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Philip J. Pellegrino

President - SuperPower, Inc.

Schenectady, NY

Progress in Scaling Up Coated Conductor Fabrication at SuperPower, Inc.

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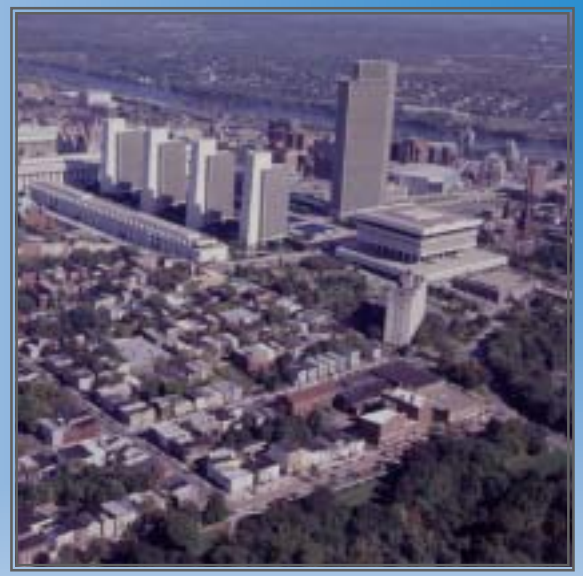
Overall Strategy of SuperPower

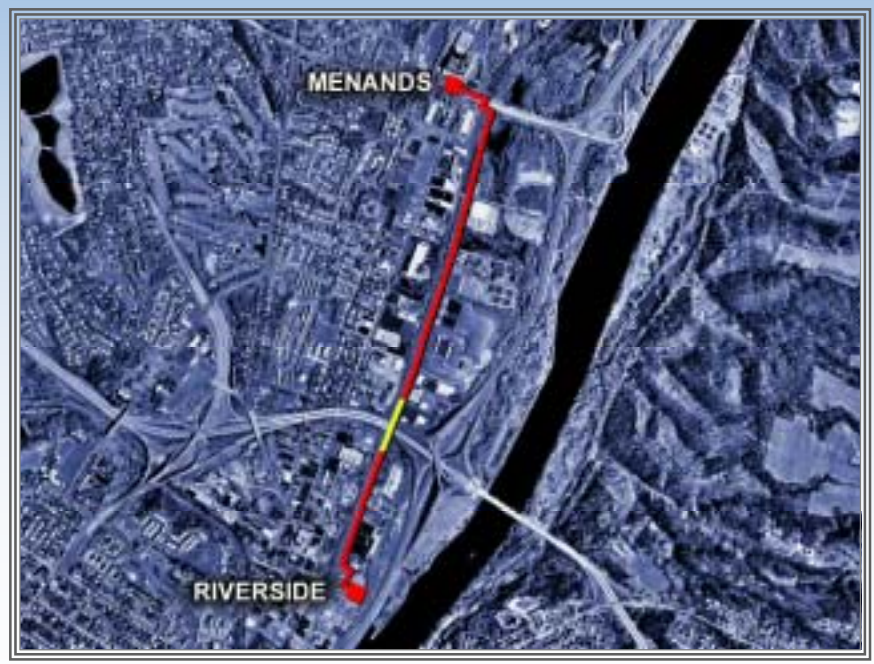
- **Devices being developed for commercialization:**
  - **FCL**
  - **Cables**
  - **Transformers**
- **Establish strategic partnerships for deployment of demonstration efforts to reduce financial, technical risk and improve likelihood of success**
- **In parallel, coated conductors are being scaled up to have them available in production volumes by mid-decade**

Albany Cable Project

(our latest Strategic Partnership)



- **SuperPower, Niagara Mohawk, Sumitomo Electric Industries**
- **34.5 kV, 1/4 mile**
- **Standard underground right-of-way**
- **Demonstrate splicing capability**
- **To include Coated Conductor section - 30 m**
- **Addresses practical utility concerns:**
  - **lightning protection**
  - **reliability**
  - **increased capacity**
  - **ease of servicing**



Conductor Objectives & Approaches

- **Objective: Scale up Coated Conductor processes to produce tape in piece-lengths greater than 1 km with performance greater than 100,000 A-m by mid-decade**
- **Current Approaches: IBAD-PLD & IBAD-MOCVD**
- **Other techniques also being examined**
- **Emphasis is on establishing**
  - **equipment suitable for long production runs,**
  - **continuous reel-to-reel on-line & off-line QC**
  - **developing robust manufacturing process**
  - **high throughput, low CapEx**

How long would it take to produce 1 km?

