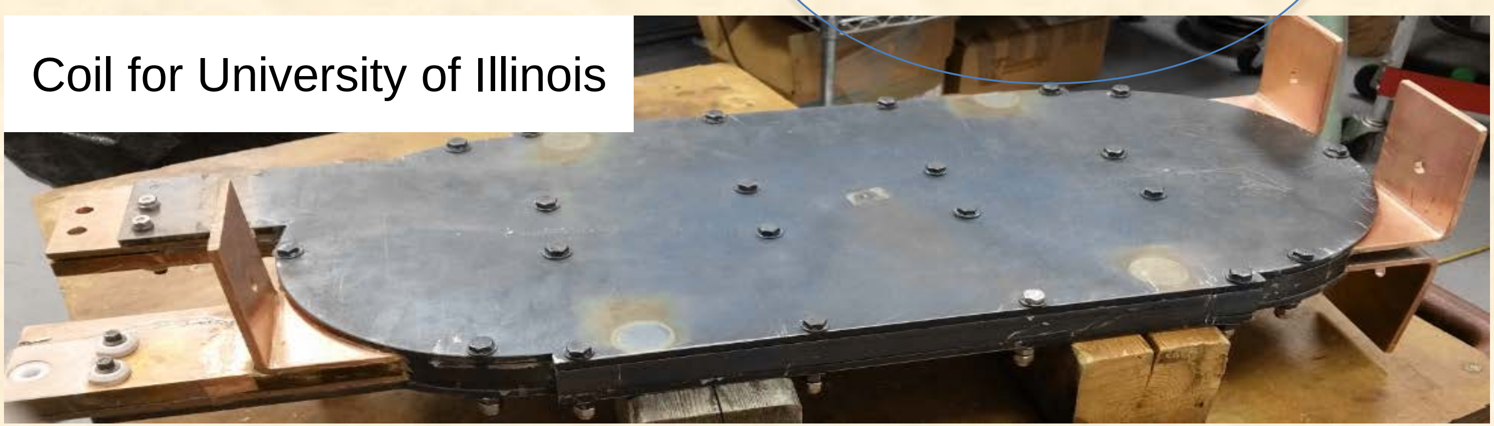
1. Standard 0.7 mm 217 – pattern Nb_3Sn Strand;
2. About 1.6 km length;
3. Coil OD = 914 mm;
4. Wind and React
5. Conductive cooling

Application: 5-11T full body MRI's that are conduction cooled and slightly larger than today's 3T systems

Big Racetrack Coil Made for NASA Project



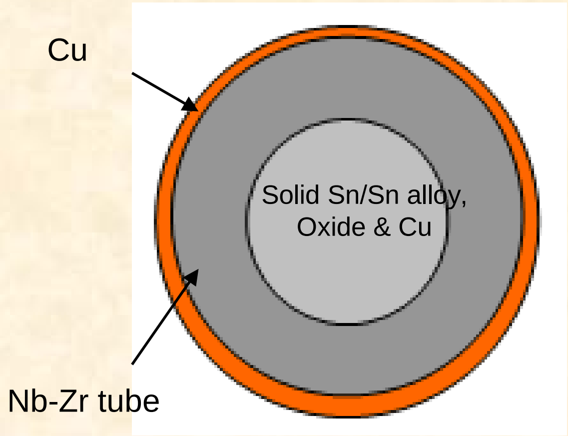
1. Standard 0.7 mm 217 –pattern Nb_3Sn Strand;
2. About 1.5 km length;
3. Dimensions: 31"x12"x6.5"
4. Wind and React;
5. Conductive cooling

