Development of cabling techniques for Nb_3Sn and Bi-2212 wires

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Presentation Outline

- Review of NbTi cabling parameters
- Modifications of cabling parameters for Nb_3Sn
- Modifications of cabling parameters for Bi-2212
- Cabling techniques for special cables (mixed strands, cores, large keystone angles)

Design process for superconducting cables

- Select magnet design parameters
- Select cable parameters to meet magnet design requirements
- Iterate cable parameters to reduce Ic degradation and improve coil winding behavior

Cable parameter spreadsheet

Input:

1. **Strand diameter**
2. **Number of strands**
3. **Pitch angle**
4. **<u>Minimum cable width</u>**

Calculate:

1. **Allowed keystone angle**
2. **Cable compaction at middle, thick edge, and thin edge for various cable thicknesses**

	INPUT A						
No. of Strands =	10	Cable Width =	5.2015			Minimum Mandrel Width =	4.2015
Strand DIA. =	1	Cable MID Thk. =	2				
Pitch Angle =	16						
CALC Compacted Cable RESET		Pitch length =	36.2796				
		Density =	0.7854	or	PI /4		

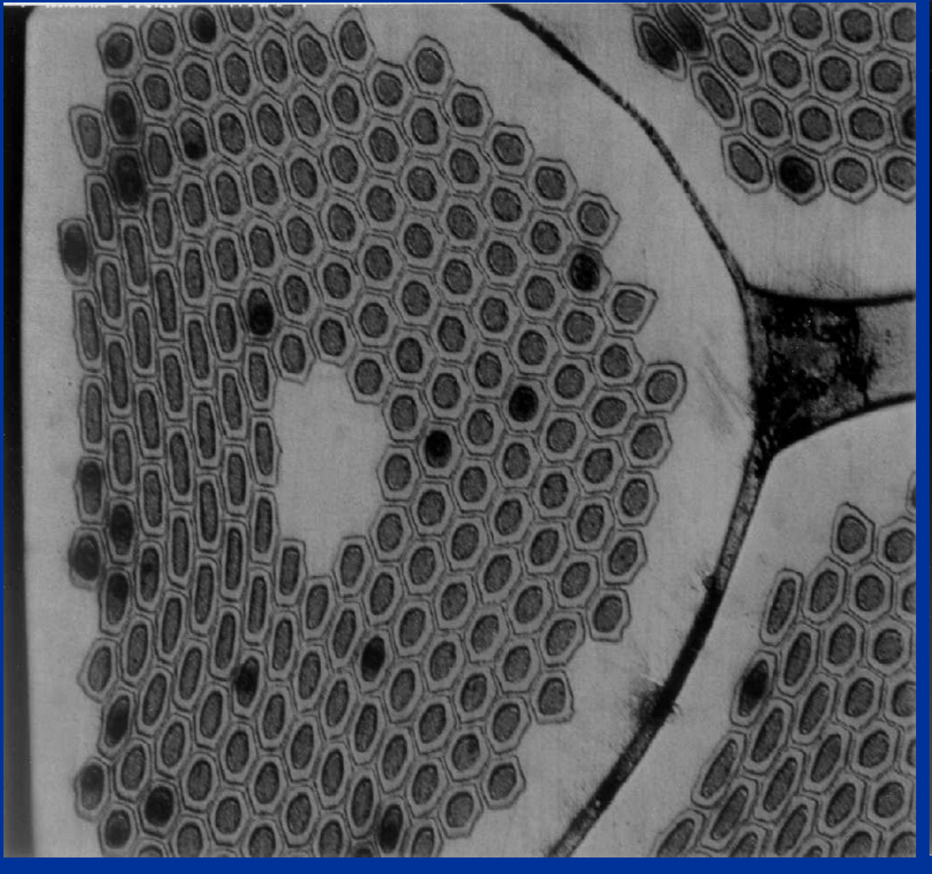
Module: [B]	INPUT B	COMPACTED CABLE	MIN.	MID	MAJ.	
Cable Width =	0					NEEW's formula
Cable Mid Thk. =	0					Mid Packing Factor
Keystone angle. =	0	Cable Thickness =	0	0	0	#DIV/0!
Pitch length =	0	Density =	#DIV/0!	#DIV/0!	#DIV/0!	
		Pitch Angle =	#DIV/0!			Print Area

Title:	Paste A	Paste B	Paste C	Paste D	Paste E	Paste F	Paste G	Paste H	Paste I	Paste J
Iteration #										
UNCOMPACTED										
No. of Strands =										
Strand DIA. =										
Pitch Angle =										
Cable Width =										
Cable MID Thk. =										
Pitch length =										
Density =										
	A	B	C	D	E	F	G	H	I	J
COMPACTED										
Cable Width =										
Cable Mid Thk. =										
Keystone angle. =										
Pitch length =										
Pitch Angle =										
Cable Thickness										
MINOR EDGE =										
MID =										
MAJOR EDGE =										
Packing Factor										
MINOR EDGE =										
MID =										
MAJOR EDGE =										

