Flex platform for Low X/X_0 MAPS readout

28/04/2025, Flex circuits for FCC-ee

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The FlexBond team

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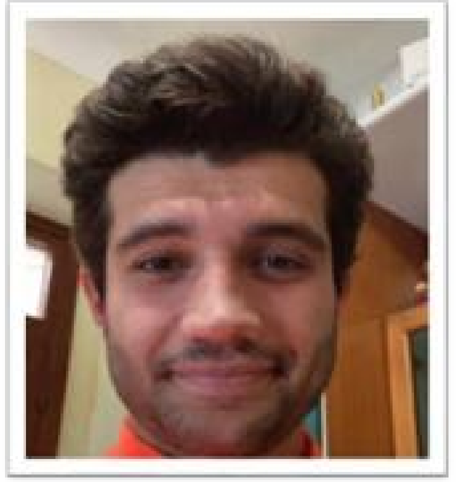

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FBK strong heritage
Radiation Detectors

Silicon Photomultipliers - SiPM

Single photon sensors produced in different technologies with range from VUV to NIR. They feature: high gain, high efficiency, low operational voltage, low power consumption, compactness and robustness.

Applications in:
Big physics experiments (DarkSide, CMS-BTL) • Space • Medical imaging (PET, ToF-PET) • LiDAR •

In partnership with: INFN, ASI, CERN, Broadcom Inc.

25 cm² SiPM array for DarkSide

Low Gain Avalanche Diodes - LGAD

Radiation sensors with low internal gain for ultra fast time resolution and improved SNR also at extreme fluences.
Technologies: Trench-Isolated LGAD, AC-coupled LGAD, Inverted-LGAD.

Applications:
• 4-D tracking for HEP (ATLAS and CMS) • Medical (hadron therapy) • Space • Soft x-ray imaging •

In partnership with: INFN, CERN, PSI, GSI

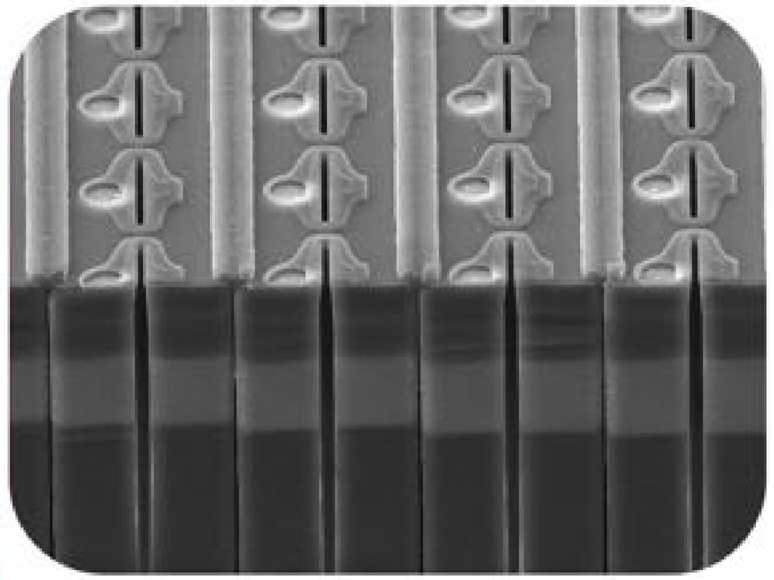
LGAD prototipe for ATLAS/CMS

Silicon 3D Detectors

Radiation sensors with vertical junction and ultra fast time resolution also at extreme fluences. Active edge technology.

Applications in:
Particle tracking and timing in HEP experiments (ATLAS ITK, CMS, CT PPS)

In partnership with: CERN, INFN



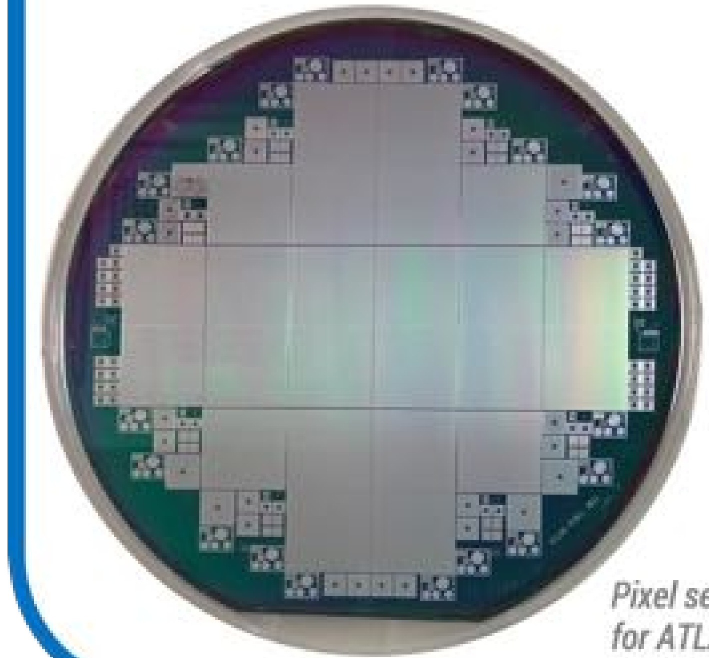
3D detector for «TimeSpot» project

Strip & Pixel Detectors

Pixelated sensors for particle and x-rays, with low leakage current, single or double sided process and thin entrance window for x-ray imaging

Applications in:
• Particle tracking and timing in HEP experiments (ATLAS, CMS) • Space experiments (LIMADOU) • X-ray imaging

In partnership with: CERN, INFN, PSI



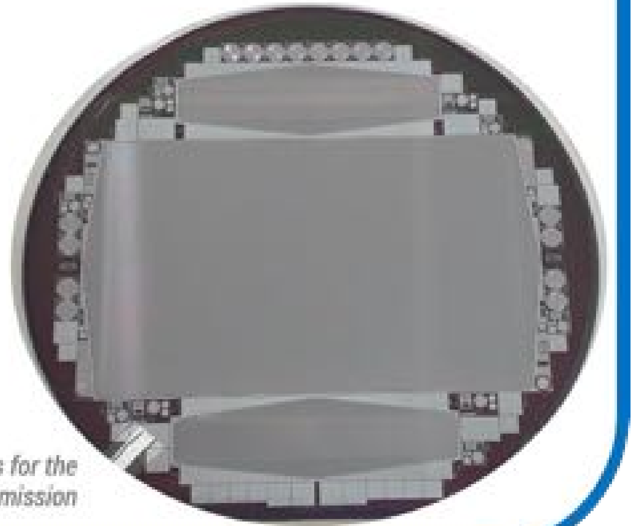
Pixel sensors for ATLAS

Silicon Drift Detectors - SDD

Low leakage radiation sensors with large area (up to 10x10 cm²), thin entrance window and high energy resolution

