

## **Quality Control Initiatives in Manufacturing Scale-up of Coated Conductors at SuperPower**

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- ▶ J. Reeves, Y. Chen, X. Xiong, Y. Li, Y. Xie, P. Hou, Y. Qiao, M. Gardner, T. Salagaj, K. Lenseth, G. Schwab, L. Hope, M. Jones, A. Rar, V. Selvamanickam

### *HTS Solutions for a New Dimension in Power*

18<sup>th</sup> International Symposium on Superconductivity 2005 - ISS 2005 – Tsukuba, Japan

October 24-26, 2005

## **Outline**

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- **Characterization of Ic non uniformity in long MOCVD tapes**
- **Development of new quality control tools**
  - Automated optical tape inspection tool
  - Ex-situ XRD measurements
  - In-situ Raman spectroscopy
  - Off-line non contact critical current profiles
- **Manufacturing of 100m+ coated conductor**
  - Performance
  - QA/QC procedures

## Characterization of $I_c$ non-uniformity in long MOCVD tapes

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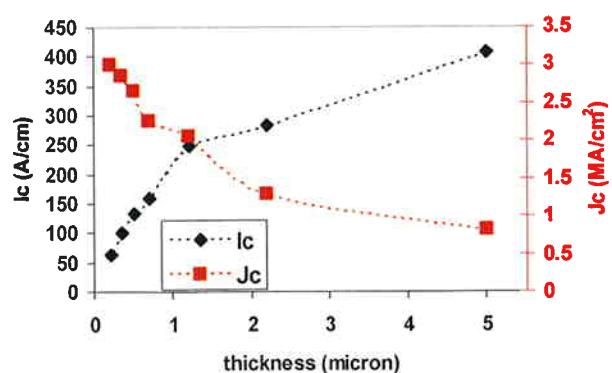
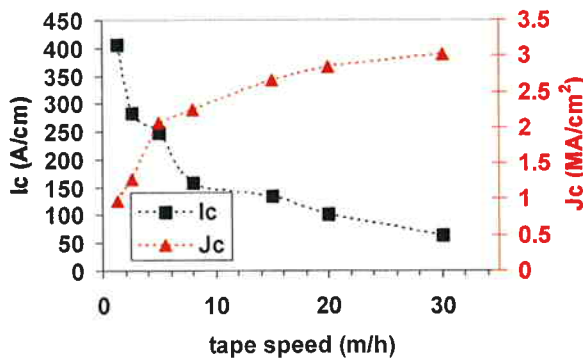
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## MOCVD was chosen for its advantages of high throughput & high linear tape speed



High deposition rates (120 Å/s) in MOCVD enable very high linear tape speeds



Even at a high linear tape speed of **20 m/h** in our Research MOCVD system with a deposition zone of 20 cm, we achieved

**$I_c$ : 100 A/cm**       **$J_c \sim 2.8$  MA/cm<sup>2</sup>**

# Pilot MOCVD system was installed for high throughput manufacturing of 100+ m tapes

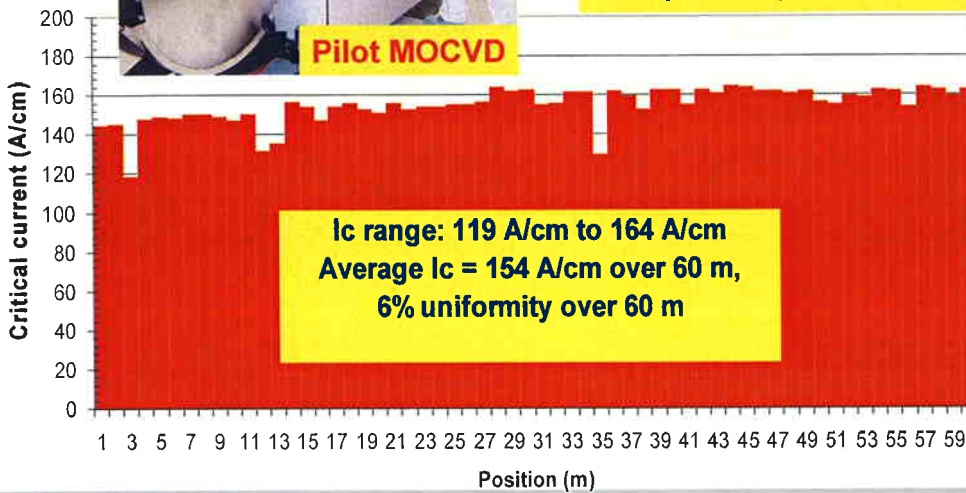
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Spool boxes fit 2 km single piece lengths

