

# Bruker Energy & Supercon Technologies (BEST)



## DOUBLE-DISORDERED HTS COATED CONDUCTORS AND THEIR ASSEMBLIES AIMED FOR ULTRA-HIGH FIELDS: LARGE AREA TAPE

Presenter: Ulrich Betz - BRUKER HTS

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## Outline

- Introduction
- Processing Technology
- Nano-Structure of HTS Layer
- HTS Coated Tapes Status
- Summary



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## Introduction

### BRUKER HTS PILOT-LINE PRODUCTION

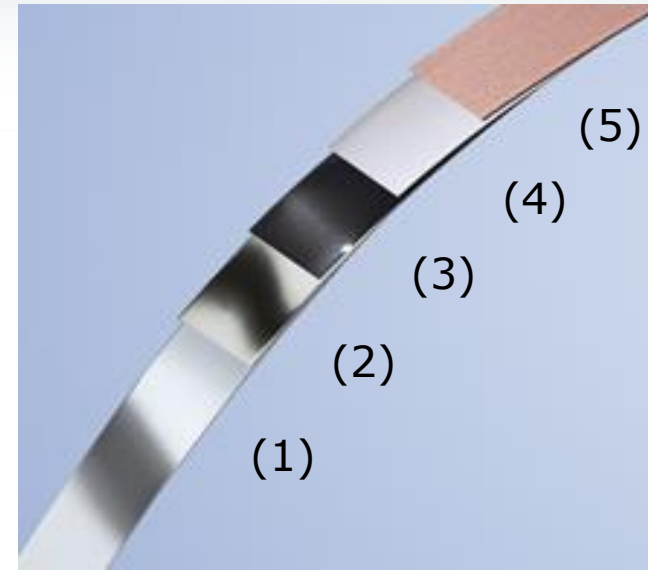


- BHTS pilot-line plant with more than 2000 sqm operation area, located in the Industrial Park North of Alzenau, Germany
- Manufacturing of HTS coated conductors tailored for it's application at ultra-high magnetic fields at intermediate and low temperatures
- Processing route based on vacuum coating technology (e.g. Pulsed Laser Deposition) with a current maximum capacity of 25 km p.a. (ramp-up to 100 km p.a. possible within the plant)

### Introduction

#### HTS COATED CONDUCTORS

- Superior  $I_c$  in-field performance of HTS tapes exceeding 750 A/cm-width at 4.2 K, 30 T, B//c
- 4 mm and 12 mm (optionally 40 mm) wide HTS tapes
- Since 2015 the maximum tape length batch sizes are 600 m for 4 mm and 90 m for 12 mm wide tapes
- Standard substrate thickness is 100  $\mu\text{m}$
- Copper layer thickness in the range of 5  $\mu\text{m}$  to 50  $\mu\text{m}$  possible
- Tape insulation if requested (e.g. KAPTON)



Standard configuration:

- (1) Stainless steel substrate
- (2) YSZ buffer layer
- (3) YBCO superconductor
- (4) Silver metal contact
- (5) Copper encapsulation



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## Processing Technology

### PROCESSING CHAIN OF HTS PILOT-LINE PRODUCTION

SUBSTRATE PREPARATION (SUB)

BUFFER LAYER COATING (ABAD)

HTS LAYER COATING (PLD)

METAL COATING (MET)

COPPER PLATING (PLA)

FINAL TAPE INSPECTION (INS)

