MAX-PLANCK-GESELLSCHAFT

MPSD

Max Planck Institute for the Structure and Dynamics of Matter

DepFET Laser Annealing ?

I. Dourki
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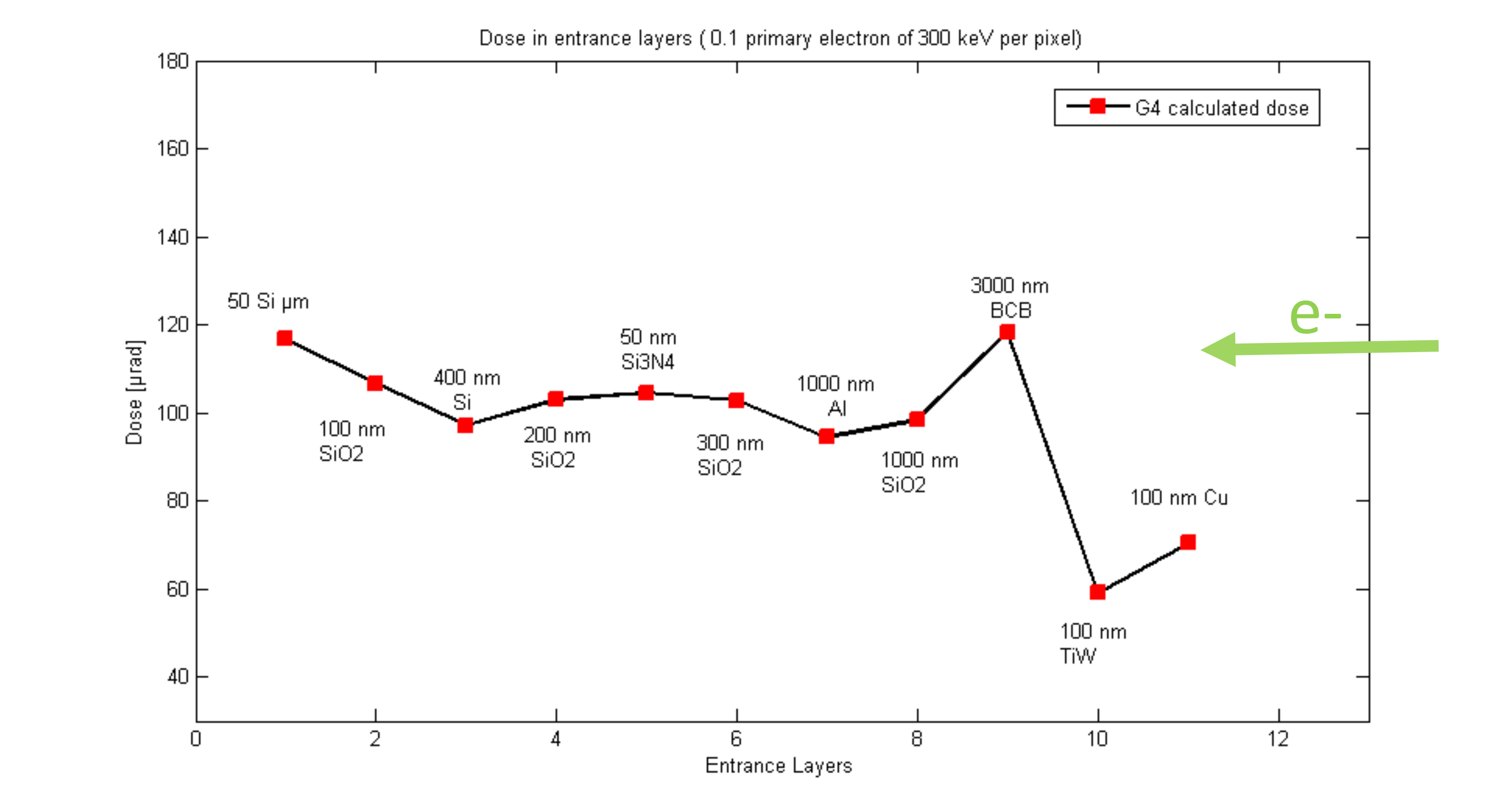
D. Gitaric
F. Tellkamp
S. Epp

CFEL SCIENCE

Center for Free-Electron Laser Science

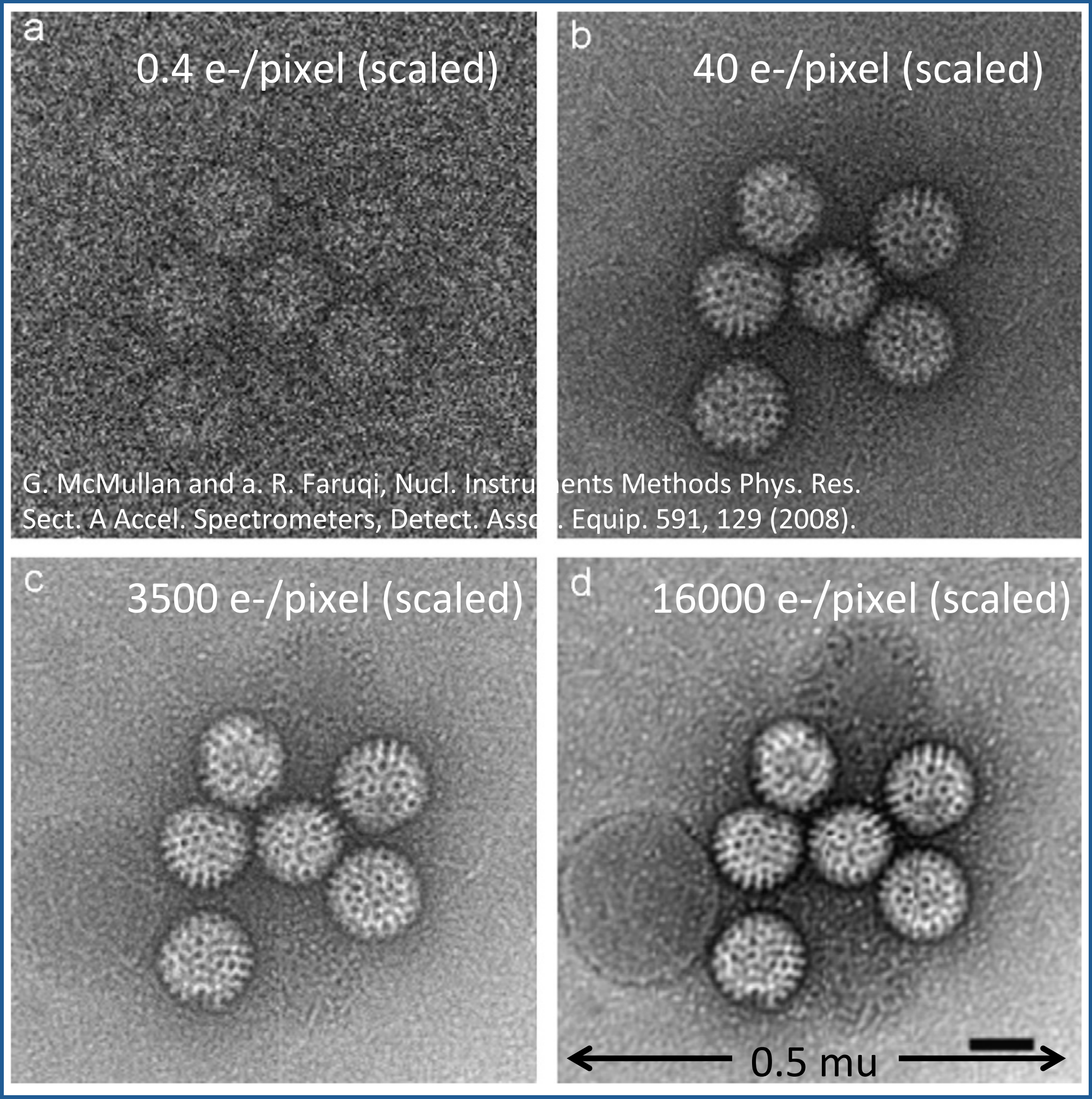
Radiation Damage
EDET layers



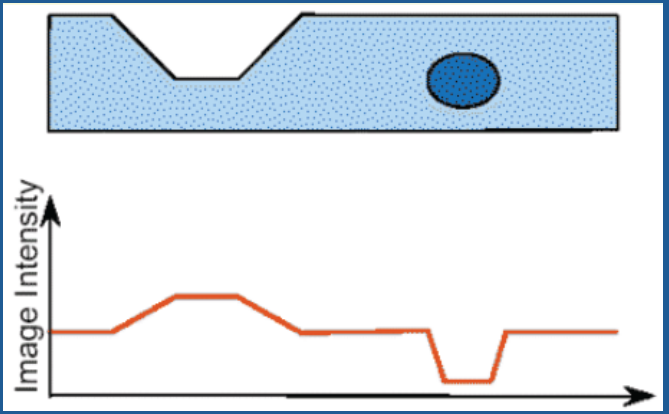
Dourki

- Catchy number: 1 milli-rad @ 1e / pixel

TEM movie

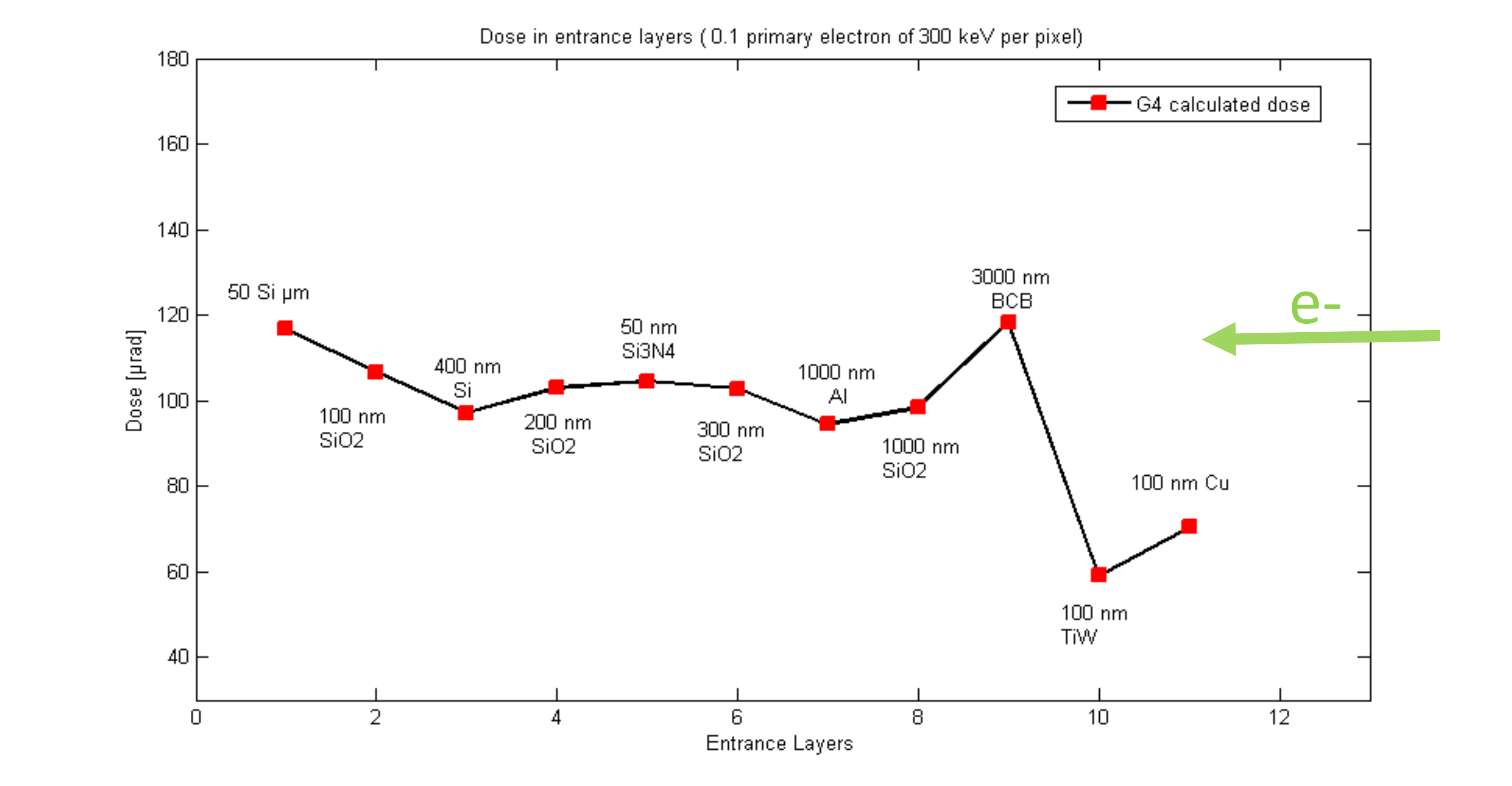


G. McMullan and a. R. Faruqi, Nucl. Instru[ments] Methods Phys. Res. Sect. A Accel. Spectrometers, Detect. Ass[oc]. Equip. 591, 129 (2008).



Radiation Damage

EDET layers

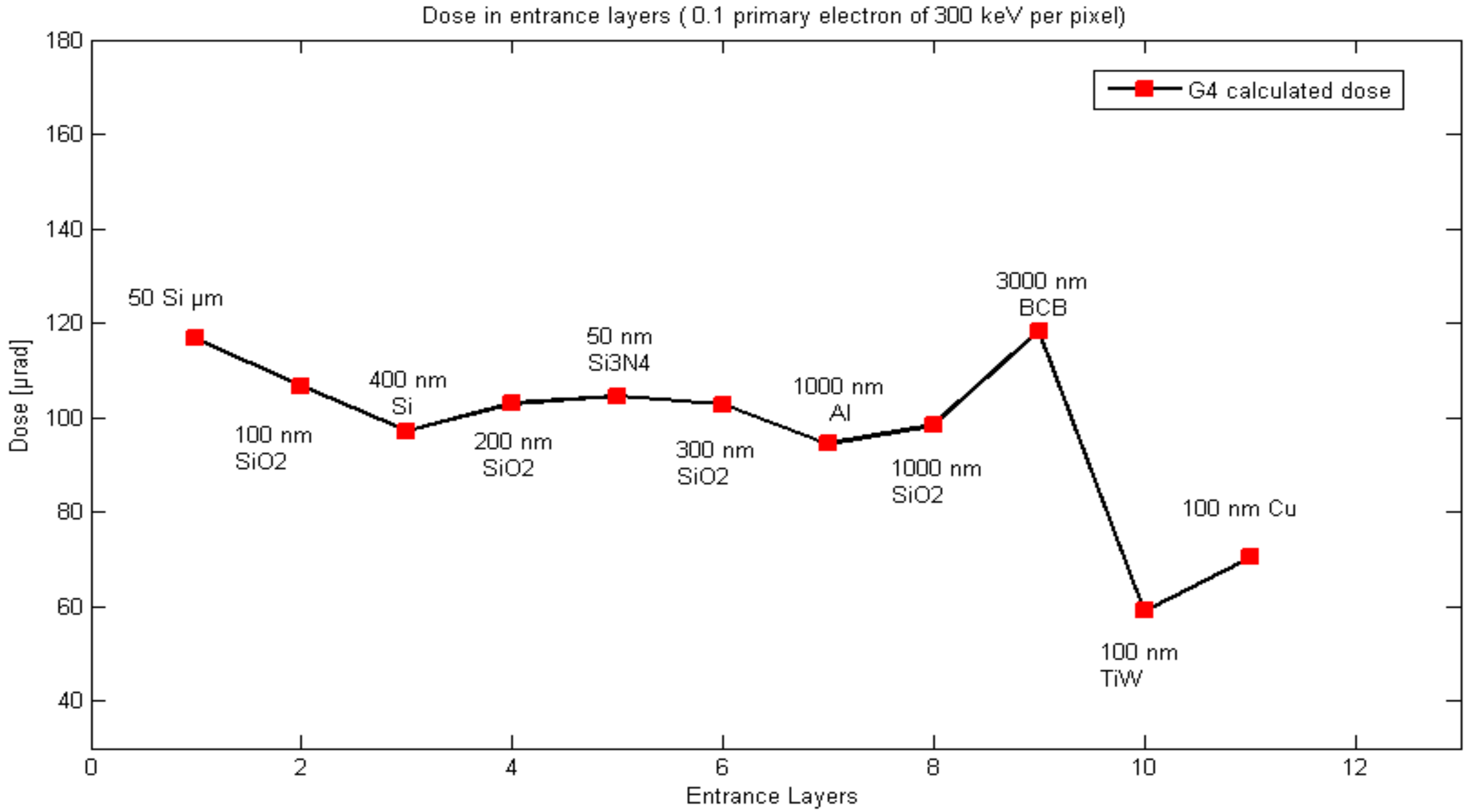


Dourki

- 40 e/px/image - > 1 Mrad @ 25 Mio. images or 250 000 movies of 100 frames
- 1000 e/px/image -> 1 Mrad @ 1 Mio. images or 275 hours of operation

