2005 ANNUAL DOE SUPERCONDUCTIVITY PEER REVIEW

Transition of LANL Technology to SuperPower

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LANL-SUPERPOWER CRADA STRATEGIC RESEARCH SESSION

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SuperPower was formed in 2000 with a primary mission of scaling up 2G conductor technology to manufacturing

With the formation of SuperPower, Intermagnetics made a commitment to aggressively add capital equipment, personnel, and collaboration to scale up 2G conductor.

In 2000, LANL was the first entity in the world that reached 100 A-m milestone in meter lengths of 2G conductor.

A 3-year CRADA with LANL was established in 2000 for transitioning IBAD-PLD technologies to manufacturing. SuperPower was internally developing MOCVD as a future alternative to PLD.

Year	*Publicly-announced Milestones in 2000*
2001	Continuous fabrication of short lengths of 2nd gen HTS.
2002	Demonstrate 2G with performance better than 100 A-m in > 1 m lengths
2003	Demonstrate performance > 1000 A-m in > 10 m lengths
2004	Demonstrate performance > 10,000 A-m in > 100 m lengths

IBAD was chosen because of its superiority over competing technologies

Virtually any substrate could be used

- High-strength substrates
- Non magnetic substrates
- Low cost, off-the shelf substrates (Inconel, Hastelloy, Stainless Steel)
- Very thin substrates
- Resistive substrates – for low a.c. losses
- Easy to handle – less possibility of defects

Small grain size – sub micron range

- No issues with percolation
- Can pattern conductor to very narrow filaments for low ac loss conductor

MOCVD provides advantages of high throughput & single-piece lengths

For a low-cost conductor, high throughput is a major requirement.

Throughput =

Deposition Rate × Deposition zone length × Deposition zone width

Single-piece length =

Deposition Rate × Deposition zone length

Pilot MOCVD

Only MOCVD offers the advantage of high deposition rates (150 Angstroms/s) as well as long and wide deposition zone

 # Hours to produce 1 km of coated conductor

1 micron thick HTS	Deposition Zone	
Deposition Rate	1 m	10 m
150 Angstroms/s	18	2
1 Angstrom/s	2,778	278
10 Angstrom/s	278	28

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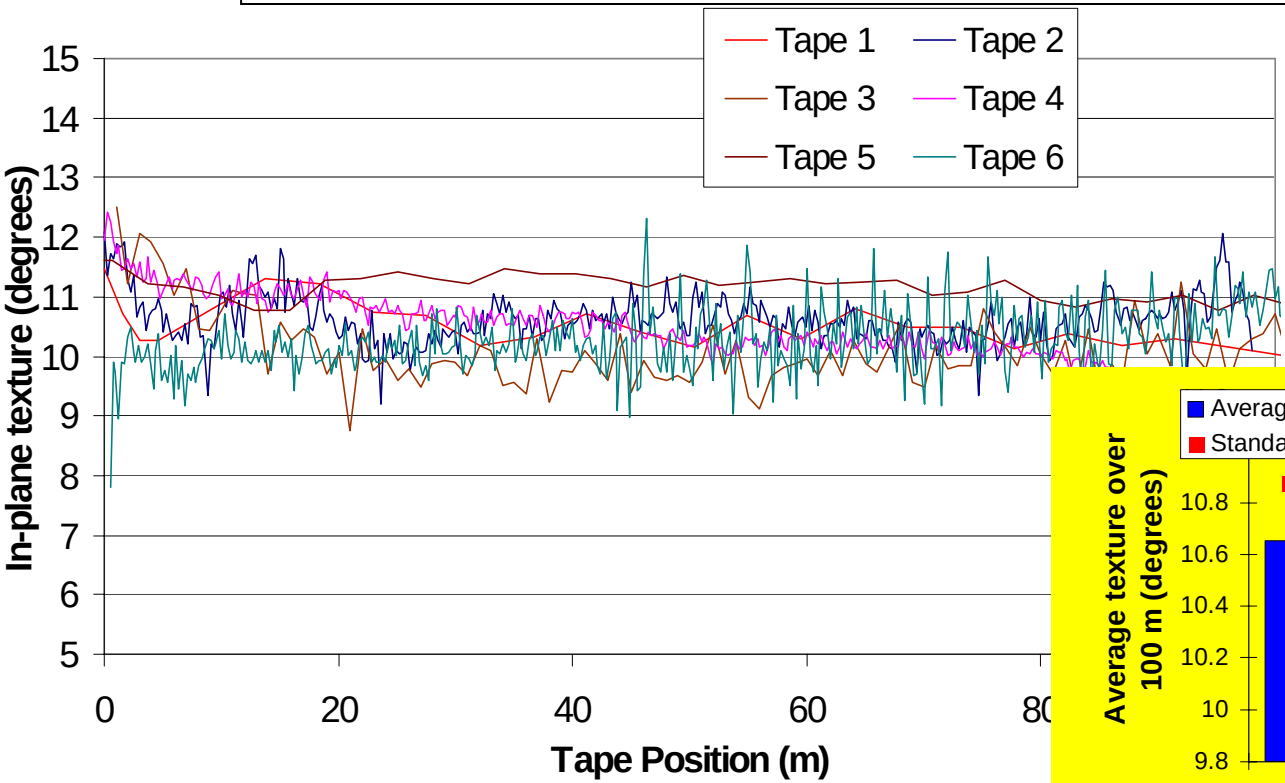
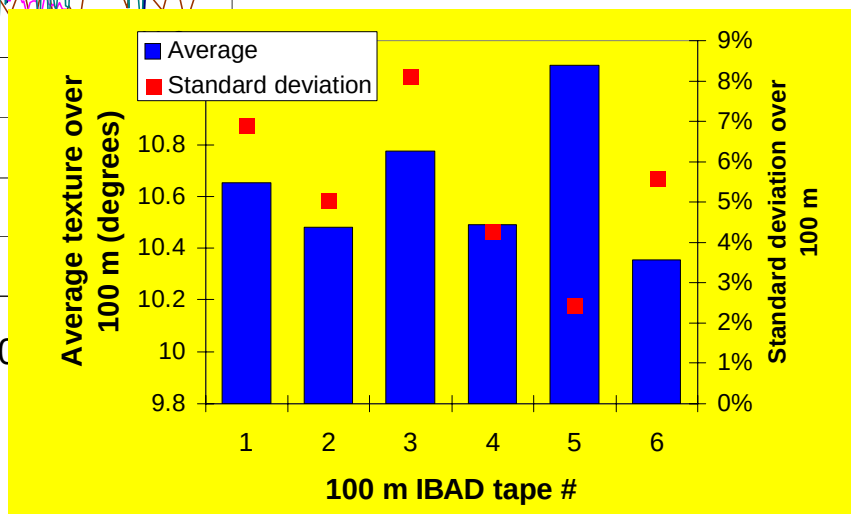
Steady progress since 2001, IBAD YSZ process transitioned from LANL to full-fledged Pilot manufacturing

