Italian National Agency for New Technologies,
Energy and Sustainable Economic Development

Purchase of a FIB-SEM equipped with EDS, EBSD and laser ablation chamber

MAG-T.01.01-T043-D001

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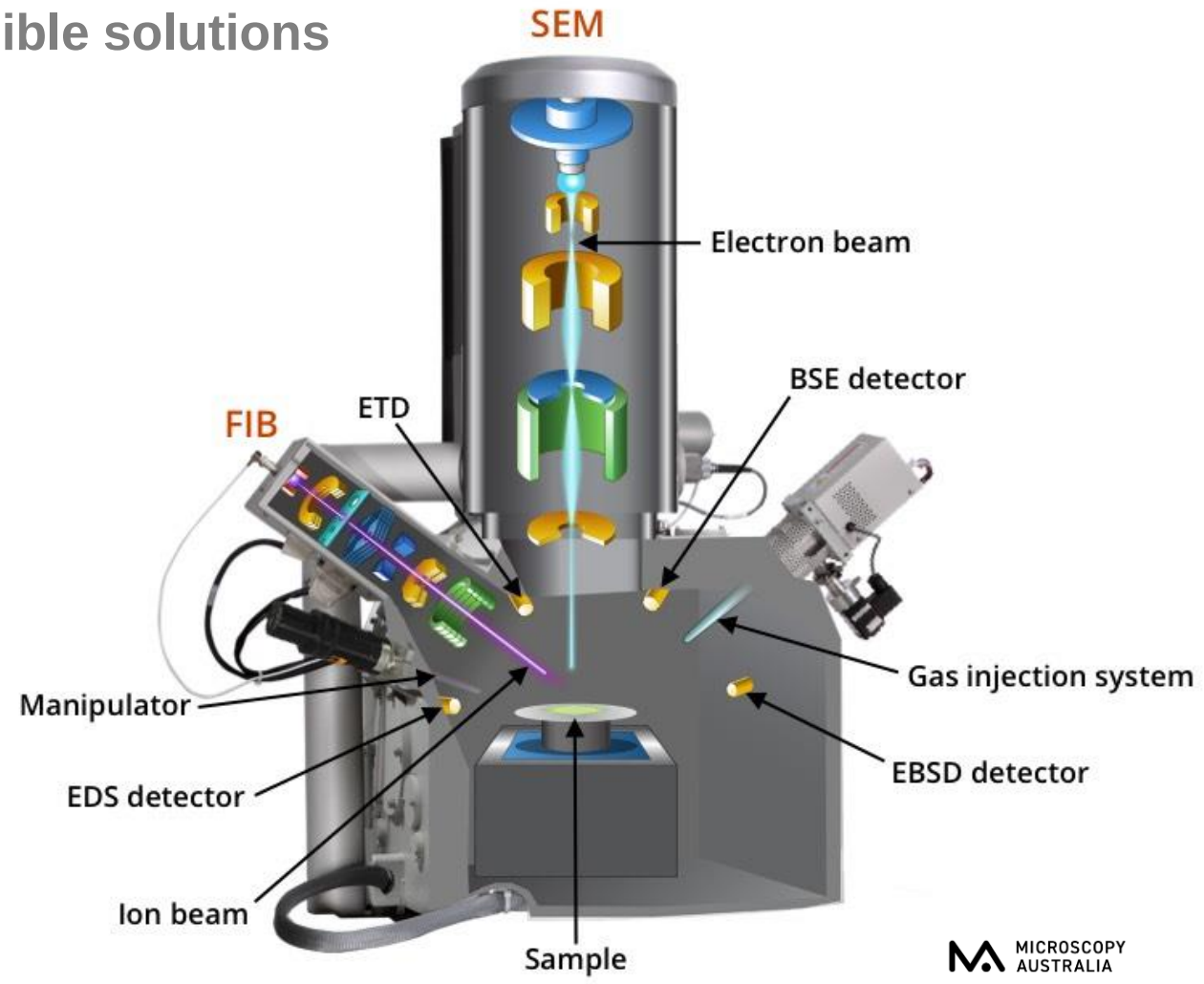
Aim and outline

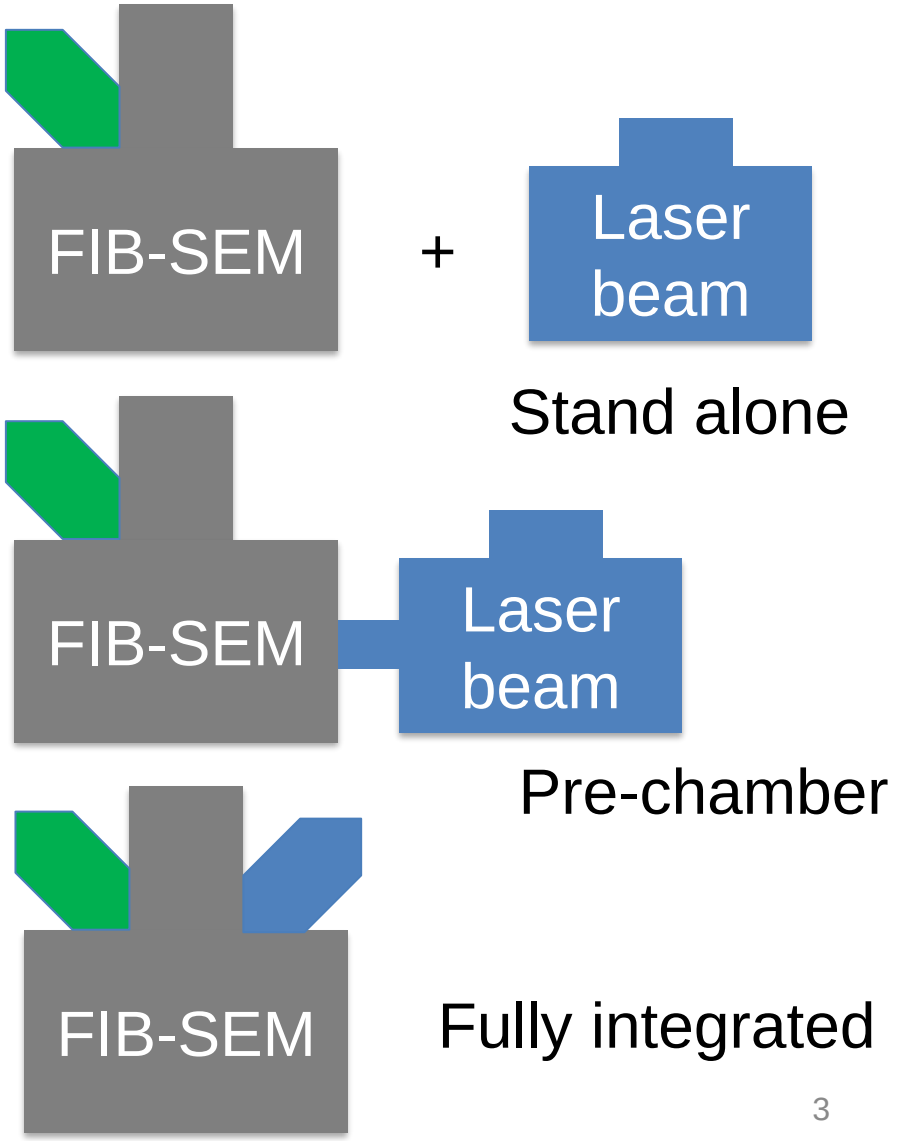
In-situ preparation and characterisation of striated commercial REBCO tapes

- FIB-SEM
- REBCO tape sample description
- Proposed tests
- Results
- Comparison
- Conclusion