Radiation Damage

EDET layers



I.Dourki

- 40 e/px/image - > 1 Mrad @ 25 Mio. images or 250 000 movies of 100 frames
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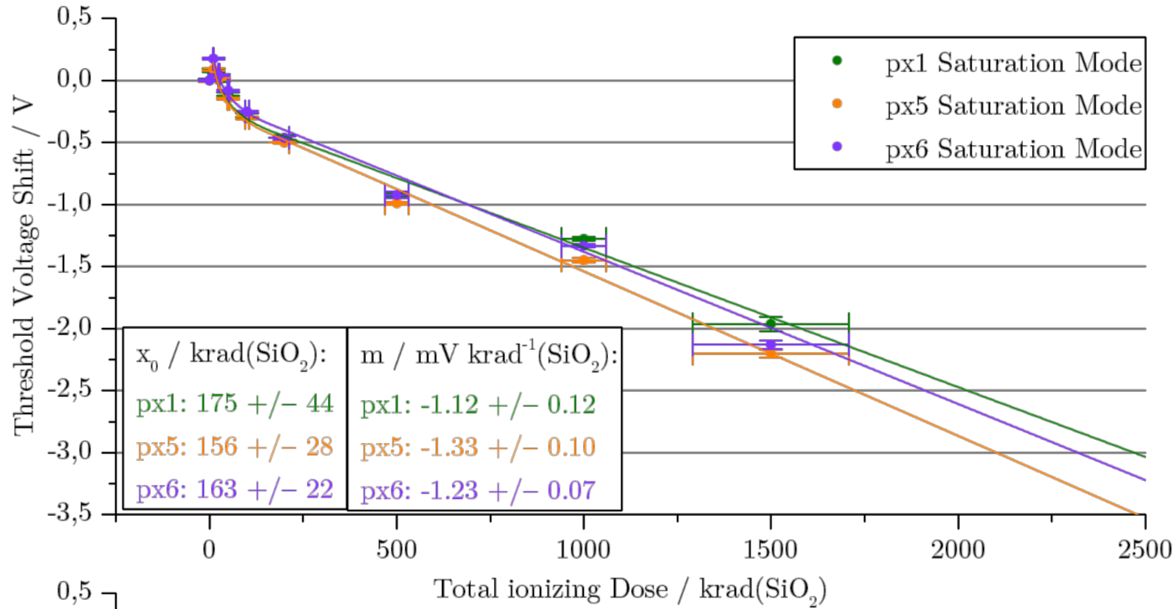
DEPFET Results – Damage Profiling

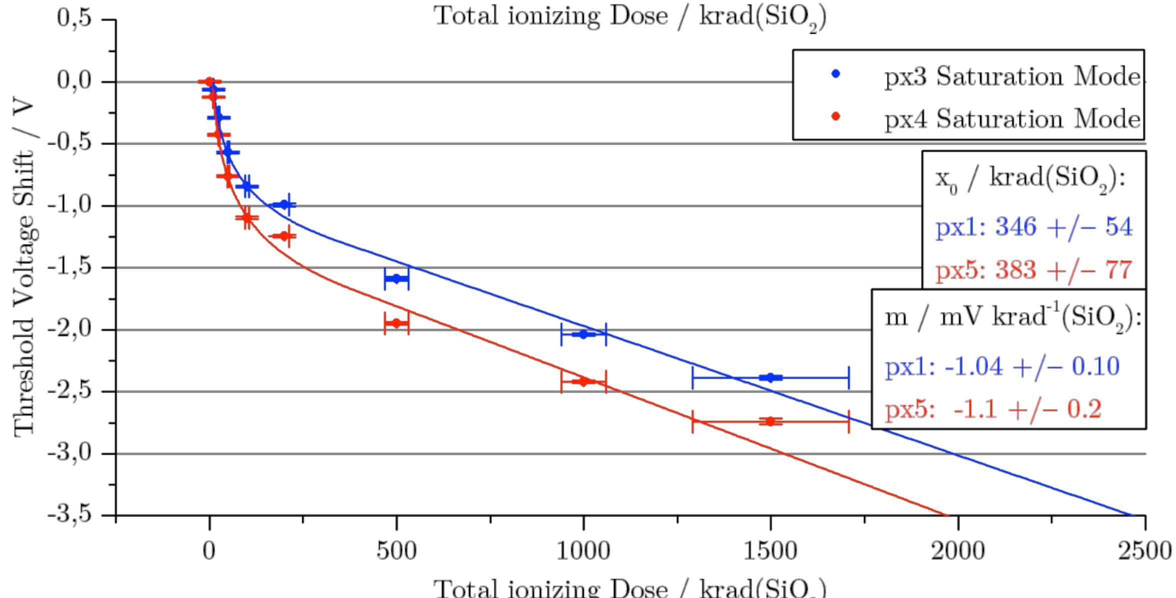
Single chip cumulatively irradiated to higher total doses up to ~ 1.5 Mrad(SiO_2)



Clear-like structures:

Gate-like structures:

Increasing margin of error due to degradation of the photo cathode at the REGAE experiment.



Problem: Radiation damage

- Chip is especially sensitive to inhomogeneous damage of p-doped layer around the n-clear
  – 2 V shift correspond to 1.5 Mrad
  – Safety margin: 3 Volt -> 2 Mrad
- Test campaign of Martin
  – On pxd6 test structures
    - W23 test structures (wafer was strongly damaged, 1 metal layer missing…)
    - Double-FET structures on 34 test chips
  – 2V shift after ~1.0 Mrad
    - Relatively early
    - No sign that trend relaxes with further irradiation

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- ▷ On pxd6 test structures
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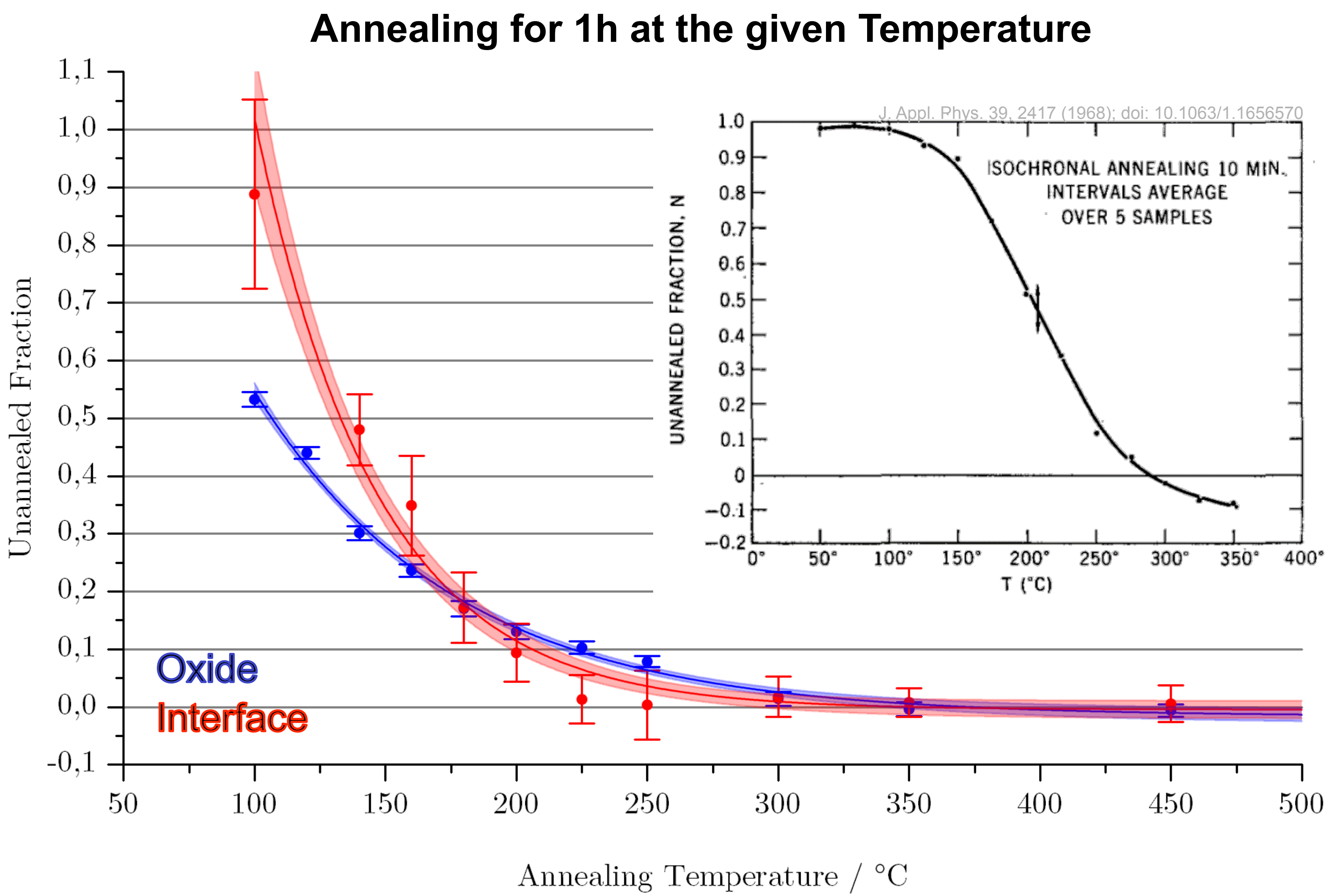
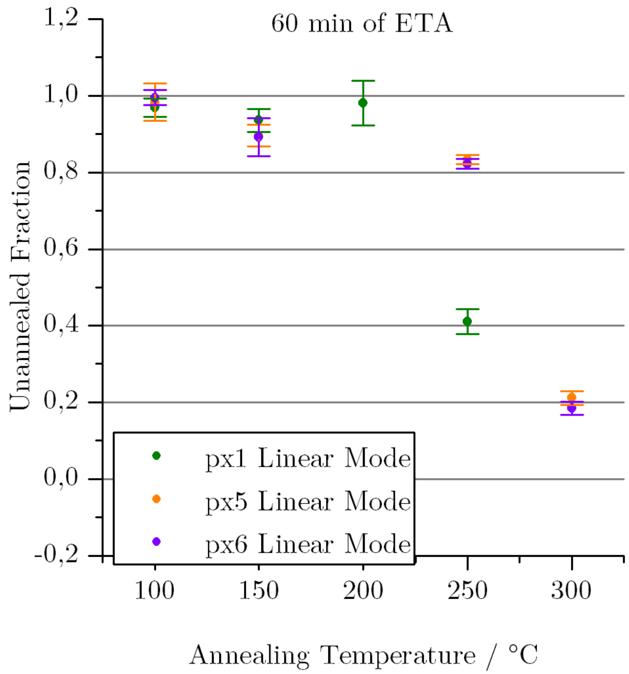
MOSCAP Results – Annealing Temperature Dependence



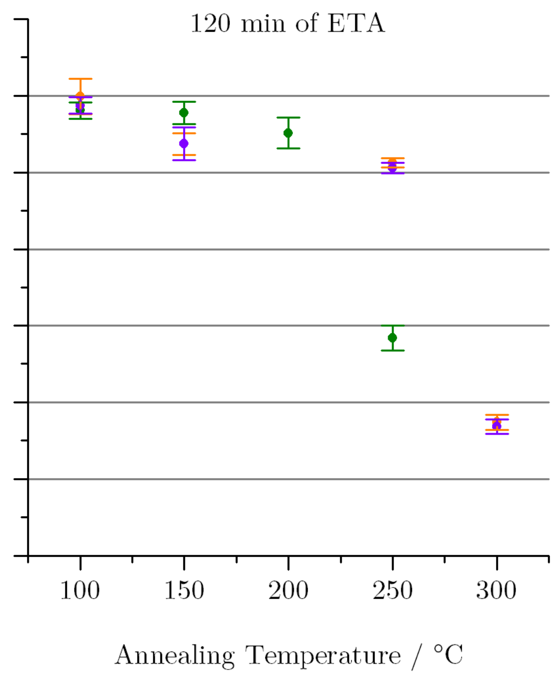
DEPFET Results – Annealing Temperature Dependence: Clear

Clear-like structures annealed for 1h



- Strong annealing effect for ϑ > 250°C
- Below: weak annealing to about 80% of damage remaining

Clear-like structures annealed for 2h



- Longer annealing periods do not improve the process significantly

Problem: Radiation damage

- Chip is especially sensitive to inhomogeneous damage of p-doped layer around the n-clear
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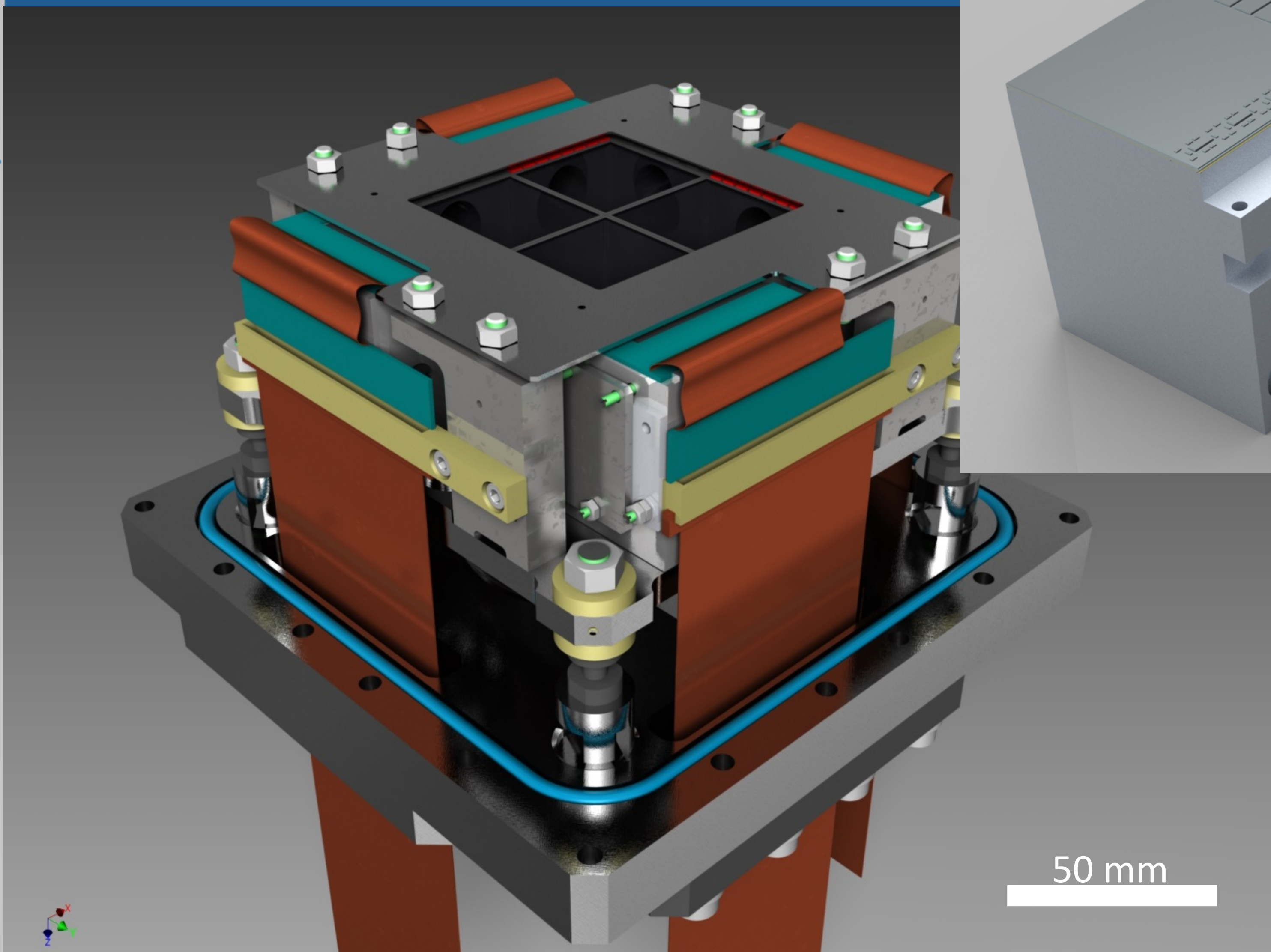
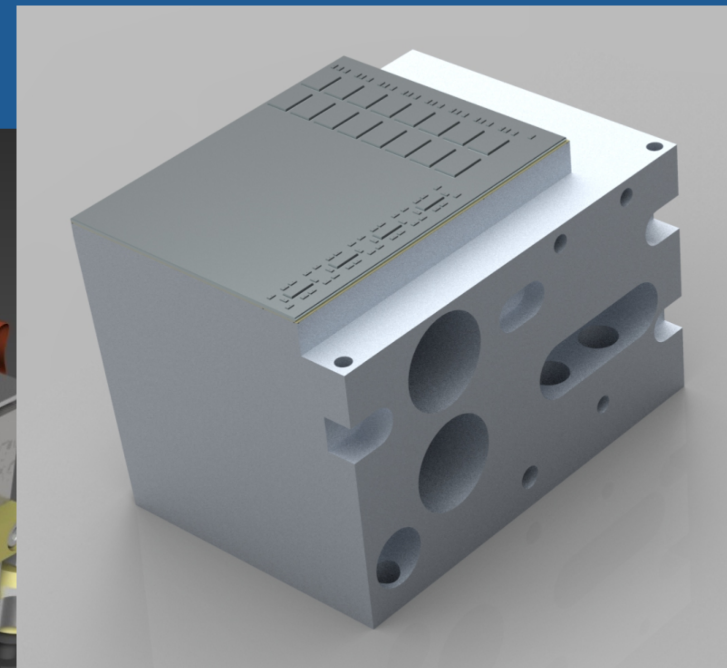
EDET

