Electromagnetic simulations of newly designed semiconductor bolometers for submillimeter observations

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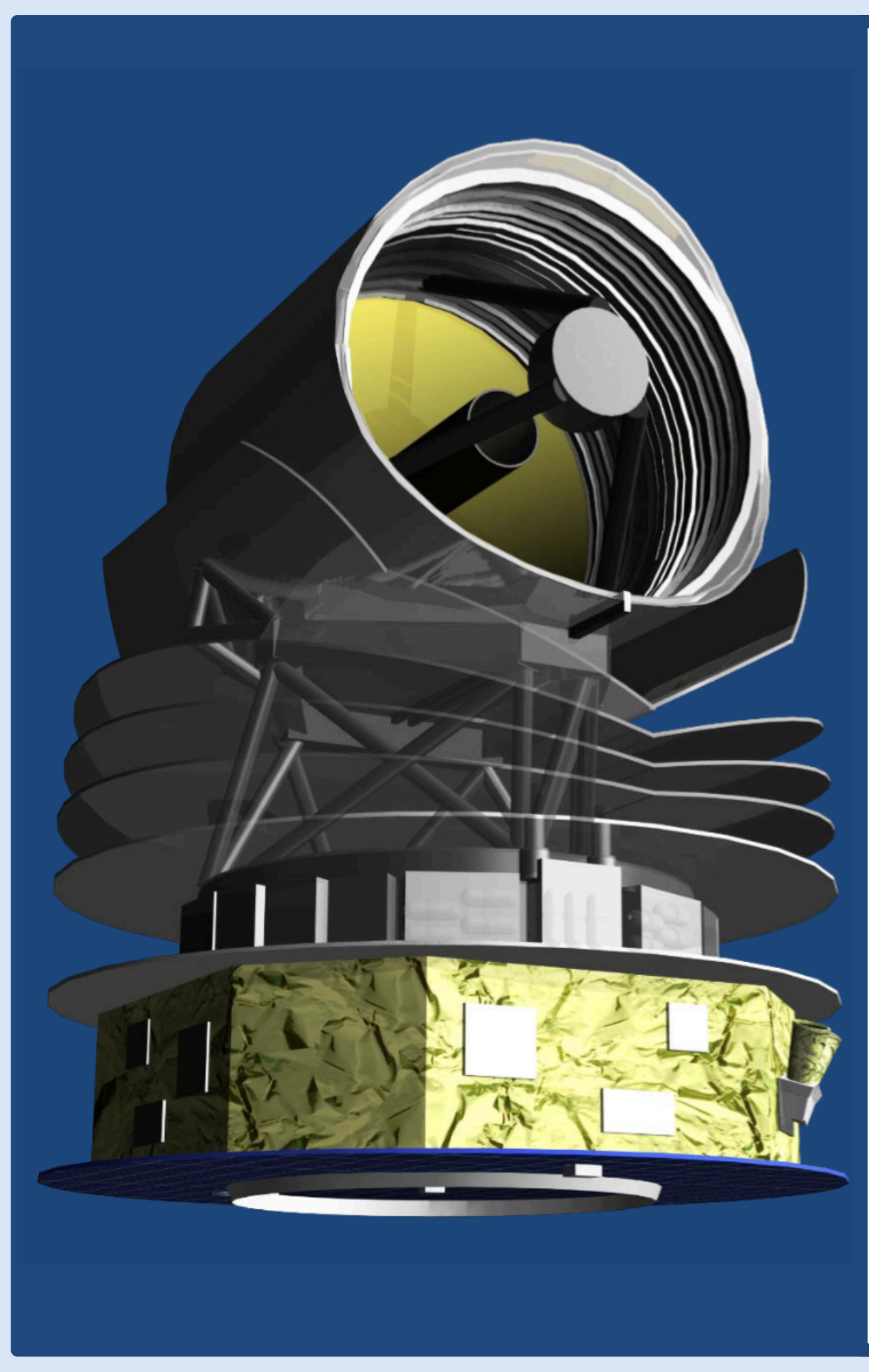