FIB-SEM configuration

Possible solutions

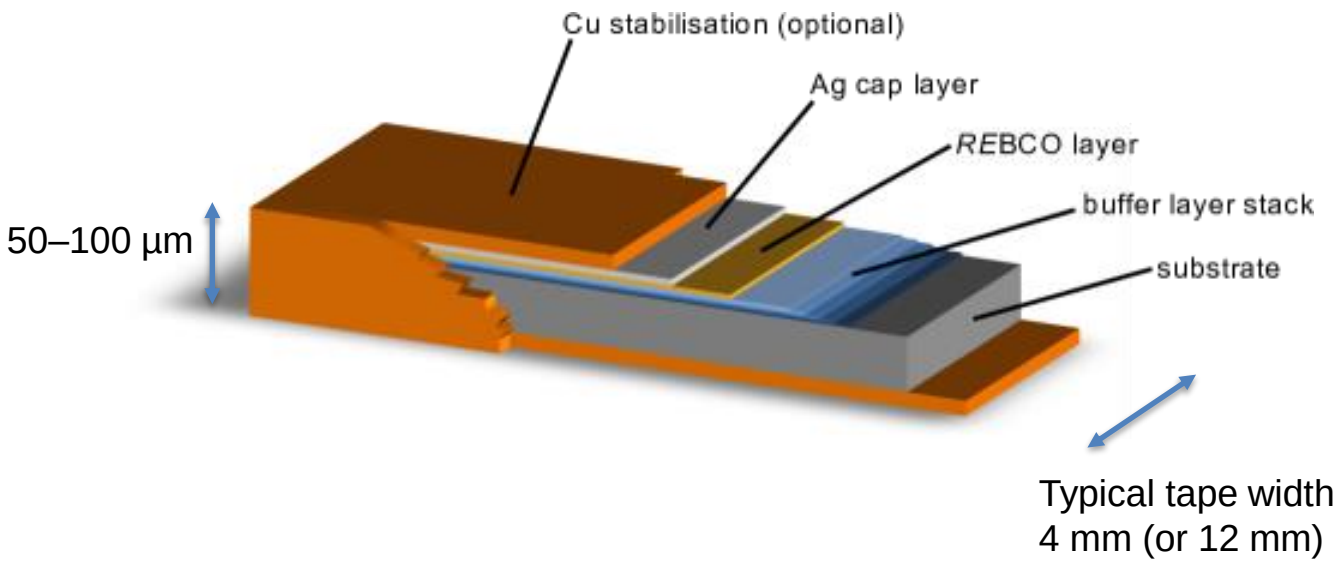


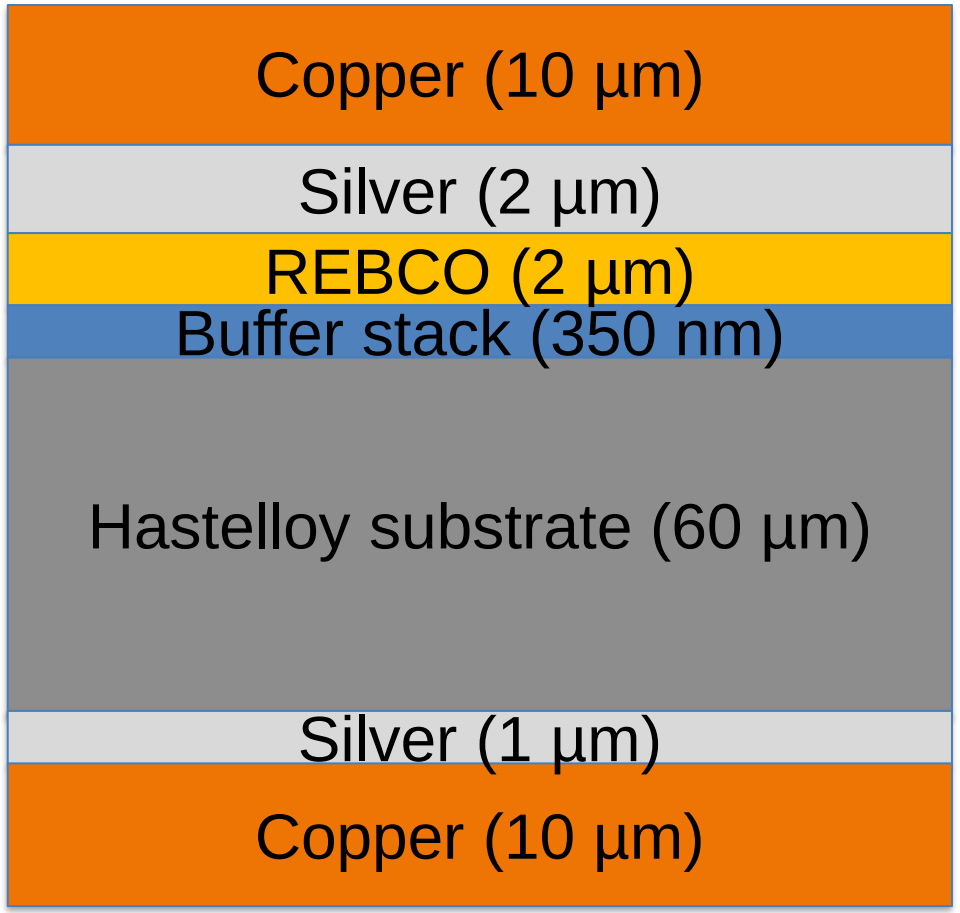


REBCO coated conductor

Multilayer architecture deposited on Hastelloy metallic substrate

REBCO: $REBa_2Cu_3O_{7-x}$ (RE=Y or rare earth)

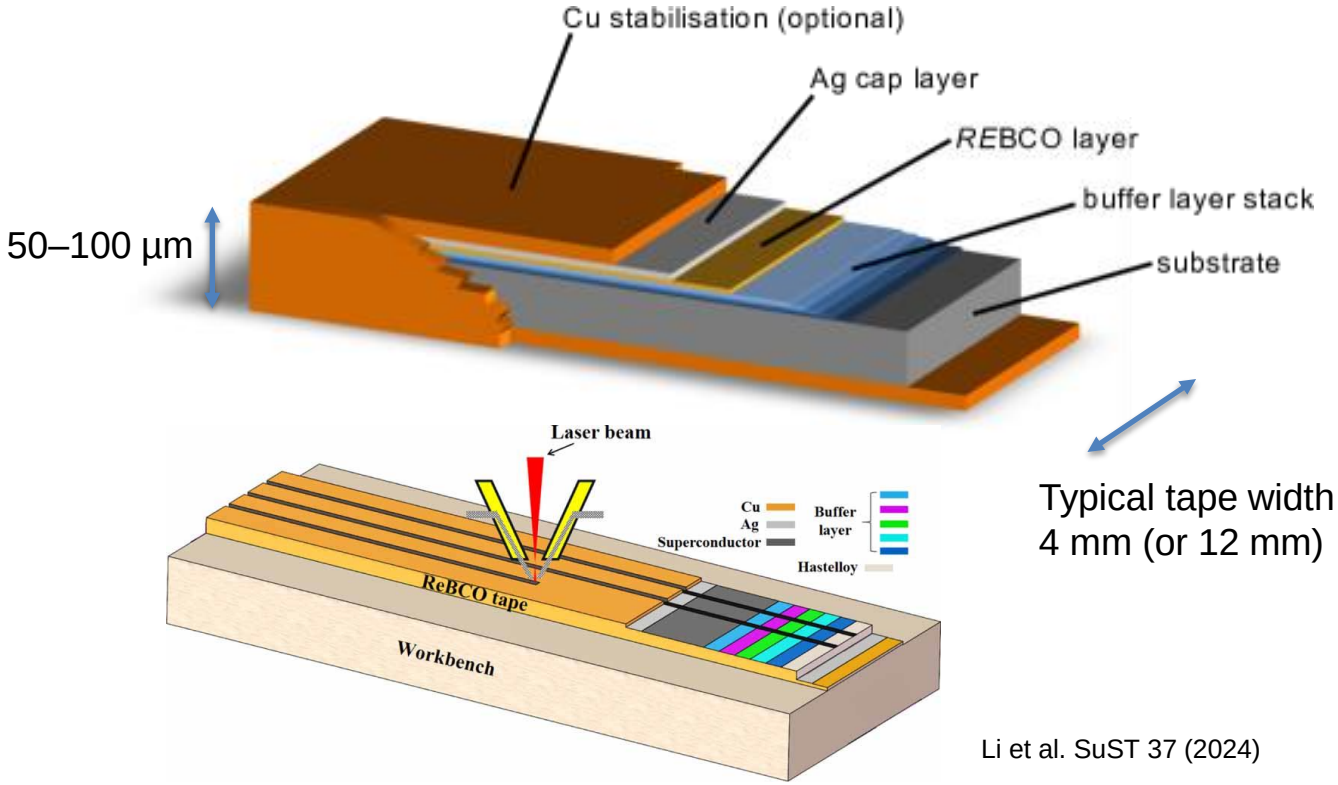




- Non-symmetric sample, REBCO film on one side only
- Region of interest: REBCO+buffer stack
- Analysis of film integrity and interfaces

