Thermal Management Solutions for Optoelectronics Packages

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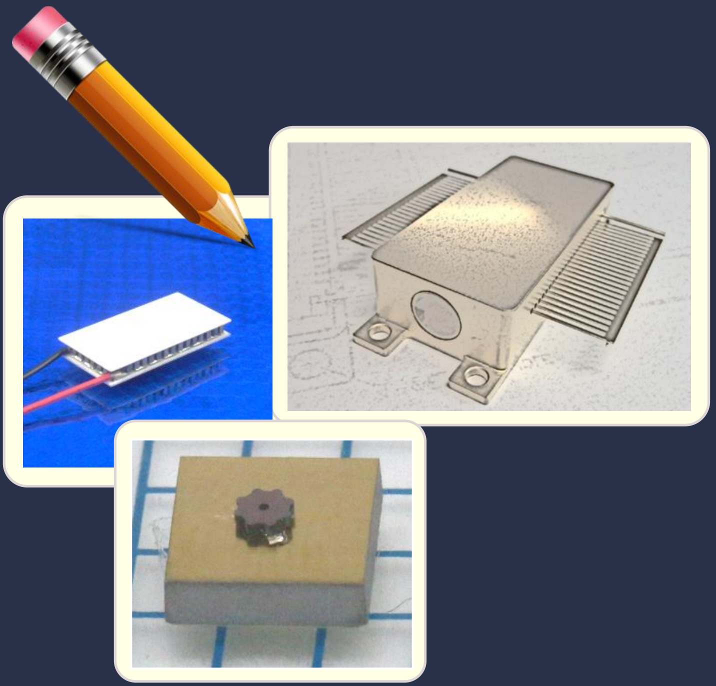


Outline

- Packaging @ CSEM
- Mid-IR Laser thermal management with TEC and in-package tracking thermocouple – Comsol FEM simulations
- Laser diode system thermo-mechanical simulations
- Concept for optical module temperature stabilisation <50mK
- Future trends in assembly materials: Ag sintering / Reactive foil bonding

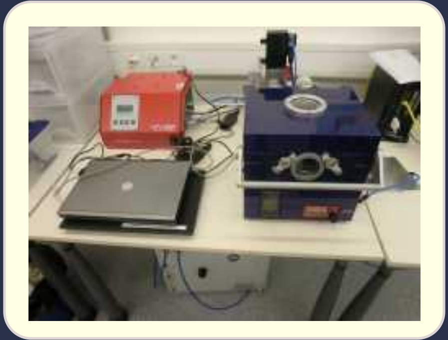
I - Packaging Infrastructure

Pick & Place
Machine

Cleanroom
class 10’000
Humidity &
Temperature
controlled

Wire Bonder

Reflow Oven with
controlled atmosphere



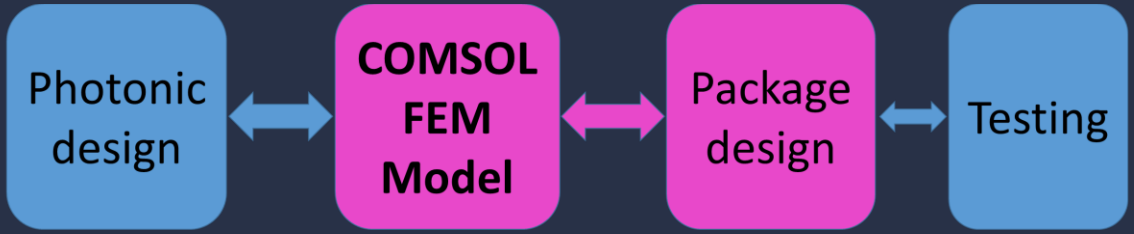
High vacuum
reflow oven

Laser soldering &
welding station

II - Mid-IR Laser thermal management considerations

- Mid-IR photonics is growing thanks to advances in Lasers, QC-Lasers, MEMS gratings and fiber optics.
- Temperature is the key to stable and reliable operation of photonic systems
- Thermal management and package design can be handled with multi-physics FEM models

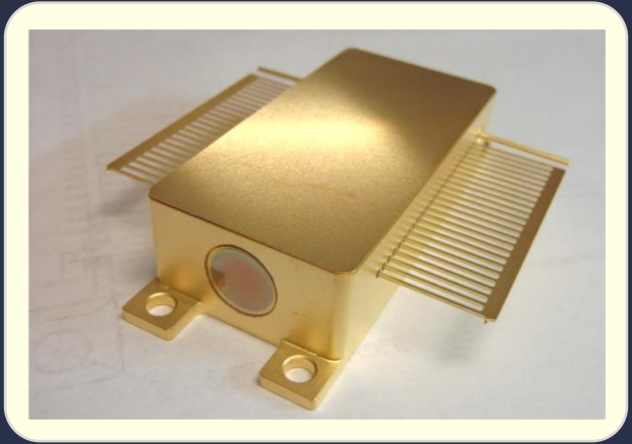
https://www.comsol.com/paper/multiphysics-model-for-thermal-management-of-packaged-mid-ir-laser-66601



Mid-IR Laser packaging considerations

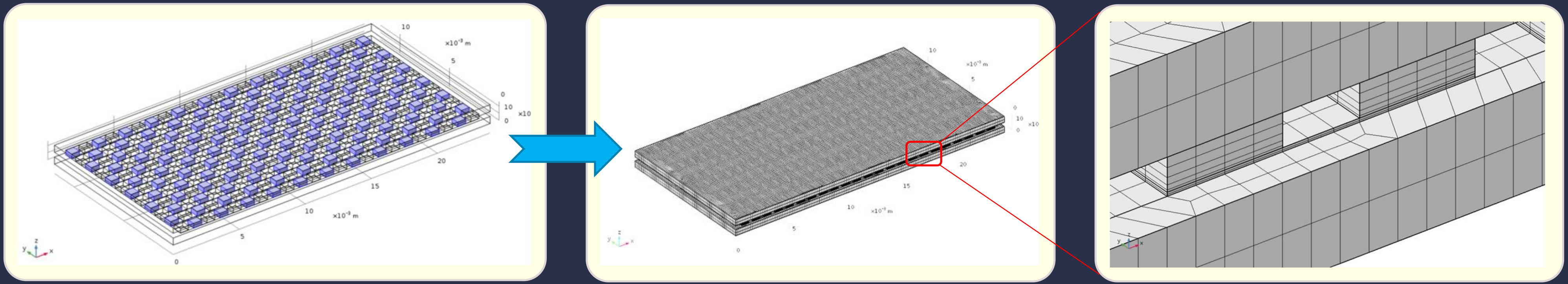
- Heat-spreading submount to efficiently remove heat
- Thermo-electric cooler (TEC) below heat spreader
- Kovar package to reduce thermo-mechanical stress and enable hermetic sealing.