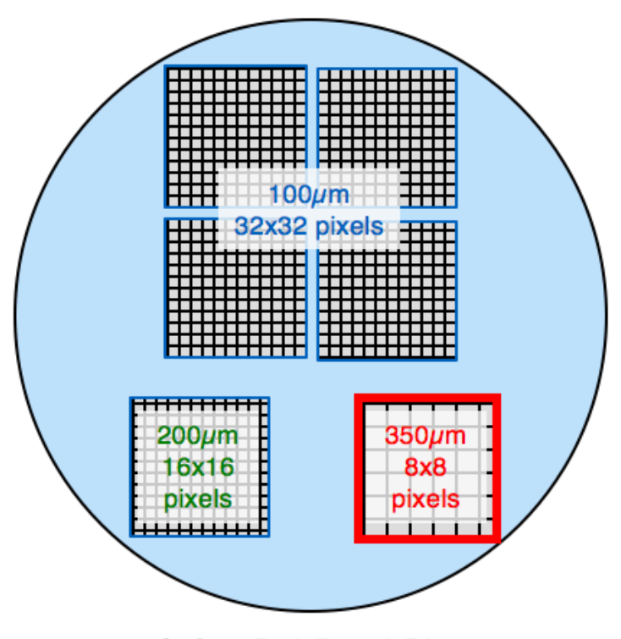
SPICA – Unveiling the obscured Universe

- Joint space mission of Japan and Europe, expected to be launched in the late 2020s
- Aims to understand the origin and evolution of galaxies, stars and planets
- Primary mirror cooled to below 8K (80K for the Herschel Space Observatory)

<u>3 instruments</u>: SMI, SAFARI-spec & SAFARI-pol

SAFARI-pol

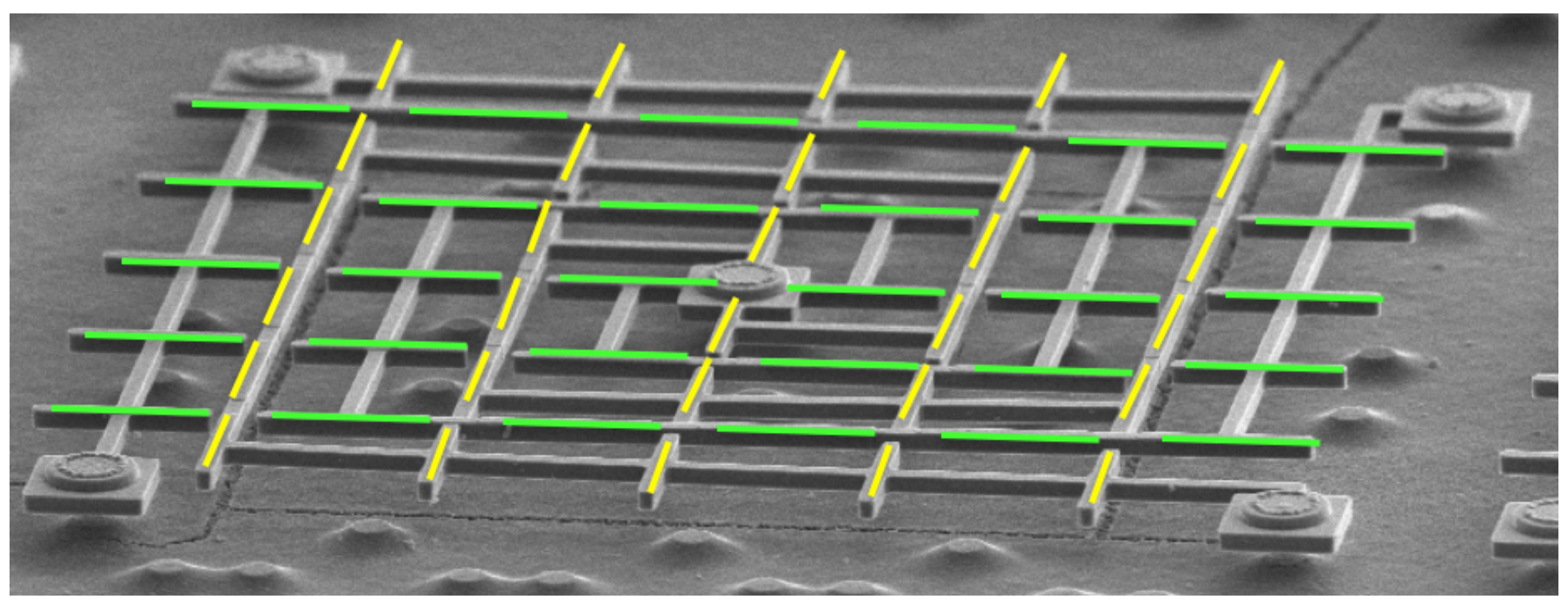
- Polarimetric mapping of Galactic filamentary structures
- Detector sensitivity of $3\text{x}10^{-18}$ W/√Hz with detectors cooled down to 50 mK