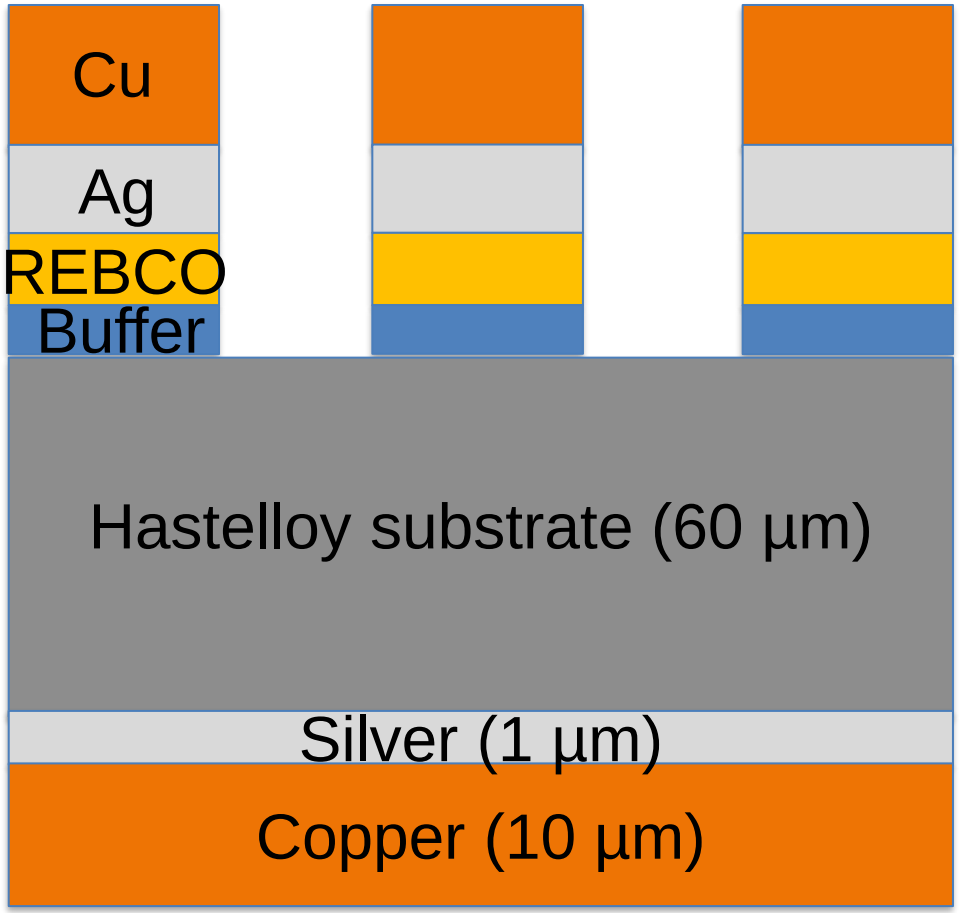
REBCO coated conductor filamentisation

Laser patterning to produce REBCO filaments



Li et al. SuST 37 (2024)

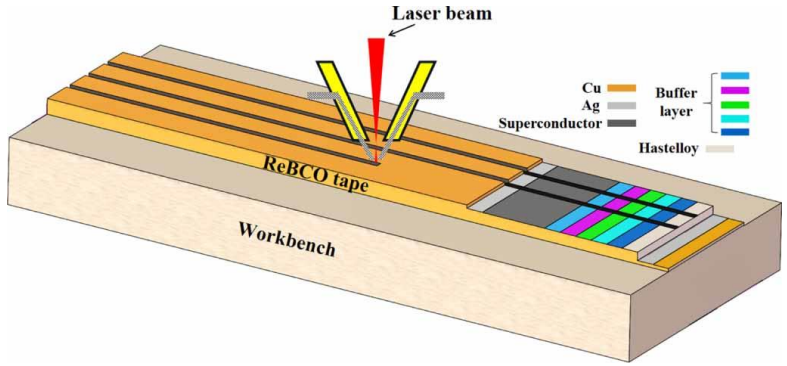
- Typical strip width 0.4–1 mm
- Useful strip length: > 4 mm



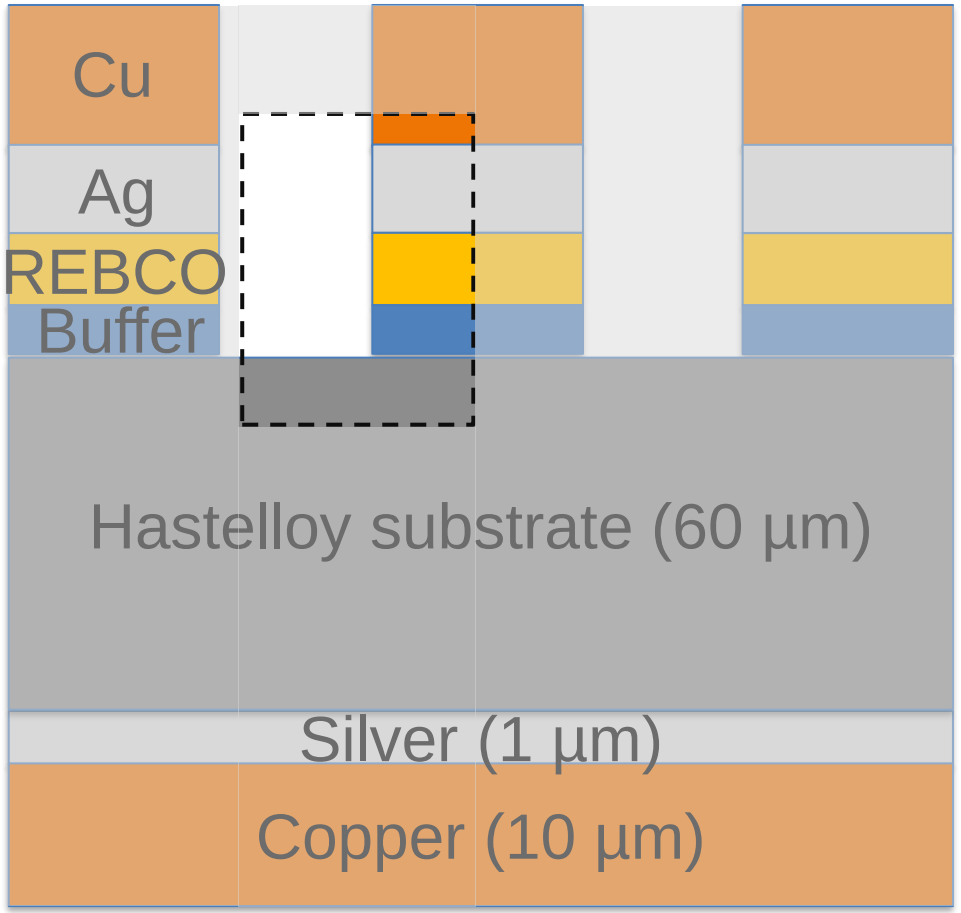
Analysis of striated REBCO coated conductor

Analysis of cross-sectional REBCO lamella extracted from patterned tape

- STEM for defect detection (cracks, voids, inhomogeneities) across filaments
- EDS (linescan or map) to detect possible compositional inhomogeneity produced by laser
- EBSD to detect possible phase modification or amorphisation produced by laser patterning



Li et al. SuST 37 (2024)