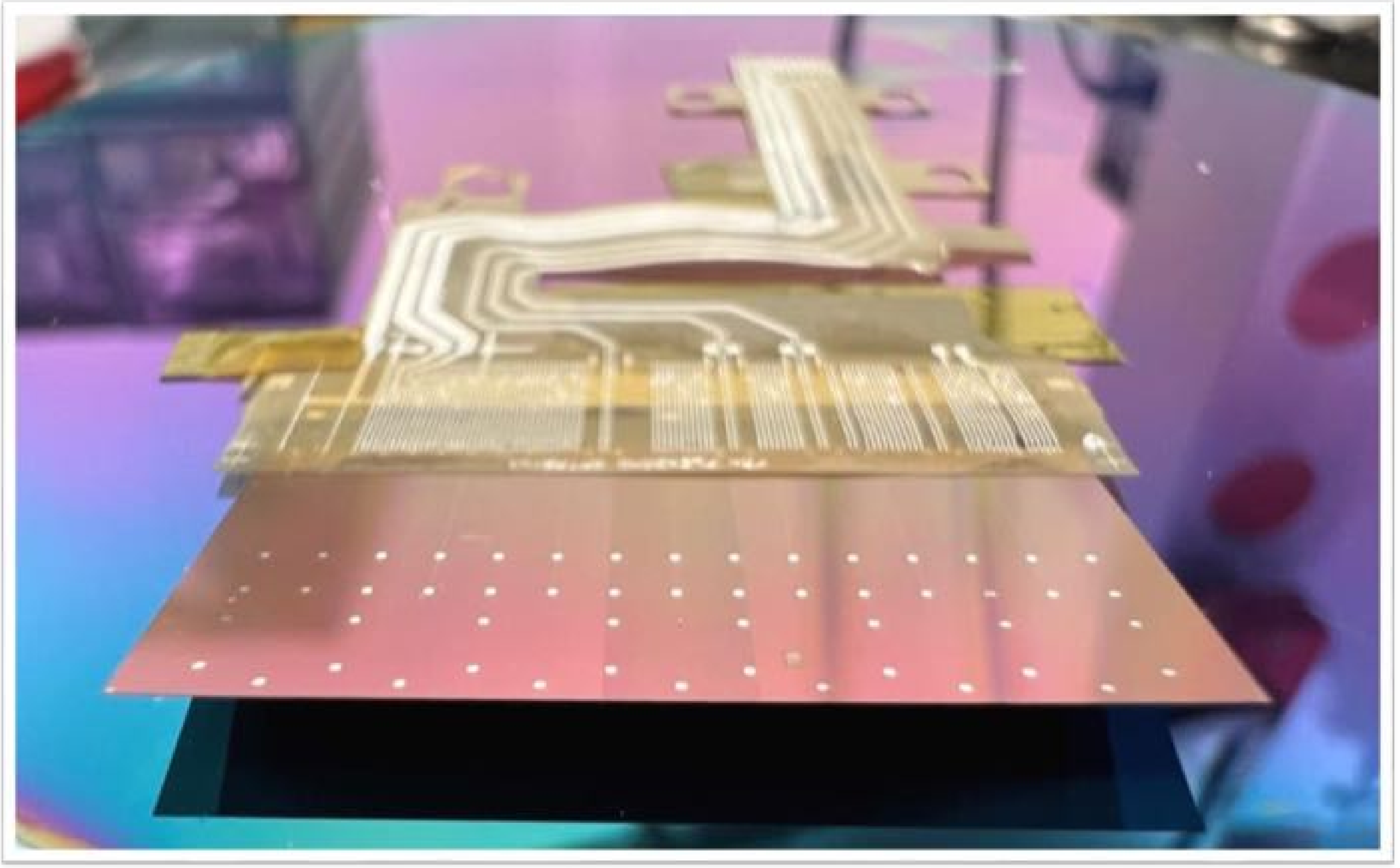
Applications in:
• γ- and x-rays spectroscopy • CsI scintillation light detection • Large area SDDs for x-ray astronomy •

In partnership with: INAF, ASI, INFN, Elettra Synchrotron



Large area SDDs for the eXTP mission

R&D towards a new tech platform: Low X/X_0 Flex
The FlexBond recipe

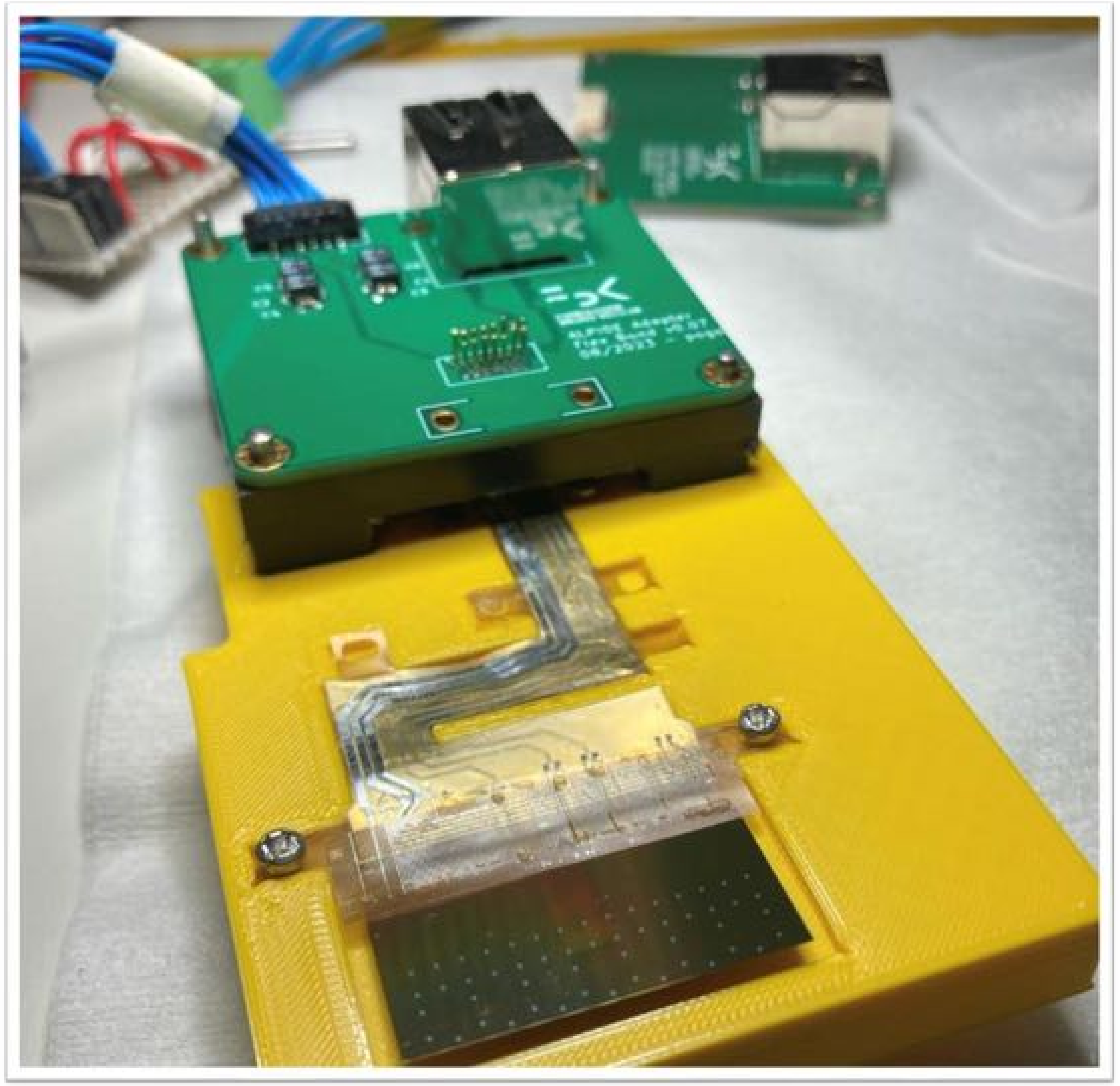


50 µm ALPIDE chip + 90 µm Aluminium-Kapton flex PCB double layer

- **Flex cable with Aluminium**
  - (X_{0Al} = 8.9 cm, X_{0Cu} = 1.4 cm)

- **Minimal thickness**
  - 20 µm Al /layer
  - 25 µm Kapton /layer
  - 0.03% X/X0 /layer
    (can be further reduced)