Up to 1 m long deposition zone

7 cm wide deposition zone (for multiple wraps in a helix)

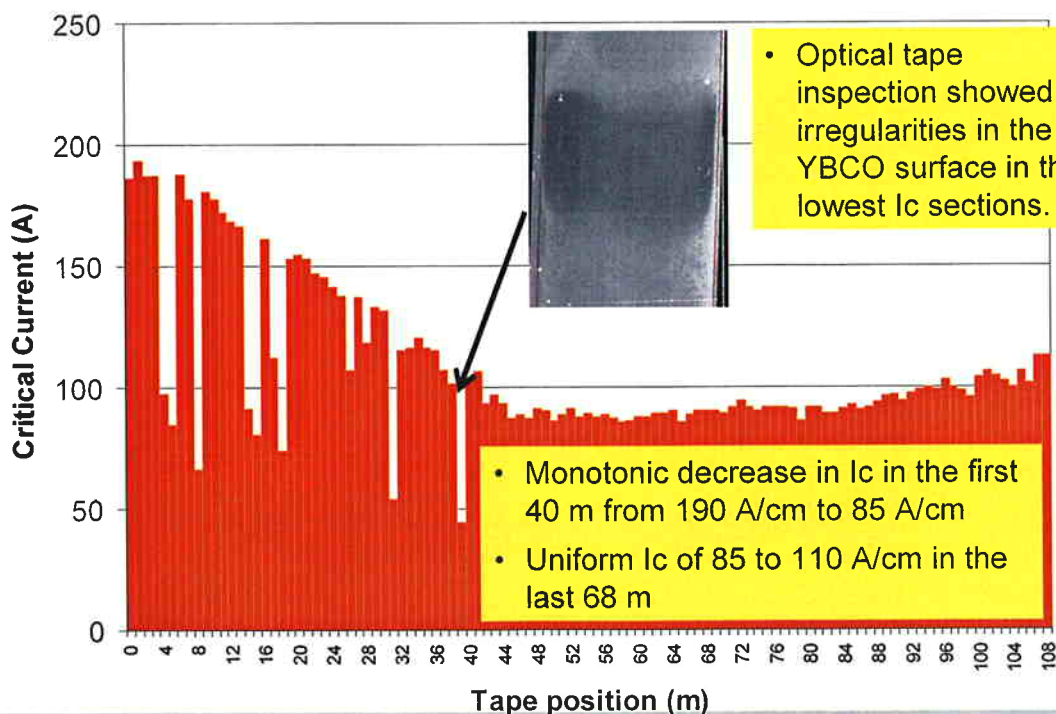


ISS 2005

-4-

# An early 100 m tape in Pilot MOCVD showed variability in performance

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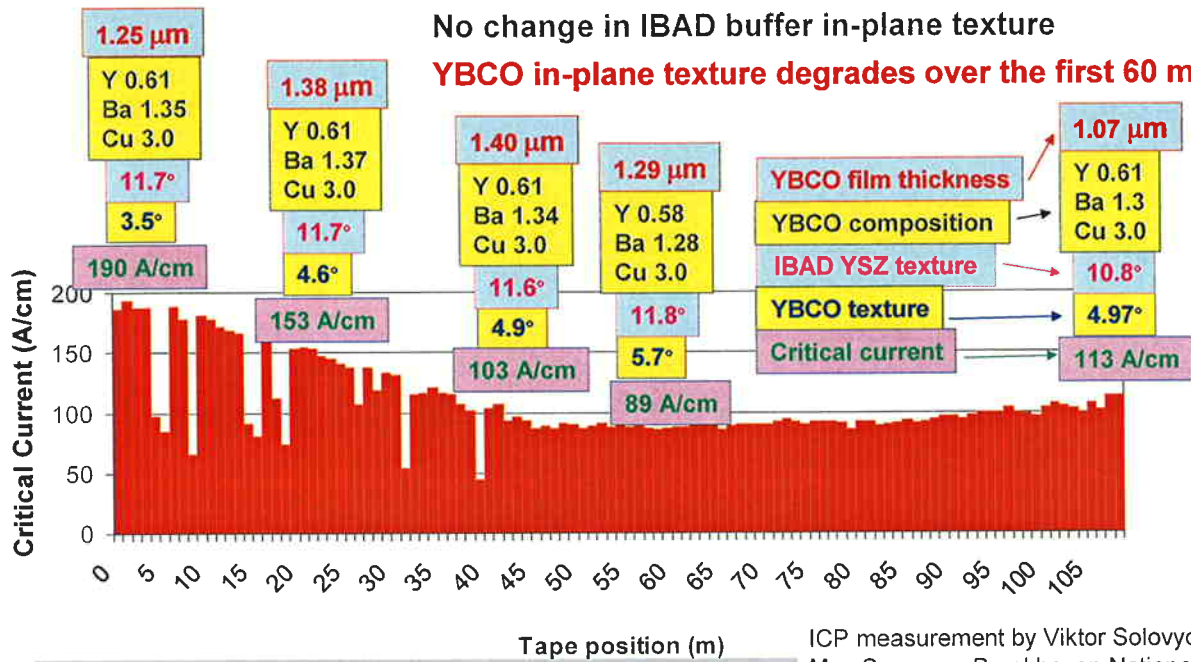
ISS 2005