Mechanical Layout





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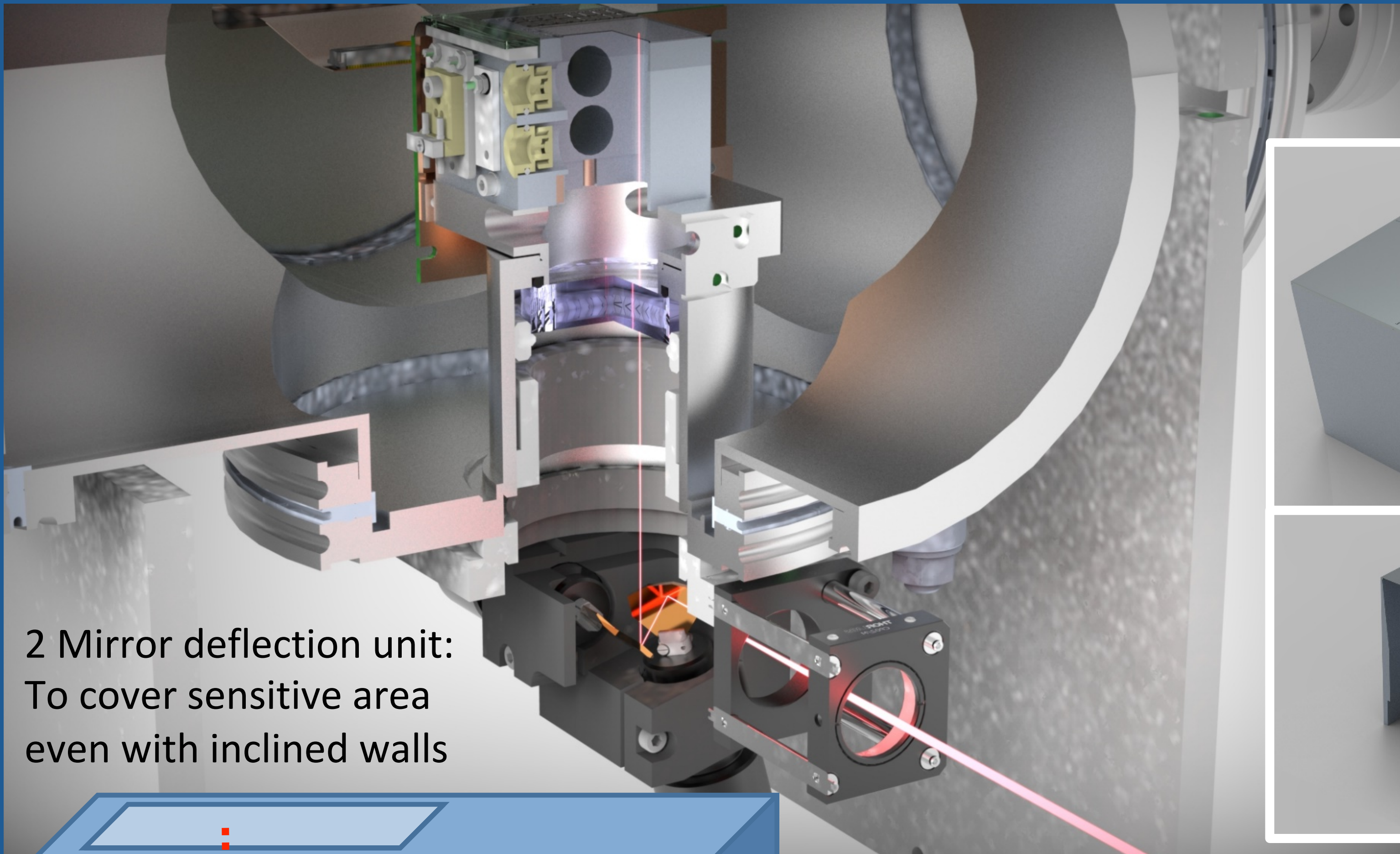
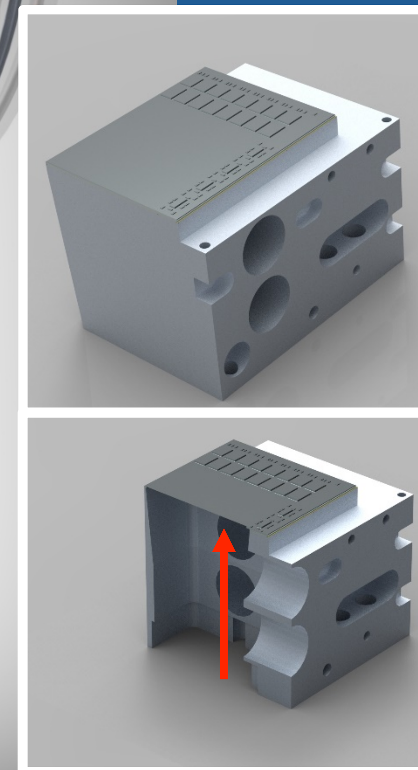
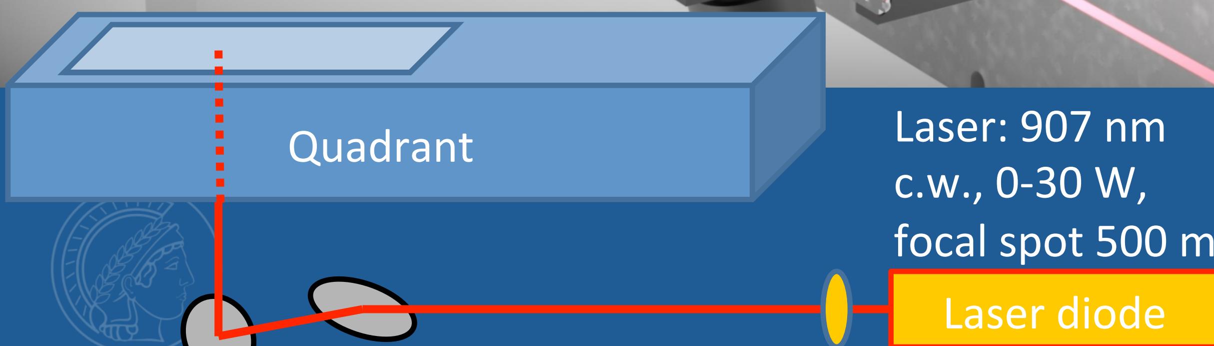
EDET

Laser Annealing Setup



2 Mirror deflection unit:
To cover sensitive area
even with inclined walls

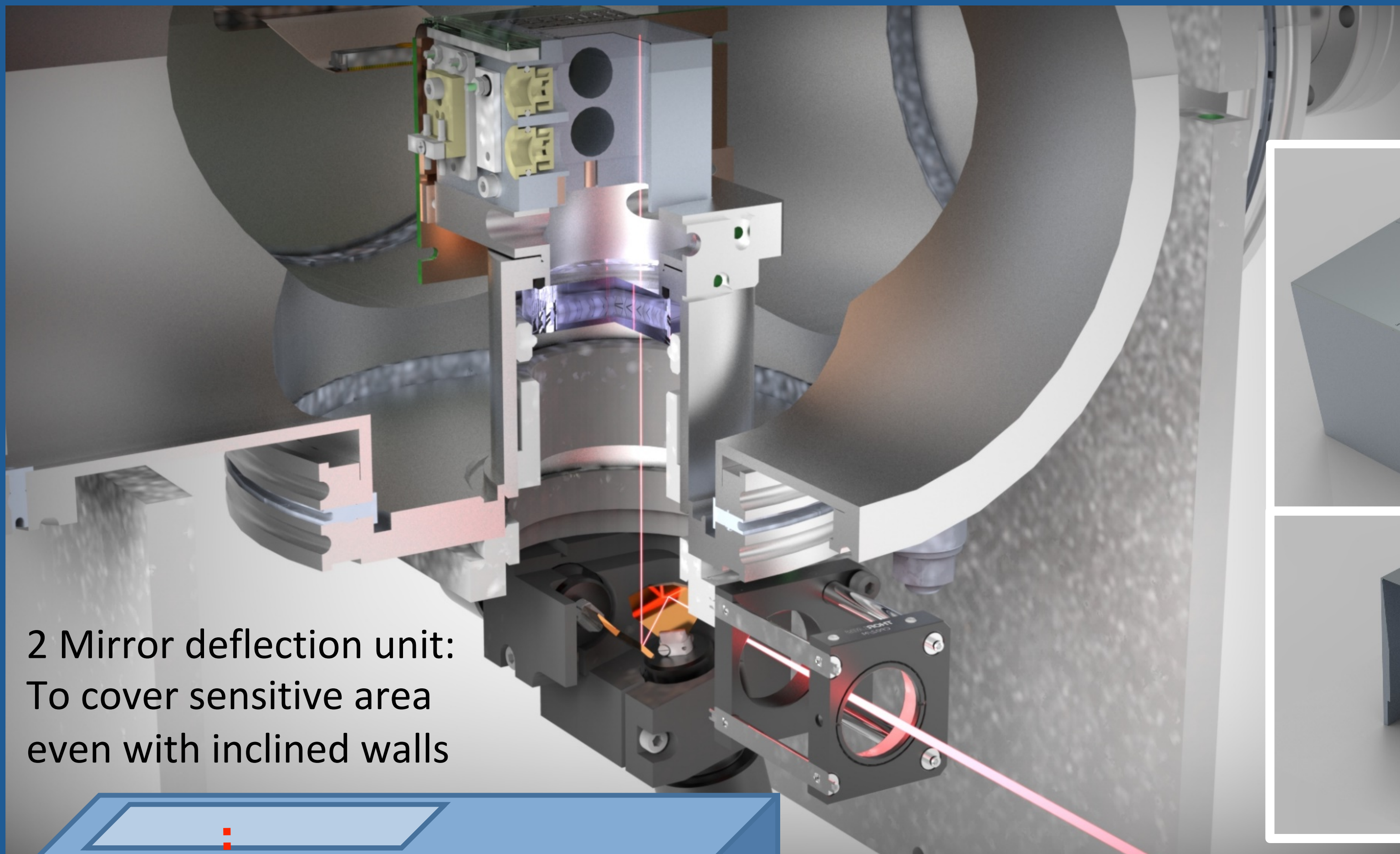




Laser: 907 nm
c.w., 0-30 W,
focal spot 500 mu

EDET

Laser Annealing Setup



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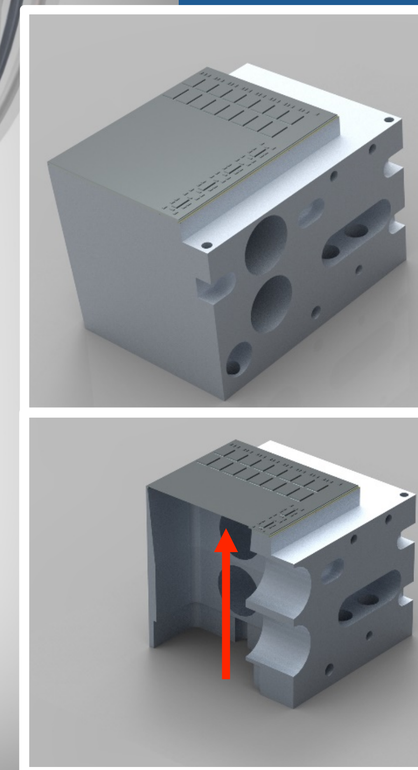
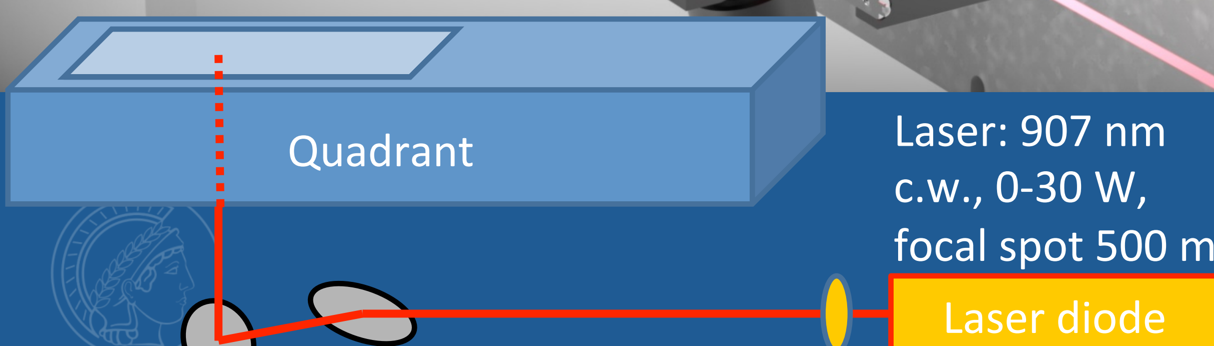
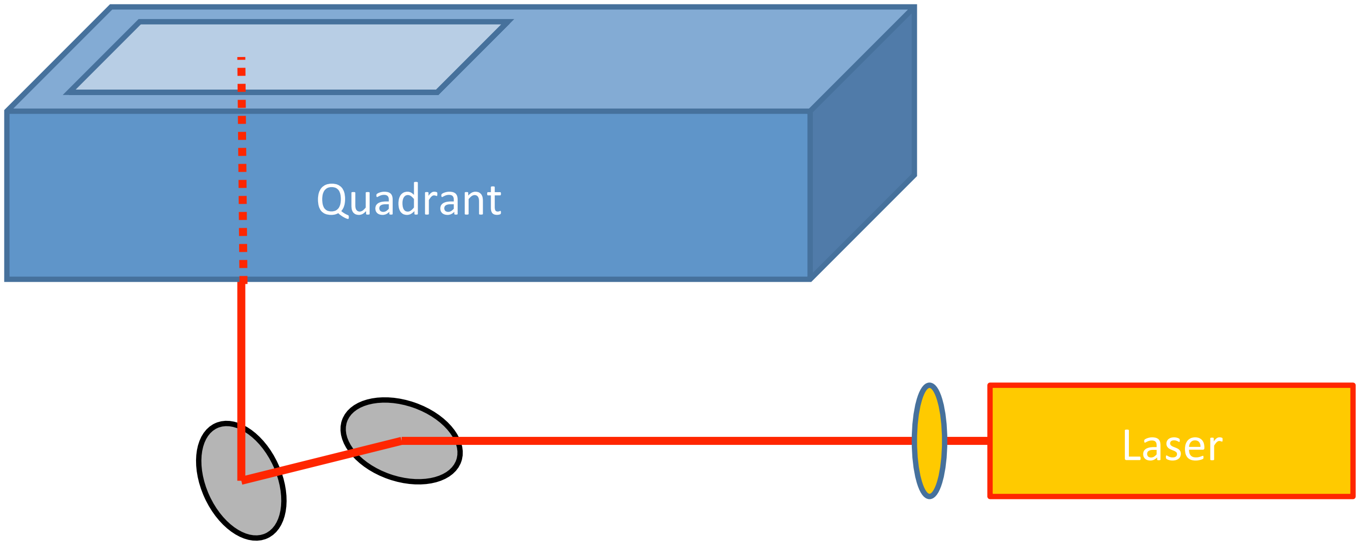




