IR Transparent Si microstrips

(alignment optimized Si sensors)

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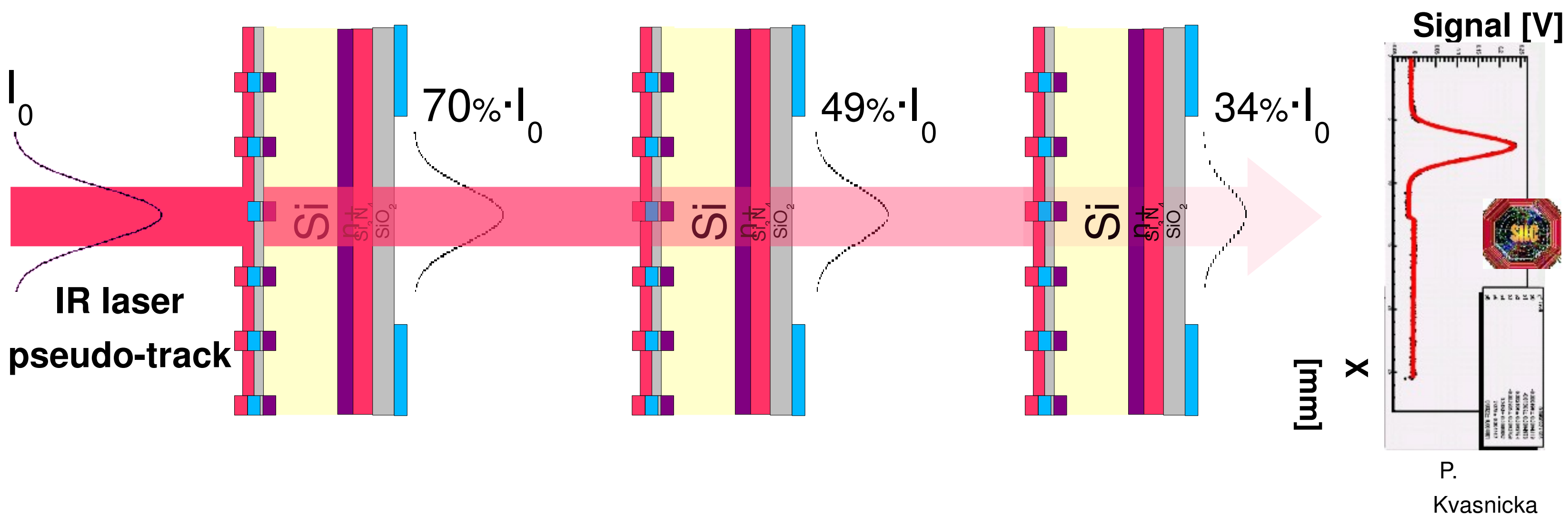
Outline

- What is an infrared hardware alignment system
- How to increase transmittance of a microstrip detector
- Simulation of prototype transparent microstrips
- Measurements of prototypes
- Conclusions and outlook

Microstrips as semitransparent light detectors

• Laser tracks can be used by a hardware system to align the tracker



• First implemented by AMS I, then AMS II and CMS

• Goal of this project is to improve transmittance to infrared light of microstrip detectors. Main constraint are:

– Do not alter the standard production process

– Do not include alien materials

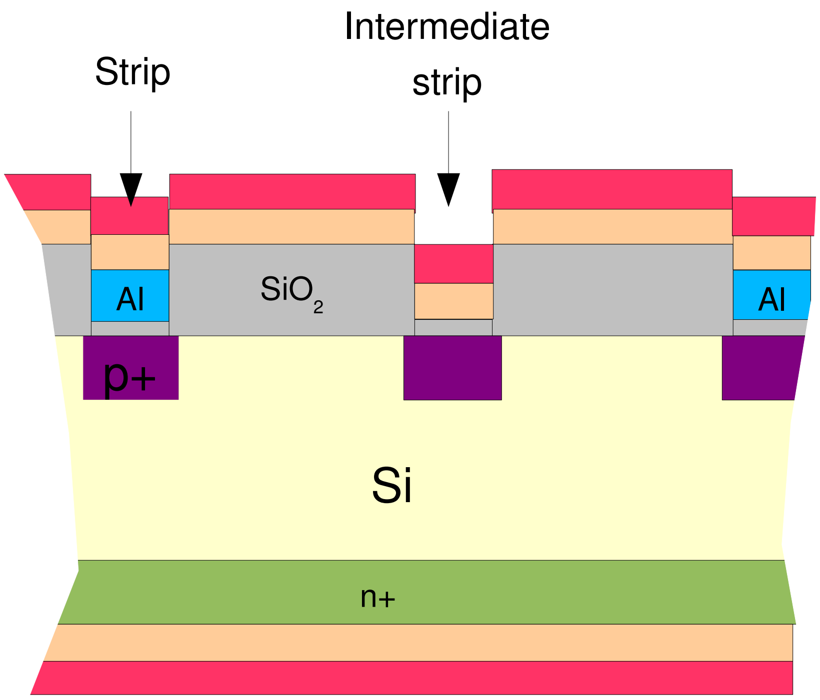
How to increase %T of a strip detector

- **Aluminum** strips act like **mirrors**. If strips are too wide, reflectance will increase too much
  - Optimize pitch to strip width ratio
  - Use transparent electrodes?

- IR light penetrates 300 μm Si. Multiple reflections at the interfaces ⇒ **Interferences**
  - Choose thickness of the materials such that **light interferes constructively**
  - Complications come from strips ⇔ **diffraction** grating (pitch~50 μm, λ~1 μm)

- We need to develop a **simulation** to calculate:
  - Transmittance (%T), Reflectance (%R) and Absorptance (%A) for a μstrip detector
  - Optimize the design (pitch, strip width, thickness of layers)
  - Define prototypes

Simplified simulation of µstrips as plane-parallel layers



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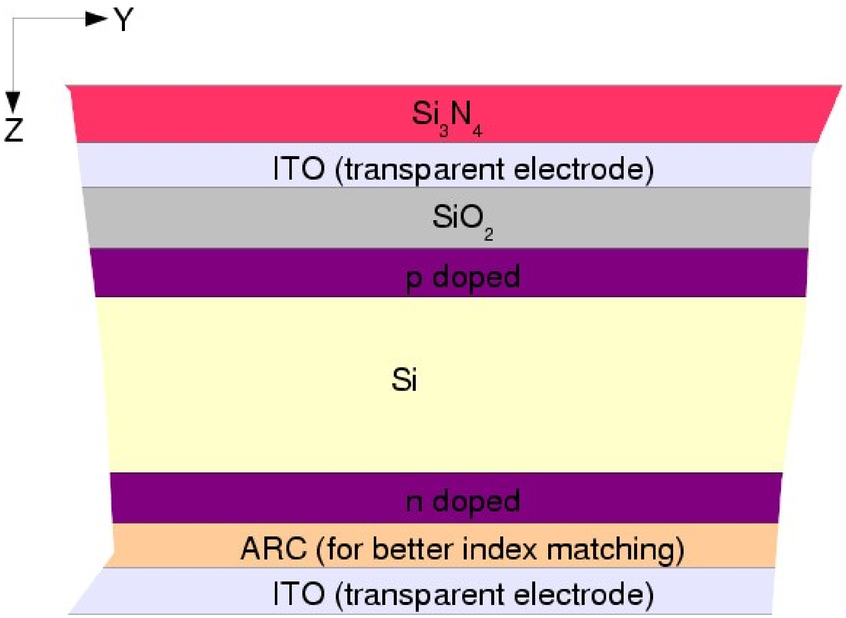