-5-

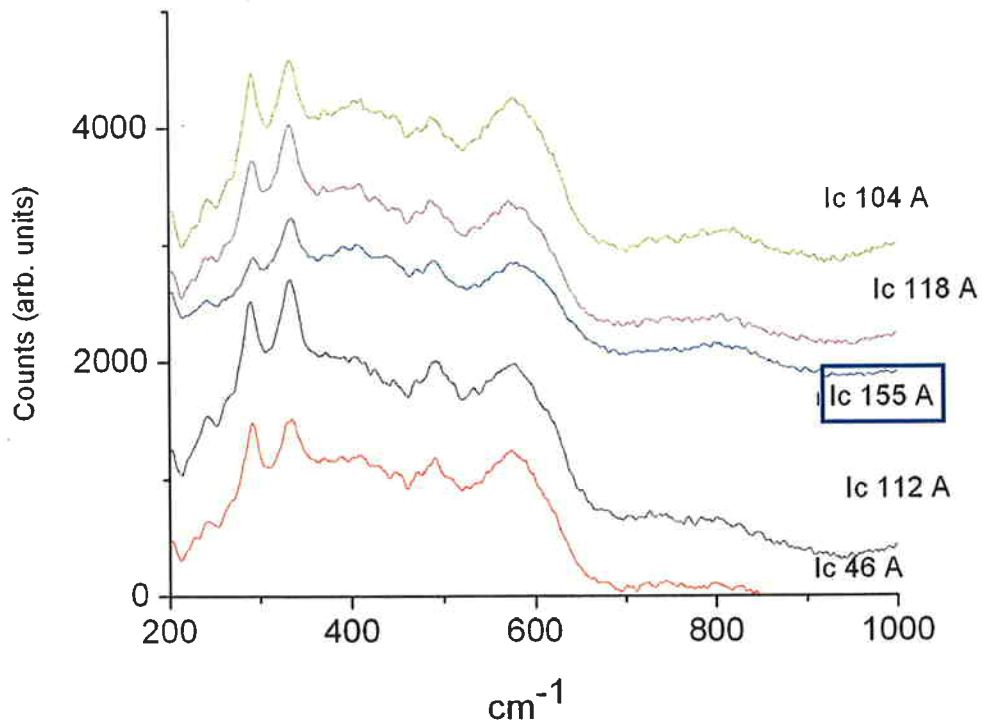
A microstructural correlation to the  $I_c$  profile over 108 m was identified.

No change in YBCO film thickness  
 No change in YBCO film composition  
 No change in IBAD buffer in-plane texture

