SWTEST

PROBE TODAY, FOR TOMORROW

2024 CONFERENCE

Fully integrated probes made by µ3D printing for customizable, fine-pitch test solutions

EXADDON

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- Introduction: µ3D printing for testing
- Goal: test µLED
- Wrap up 2023
- µLED testing method
- µLED testing results
- Discussion of results
- Summary
- Follow-on work: more than µLED

Introduction of µ3D printing

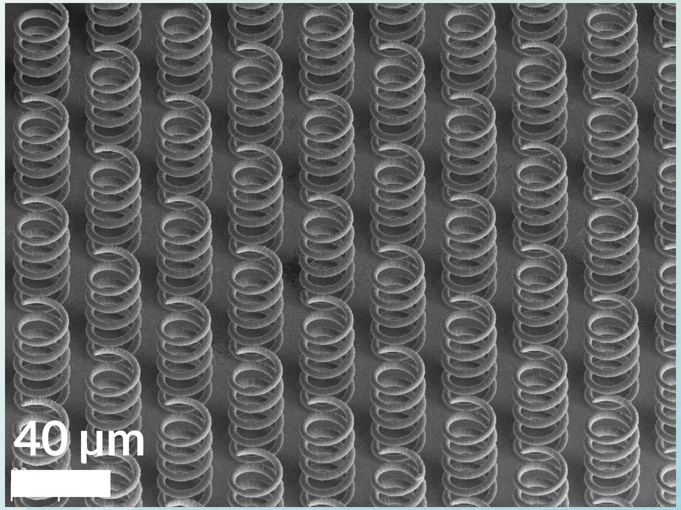
- 3D print with a 500-nm-wide nozzle
- Print pure copper
- Template-free
- Local electrodeposition

Next level benefits for testing

- Unlock a small probe pitch
- Automated process
- High degree of force control

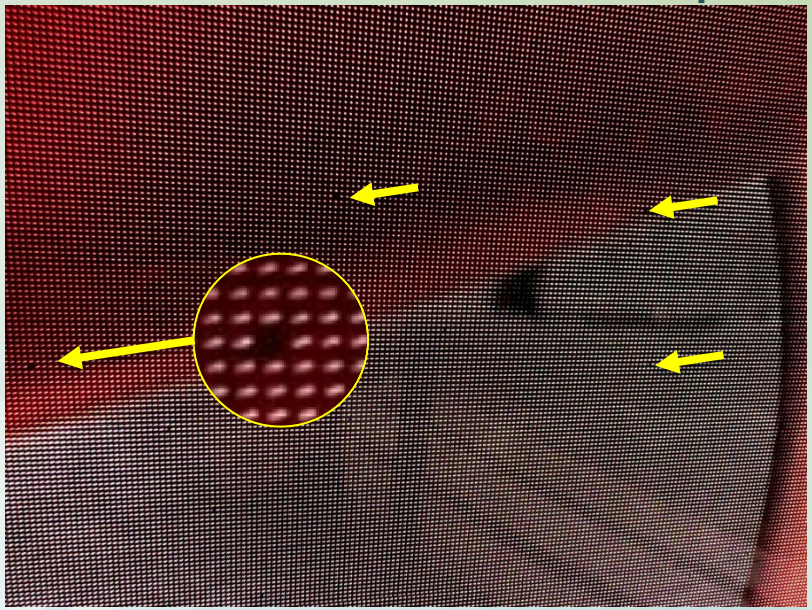
render

SEM



µLED has a bright future

- µLED is a promising, new display technology
  - Extreme brightness
  - No burn-in
- The testing is crucial, but not yet satisfactorily solved



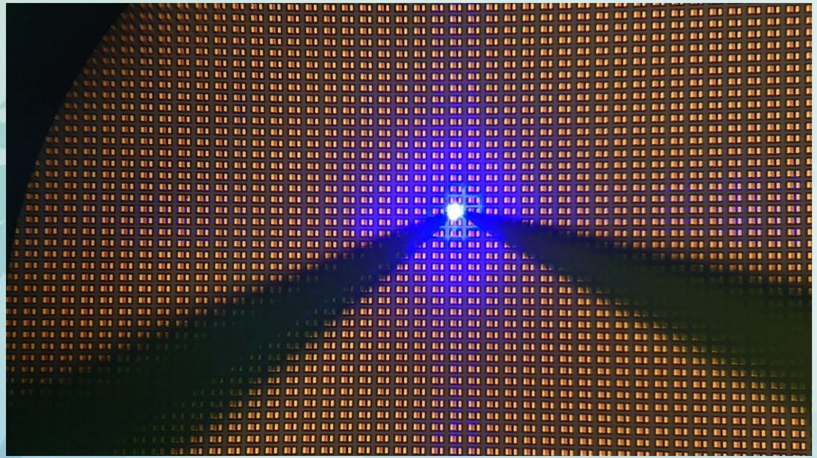
Reasons to test on the wafer:

- Only transfer the known-good µLEDs to the display
  - Reduce display repair
  - Higher quality display
    - less defects
    - uniform intensity
    - correct wavelength
- Get direct feedback on manufacturing process
  - Much faster yield increase in µLED production
- Classify wafers, µLEDs and vendors based on quality

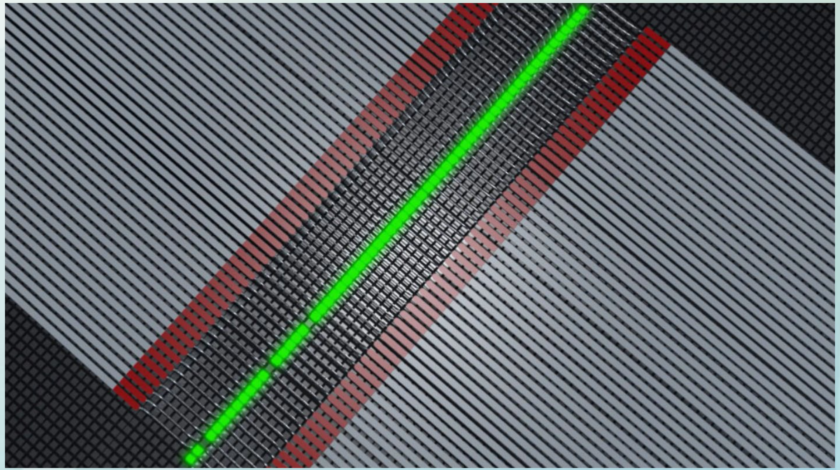
µLED testing challenge

- Challenge 1: test fine pitch µLEDs
  - 18.5 µm / 35.5 µm (provisional)
- Challenge 2: leave tiny scrub mark
- Challenge 3: test many µLEDs

1 Device Under Test



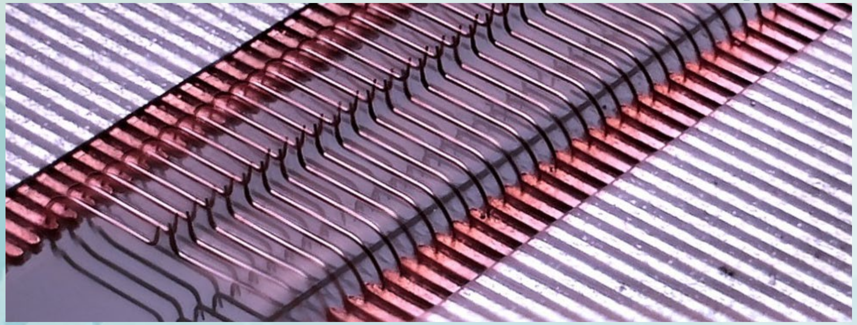
64 Devices Under Test



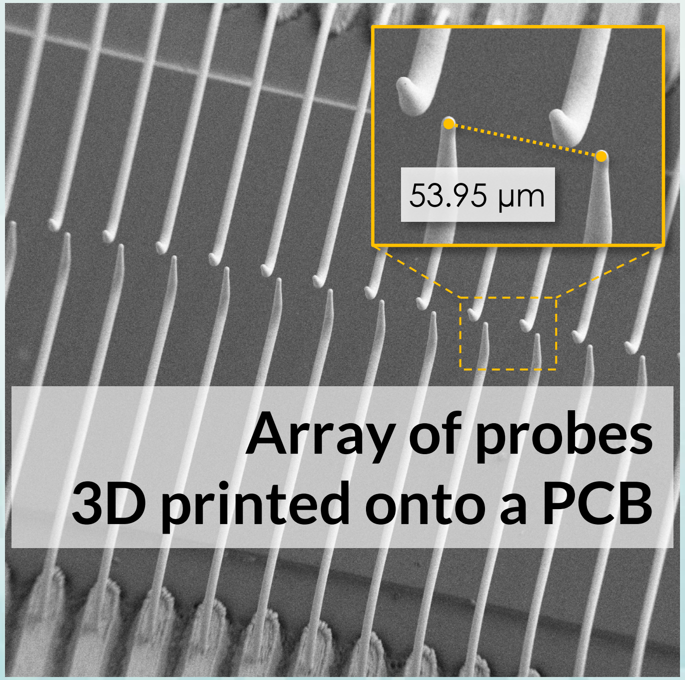
Wrap up 2023

- µ3D printing produces high-quality probes
- Excellent geometrical accuracy at required pitch
- Material properties outstanding, both mechanical and electrical
- Manufacturing process established