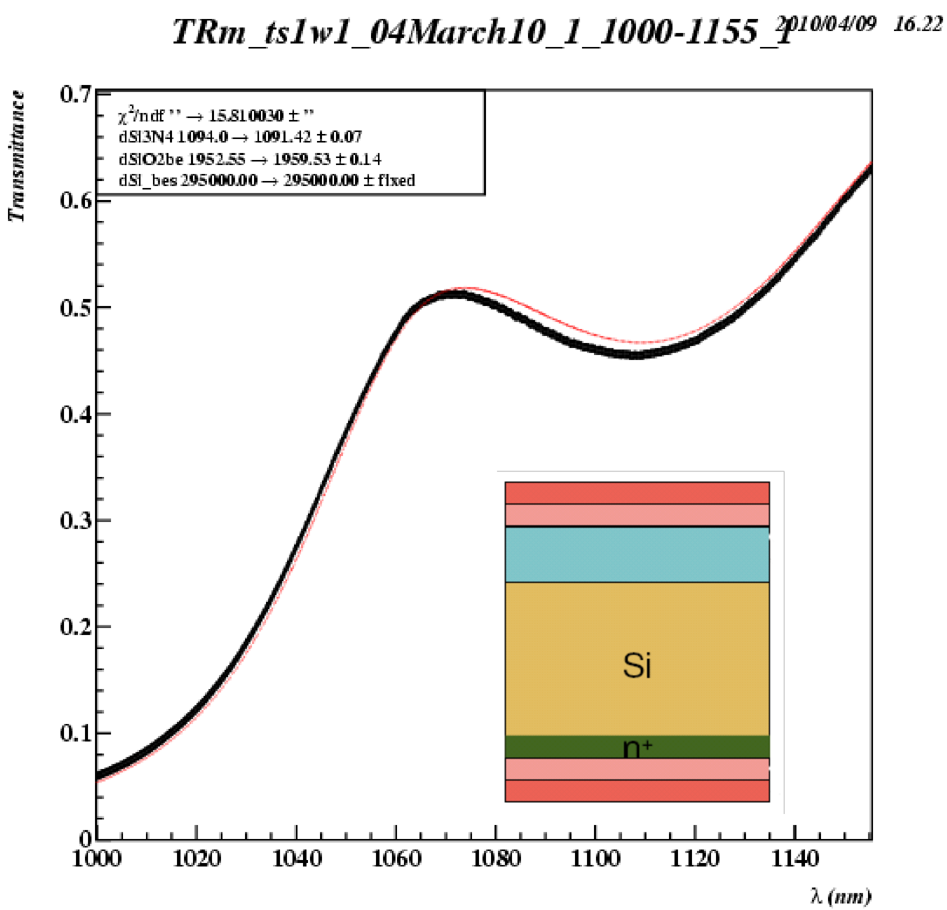
- ✔ Interference
- ✔ Diffraction

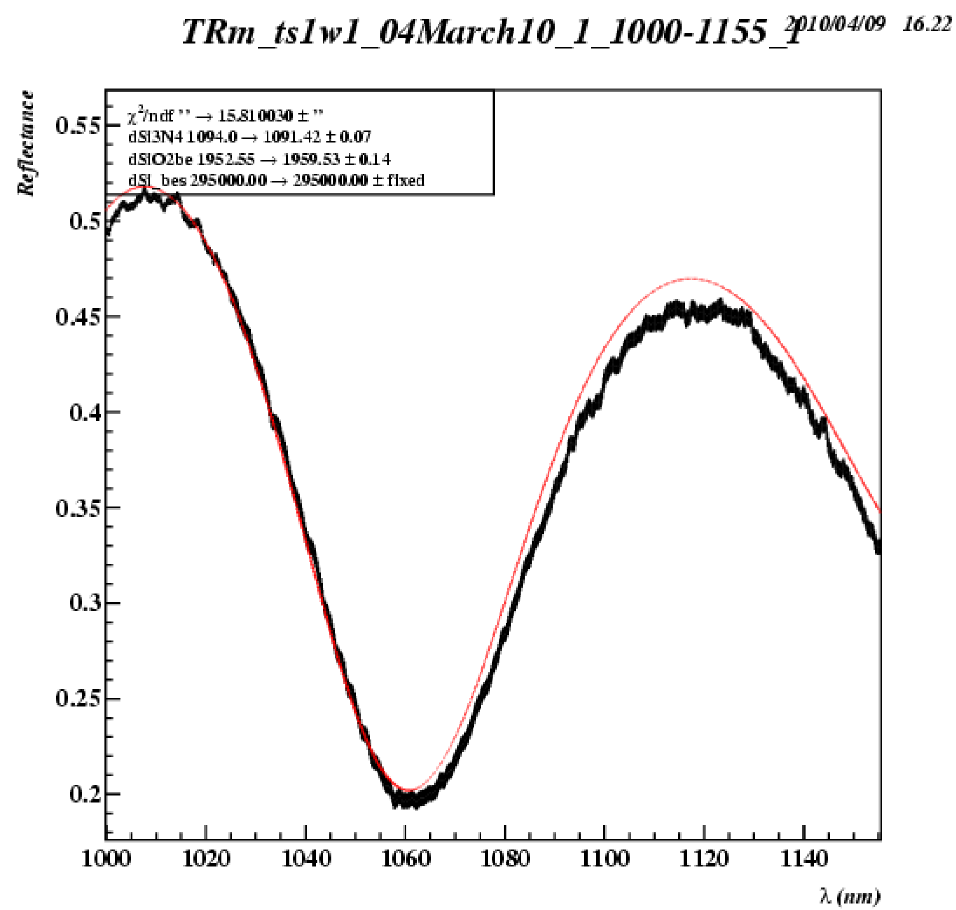
- ✔ Interference
- ✘ Diffraction

Planeparallel layers simulation

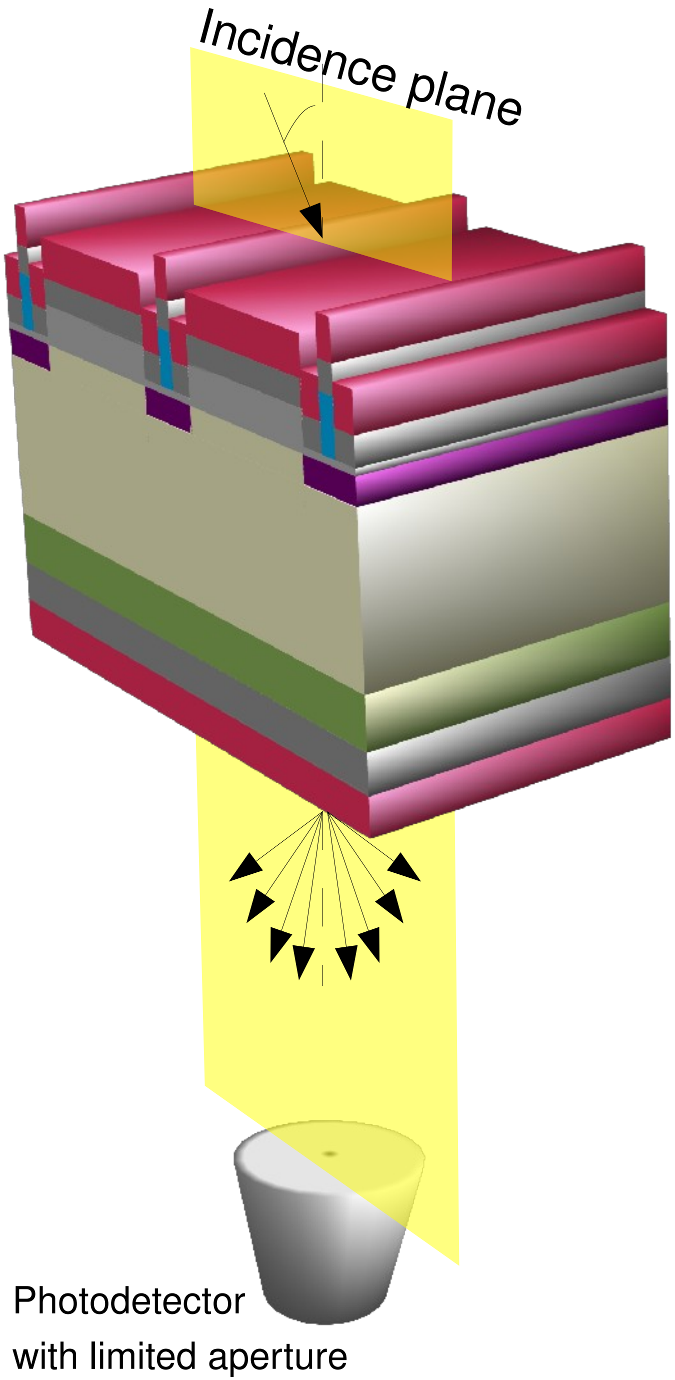
- Ideal layout: no strips ⇒no diffraction ⇒ all energy goes forward
  - Useful to estimate maximum performance (T_{max}~75-80%)

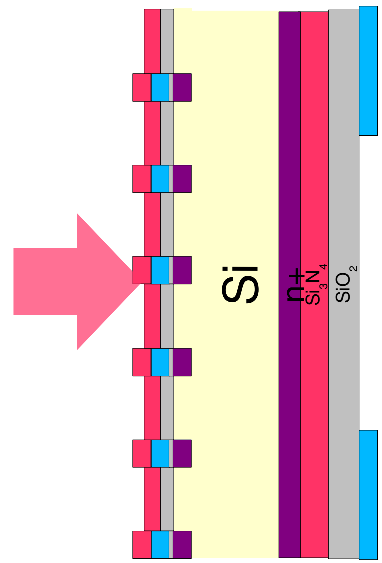
- Useful to characterize refraction index of materials and deposition tolerance (backengineering)

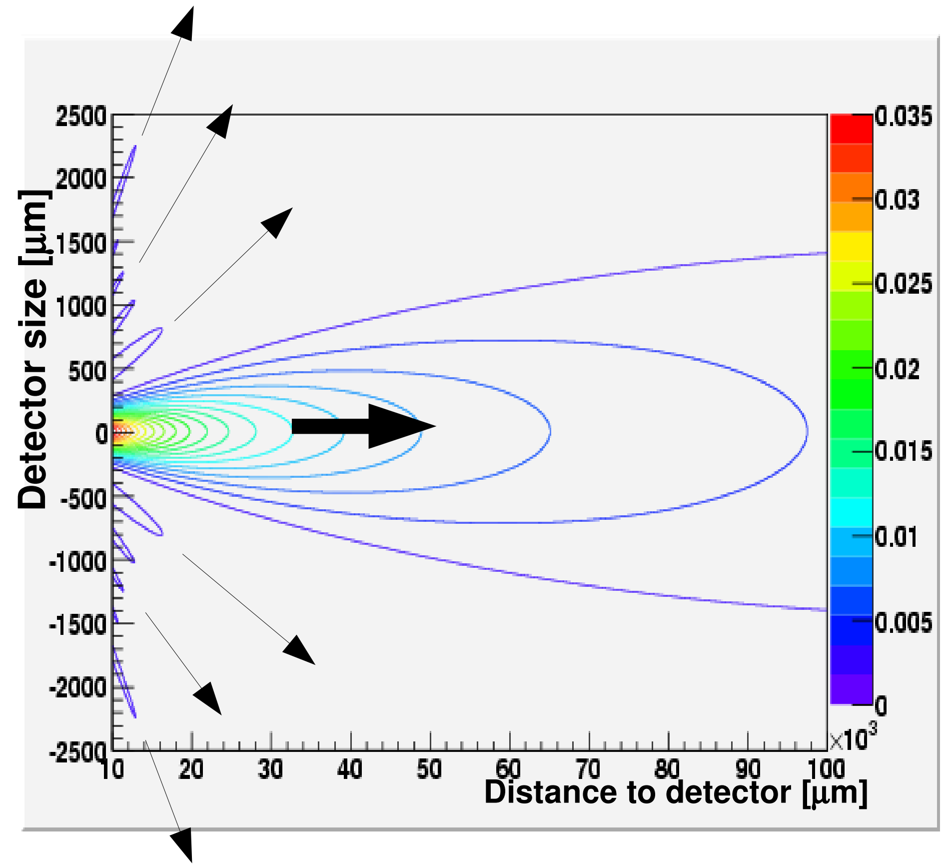




Including diffractional effects







- Diffraction here means that:
  - — Energy spreads in secondary maxima
  - — Light spreads off the central beam
  - — Experimentally T=T(distance to detector)

Main conclusions from full simulation

See for instance: Eudet-Memo-2009-23

— Strips (having metal or not) behave as a diffraction grating.
Sensors with intermediate strips are more “efficient” gratings ⇒ worse as %T devices

— Pitch reduction (=closer strips):
→ decreases transmittance (1^{st} order effect)
→ increases reflectance (2^{nd} order).

— Strip width increase:
→ increases reflectance (1^{st} order)
→ reduces transmittance (2^{nd} order).

