Mechanical system integration of MIMOSIS-family sensors.

- *The Goal*
- *Sensors and QA*
- *Wire bonding and QA*
- *The Carrier of choice + potential risks*
- *Gluing procedures*
- *Mechanical "optimization" of the carrier*
- *Thermal optimization of the carrier*
- *Assembly JIGs*
- *Heat-sink*
- *Cooling liquids available*
- *Flex Print Cables*

eurizon
European network
for developing new horizons for RIs

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EURIZON Annual Meeting, 2023

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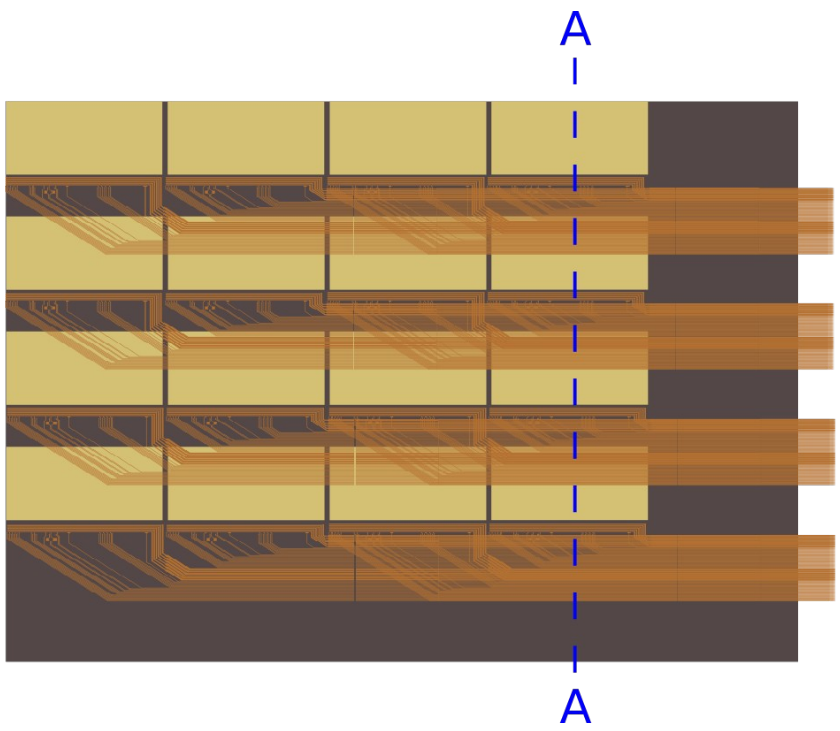
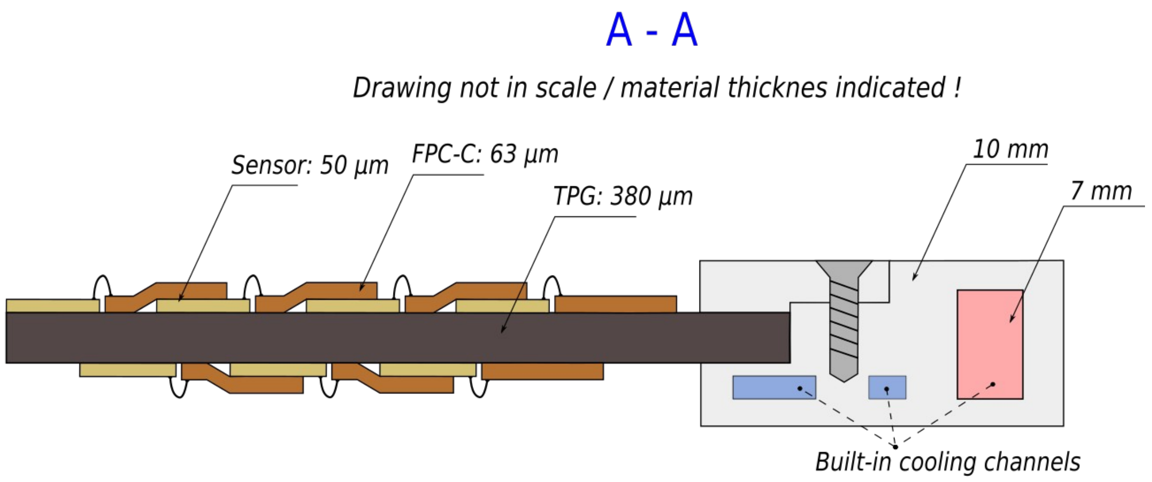
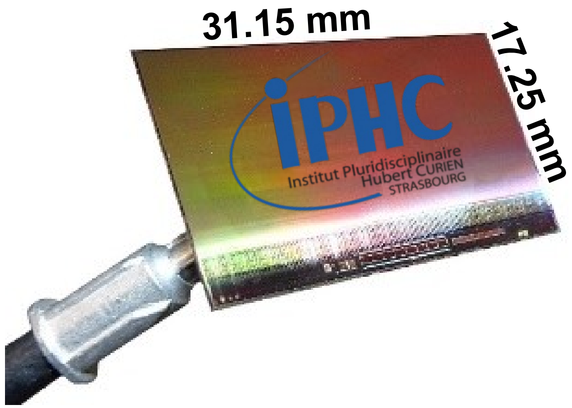
The goal