Laser: 907 nm
c.w., 0-30 W,
focal spot 500 mu

Possible setup

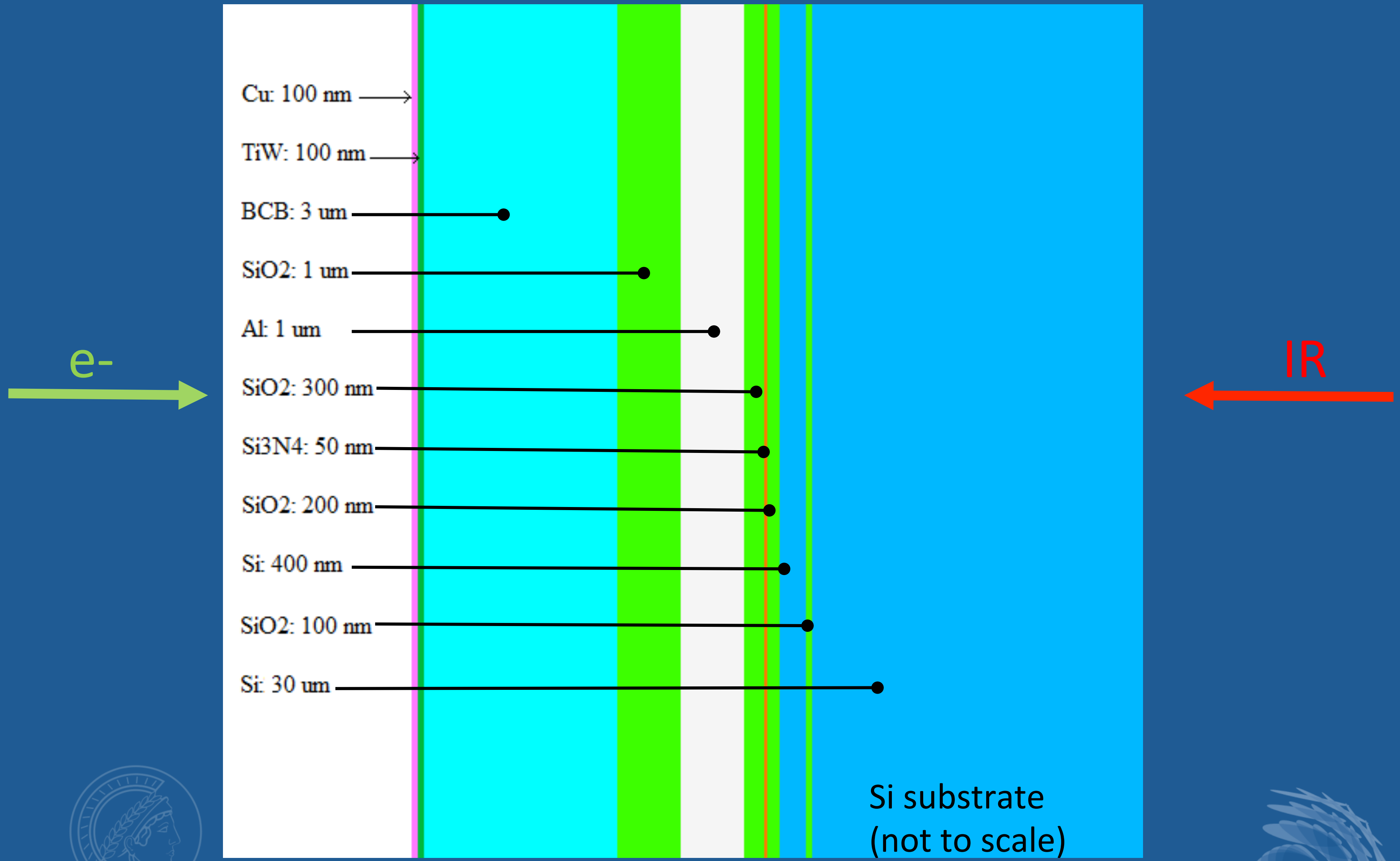


2 Mirror deflection unit:
To cover sensitive area
even with inclined walls

Laser: 810 nm
cw, 10-20 Watt

EDET DepFET

Layers Structure (simplified)



EDET DepFET

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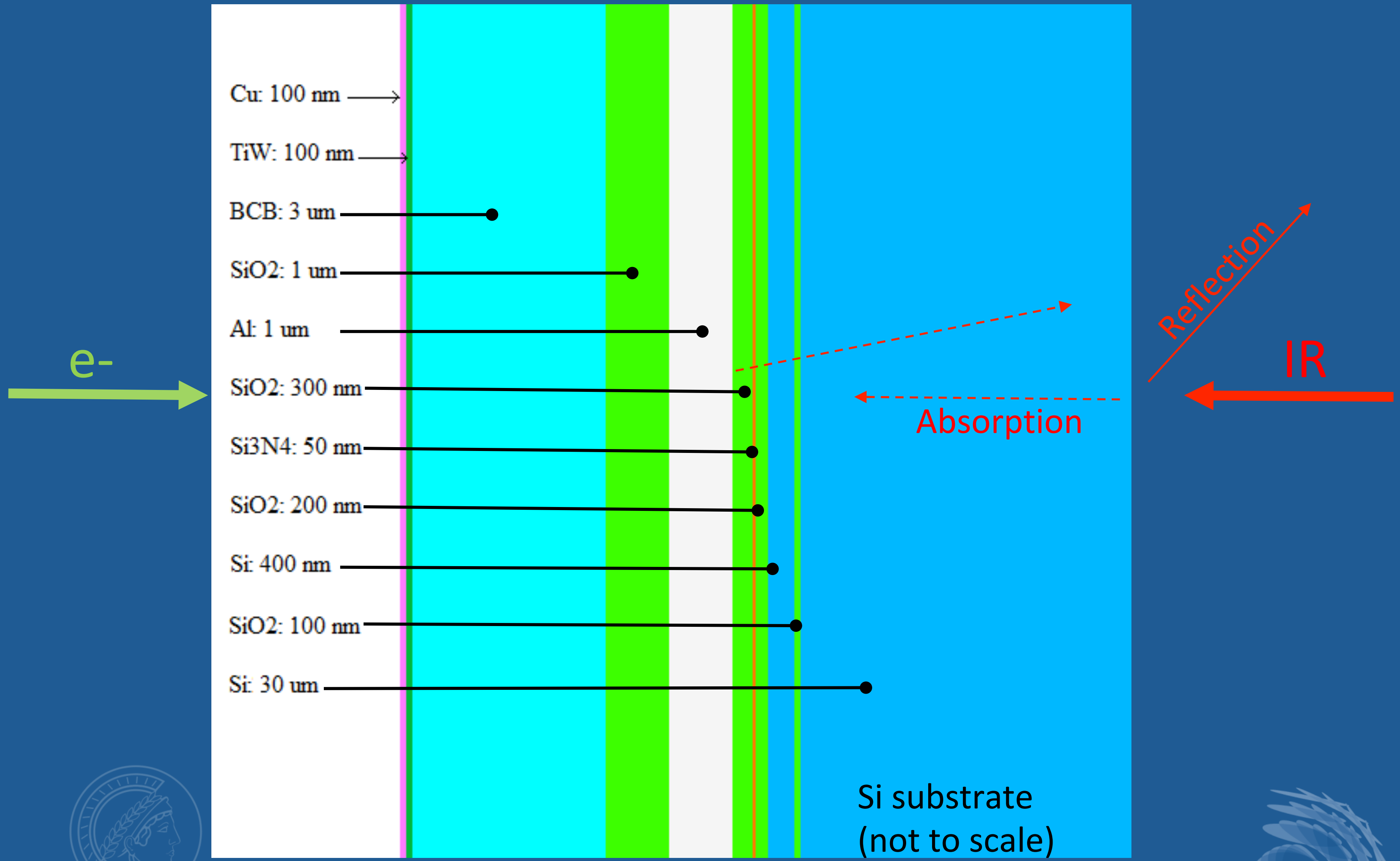


Surface layers

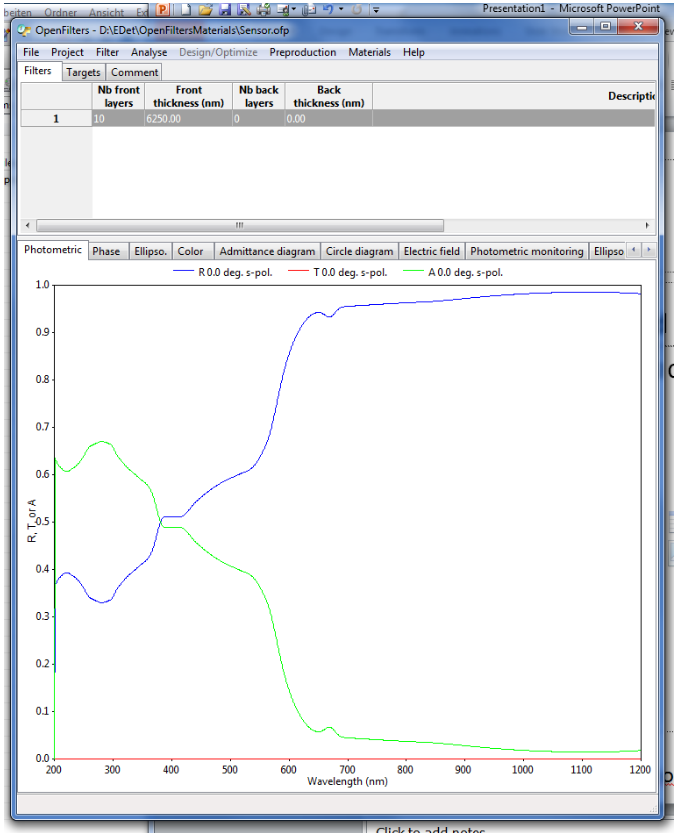
- Surface layers
  - 100nm Cu
  - 100 nm TiW
  - 3000 nm BCB
  - 1000 nm SiO_2
  - 1000 nm Al
  - 300 nm SiO_2
  - 50 nm Si_3N_4
  - 200 nm SiO_2
  - 400 nm Si
  - 100 nm SiO_2
  - Sensitive layer

- For back illumination
  - Absorption:
    - Mainly in Si
  - Reflection
    - At surface and internal Alu
  - Transmission
    - No Transmission