**YBCO in-plane texture degrades over the first 60 m**



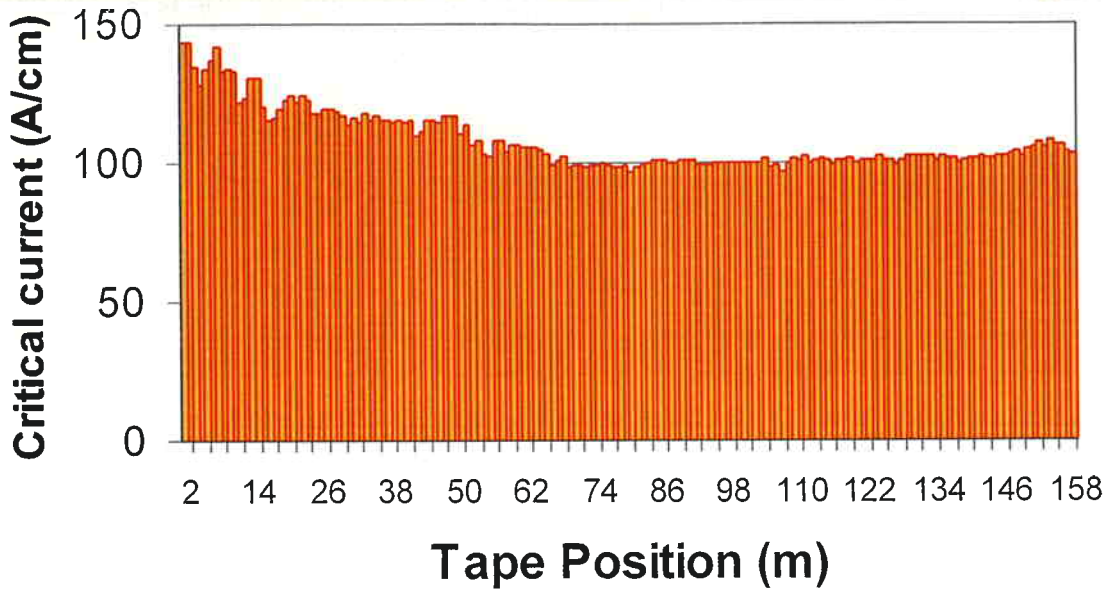
Raman spectra show a less intense peak (Y211 phase) in the highest  $I_c$  section.





Multi-pass process successfully used to produce 158 m long tape by MOCVD with improved  $I_c$  uniformity

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$I_c \sim 100$  A/cm over 158 m

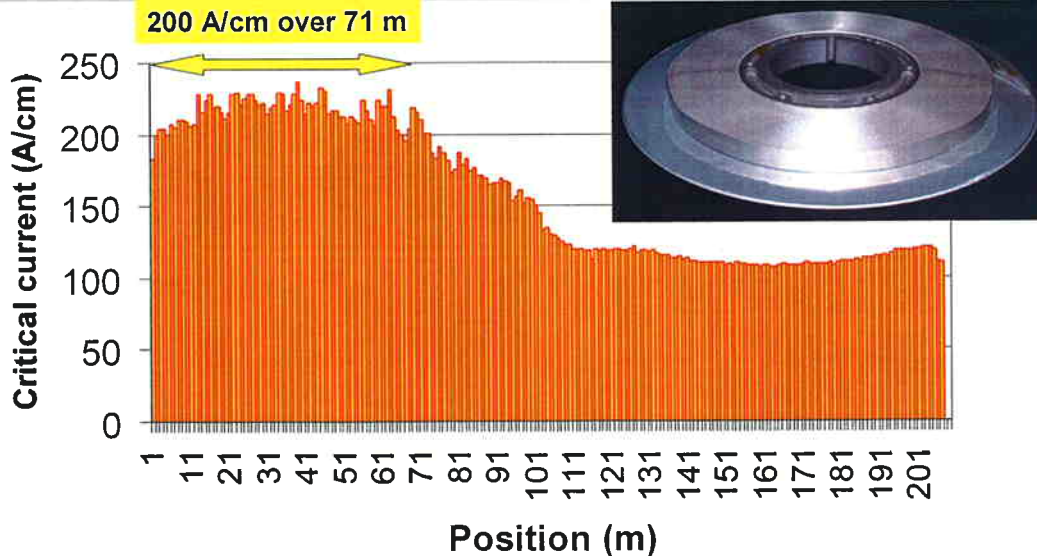
Standard deviation = 2% over last 100 m

ISS 2005

- 8 -

200 m long 2G conductor by MOCVD

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Minimum  $I_c$  of 106.7 A/cm over 206.7 m (22,030 A-m)