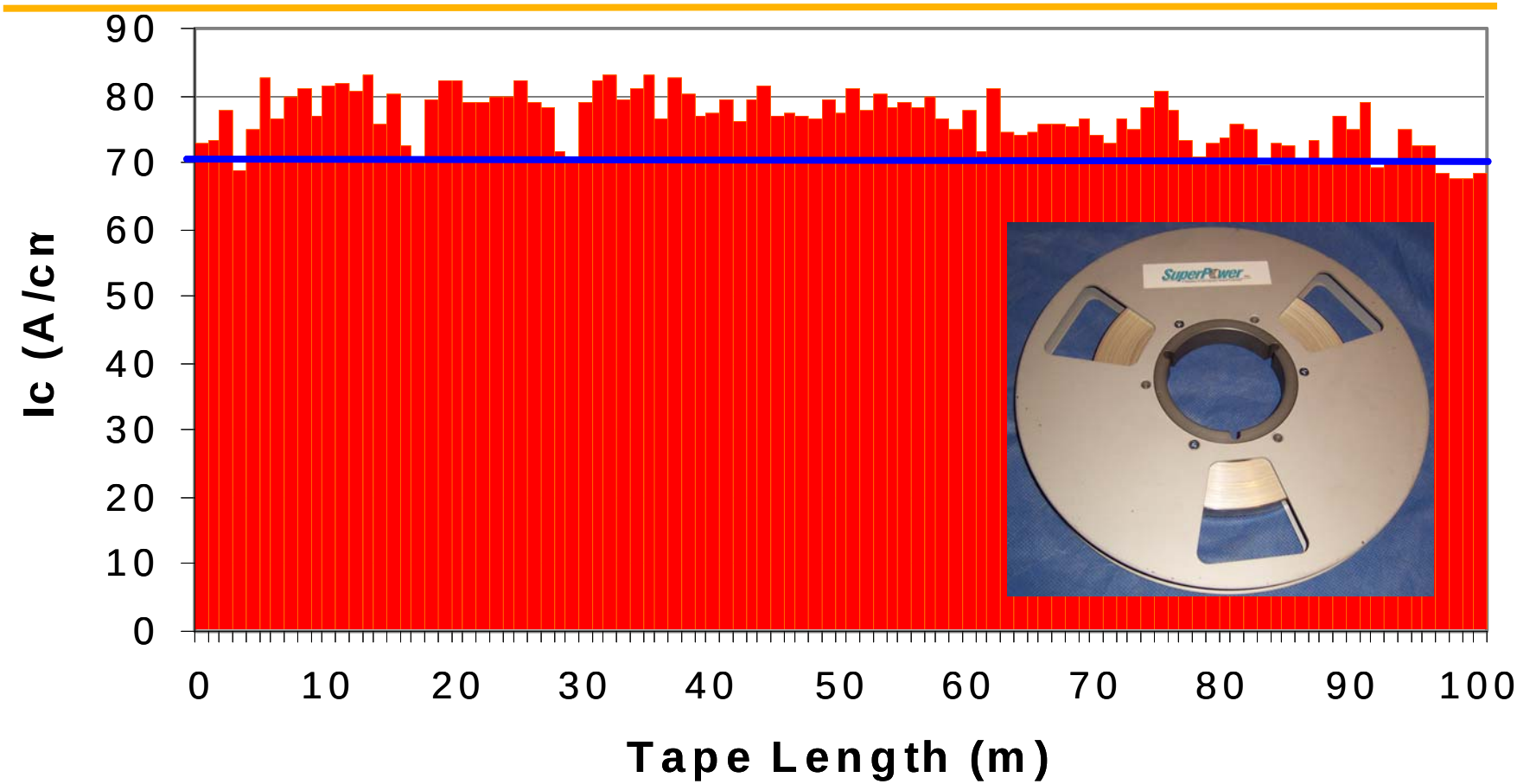
Over 25, 100 m IBAD tapes produced with same process





IBAD YSZ process has been produced in 100+ m lengths routinely with excellent texture uniformity and reproducibility

At the 2004 Peer Review, we announced our 1st 100 m conductor using IBAD YSZ & PLD