Open filters

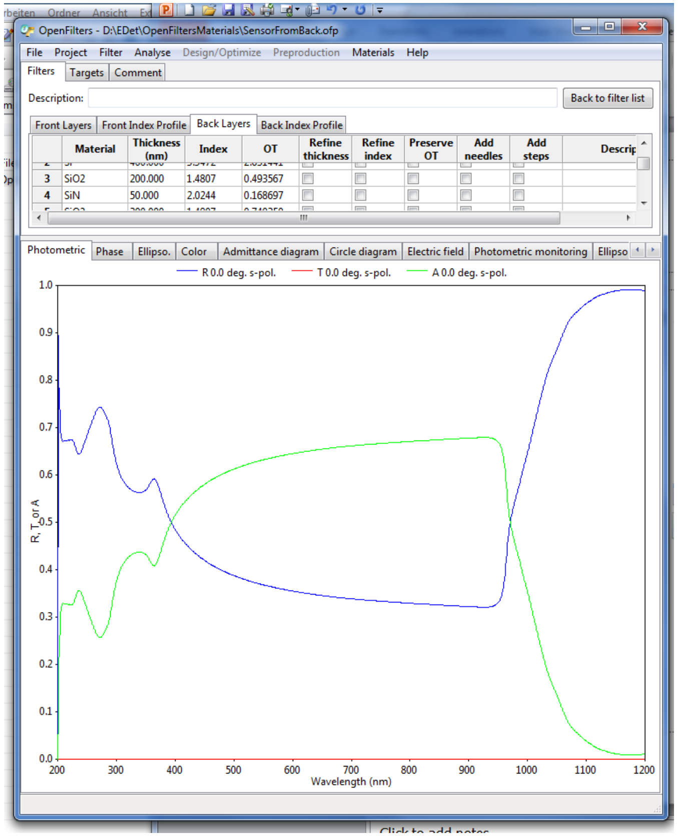
Frontside illumination

Optimum: 300 nm



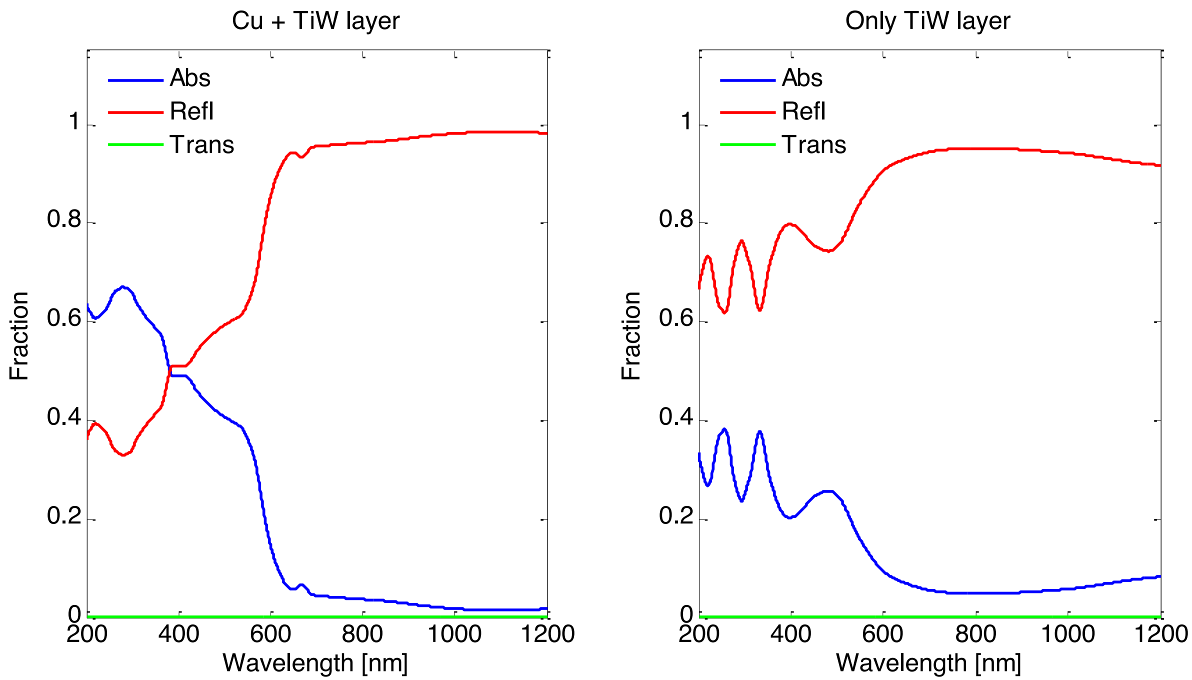
Backside illumination

Optimum: 600-900 nm



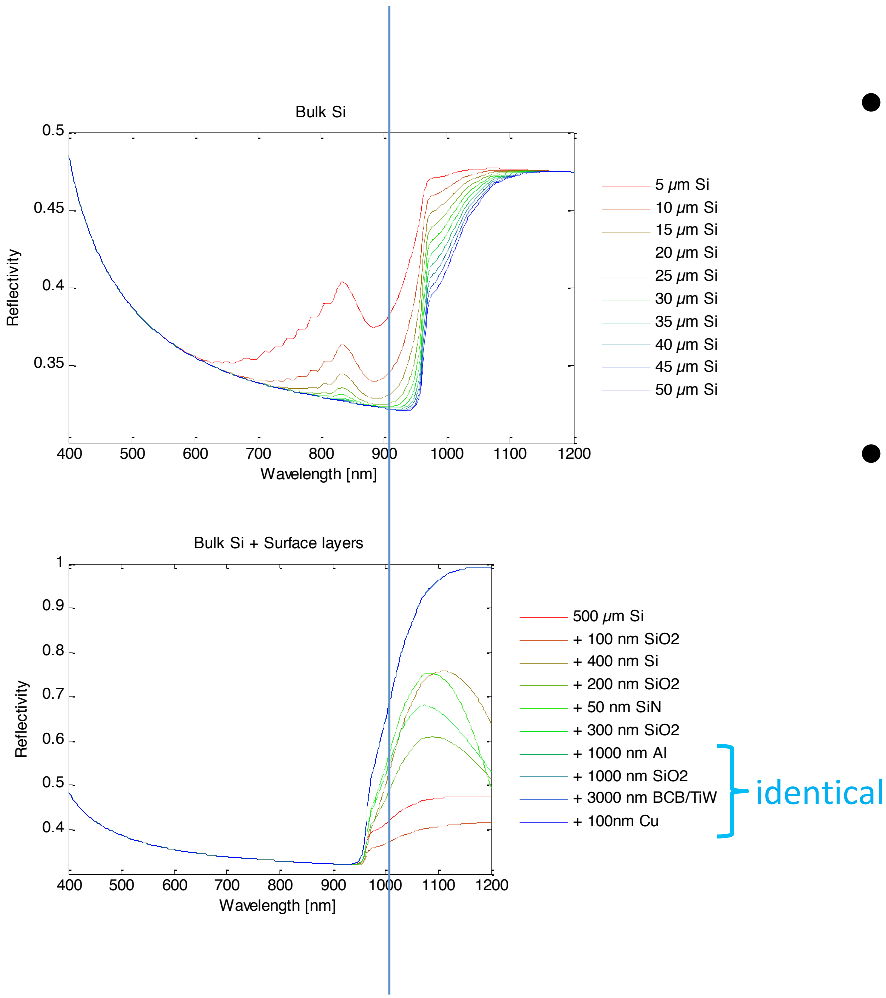
Blue: Reflection / Green: Absorption / Red: Transmission

Illumination from front



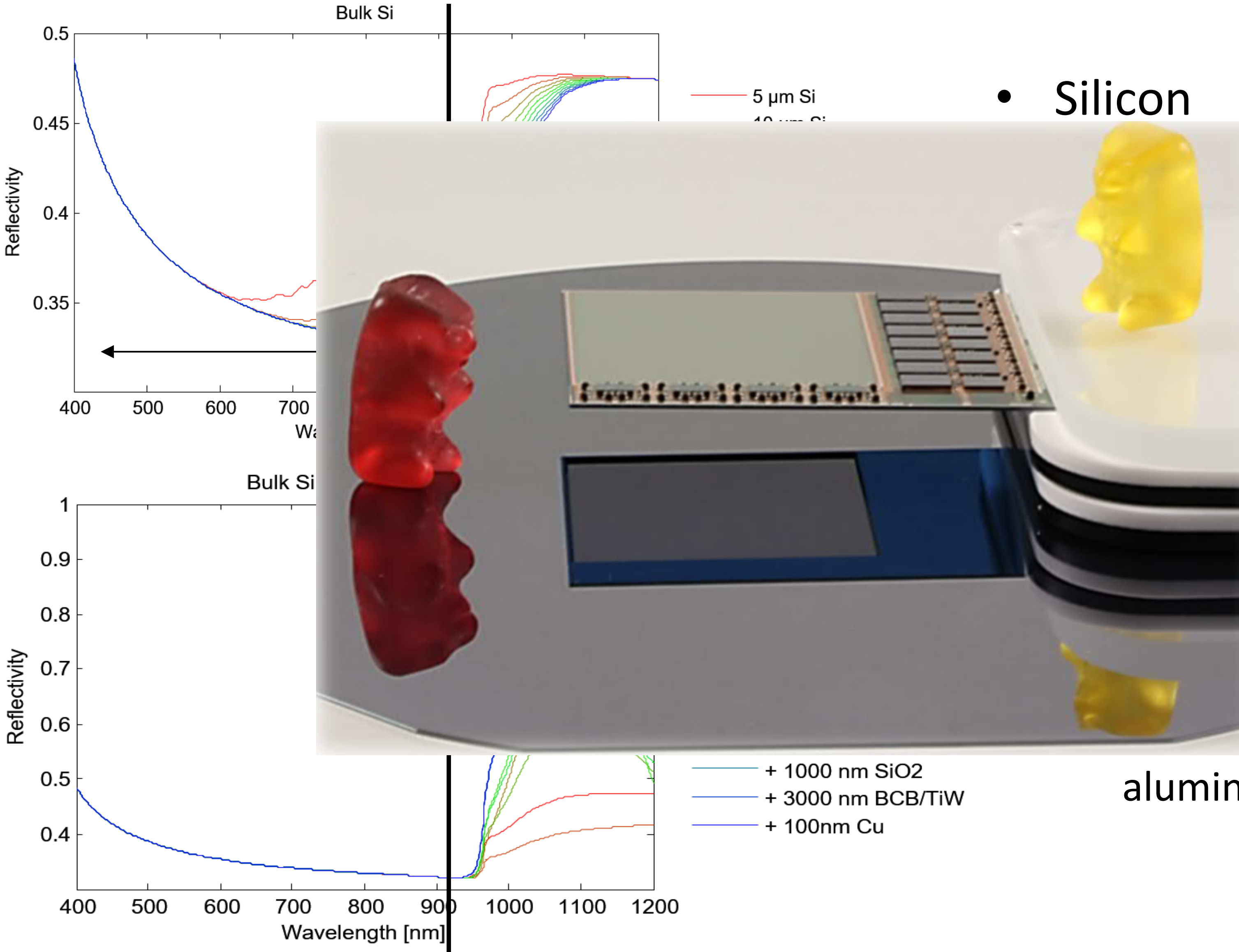
- Left: 100 nm Cu + 100 nm TiW
- Right: Only 100 nm TiW
- Less than a fraction of 10^{-5} (10^{-7} for Cu+TiW) of incoming light is transmitted to the layers below

Illumination from back Reflection



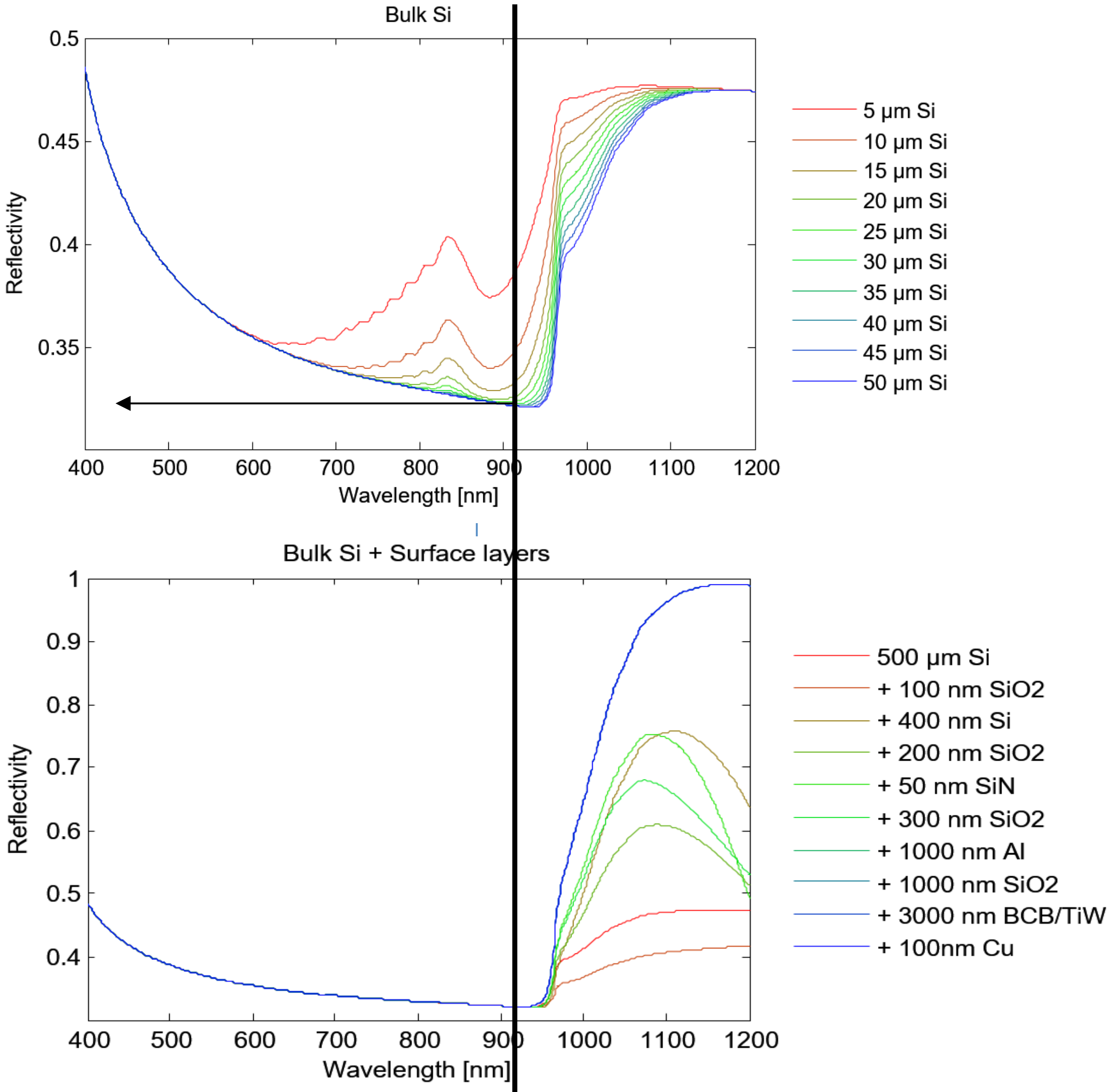
- Silicon
  - Reflection decreases with increasing Si thickness
- Surface layers
  - Below 950 nm: Surface reflection of Si
  - Above 950 nm: Reflection mainly at internal aluminum layer

Illumination from back Reflection



- Silicon
  - …tion
  - …ses with
  - …sing Si
  - …ess
- …ayers
  - …950 nm:
  - …e reflection
  - …950 nm:
  - …tion mainly
  - …rnal
  - aluminum layer

Illumination from back
Reflection



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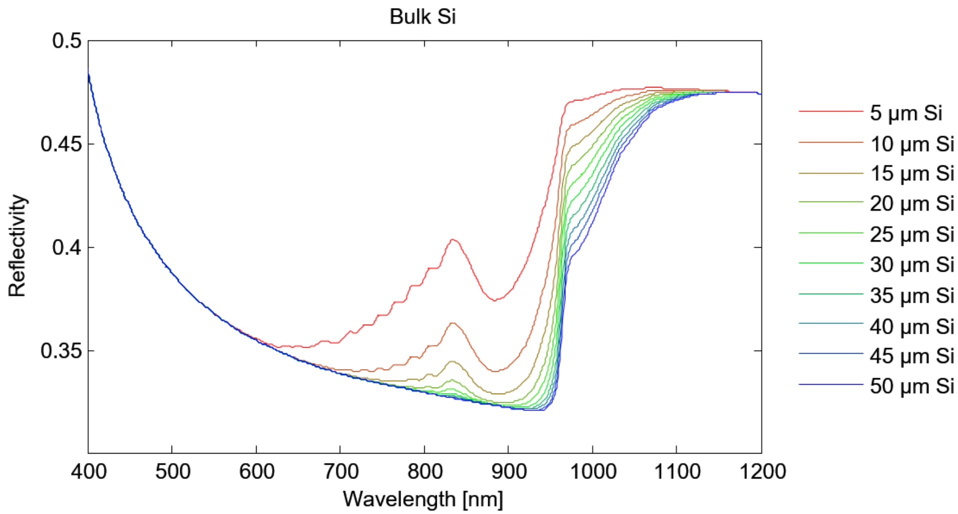
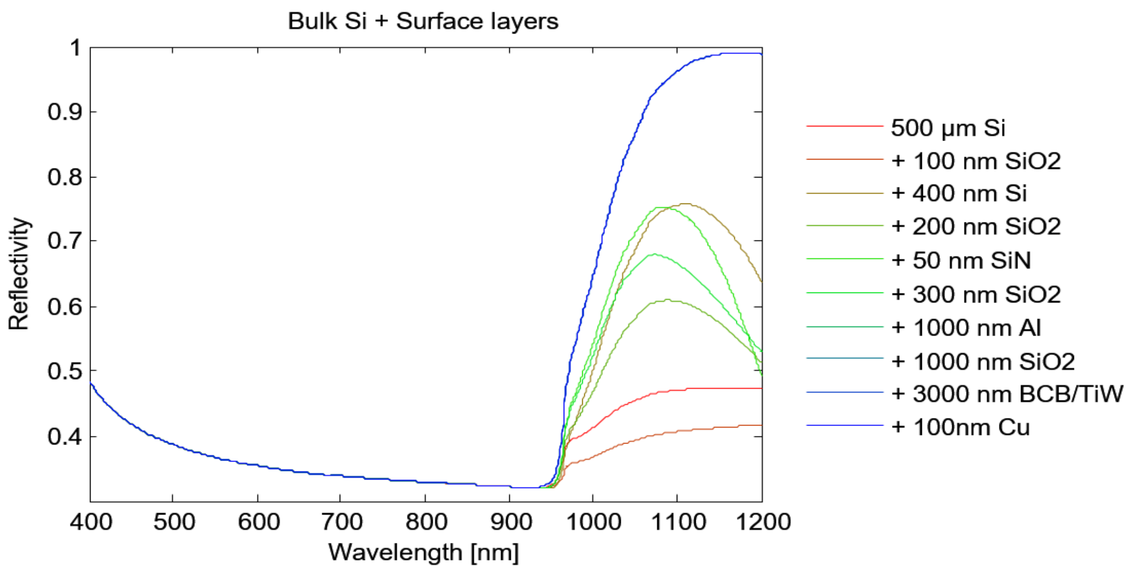
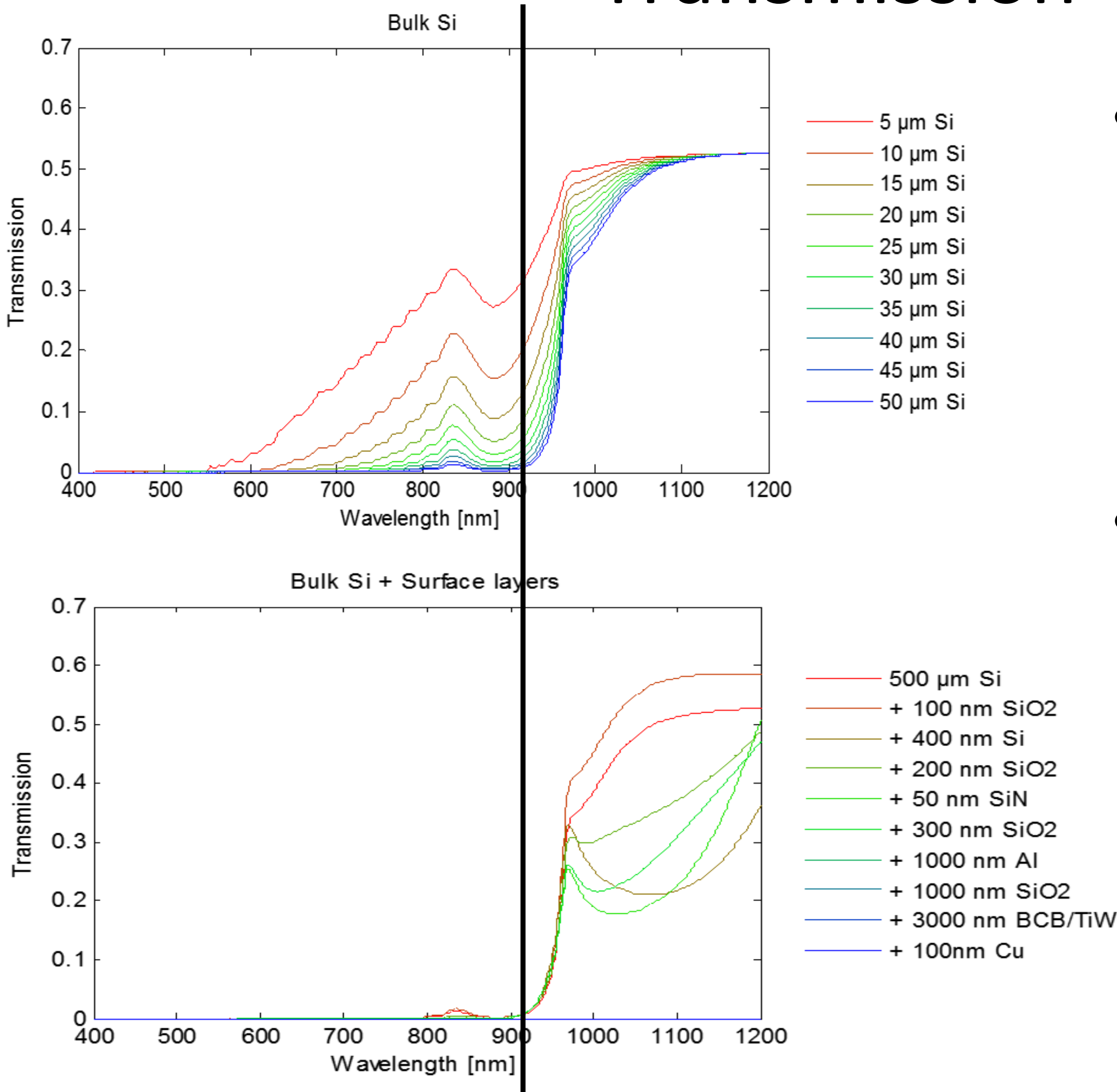