Mid-IR Laser
with Joule heating
loss of P_{th} ~40(W)



Thermo-Electric Cooler (TEC) model implementation

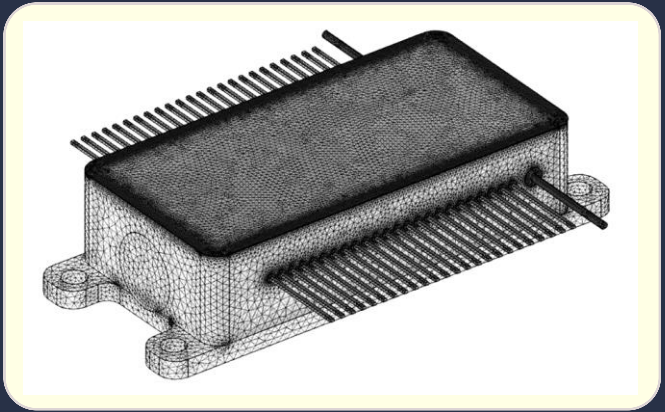
- Use of Comsol Application available in the Application Library
- Improved Mesh approach to cope for large model with 12x24 pellets
- <u>TEC model calibrated with supplier material data</u> (Seeback, k, other…)
- <u>Calibrated TEC model comparison with lumped-model simulator.</u>
  - <u>Heat flux accurate to >99% compared to results from lumped model software developed by TEC supplier</u>



- 120K Elements
- Avgerage Element Quality is 0.99 (Skewness)

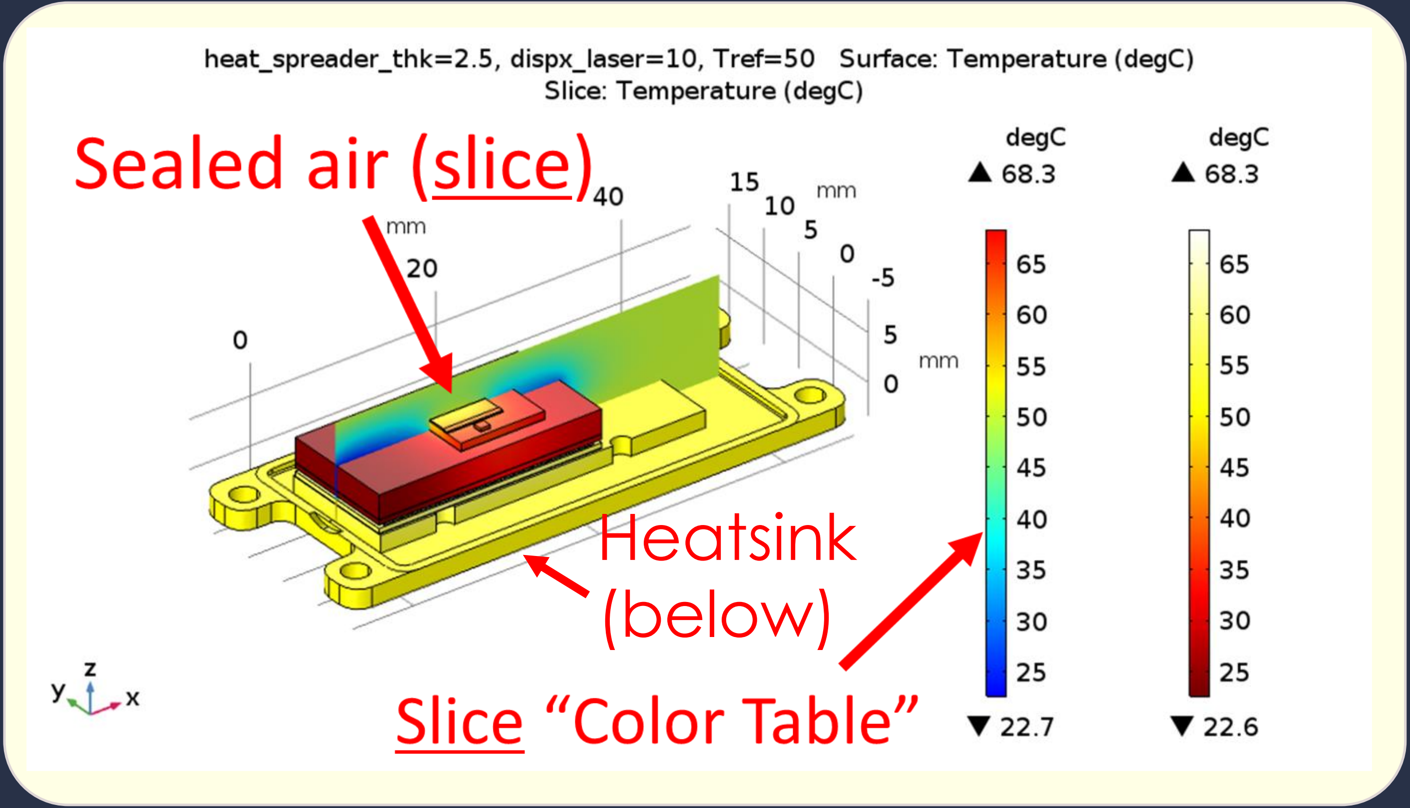
Full Package simulations model implementation

- Large model (high resolution) with 9 independent parameter set
- 112h total solution time