R&D towards a new tech platform: Low X/X_0 Flex
The FlexBond R&D



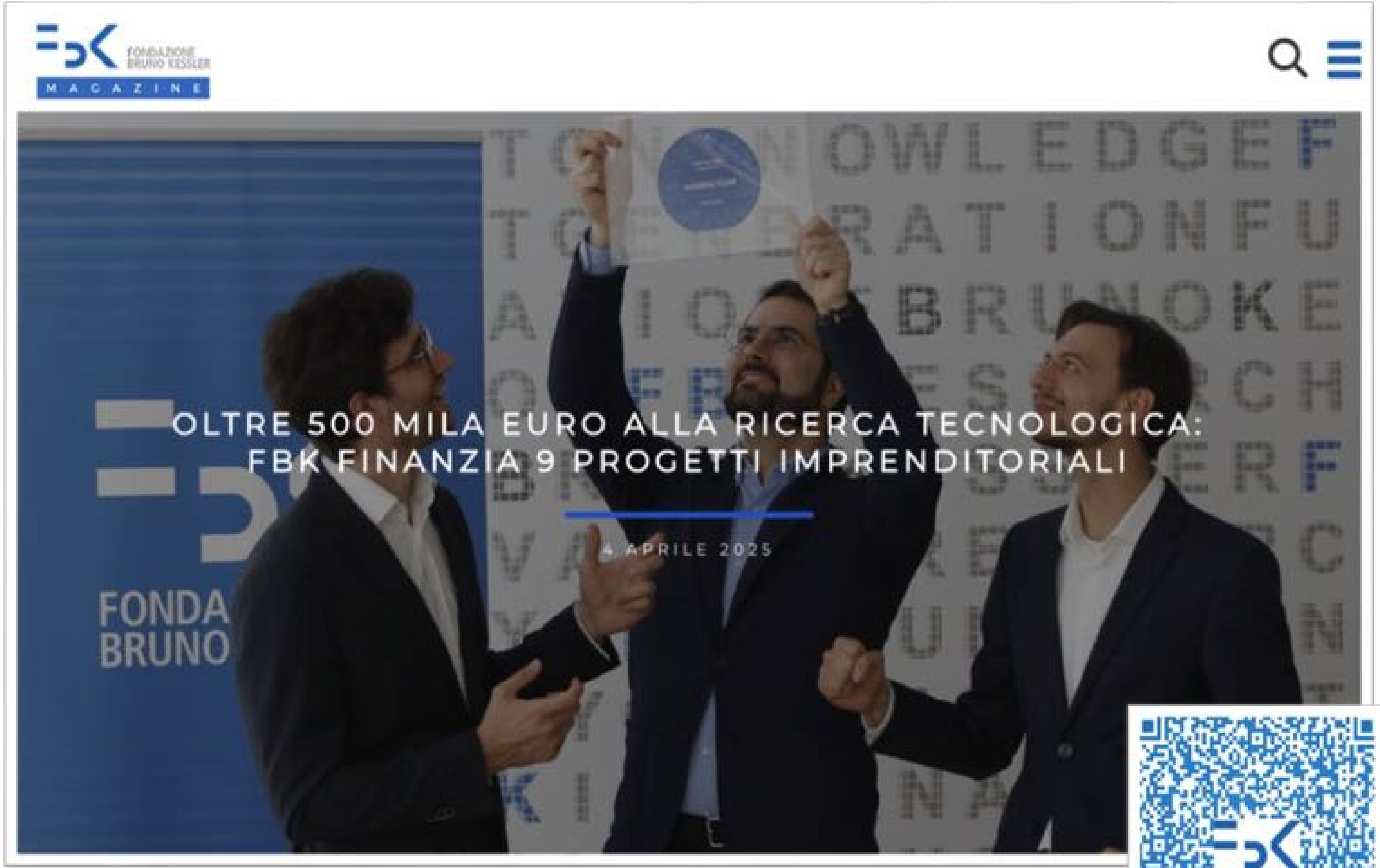
50 µm ALPIDE chip + 90 µm Aluminium-Kapton flex PCB double layer and readout electronics

- ❑ **Space**
  - SiliciSpazio (INFN)
  - SPES (ASI)
  - THESEUS (ESA)
- ❑ **Medical (potential)**
  - Microdosimetry
- ❑ **HEP (potential)**
  - ALICE3

POC by FBK
Flex Productions

❑ "**PoC by FBK**:
Test your idea!"

❑ Participation of **37 Teams**
Our Team got First



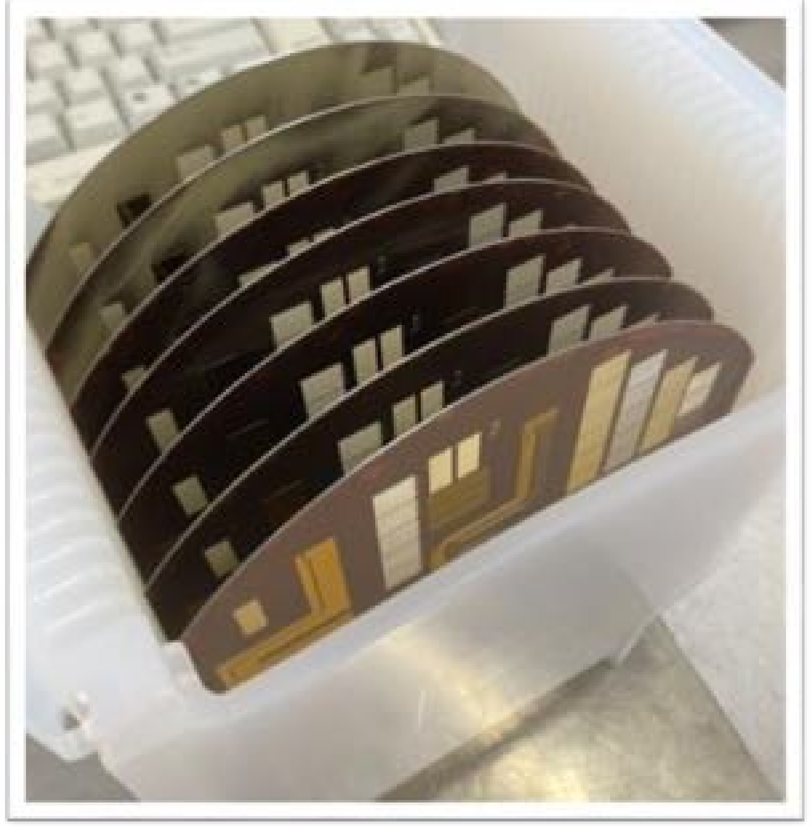
❑ Push towards **entrepreneurship**
We will explore solutions for the scaling of our technology and evaluate:
Spin-off,
licensing opportunities,
technology transfer.

Research Fabrication
Facilities @ FBK

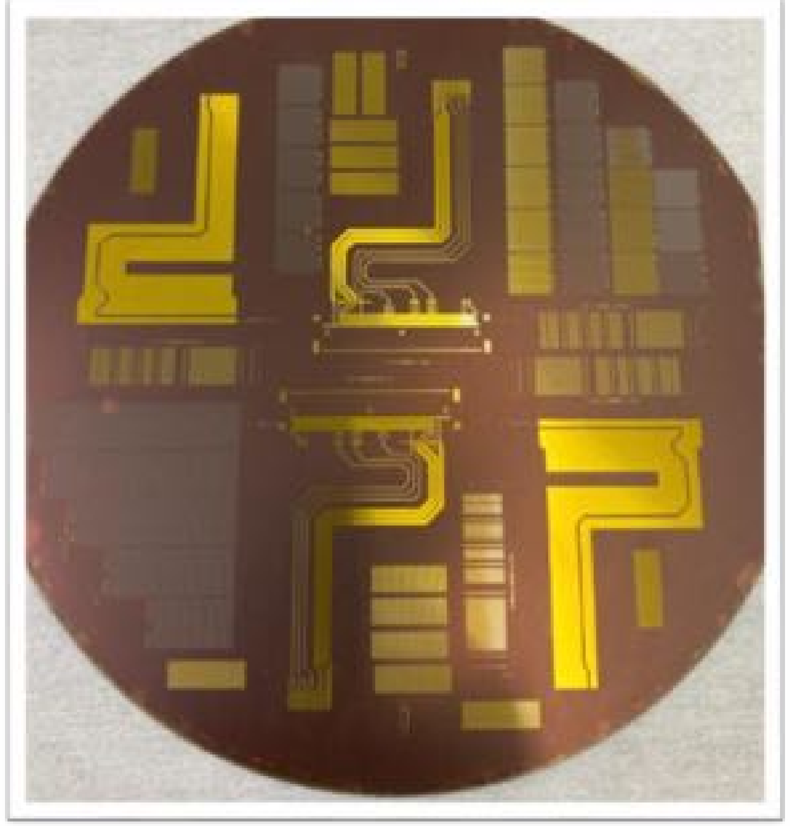
4 Clean Rooms & Other laboratories

- CRD (Production of silicon radiation detectors)
- CR3D (Wafer level 3D integration, wafer thinning & bonding)
- CRM (MEMS, multiple metals compatibility)
- CRP (Chip level packaging @ small scale)
- Gas Sensing Laboratory (Testing chambers)
- Electrical Testing Lab (Wafer level probing)
- Integration Lab (Prototype system integration @ small scale)
- Material Characterization Laboratories (Chips & material science)

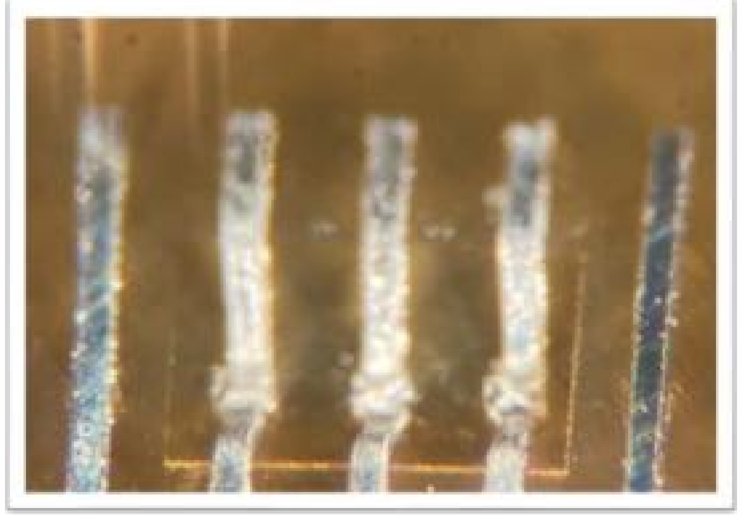
Flexible PCB design
Wafer-level manufacturing