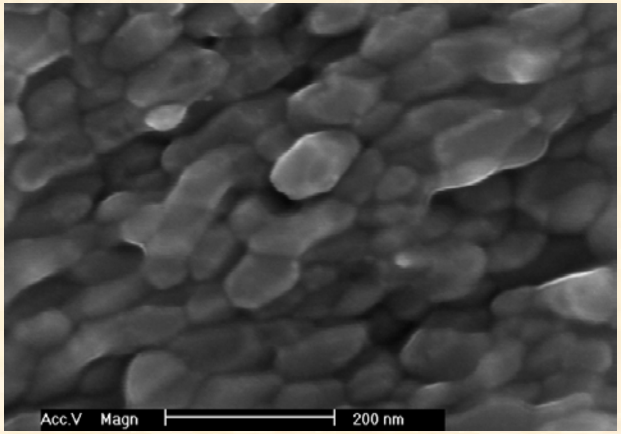


Coil for University of Illinois

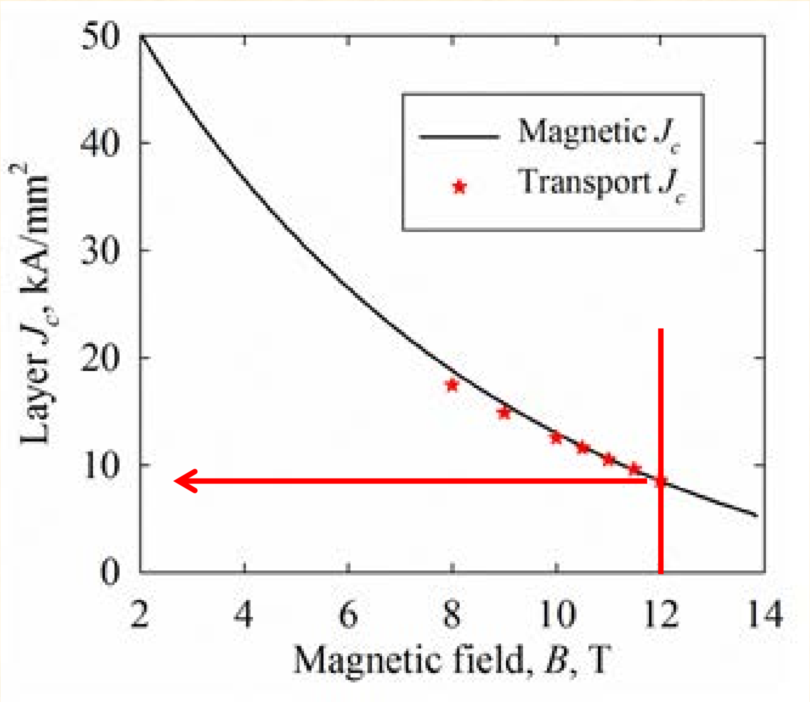
Enhanced Pinning in Binary and Ternary Nb_3Sn strand by using Internal Oxidation approach.

Use Internal Oxidation to Improve Jc



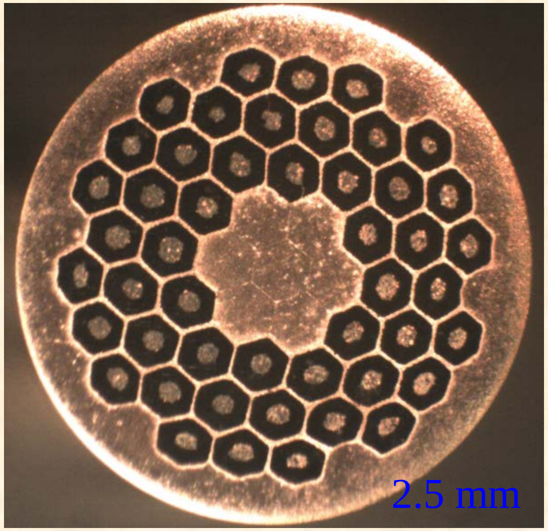


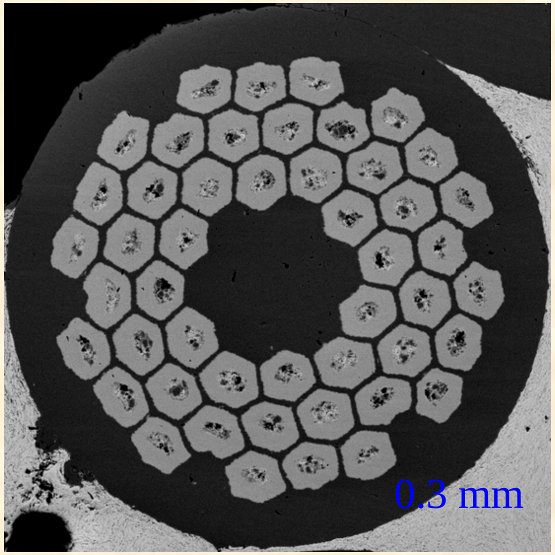
The average grain size is about 50 nm after heat-treatment of 650C for 52 hours



