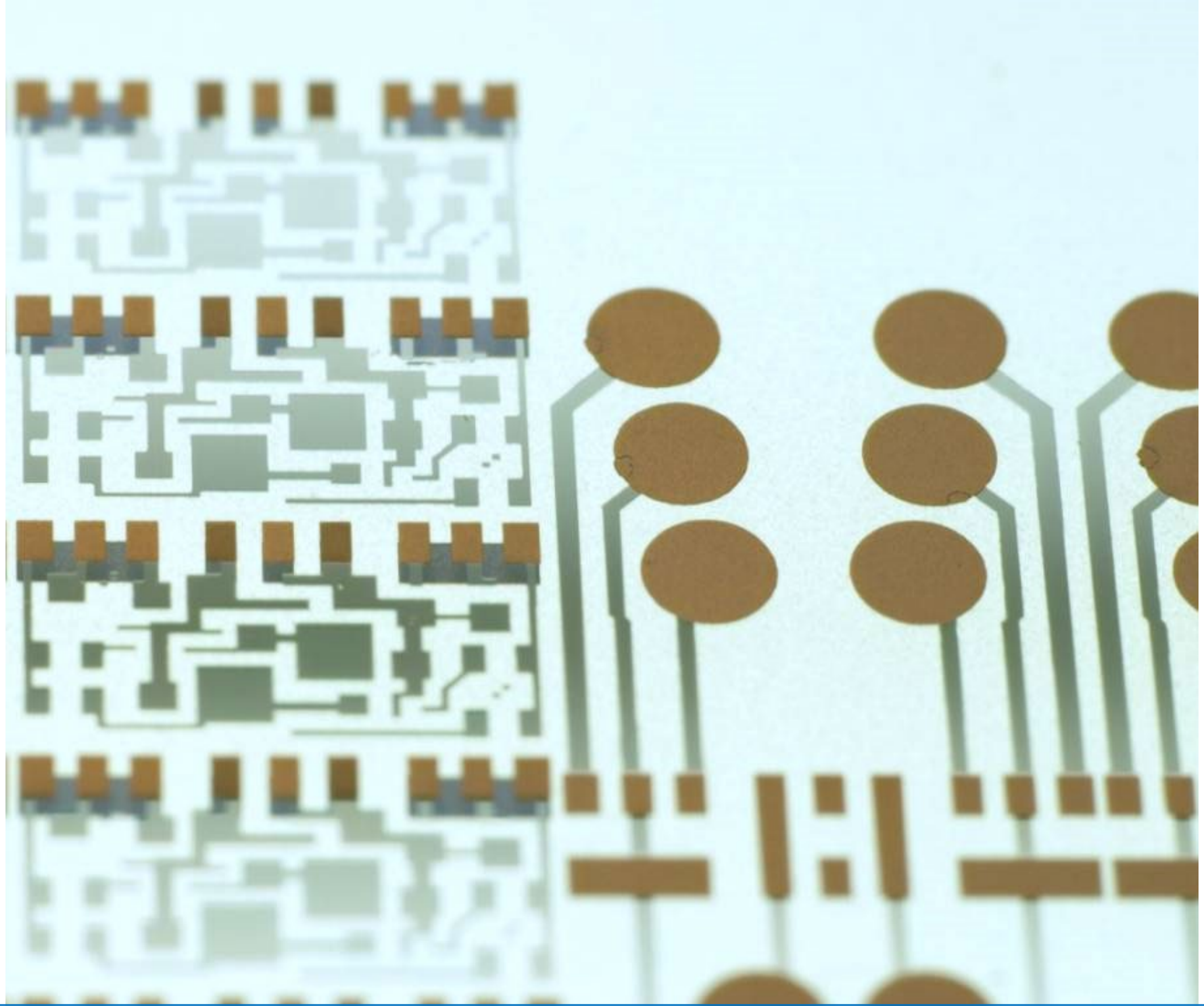
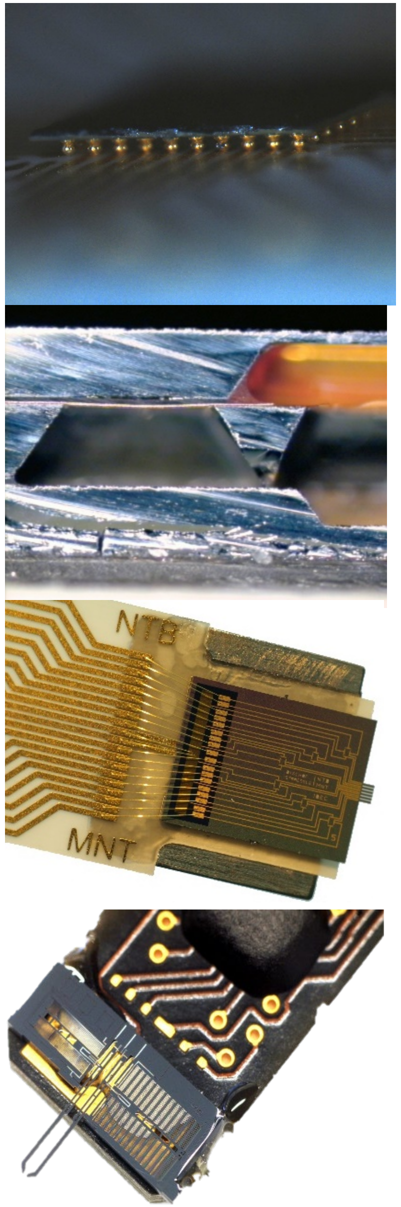
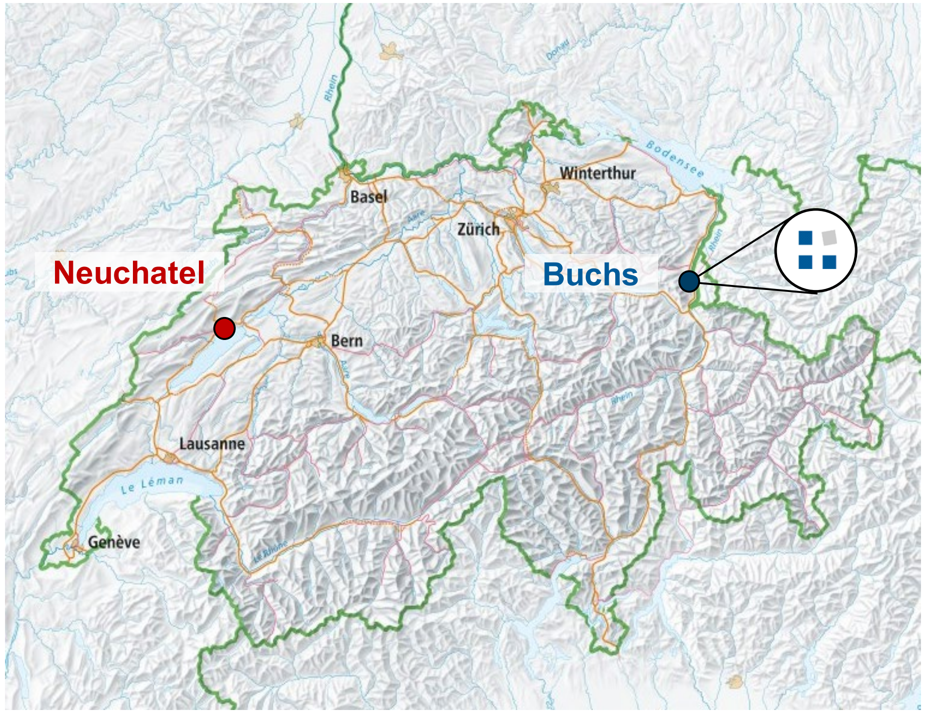
NTB
Interstaatliche Hochschule
für Technik Buchs
FHO Fachhochschule Ostschweiz

MNT INSTITUT FÜR MIKRO-
UND NANOTECHNOLOGIE





Institute for Micro and Nanotechnology MNT
SPPL- Cooling methods for high thermal load devices



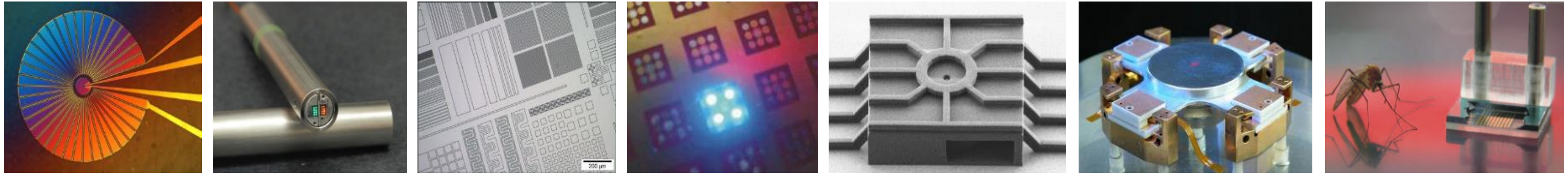
Interstate University of Applied Science Buchs, NTB

- Member of the FHO
- Systems engineering with 6 profiles
- 400 Students, 40 Professors, 150 Staff
- 7 Institutes
- 49 years on market (Nov. 1970)

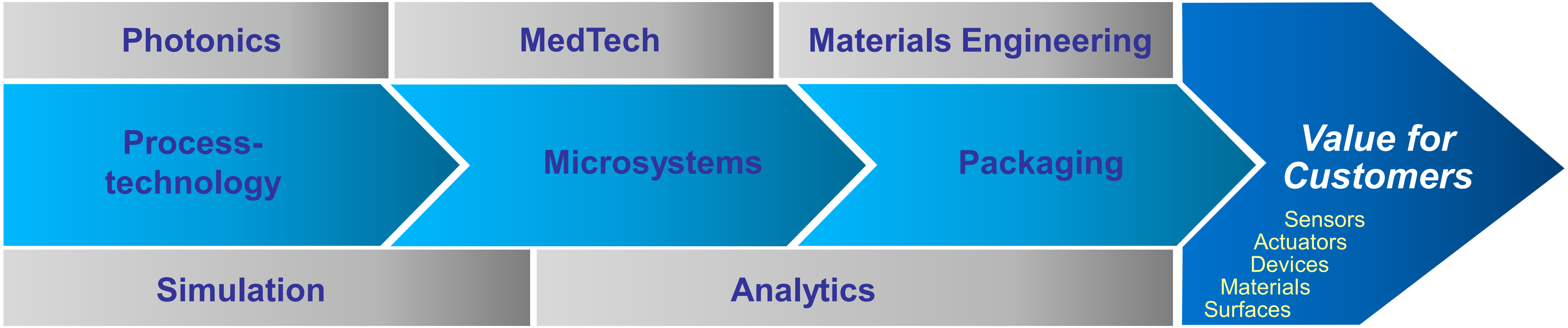
Technology Transfer as «Partner of Industry»