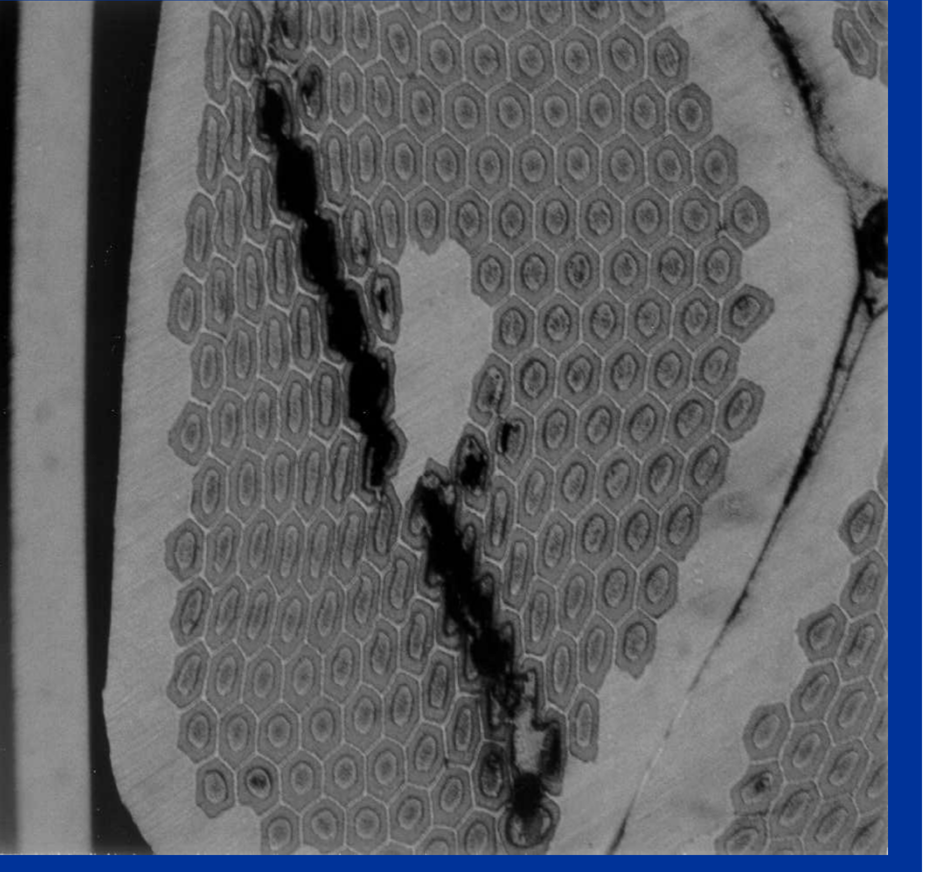
Parameters modified for Nb_3Sn include:

- Cable width--minimum width increased after subelement shearing was observed using NbTi cable parameters
- Cable compaction--reduced to minimum acceptable for coil winding
- Lubrication is changed depending on whether cable is to be used in wind/react or react/wind magnet