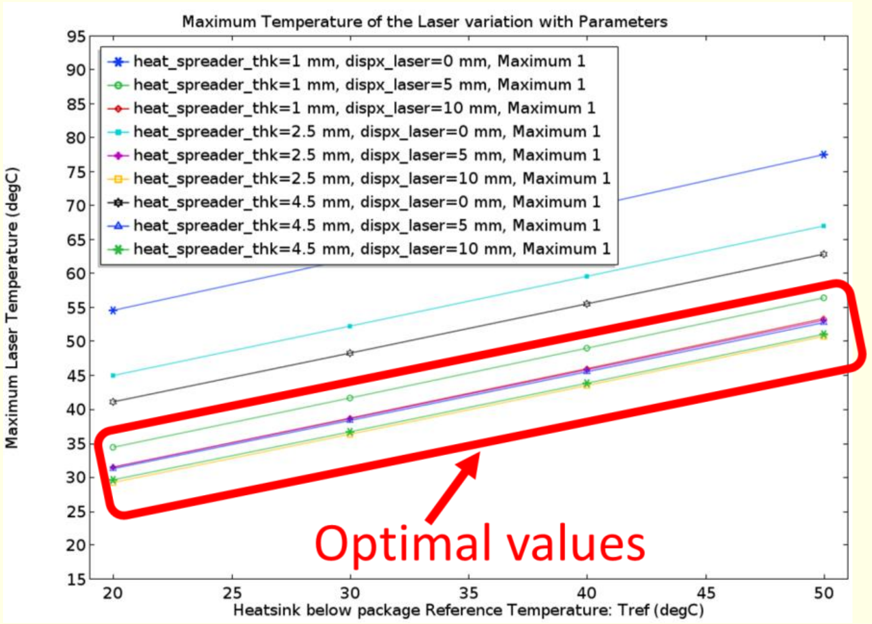
2450K Elements

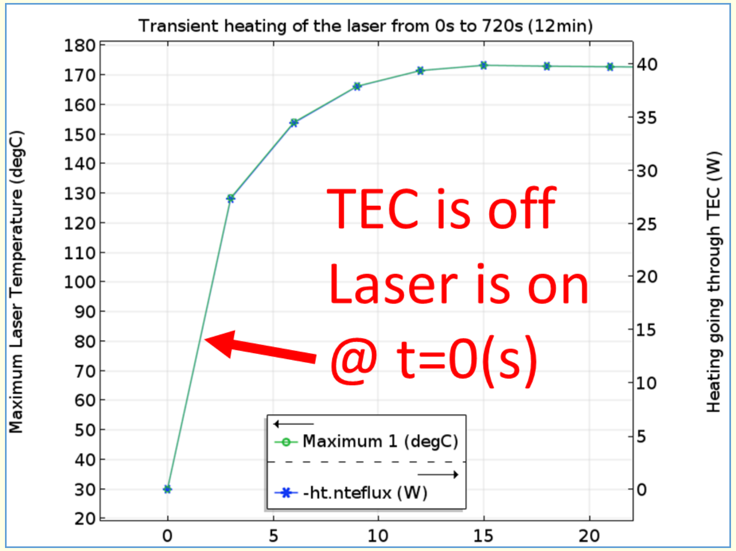
Ambient @ 50°C, Heatsink @ 22°C



Full Package simulations qualitative results

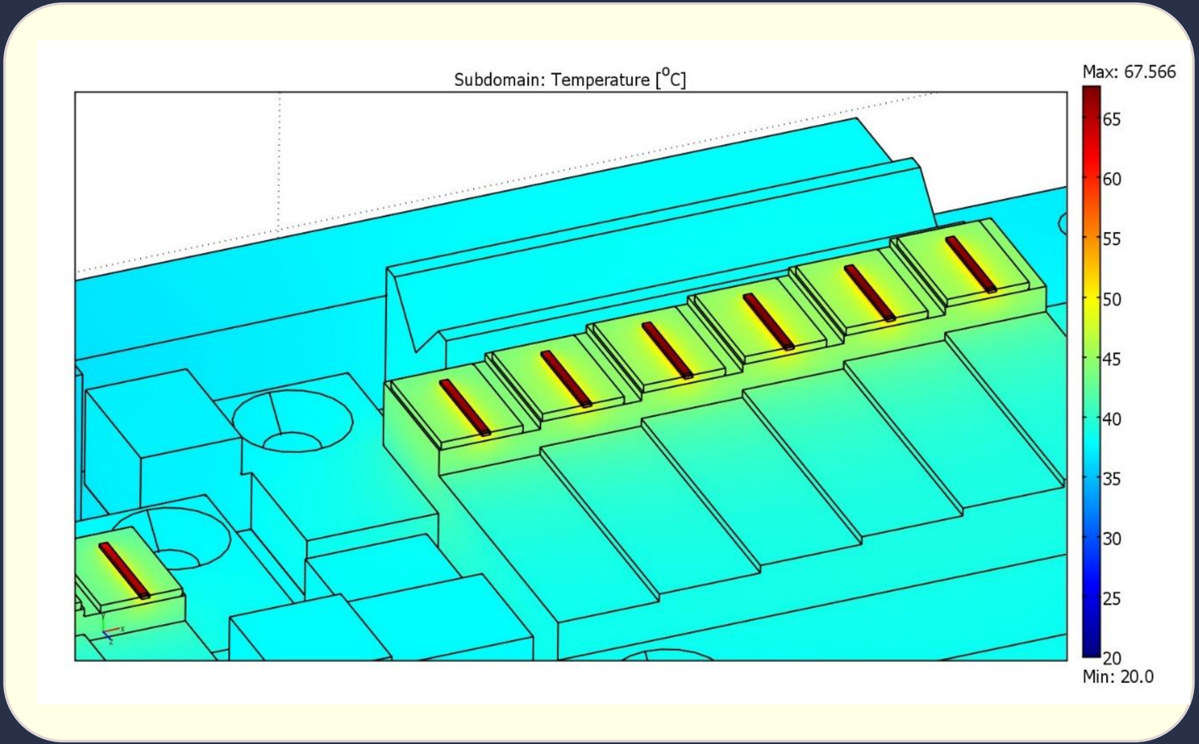
- Optimal set of submount parameter to minimize the laser peak temperature
- Optimal laser mount position was found to minimize laser peak temperature
- Impact of reference heatsink and ambient temperature has been assessed
- Transient simulation to check the full package thermal time-constant(s)