- Services in processing, metrology and consulting
- Applied R&D projects
- Feasability studies
- Diploma works
- Different hands on courses (MEMS, Vacuum,…)

Our core competencies, infrastructure, processes



- Sensors and Actuators (MEMS)
- Photonics, Micro-optical Systems (MOEMS)
- Packaging Technologies
- Thin Films, Micro- and Nanostructures
- MedTech & Microfluidics Devices
- Characterization & Failure Analysis
- Polymers and Adhesives
- Additive Manufacturing



Photonics | **MedTech** | **Materials Engineering**

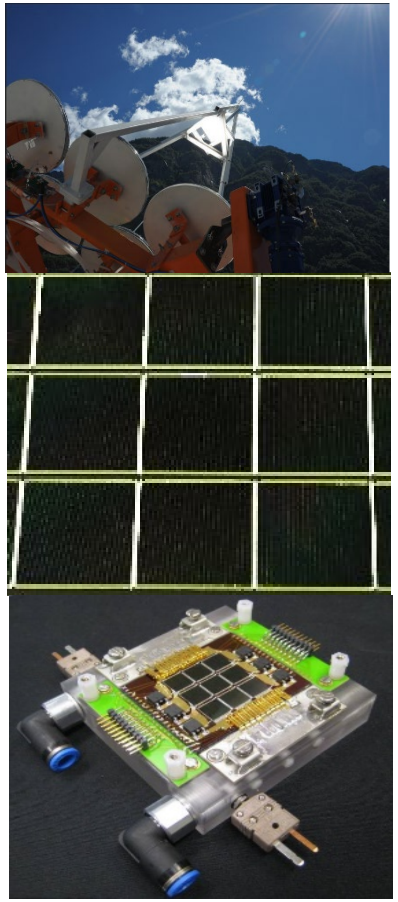
Process-technology → **Microsystems** → **Packaging** → ***Value for Customers***

Sensors
Actuators
Devices
Materials
Surfaces

Simulation | **Analytics**

Why thermal management

Solar cells, LEDs, power electronics



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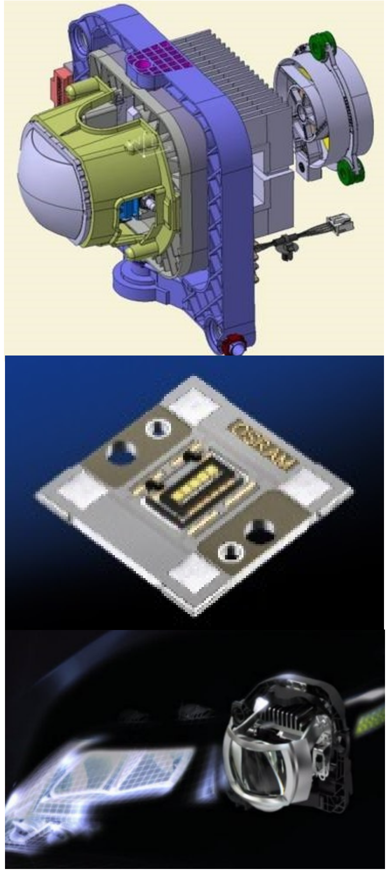

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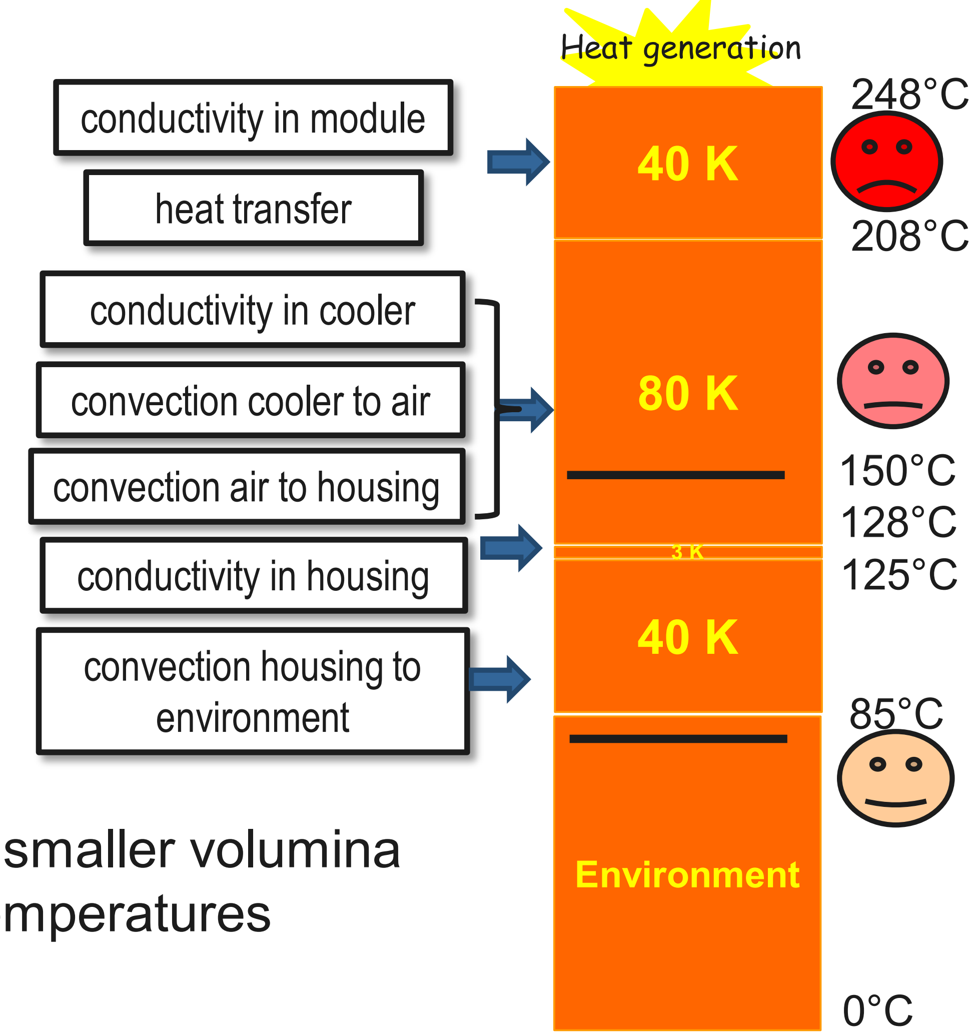
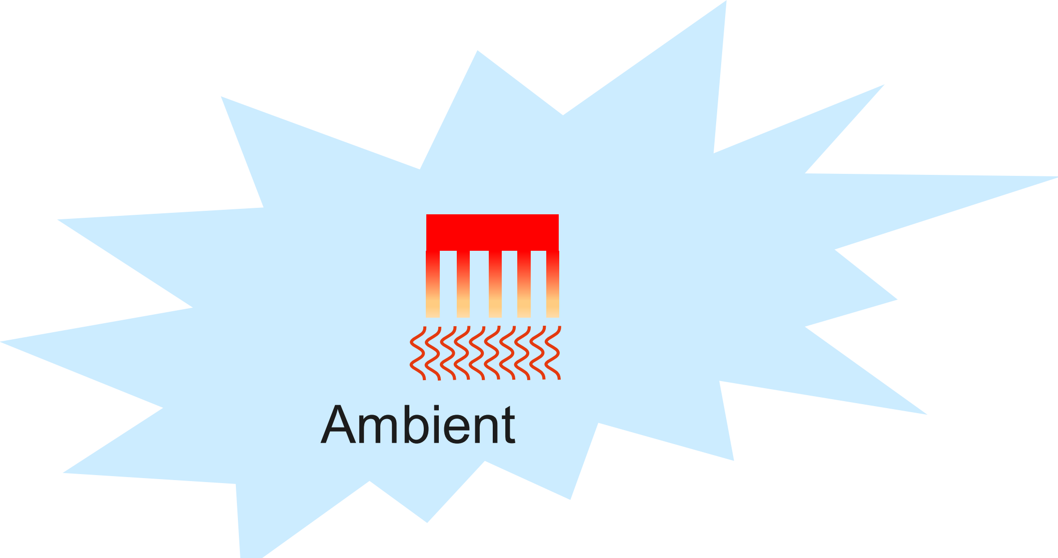
e.g.: LED in car frontlight