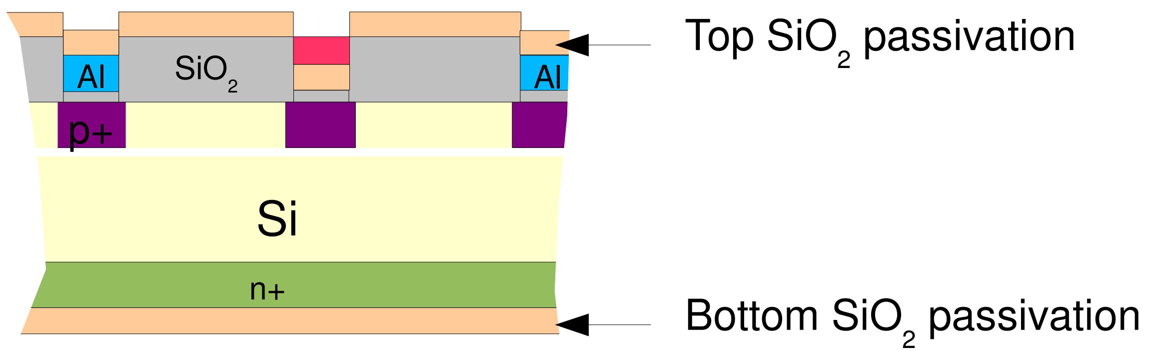
— Top and bottom passivation layers(*) behave as an **A**nti**R**eflection **C**oating (ARC)
Top passivation thickness more critical than bottom.

(*) Passivation=Si_3N_4 on SiO_2

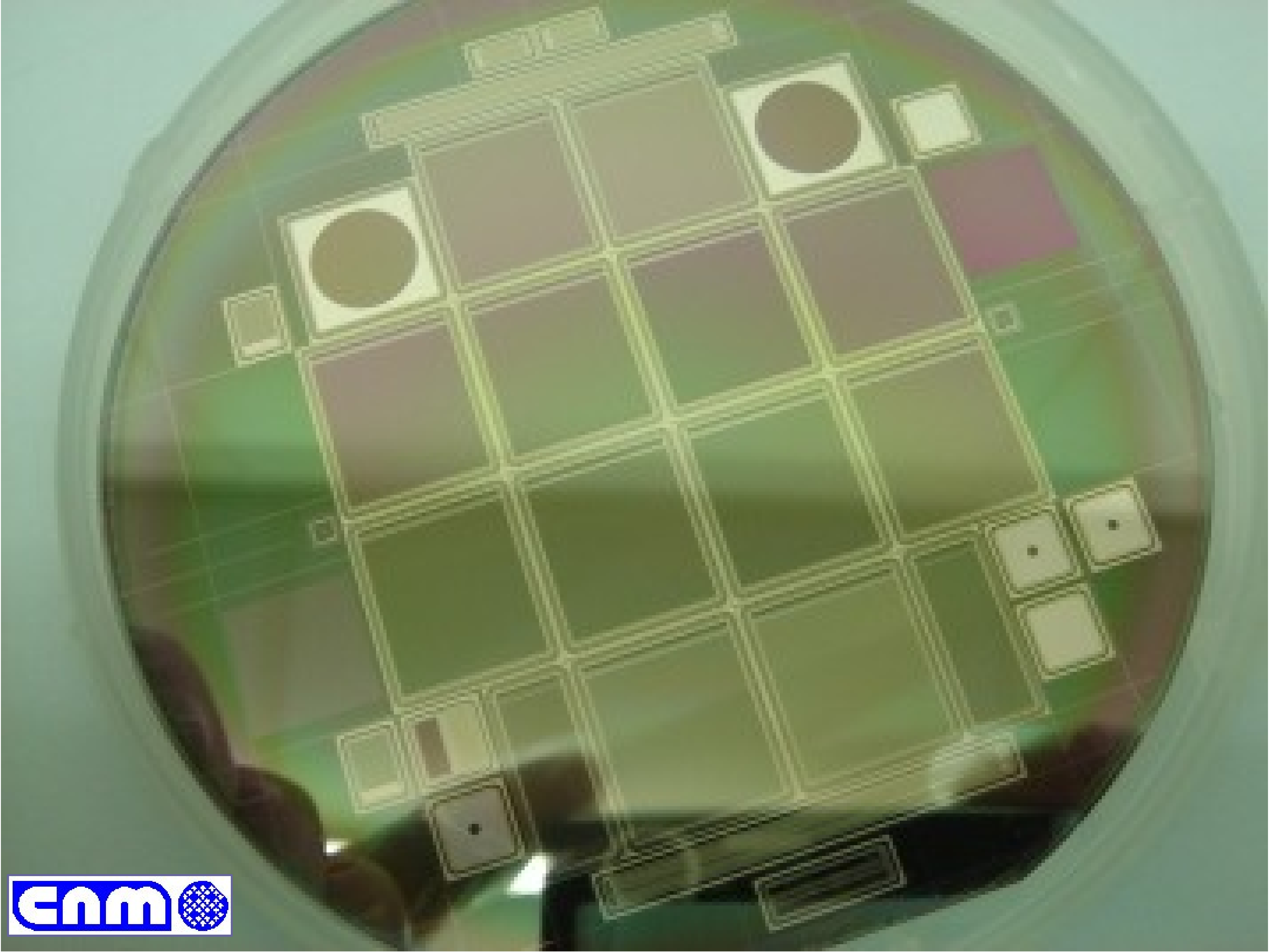
Validation of full simulation (interference + diffraction)

- Validation of simulation not possible with already existing sensors from Hamamatsu
  - No information available on layers and thicknesses

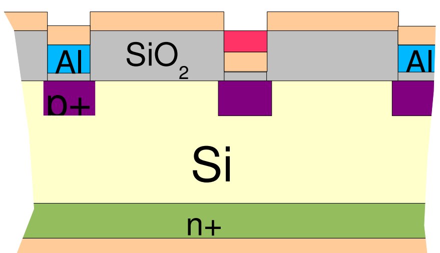
- Therefore we need to validate the simulation with the same sensors we want to optimize
  - Flexibility of CNM allows to hold processing after first layer of passivation