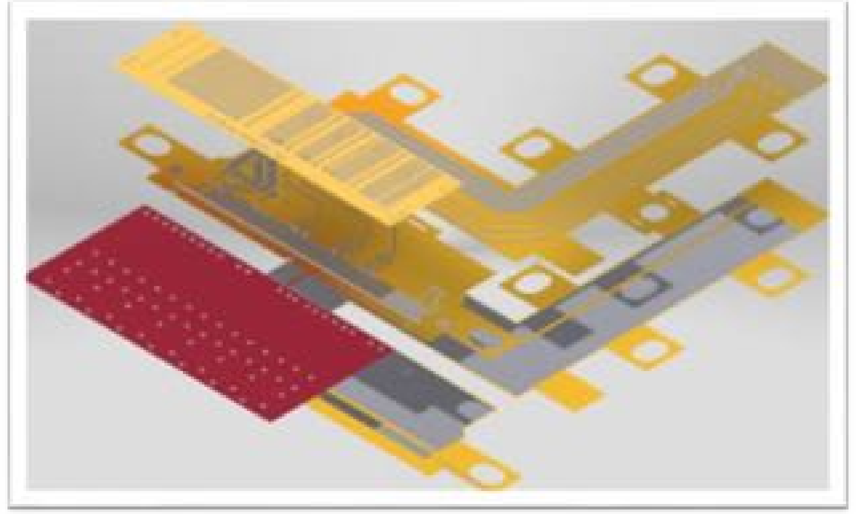
7 wafer batch of flex PCBs



Single wafer containing flexible PCB prototypes



spTAB bonding on Flex

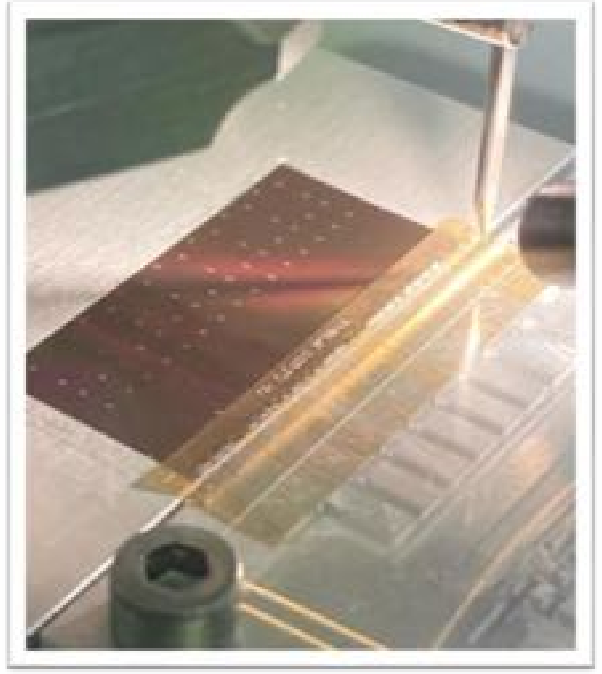


Three-layer PCB + ALPIDE CAD design

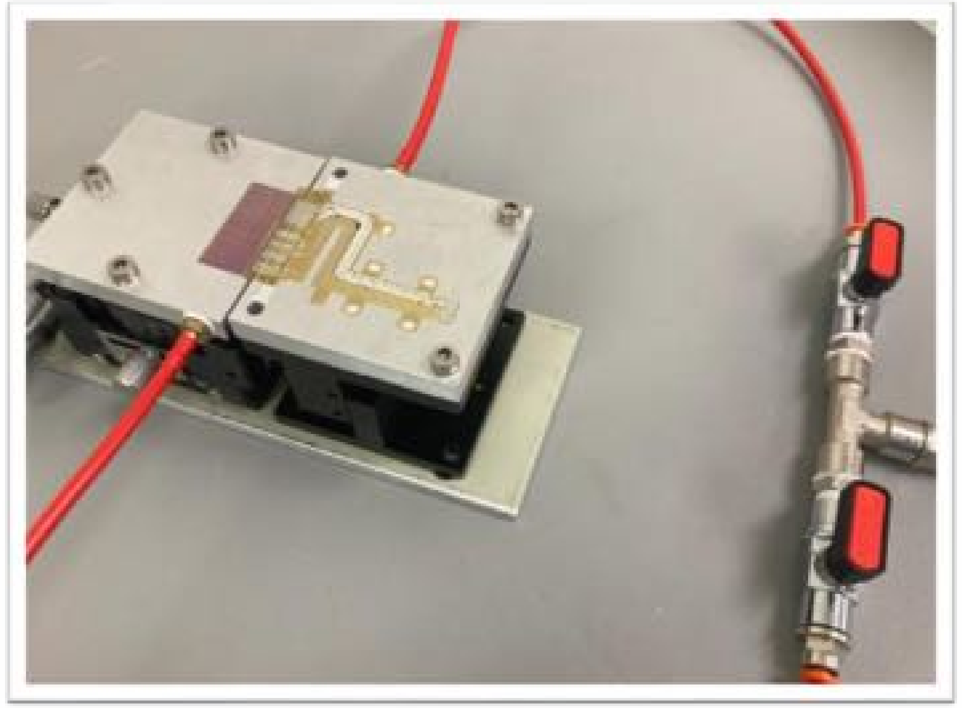
- Wafer-compatible process
  - Few µm precision
  - Scalable
  - No contamination
  - The PCB can be bonded in the "same" cleanroom it was manufactured

FBK cleanroom

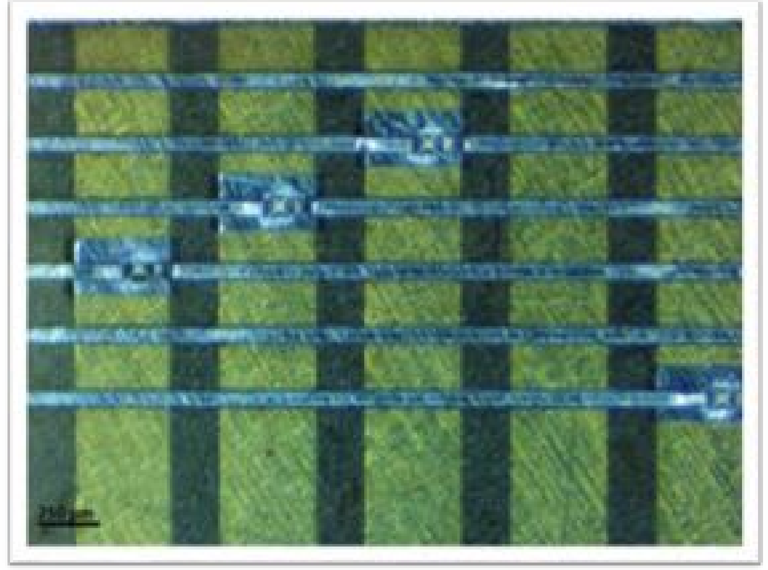
Flexible PCB integration
Single Point Tape Automated Bonding



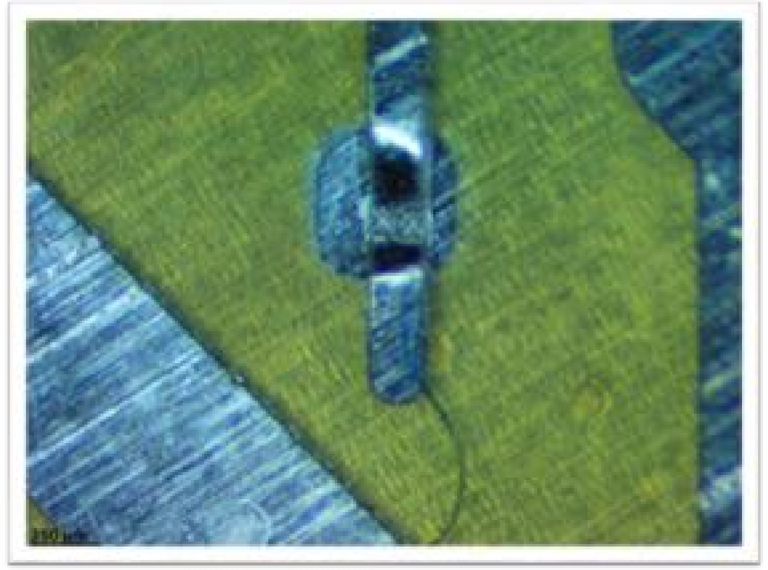
Bonding between the chip layer and the chip