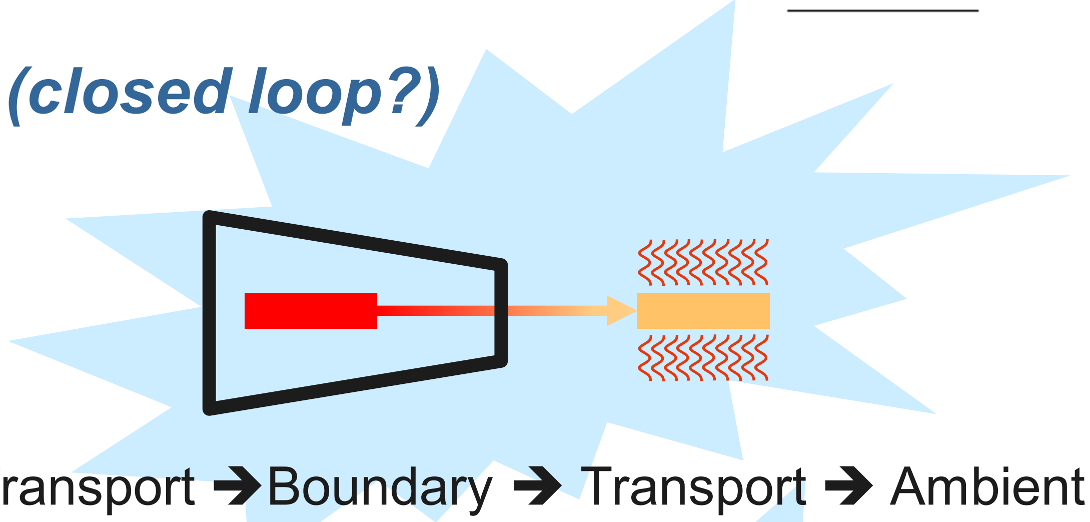


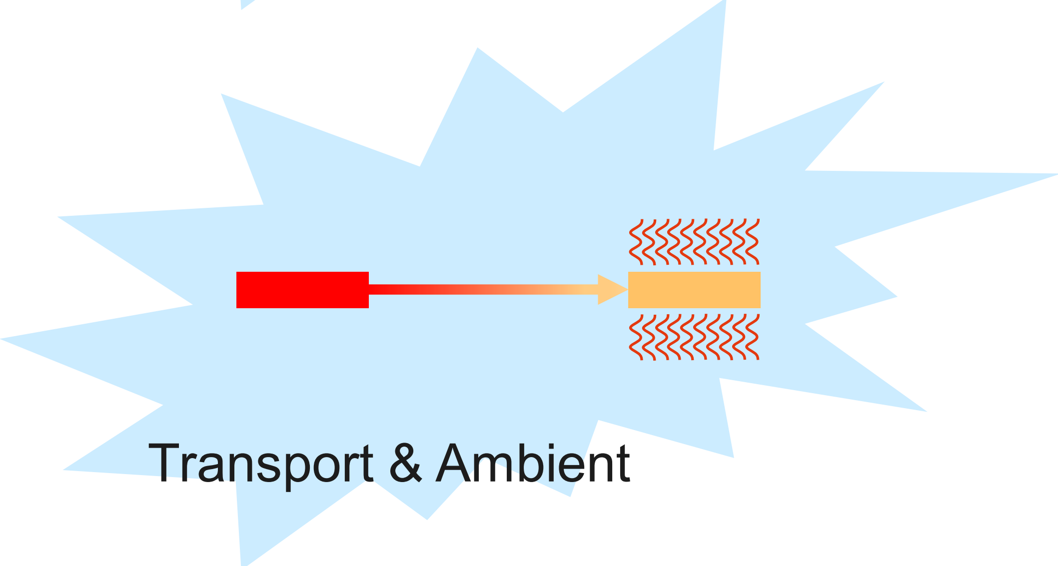
- conductivity in module
- heat transfer
- conductivity in cooler
- convection cooler to air
- convection air to housing
- conductivity in housing
- convection housing to environment

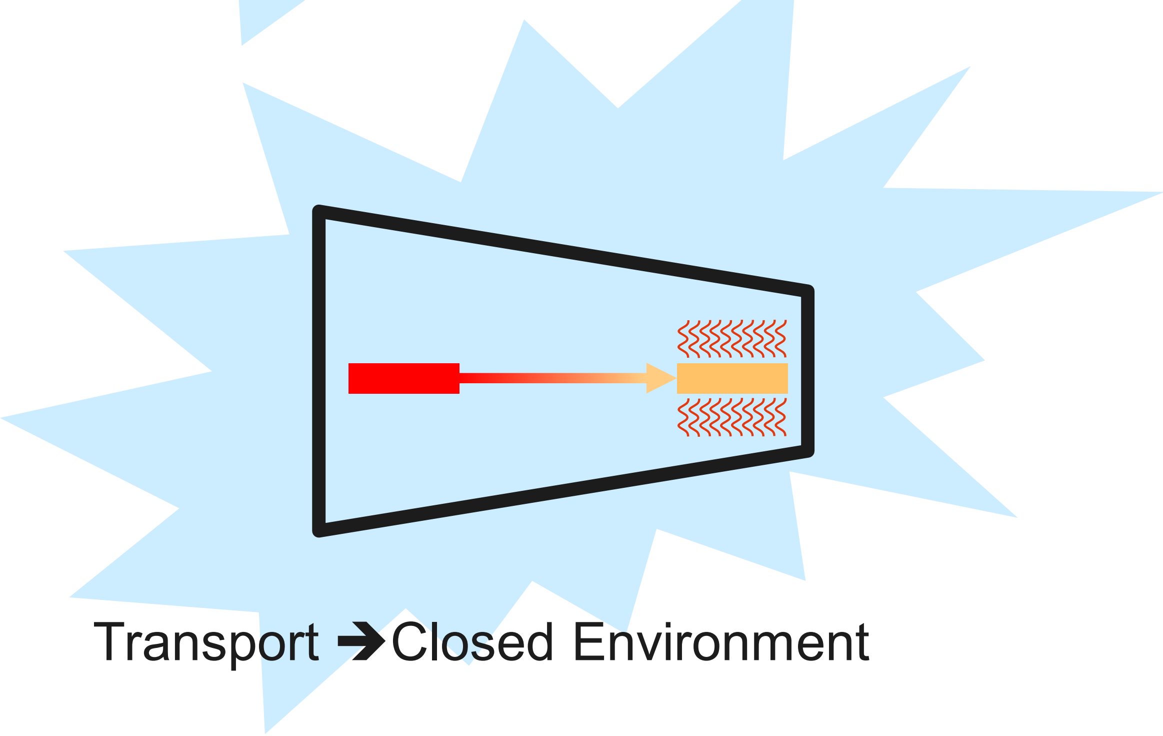
High thermal loads in smaller volumina and higher ambient temperatures

Where is the system boundary (closed loop?)


Ambient


Transport ➔ Boundary ➔ Transport ➔ Ambient


Transport & Ambient


Transport ➔ Closed Environment

What is done today

- Smaller traces and thicknesses for the copper and isolators, but no vast improvement in thermal conductivity of the isolators, other than reducing layers and base material thicknesses for PCBs.

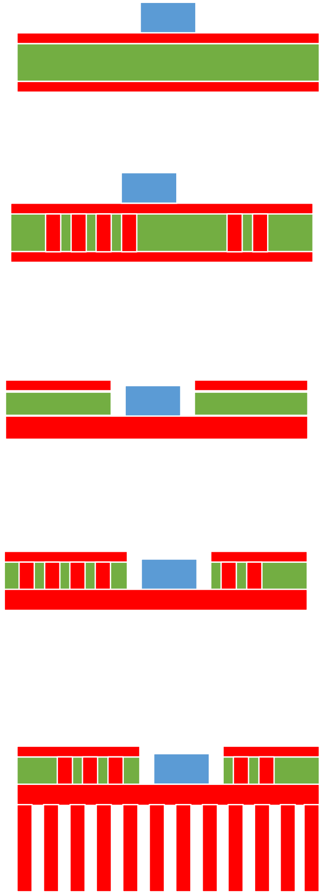
- Potting of devices using thermal conductive adhesives / Pastes to have better heat transfer and homogenisation in a device (no unfilled air rooms)
➔ Nowadays projects to improve the thermal conductivity using particle filled mould systems.

- Populating the Electronic boards onto the «cool» / «cooled surfaces»

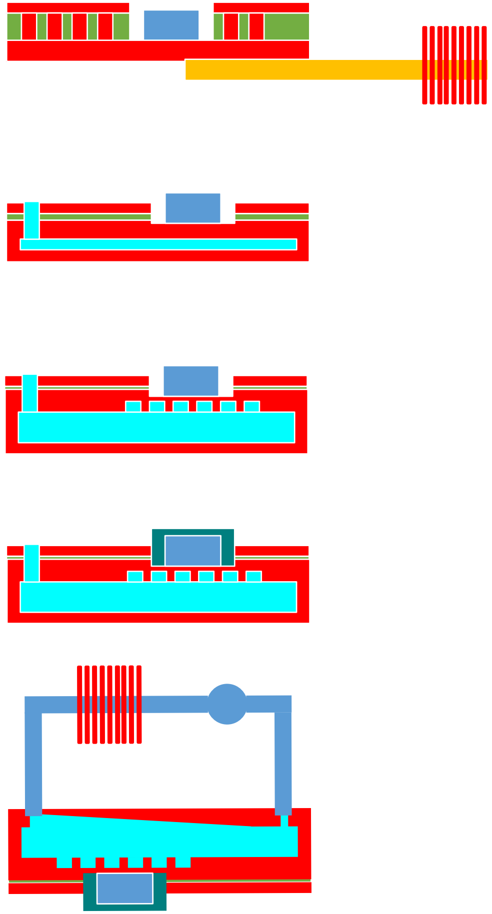
- Using the available cooling systems for example a cars air conditioning to cool the electronic parts.

- Special coatings to have «submerged» electronics

Strategies for cooling



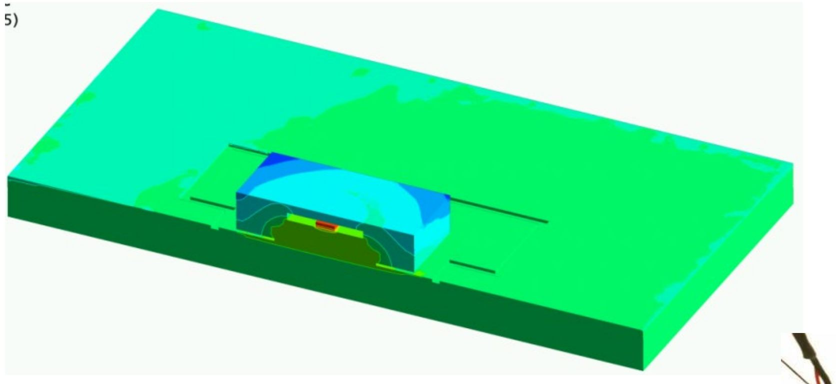
Principle Medium	no external drive	External drive (motor, compressor unit)
1 Phase: Air	natural convection & heat sink	forced convection (heat sink & fan)
1 Phase: Liquid	natural convection using density differences	liquid pump
2 Phase: liquid and vapour	heatpipe vapour bubble pump	refrigerator pump
Short time / Power bursts	phase change materials	Peltier element