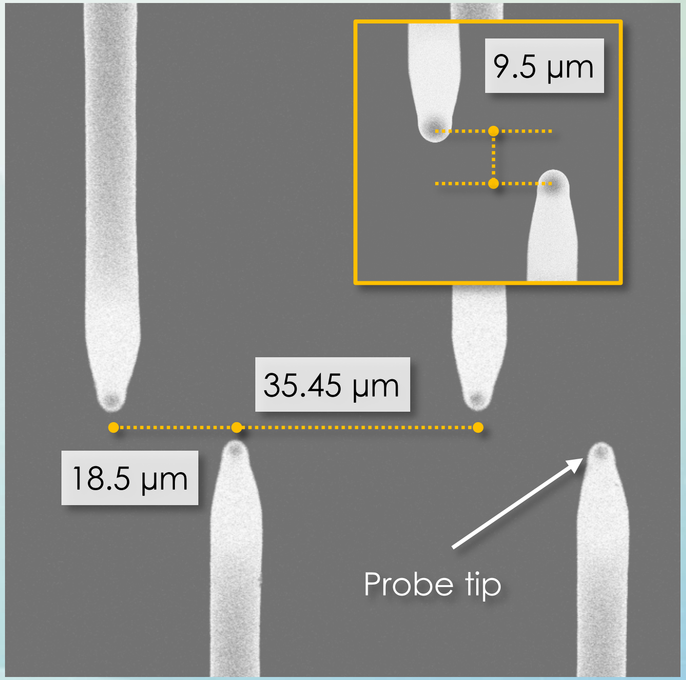
optical



SEM



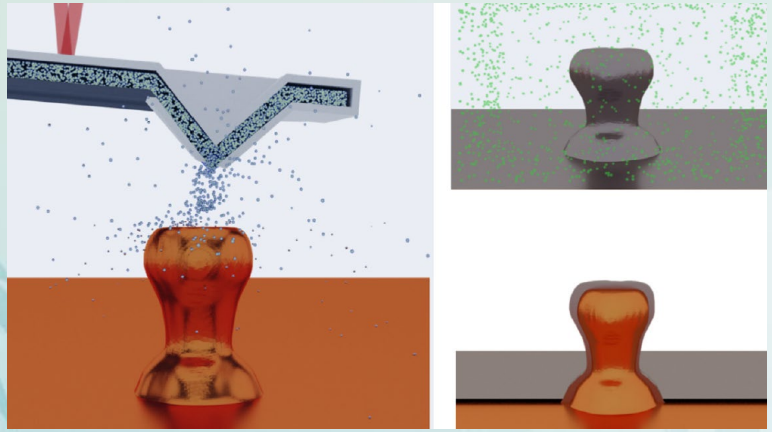
SEM

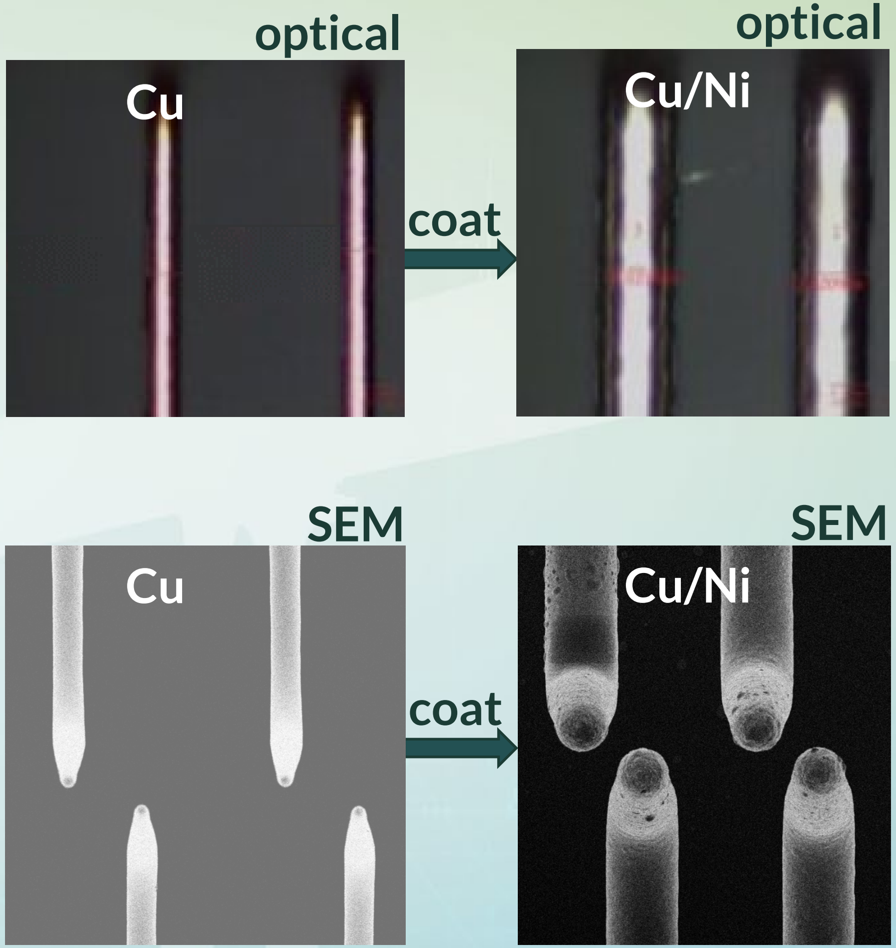


Probe design by A. Wang, Premtek

Core - shell

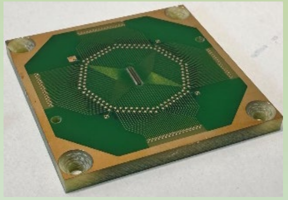
- Print copper
  - Conductivity: 87% of bulk[1]
  - Yield strength: 0.4 to 1.0 GPa[2]
- Plate with nickel for strength[3]:





[1] Schürch *et al.* Materials & Design, 2023.
[2] Ramachandramoorthy *et al.* Appl. Mat. Today, 2022.
[3] Jain *et al.* Materials & Design, 2023