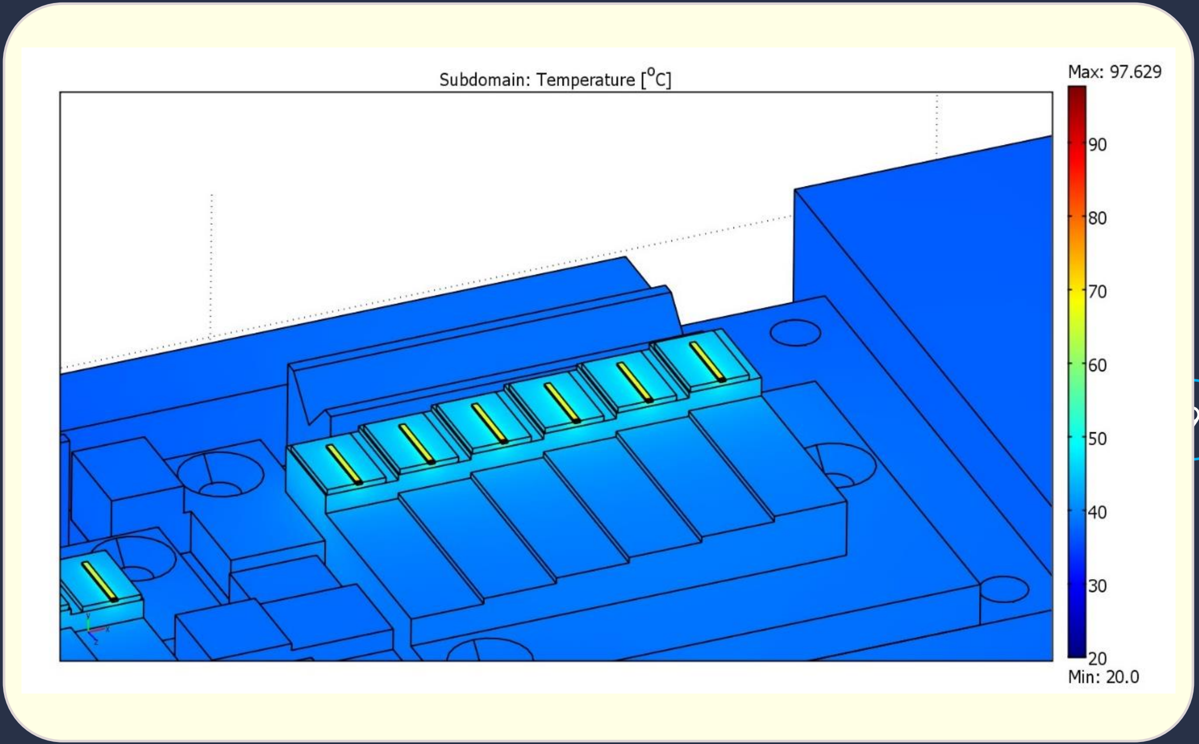




- **Example of transient results**

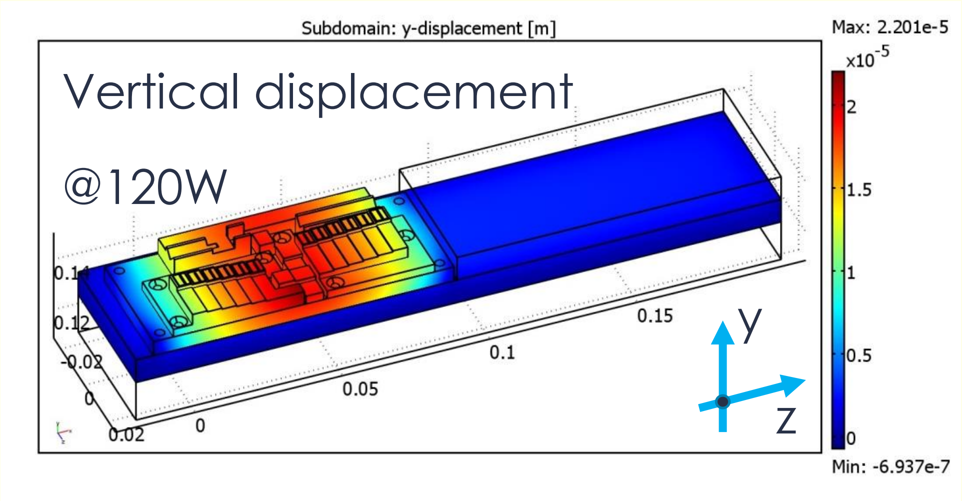
III – Laser system thermal modeling

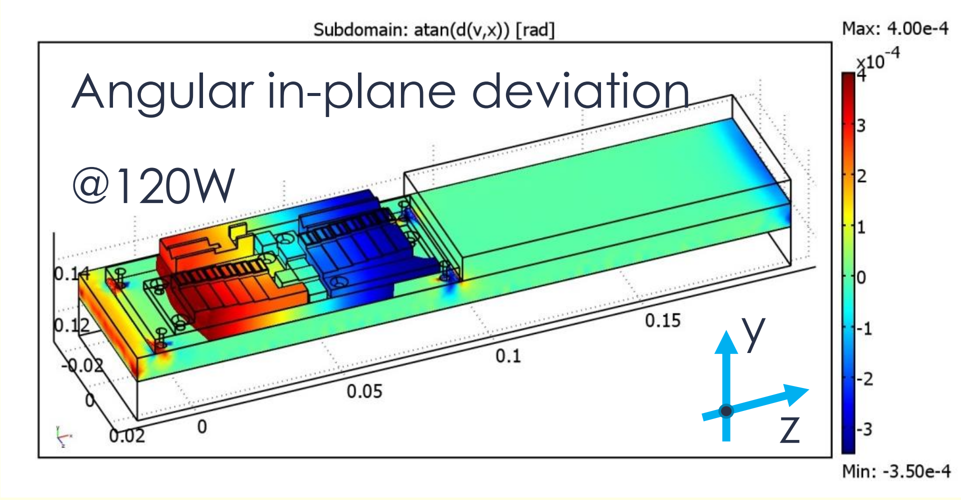




- Laser overhanging ~200µm do heat up +30°C !

Laser system thermo-mechanical modeling

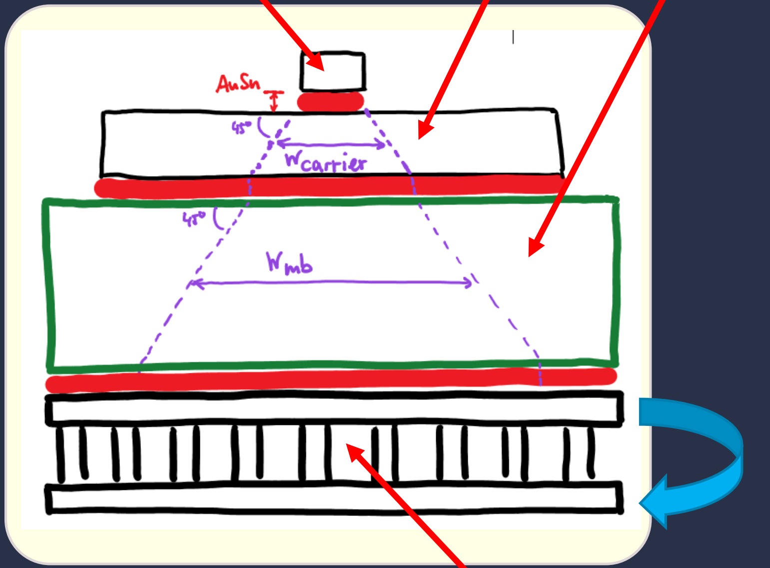




Checking <u>geometrical</u> multiplexing at 120W power:

- Maximum vertical displacement (y-direction) ~22µm
- Maximum angular in-plane deviation (yz-plane) 400µrad

IV - Temperature stabilization by Peltier cooling



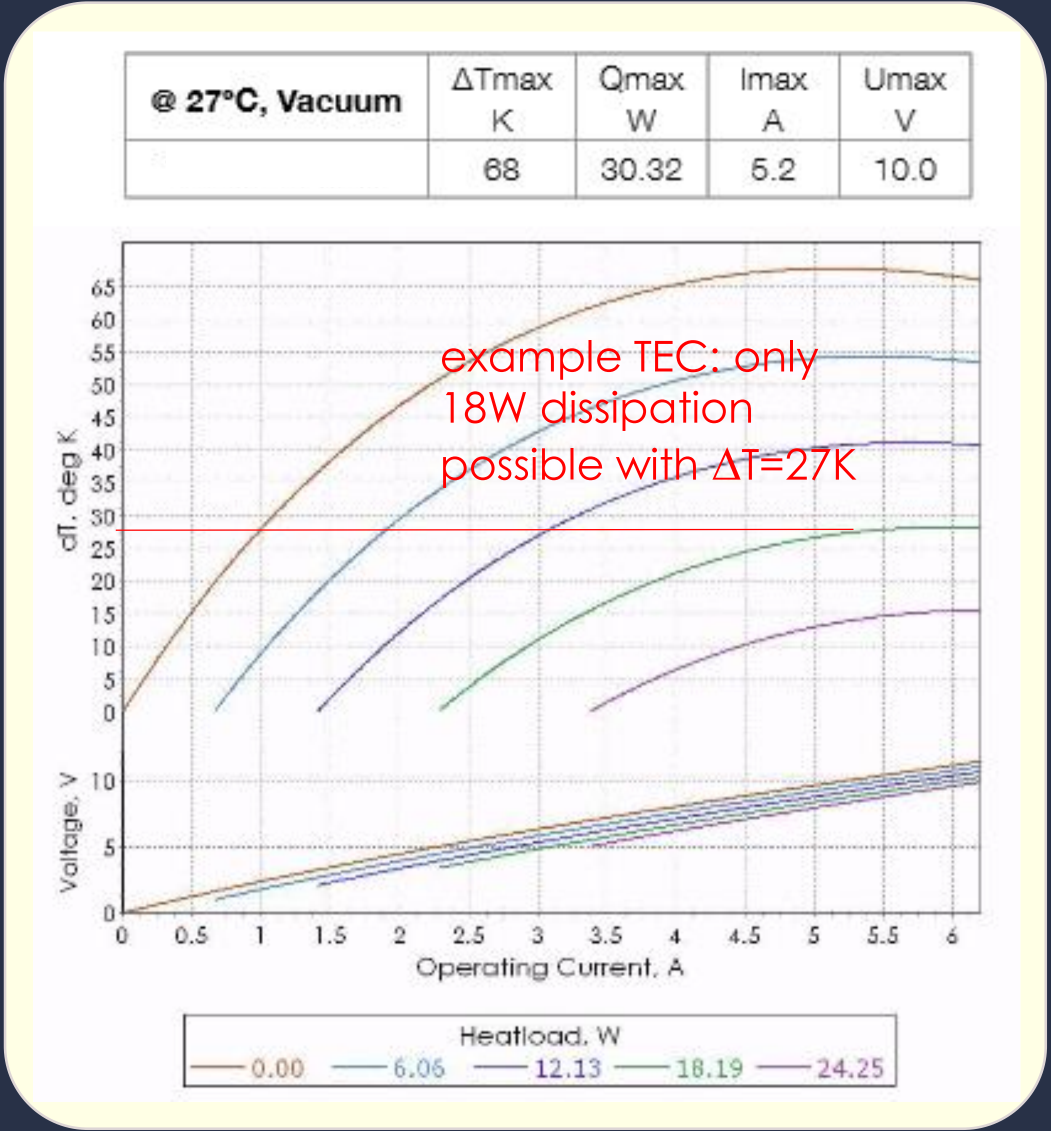
Power laser

Component Carrier

Substrate

ΔT_{TEC}

Peltier-effect based Thermo-electric Cooler (TEC)



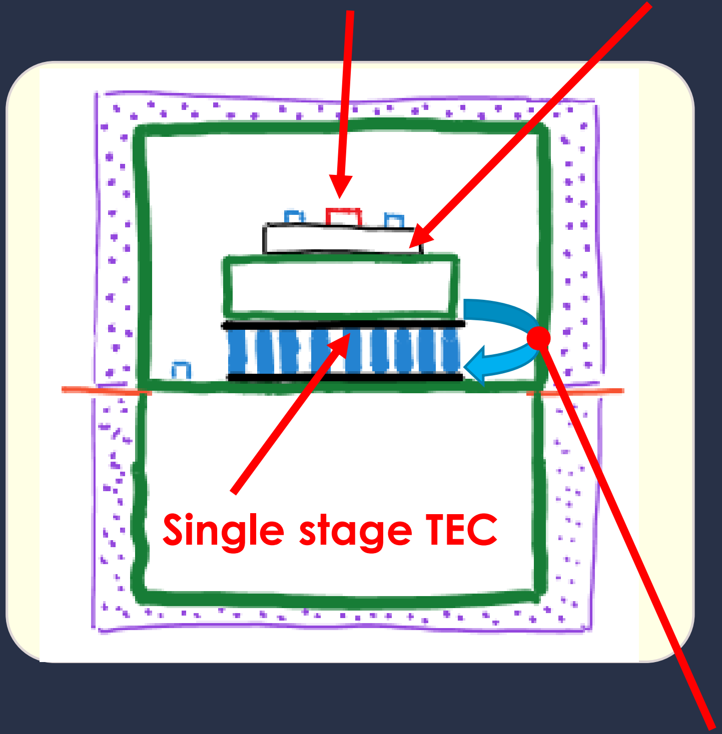
@ 27°C, Vacuum	ΔTmax K	Qmax W	Imax A	Umax V
	68	30.32	5.2	10.0