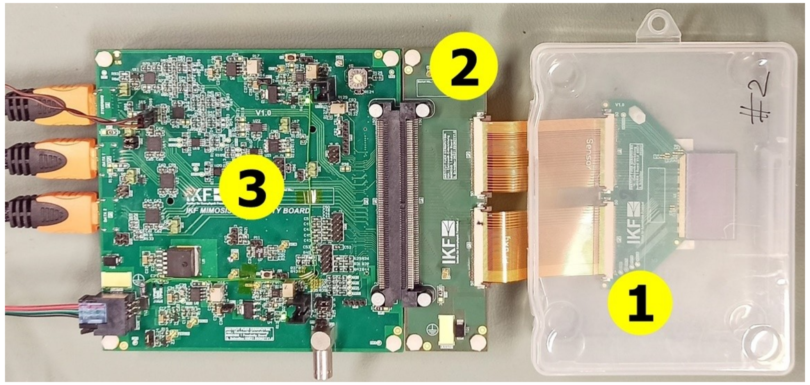




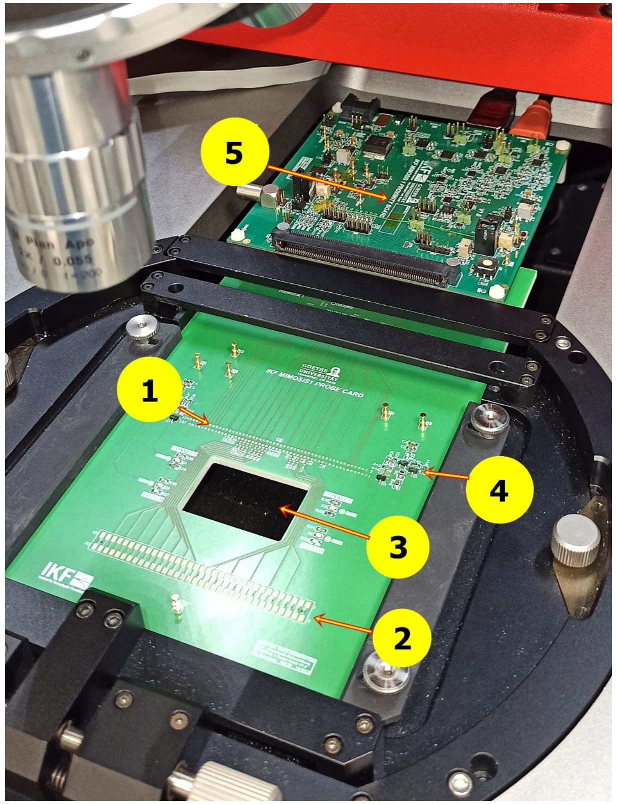
- Sensors on both side of the carrier: 16 (front) + 12 (back)
- Sensor thickness ~50 μm
- Highly thermally-conductive sensor carrier
- Low material budget of ~0.5 % x/X_0
- R/O and powering by the means of FPC
- Al heat-sink
- Active cooling
- Vacuum compatibility

Sensors and QA





- CMOS process
- Working name: MIMOSIS
- Thicknes: ~50 µm
- Power consumption: ~200 mW/cm^2
- Availability:
  - Sufficient number available for prototyping
  - Sensors after "upgrade" will be available at the end of May '23 for thining and dicing
- Planned QA
  - Visual inspection
  - Probe tests
    - Yield before assembly
    - Test time / sensor (currently ~24 hours)
    - Probe card design and production
      - PCB design @IKF + production externally, needles assembly @HTT-Dresden (2 pieces to start) => delivery this week
      - IKF Proxy PCB
        - 1st version tested and running but…
        - Upgrade of the IKF Proxy board required



Wire bonding and QA for the EURIZON deliverable

Wire bonding

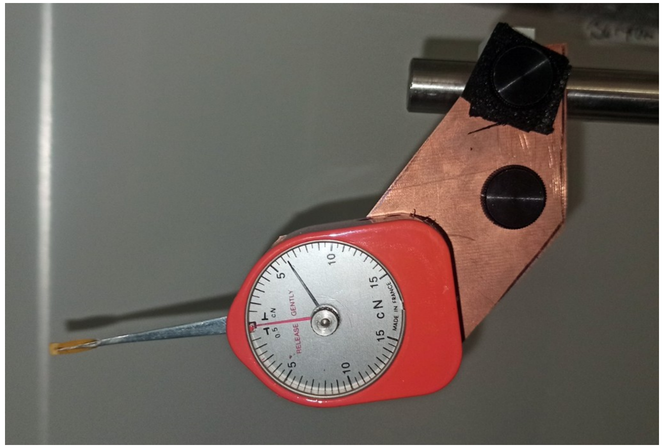
- Not @IKF => only very old manual bonder (~2h / sensor) . This is 3-4 weak to bond 28 sensors ...+ currently under "self" maintenance

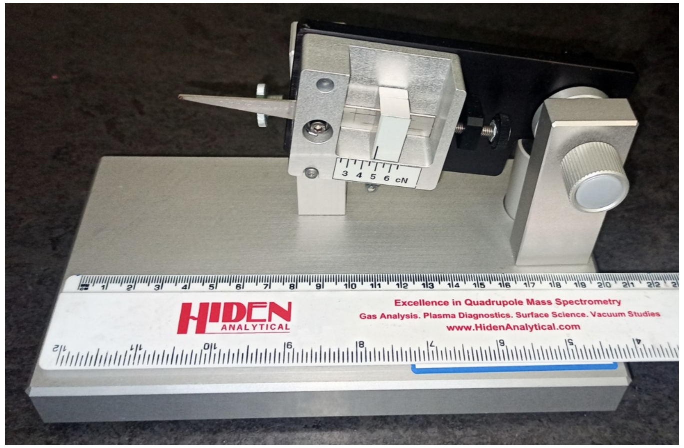
→ Access to more sophisticated bonder, best fully-automatic, is welcome.

Pull tests

- Destructive pull tests to optimize settings
- Simple manual pull-tester available at GSI and IKF
- Ideally, non-destructive pull tests for all assembled modules
- No machine available in the collaboration (?)
- Purchase (>20k€) => no budget

→ Pull tests only to optimize bonding parameters.