Manufacturing process



Step 1.
Make µPCB

Step 2.
Local 3D printing

Step 3.
Global electroplating

Full integration for wafer test

MPI Photonics Automation — Probe station

ADVANTEST — Multichannel tester

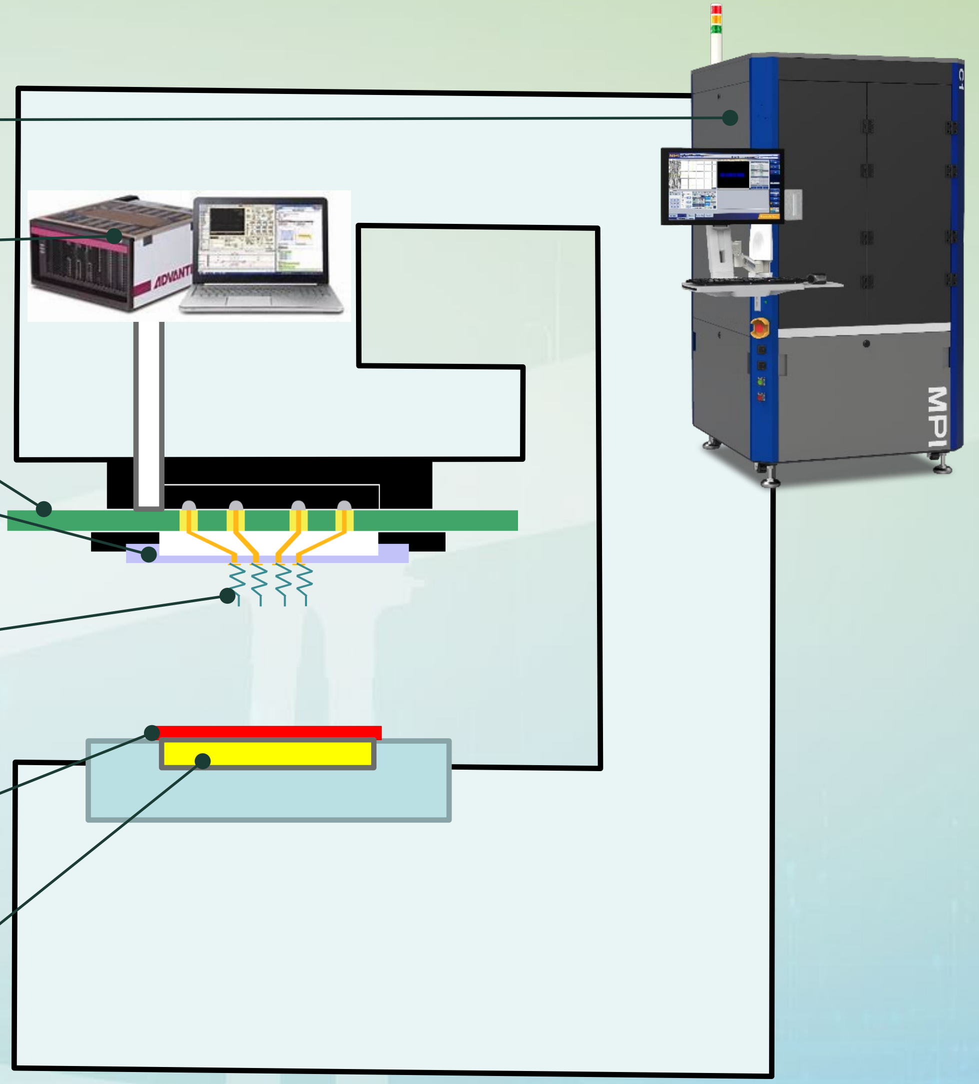
SYNERGIE CAD GROUP — Probe card

SYNERGIE CAD GROUP — µPCB

EXADDON — µ3D probes

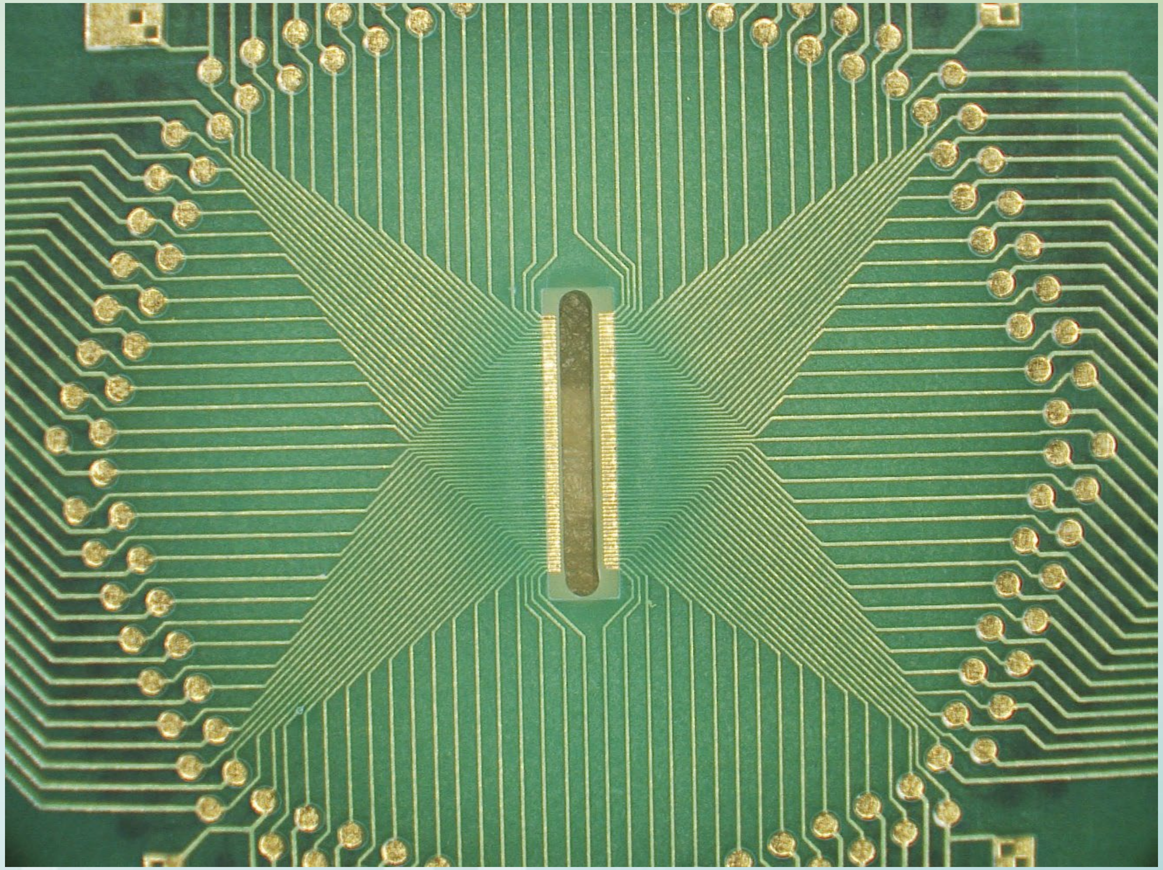
End customer — µLED wafer

ADVANTEST — Optical read out



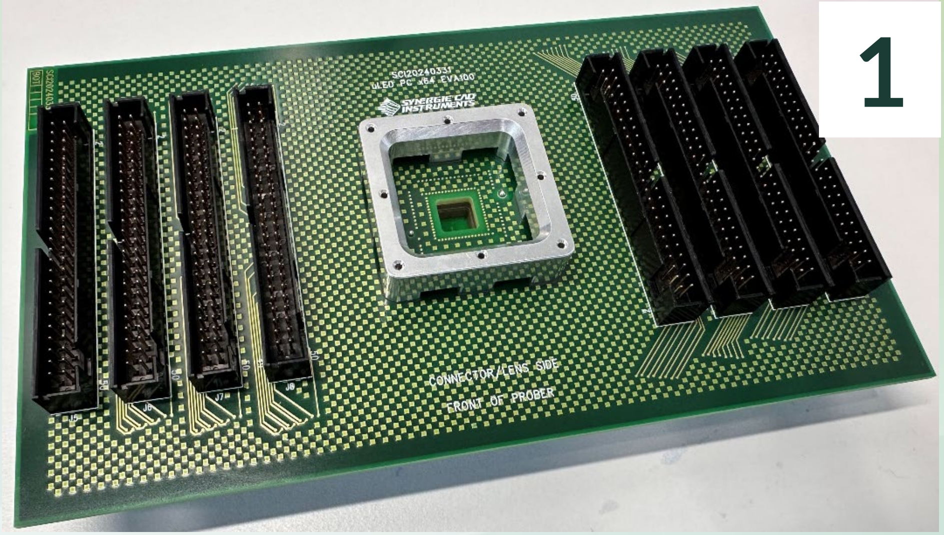
Integration: create µPCB

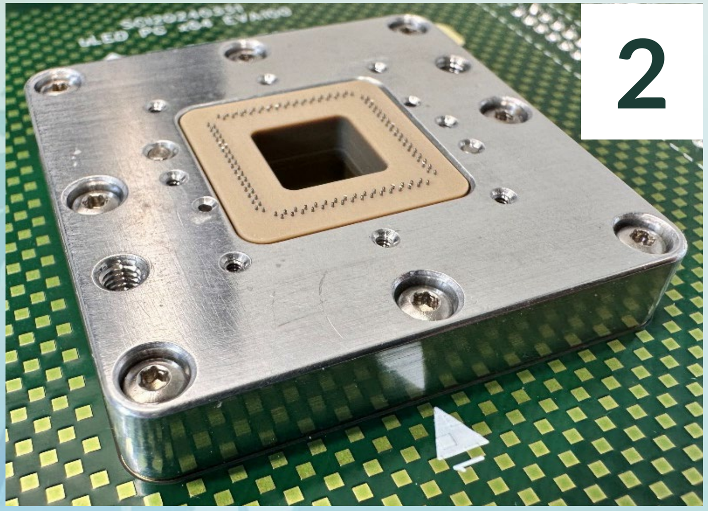
- Multi-layer µPCB acts as:
  - Interposer
  - Probe head
  - Fan-out
- 27-µm-wide metal traces at a pitch of 54 µm
- Highest accuracy in the manufacturing process needed

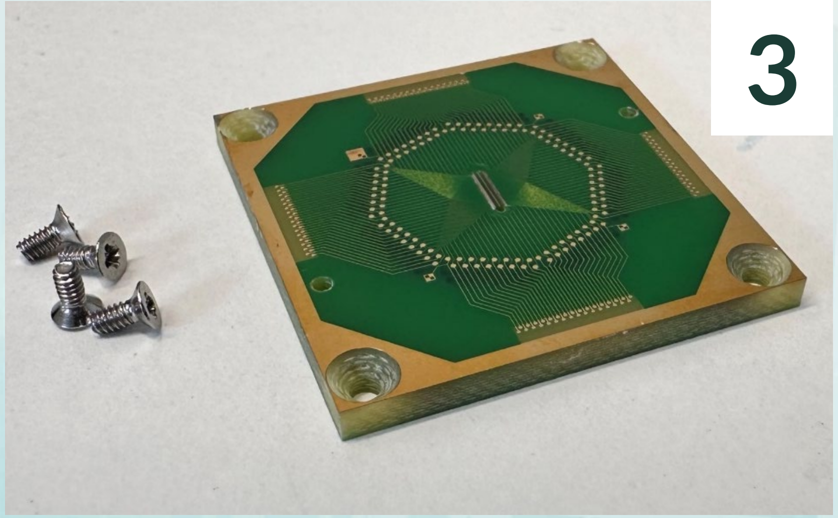


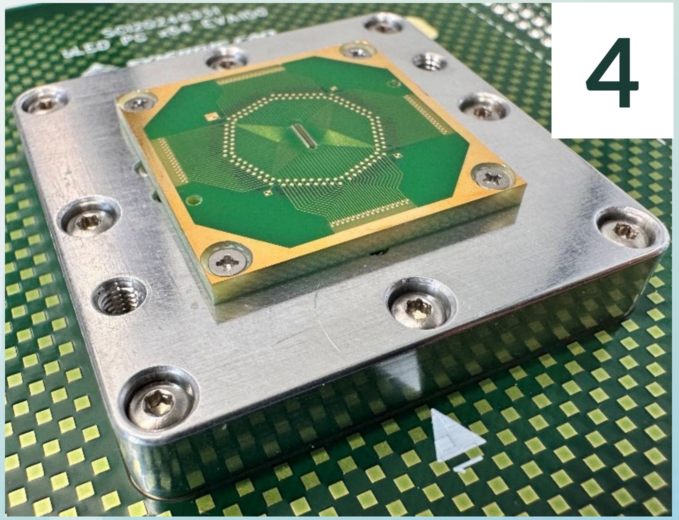
Integration: µPCB onto probe card

- Modular probe head
- Force-sense (Kelvin probe)
- Fast exchange of µPCB
- High up-time of probe station