example TEC: only 18W dissipation possible with ΔT=27K

Solution with single stage TEC in package

Optoelectronic component
dissipated power fix: 30W

Carrier set
temp. fix: 20°C



$\Delta T_{TEC} \approx -22°C$

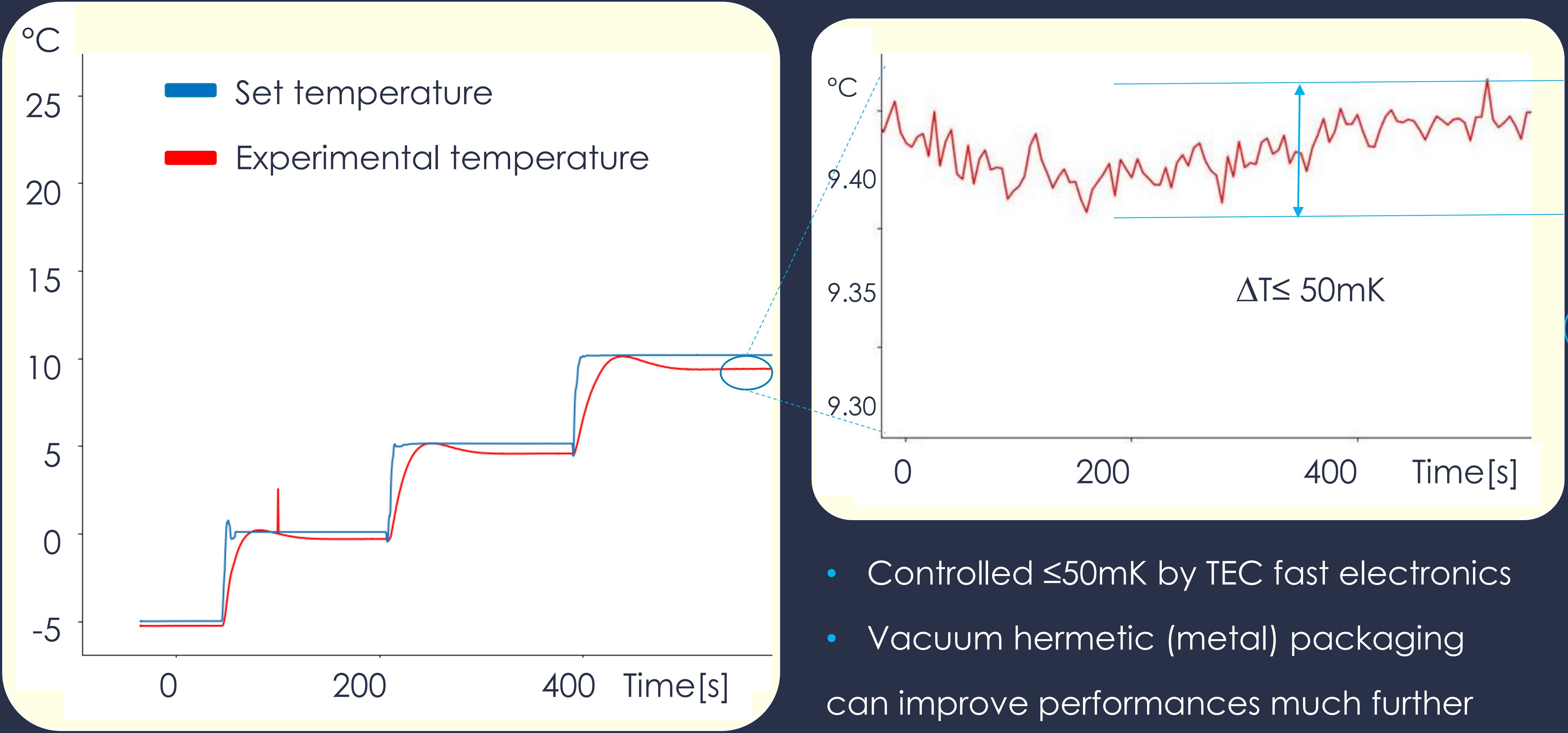
Advantages over multistage TEC:

- less thermal interfaces
- less assembly steps

Disadvantages over multistage TEC:

- limited ΔT vs. thermal load possible
- size of TEC (usually larger for larger thermal load and ΔT)
- large temperature gradient inside of package not optimal for stabilization of temperature

Temperature stabilization TEC results

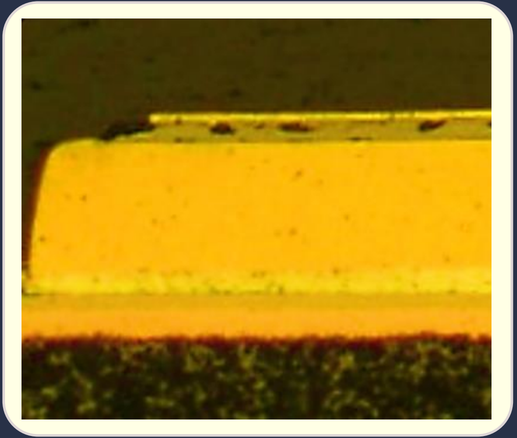


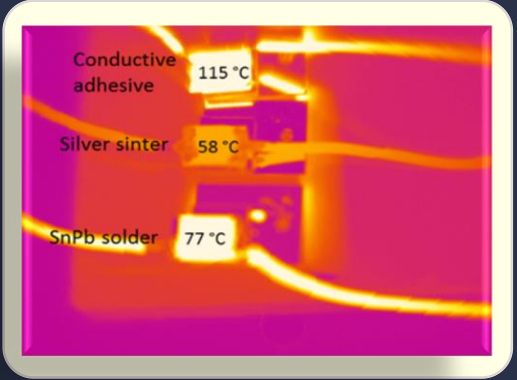
- Controlled ≤50mK by TEC fast electronics
- Vacuum hermetic (metal) packaging

can improve performances much further

V - Future trends for assembly: Silver sintering

- **High power semiconducters mounting using Silver sintering**
  - Alternative to brazing or high temperature soldering
- **Advantages**
  - Low temperature **Mounting : 175 to 250°C**
  - High thermal conductivity : **150 to 300 W/m*K**
  - High Homologues temperature / melting 962°C
    - **High thermal cycling reliability** compared to soldering
- **Evaluation testing under space relevant conditions**
  - Mechanical, thermal and thermal shock reliability testing
  - Analysis of failure modes