  - Observed simulation ≠ measurement ⇒ Tune simulation

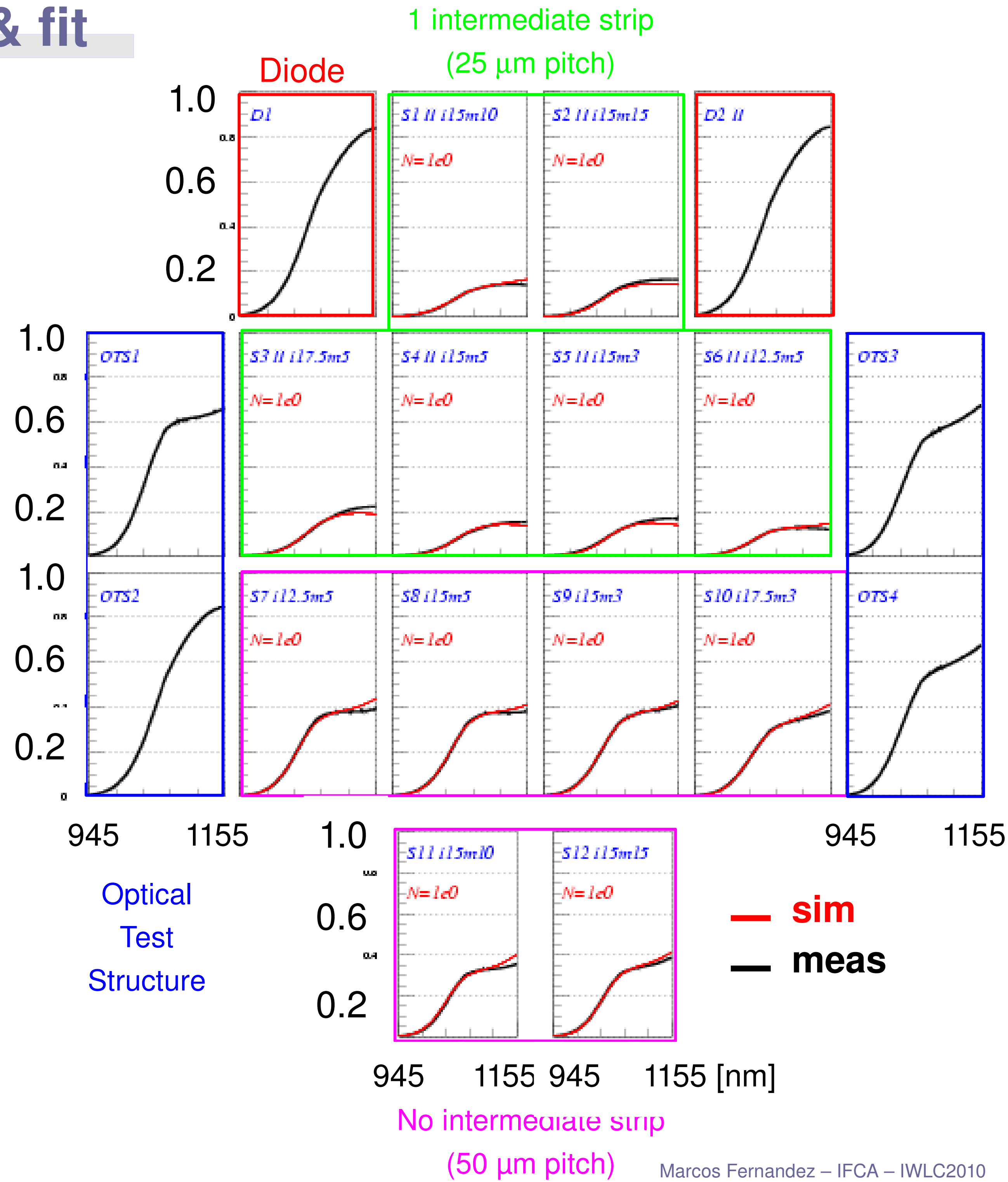

cnm

Wafer 1, measured & fit



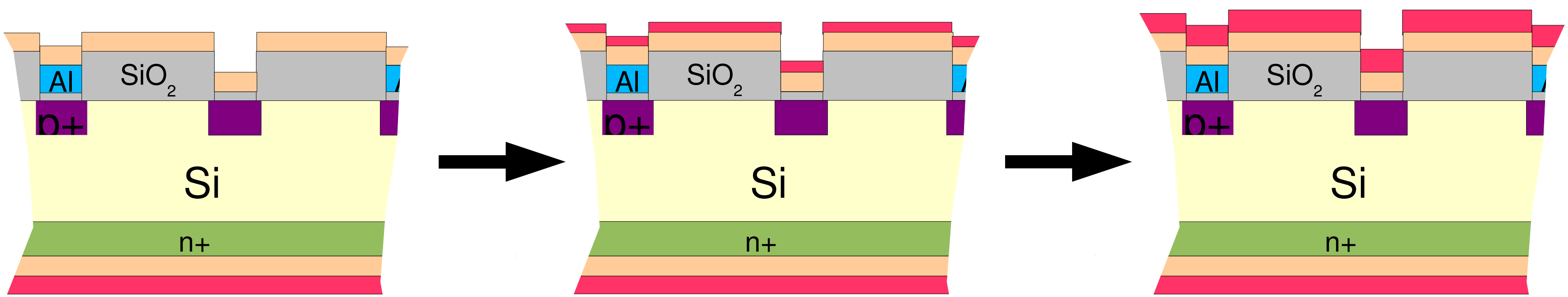
Uncomplete top&bottom passivation

Transmittance~40%



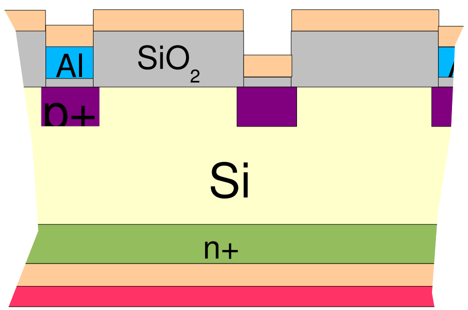
Last steps before the end of the run

- Now, for the last 3 wafers:
  - Iterative process: deposit Si_3N_4 → measure %T → fit → correct if needed



Current situation
(18th October 2010)

Wafer 3, measured



Current situation

(measured yesterday at CNM)