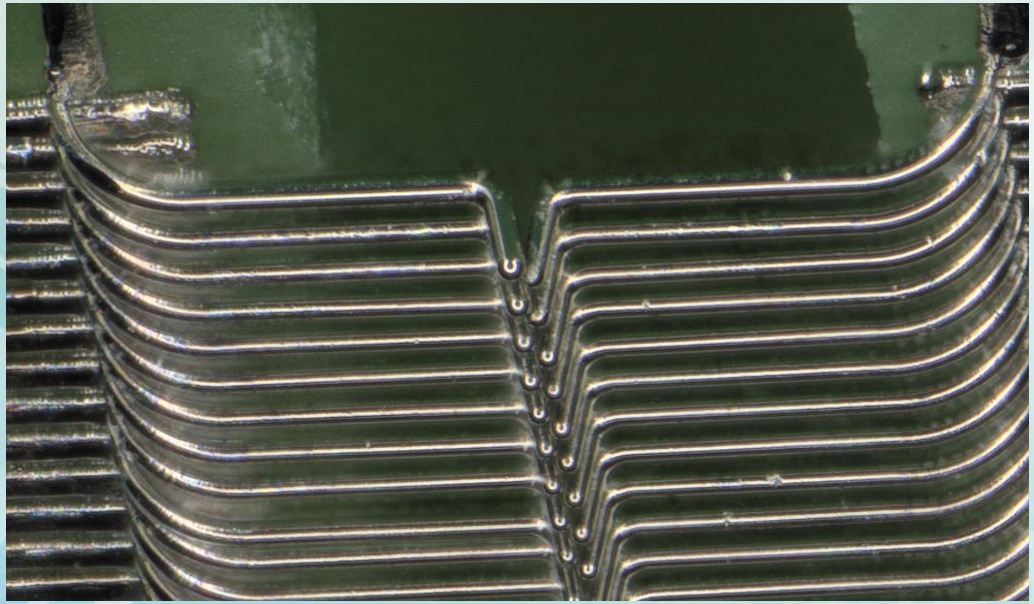


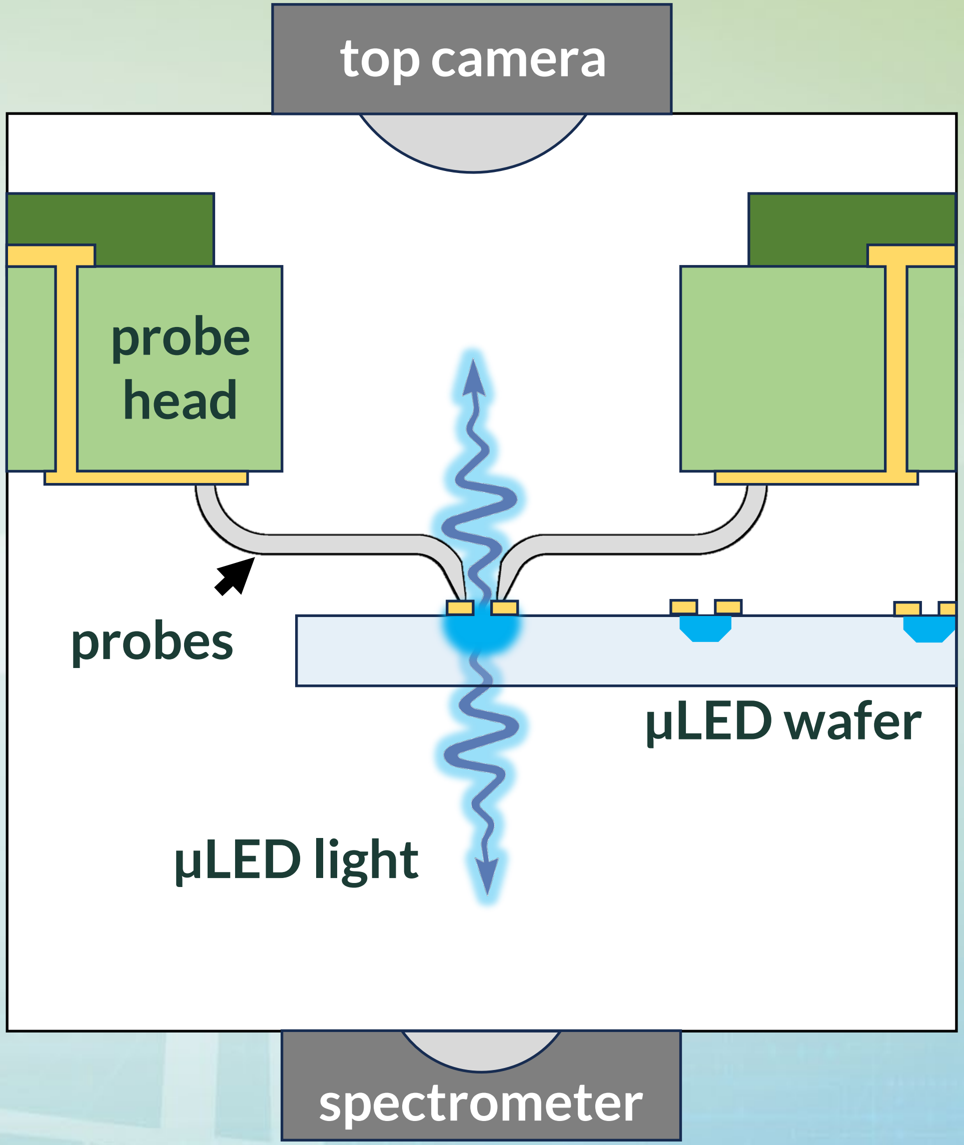


Testing protocol

- 64 channels parallel
  - Advantest EVA 100
- Probe card into probe station
  - MPI C1 prober

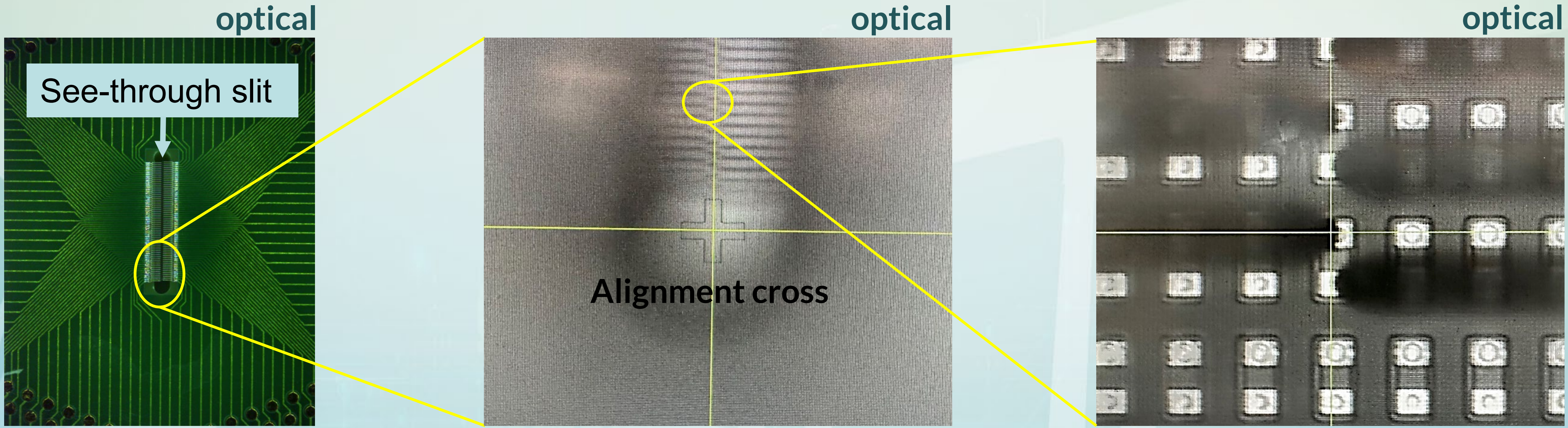
optical



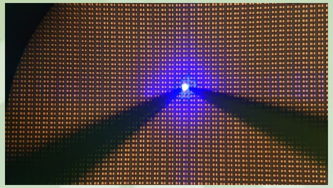


Dual testing & alignment

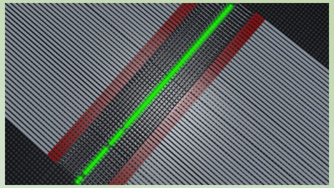
- Simultaneous testing
- Probes for the electrical test
- Slit for the photo detector



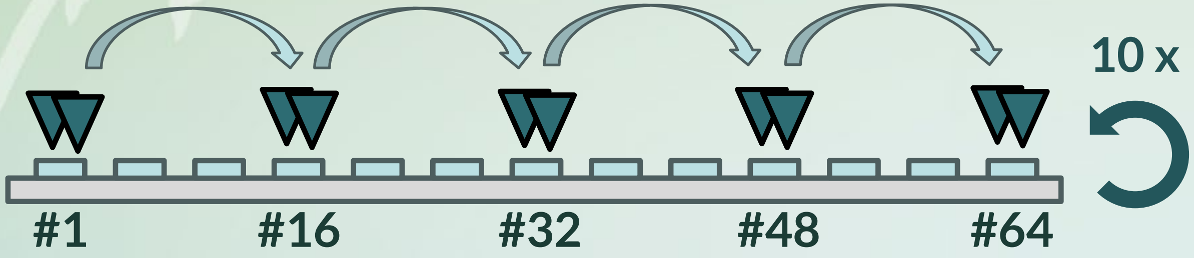
Probe 1 DUT or 64 DUT



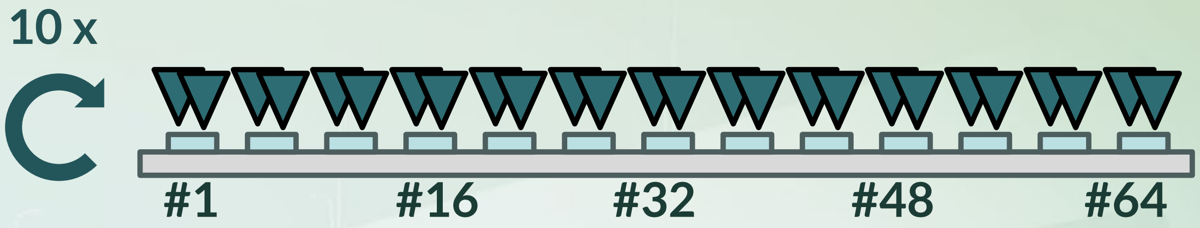
2 probes (conventional)