Safari-Pol Focal Plane

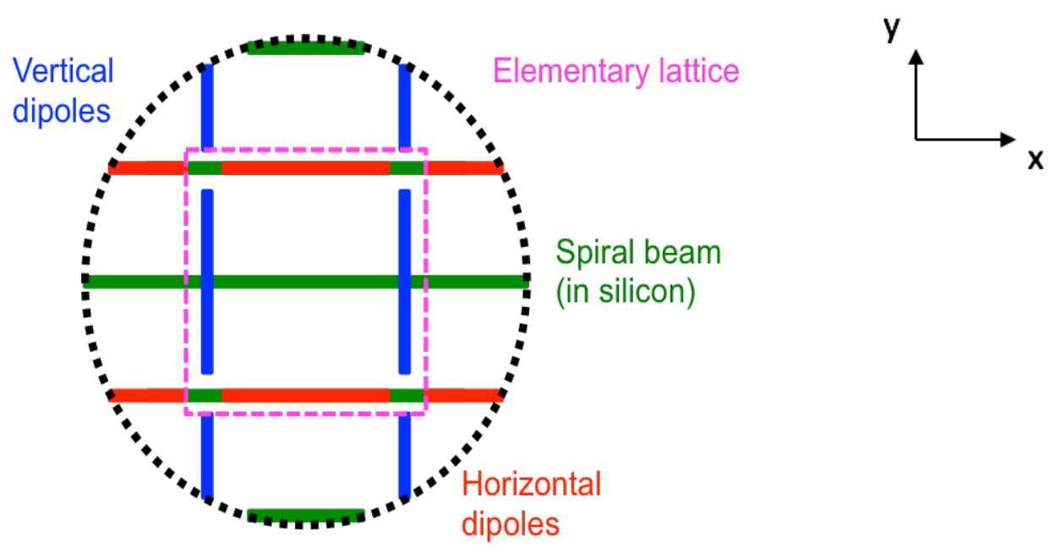
SAFARI-pol detectors

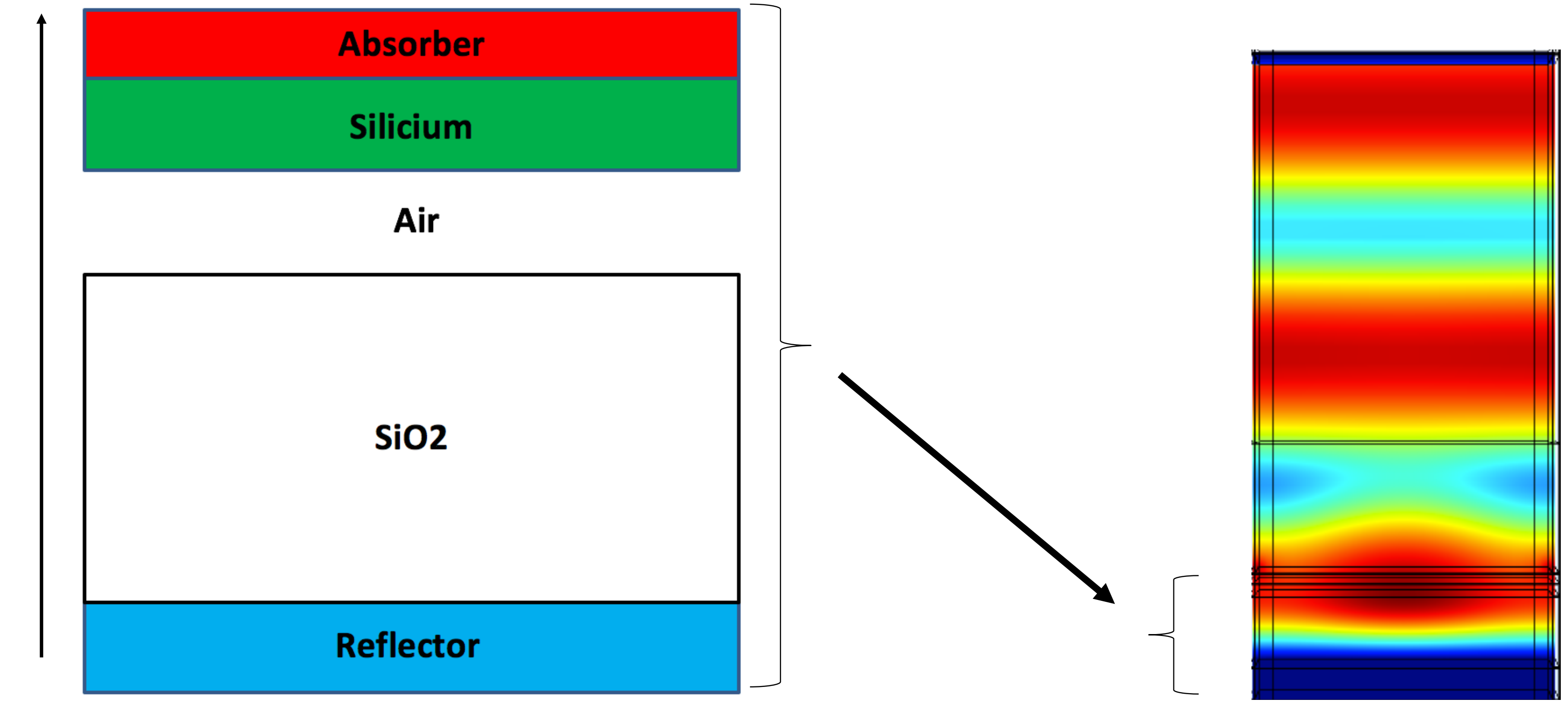
- Semiconductor bolometers, directly part of the HERSCHEL/PACS legacy:
  a $\lambda/4$ cavity formed by a reflector and absorbers supported by silicon
- Sensitive to the polarization thanks to dipole antennae