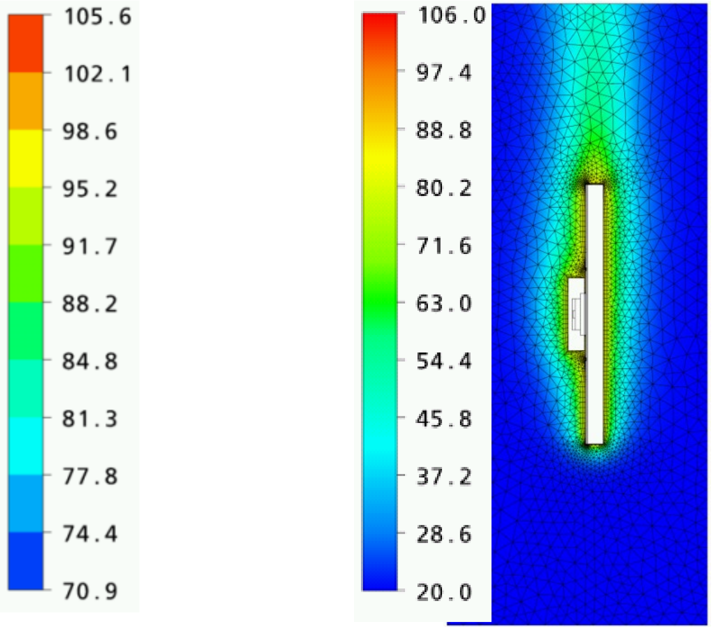


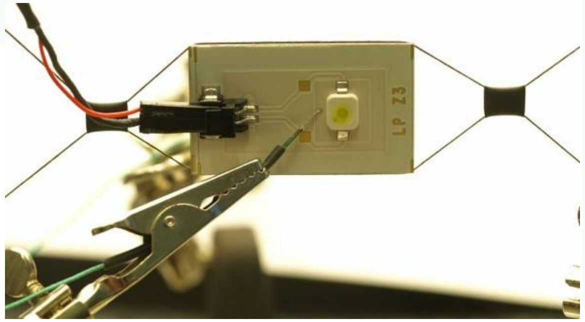
Also mixing of the above mentioned methodes (e.g.: liquid pump combined with vapour bubbles)

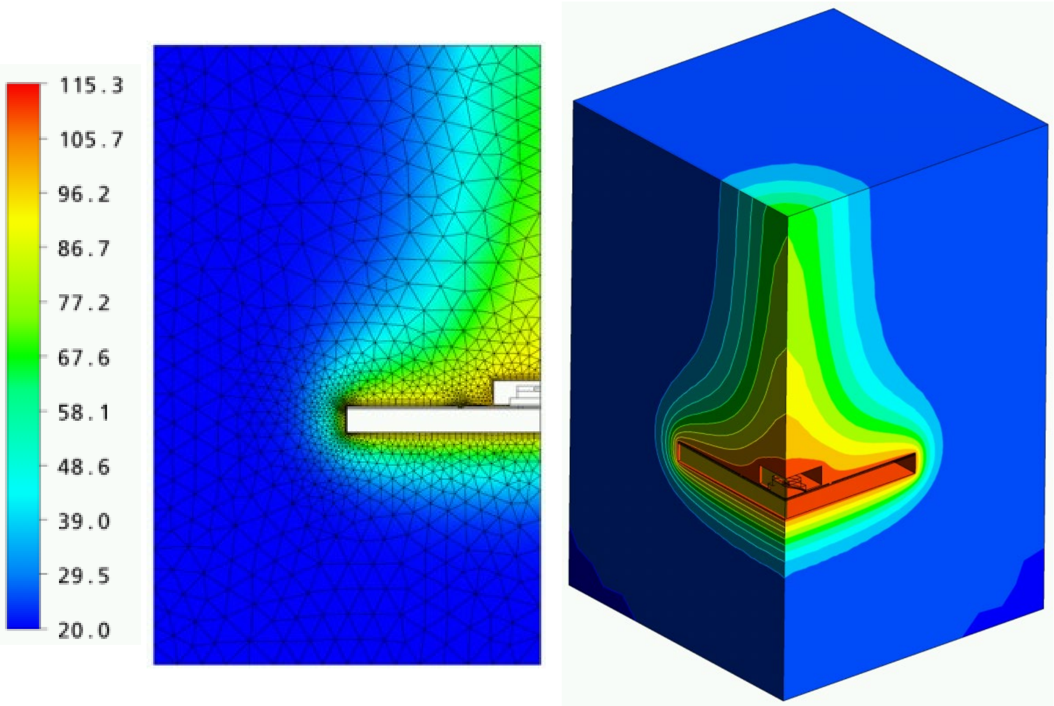
Fundamentals of Heat and Mass Transfer
Incropera, DeWitt

Natural convection









T_{∞} = 20 ºC

$T_{Substrate}$ = 85.6 ºC

α =9.96 W/(m² · K)

$R_{th\ BA}$ = 65.6 K/W

T_{∞} = 20 ºC

$T_{Substrate}$ = 94.8ºC

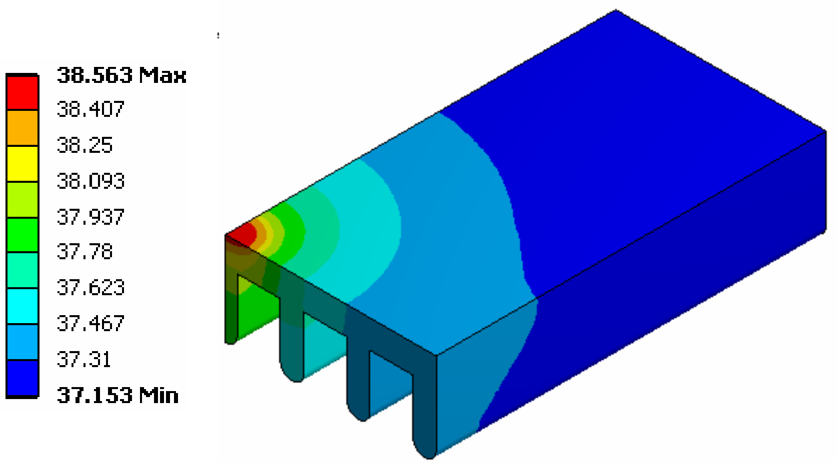
α = 8.73 W/(m² · K)

$R_{th\ BA}$ = 74.8 K/W

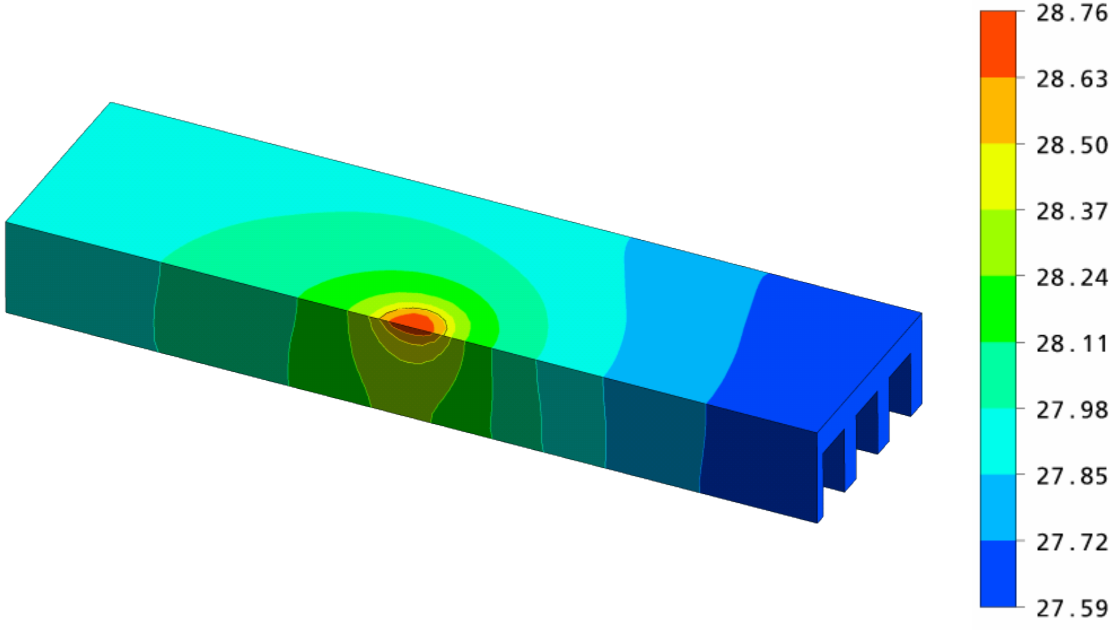
Vertial System

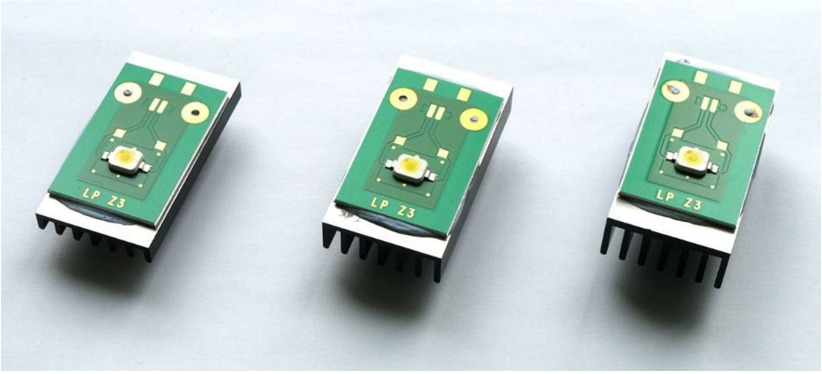
Horizontal System

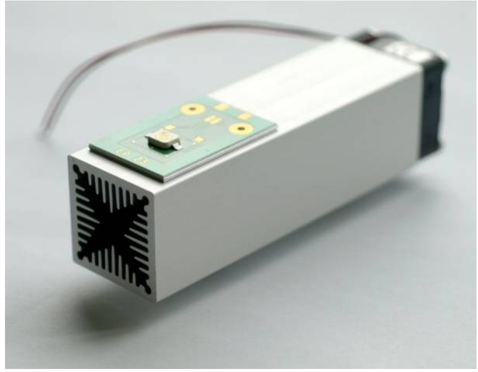
Heat sink natural or forced convection



Einspeisung punktförmig
Rth= 17.9 K/W
(bezogen auf mittlere Temperatur)