- **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**

Process	*Deposition Rate for Jc > 1 MA/cm^2 (Angstroms/second)*
PLD	650
MOCVD	150
E-beam BaF_2	1
MOD	1

For 1 m deposition zone length and 1 micron HTS, time to produce 1 km:

~ 18 hours at 150 Angstroms/s

~ 4 months at 1 Angstrom/s !

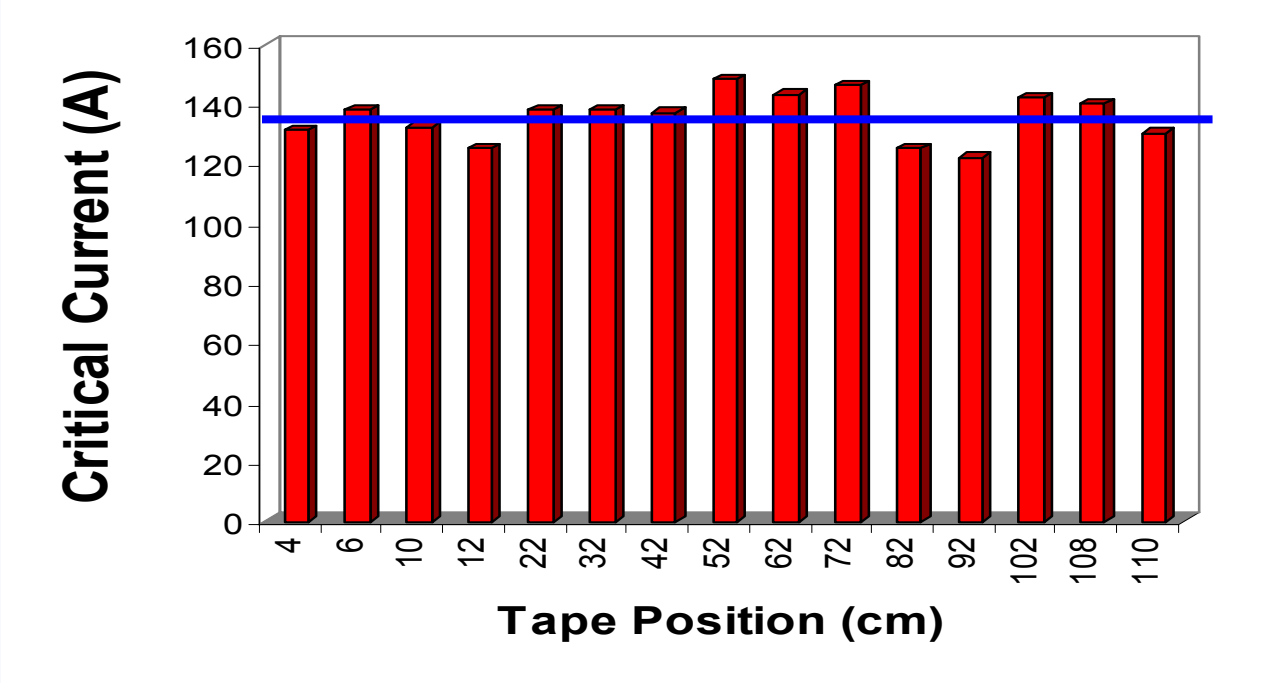
PLD scale-up focused using Industrial Laser

- **PLD has been used by several groups to demonstrate high performance coated conductors in lengths of 1 - 50 m**
- **Our objective is to demonstrate long-length conductors in reel-to-reel mode by PLD using Industrial Laser (important to achieve high throughput)**

At 300 Hz, 670 mJ/pulse, 1 m tape < 10 min.