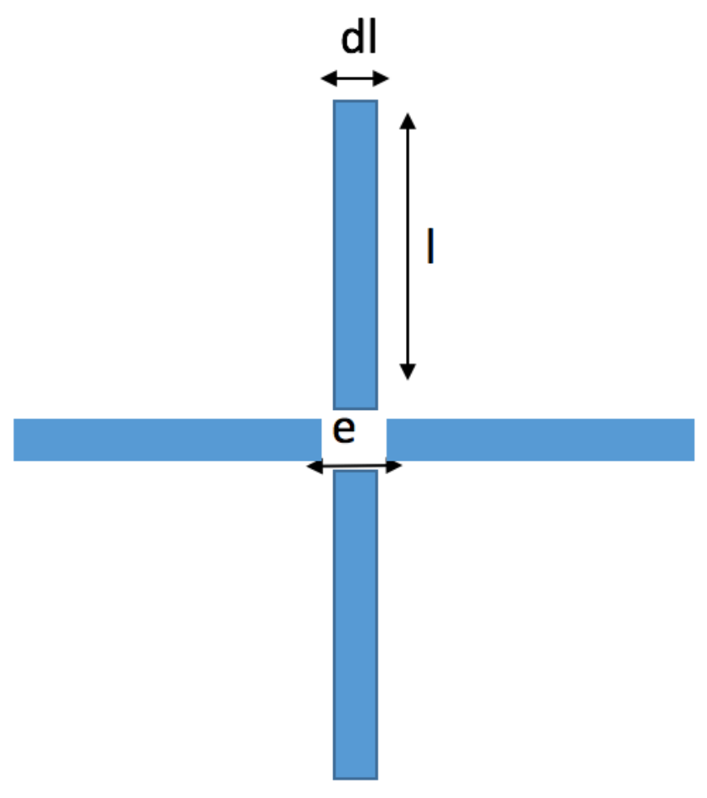
Electromagnetic simulations for the SAFARI-pol detectors

Using the software COMSOL Multiphysics to simulate one unit cell of a pixel (in the xy-plane) and the stack of thin layers (in the z-direction):