Transport layer J_c and magnetic layer J_c of the subelements

Could we make the filaments into practical strands?

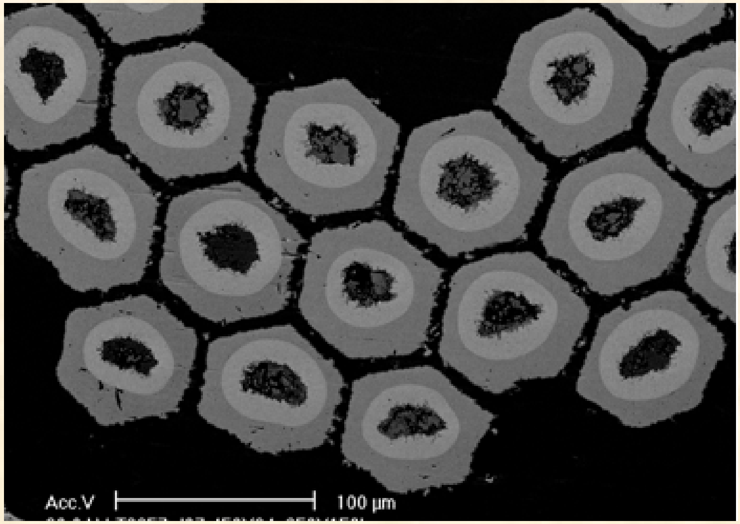


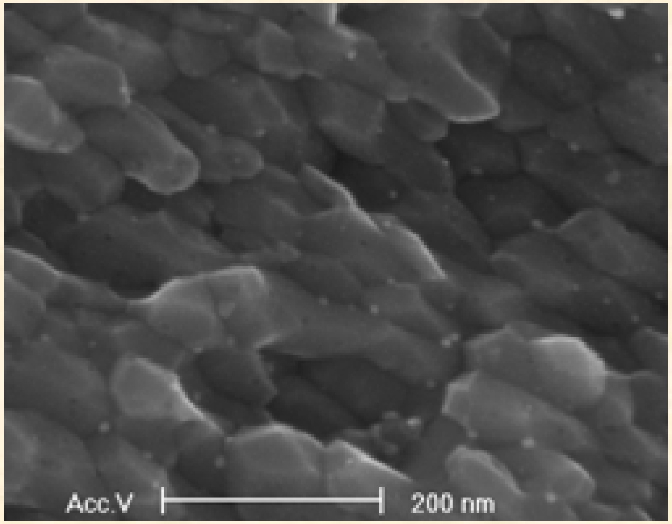


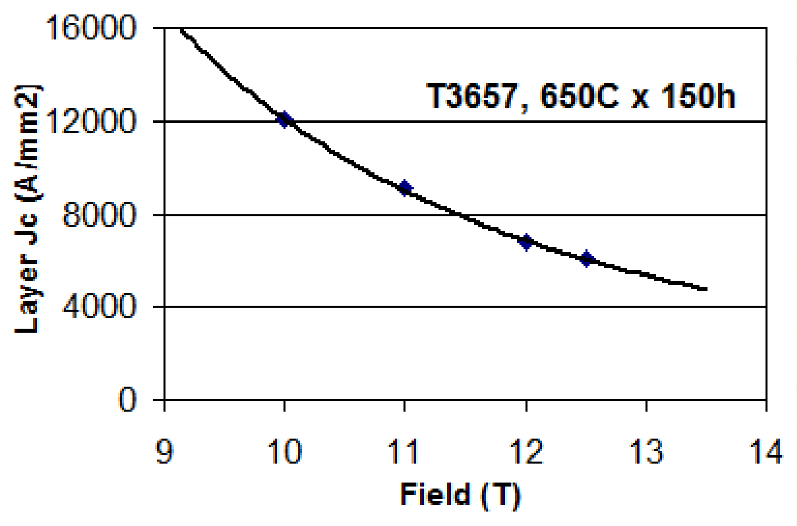
The (48+7) restack wire was drawn down to 0.3 mm without any breakage, which have filament size of about 27 μm.