### OVERVIEW PROCESS STEPS

- Wet chemical processes: SUB, CAP
- Vacuum coating processes: ABAD, PLD, MET

PLD production coater





# BRUKER HTS

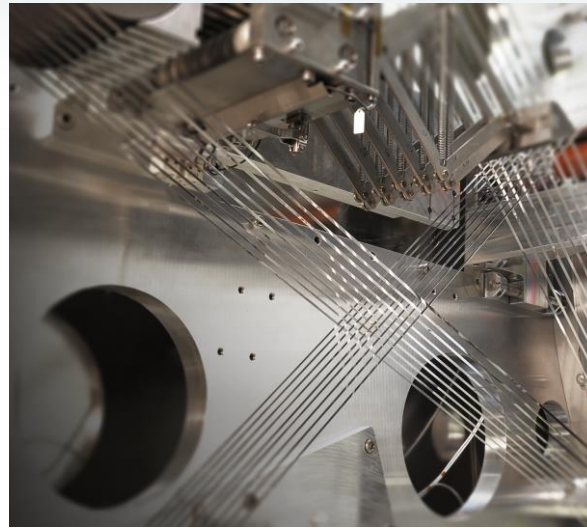
## DD HTS COATED CONDUCTORS



### Processing Technology

#### TAPE PROCESSING

- Reel-to-Reel
- Substrate on drum



PLD application coater\*  
in operation since 2016



\*built with support from CERN



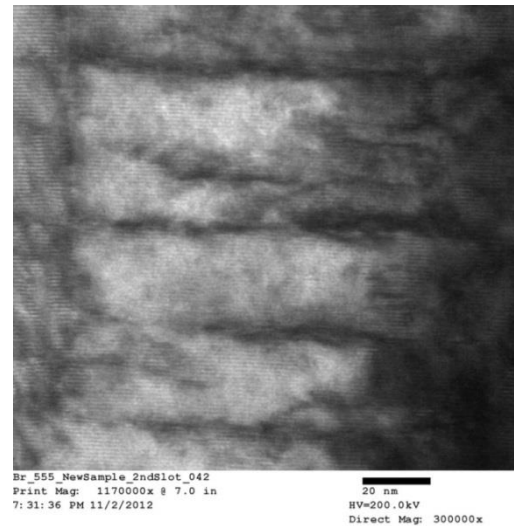
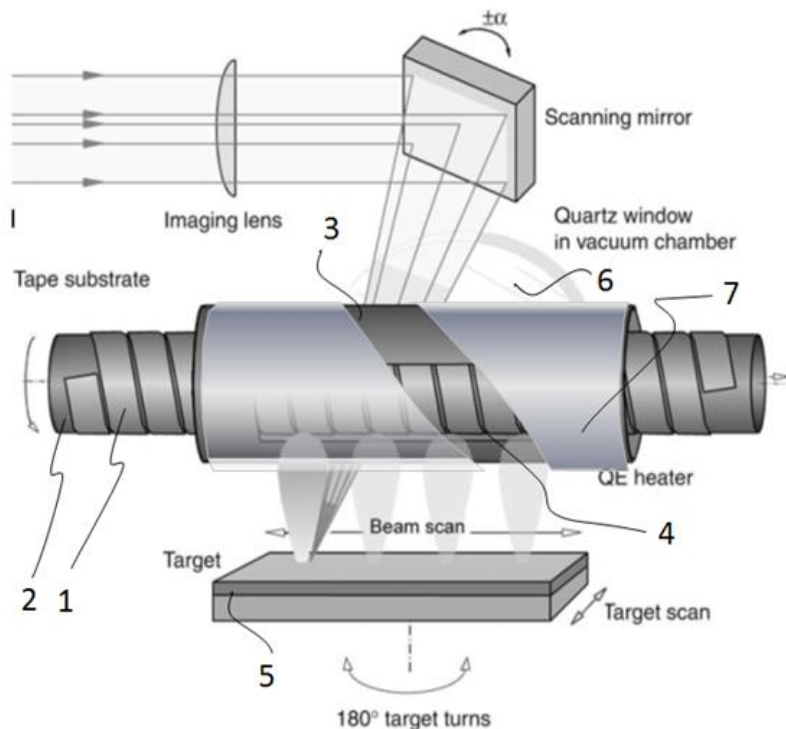
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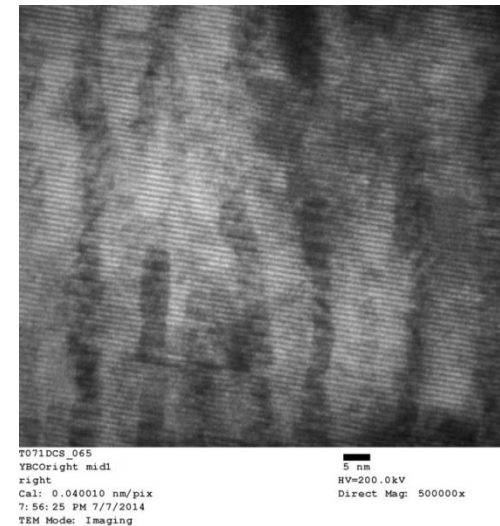
### Nano Structure of HTS Layer