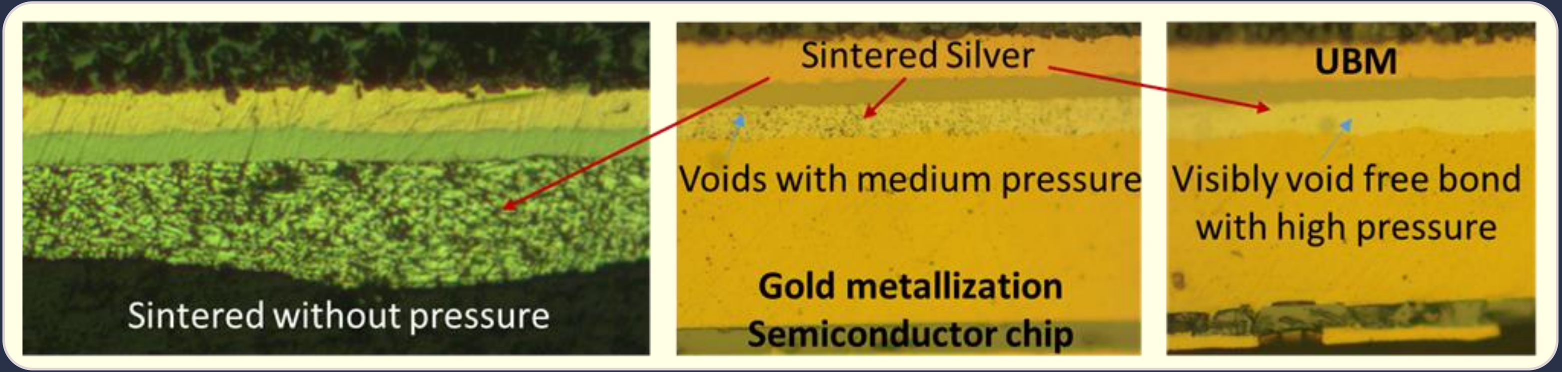




…A good Process is important!!

Process and design will have direct impact on thermal conductivity and reliability

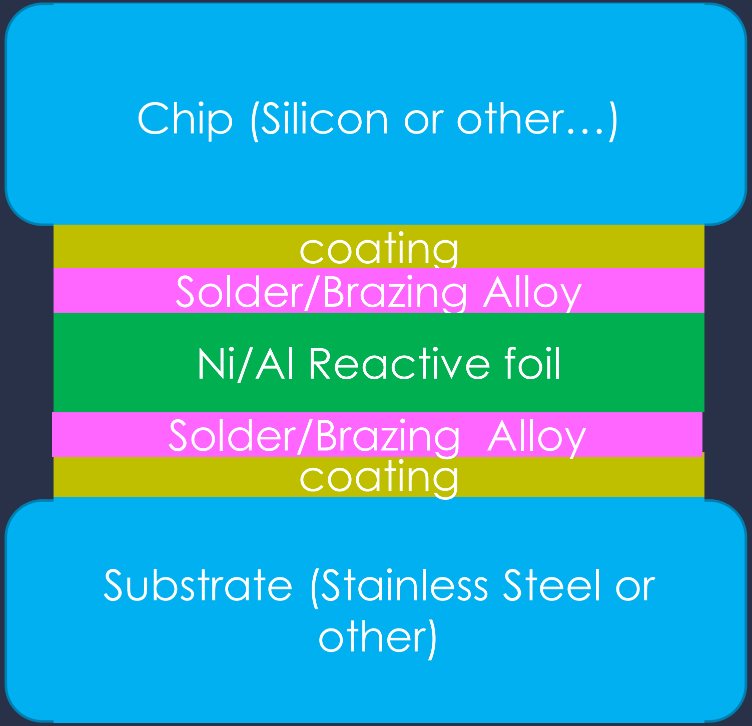
- Higher the temperature the better the sintering and lesser voids.
- Pressure is critical but new materials with no-pressure sintering are now commercially available, but need to be extensively tested.
- Right choice of metallization and UBM is critical.



Future trends: packaging with reactive foils

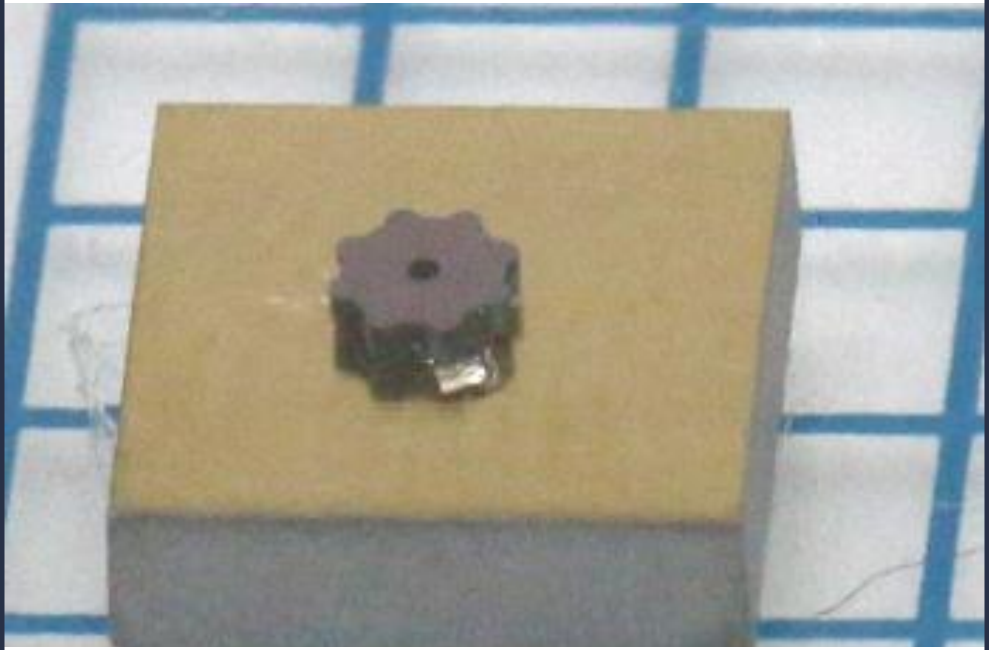
Reactive foil technology benefits

- Enables fast solder process ~ms range
- No furnace is required, therefore enabling assembly of small IC/MEMS/Optoelectronic elements on large metal manufacts (with coatings)
- Enables low-temperature bonding i.e. low thermal mismatch stress
- Possible use case: replacement of thermal conductive adhesive bonding