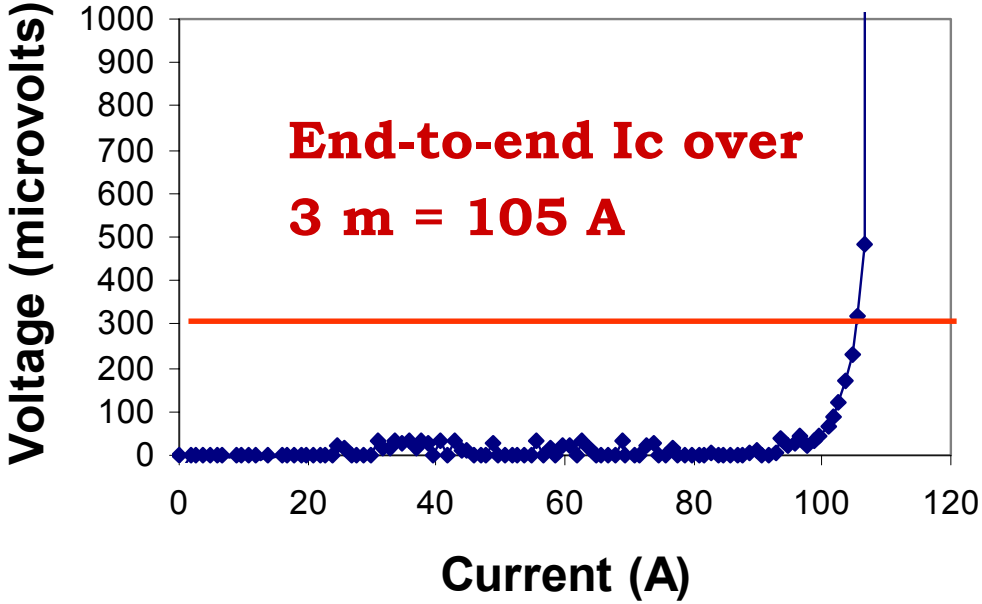
Progress in high-amperage, meter-long conductor by PLD

- **At the DOE Peer Review in July 2002, we reported 43 A over 1 m by PLD**



In Oct. 2002, end-to-end Ic = 135 A over 1.1 m

100 A-class performance with Industrial Laser scaled to 3 m



Performance of tape produced with 308 nm, high repetition rate industrial laser similar to performance of tape produced by others using 248 nm research lasers

Only MOCVD offers advantage of BOTH high deposition rate & large deposition area

Process	*Deposition Rate*	*Deposition Area*
PLD	High	Small
MOD	Low	Large
E-beam BaF_2	Low	Large
MOCVD	**High**	**Large**

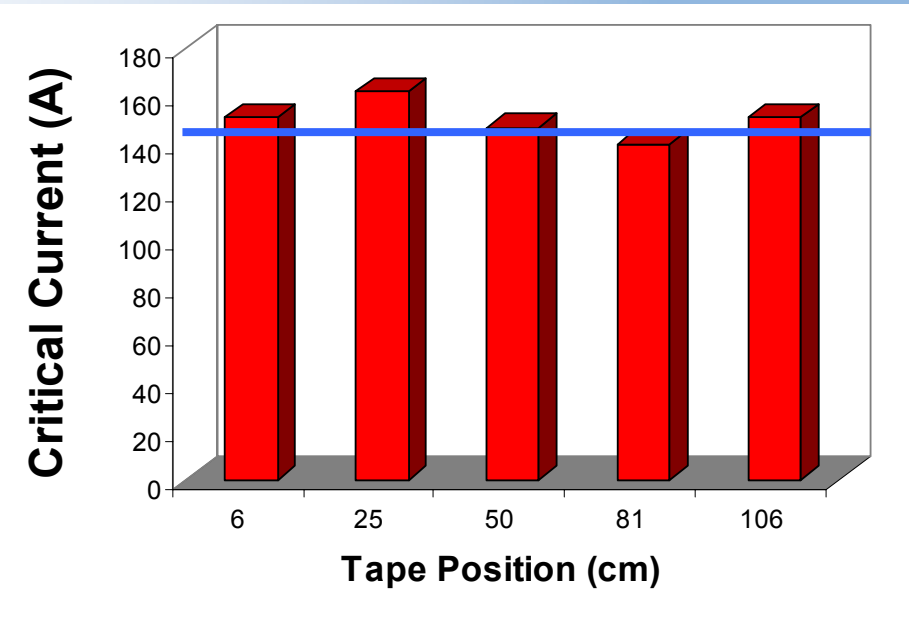
Throughput = Deposition Rate x Deposition Area