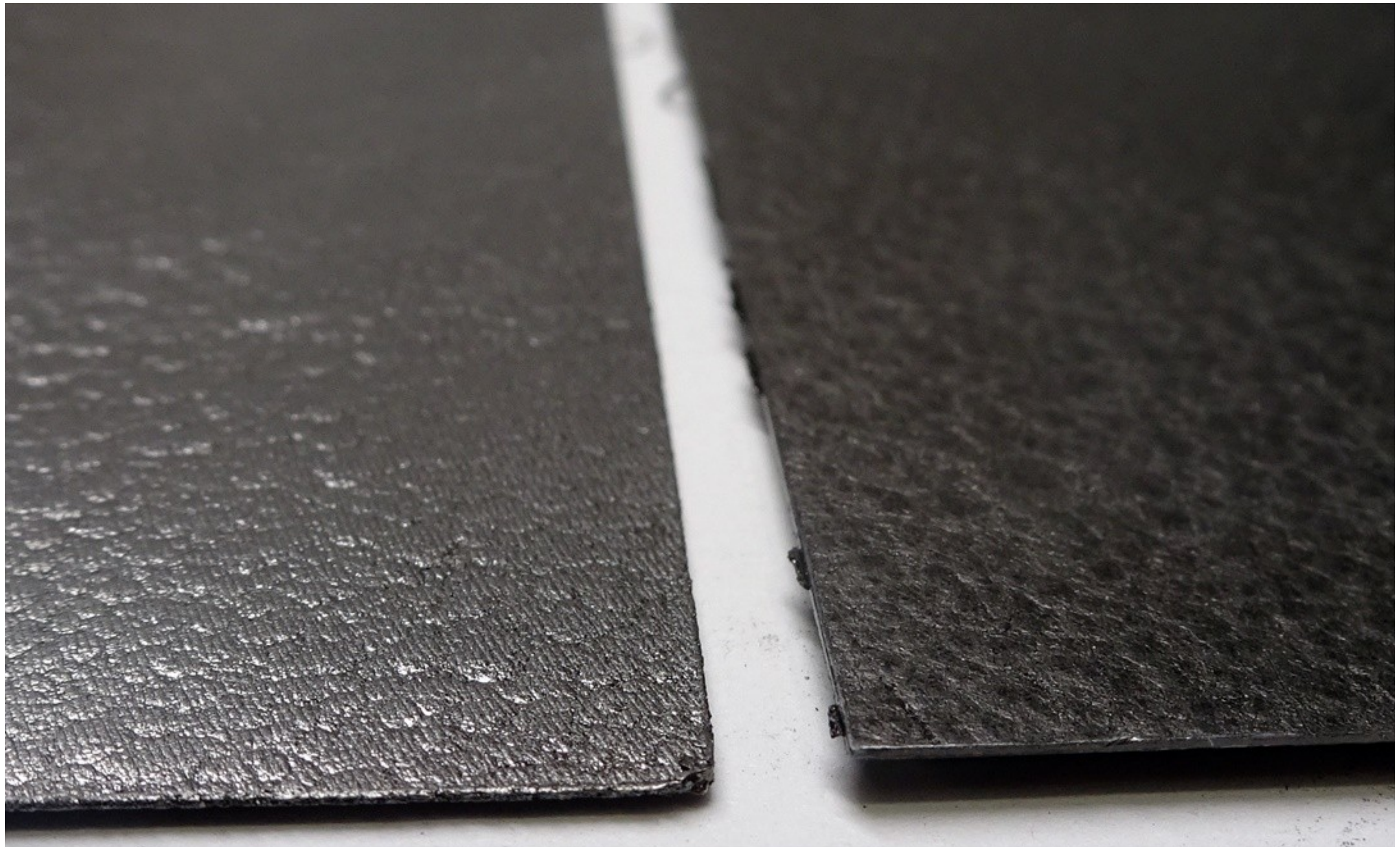
→ 20 k€

F&S BONDTEC

The carrier

Property of TPG	Value
Young's modulus	1050 (36) GPa
Density	2.26 g/cm^3
Radiation length X_0	19.03 cm
Surface roughness	not specified
Thermal expansion coefficient	$-1.0...0$ (25) $\times 10^{-6}$/K
Thermal conductivity	1500 ($<$ 20) W/mK
Electrical Resistivity	1×10^{-4} (Ω cm)
Price tag (2020)	0.15 €/mm^3

Price: ~500 USD gross / 100 x 100 mm^2



Issues addressed:

Mechanical stability at low thicknesses

- 250 µm seems to unstable for handling if not fully supported => two single sided units glued together

Electric conductivity

- Sensors have to back-biased => TPG electrical insulation => Hydrophobic Parylene

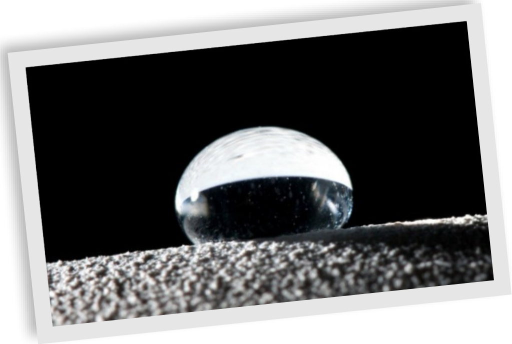
Manufacturing

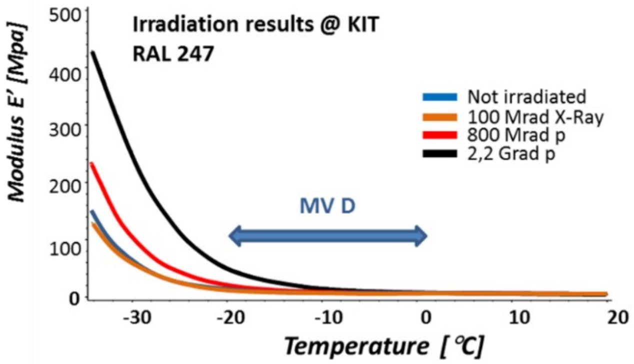
- Cut: no 90^o corners, no straight edges