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

Standard deviation of 4.3% over the last 100 m

ISS 2005

- 9 -

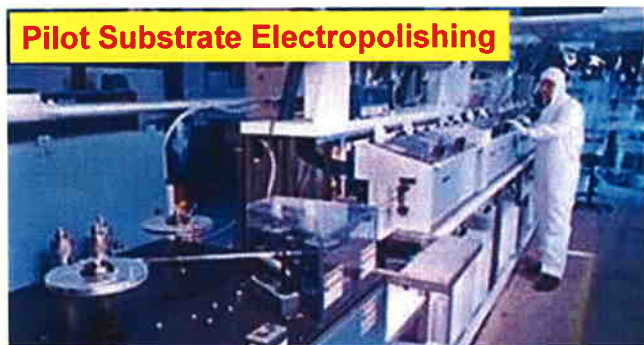
## Quality Control Tools for Coated Conductor Manufacturing

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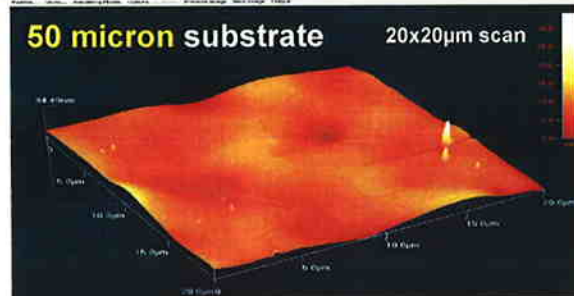
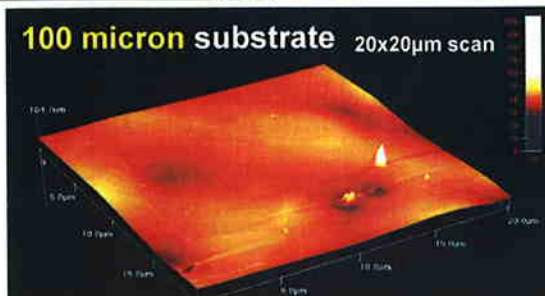
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### On-line roughness monitoring and off-line AFM measurements used as QA/QC for substrate polishing



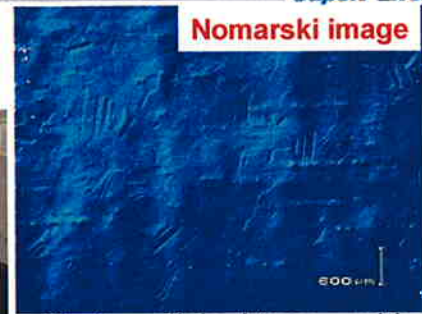
	100 micron substrate	50 micron substrate
Lengths	150 m	300 m
Roughness	2.8 nm	1.9 nm
Slope	~ 3.3°	~ 7°
G.B. slope	< 1°	< 1°



Quality of electropolished 50 micron substrates meets even the stringent requirements of IBAD MgO

## Reel-to-reel Nomarski microscopy & optical profilometry are used for substrate characterization

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Electropolished tape – with grain boundaries



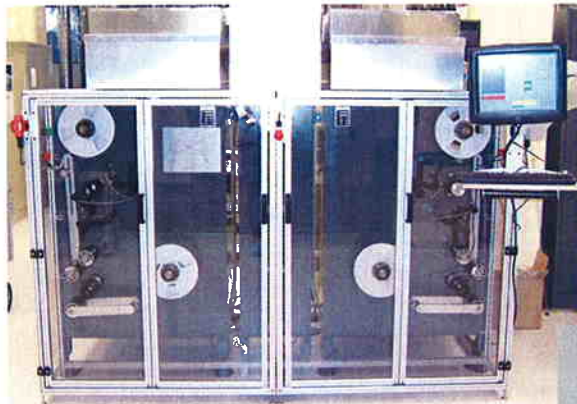
Electropolished tape – no grain boundaries

ISS 2005

-12-

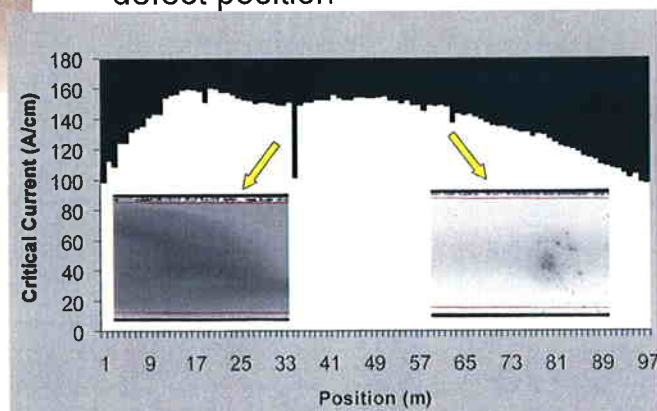
## An automated optical tape inspection system is used for QC/QA between every process step.