Shanghai SST 2206 tape was selected for tests

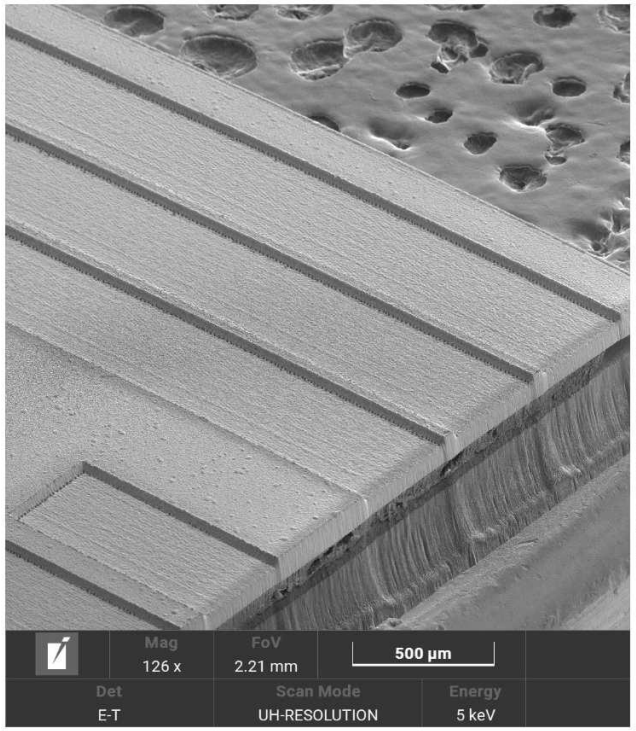
Experimental

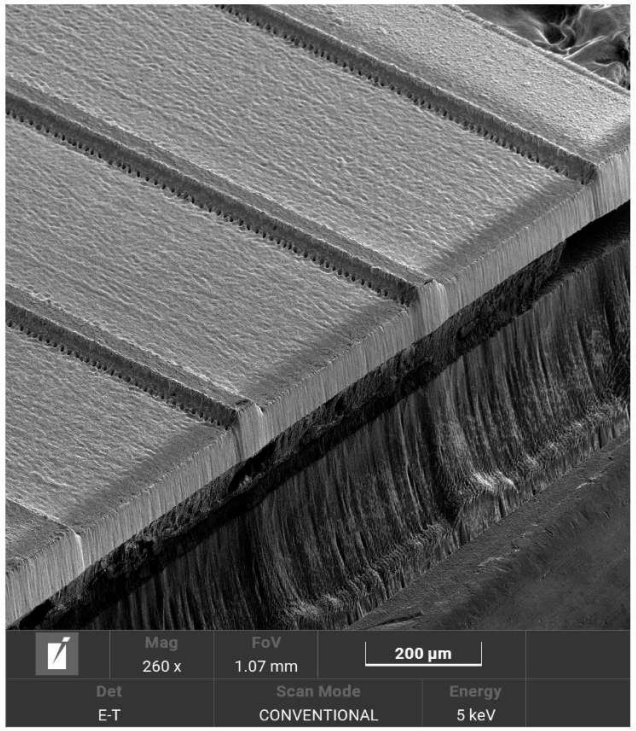
Three main tests requested

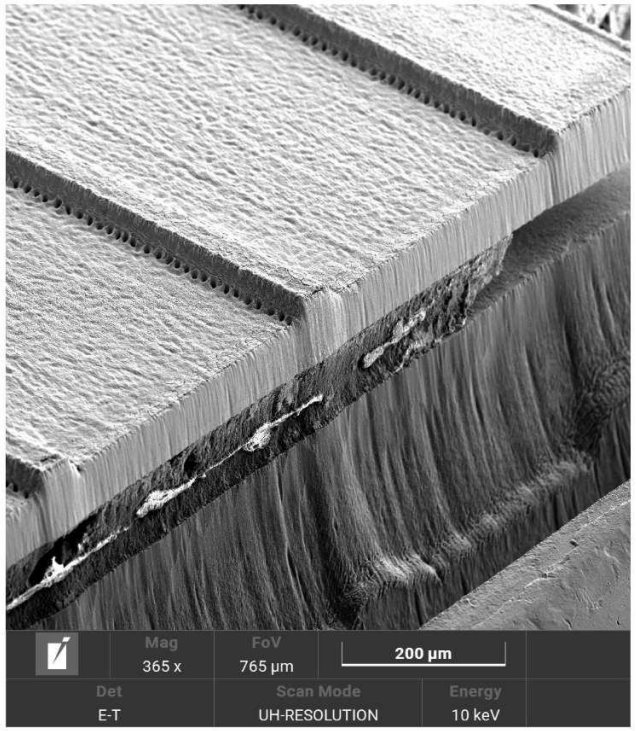
1. Tape filamentisation by laser patterning to obtain several REBCO strips running parallel to the rolling direction
2. Extraction of cross-sectional lamella on patterned REBCO tape in correspondence of strip edge
3. Analysis of cross-sectional lamella with focus on possible damage caused by laser patterning, including STEM, EDS and EBSD