Optimization parameters of the dipoles



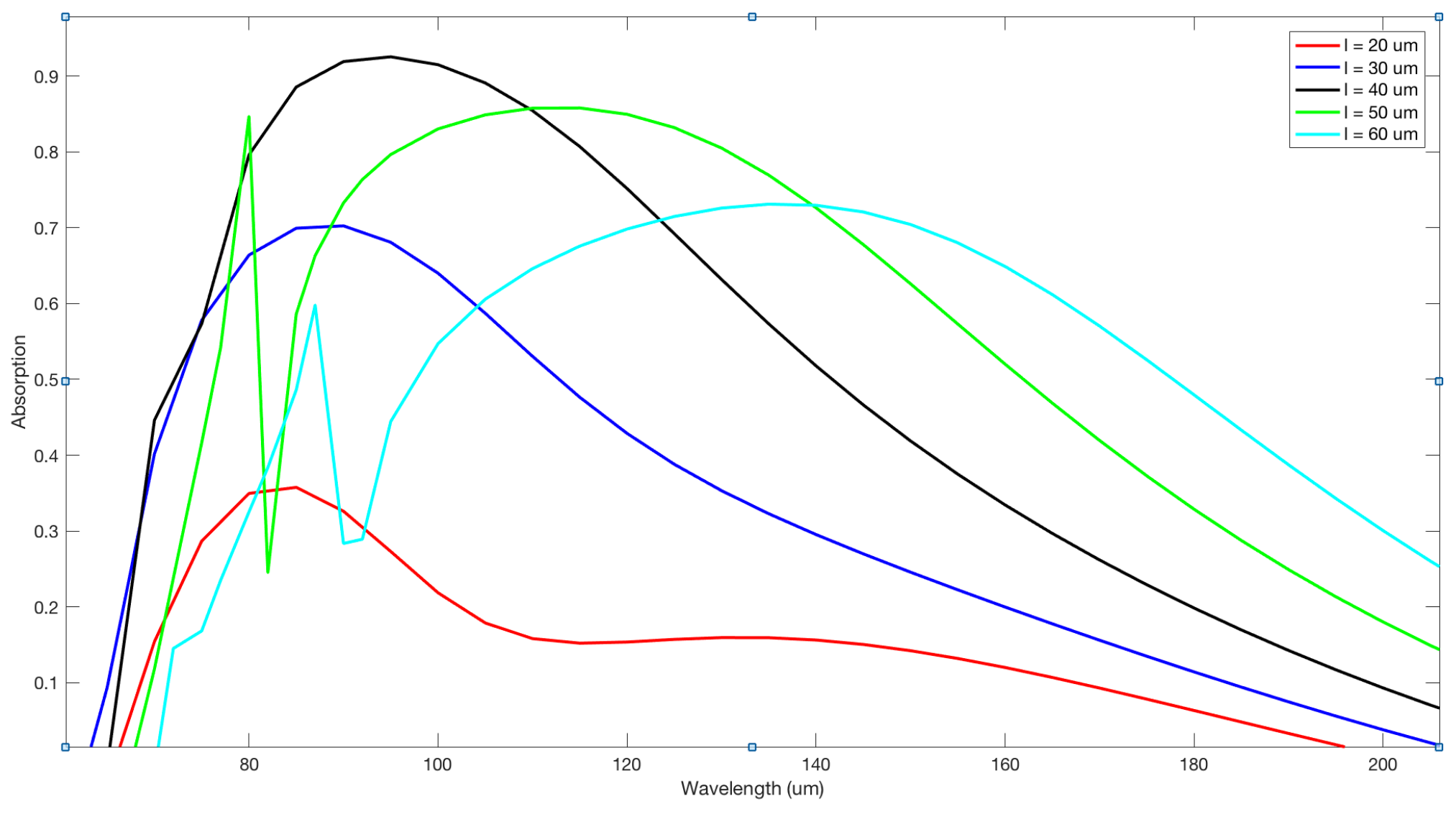
Absorption has been computed for different optimization parameters :
-Length of dipoles l
-Spacing between dipoles e

For each calculation, the thickness of the dipoles d_{abs} is adapted as:

$$d_{abs} = \frac{\rho\, l}{dl\, Z},$$

where Z is the free space impedance.

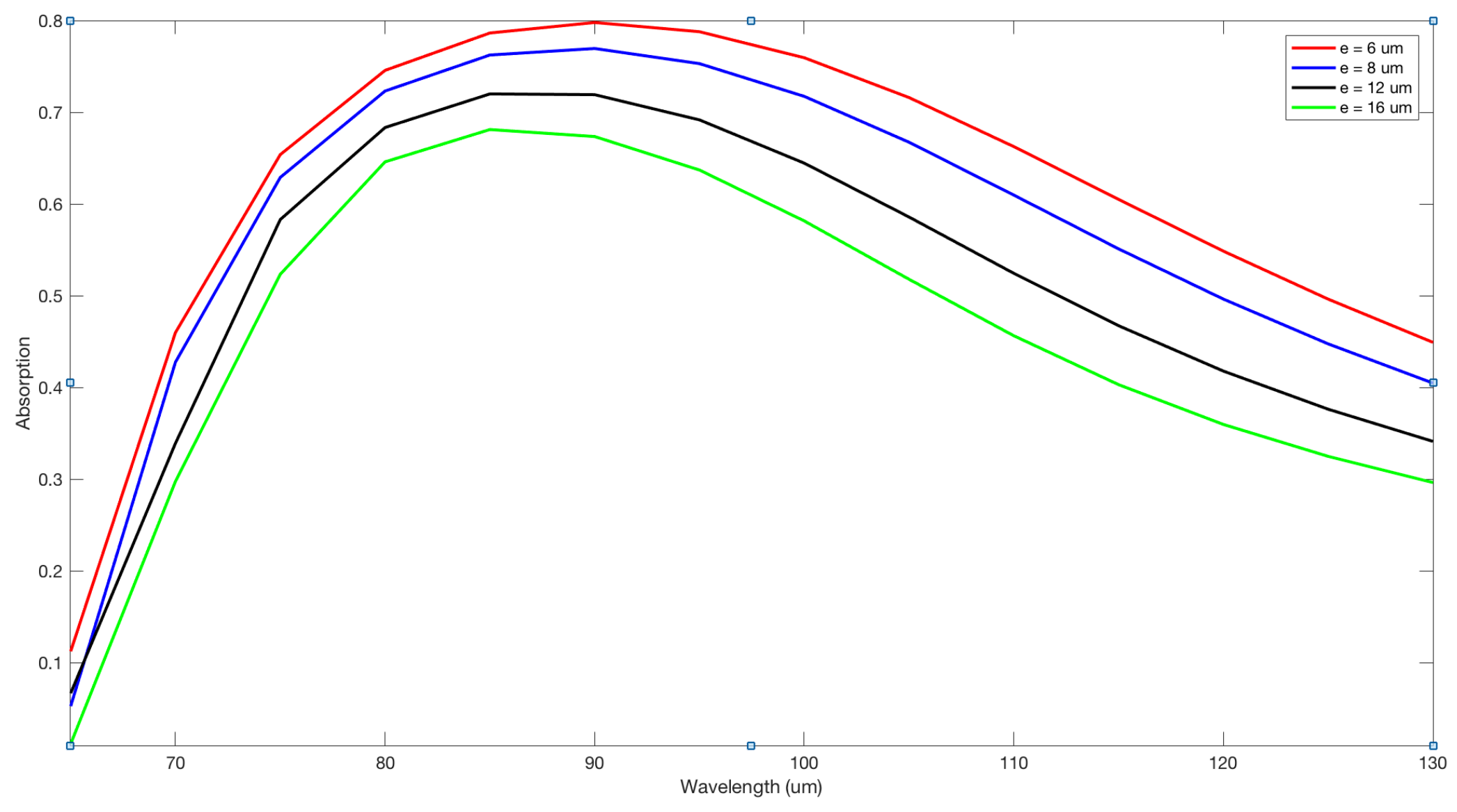
Optical absorption for different lengths of dipoles