#### DOUBLE DISORDERED YBCO FILMS

- Structural design of the YBCO superconducting thin films on a nano-scale by pulsed laser deposition PLD



INTRINSIC stoichiometric deviations in the YBCO film

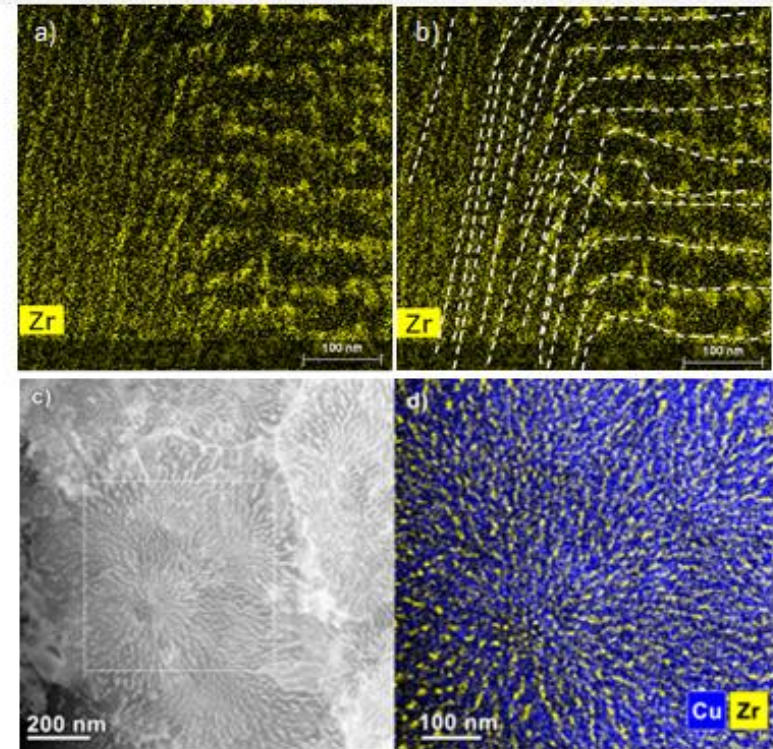
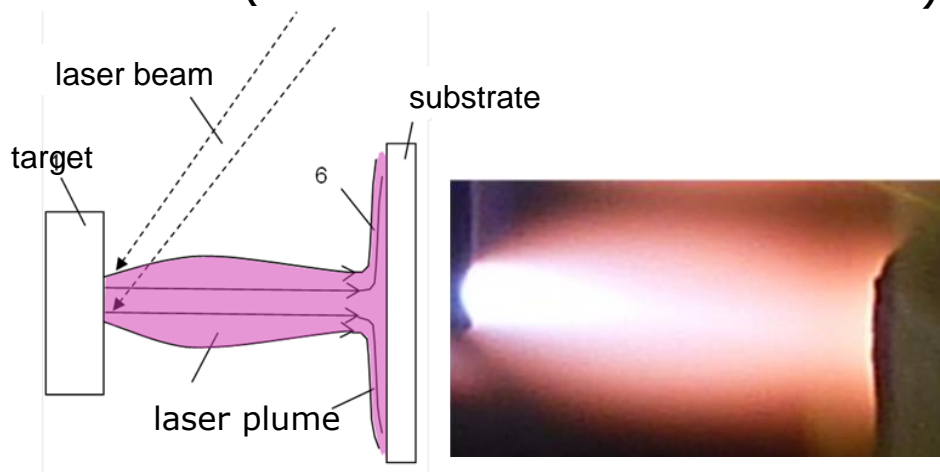