End-to-end Ic : 70 A/cm over 100 m

Ic range : 68 A to 83 A

Standard deviation = 5.2%

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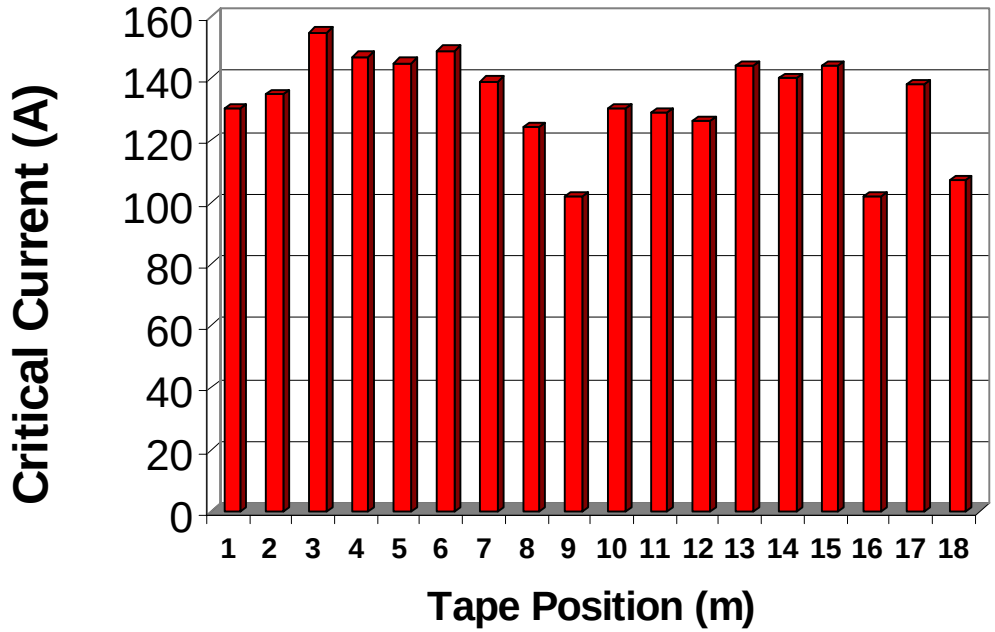
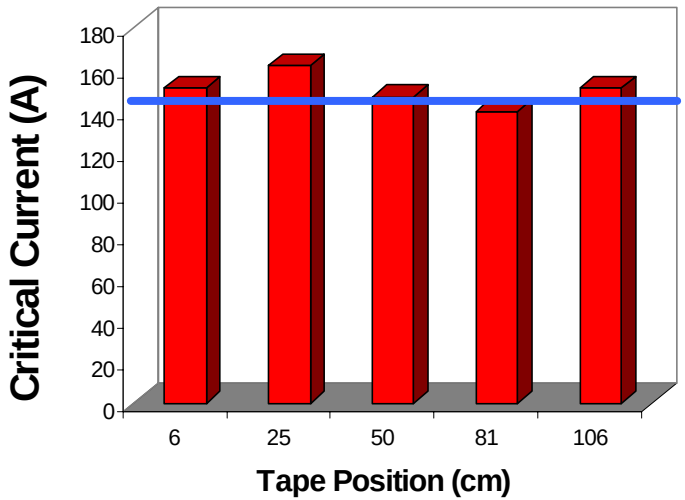
In parallel, MOCVD was being developed using a robust IBAD YSZ template