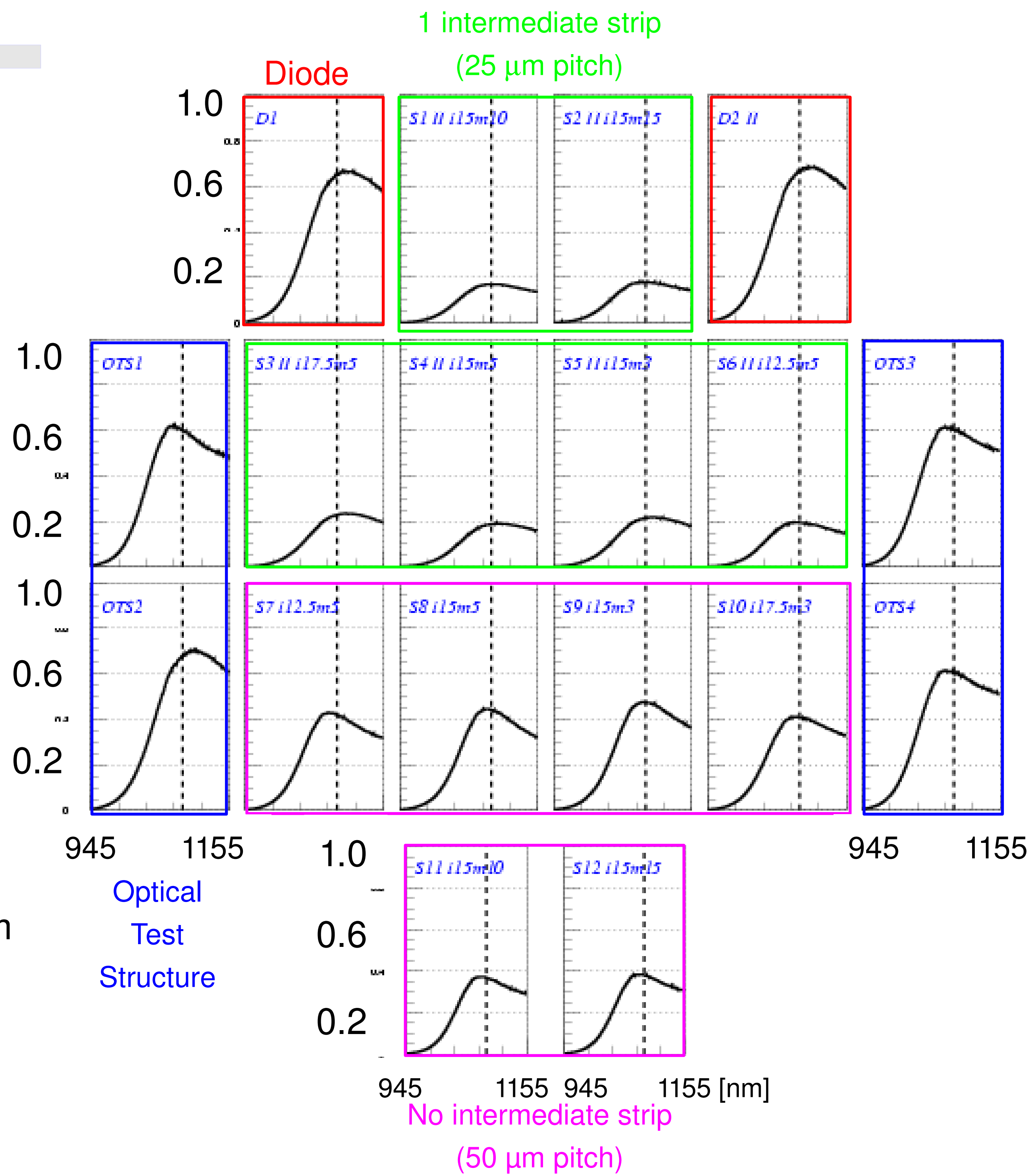
Complete bottom passivation

Transmittance~45%

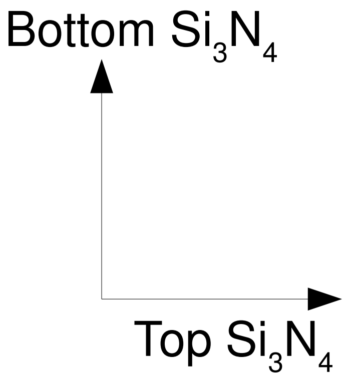
For comparison:

CMS=20% with pitch > 80 µm

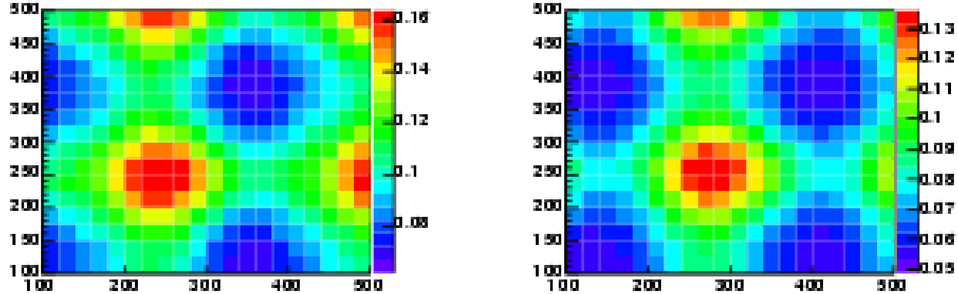
AMS=50% with pitch 110 µm

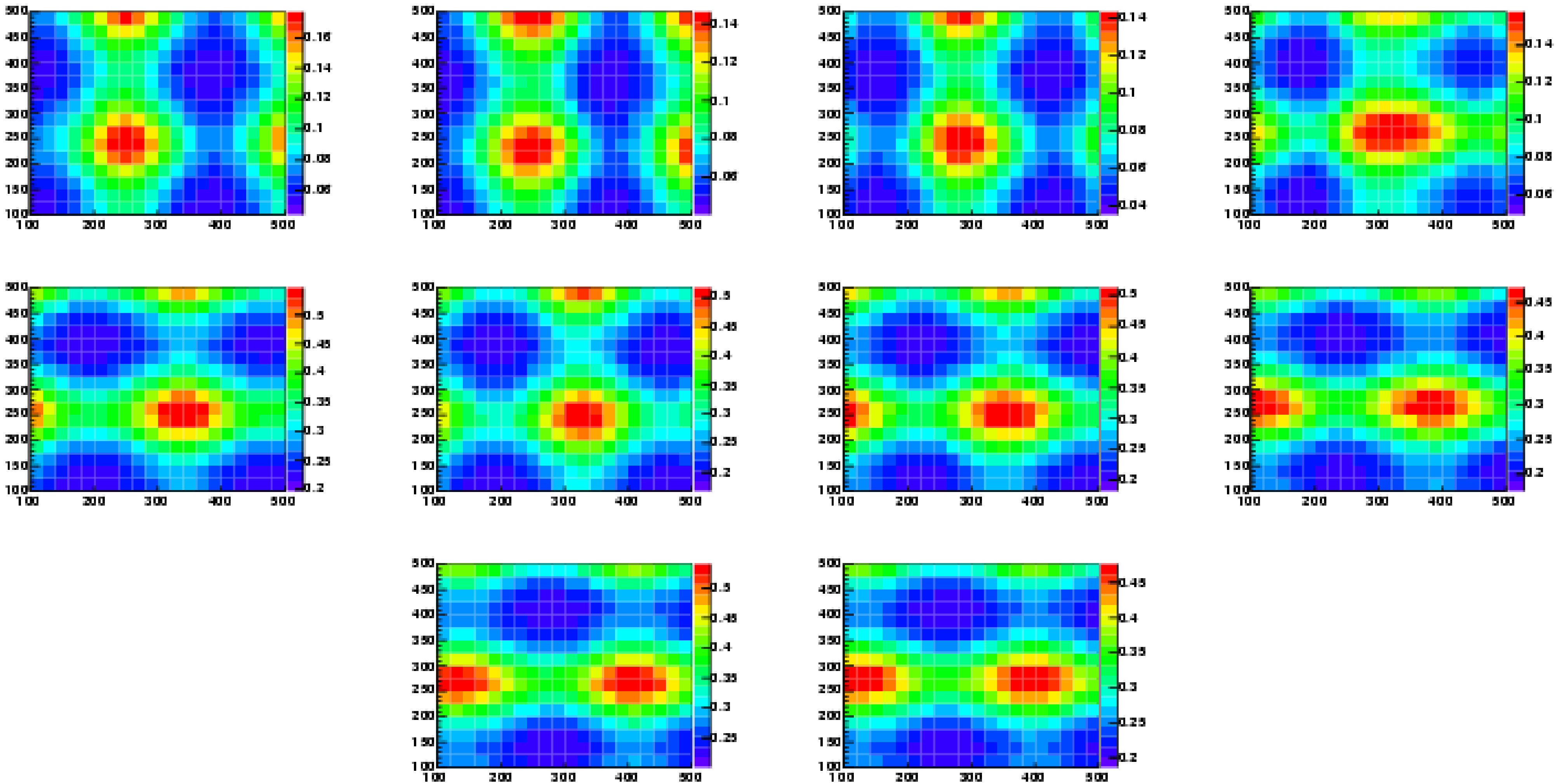


Wafer 3: Sequential deposition of Si3N4 (using measured thickness)