Adhesives and gluing procedures

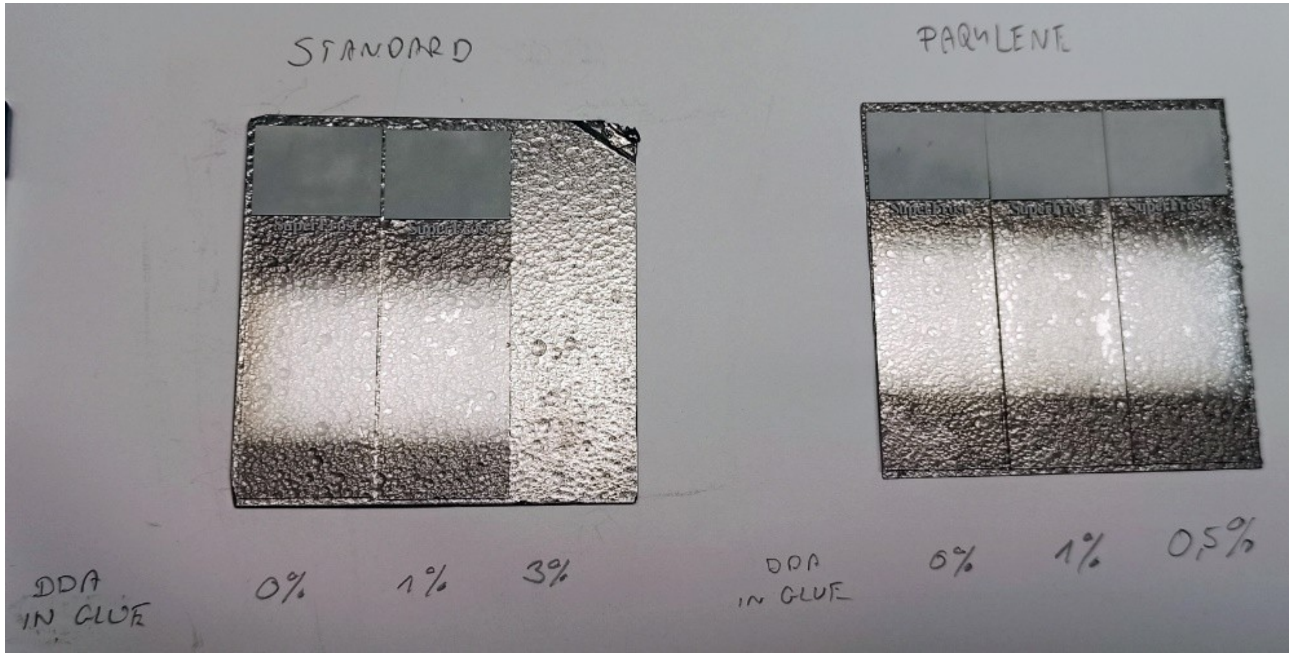
- Available adhesives (proved for radiation, outgassing, viscosity)
  - RAL 247 custom made @RAL (preferred)
  - Epo-Tec 301-2

- Vacuum compatible gluing on Parylene – coated TPG
  - Tests with glass dummies only
  - Polished surface => better adhesive flow + less amount needed
  - RAL-247 with wetting agent “solves” the problem but..
  - ...curing time ofr the latest RAL-247 adhesive is very long (>2weeks @ +20 °C)
  - Discussion with RAL plus order together with PANDA experiment soon





Issue:
low wetting on Parylene-coated surfaces

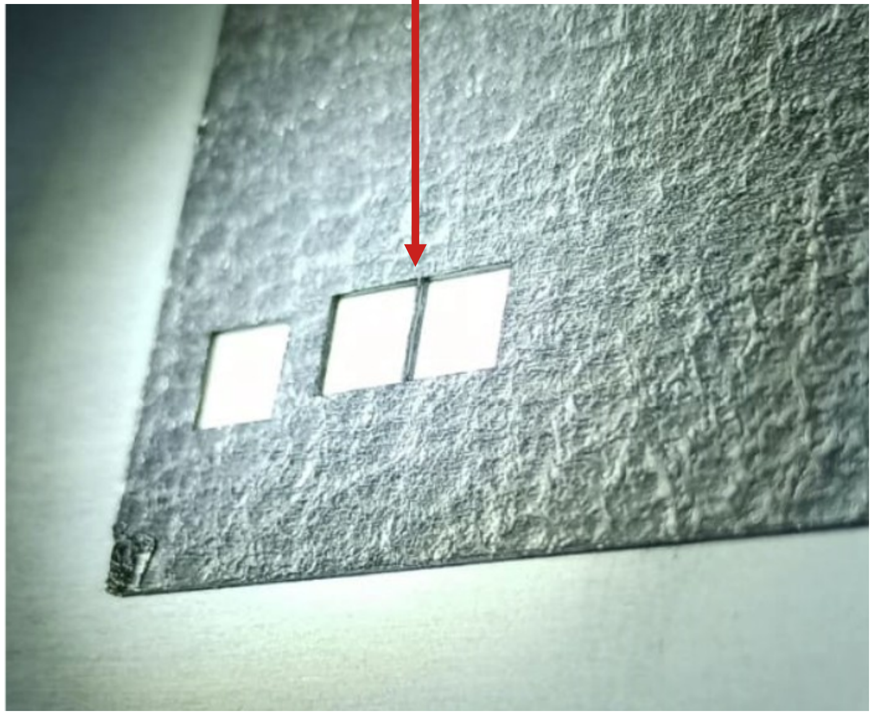


Mechanical carrier “optimization”