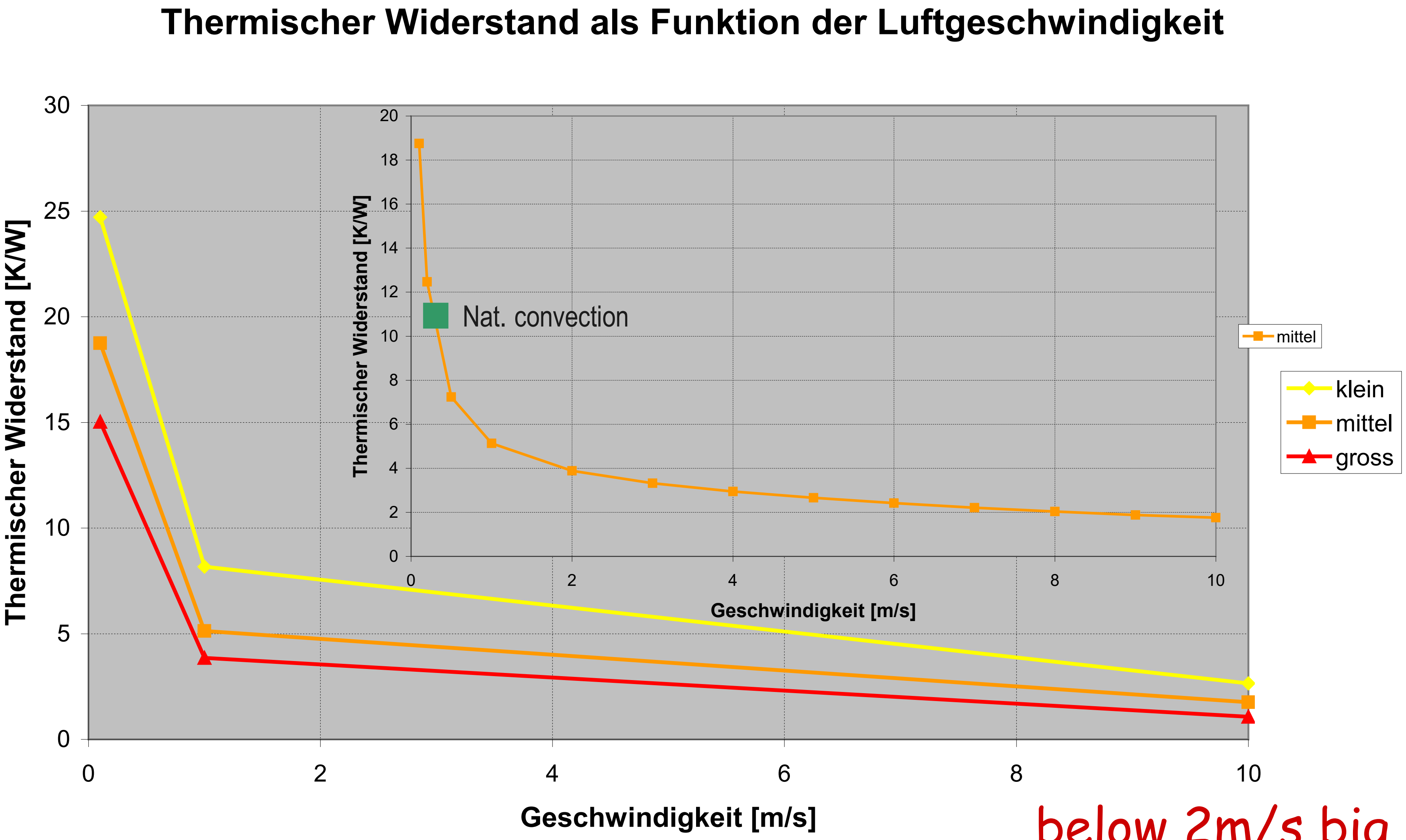




v_{Luft} = 1m/s
T_{∞} = 20 °C
$T_{Substrat}$ = 28.1°C
$\alpha = 23.6\ W/(m^2 \cdot K)$