- ✓ Up to l~40 µm, the longer the length of the dipoles, the greater the absorption.
- ✓ After l ~40 µm, the absorption decreases: if you have long dipoles (in comparison to λ) you are not efficient because the filling factor is small.

→ **Need to optimize vertical AND horizontal resonances !**

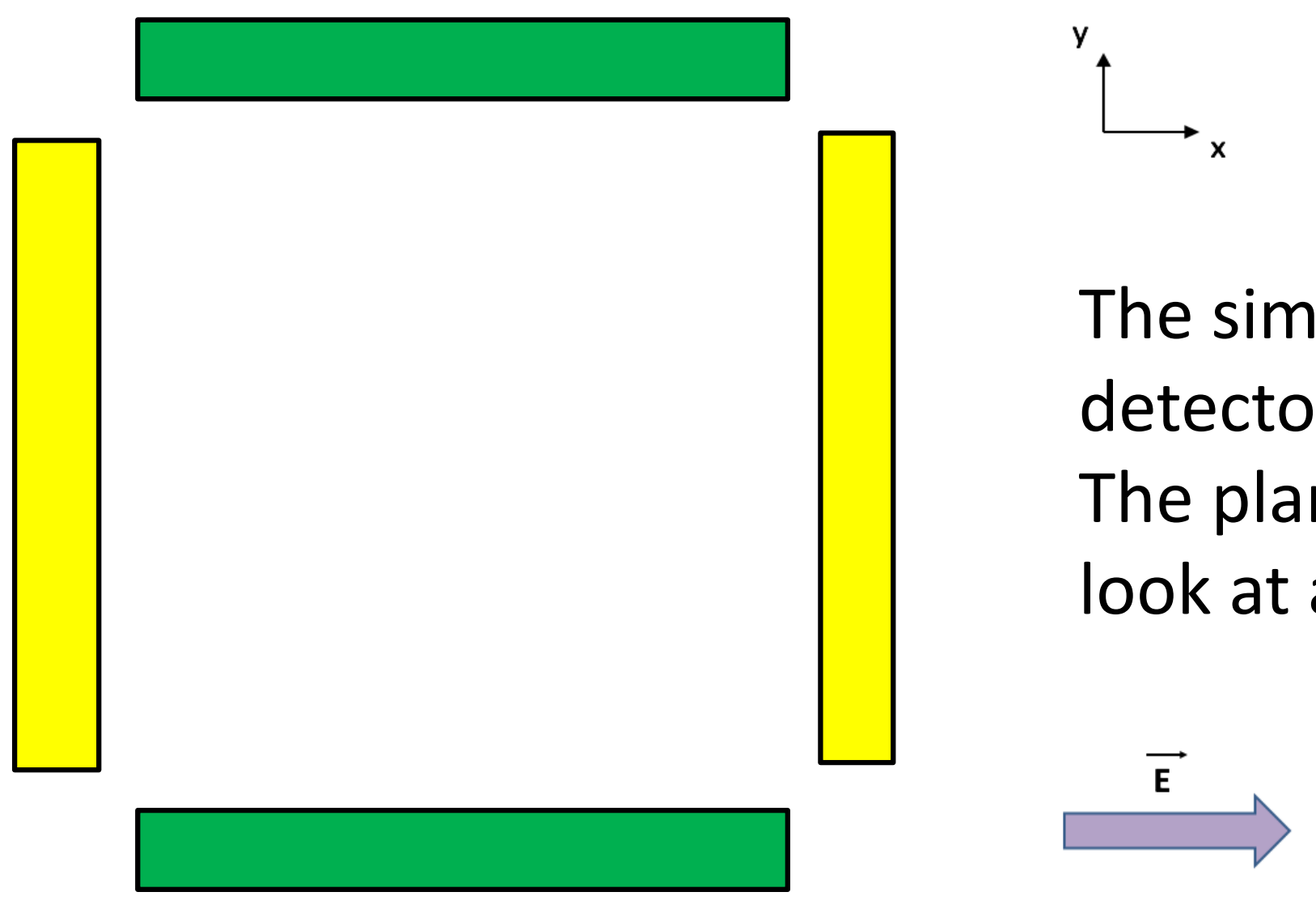
Optical absorption for different spacing between dipoles