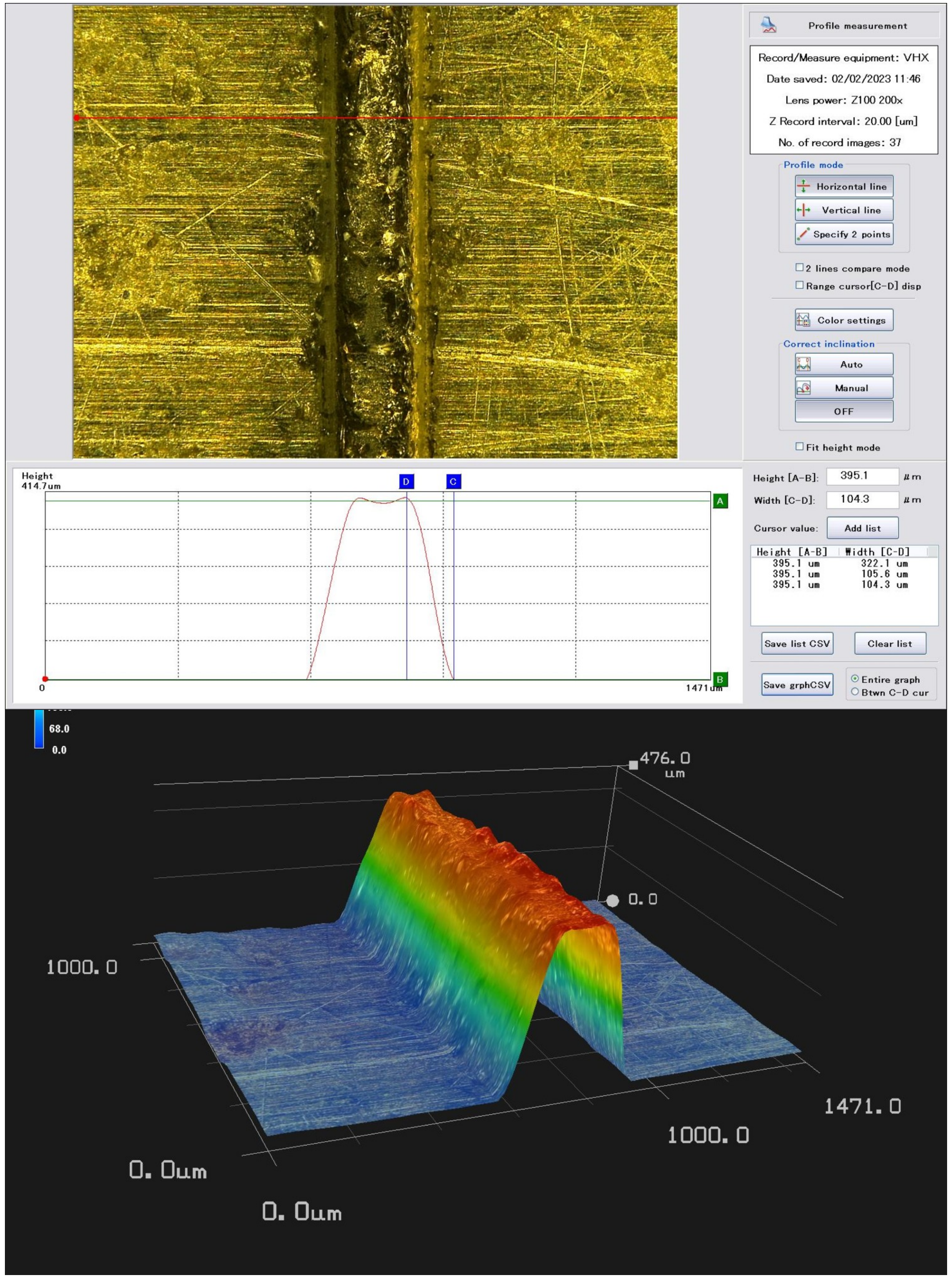
TPG laser cut

1st try @GSI electronic lab =>

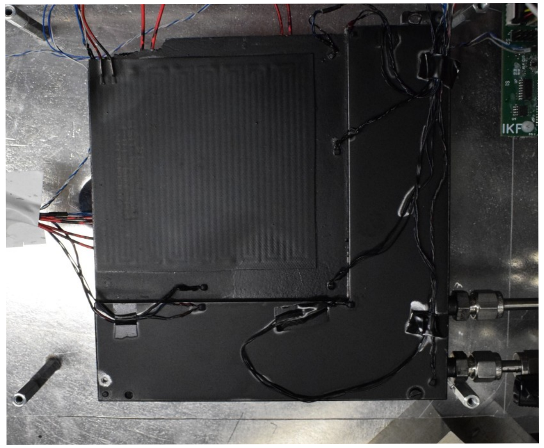
5 mm x 5 mm squares with aimed spacing of 100 μm