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- Reel-to-reel tape drives for edge guided, tension control for over 2 km long tapes at a maximum speed of 450 m/h
- Camera system inspects tape at 90m/hr and correlates defect type to defect position

- 100 - 300 m long tapes inspected - as polished substrate, buffer, MOCVD YBCO
- Tape Inspection system was used to locate weak spots in the first 100 m MOCVD tape *before*  $I_c$  testing



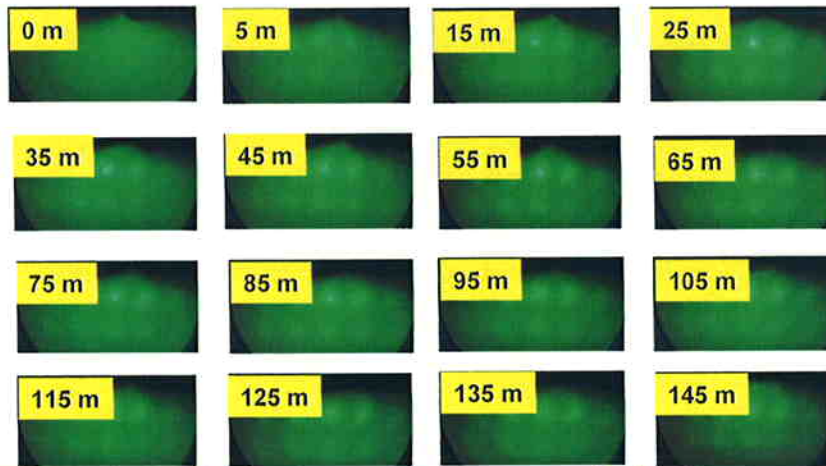
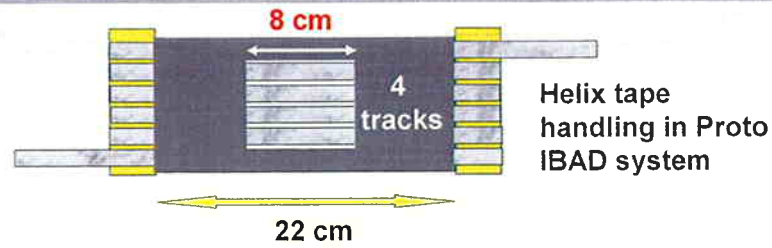
ISS 2005

-13-



# On-line RHEED qualifies the buffer surface texture during IBAD MgO processing

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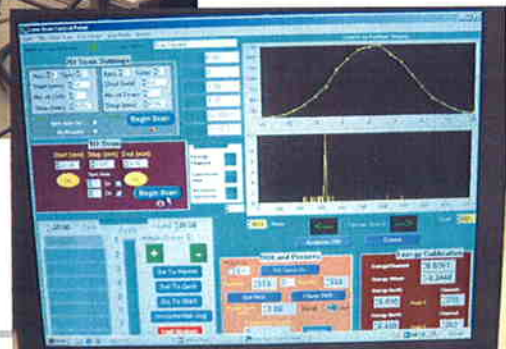
- 14 -

# High-speed, novel in-plane texture measurement system used for texture measurements on long IBAD tapes

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- ⊕ Acquisition time: 1 sec per point with detector averaging 5000cps
- ⊕ Cycle time for complete pole figure = 35 seconds !