- ✓ The more the distance between 2 dipoles is decreased, the more they absorb.
  Once again, this is consistent with the geometric efficiency study.

→ **Need for very close dipoles** !

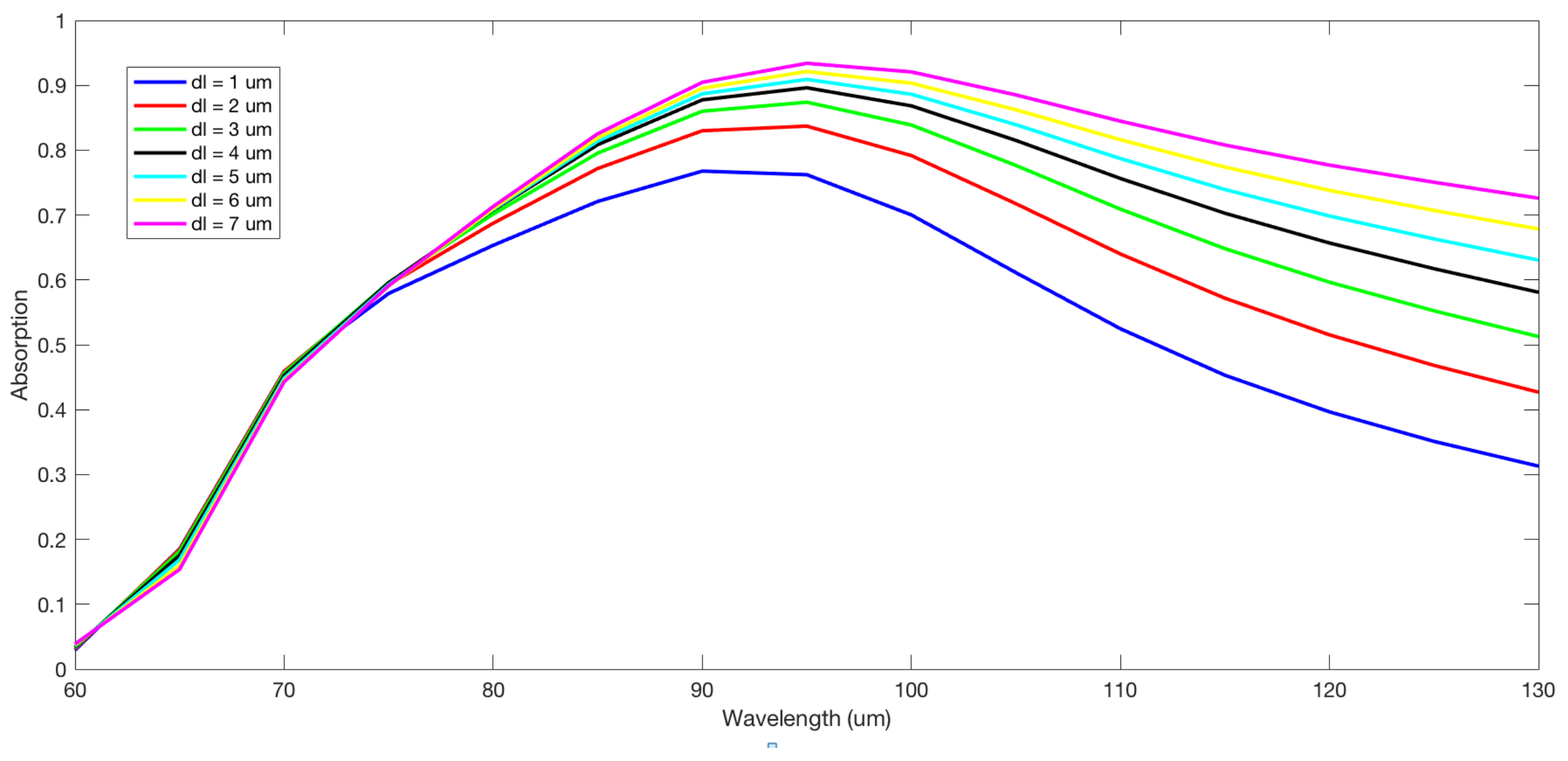
Cross-polarization inside dipoles



The simulations have been computed by shining the detector with a linearly polarized wave.
The plane wave is polarized in the x-direction and we look at absorption inside dipoles for both directions.