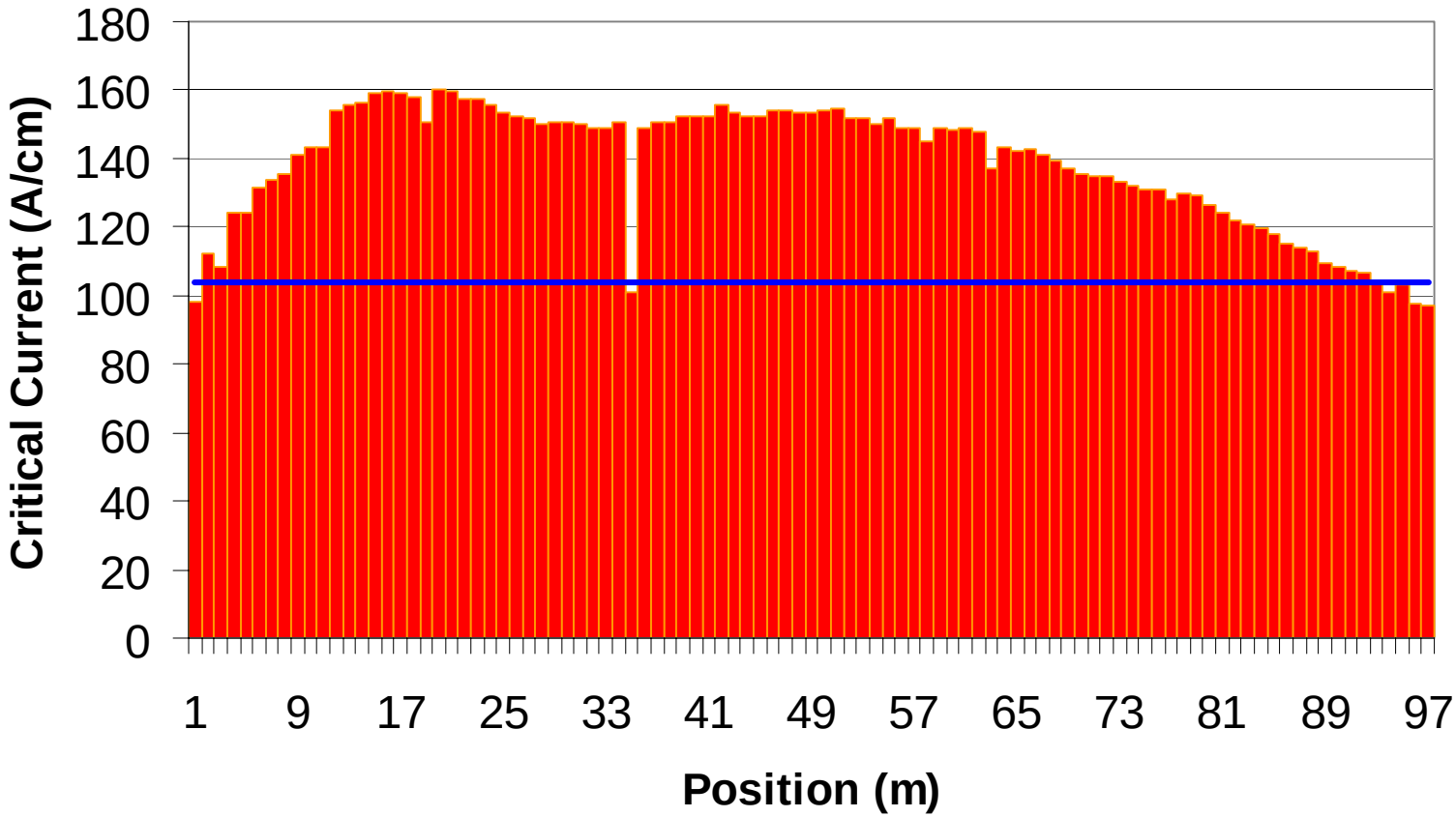
In 2002, 147 A/cm over 1 m by MOCVD





In 2003, 117A/cm over 18 m by MOCVD

At the 2005 Wire Workshop, we announced a 10,000 A-m milestone achievement with MOCVD