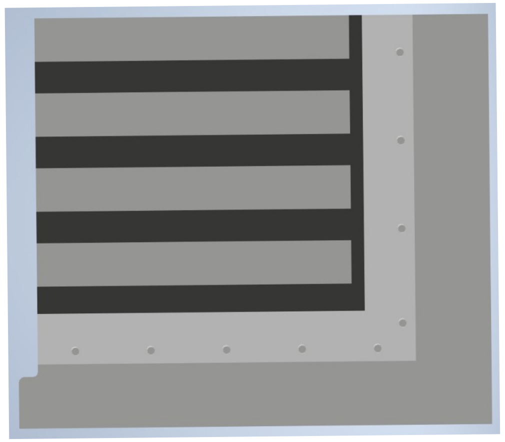


Next => minimize the cone



Thermal carrier optimization



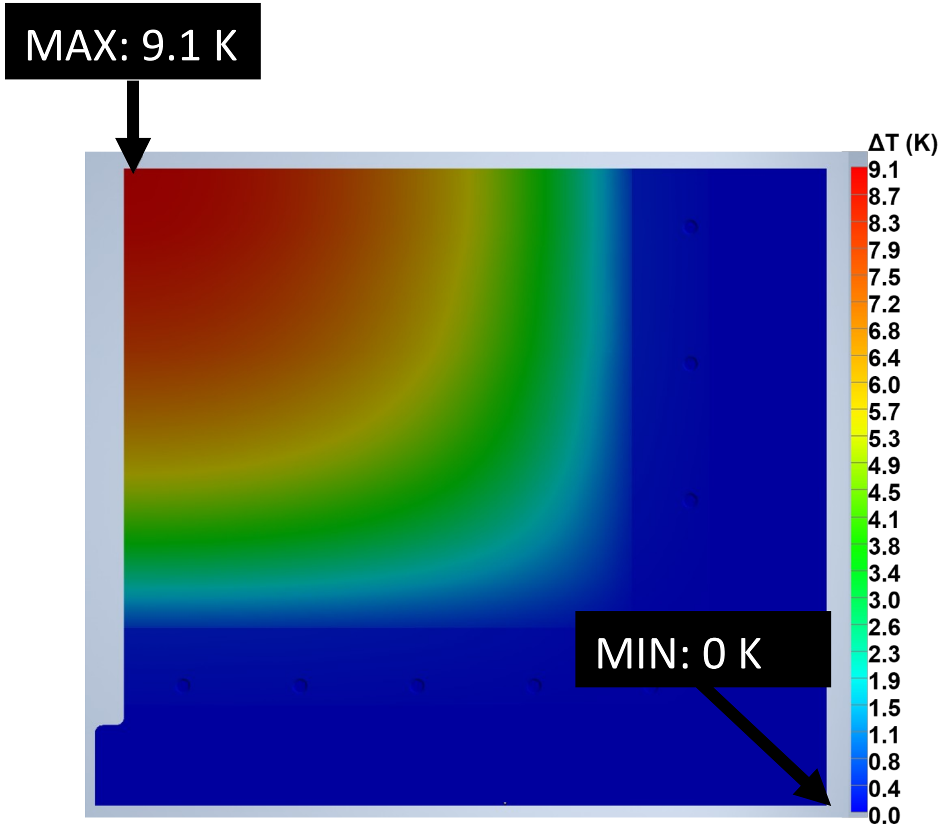


Measurement (at room temperature):

- Carrier: 117.5 mm x 130 mm TPG
- $\lambda_{x,y}$=1500 W/mK, λ_z=15 W/mK (specs)
- P=2 x (87 mm x 87 mm) x 100 mW/cm^2=15 W (Kapton heaters)
- Heat sink actively cooled
- ΔT=(11.5±0.5)K

CAD NASTRAN & ThSim:

- Carrier: 117.5 mm x 130 mm TPG
- $\lambda_{x,y}$=1500 W/mK, λ_z=15 W/mK
- P=28 x (17.25 mm x 31.20 mm) x 100 mW/cm^2=15 W
- Heat sink on fixed temperature
- ΔT=9.1 K



Comparison:

- Small discrepancy, but same order of magnitude
  - Optimize thermal junctons and λ_{TPG}
- Good approximation, espically for low P (p_{mi-1}=43 mW/cm^2)
- ΔT on heat sink not considered

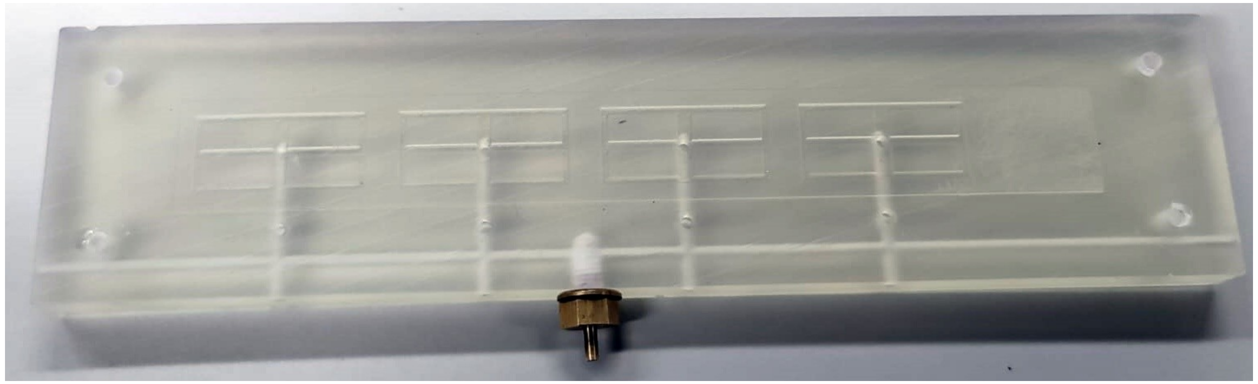
JIGs

Base idea:

Requirements
- MIMOSIS form factor
- ESD safe
- Optimize carrier fixation
- Include 100 µm spacing between sensors in a row

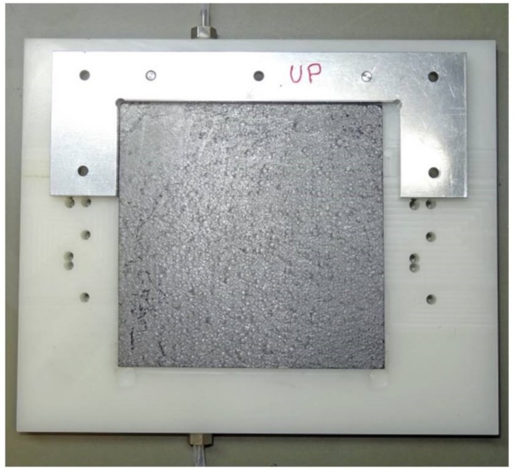
Design & production
- 3D print & usability check
- Design correction
- 3D print + check
- CNC machined Al production (IKF local workshop)

- Heat-sink = JIG option (not yet followed-up)