EXTRINSIC second phase nano-structures in the YBCO film

### Nano Structure of HTS Layer

#### DOUBLE DISORDERED YBCO FILMS

- Further structural analysis of YBCO films show strongly inclined nano-columns of extrinsic phase
- Possible explanation is the observed PLD laser plume lateral flow of material deflected and “guided” by substrate surface including etching effects (dev. model fits well to data)



“Firework” structure of extrinsic phase,  
columnar nano-chains tilting to  $90^\circ$   
a, b – YBCO layer cross-section  
c, d – views along c-axis





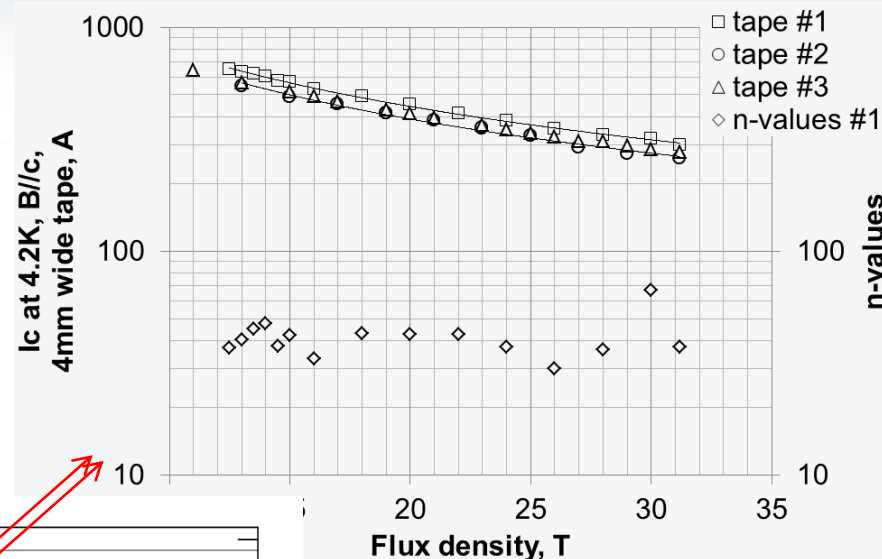
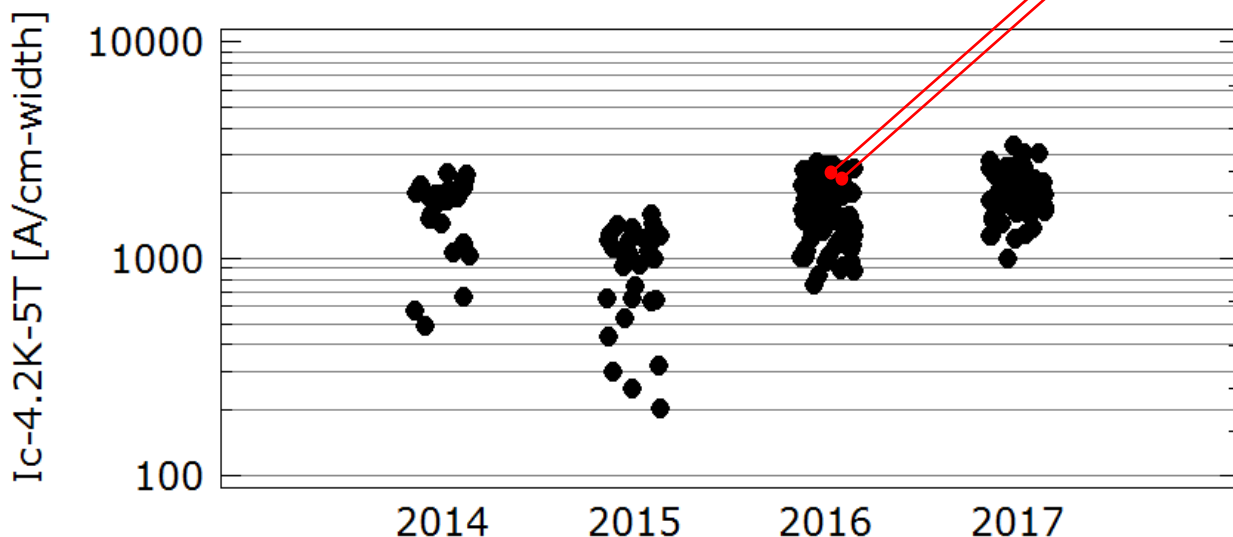
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### HTS Coated Tapes Status