PIT Nb_3Sn strands at edge of Rutherford cable



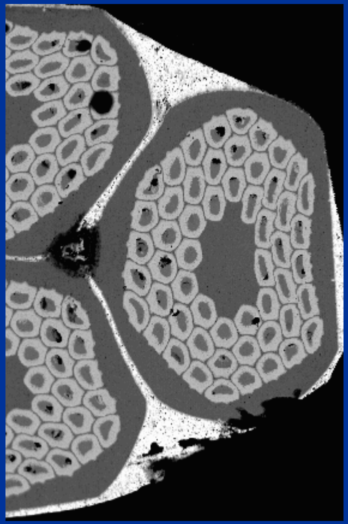
Moderately compacted

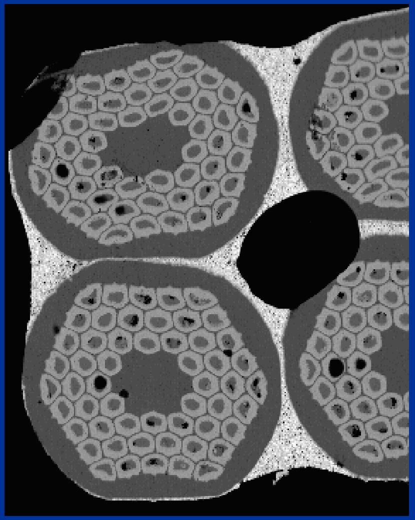


Highly compacted

Cable Compaction

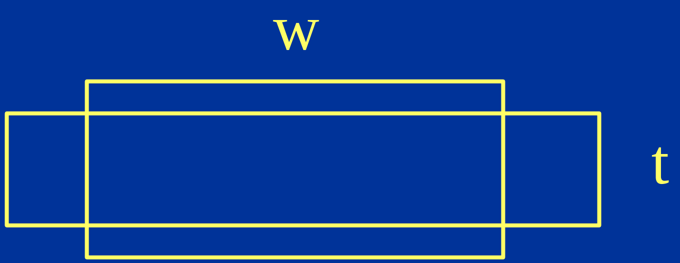
Decouple thickness & width





0.8 mm strand diameter
40 Strands
Area = 20.11 mm^2
87 % Compaction

Problem with Area Compaction



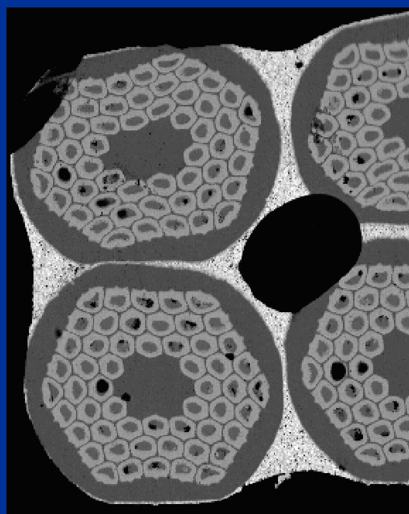
2 Cables: Same compaction

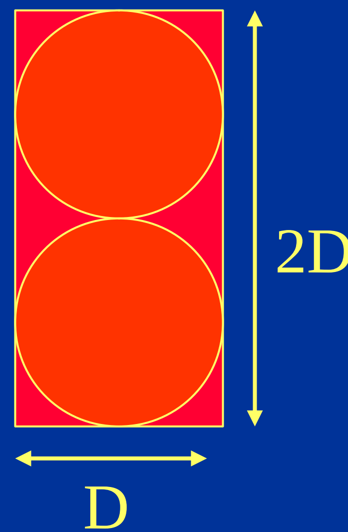
16.4 mm x 1.400 mm = 22.96 mm2

16.0 mm x 1.435 mm = 22.96 mm2

0.4mm half a strand diameter

Cable Compaction-1



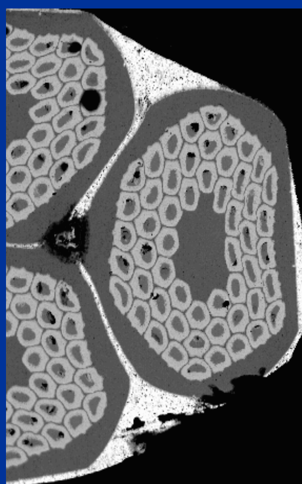


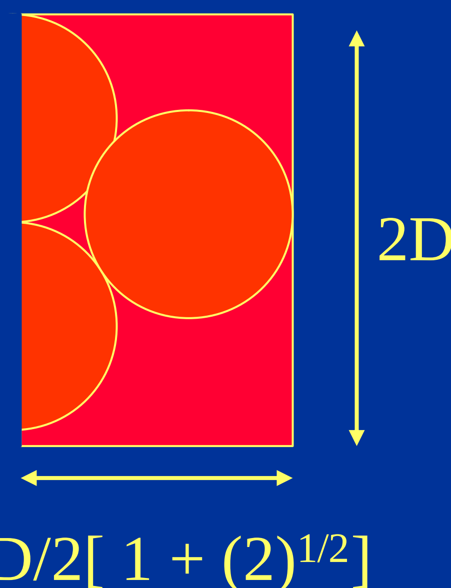
$$\frac{2\left(\pi D^2\right)}{4} = \text{Area of 2 wires}$$

$$t \times D = \text{Area of box after cabling}$$

$$\frac{t}{2D} = \frac{\pi}{4} \qquad 0.785$$

Edge Compaction-2



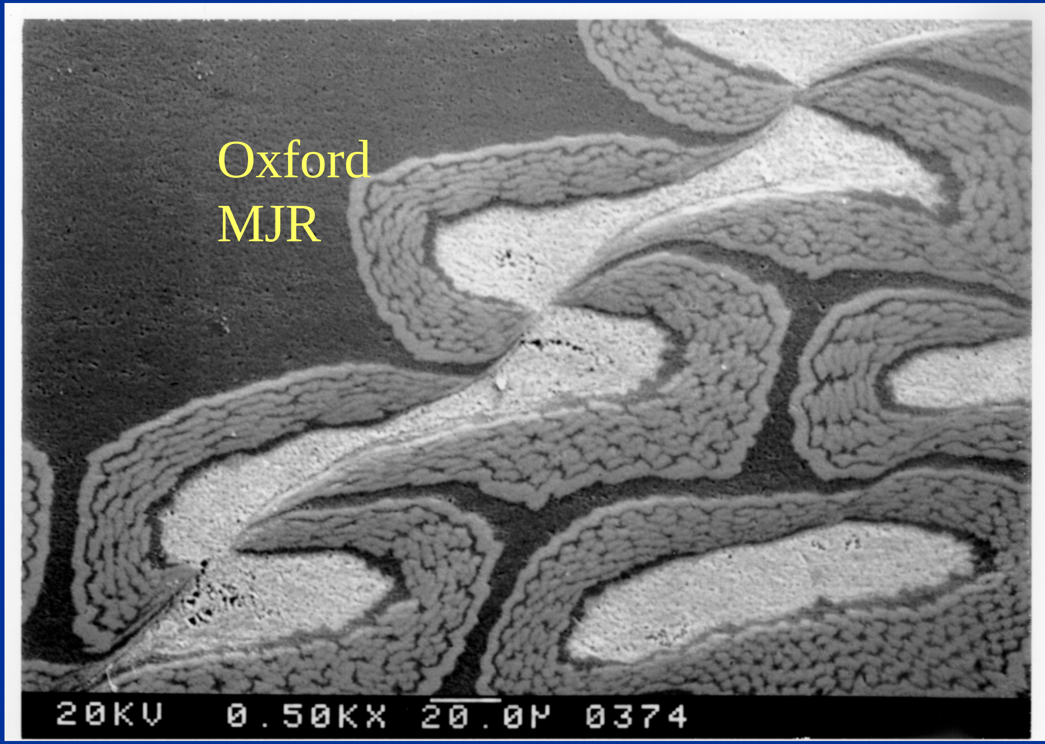


- More void space near edge of cable (0.65 filling factor
- Must balance thickness reduction and width reduction