Yes, we can make it into high count restack

Improve Jc in Tube Type Strands using APC

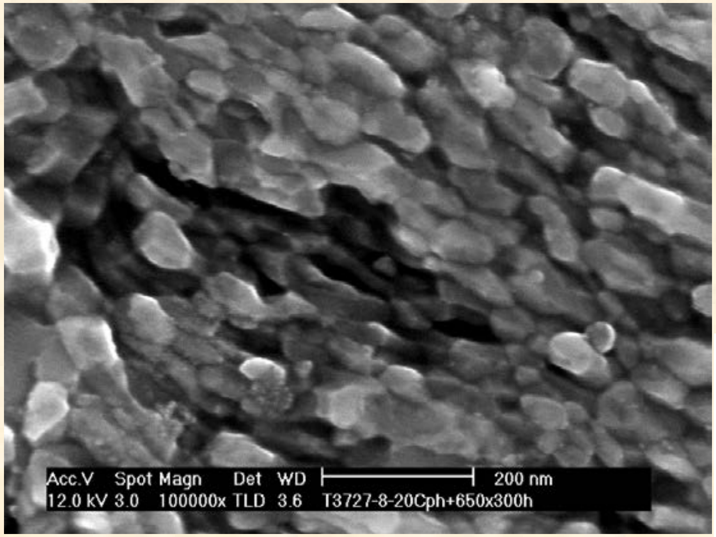




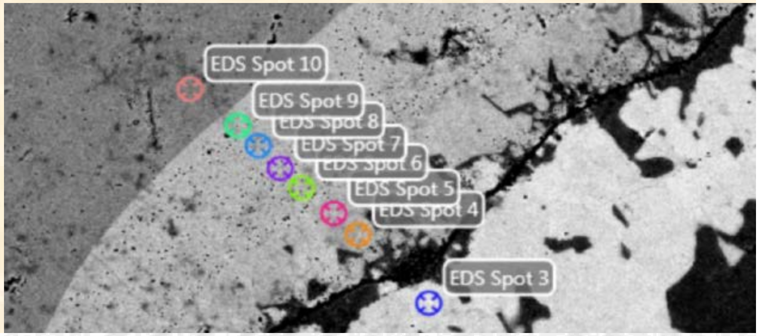


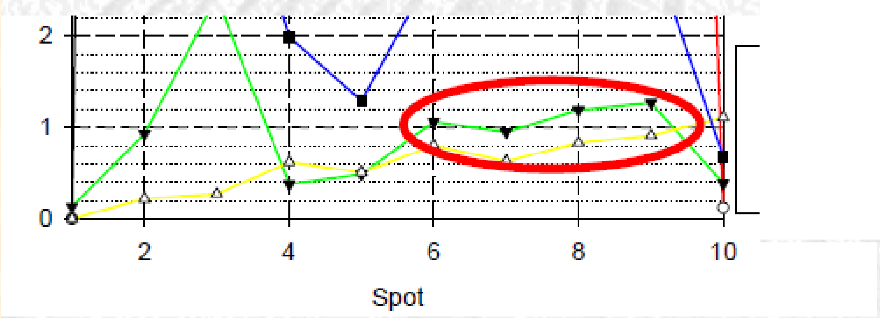
The grains were slightly refined as about 80 nm. The layer J_c at 12 T is about 6800 A/mm^2 which is lower than the subelement since the grains are not fully refined.