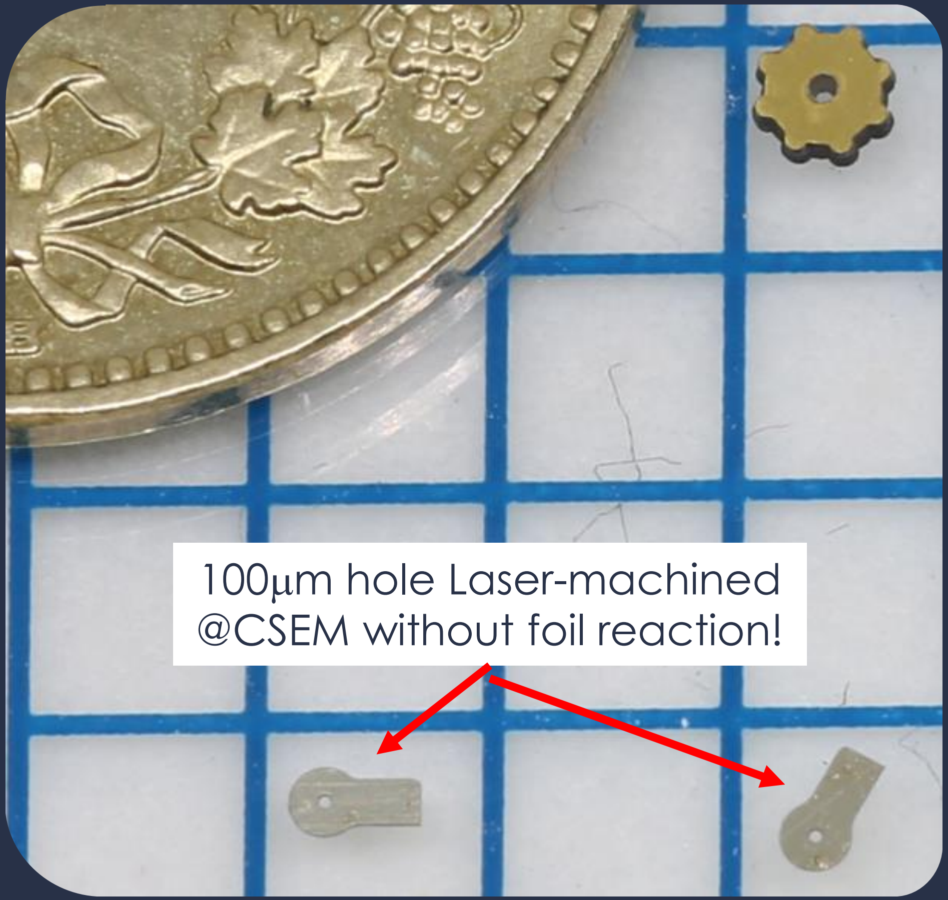

Chip (Silicon or other…)
coating
Solder/Brazing Alloy
Ni/Al Reactive foil
Solder/Brazing Alloy
coating
Substrate (Stainless Steel or other)

Bonding with reactive foils – Laser cutting preforms successfull!

Silicon Gear bonded on Stainless Steel
with AuSn solder preform

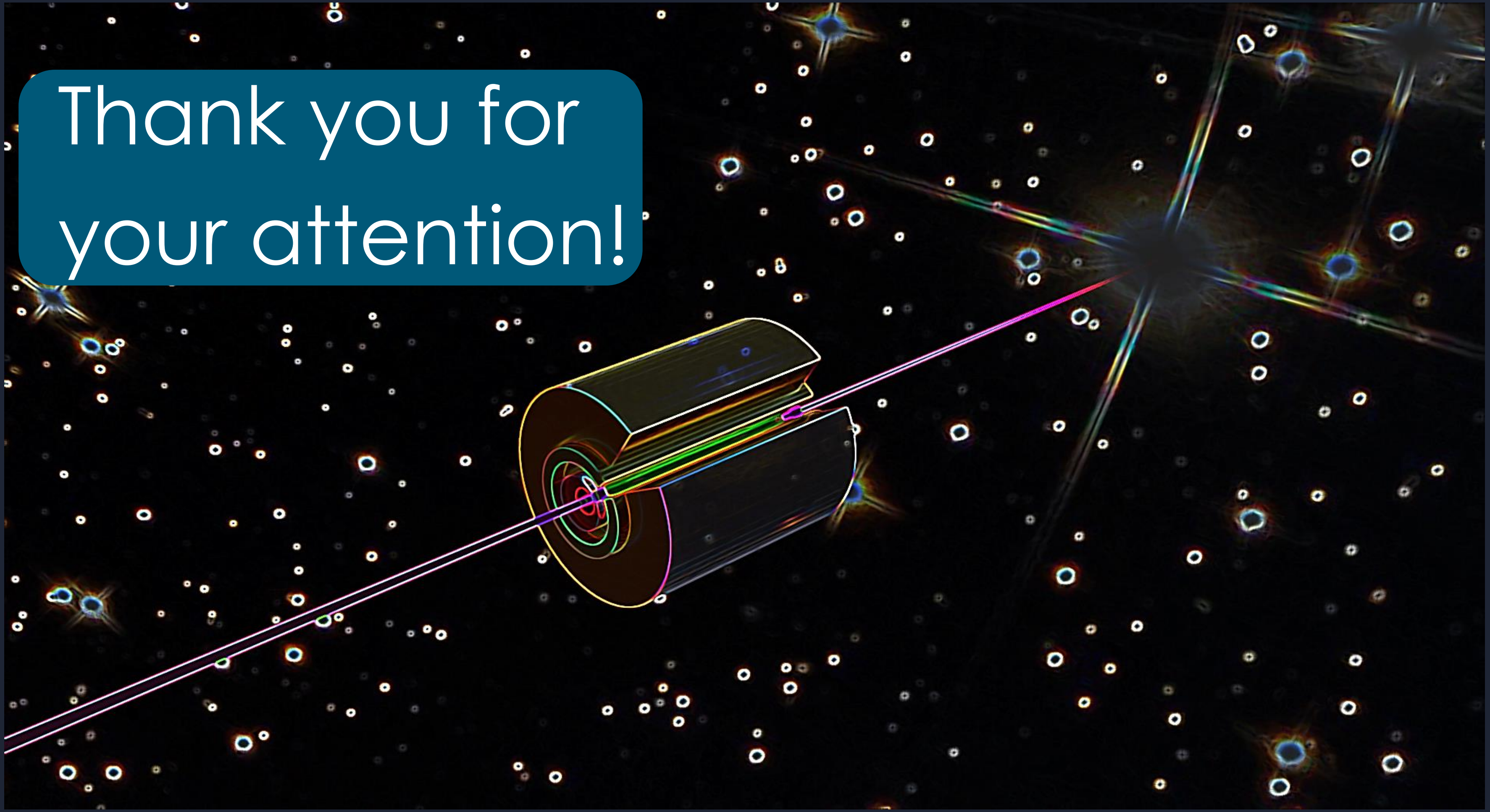


Low temperature bonding
with Nanofoil™ reactive foil



100µm hole Laser-machined
@CSEM without foil reaction!

SWISS PHOTONICS



Thank you for your attention!

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