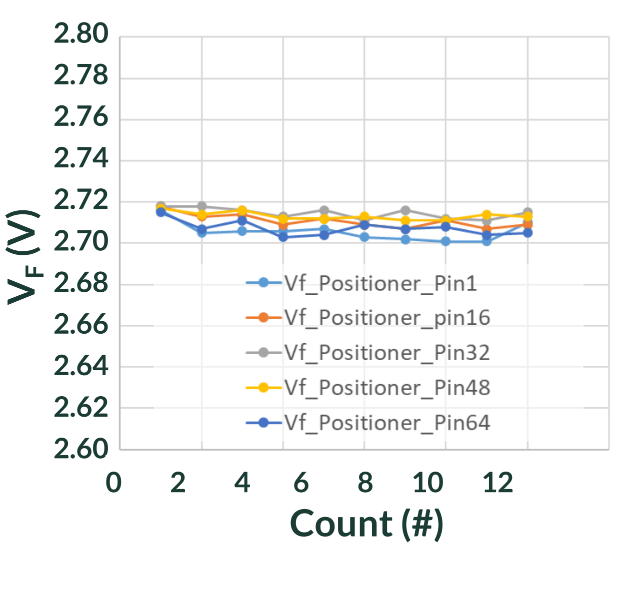
128 probes (µ3D printed)

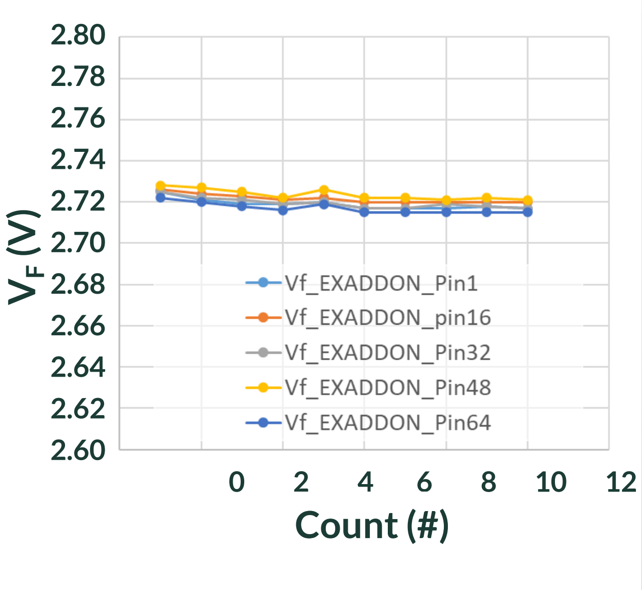


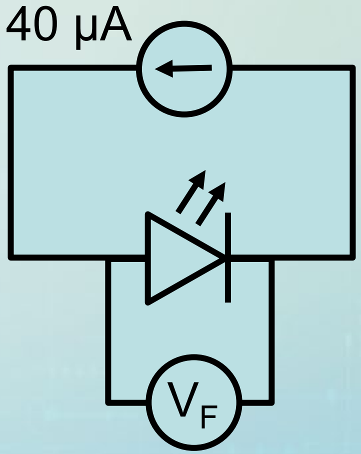
1 DUT (sequential)



64 DUT (parallel)

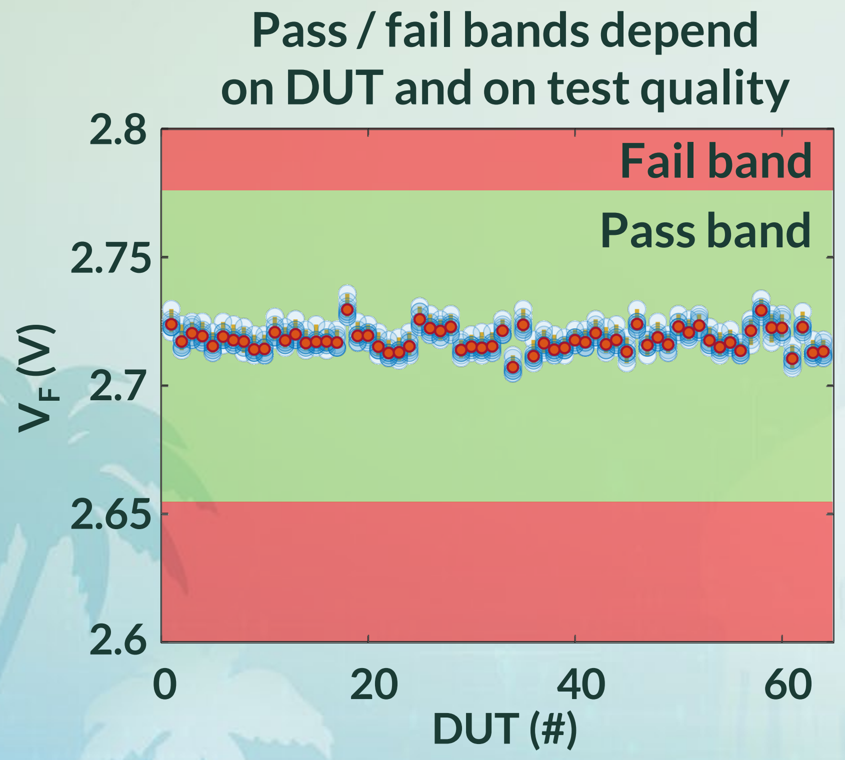


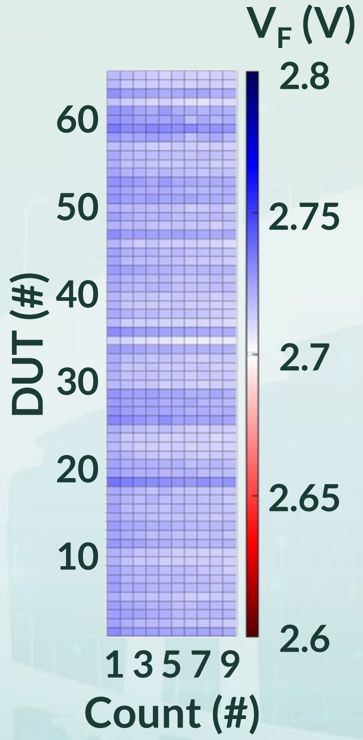


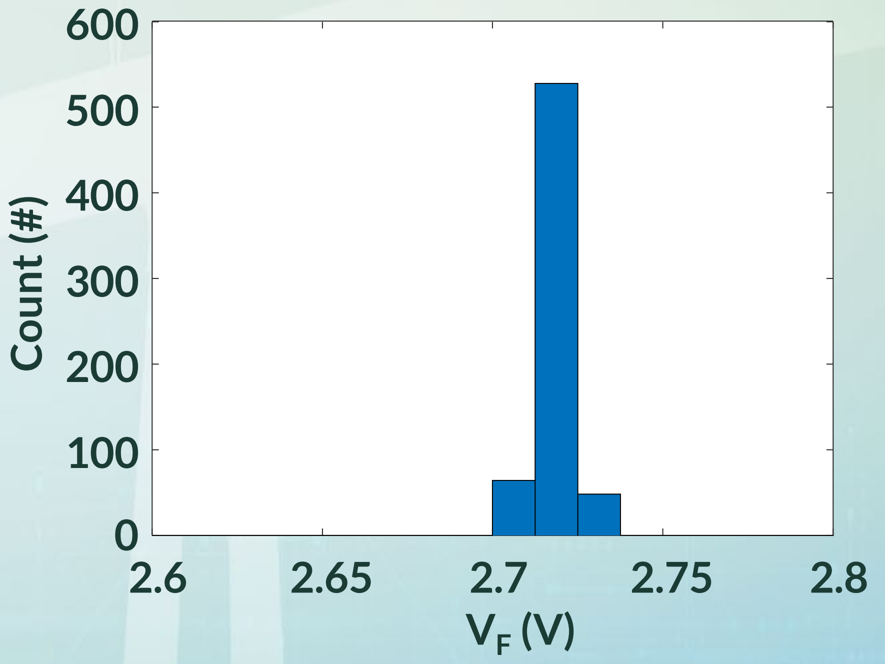


Repeatability @ 12 µm OD

- Measure forward voltage at 12 µm overdrive (OD)
- 64 channels – 10 repetitions on same set of 64 µLEDs