1) Stand-alone laser

REBCO tape striation



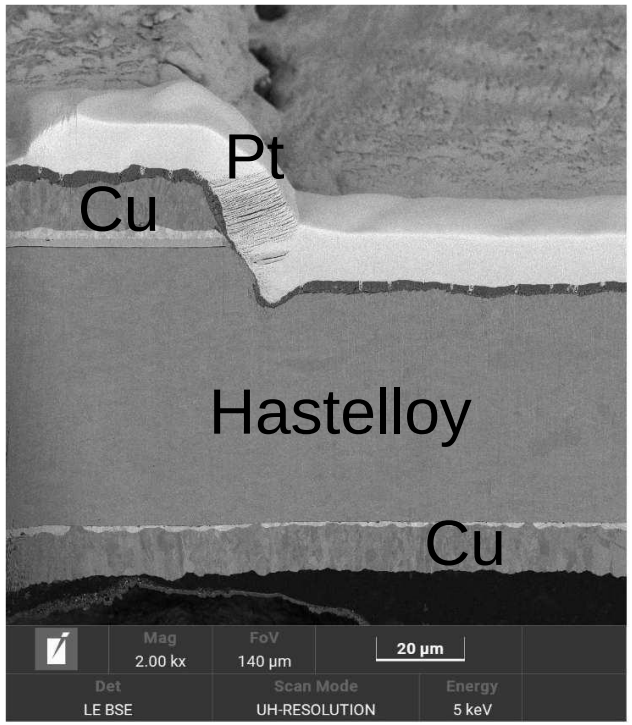


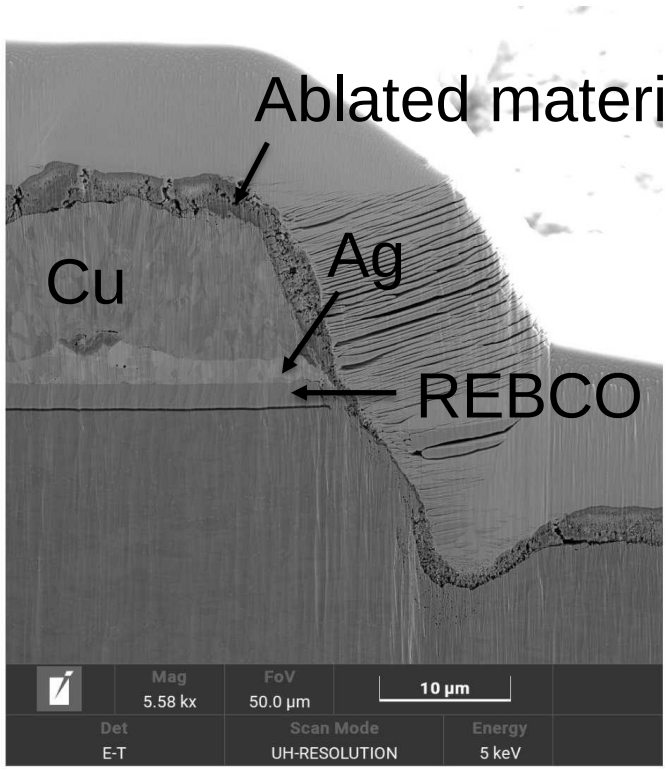


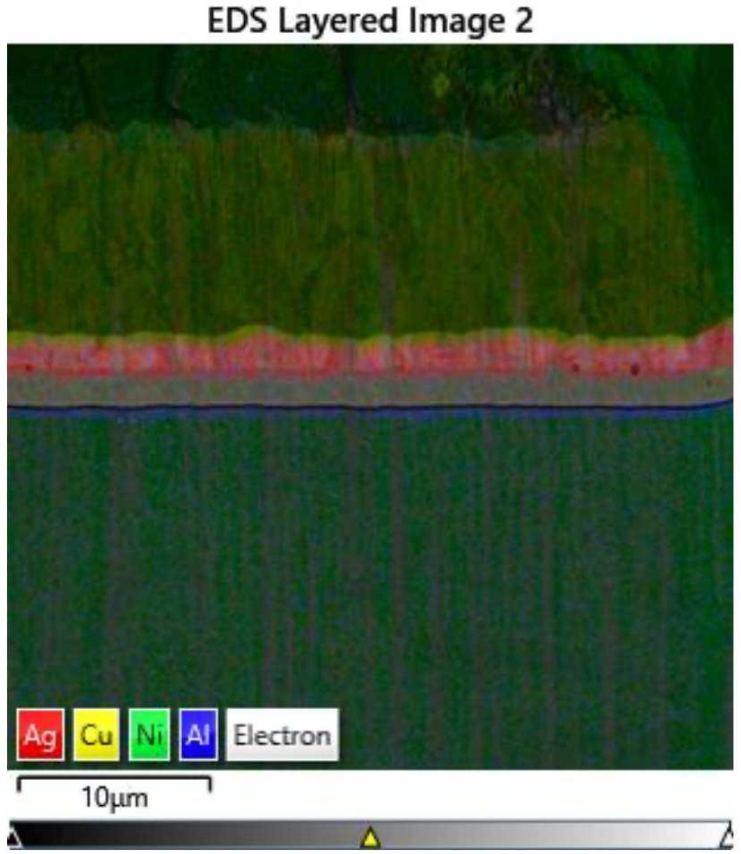
- Size 3 channels 6.5 mm x 0.4 mm x 40 µm depth
- Power 100 mW, Time 57', *f*=20 kHz
- Spot diam. 10 µm

1) Stand-alone laser

Cross section (filament edge)







- Bulk cross section obtained with plasma-FIB
- Ablated material redeposited on the sample

2) Integrated laser unit (pre-chamber)

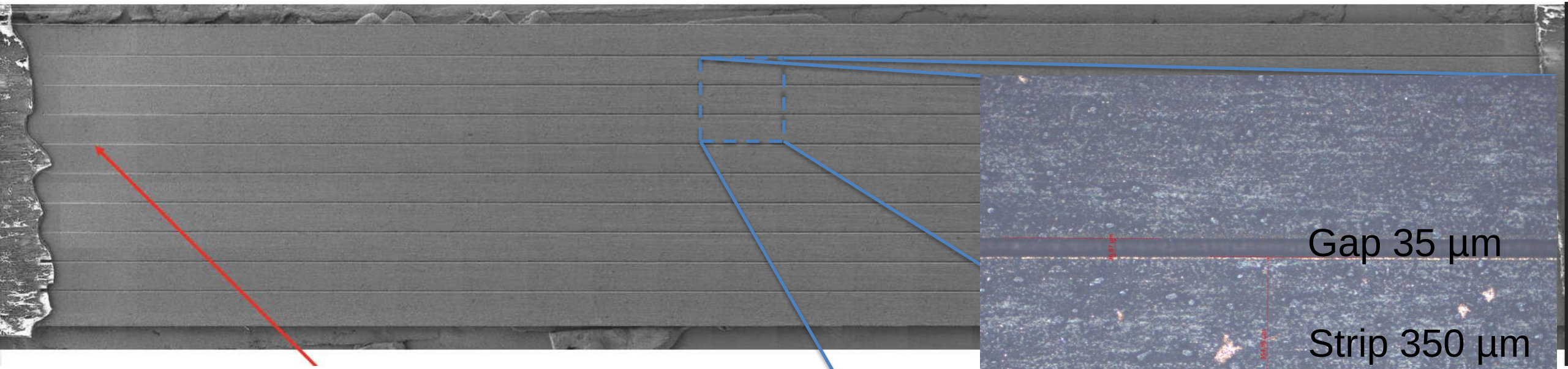
REBCO tape striation

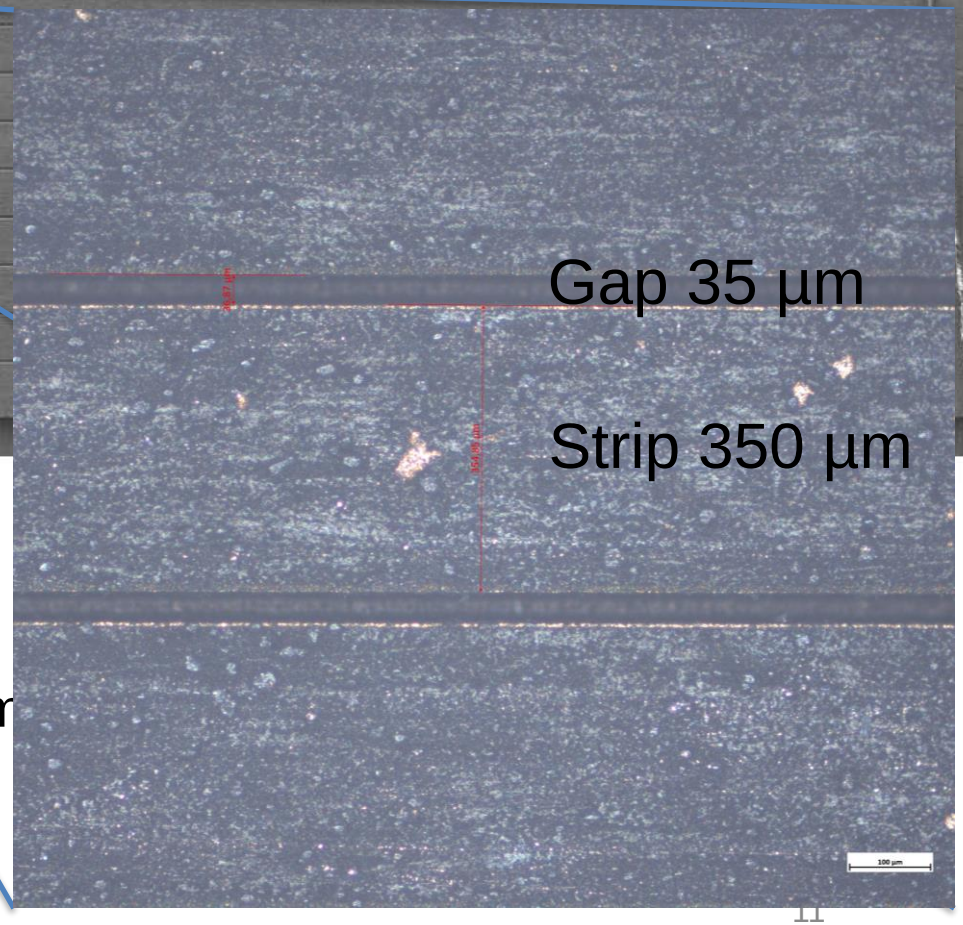
inhomogeneous milling (bending effect)

- Size 20 mm x 35 µm x 23 µm (9 trenches)
- Power 50 mW, pulse 350 fs, 10 passes, removal rate c. 2 µm/pass, strip width 350 µm
- Time 2.5 h

2) Integrated laser unit (pre-chamber)

REBCO tape striation





inhomogeneous milling (bending effect)

- Size 20 mm x 35 µm x 23 µm (9 trenches)
- Power 50 mW, pulse 350 fs, 10 passes, removal rate c. 2 µm
- Time 2.5 h
- Thick ablated material layer redeposited on the strips

2) Integrated laser unit (pre-chamber)