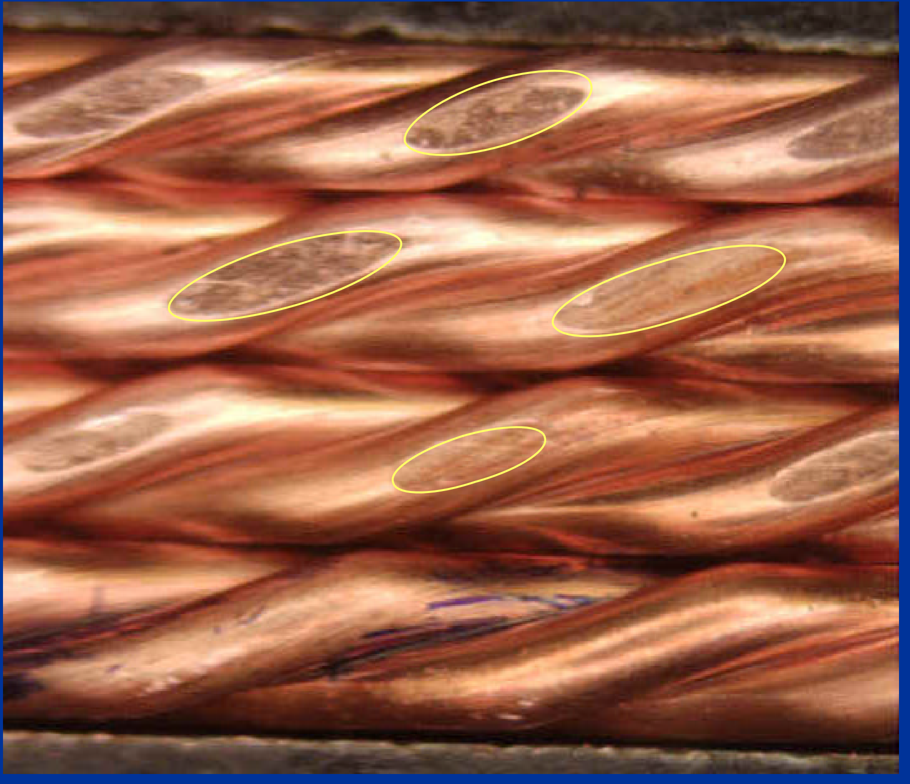
Note: effect of friction between rolls and strands is not in model

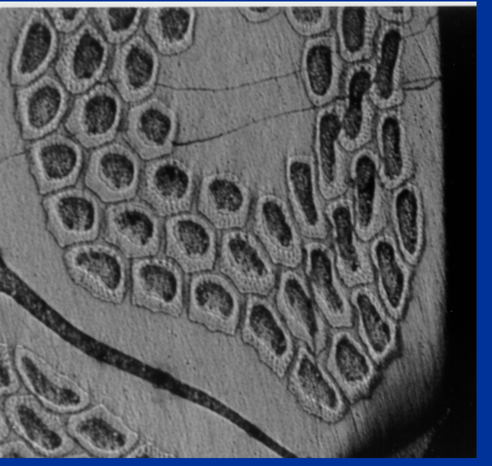
Can we quantify cable degradation?

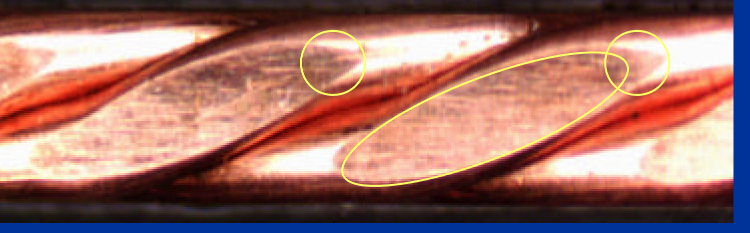
- Polished cross-section of cable: sheared subelements



Cable quality control



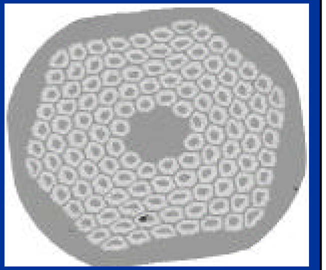




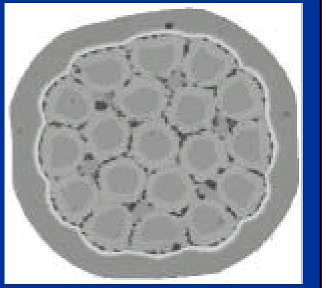
- Area of edge facets is a measure of strand deformation
- Use CERN optical imaging equipment to monitor facets