Bulk Si
0.5
0.45
0.4
0.35
Reflectivity
400
500
600
700
800
900
1000
1100
1200
Wavelength [nm]
5 µm Si
10 µm Si
15 µm Si
20 µm Si
25 µm Si
30 µm Si
35 µm Si
40 µm Si
45 µm Si
50 µm Si

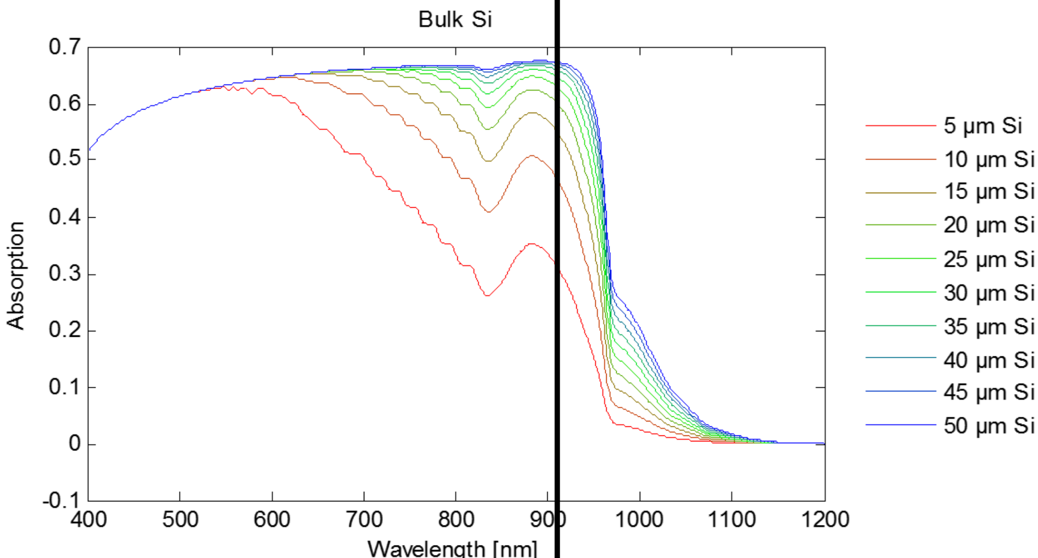

Bulk Si + Surface layers
1
0.9
0.8
0.7
0.6
0.5
0.4
Reflectivity
400
500
600
700
800
900
1000
1100
1200
Wavelength [nm]
500 µm Si
+ 100 nm SiO2
+ 400 nm Si
+ 200 nm SiO2
+ 50 nm SiN
+ 300 nm SiO2
+ 1000 nm Al
+ 1000 nm SiO2
+ 3000 nm BCB/TiW
+ 100nm Cu

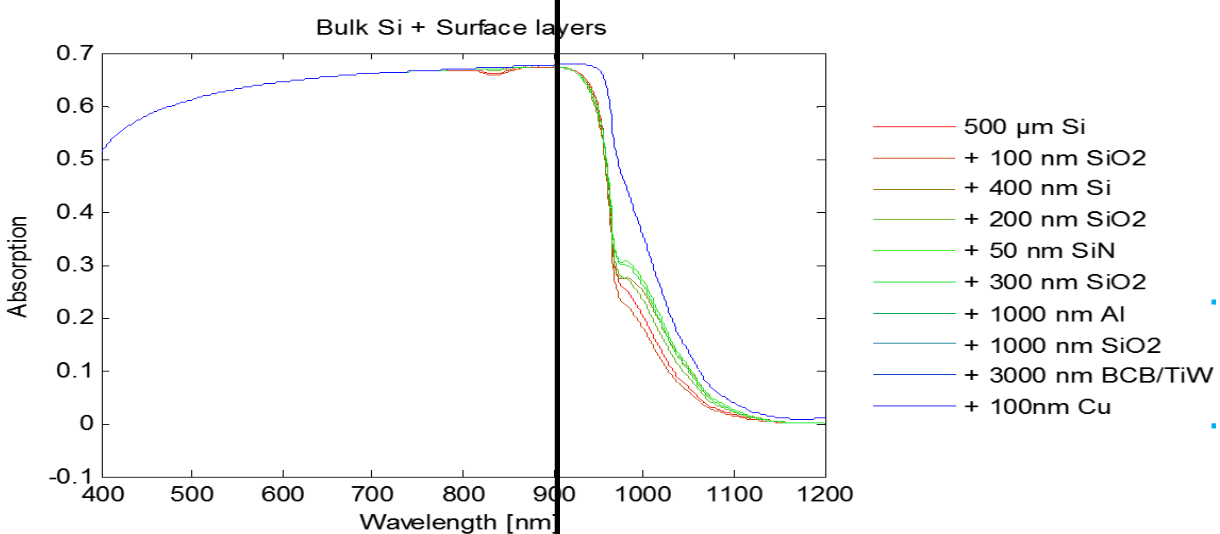
Illumination from back Transmission



- Silicon
  - Transmission decreases with increasing Si thickness
- Surface layers
  - With Al layer:
    - Transmission = 0

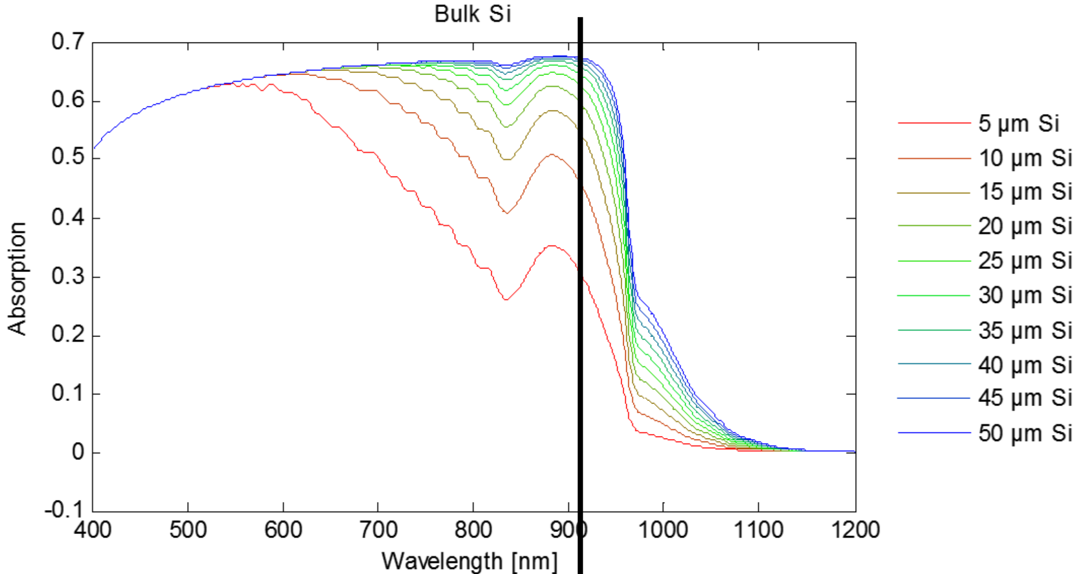
Illumination from back Absorption

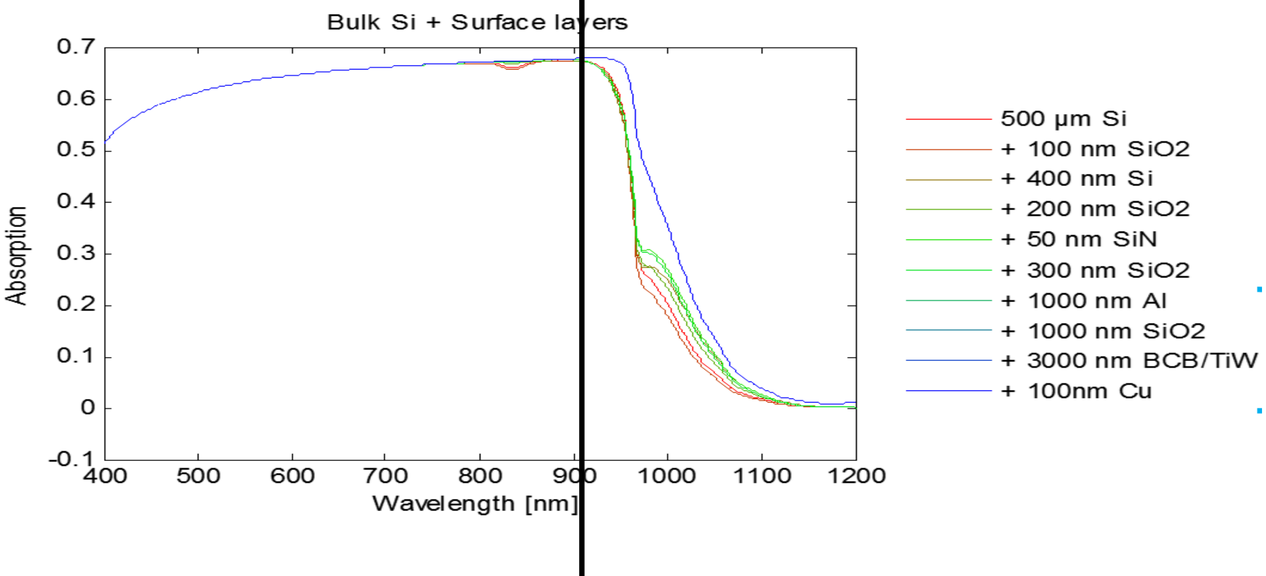




- Silicon
  - Absorption increases with increasing Si thickness
- Surface layers
  - Absorption increases with increasing number of surface layers

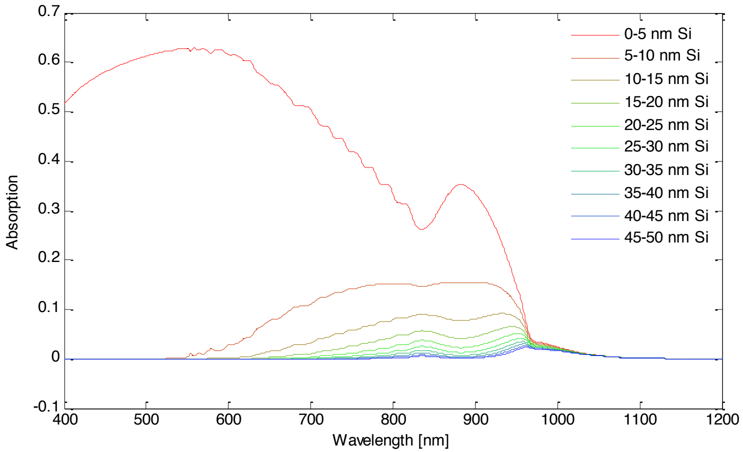
Absorption depth

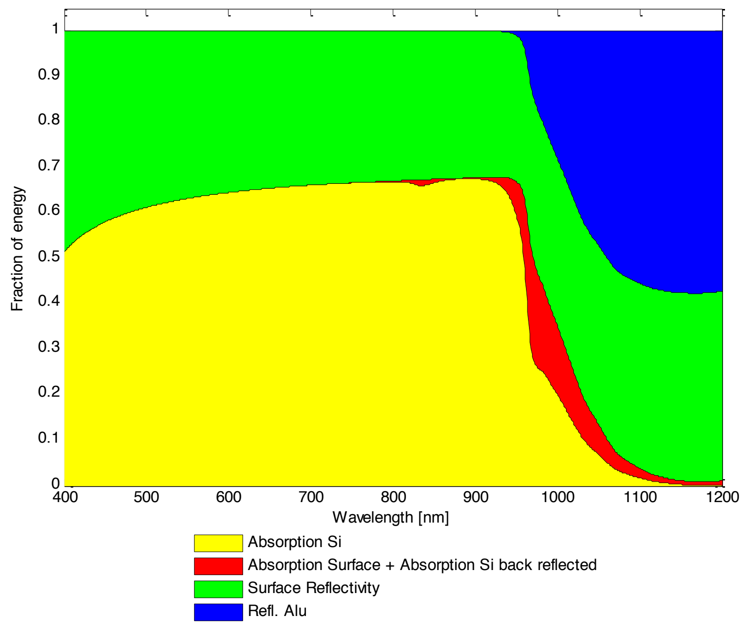




- Silicon
  - Absorption increases with increasing Si thickness
- Surface layers
  - Absorption increases with increasing number of surface layers