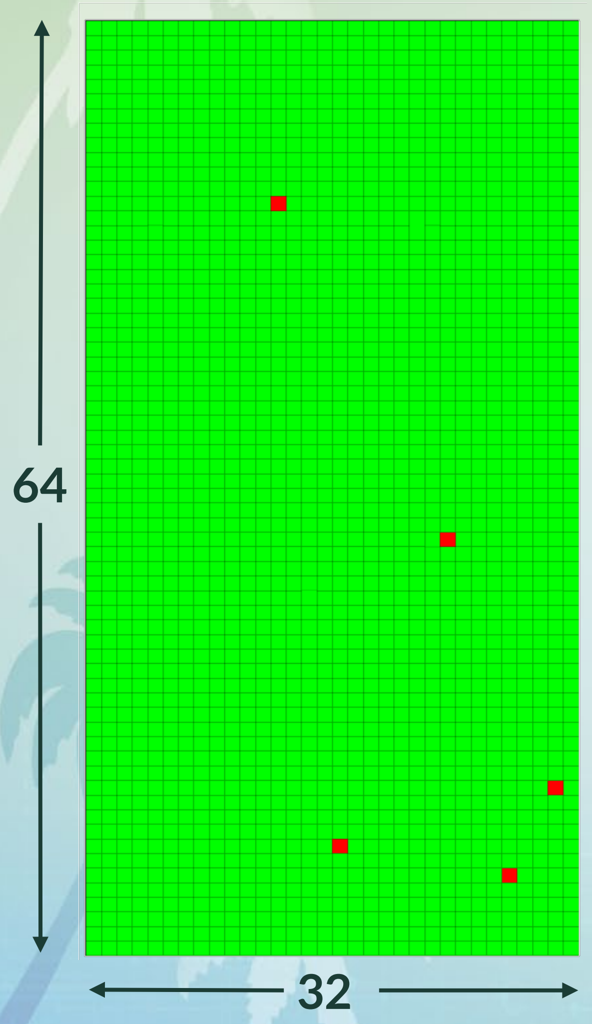




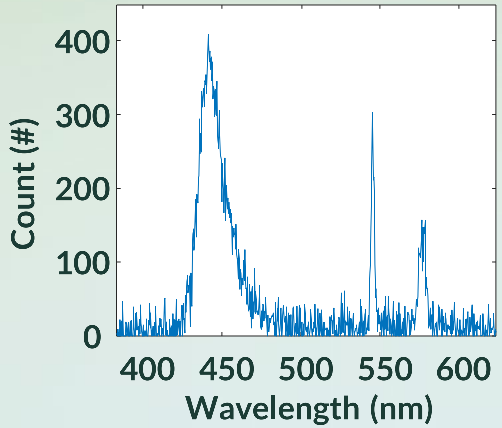


Wafer scan of a 64 x 32 µLED matrix

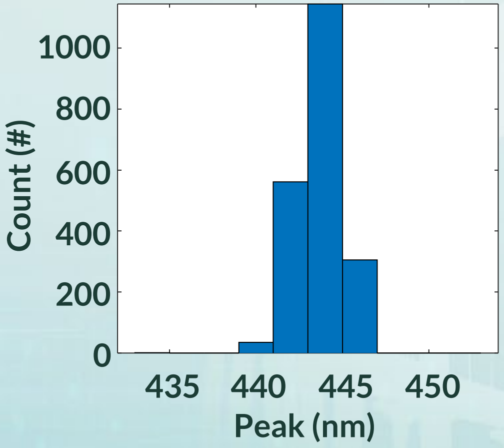
Electrical screening



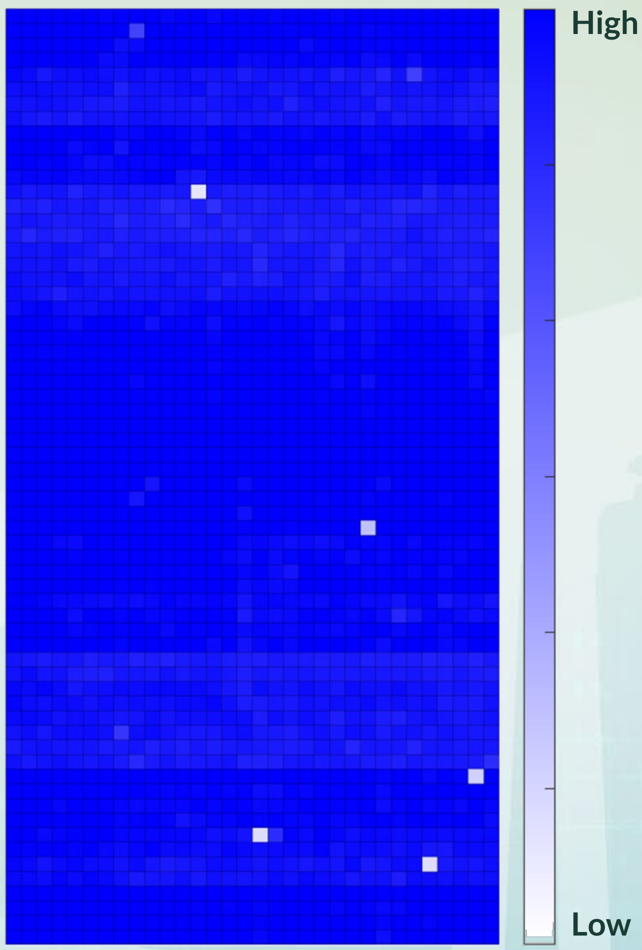
Optical spectra



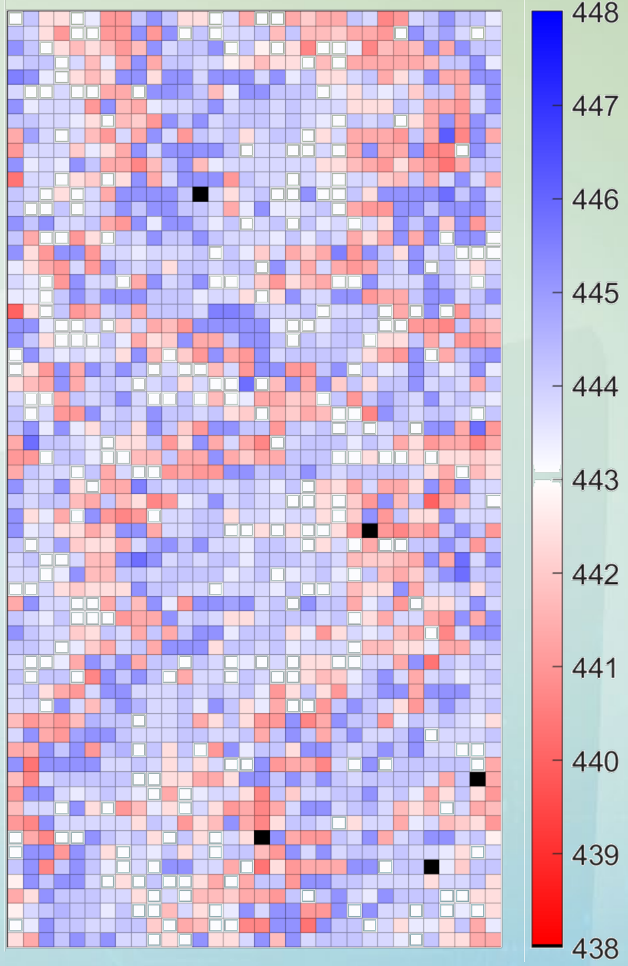
Wavelength



Light intensity



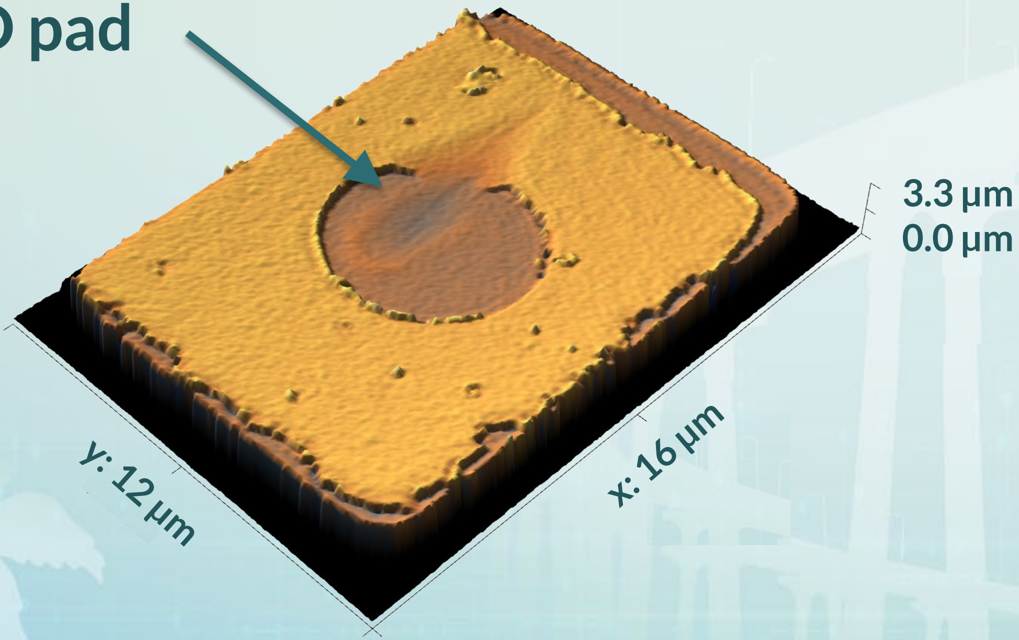
Peak wavelength (nm)



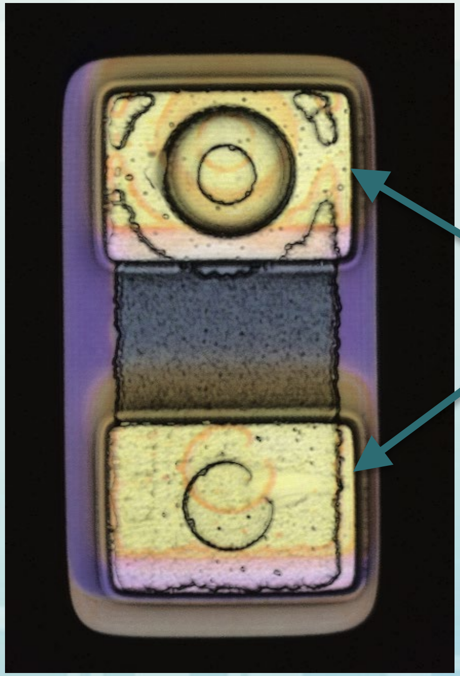
Scrub mark

- High-planarity allows a low OD
- Gold pads allow low force
- 34 touchdowns @ 16µm OD: 100-nm-deep scrub mark