Cables for D-20, RD-3, and HD-1

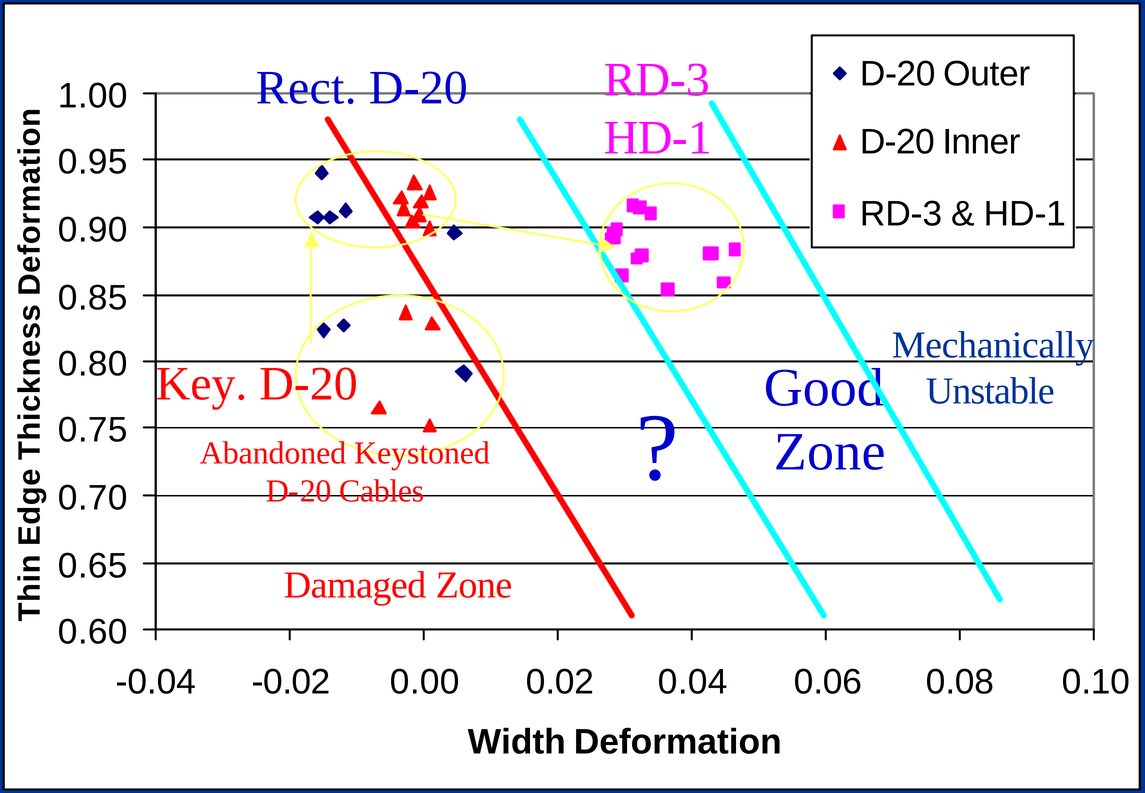
D-20



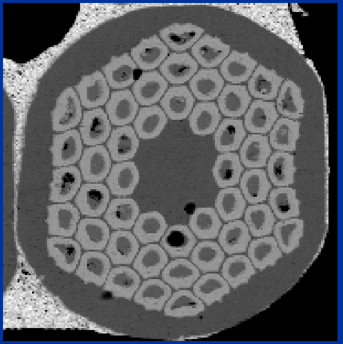
LBL Cable # 523
MJR-TWCA



LBL Cable # 522
IGC-Int. Tin

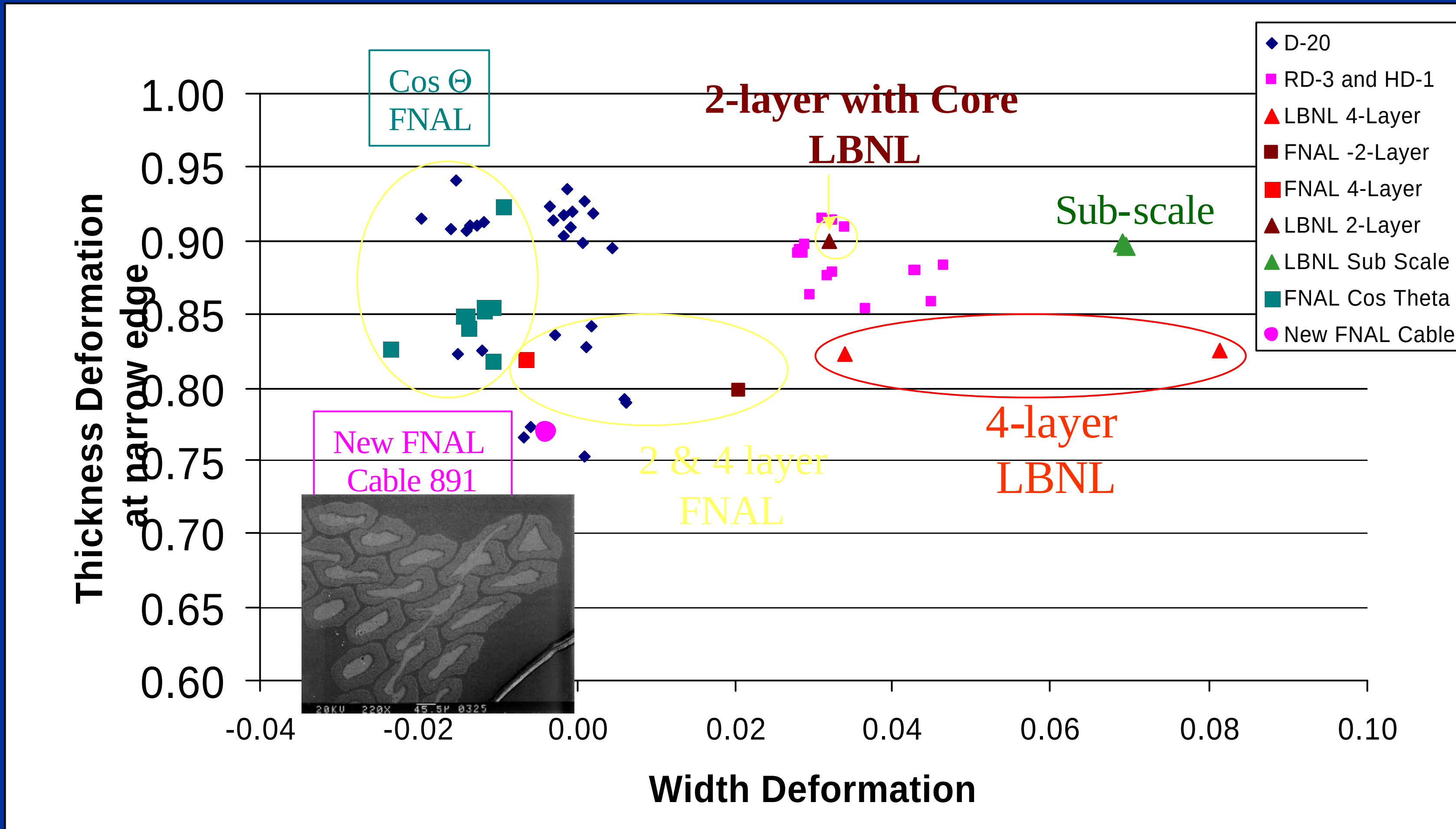


RD-3

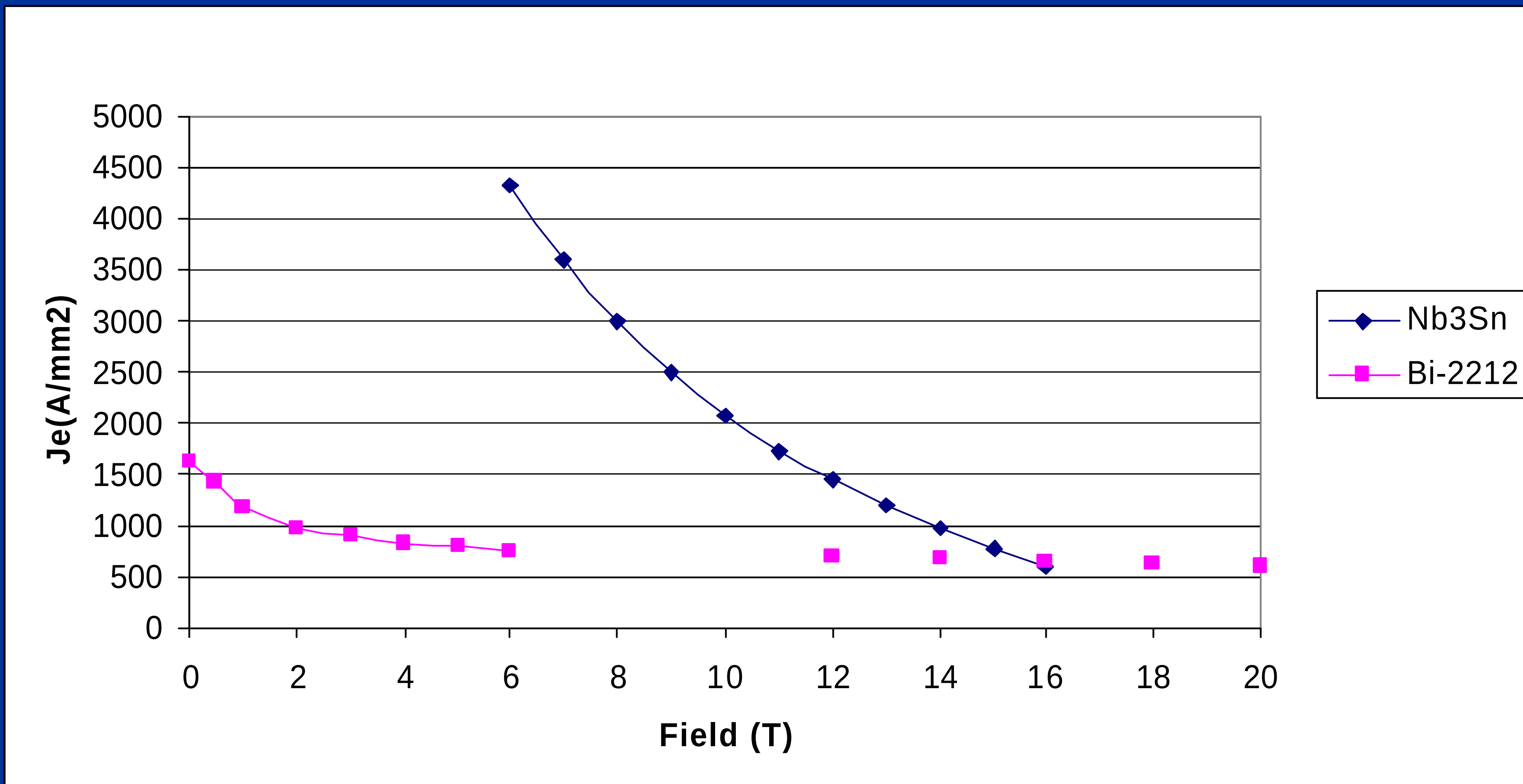


LBL Cable # 805R
Oxford-ORe

Fully Keystoned Cables for LARP

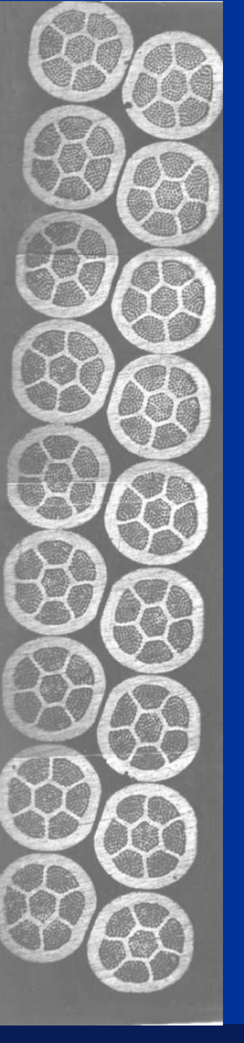


Comparison of Je for Nb_3Sn and Bi-2212



Bi-2212 round wire shows promise for accelerator magnets