Alignment jig for multilayer assembly and bonding

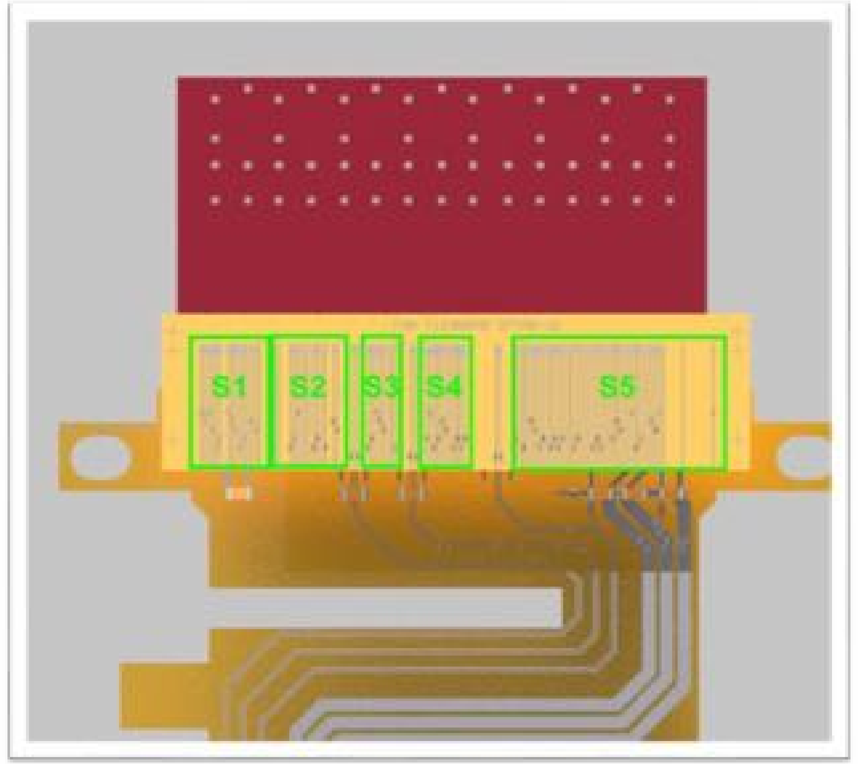


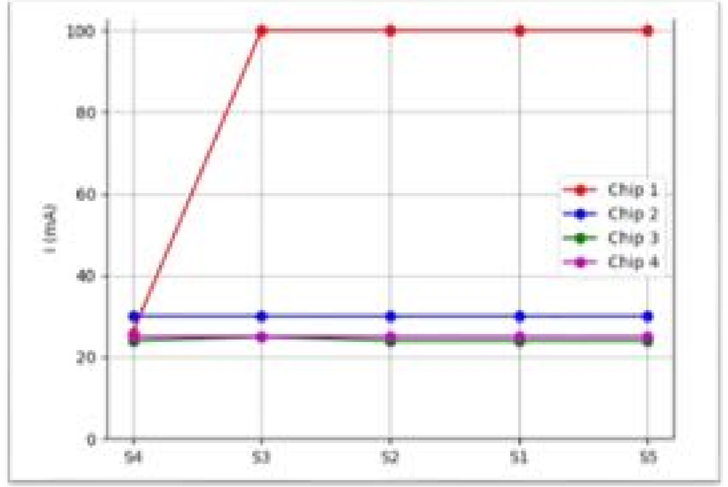
Bonding between the signal layer and the chip layer



Bonding between the signal layer and the ground

- **Bonding procedure**
  - Bonding between flex to flex and flex to chip
  - Electrical testing during the bonding procedure
  - 75x75 μm^2 bonding tip area





Chip1 was damaged during the bonding of region S3; 100 mA = compliance

!! Supply current monitored during the bonding procedure to detect potential damage !!

Flexible PCB integration
Electrical/thermal testing on ~50 samples

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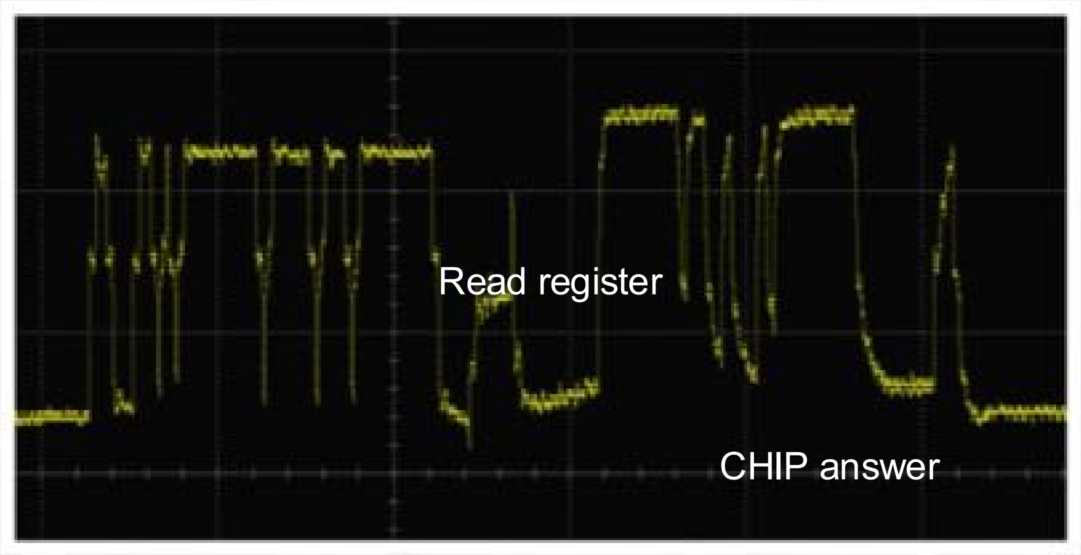
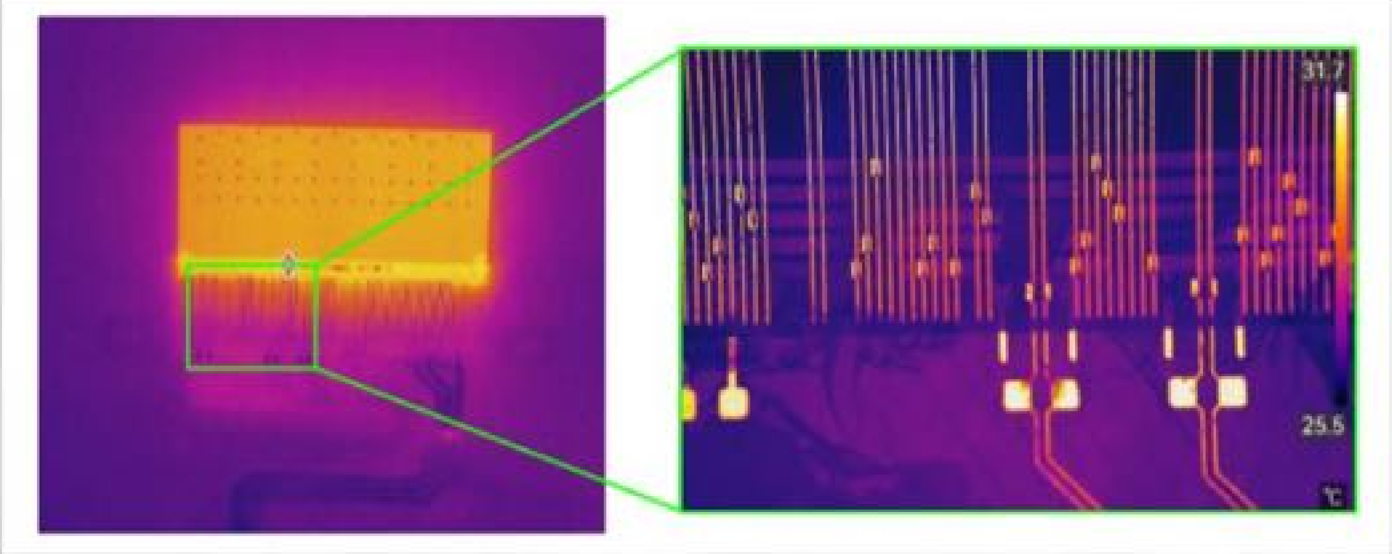
Electrical testing setup