Scrub mark on µLED pad



Low-invasive testing



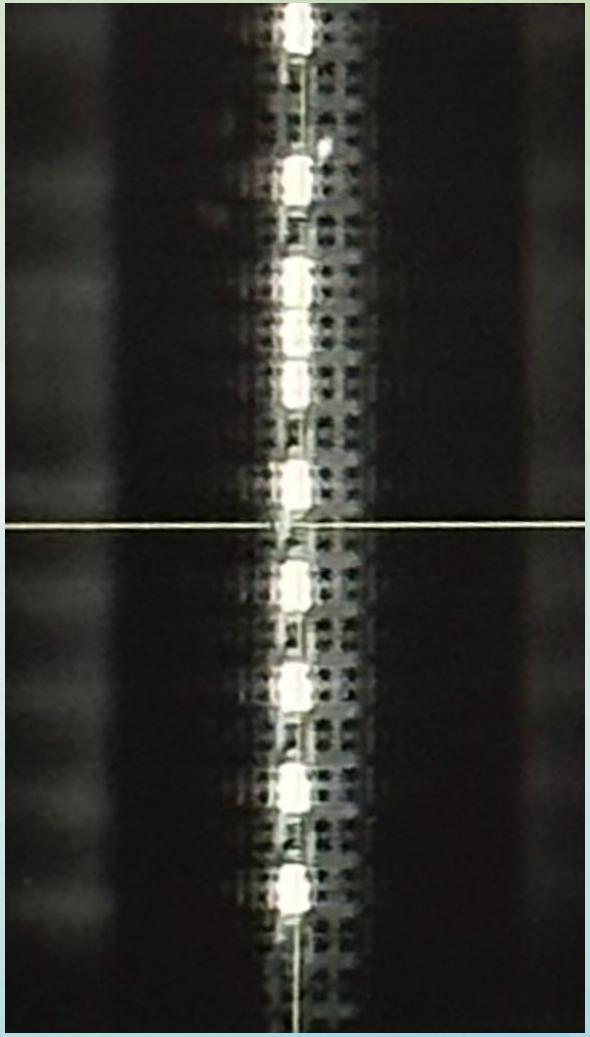
Scrub mark on µLED pad

Discussion

- Replace probe substrate instead of probe repair
- Massively parallel: 64 DUTs → 128 DUTs → 256 DUTs
- Probe substrate and redistribution not trivial
- Life-time test on device to be done
  - Aiming for 2 million touchdowns

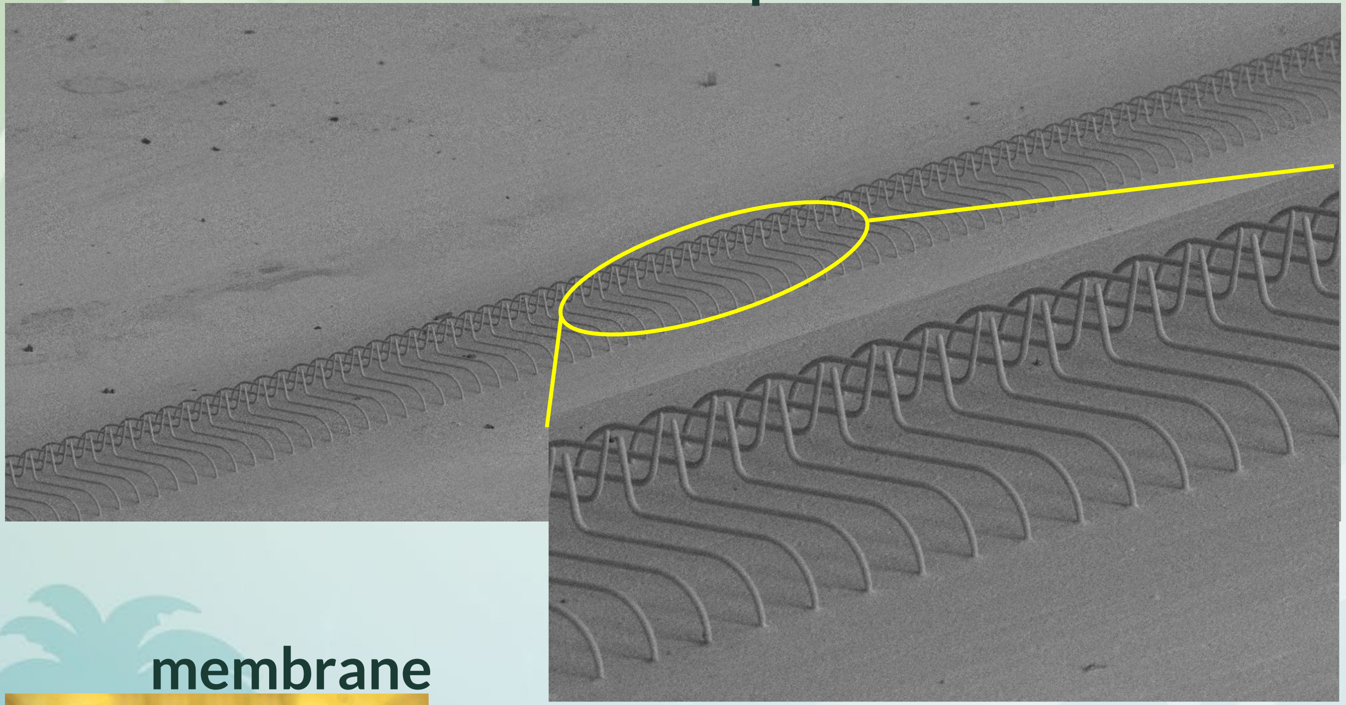
Summary

- Fully integrated demo of parallel probing of fine-pitch μLED
  - 64 DUT
  - Optical and electrical screening
- Extremely small scrub marks: < 100 nm deep
- Fast customization leads to low lead-time for a probe card
- Good probe station up-time due to modularity

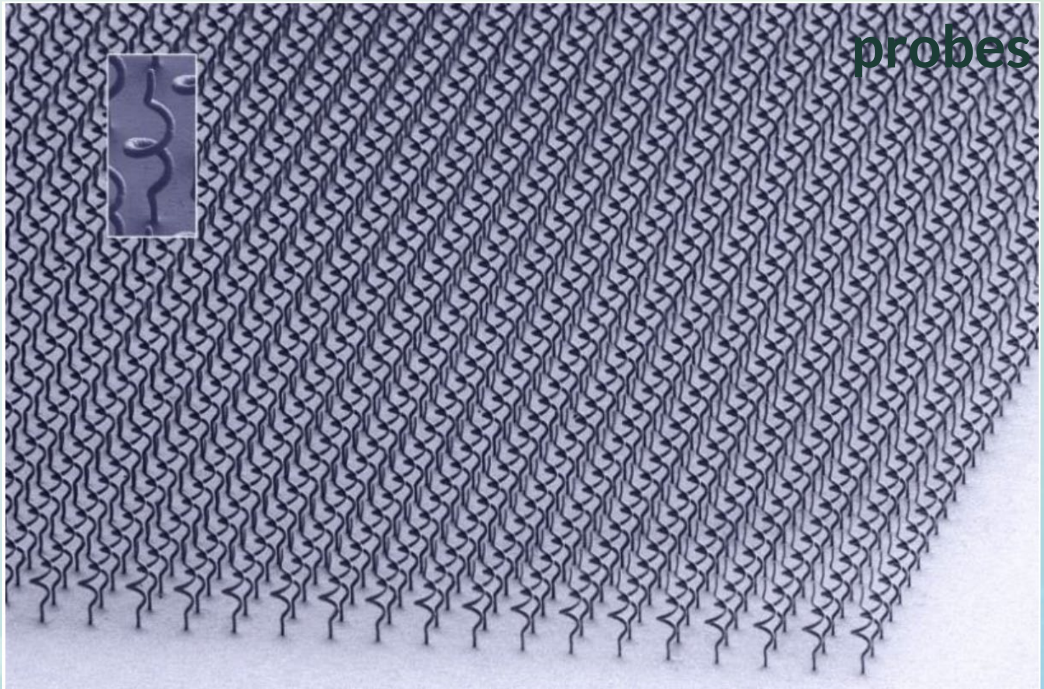


Follow on work: more than µLED

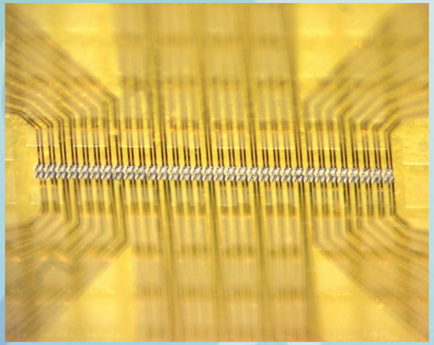
256 probes: 64 to 128 DUT



2000+ vertical probes



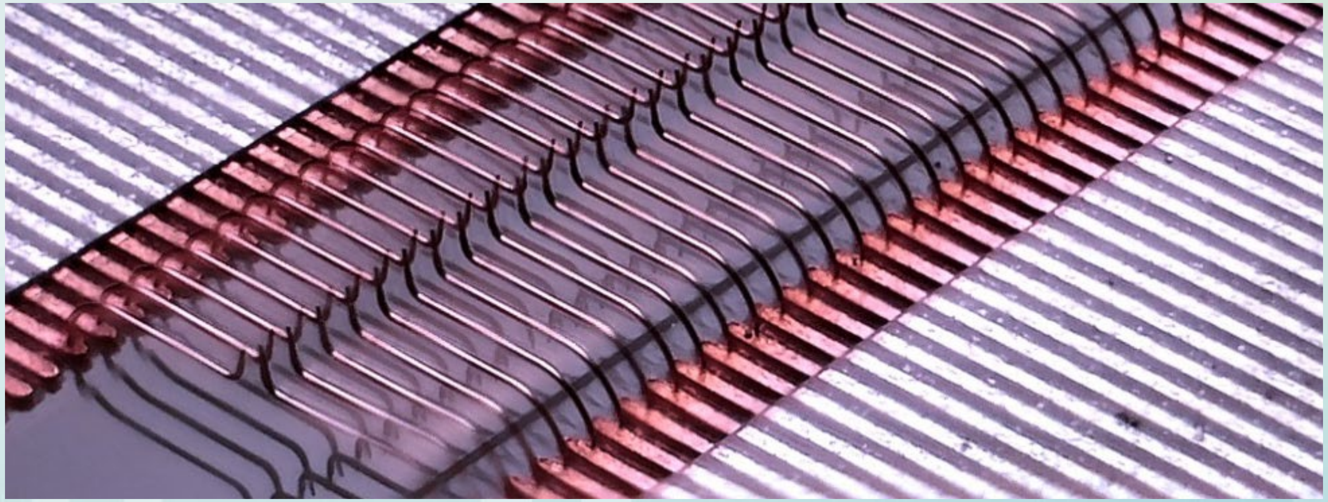
membrane



Thank you!