#### DEVELOPMENT OF HTS PILOT-LINE CAPABILITIES

- $I_c$  in-field performances of HTS production tapes during the ramp-up phase, max. batch size ...  
... until 2014: 4 mm / 200 m  
... from 2015: 4 mm / 600 m



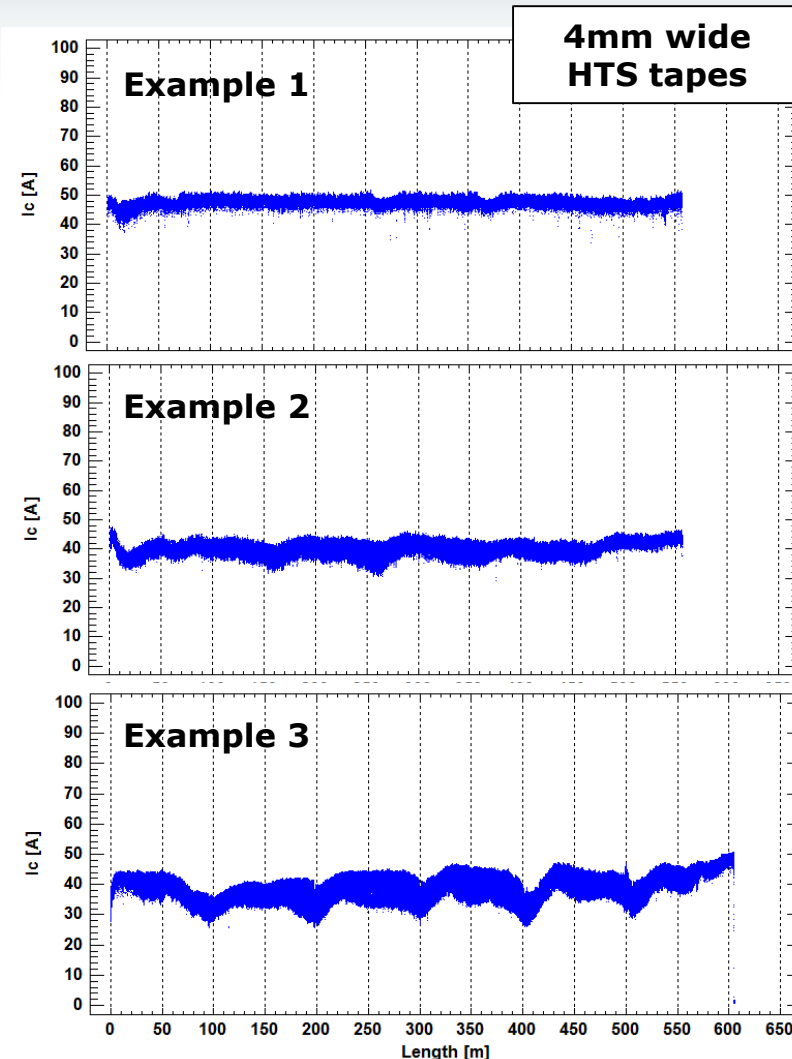
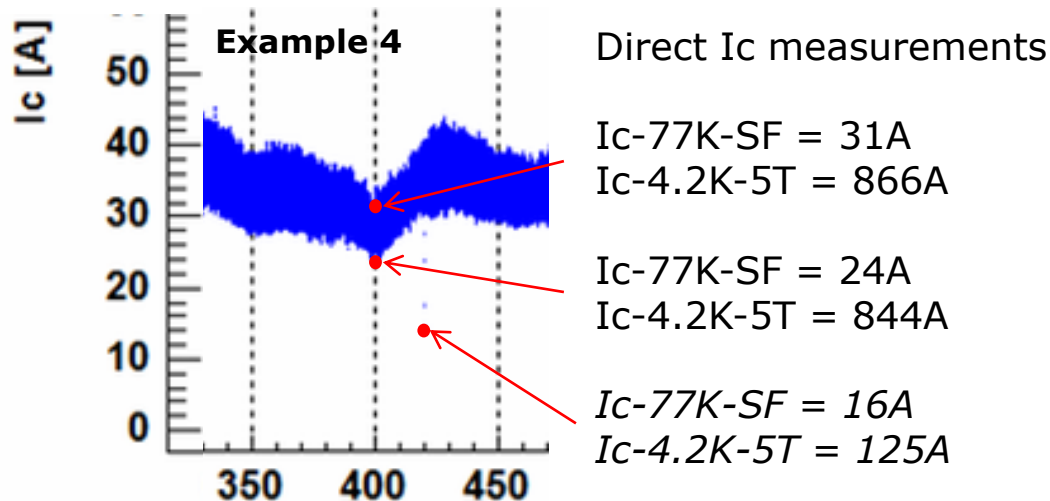
Two production tape samples, 4 mm x 600m (tape #2, tape #3)  
n-values: >30  
 $\alpha$ -values: 0.85