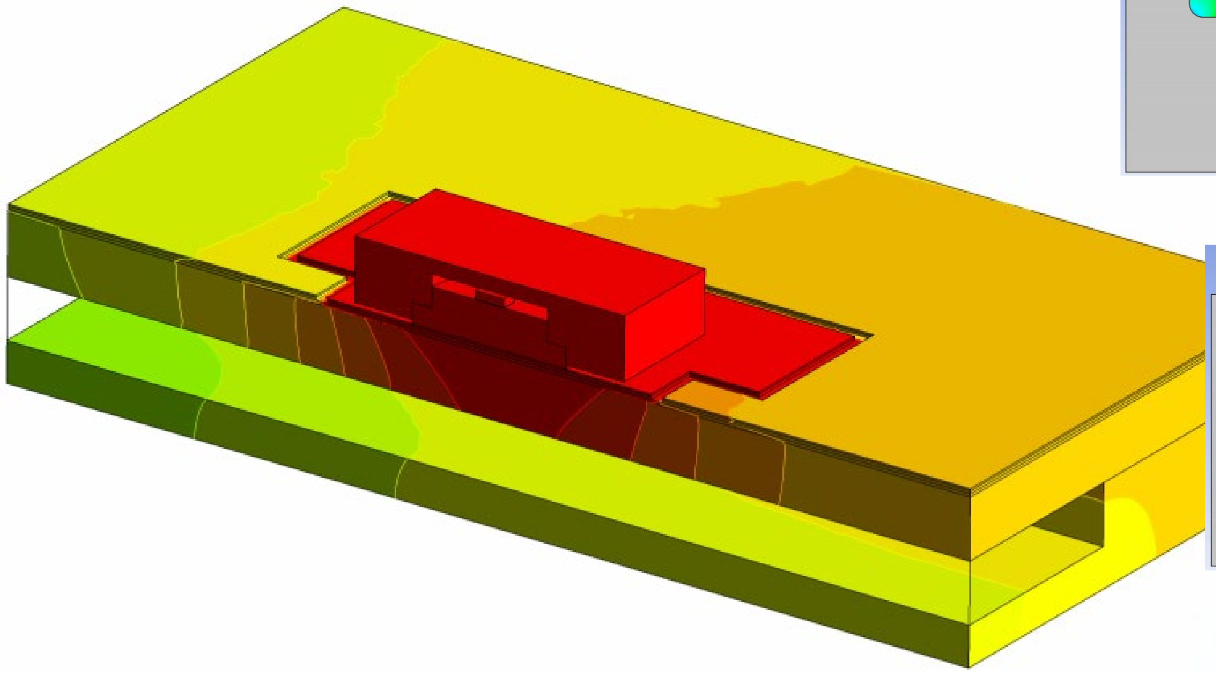
$R_{th\ BA}$ = 8.1 K/W

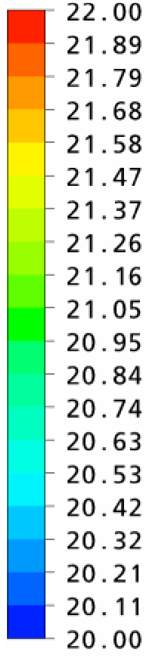
Heat sink and airflow behaviour

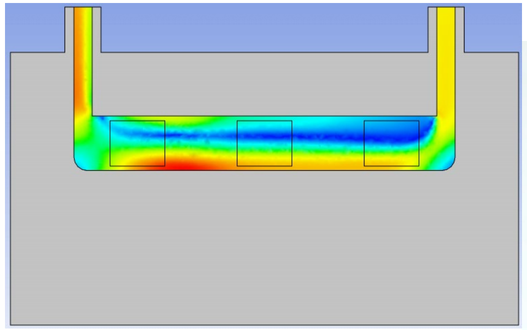


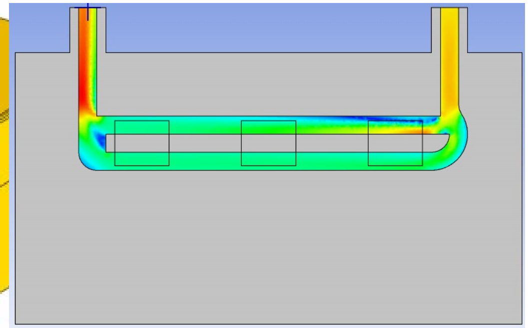
below 2m/s big influence

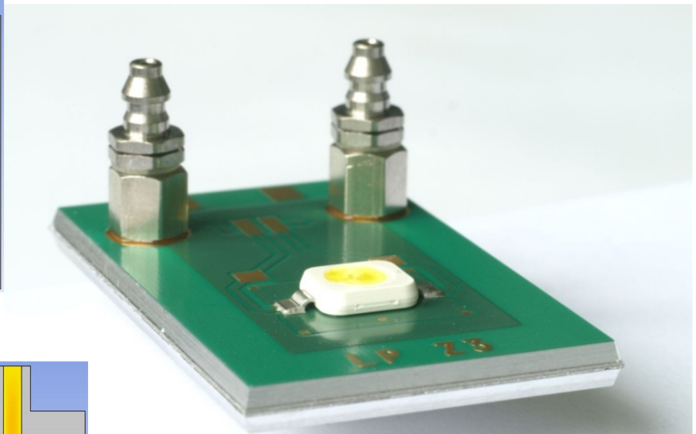
Flow in IMS Substrate

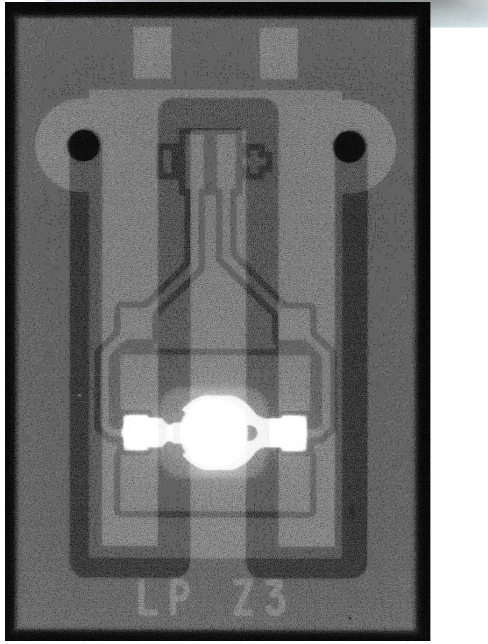




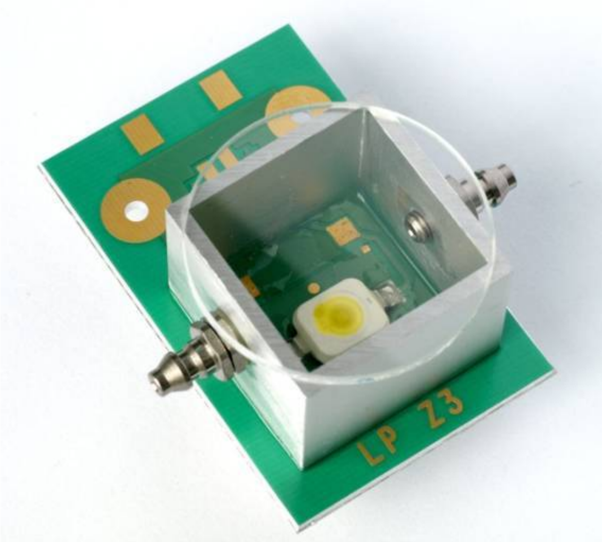








Tested to 28 bar pressure



Flow: 1000 ml/h

$T_{\infty} = 20\ ^{\circ}C$

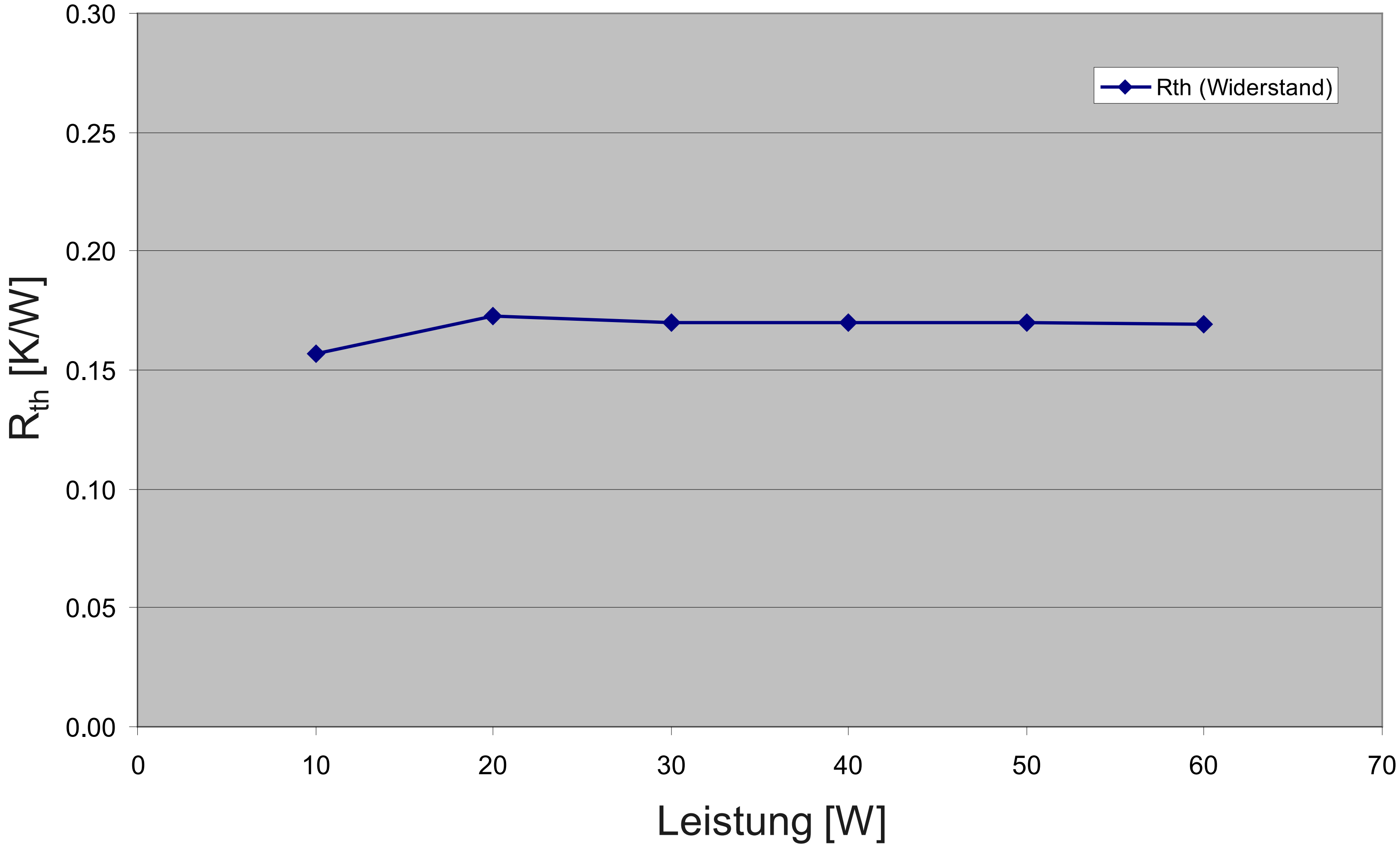
$T_{Substrat} = 21.6^{\circ}C$

$\mathfrak{a} = 1129\ W/(m^2 \cdot K)$

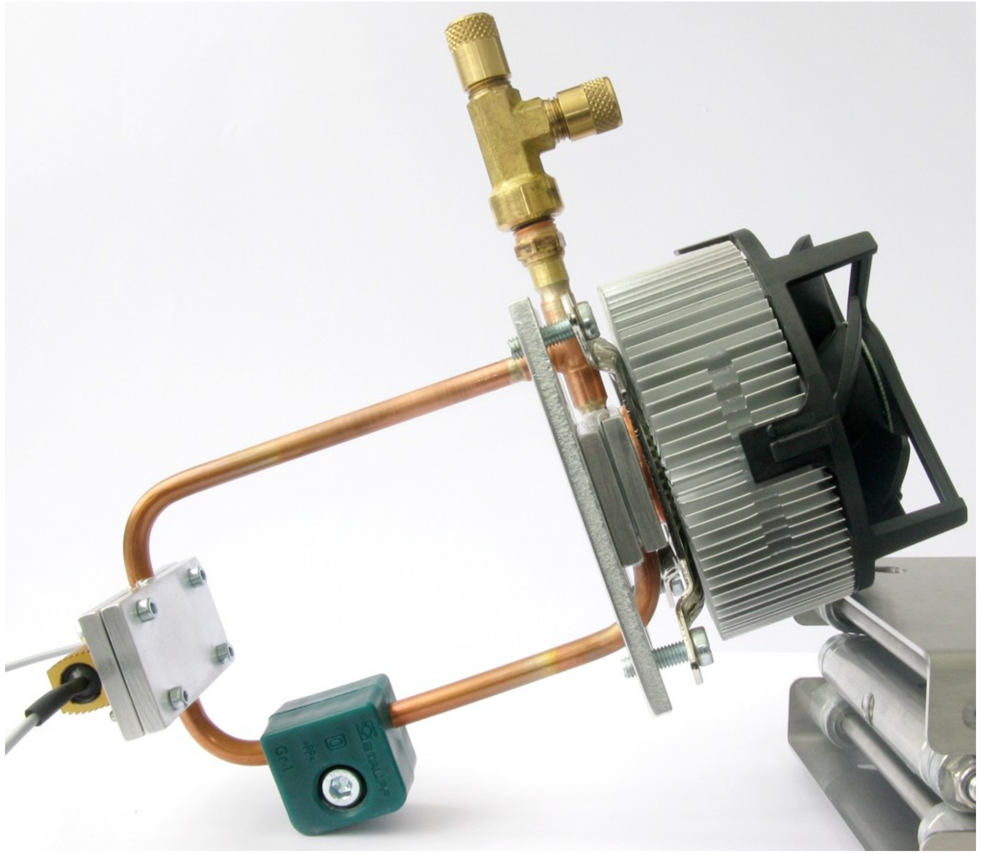