***Unlimited* Deposition Area with MOCVD:**

As long & as wide as showerhead

Progress in high-amperage, meter-long conductor by MOCVD

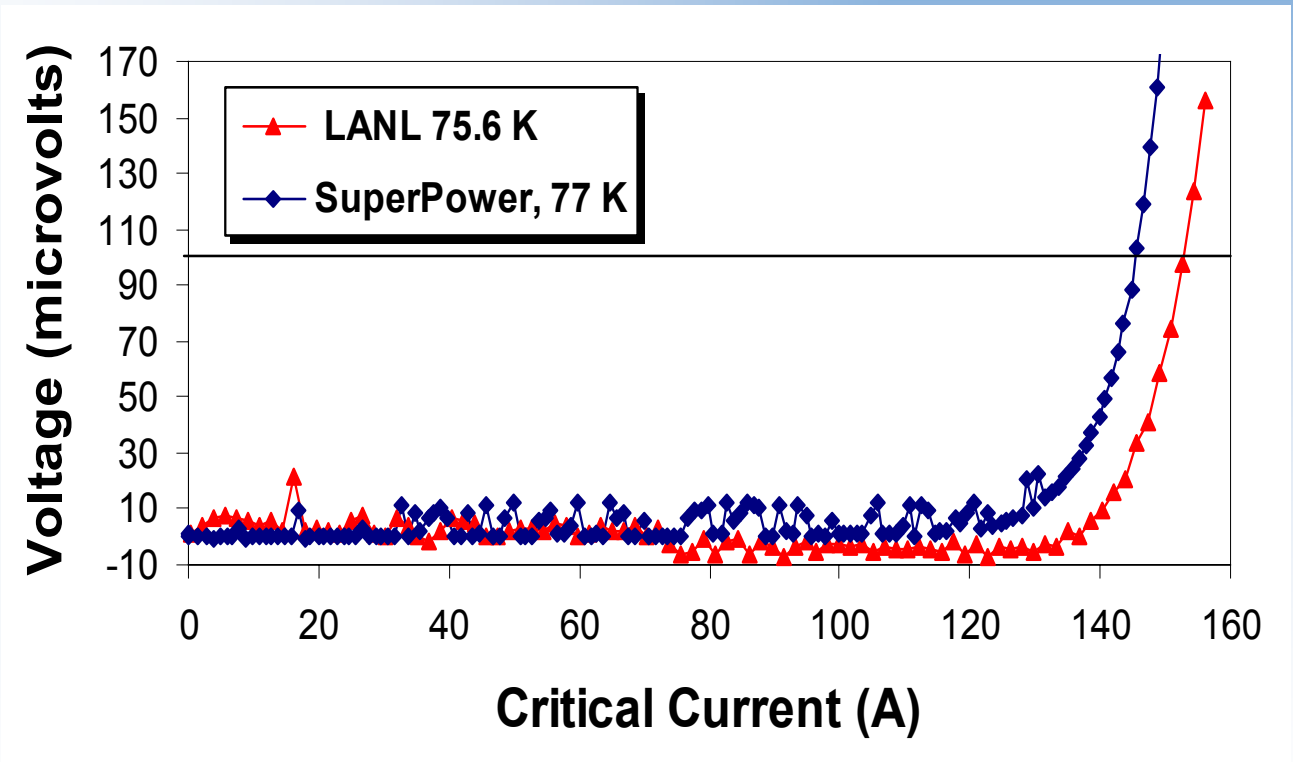
- **At the DOE Peer Review in July 2002, we reported 90 A over 1 m by MOCVD**