### HTS Coated Tapes Status

#### UNIFORMITIES

- Hall-probe measurements at 77K reveal the  $I_c$  drop-free single piece length of HTS tapes
- Depending on the coating parameter settings a characteristic PLD fingerprint appears in  $I_c$  measurement curves at 77K





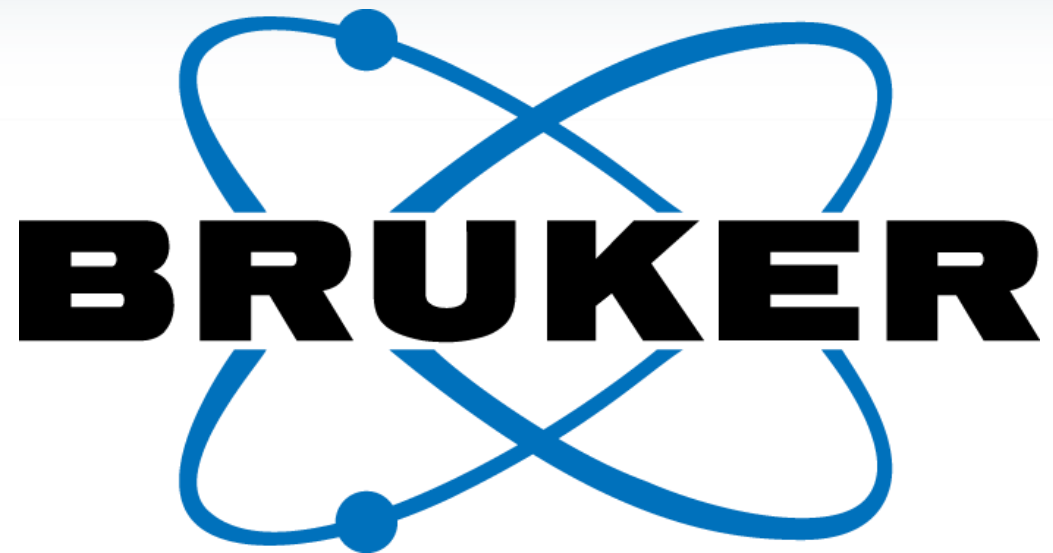
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### Summary

- A successful capability ramp-up of the pilot-line production of HTS coated conductors for high field magnet application has been realized starting in 2015 until today
- Substantial progress has been achieved in  $I_c$ -performance and  $I_c$ -uniformity in long HTS coated tapes aimed for ultra-high-field (UHF) applications
- Nano-structural features of the YBCO films have been analyzed in detail. Origin of strongly inclined nano-columns of the extrinsic phase in the YBCO films has been described in terms of model of film growth by PLD based on lateral flows