$R_{th\ BA}$ = 1.6 K/W to 0.31 K/W

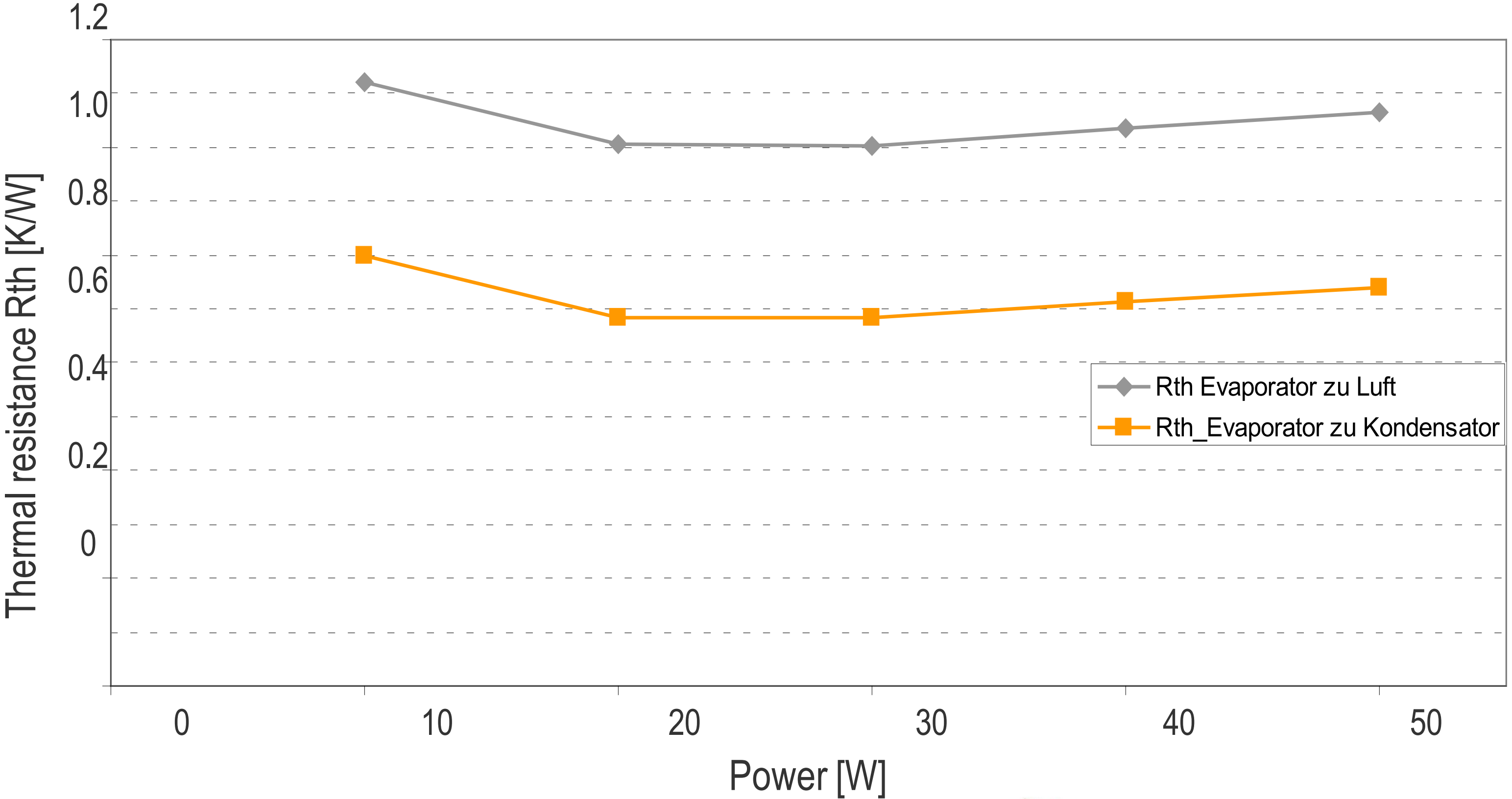
Depending on Channel geometry and flow rate

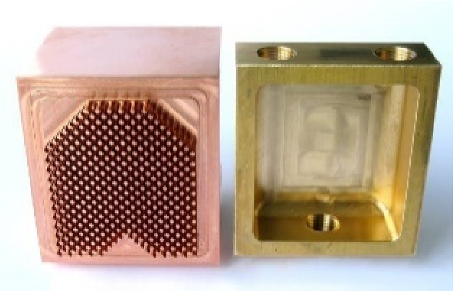
Thermal resistance of a closed fluid loop system

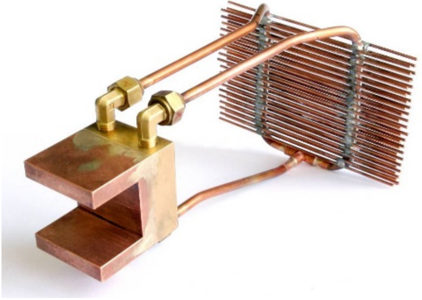


Vapour bubble pump with air cooling



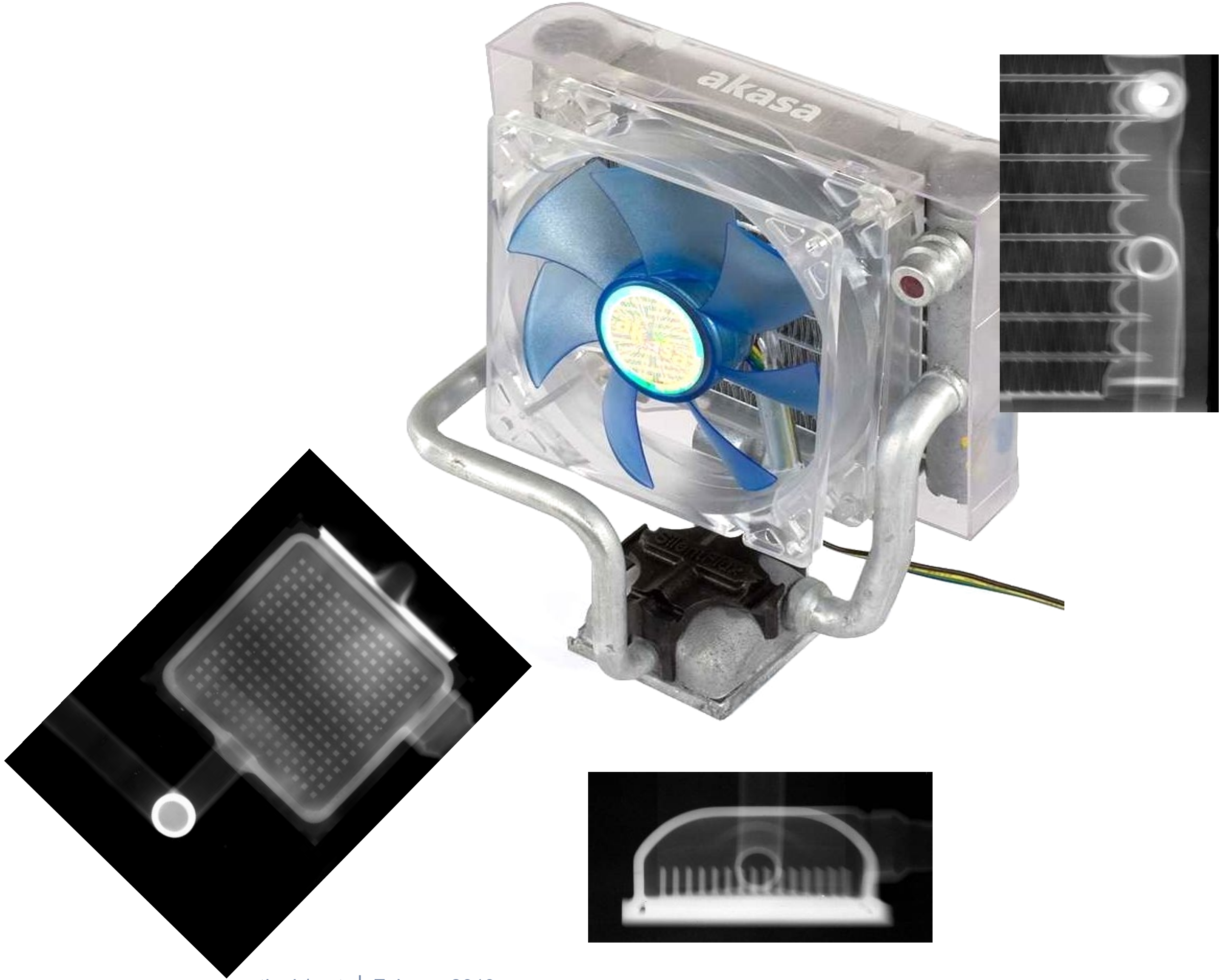




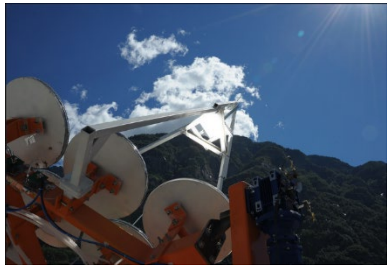


REVO processor cooler using bubble pump

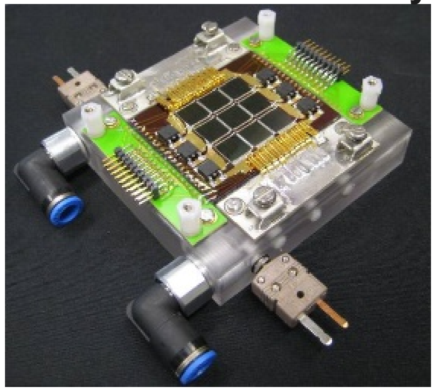
- Closed system loop
- Medium: R134a
- Al-construction
- Fine pitch fin cooler
- Different orientations possible
- Rth = 0.3…0.4 K/W
  (measured up to 60W)