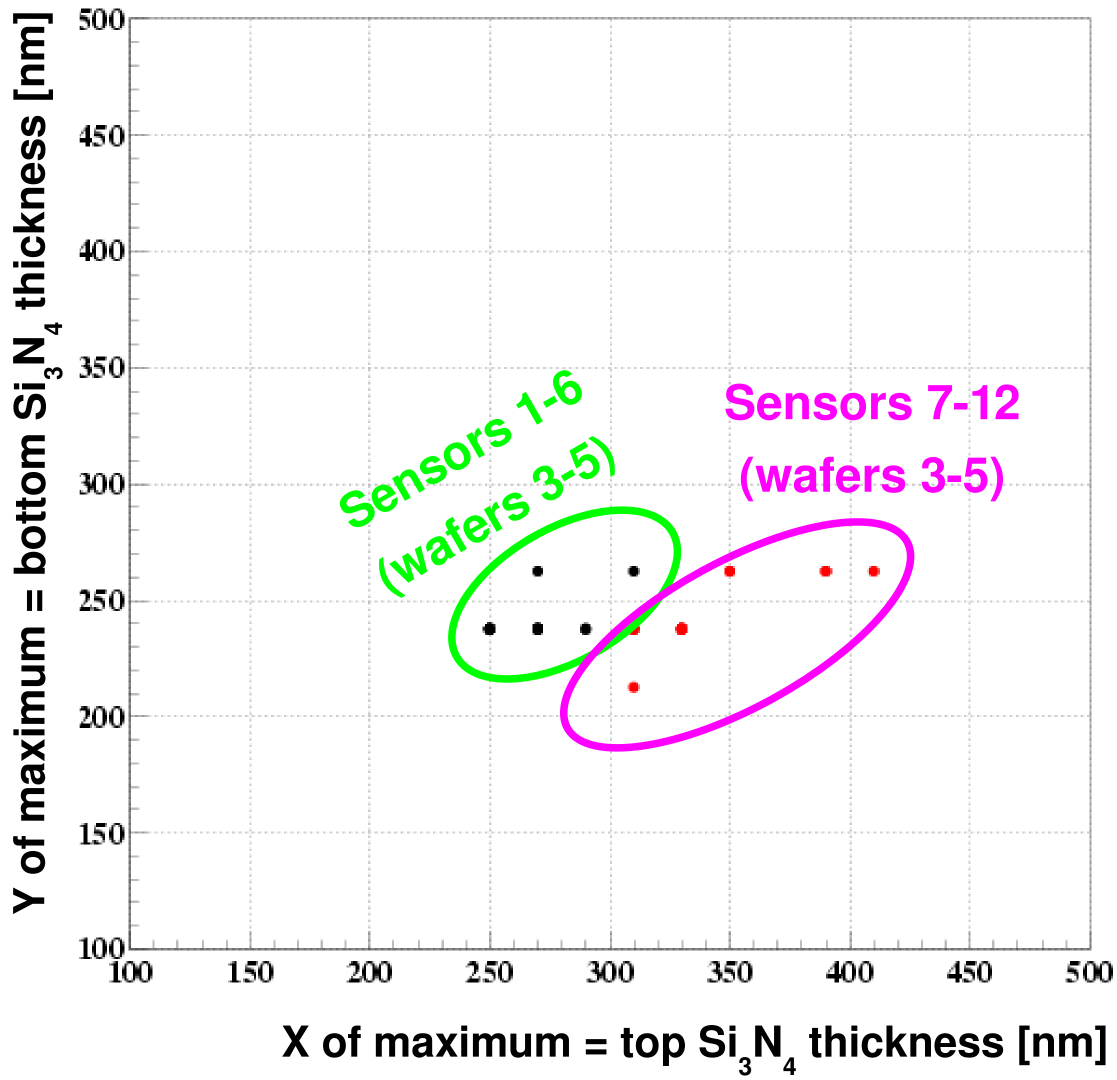


T=T(top Si_3N_4 thickness , bottom Si_3N_4 thickness) for the 12 sensors





Best top and bottom thickness (wafers 3-5)



– Thickness of bottom Si3N4 passivation layer does not depend on intermediate strip