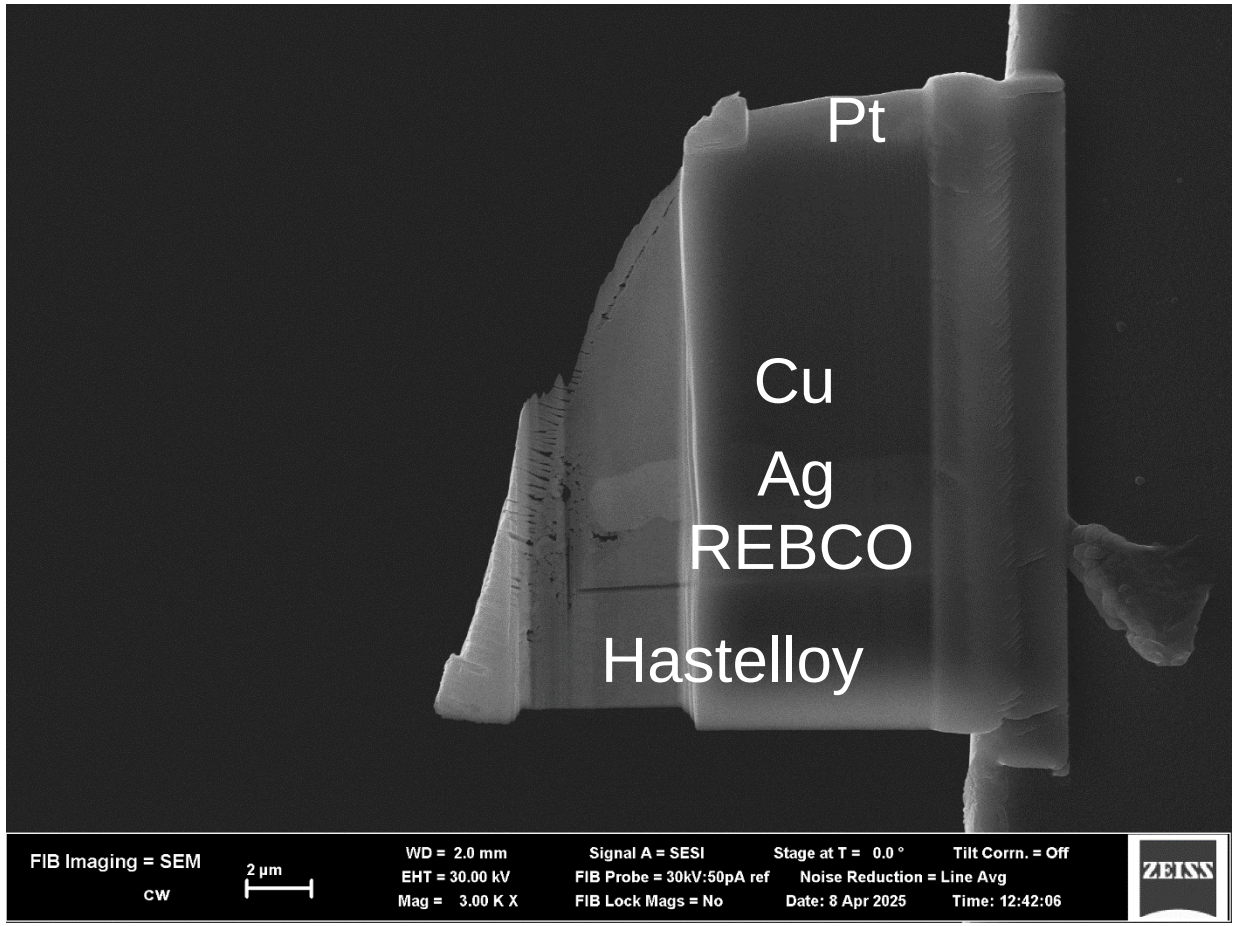
REBCO tape striation

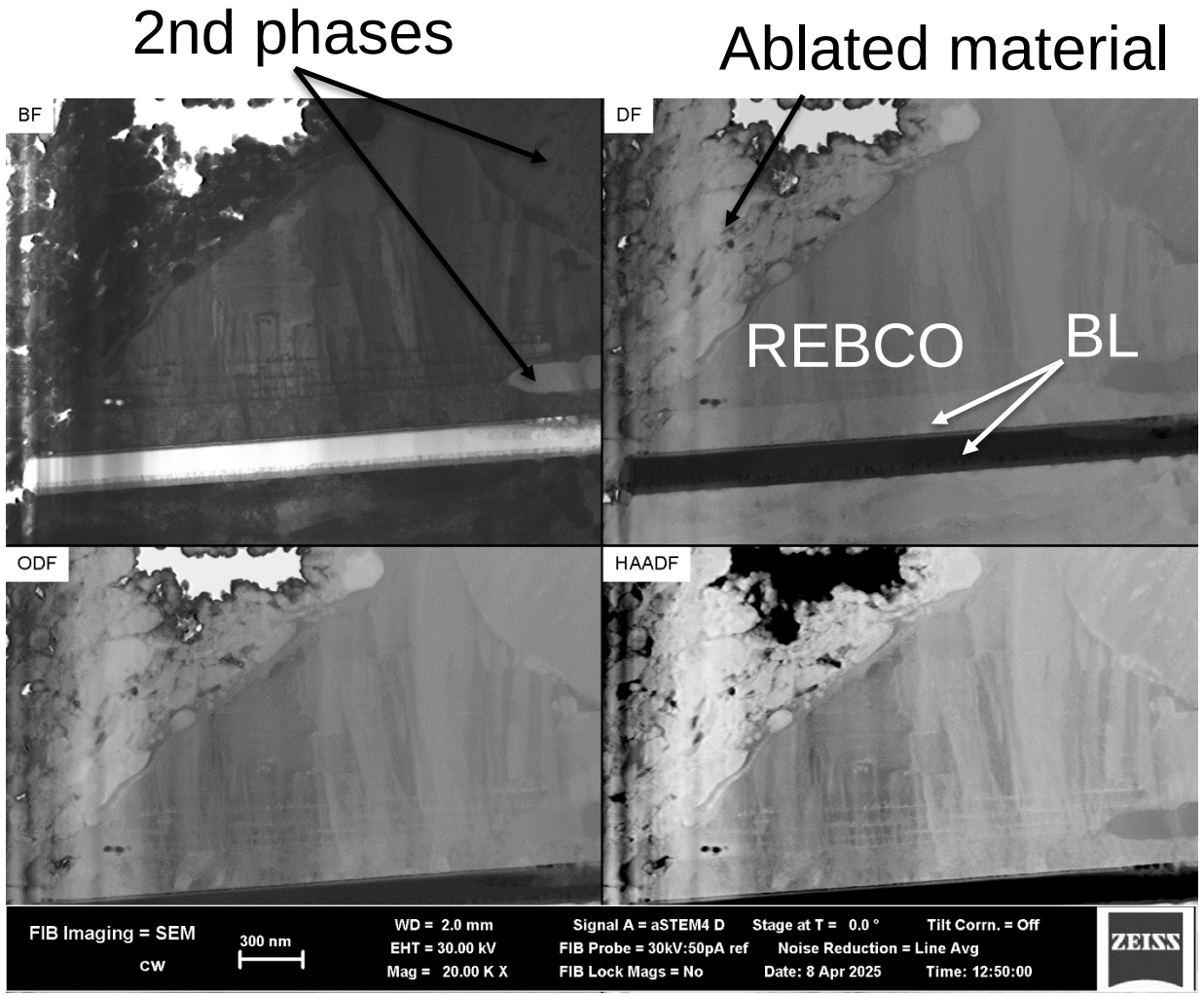
inhomogeneous milling (bending effect)

- Size 20 mm x 35 µm x 23 µm (9 trenches)
- Power 50 mW, pulse 350 fs, 10 passes, removal rate c. 2 µm/pass
- Time 2.5 h
- Eventually measured I-V (whole sample) and VSM+OM (box) ⟶ next presentations

2) Integrated laser unit (pre-chamber)

Cross section (filament edge)