HCPVT

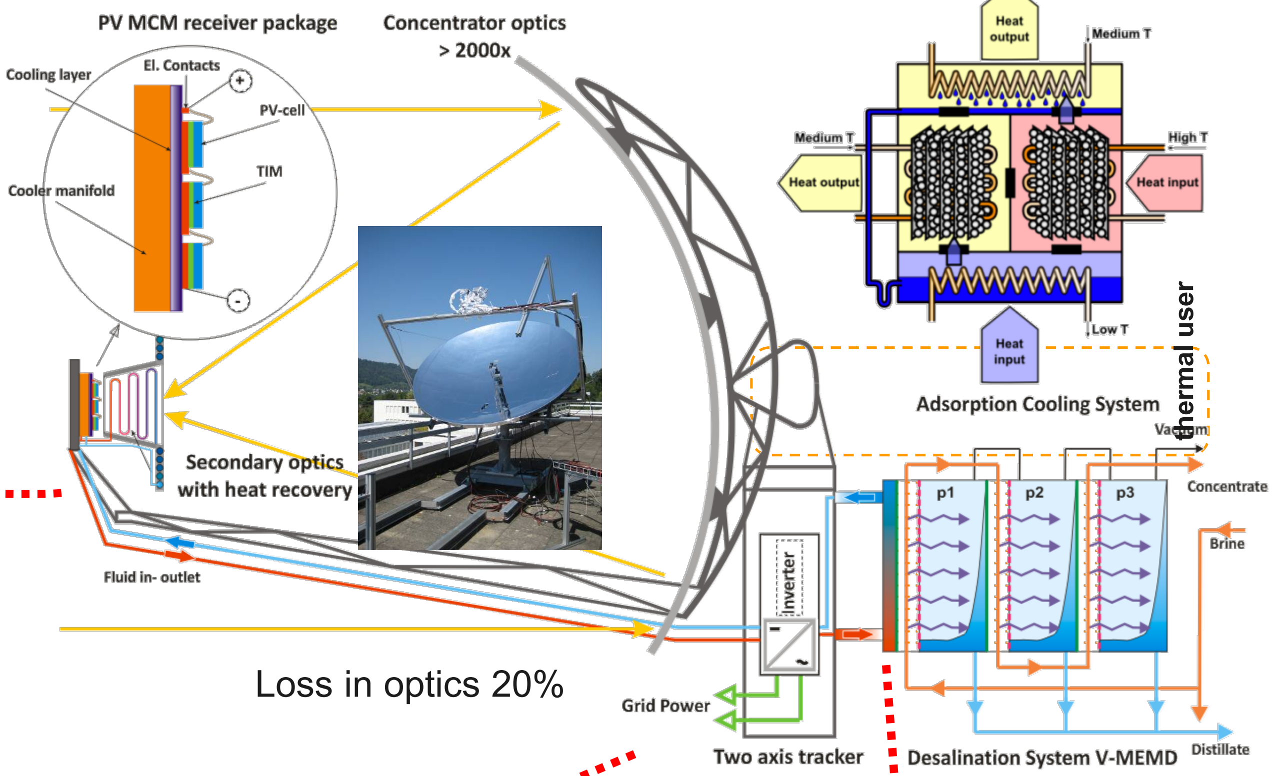


Radiation input
850 W/m^2
for 7.1h / day



Overall System Yield 80%

Energy recovery fraction from sunlight 50%



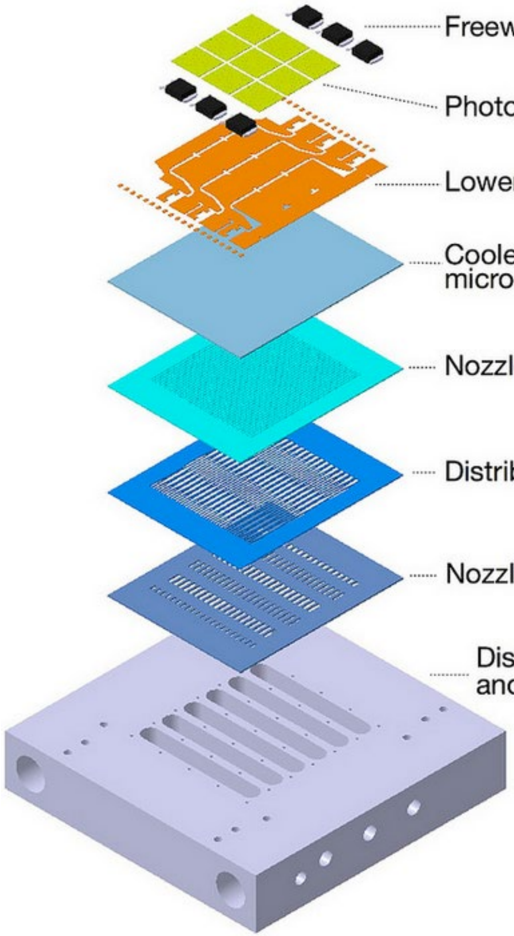
Loss in optics 20%

Receiver technology:
Multichip package with 10x lower thermal resistance
concentration up to 5’000x and improved lifetime of >25 years

Electrical yield 25%
204 W/m^2 using triple junction chip
Potential for long-term improvement to 35%

Thermal yield: 55% 460 W/m^2 converted to:
Cooling **yield of 1.3 kWh/(m^2 day)** with a COP of 0.6
Desalination **yield of 30 l/(m^2 day)** with GOR of 7

HCPVT



Freewheeling Diodes

Photovoltaic Cells

Lower Electrode

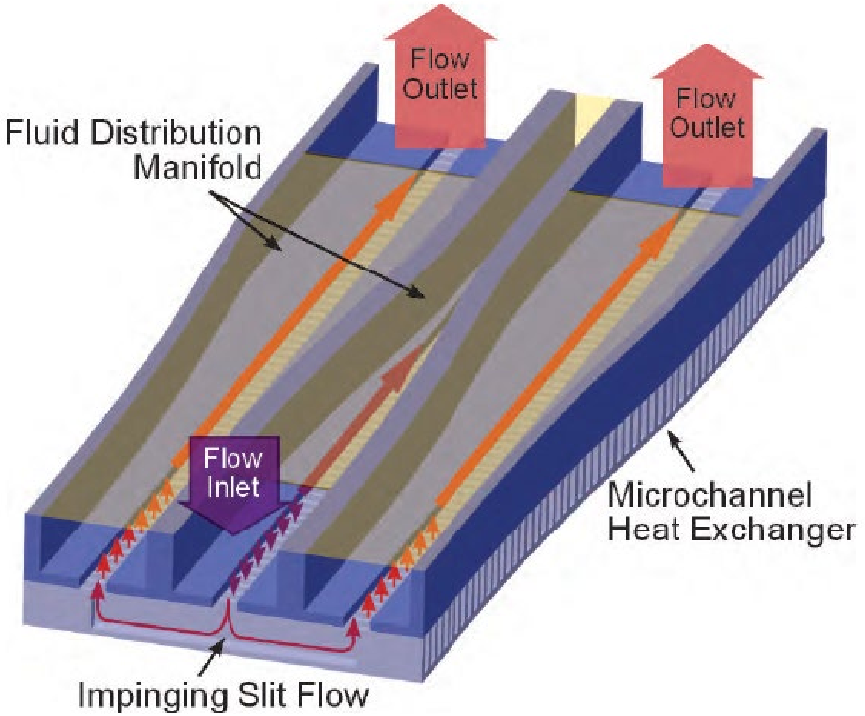
Cooler with micro-channels

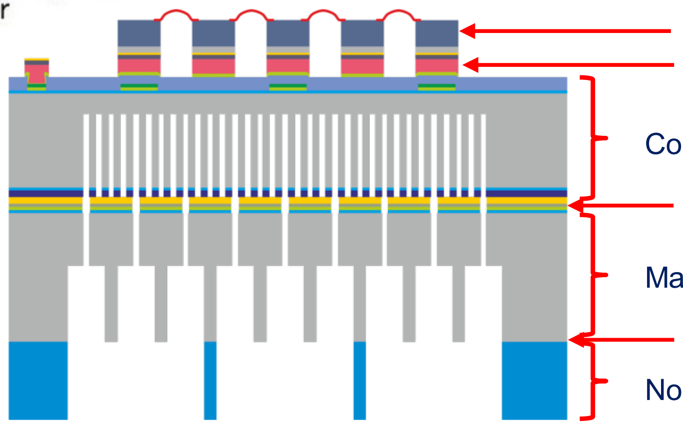
Nozzle position 1

Distribution Layer

Nozzle position 2

Distribution Layer 2 and Carrier





3J PV-Cell

Bottom Electrode

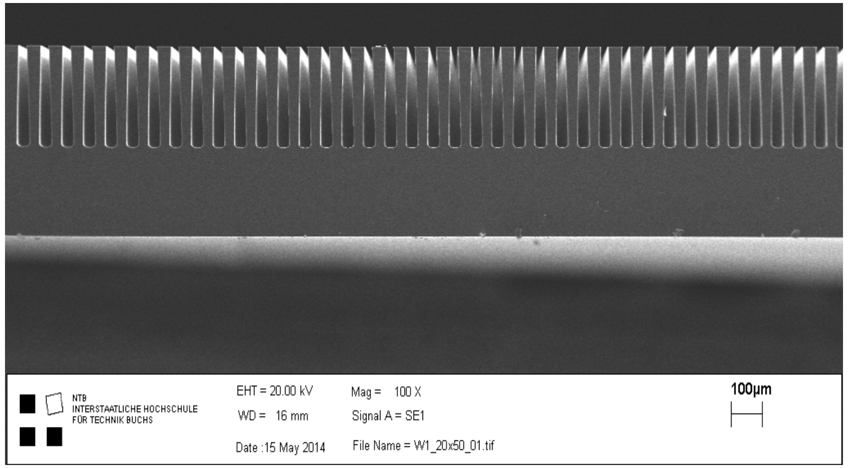
Cooler Substrate (Top Wafer)

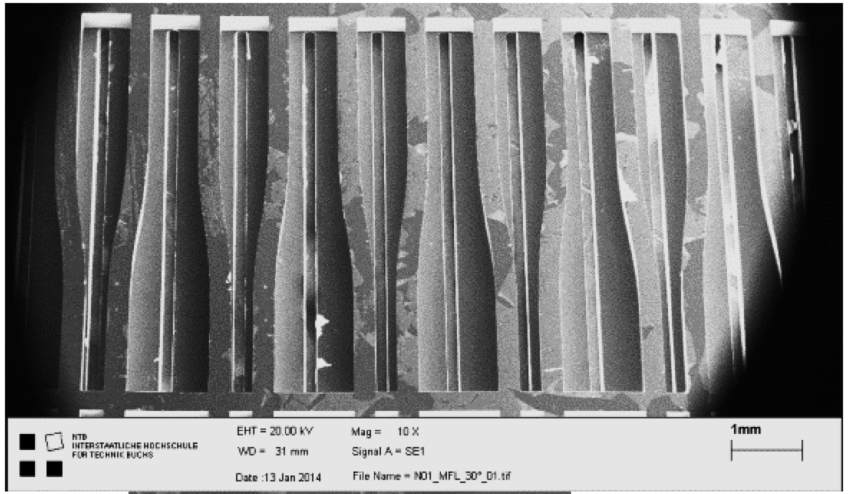
Eutectic Bonding Interface

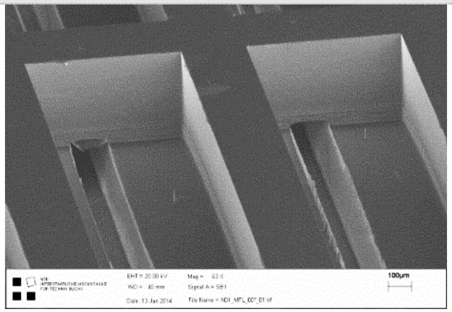
Manifold Substrate (Bottom Wafer)

Anodic Bonding Interface

Nozzle Substrate







Conclusion

- You have to know your system, its boundaries and interfaces quite well even more if the thermal load increases.

- Depending on the amount of heat you have to transfer the methods will shift towards cooling with liquids and or two phase systems even more.

- High Power System desing including cooling will be getting more crucial as the power increases and the volume decreases therefore a wholistic view of the system and the environment is needed.