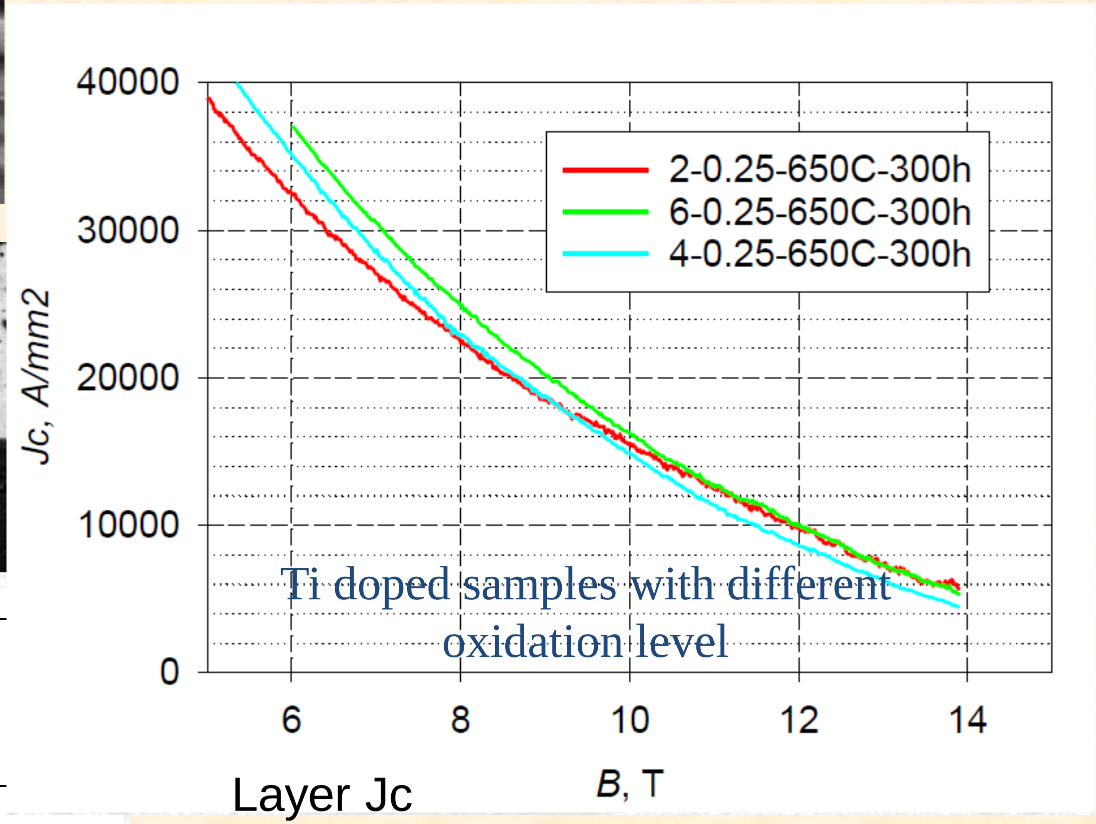
Ti doped Ternary Tube Type strands using APC



1. The average grain size is about 50-60 nm after heat-treatment
2. 1-1.5 at% Ti in Nb_3Sn layer







Ti doped samples with different oxidation level

Summary

1. Manufacture 919-pattern restack wire with diameter of 1 mm and 0.7 mm at Hyper Tech, which could be used for future fusion applications;
2. Manufacture 217-pattern restack wire with diameter of 1 mm and 0.7 mm at Hyper Tech, which is ready for high field applications;
3. Demonstrated grain refinement by a factor of 3 and a doubling of 12 T *Jc* in monofilaments.
4. Draw multifilamentary strands down to small diameter with filament size less than 30 μm and demonstrated multifilamentary strands with refined grains and enhanced Jc values.
5. Preliminary work on Ternary by doping Ti shows high feasibility to improve Jc and B_{C2}
6. **Great potential for Nb_3Sn to provide the desired engineering current densities to enable 16 T HEP magnets for FCC with big margin.**

Thank you for your attention