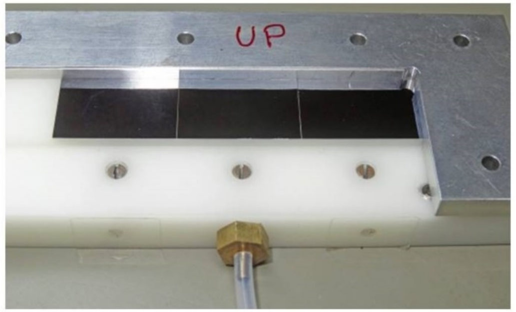


3D printed mock-up JIG for holding MIMOSIS sensors

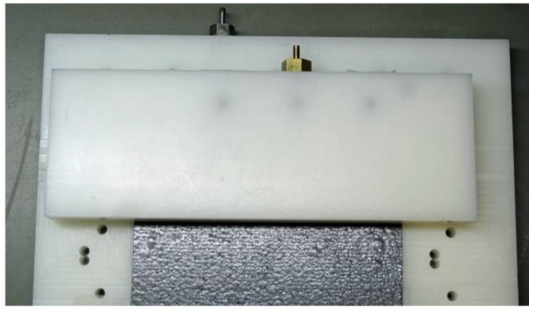
Align carrier w.r.t. defined (0,0) point



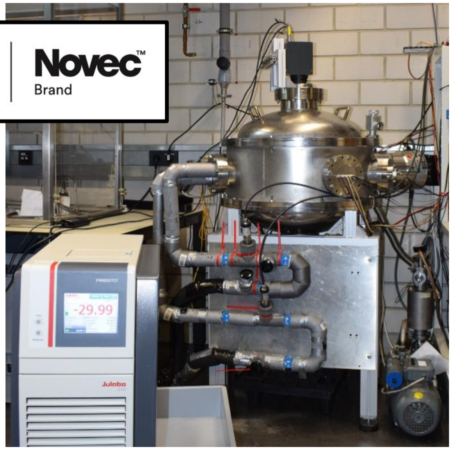
Align sensor w.r.t. defined (0,0) point

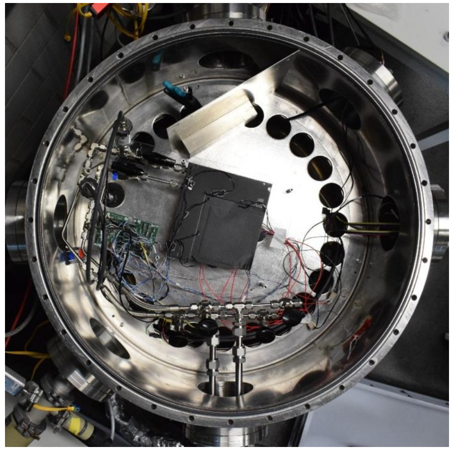


Bring both together



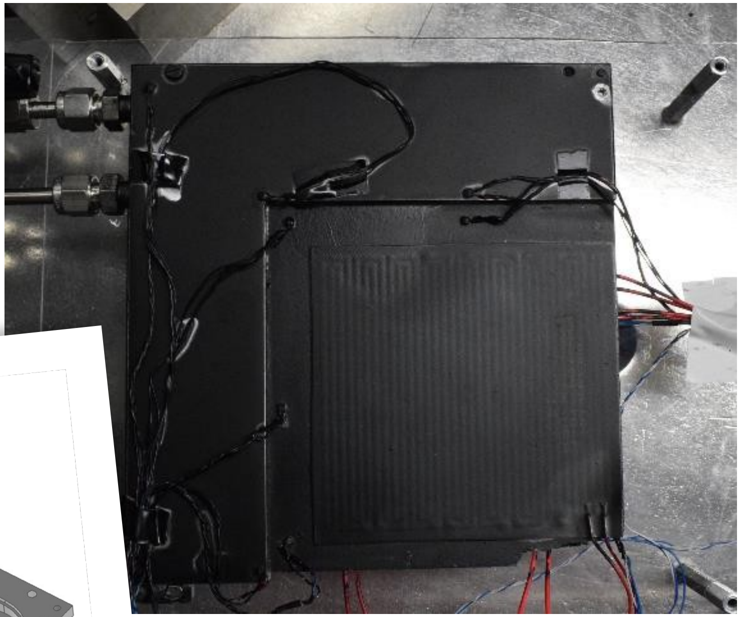
Heat-sink





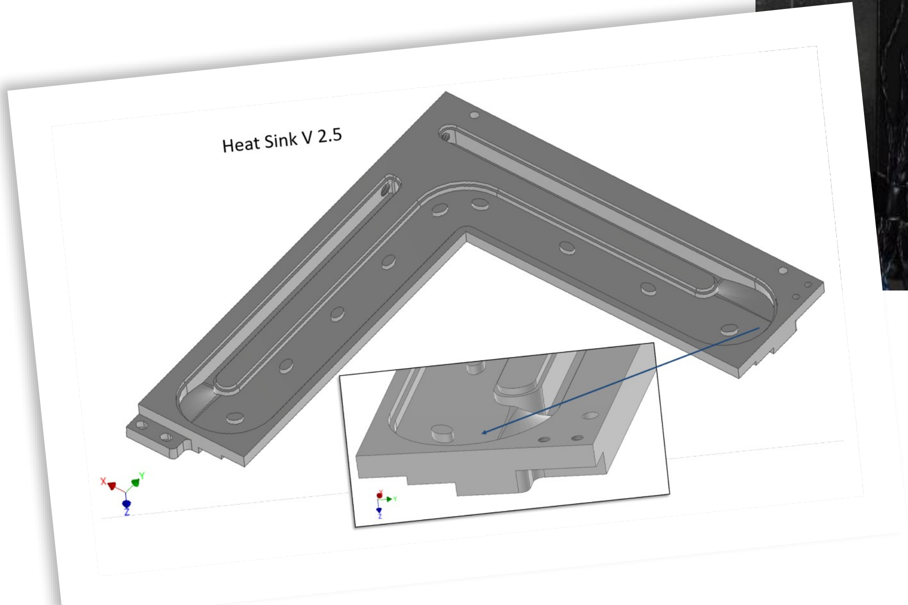
Accomplished:

- 2 predecessors optimized for flow and cooling liquid to carrier temperature gradient
- Tested successfully with TPG carrier => offers targeted temperature gradient across the carrier
- Since several months running routinely with NOVEC 649



To be done:

- Finalize the form factor for the TPG
- Re-design to include copper fittings to eliminate the use of Loctite sealing
- Explore option to use it as a JIG



Lack of cooling liquid @ T < 0 °C

EP-DT
Detector Technologies

Cooling fluids used at CERN
(with room temperature reference)

No future

	Normal boiling conditions P=1atm or T=20 °C		2-Phase properties at 20°C	Critical point		Properties at normal conditions T=20 °C, P=1atm or normal boiling pressure in case of liquefied gas			Other properties	
Fluid	Boiling temperature (°C)	Boiling pressure (bar)	Latent heat (kJ/kg)	Critical temperature (°C)	Critical pressure (bar)	Density (kg/m3)	Heat capacity (kJ/kg*K)	Viscosity (µPa*s)	GWP	Prize €/kg
Water	100	0.023	2453	373.9	220.6	998	4.18	1001.6	-	0
~~**Novec 649** [1]~~	~~49.1~~	~~0.326~~	~~96.2~~	~~168.7~~	~~18.7~~	~~1617~~	~~1.10~~	~~756.6~~	~~1~~	~~47,-~~
C6F14	56.9	0.236	94.0	175.9	18.3	1703	1.03		9300	30,-
C5F12	29.8	0.695	95.0	147.4	20.5	1632	1.07	497.6	9160	
C4F10	-2.2	2.29	88.9	113.2	23.2	1516	1.07	230.9	9200	138,-
C3F8	-36.8	7.56	79.1	71.9	26.4	1352	1.15	180.6	8900	38,-
C2F6	-78.1	Super critical		19.88	30.5	Super critical			11100	100,-
CO2	-78.4	57.29	152.0	30.97	73.8	773.4	4.3	66.1	1	0.015

[1] Not well understood radiation and material compatibly issues

12/11/2020 B. Verlaat 8

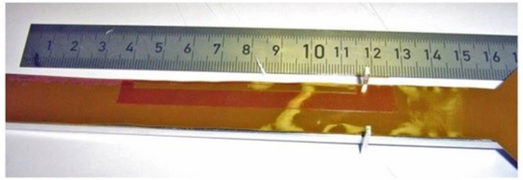
- 3M will not continue the NOVEC line
- Patent is expired => hope that other producers will take over
- At present => cooperation with CBM-STS and CERN Detector Cooling Section to find possible replacement / solution
- Outcome = unknown

Flex Printed Circuit Cable (FPC)

FPC Cables (thin, ~60 µm / single layer, Cu – based)

- Design
  - Minimum number of signals ?
  - No. versions ? (front/back)
  - Partially single + partially double layer FPC
  - Length(s) ?
  - Design still this year
- Production @ILFA
- QA (done at ILFA)

Still to be understood:
- Sensor performance while running with (max ~25 cm) long FPC
- Decoupling capacitors

a)


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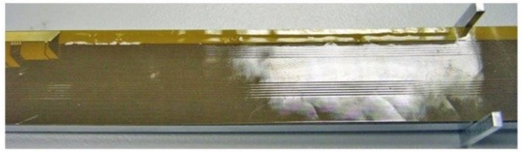
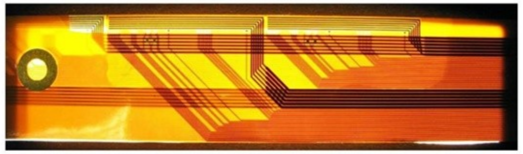


c)


d)


e)


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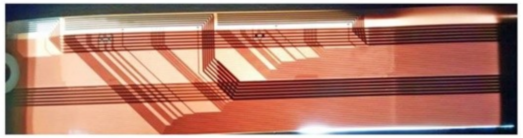
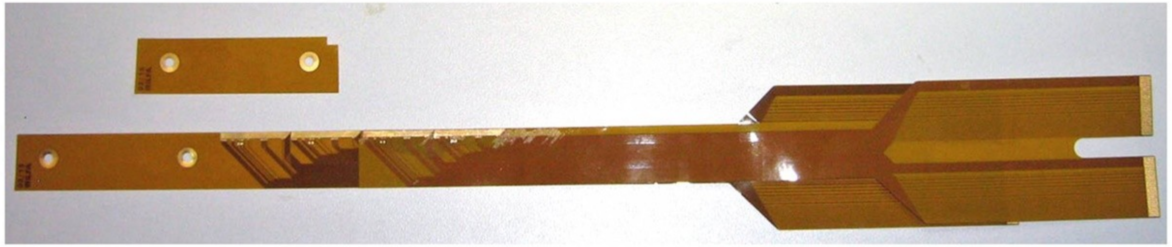


g)


h)


Outlook & Summary

Sensors and QA => sensors available, QA will start soon after delivery of the probe-card

Wire bonding and QA => hope for cooperation with GSI DL

The Carrier of choice + potential risks => base line chosen + some other options to be considered

Gluing procedures => RAL-247 must be optimized for its curing time or/and we are forced to cure at +50 ^{o}C

Mechanical "optimization" of the carrier => VERY promising , laser cut optimization missing

Thermal optimization of the carrier => simulations in agreement with measurements model

Assembly JIGs => sensor JIG to be produced in Al, carrier JIG R&D needed

Heat-sink => not far from a final design

Cooling liquids => replacement for 3M NOVEC 649 must be found

Flex Print Cables => R&D to be addressed