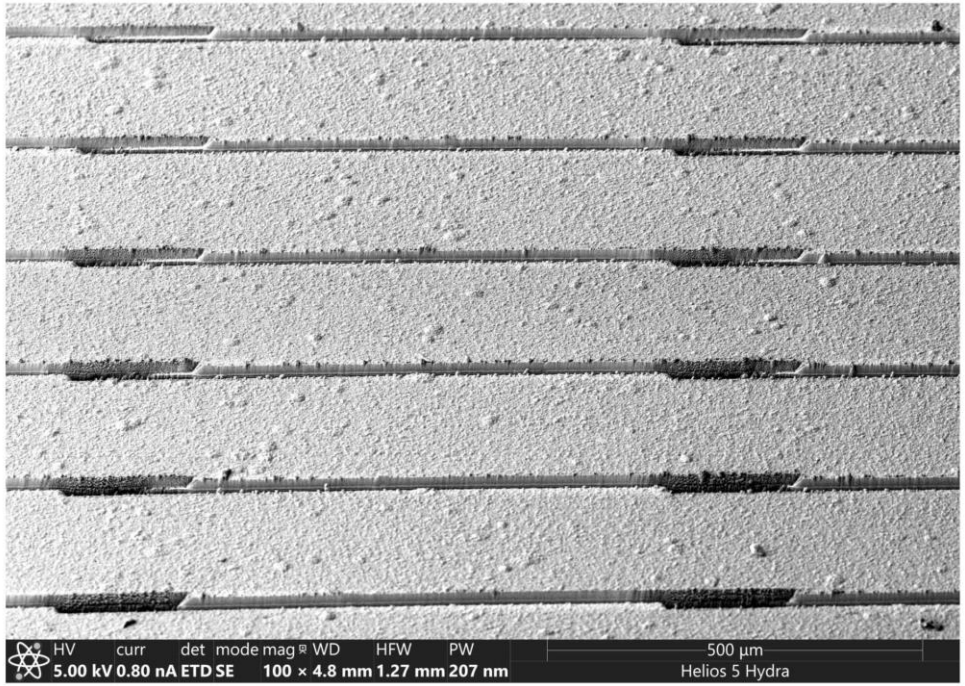


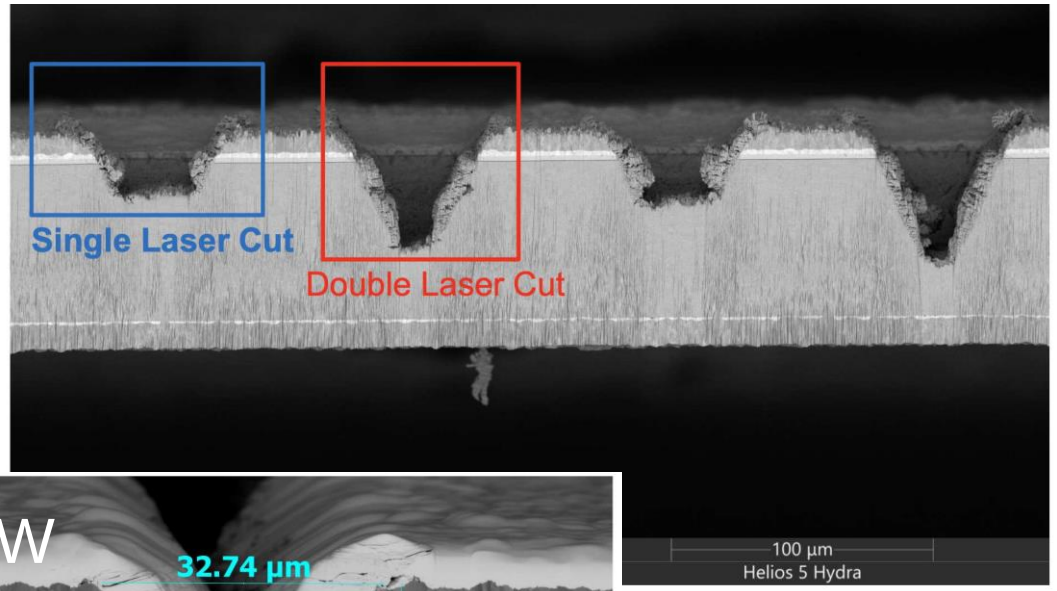


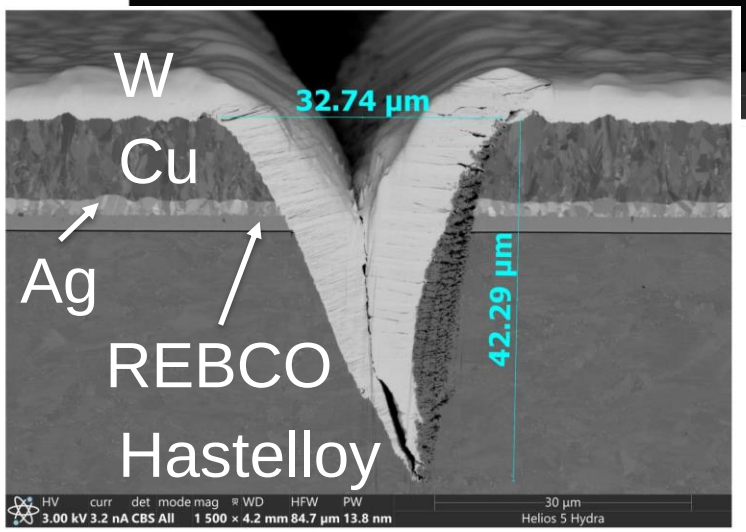
- STEM imaging on thin cross-sectional lamella (4 different signals)

3) Fully integrated laser beam

REBCO tape striation





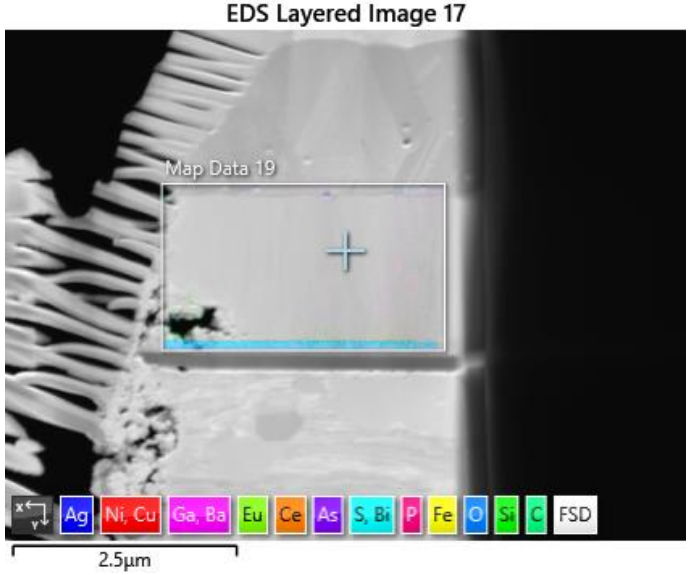


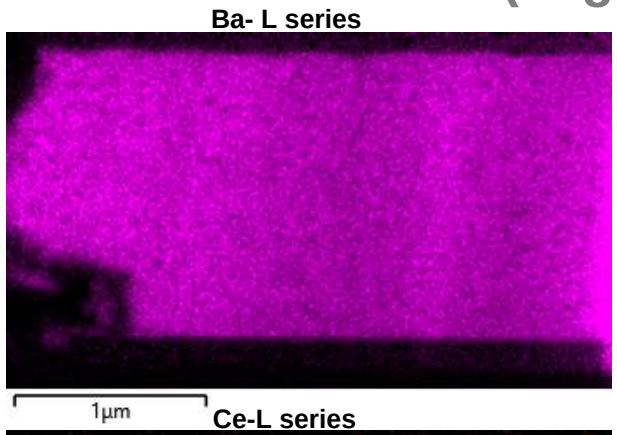
- Size 1 mm x 30 µm x 15 µm (6 trenches)
- Power c. 1.2 W, pulse energy 15 µJ, 1-2 passes, removal rate c. 15 µm/pass
- Overlap between meeting segments critical

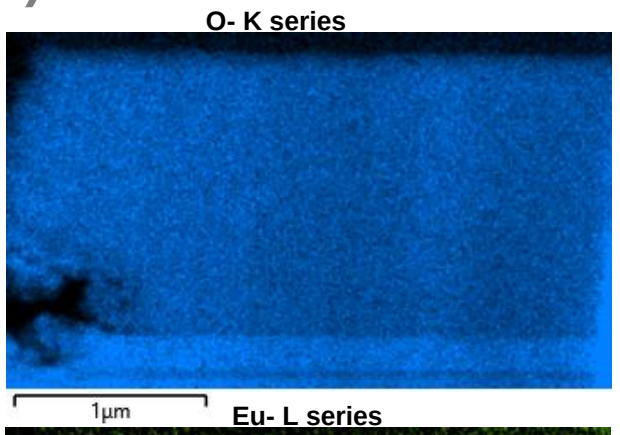
- After plasma FIB rocking polishing

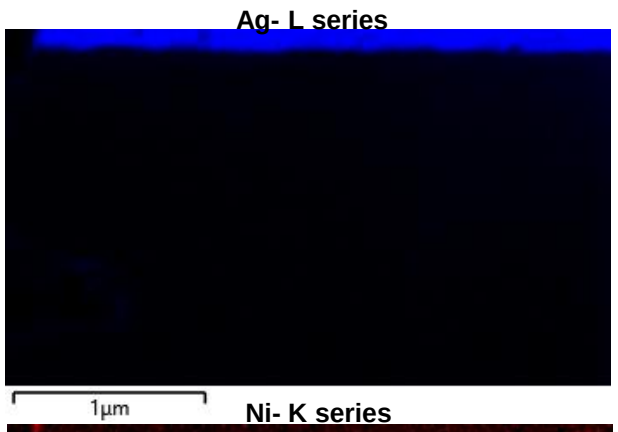
Additional analysis: EDS (producer 2)