103.7 A/cm over 97 m = 10,050 A-m

5% uniformity over mid 50 m

2% uniformity over mid 50 m except for 1 m segment

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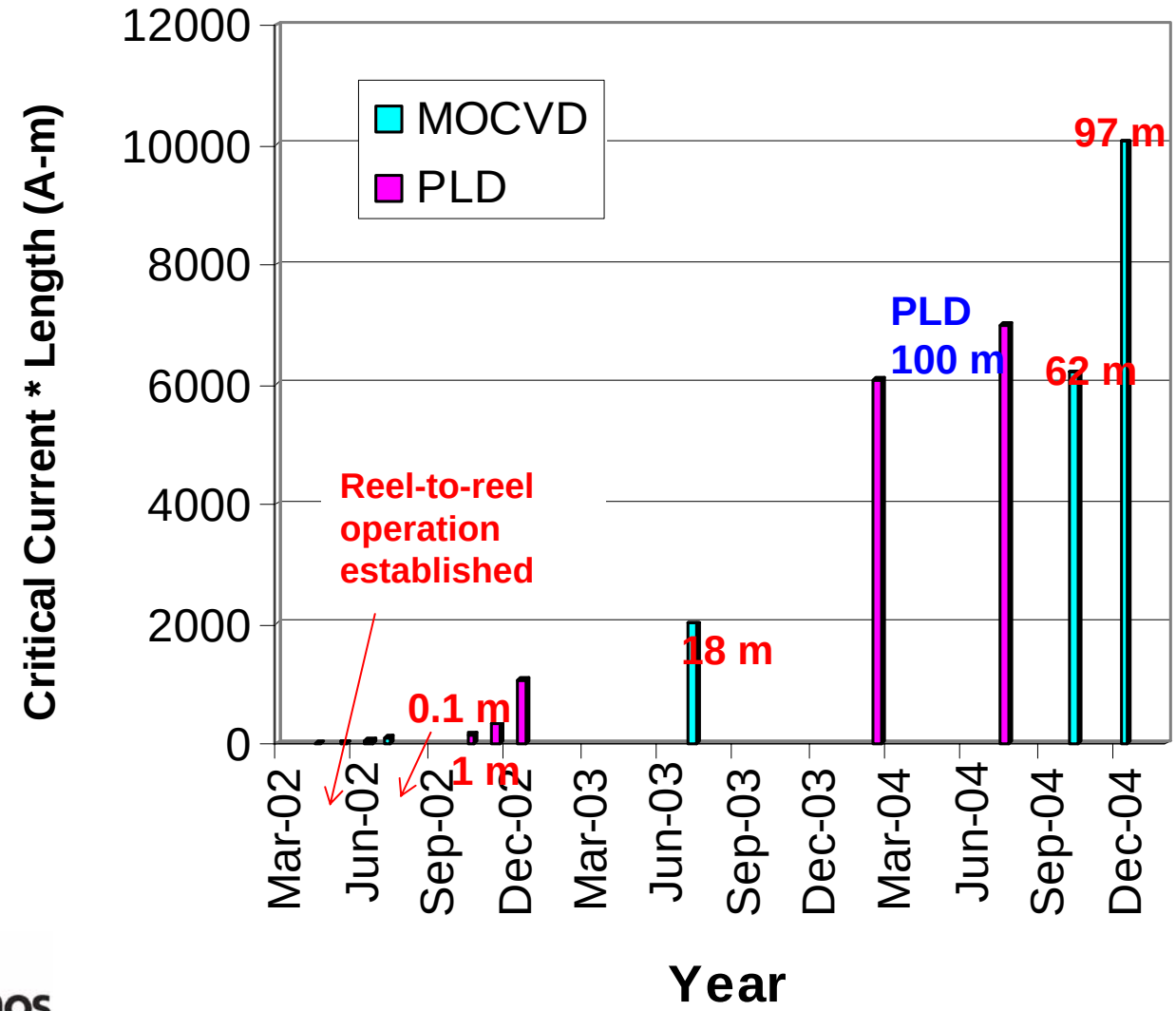
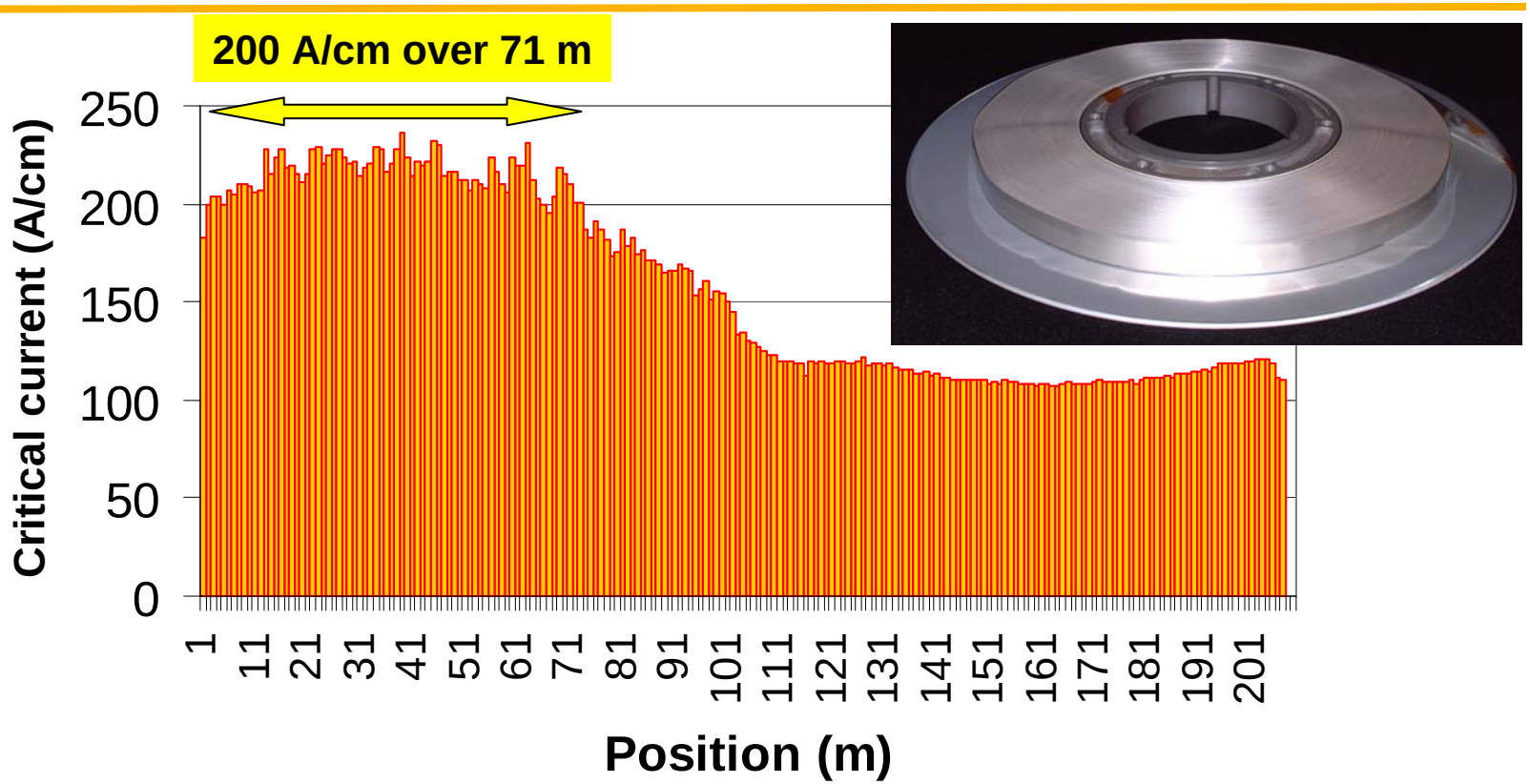
10,000 A-m milestone achieved in 3 years of operation after reel-to-reel installation



Performance milestones for 2G coated conductor met or exceeded

Year	*Milestones*	*Accomplishment*
2001	Continuous Production of short lengths of 2nd gen HTS.	Demonstrated
2002	Demonstrate 2G with rated performance better than 100 A-m in > 1 m lengths	315 A-m achieved
2003	Demonstrate performance > 1000 A-m in > 10 m lengths	~ 2000 A-m achieved
2004	Demonstrate performance > 10,000 A-m in > 100 m lengths	10,050 A-m achieved

And now: First 200 m long 2G conductor



Minimum Ic of 106.7 A/cm over 206.7 m (22,030 A-m)
(End-to-end Ic expected to be slightly higher)

71 m with Ic of 200 A/cm with standard deviation of 4.3%

Standard deviation of 4.3% over the last 100 m

SuperPower's strategy for manufacturing scale-up of IBAD technology

Pilot IBAD facility

Prototype IBAD facility

Scale up mature YSZ process to 100+ m lengths in Pilot IBAD facility: 01 – 04

- Establish long-term reliability, uniformity & stability of ion sources
- Develop on-line process controls
- Develop helix-tape handling system for high throughput & long single-pieces
- Use a reliable template for MOCVD process scale up

Transfer IBAD MgO technology from LANL in Prototype IBAD facility & scale-up to 100 m using lessons from Pilot IBAD : 2004 (Follow-on 2 year CRADA with LANL)