- Electrical testing
  - Current consumption check
- Thermal camera imaging
  - Optimal trouble shooting test for the bonding process

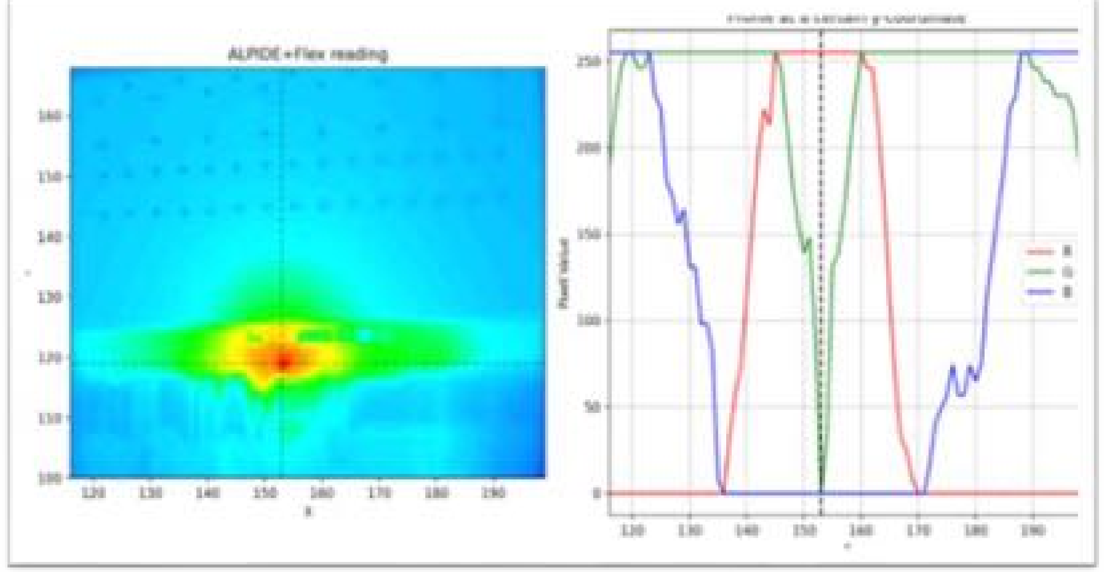
- Digital testing
  - FPGA write/read register communication



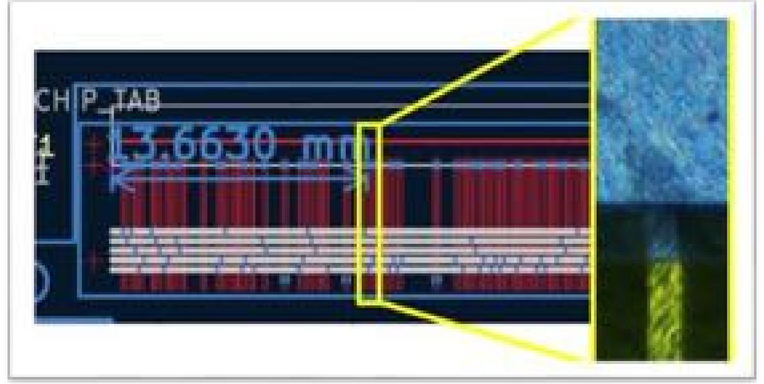
Digital communication measured with oscilloscope



Thermal camera image with of an ALPIDE chip in operation

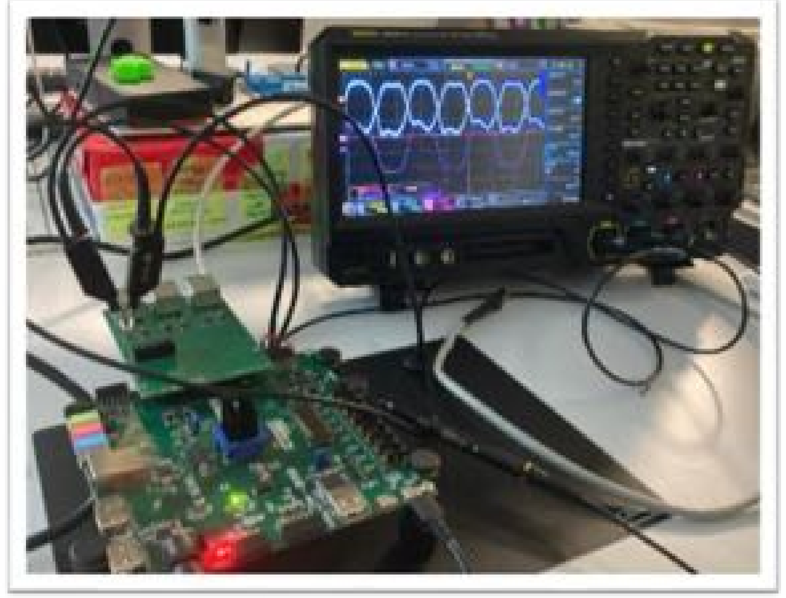


RGB spectra analysis to find the precise position of the hotspot

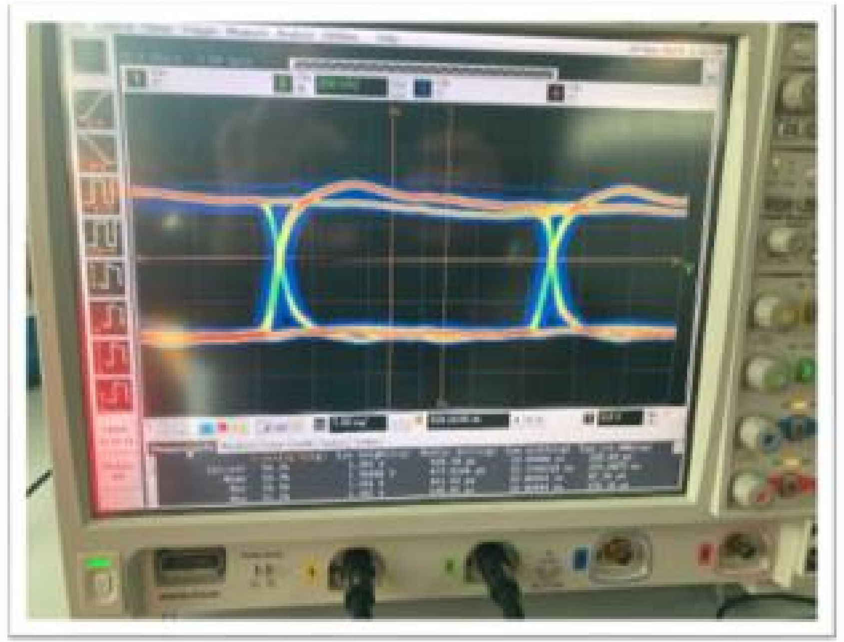


Damage found in correspondence to hotspot

What we are working on
Characteristic impedance and eye diagram measurements

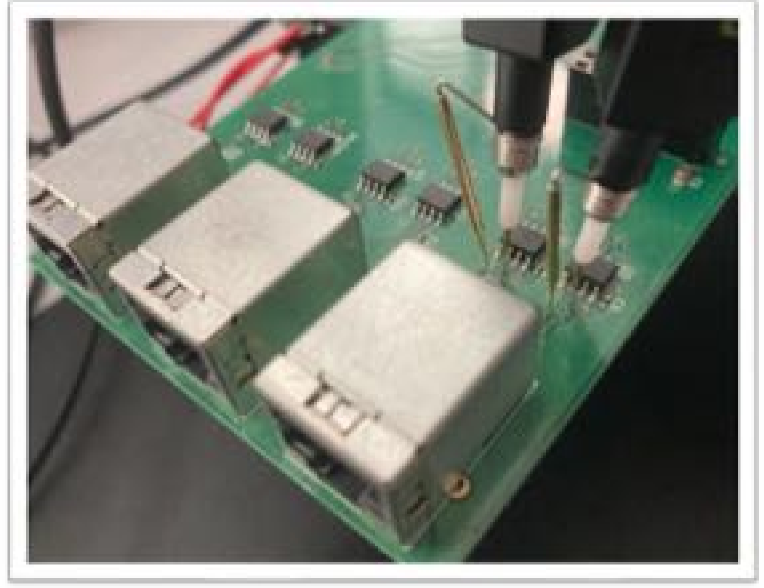


The setup for measuring the eye diagram is currently under development; shown here is the eye diagram of the generated signals from the FPGA. (fr. Max 400 Mhz with this oscilloscope)