Illumination from back Conclusion

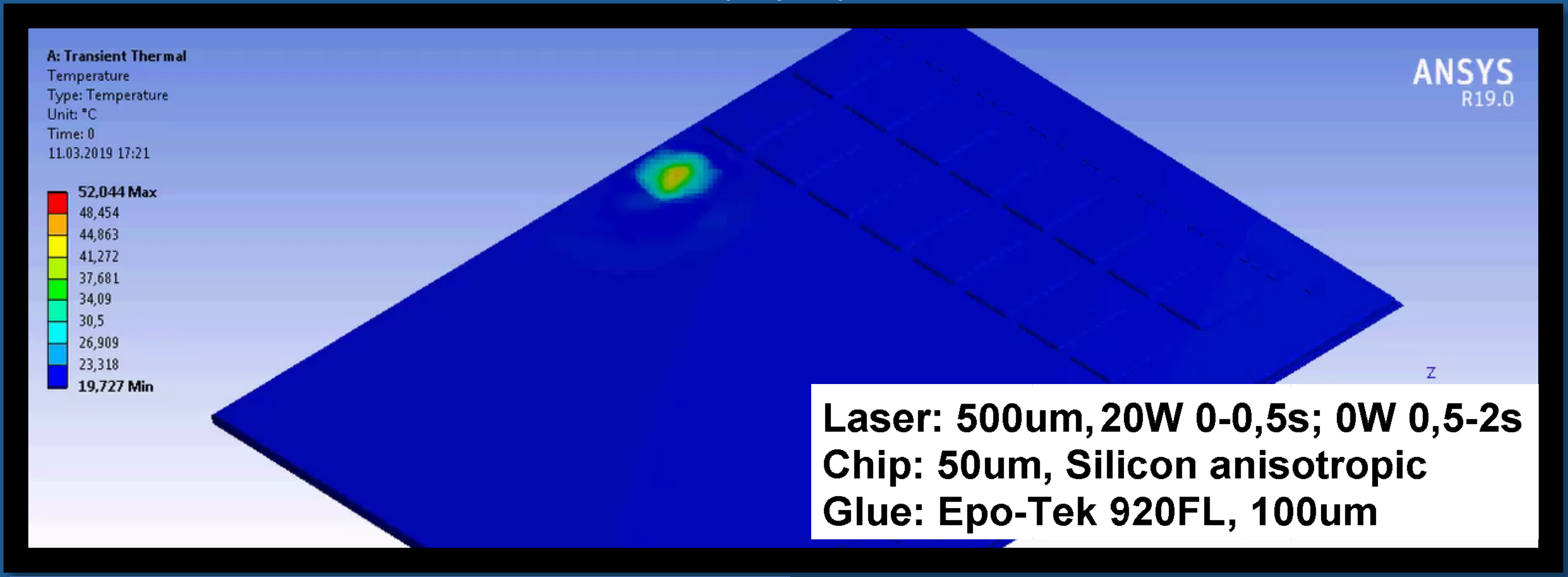




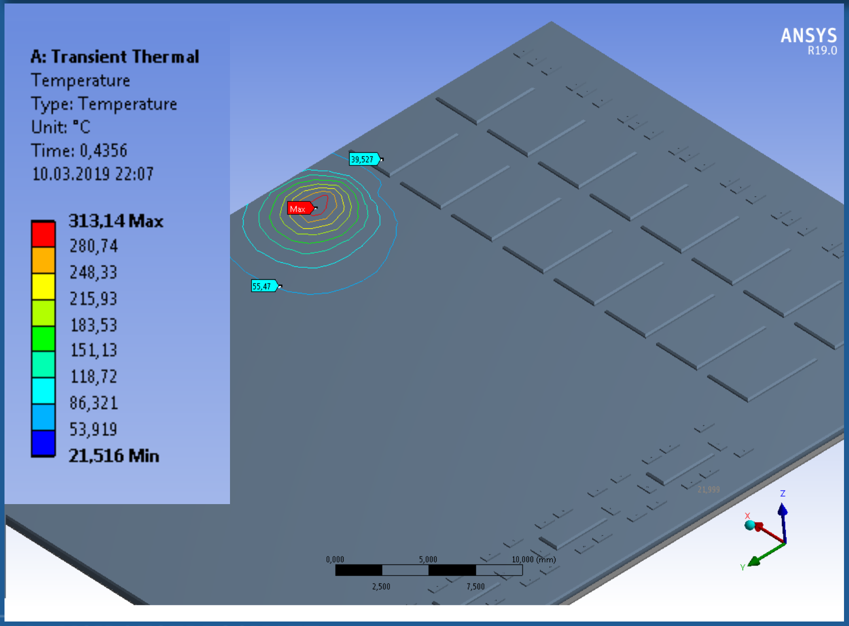
- 4 processes:
  - Si absorption
  - Surface reflection
  - Internal reflection (Alu)
  - ‘Surface layer’ absorption and absorption of reflected light
- Absorption occurs throughout the ‘thick’ Si layer
- Light is reflected/absorbed latest at the internal Aluminum layer

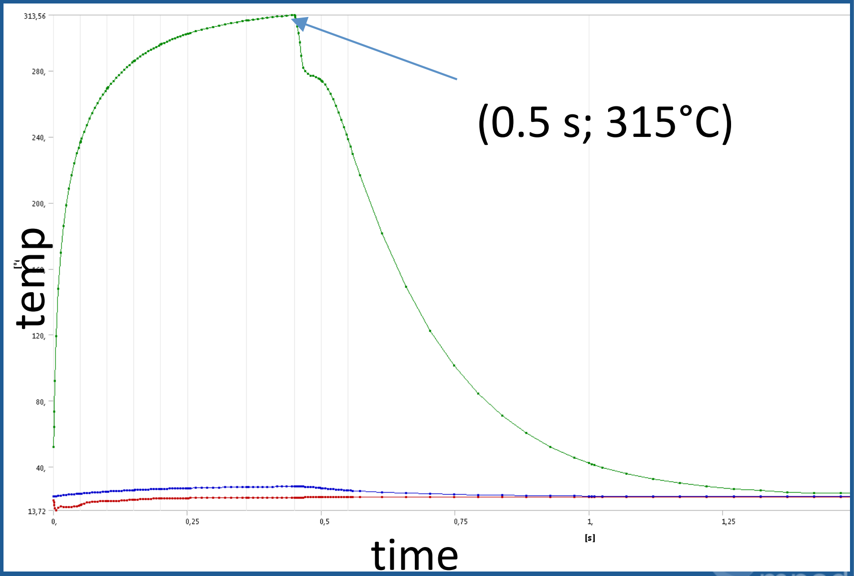
Simulations

By Djordje



Laser: 500um, 20W 0-0,5s; 0W 0,5-2s
Chip: 50um, Silicon anisotropic
Glue: Epo-Tek 920FL, 100um





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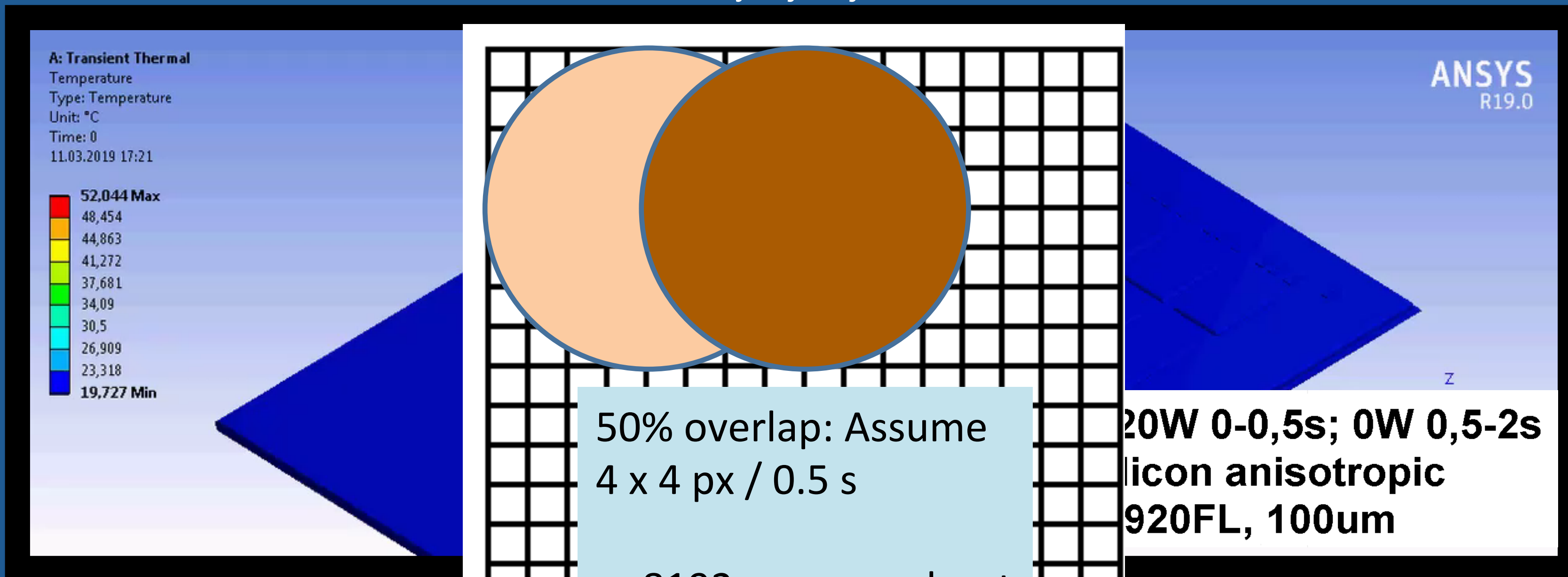
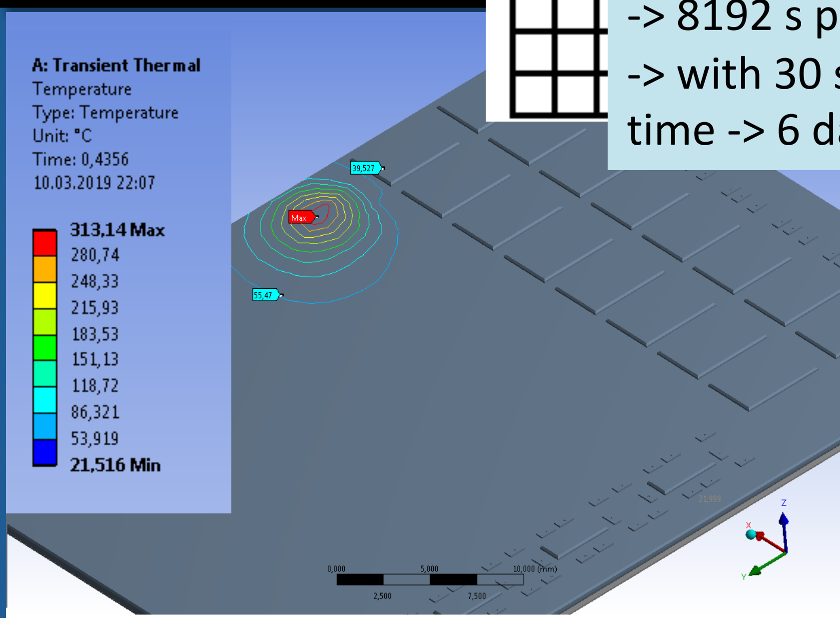
Simulations

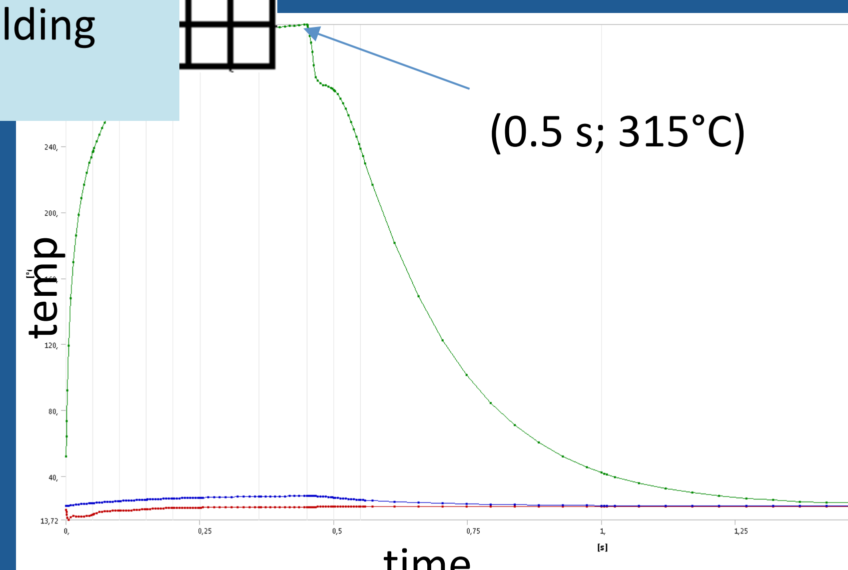
By Djordje



50% overlap: Assume 4 x 4 px / 0.5 s

-> 8192 s per quadrant
-> with 30 s holding time -> 6 days





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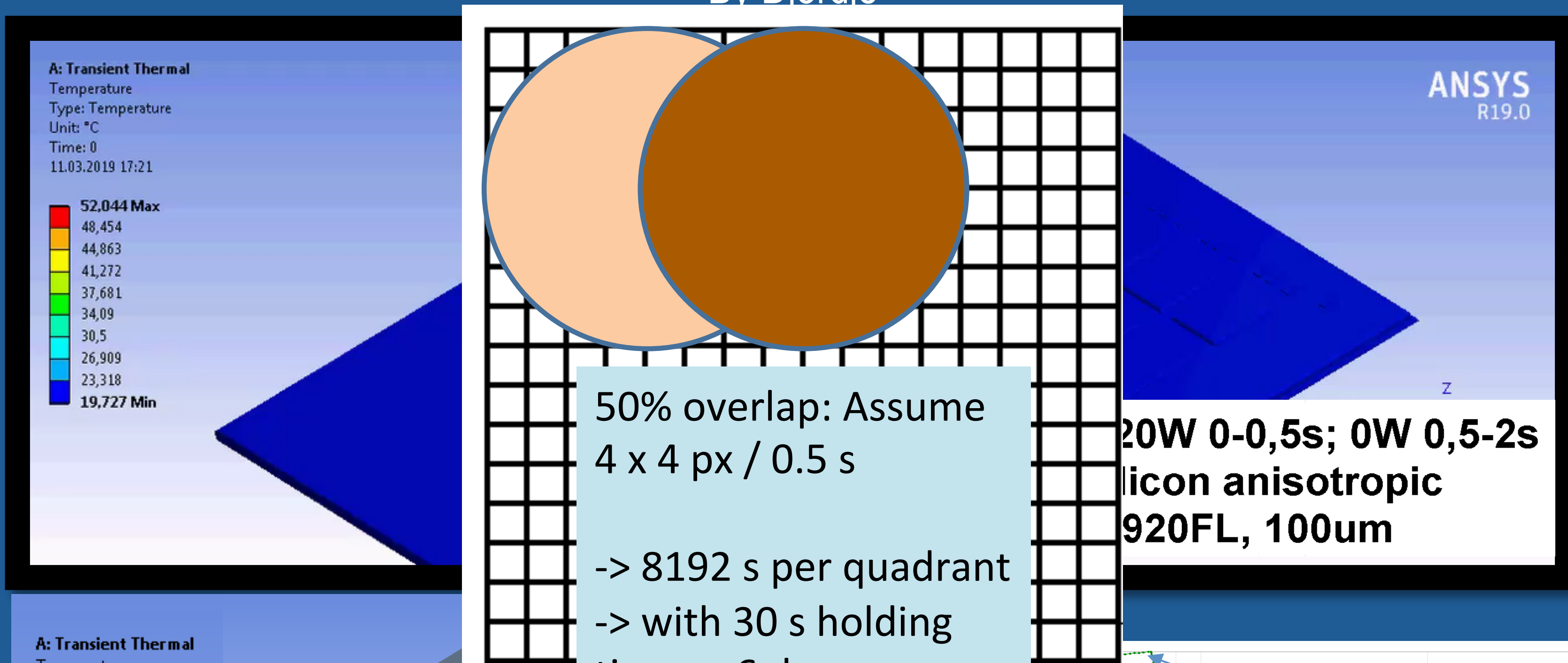