Integrate IBAD MgO with MOCVD & then transfer MgO to Pilot IBAD : 2005

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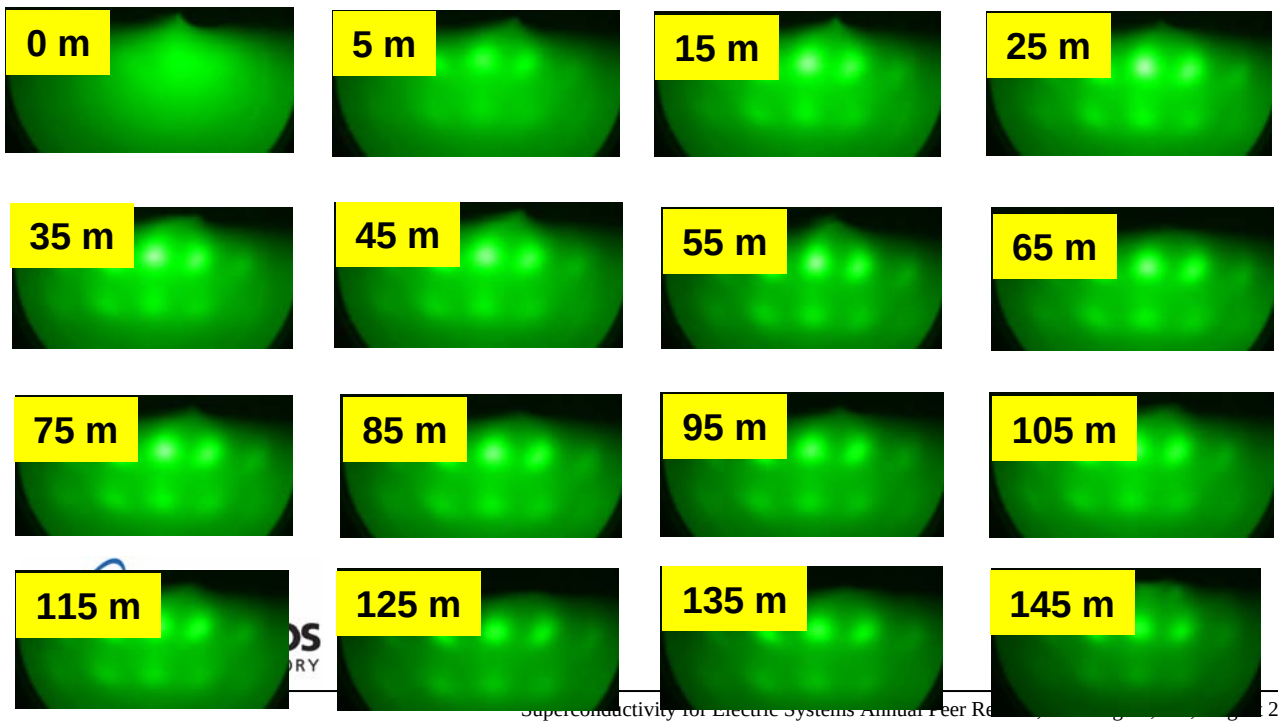
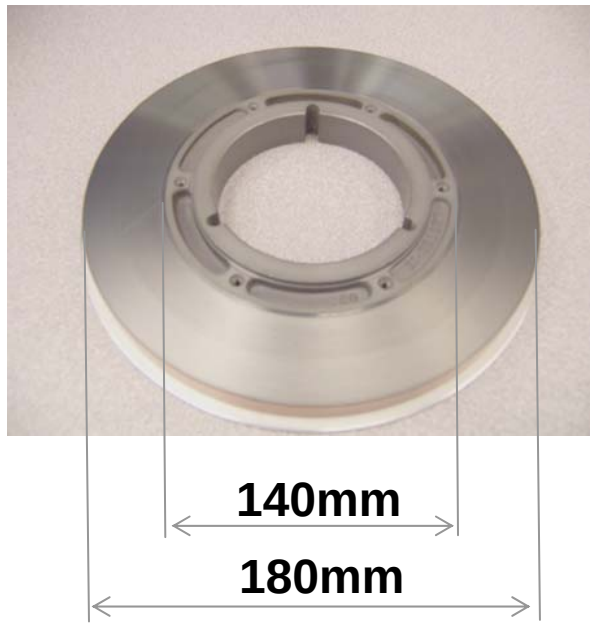
IBAD MgO is being routinely fabricated in 135 m lengths at 10 m/h even in a Prototype IBAD system