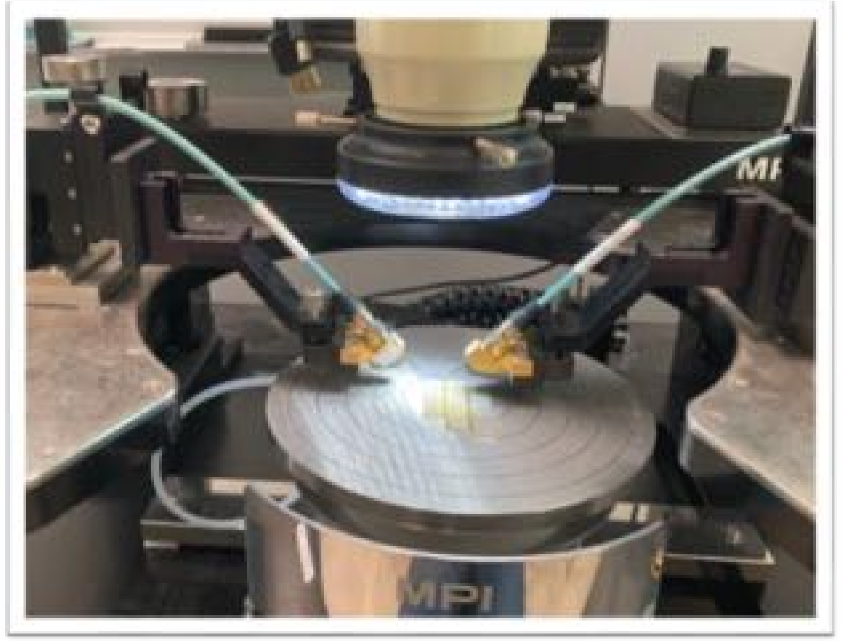


Tests with new oscilloscope (fr. max 1 GHz)

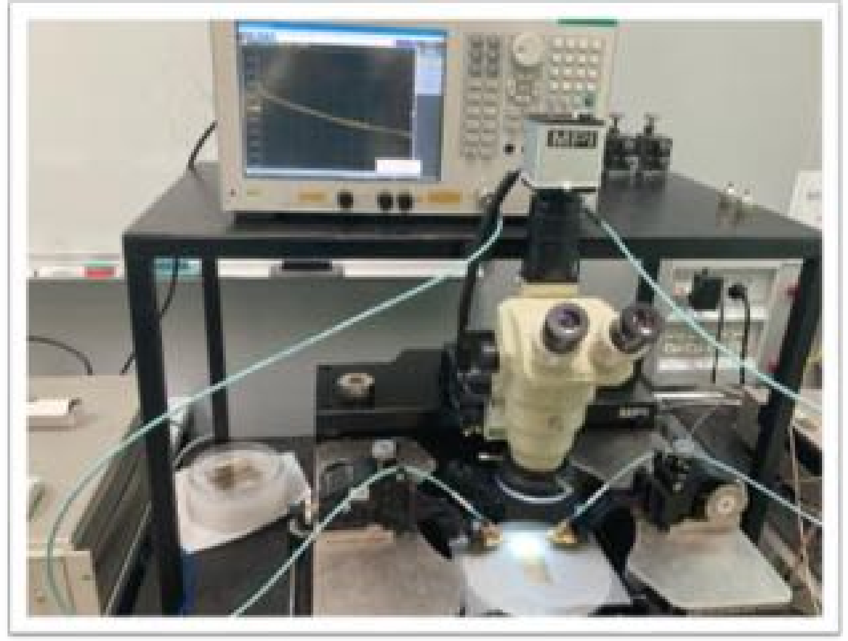
- ❑ **Measurements**
  - Eye diagram to measure the signal integrity along the transmission line with oscilloscope (ongoing)
  - Z0 and Z0 diff measurements with VNA (ongoing)