- Questions?
- Comments?

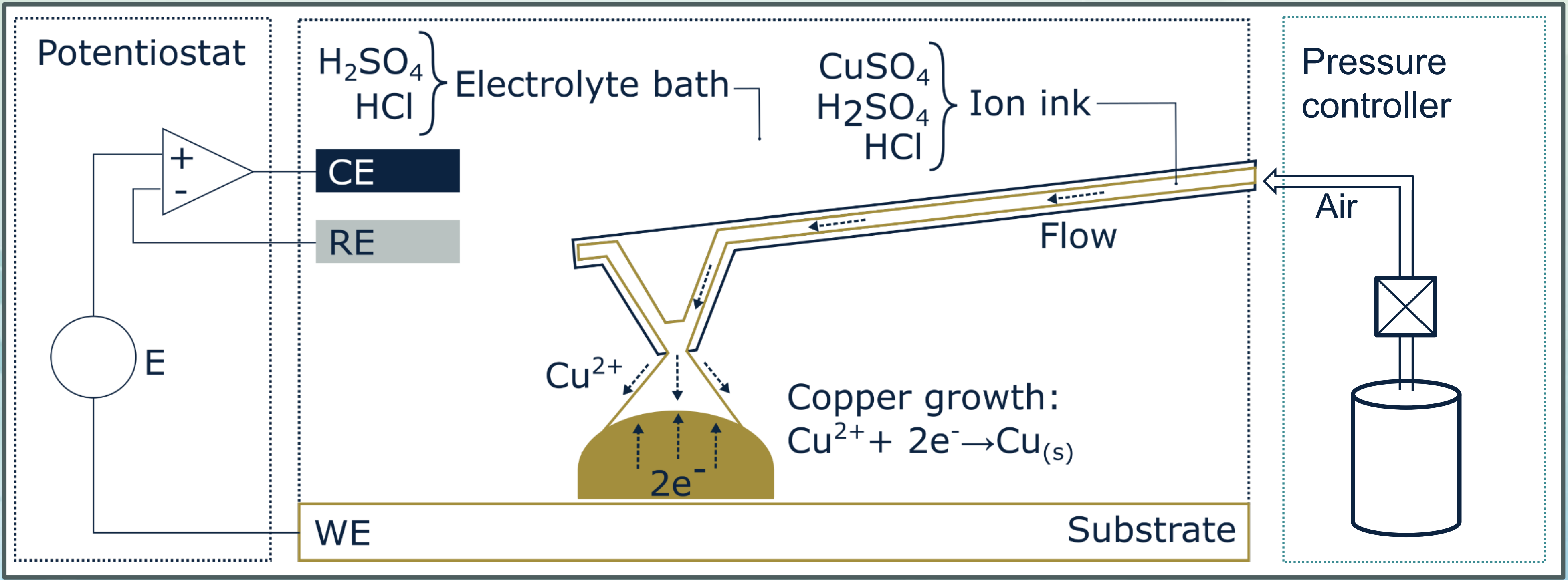
► Meet us at the Exaddon booth
► E-Mail: hello@exaddon.com
► Web: probes.exaddon.com



BACKUP SLIDES

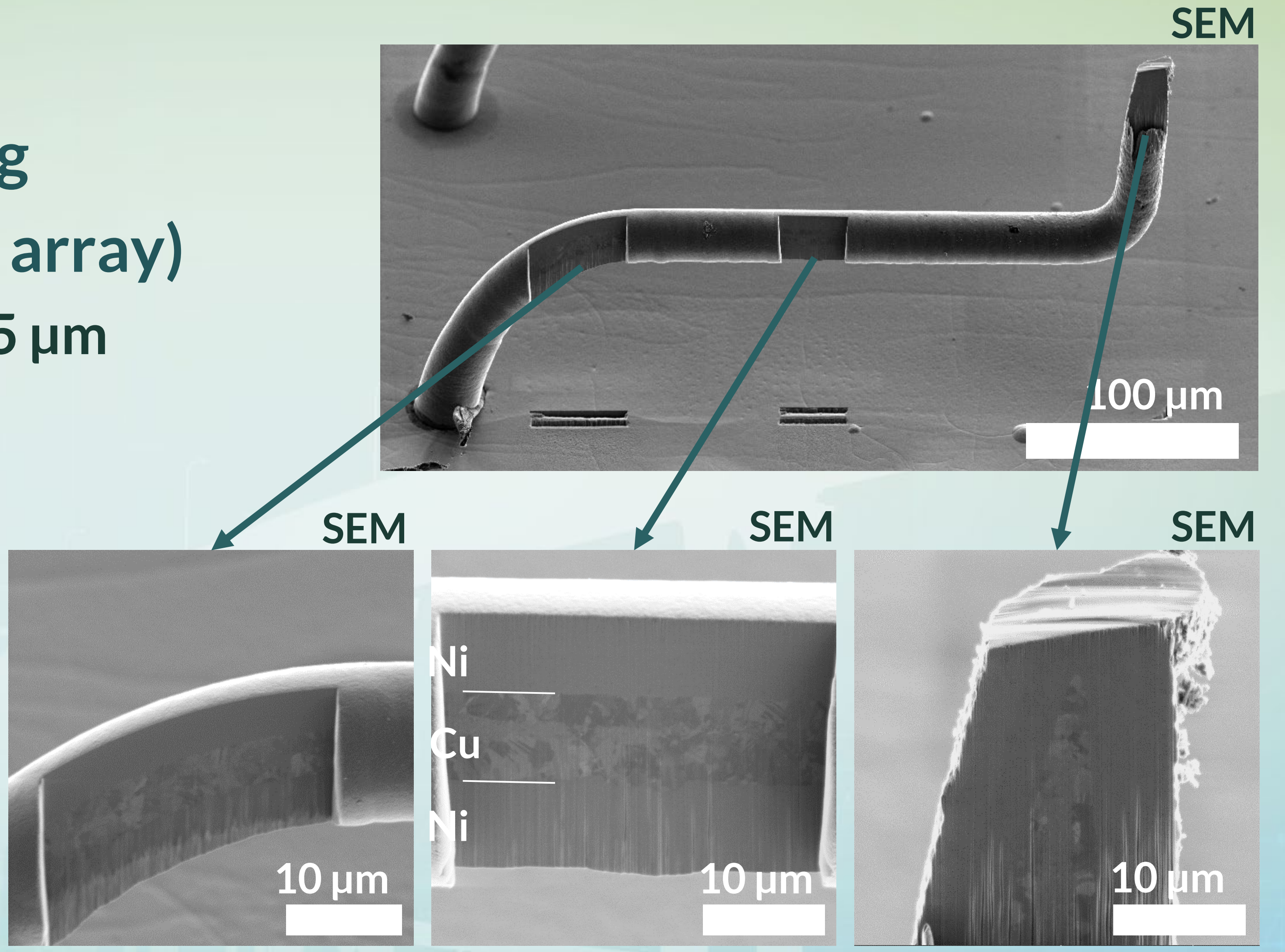
μ3D printing process

- The metal printing is conducted within an electrochemical cell
- The ion ink is delivered via a microchannel inside the cantilever
- Pressure controller regulates the air pressure propelling the electrolyte
- A potentiostat regulates the voltages required for deposition



Quality inspection by Focused Ion Beam

- Void-free materials
- Seamless layer merging
- Diameters (128-probe array)
  - Cu: 8.6 ± 0.5 µm
  - Cu / Ni: 21.9 ± 1.5 µm

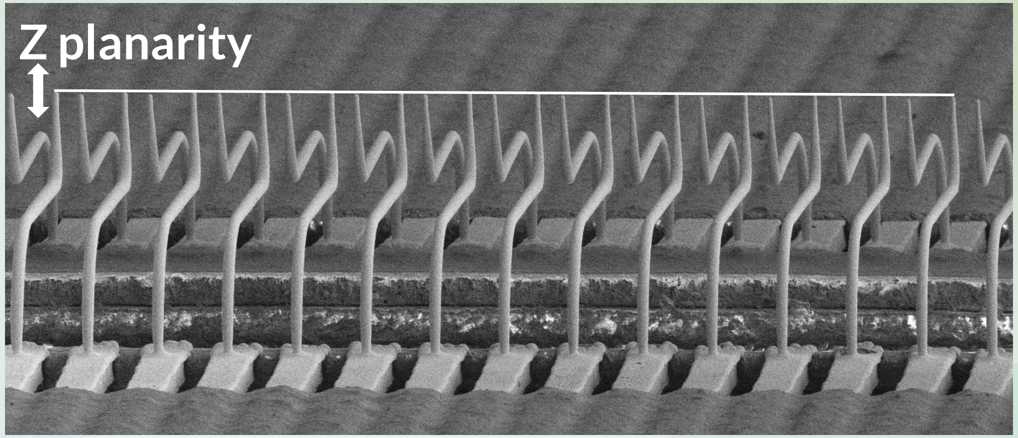


Z planarity and XY position in array

Analysis on 128-probe array:

- **Z-planarity:** ± 1.4 μm
  - Space transformer: ± 1.0 μm
  - Printing: ± 0.1 μm
  - Coating: ± 0.3 μm
- **XY position accuracy**
  - ΔX: < ± 1.5 μm
  - ΔY: < ± 1.5 μm

side view SEM



top view SEM