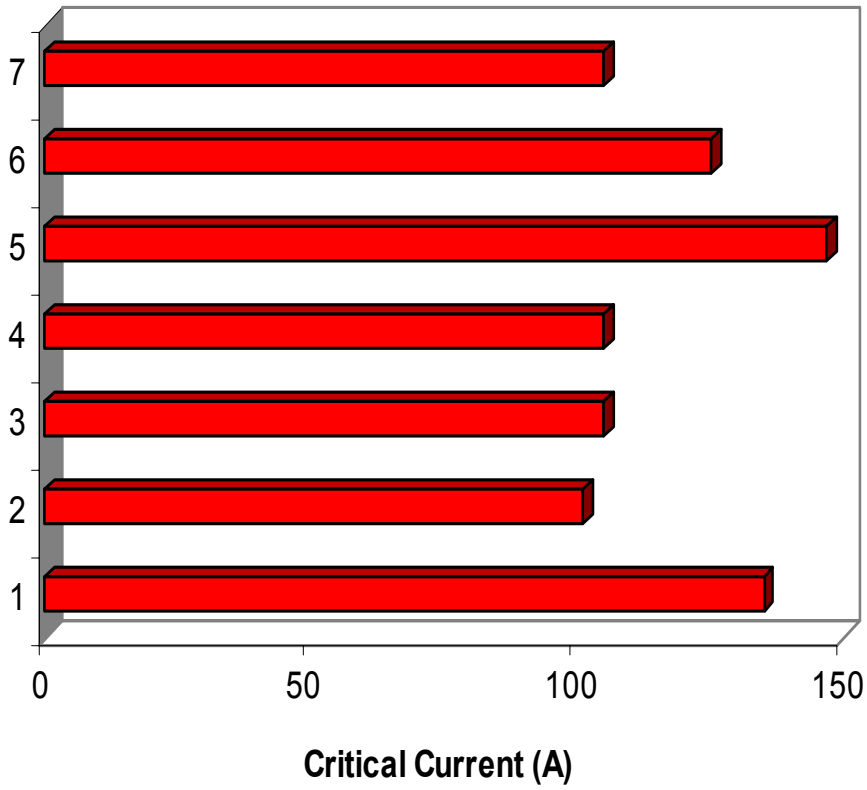
In Oct. 2002, 147 A over 1.06 m

Performance of 1.23 m long 147 A tape verified at LANL

- **1.23 m section re-measured at SuperPower. Ic =** 147 A **at 77 K**
- **Same 1.23 m section measured at LANL. Ic =** 153 A **at 75.6 K**



100 A Class, Meter-long Coated Conductor tapes are routinely produced with both high deposition rate processes, PLD & MOCVD