Dual probe system to measure the eye diagram

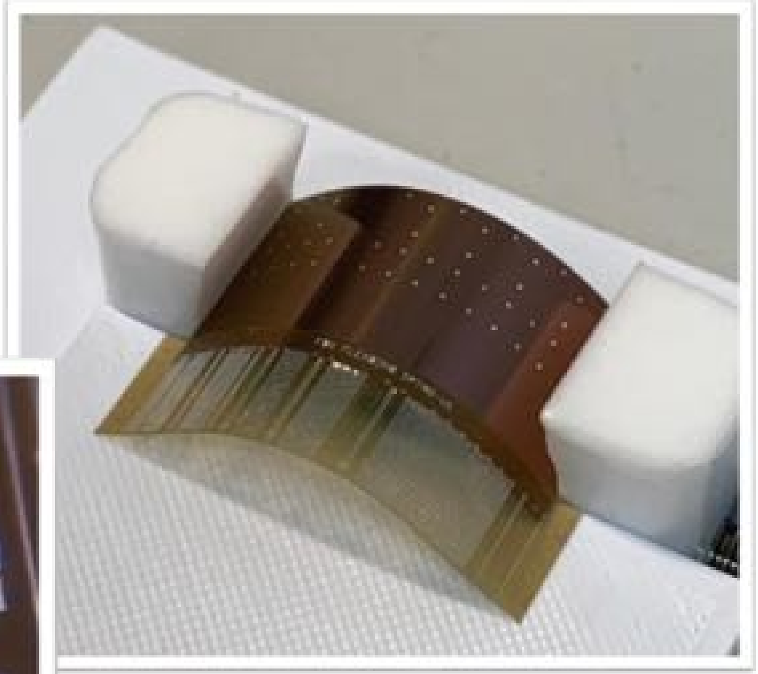


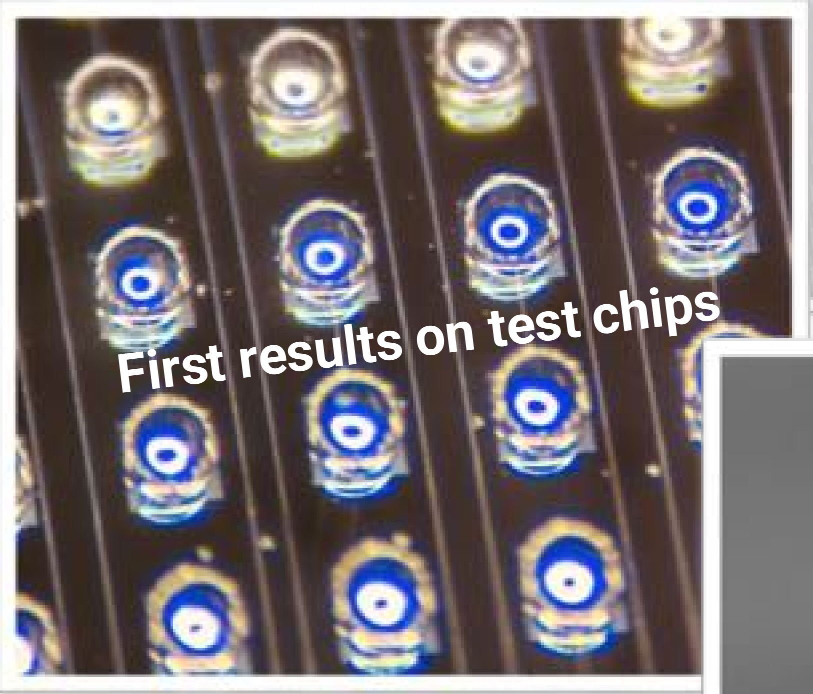
VNA setup to measure Z0

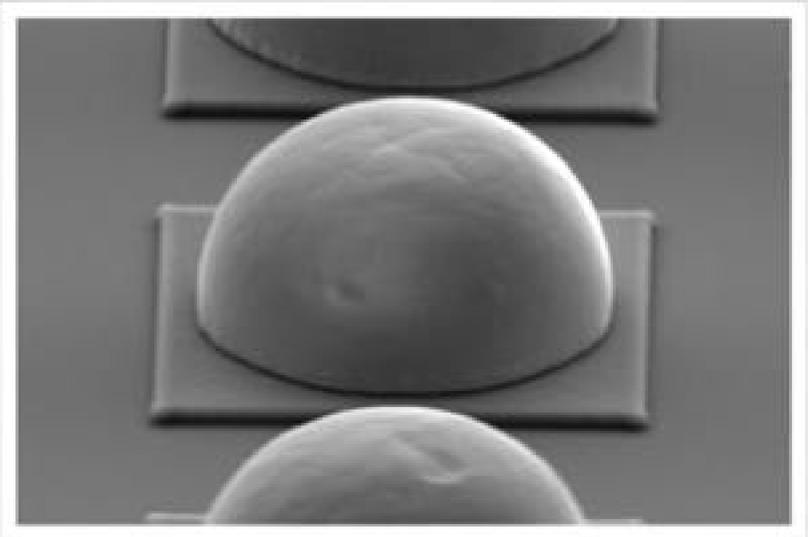


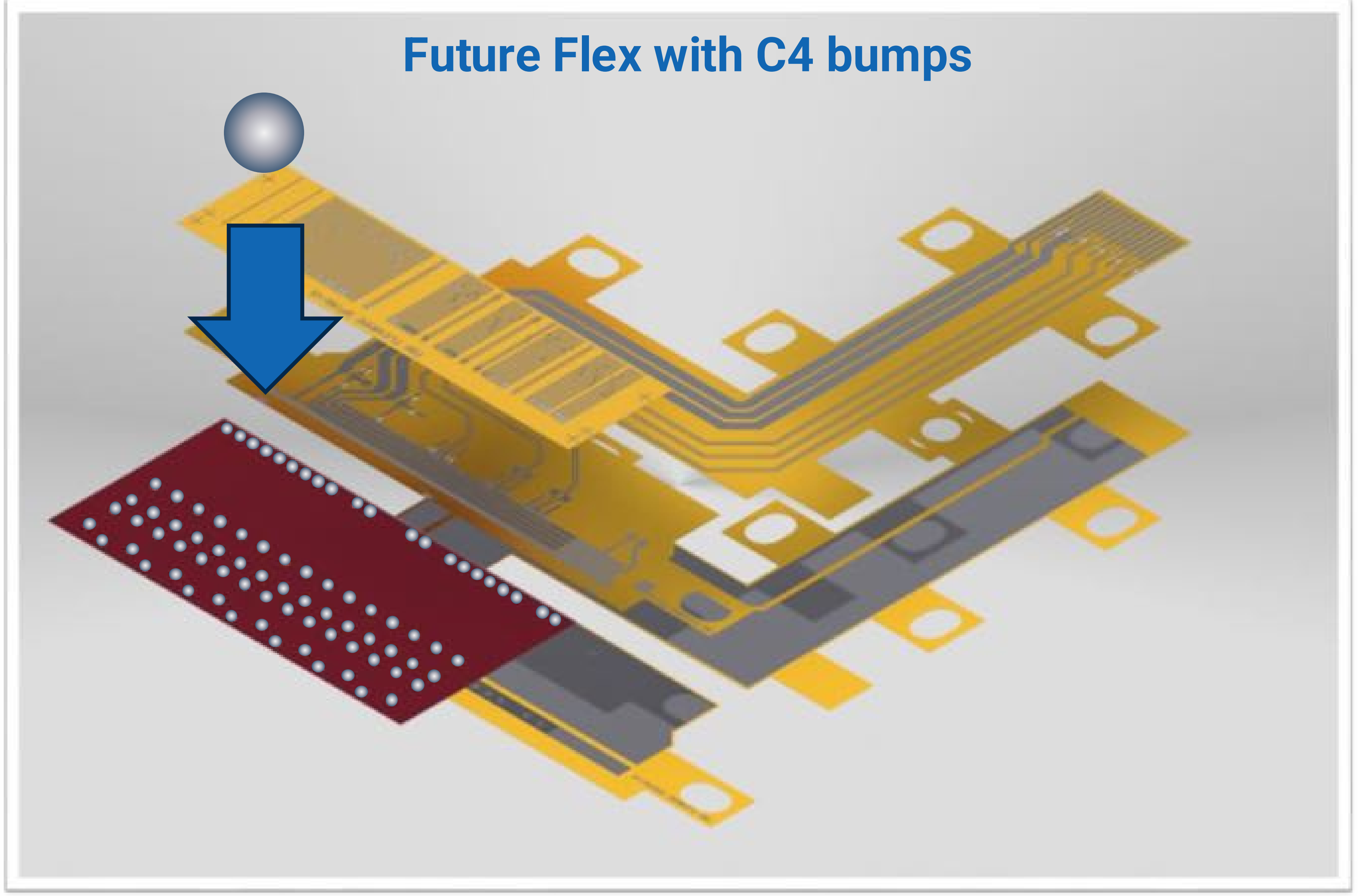
VNA setup to measure Z0

Future Developments
Current Roadmap









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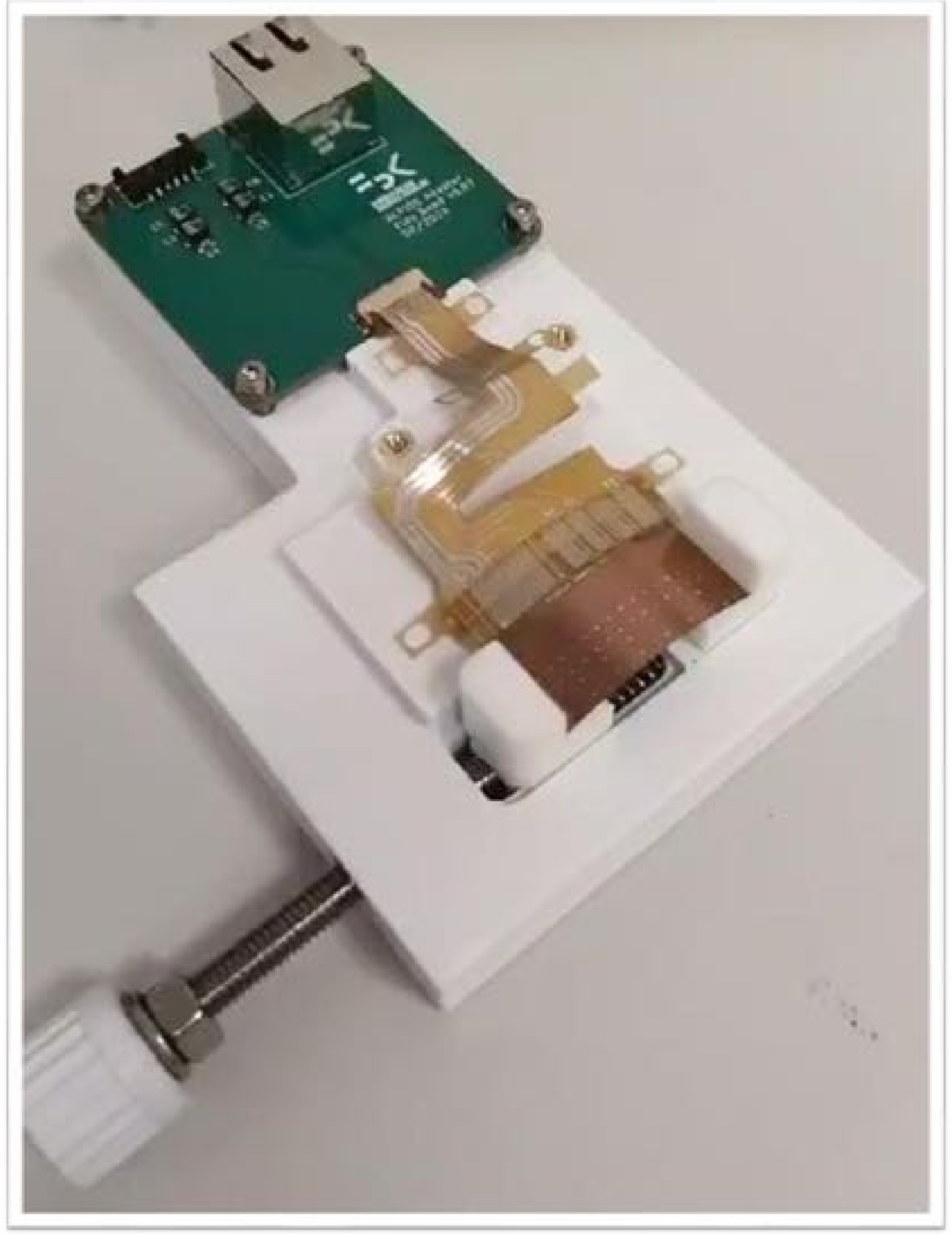
Current Tech Roadmap priorities

- Stacking
- Plating (Ni, ENIG)
- SMD components

- Space qualification
- Low X/X_0 Flip-Chip on Flex
- Signal integrity

- High data rates (few GHz)
- Scalability for larger volumes (≥ few m2)
- Larger area designs



Thank you!