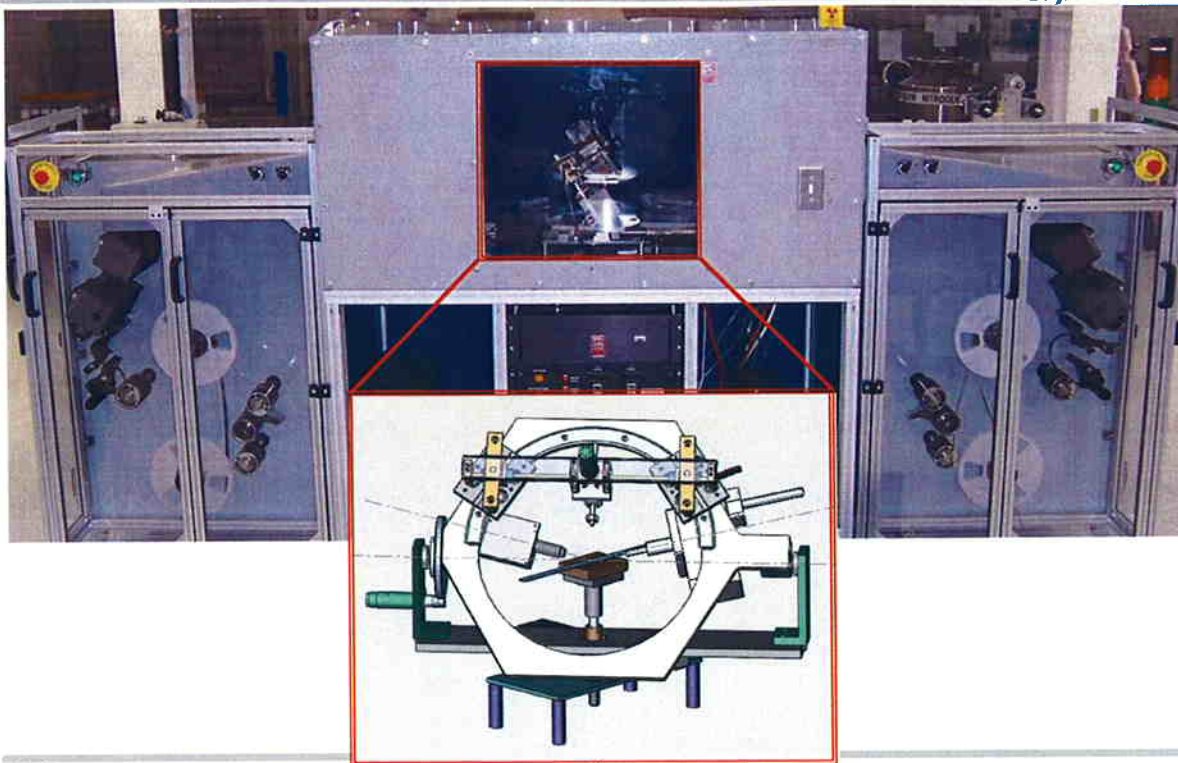
ISS 2005

- 15 -



Upgrade to XRD system will allow rapid texture measurements of up to 1km of any material

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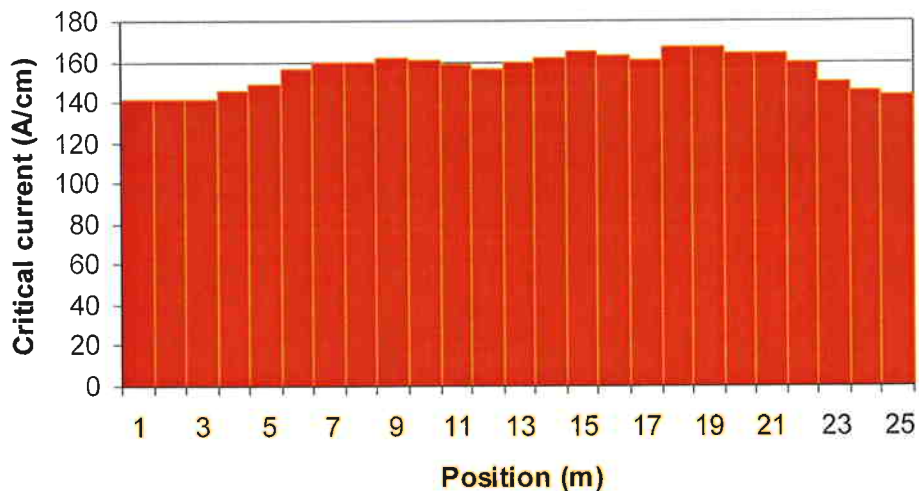


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- 16 -

25 m MOCVD tape demonstrated with LMO buffered IBAD MgO: all buffers @ 10 m/h

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Long length performance: 142 A/cm over 25 m

Short length performance:

220 A/cm, 1.1 micron YBCO,  $J_e = 40 \text{ kA/cm}^2$

400 A/cm, 3.0 micron YBCO,  $J_e = 71.4 \text{ kA/cm}^2$

ISS 2005

- 17 -