- Jc(12T, 4.2K, non-silver) > 2000 A/mm^2 in new material (Showa, OST)
- Long lengths(> 1500 m) are being produced
- New result: 30 strand cable; Ic = 6.8 kA at 6 T
- Over 1000 m of 30 strand cable produced in 2003-2004



Bi-2212 R&D goals for 2003-2004 (Work for others contract with Showa)

- Reduce Ic degradation for 30 strand x 0.8 mm wire diam. cables
- Evaluate cabling properties of wires with different Ag alloy compositions
- Demonstrate long length fabrication (>300 m)
- Status:

  Long length fabrication established

  Methods for improving wire quality identified

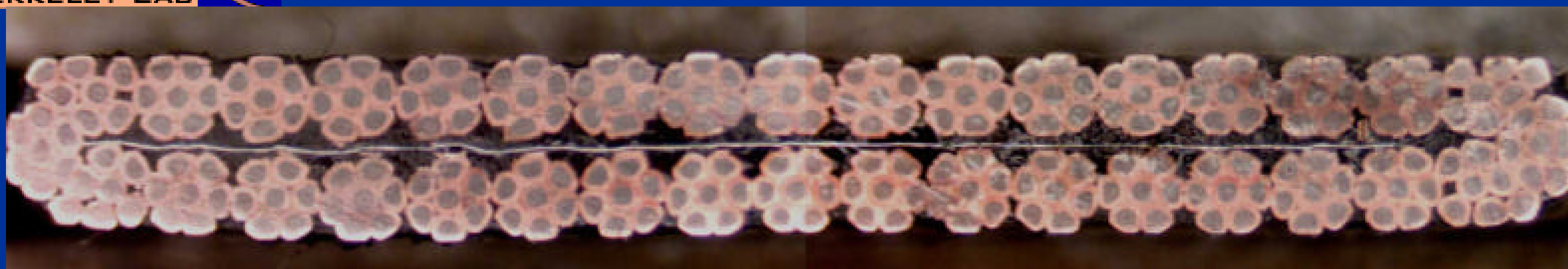
  Ic degradation reduced to 10-15 % range

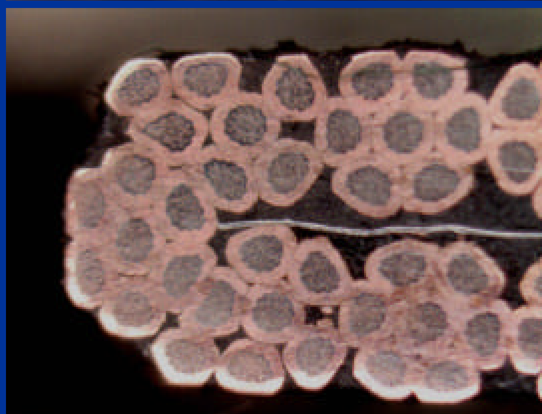
Showa goal is to demonstrate long length cable performance to Chubu Electric for their proposed SMES project

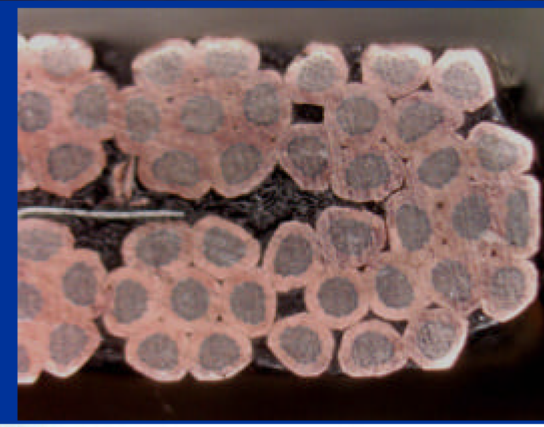
Mutual benefits from Showa/LBNL/BNL collaboration include:

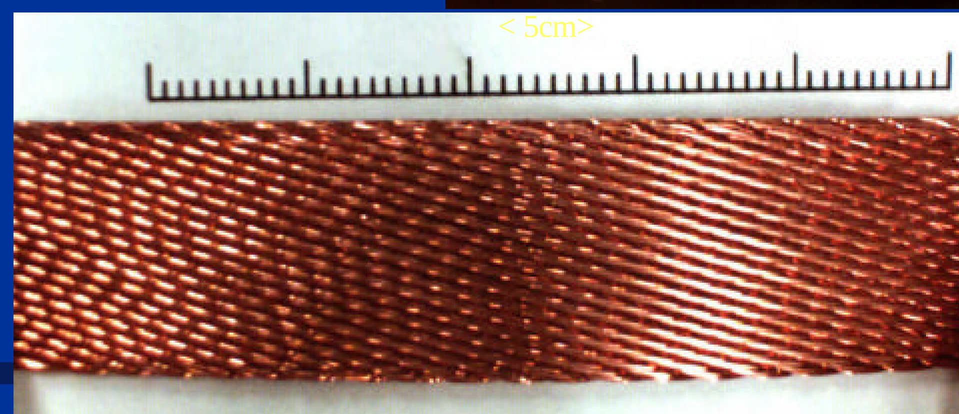
- Cabling expertise (LBNL) and Ic testing (BNL)
- Wire for cabling R&D at LBNL (30,000 m of wire delivered in 2003-2004)
- Cable for react and wind magnets at BNL
- Cable and coil reaction (Showa) for wind and react magnets at LBNL

FNAL R&W R3I-00741a Mfg. LBNL 2/17/00



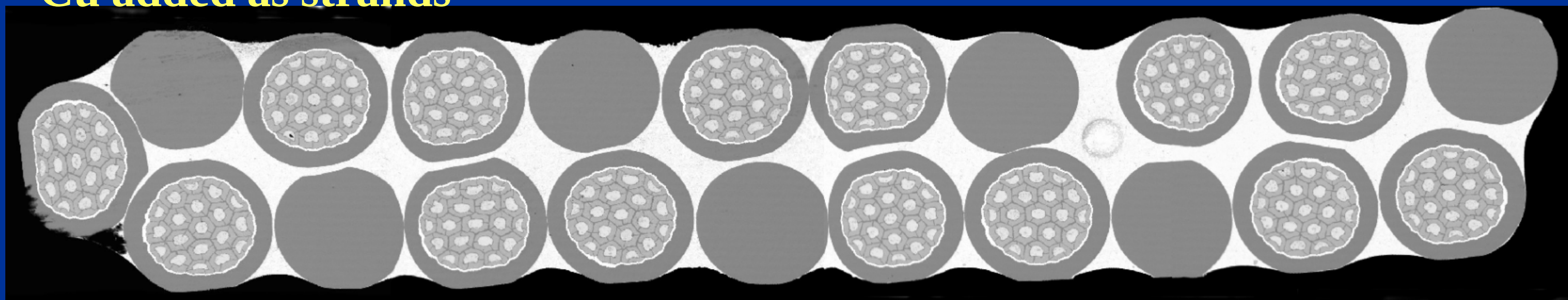




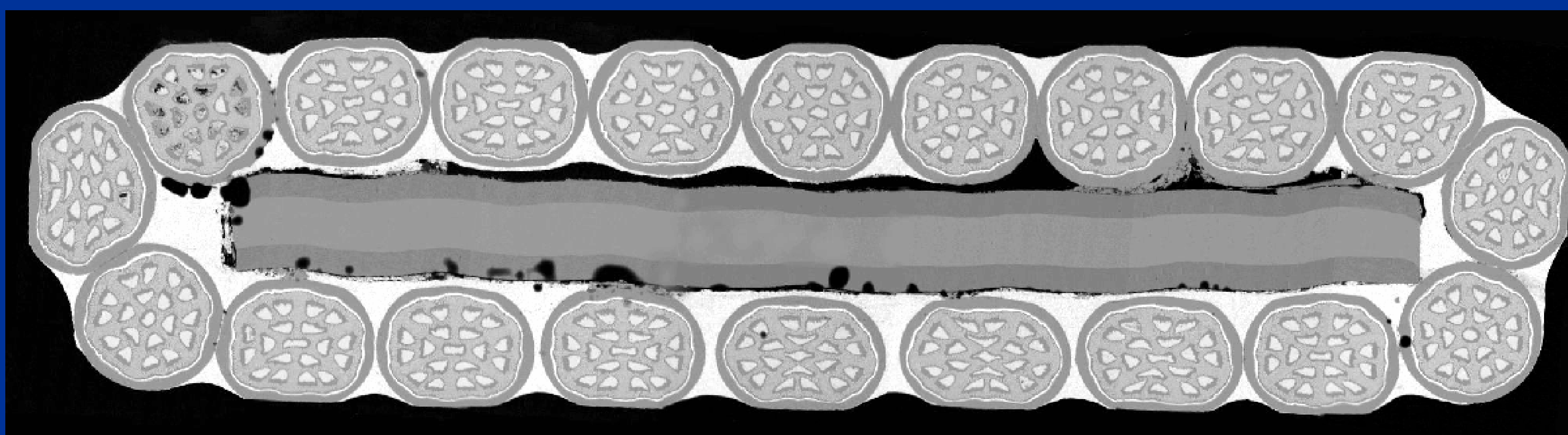


Cu added at cabling stage

Cu added as strands



Cu added to core



Summary

Cabling guidelines are being developed for "difficult to cable" materials (Nb_3Sn; Bi-2212)

- nearly complete for rectangular cables
- just begun for keystoned cables

Non-standard cables have been evaluated; all are more difficult to fabricate than the standard Rutherford design

- Mixed strand cables
- Cored cables
- Two-level cables