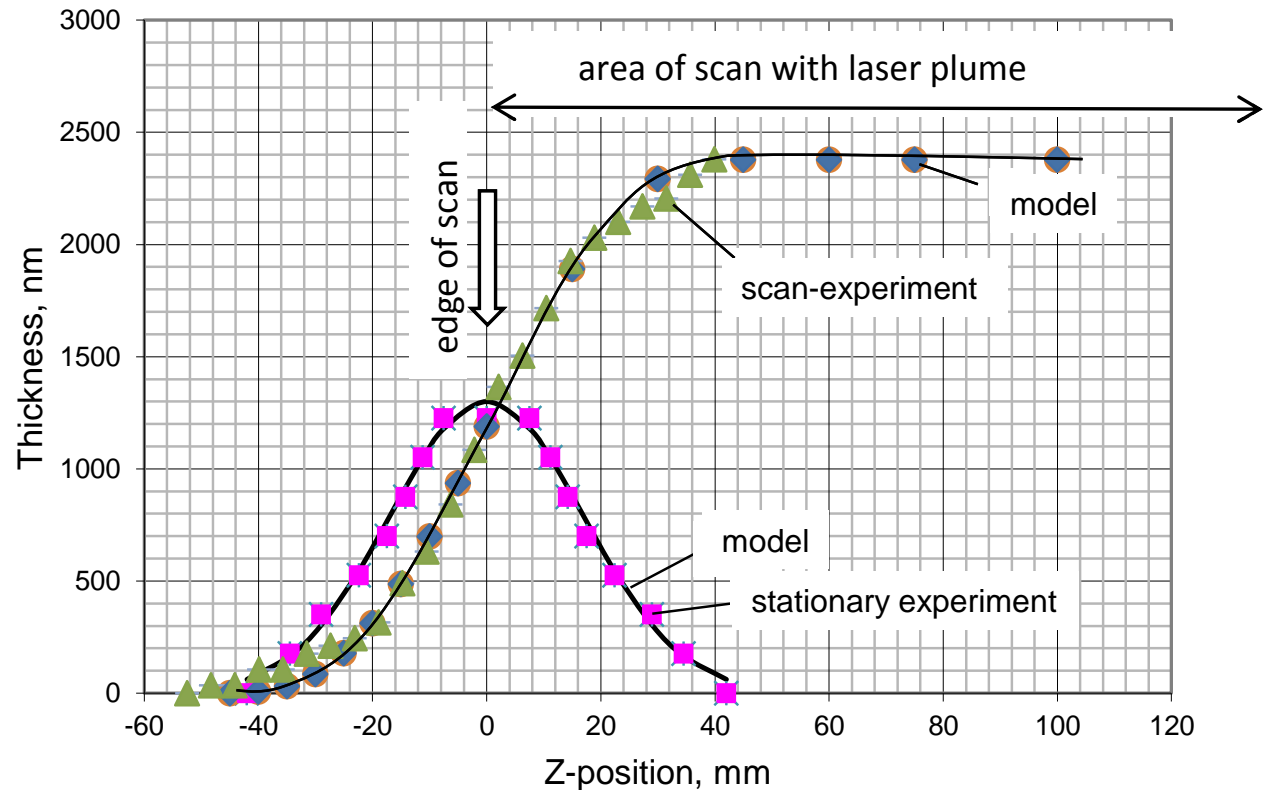


Innovation with Integrity

### Nano Structure of HTS Layer

#### DOUBLE DISORDERED YBCO FILMS

- Lateral Flows (LF) originating from laser plasma plume deflected and “guided” by substrate surface
- LF-PLD leads to wide propagation of material flow and self-etching effects



### HTS Coated Tapes Status

#### UNIFORMITIES

- Lift factor as a ratio of  $I_c(18T, 4.2 K, B//c)$  to  $I_c(SF, 77 K)$  is shown below
- No obvious correlation of these  $I_c$ -s was observed