MOCVD: 105 A over **2.8 m**

MOCVD: 125 A over 1.1 m

MOCVD: **147 A** over 1 m

PLD: 105 A over **3.0 m**

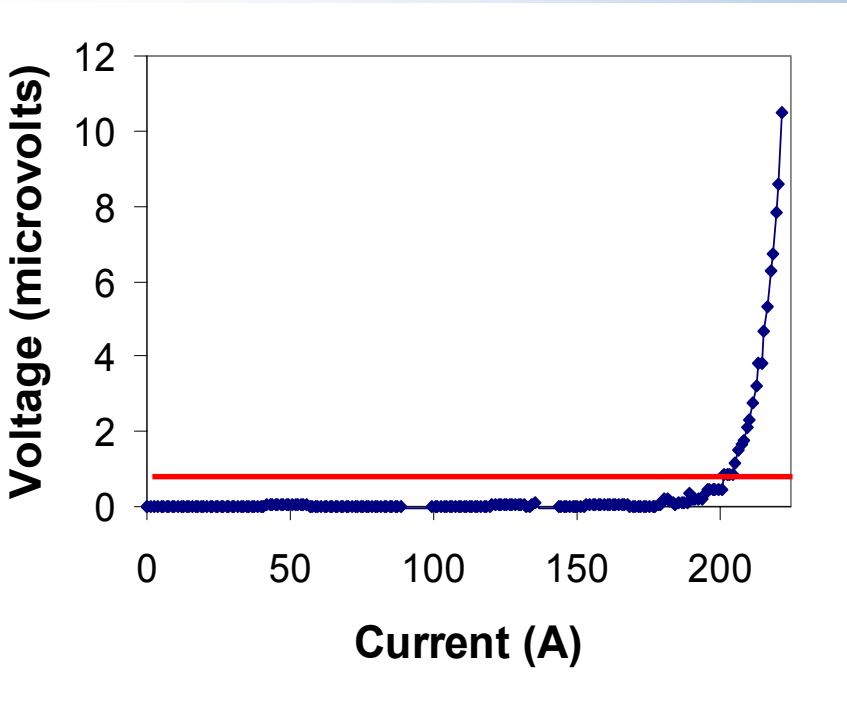
PLD: 105 A over 1.0 m

PLD: 101 A over 1.24 m

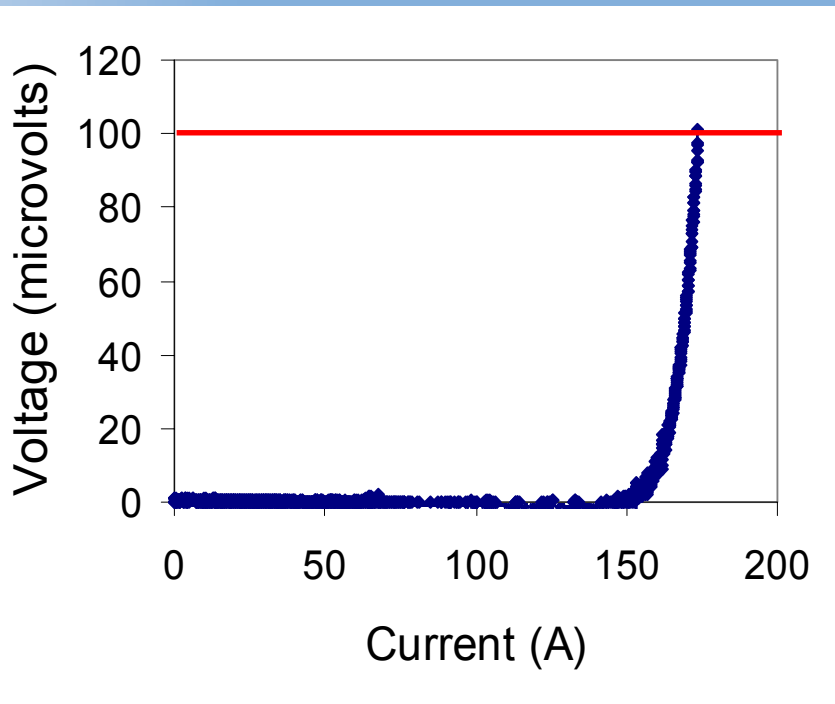
PLD: 135 A over 1.1 m

Higher currents achieved by MOCVD beyond routine 100 A

205 A over 1 cm



173 A over 1 m



Samples measured from longer piece lengths

Process Reliability testing with MOCVD

Short process cycle times not only desired for a low-cost conductor, but also to increase the process reliability

First Pass: Deposit first *half* thickness of HTS layer

↓

Second Pass: Deposit second *half* thickness of HTS layer

↓

120A over 1-meter

No Jc degradation even when process cycle time is reduced to 1/2

Shutdown the system during run (*on purpose*)