– Upper Si3N4 layer is thicker for sensors without intermediate strip

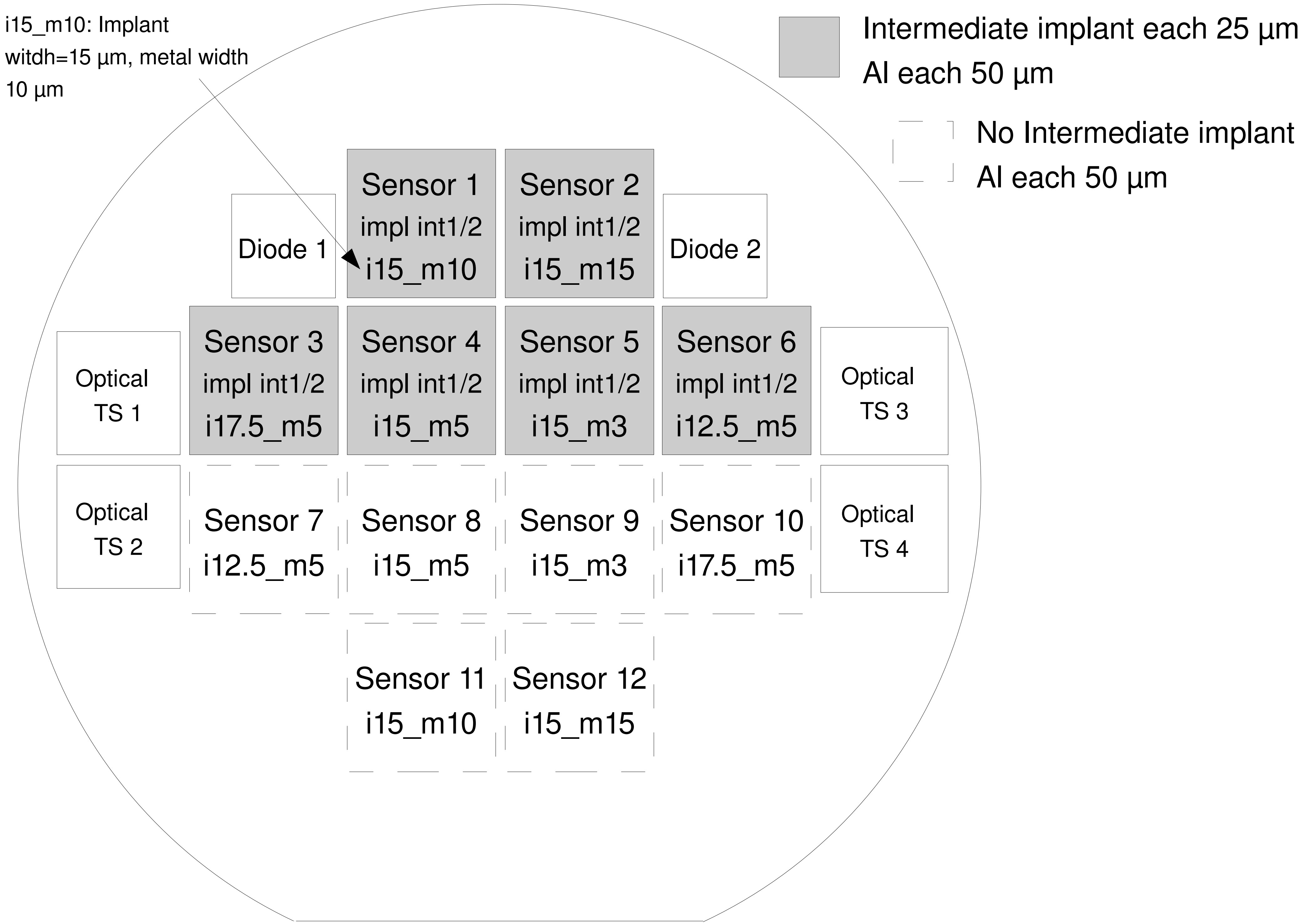
Conclusions

– Densely populated microstrip silicon sensors can be made >50% transparent
– Transmittance depends more on pitch and less on strip width
  → Sensors with intermediate microstrips have lower %T
– Reflectance depends more on strip width
– Overall transmittance defined by the thickness of upper passivation Si_3N_4 layer
  → Aiming for 55%
– We have very good transmittance for a very busy structure
– Upper Si_3N_4 layer is thicker for sensors without intermediate strip
– Run will be finalized in October.

Outlook

– Apply lessons learnt in a new run of highly transparent sensors
  → Aiming for >60%

BACKUPS

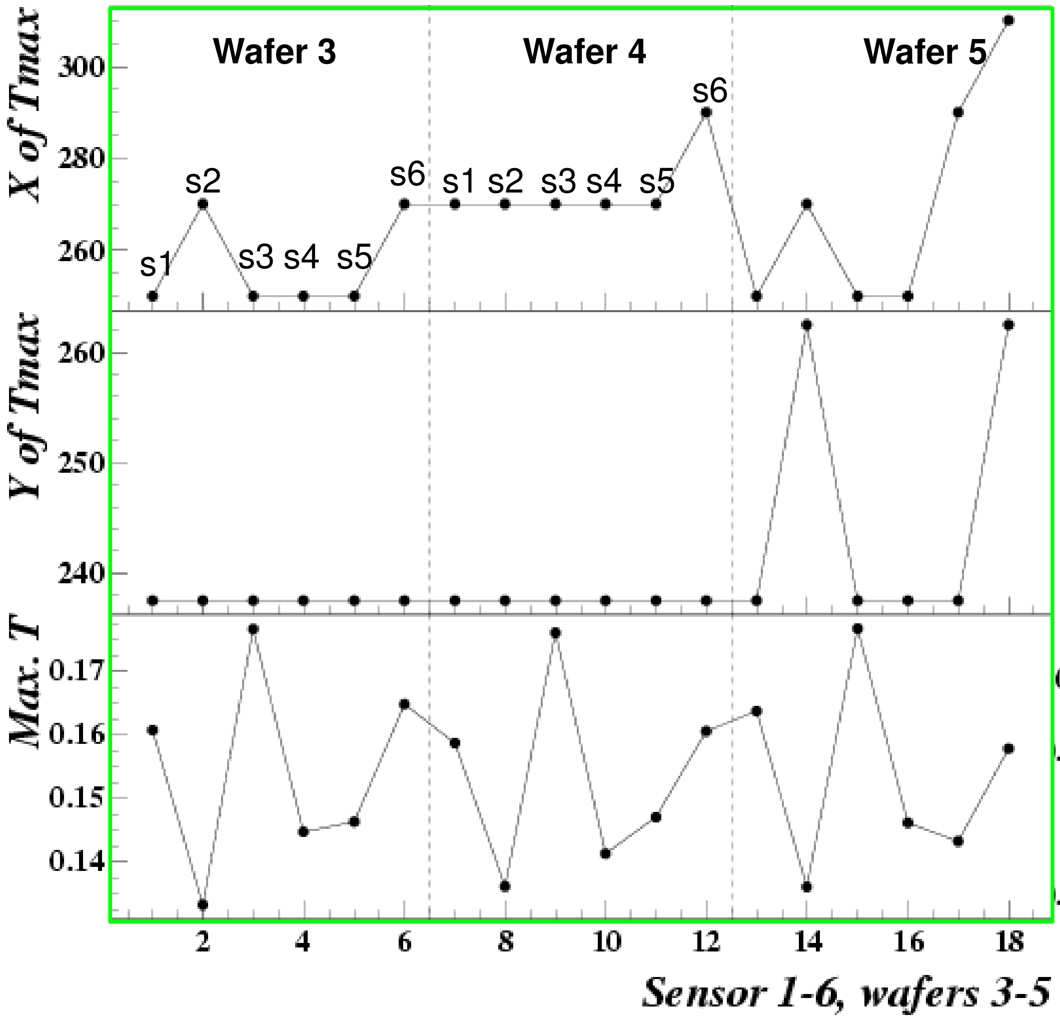

i15_m10: Implant
witdh=15 µm, metal width
10 µm
Intermediate implant each 25 µm
Al each 50 µm
No Intermediate implant
Al each 50 µm
Diode 1
Sensor 1
impl int1/2
i15_m10
Sensor 2
impl int1/2
i15_m15
Diode 2
Optical
TS 1
Sensor 3
impl int1/2
i17.5_m5
Sensor 4
impl int1/2
i15_m5
Sensor 5
impl int1/2
i15_m3
Sensor 6
impl int1/2
i12.5_m5
Optical
TS 3
Optical
TS 2
Sensor 7
i12.5_m5
Sensor 8
i15_m5
Sensor 9
i15_m3
Sensor 10
i17.5_m5
Optical
TS 4
Sensor 11
i15_m10
Sensor 12
i15_m15

(x,y) of first maximum vs sensor id in wafers 3, 4, 5

X= top Si_3N_4 thickness

Y= bottom Si_3N_4 thickness

Sensors with intermediate strips=25 µm pitch



Sensors without intermediate strips=50 µm pitch