April 2004 : LANL staff transferred IBAD MgO process at SuperPower

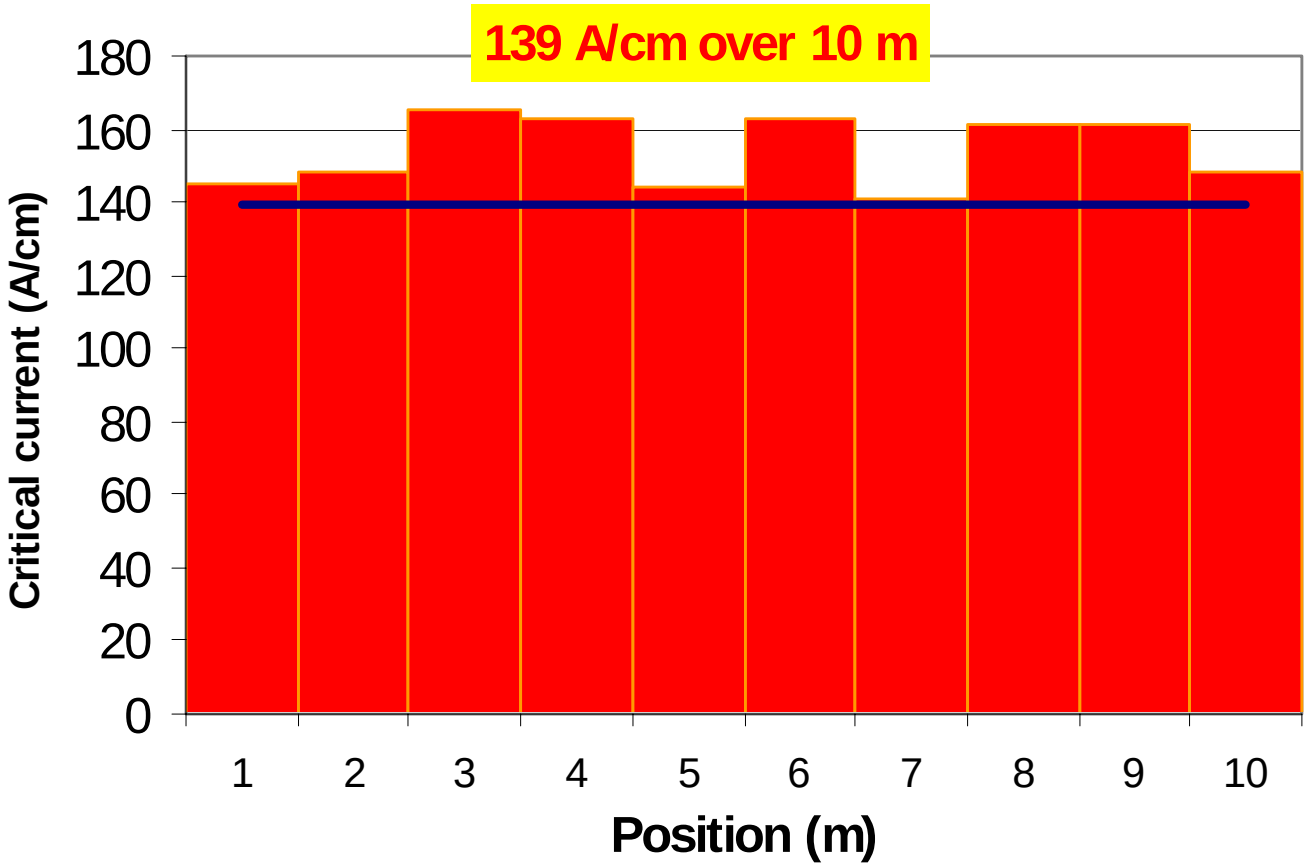
July 2004 : Uniform in-plane texture of 6-7 degrees over one 40 m IBAD MgO produced at 10 m/h throughput





June 2005: Twelve 135 m IBAD MgO tapes have been fabricated on 50 micron thick substrates at 10 m/h

MOCVD has been successfully integrated with IBAD MgO in 2005



10m length MOCVD-YBCO conductor on RF sputtered STO/reactively sputtered MgO on 50 micron substrate.

End-to-end Ic* = 139 A/cm. Standard deviation = 6%

*YBCO film thickness = 1.1 microns

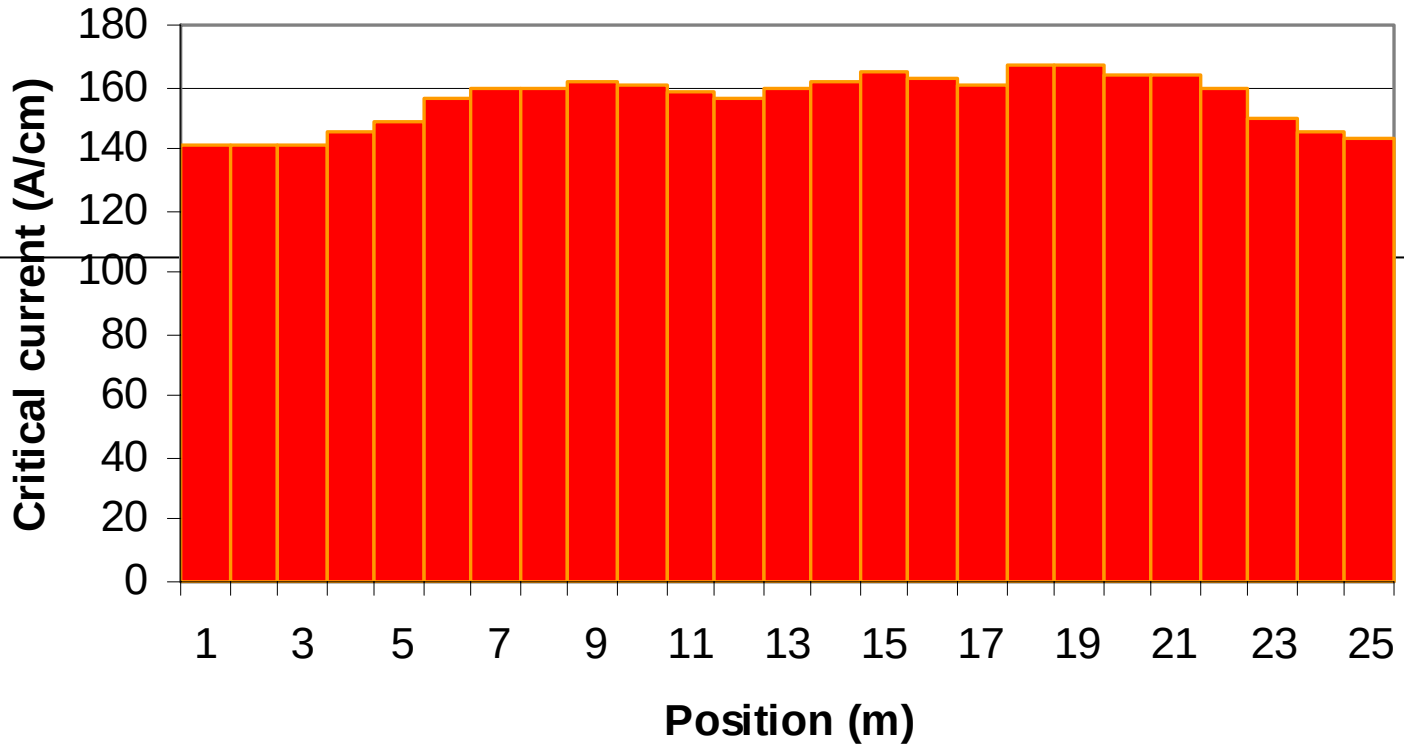
And Now: 25 m MOCVD tape demonstrated with LMO buffered IBAD MgO