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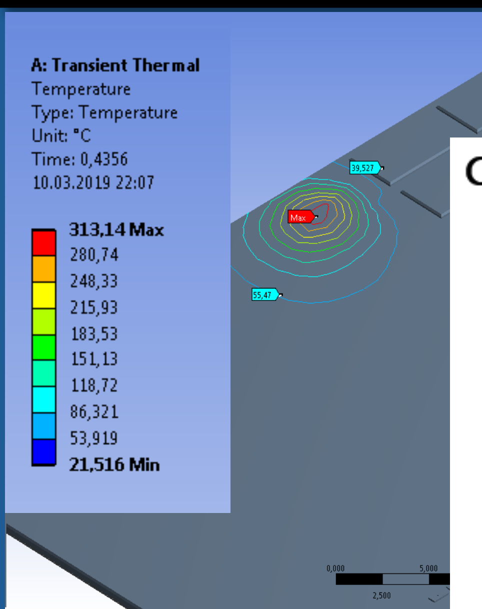
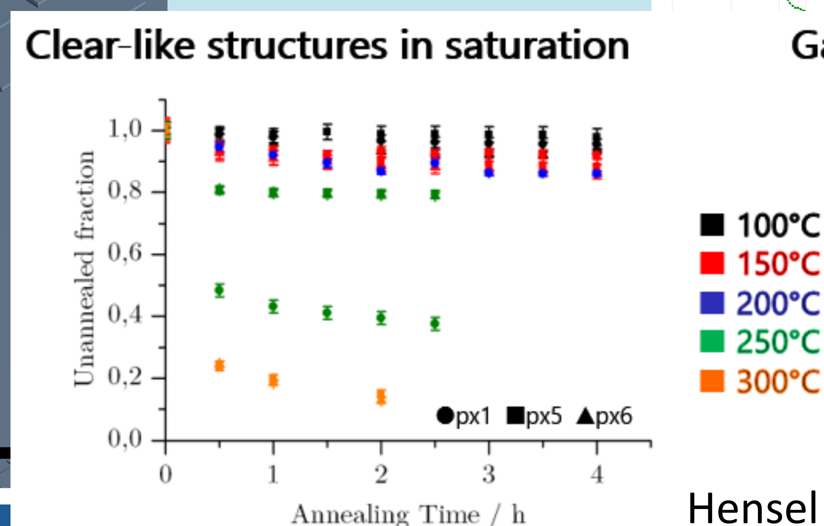
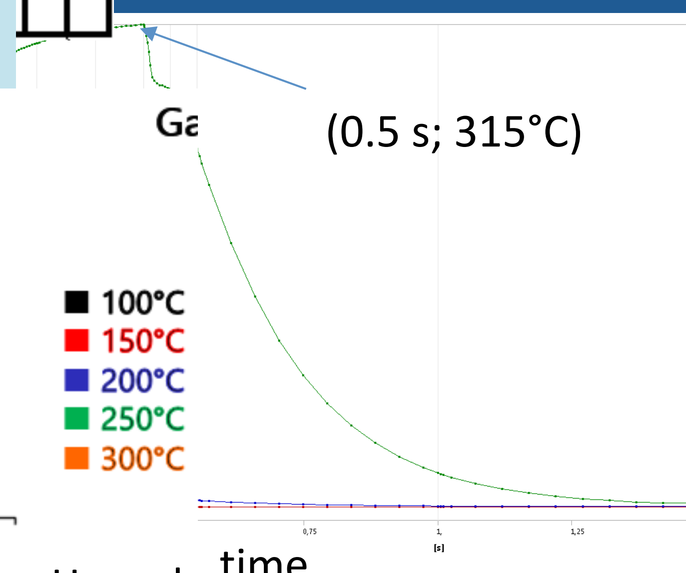




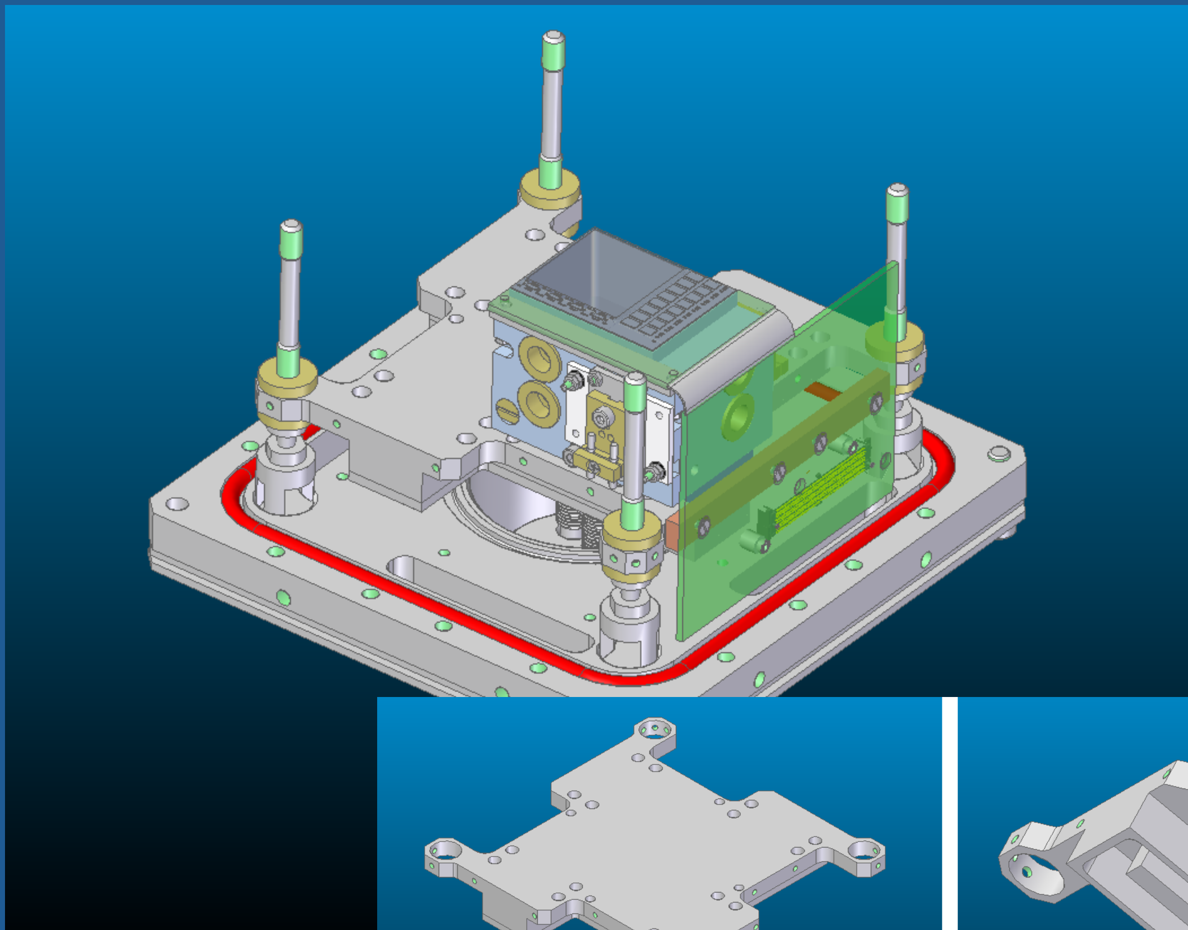


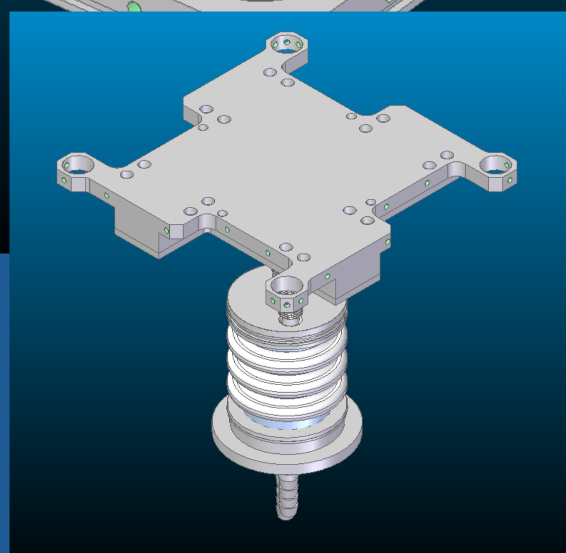
Conclusion

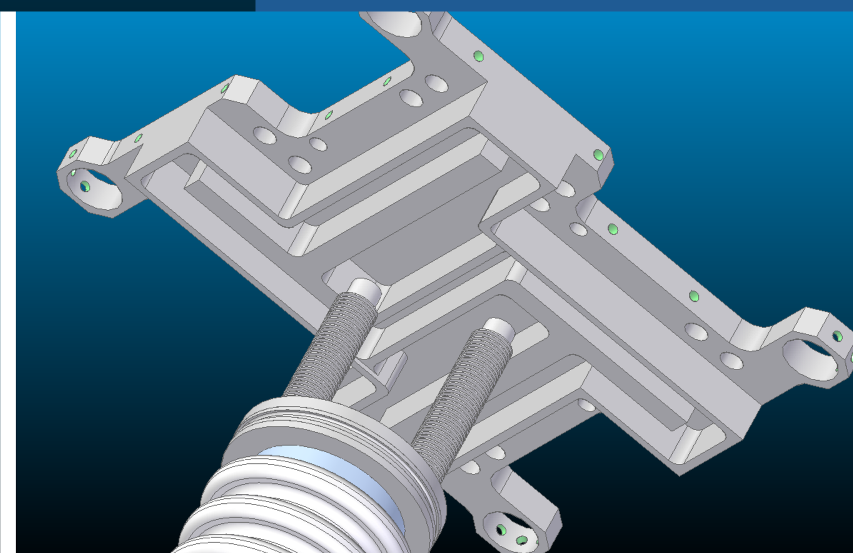
- Mechanical Setup almost completed
- Scanning algorithm yet to be implemented
- Simulation promisses precise injection of heat temperatures not rechable by other techniques
- Possibility to anneal „live“ Sensor -> new insight?
- Annealing time could be 1 week or more
- Test structures (irradiated?) for commissioning

EDET

Thermal Concept







EDET

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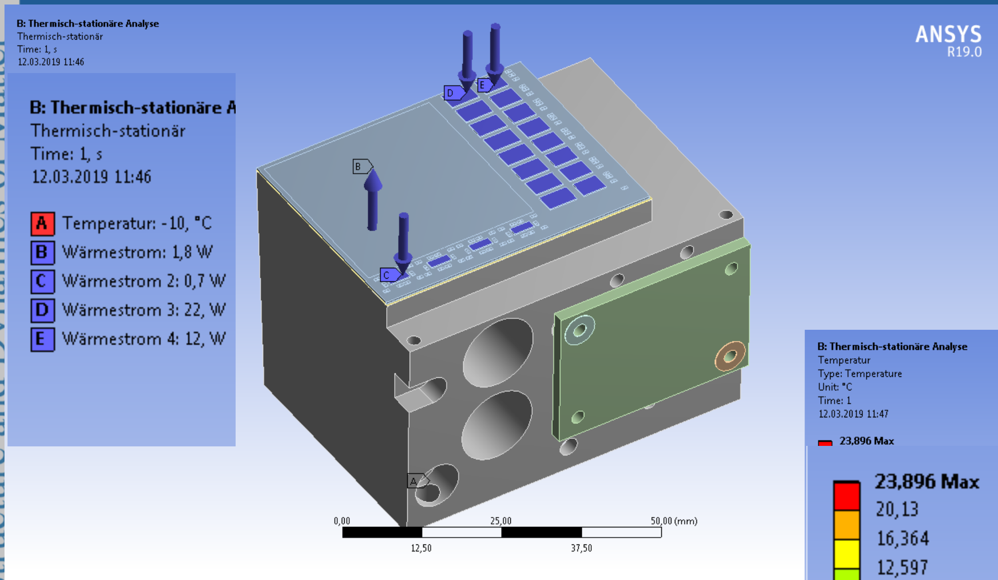

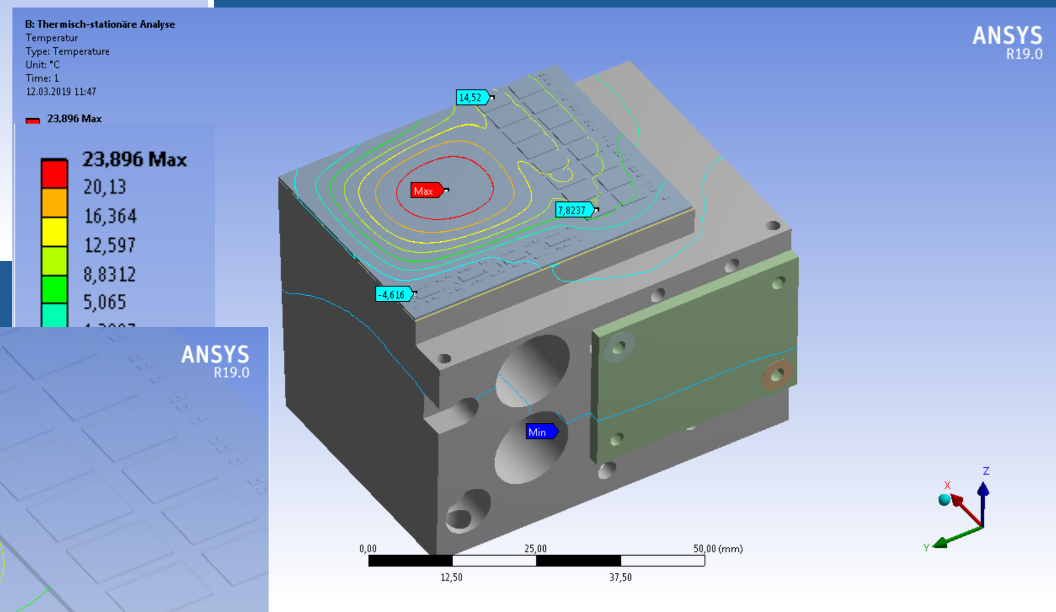

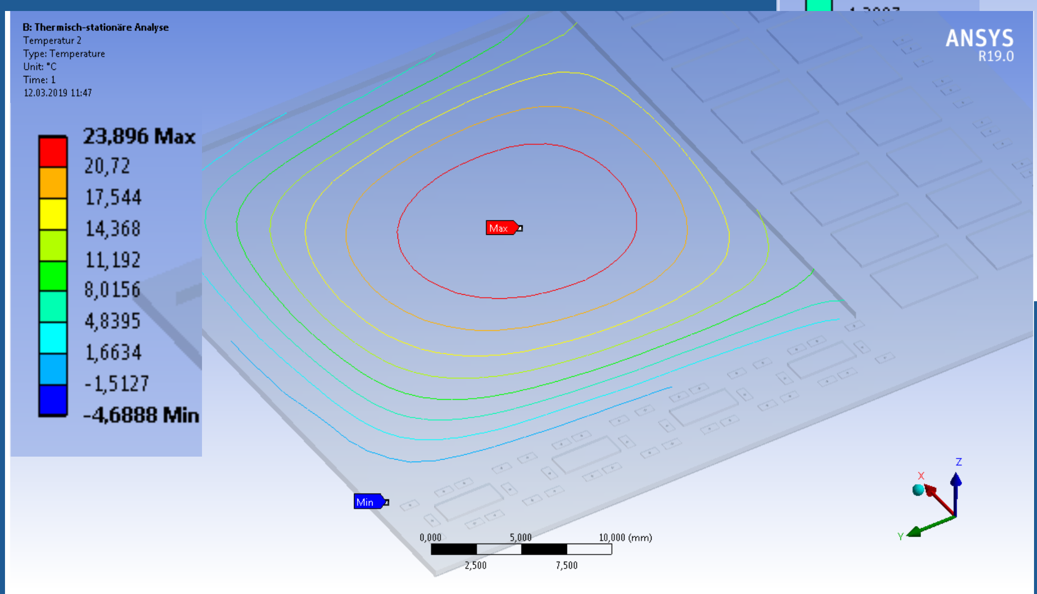

Summary

- Illumination from top
  - Everything is either reflected or absorbed by the top Cu (and TiW) layer
- Illumination from back
  - Absorption occurs throughout the ‘thick’ Si layer
  - Light is reflected/absorbed latest at the internal Aluminum layer

Questions

- Maximum ‘safe temperature’ for complete quadrant
- Test structures for laser tests
- Irradiation / radiation damage tests
  - X-rays
  - electrons
  - annealing