↓

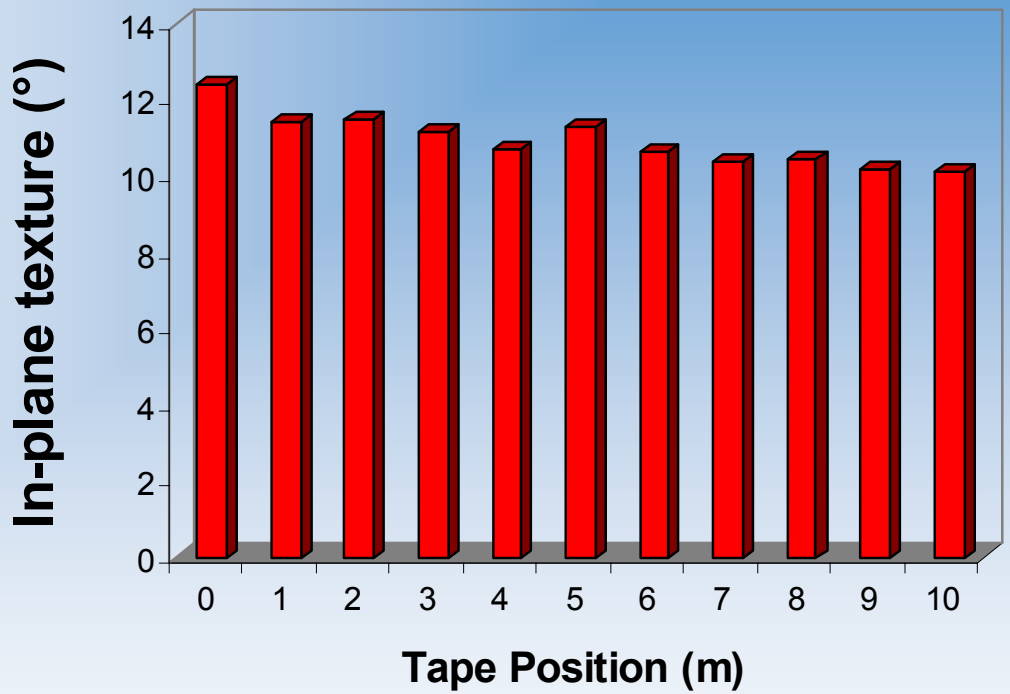
Restart system & continue run

↓

114A over 15cm

High Jc even if run is drastically interrupted!

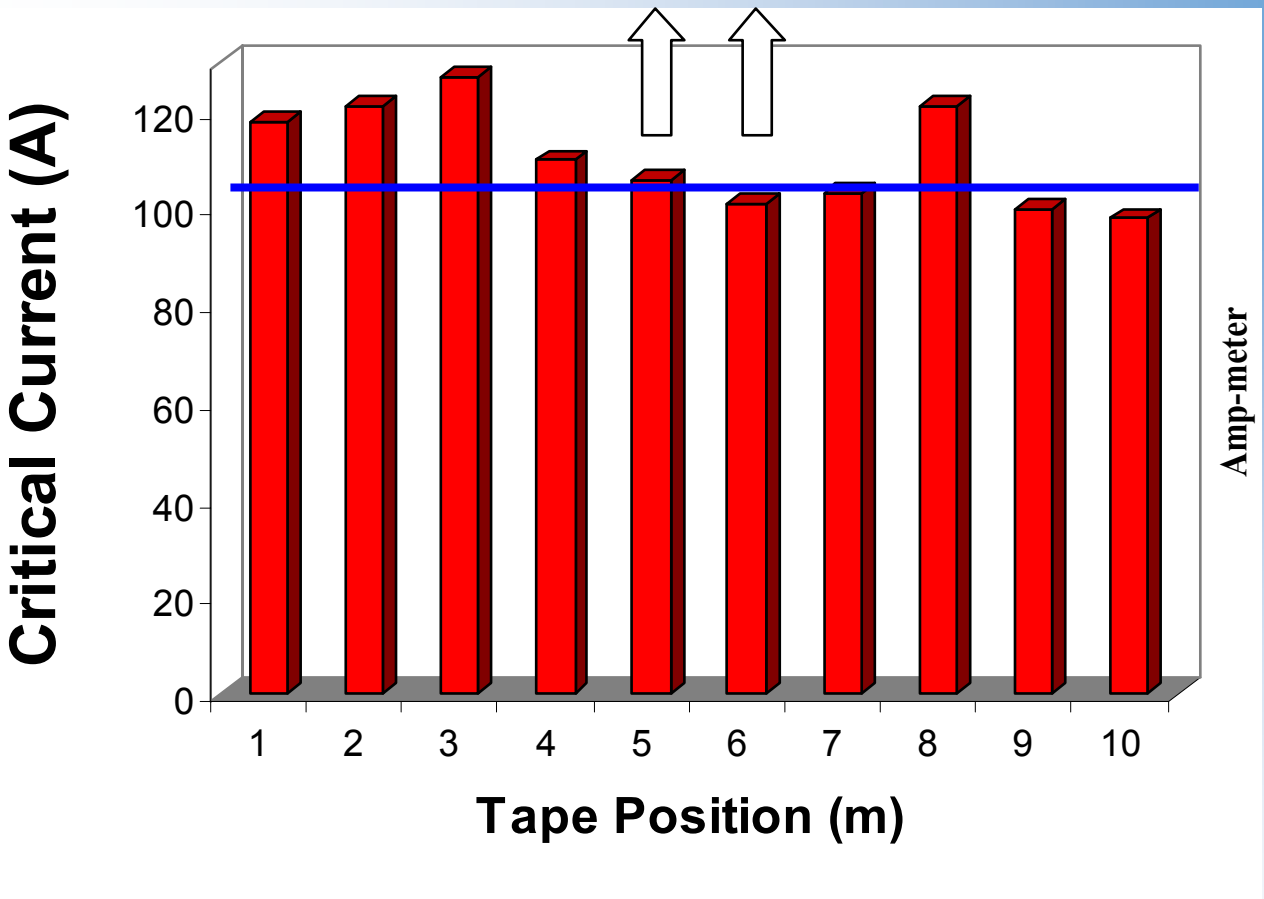
Uniform, well-textured 10 m IBAD tapes produced