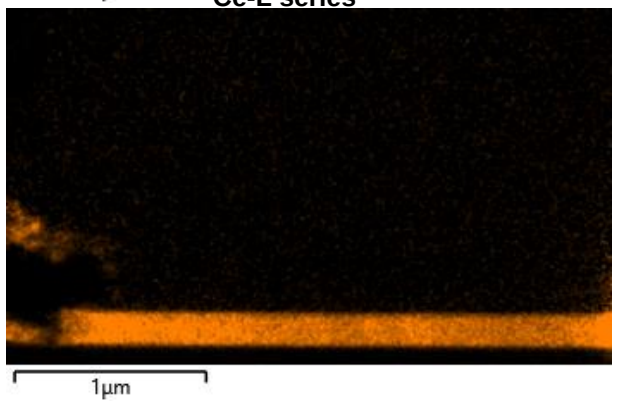
EDS on extracted cross-sectional lamella (edge)

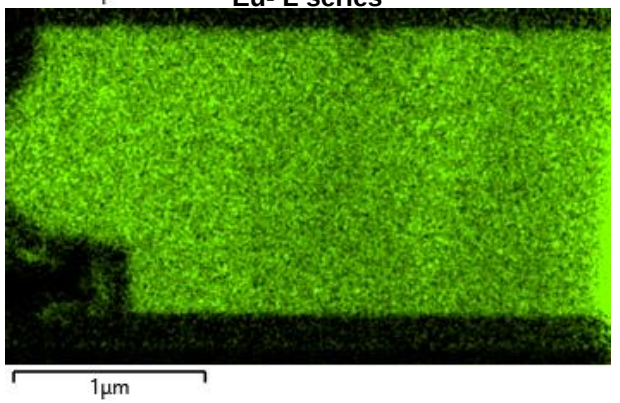


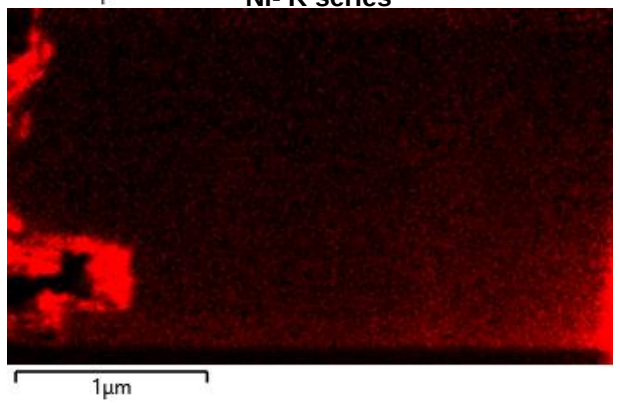








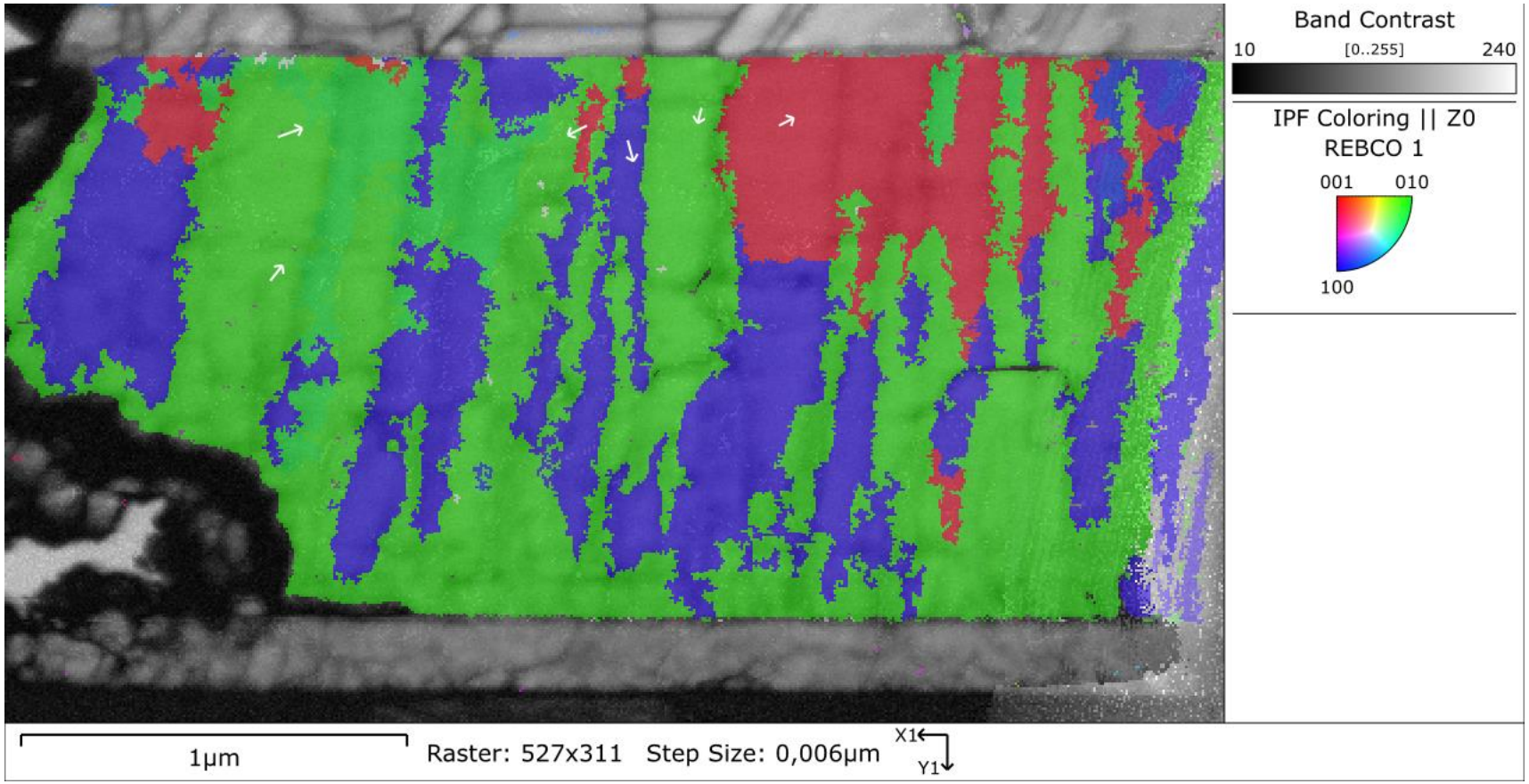




- Contamination due to Ni ablated from the substrate
- Slight thickness effect (lamella thickness inhomogeneity)
- No obvious oxygen content gradient

Additional analysis: EBSD (producer 2)

EBSD on extracted cross-sectional lamella (edge)



- Majority of REBCO film c-axis oriented; a-axis regions possible, but further investigation required

Comparison

Comparison of different configurations proposed

Producer	1	2	3
FIB source	Xe	Ga	Xe
Laser	stand alone	integrated (pre-chamber)	integrated
Laser type	ps/fs	fs	fs
Single trench length (mm)	45	40	1
Load lock	Y	Y	N

Comparison

Comparison of different configurations proposed

Producer	1	2	3
FIB source	Xe	Ga	Xe
Laser	stand alone	integrated (pre-chamber)	integrated
Laser type	ps/fs	fs	fs
Single trench length (mm)	45	40	1
Load lock	Y	Y	N

Conclusion

Preliminary test of REBCO tape filamentisation using laser beam integrated in FIB-SEM

- Three FIB-SEM producers considered
- Different FIB sources proposed: Xe (plasma FIB) or Ga (conventional source)
- Three laser configurations proposed: stand alone, integrated (pre-chamber) and fully integrated
- Single trench length varies considerably, from c. 1 mm to > 40 mm
- After patterning a considerable amount of material ablated redeposited on the strips
- EDS and EBSD on cross-sectional lamella feasible
- Analysis of cross-sectional lamella to detect possible negative effects due to laser patterning revealed no apparent damage on REBCO film integrity

Thank you
for your attention

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