IBAD MgO @ 10 m/h

RF Sputtered LMO @ 10 m/h

Reactively sputtered MgO @ 10 m/h

MOCVD @ 10 m/h × 2 passes



Ic* of 142 A/cm over 25 m MOCVD tape with all high throughput buffers

*YBCO film thickness = 1.1 microns

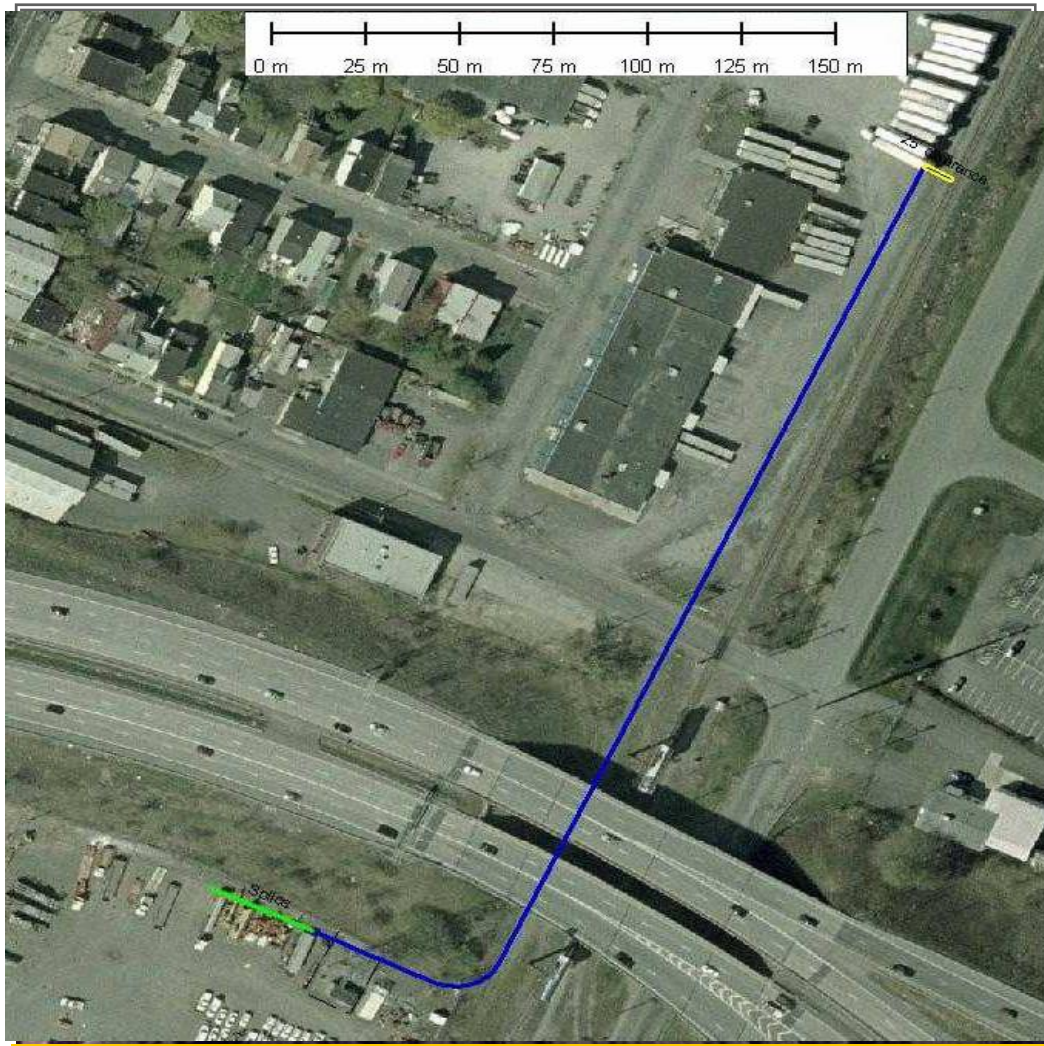
Outlook for SuperPower's 2G program

We have come a long way in the last 4 years from centimeter sized tapes to 200 m long tapes

Commercial manufacturing of 2G conductors will begin in 2006.

SuperPower will deliver ~ 10 km of 2G conductor for the Albany Cable Project by summer of 2006

Large electric power prototype devices with 2G conductors will begin appearing by late 2006



Albany Cable project : National Grid, 350 m long cable. World's first in-grid cable, first underground cable, first cable-to-cable joint. World's first 2G device (30 m)

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