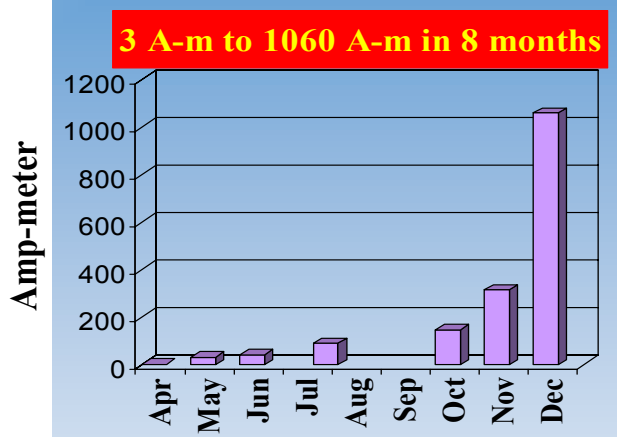


Average in-plane texture over 10 m = 10.9°

Standard deviation = 0.7°

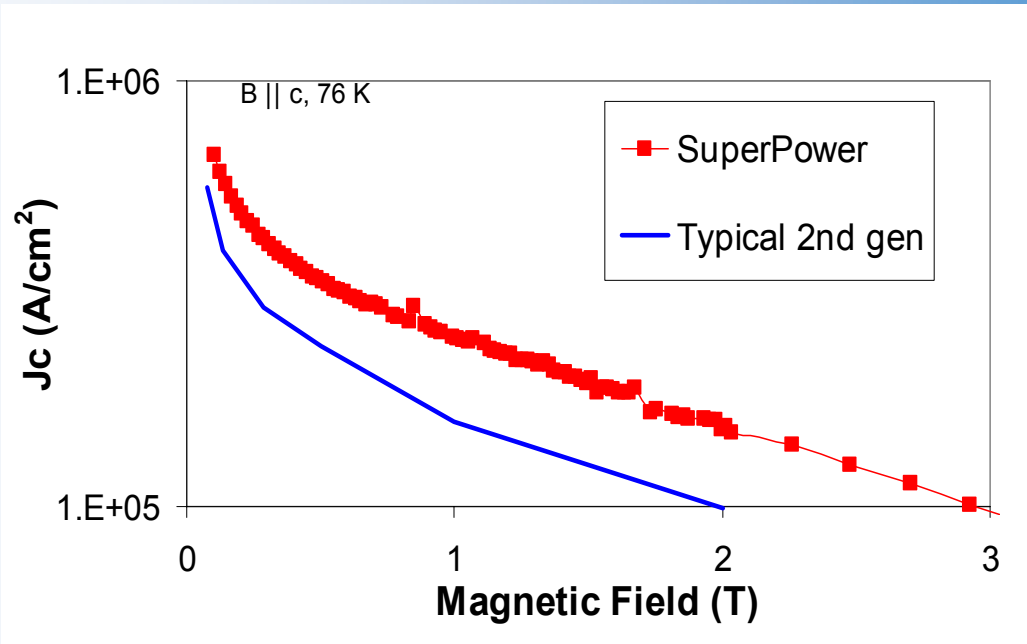
10 m Coated Conductor demonstrated





In Dec. 2002, 106 A over 10 m

SuperPower tapes retain 2 times higher Jc in magnetic fields



SuperPower tape measured at LANL

36% retained at 0.5 T; compares with a typically reported value of 20%

27% retained at 1 T, compares with a typically reported value of 10-15%

A 100 A SuperPower tape is equivalent to a 200 A typical 2nd gen. tape!