Absorption in yellow dipoles ?

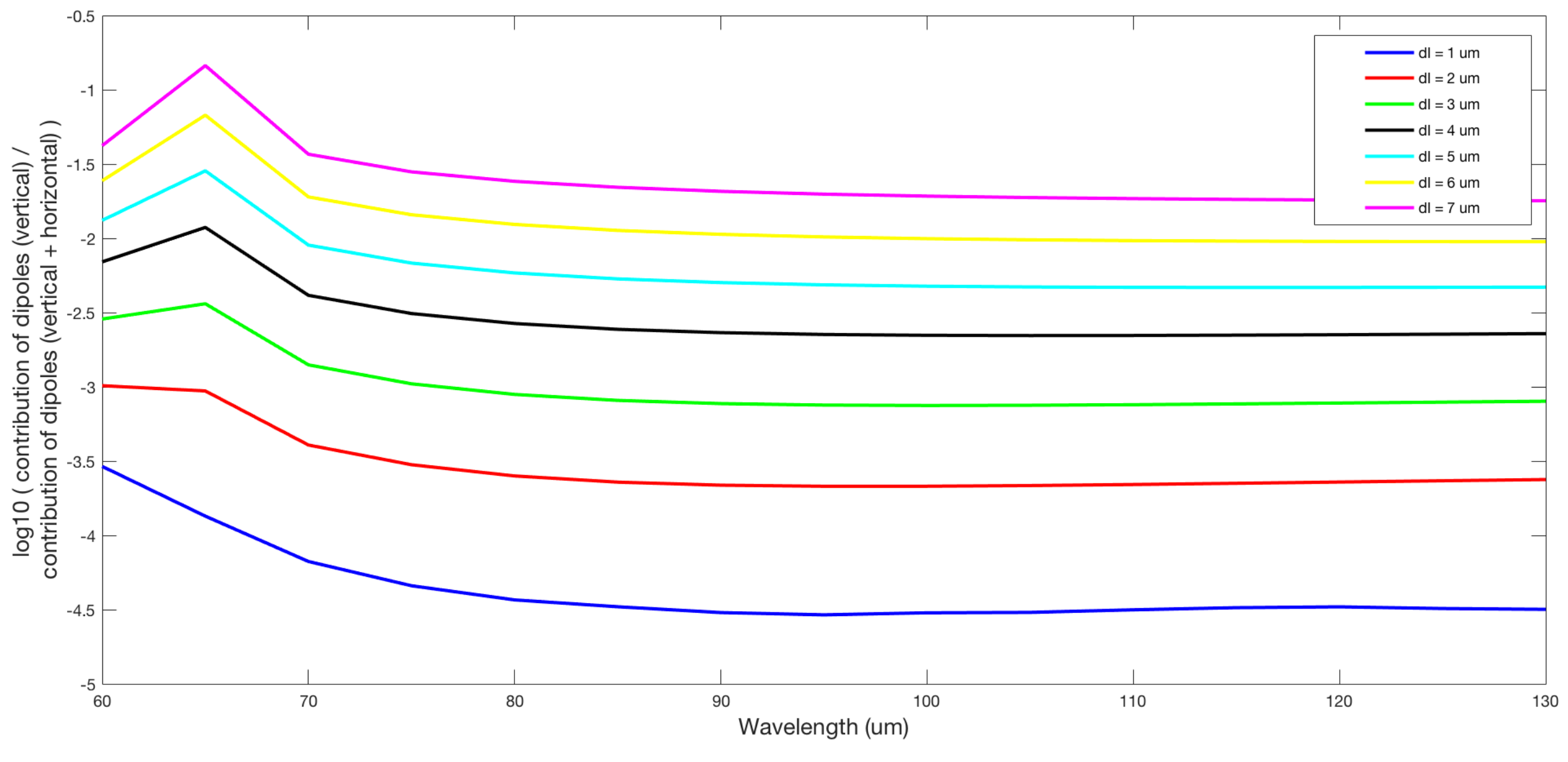
Optical absorption for different widths of dipoles



- ✓ The total absorption increases when making larger dipoles.

→ Need to pay attention for cross-polarization i.e.: be sure that the increasing absorption is due to the dipoles in the x-direction.

Contribution of the vertical dipoles over the total contribution of dipoles



→ The wider the dipole, the more vertical dipoles contribute to the absorption: Consistent !

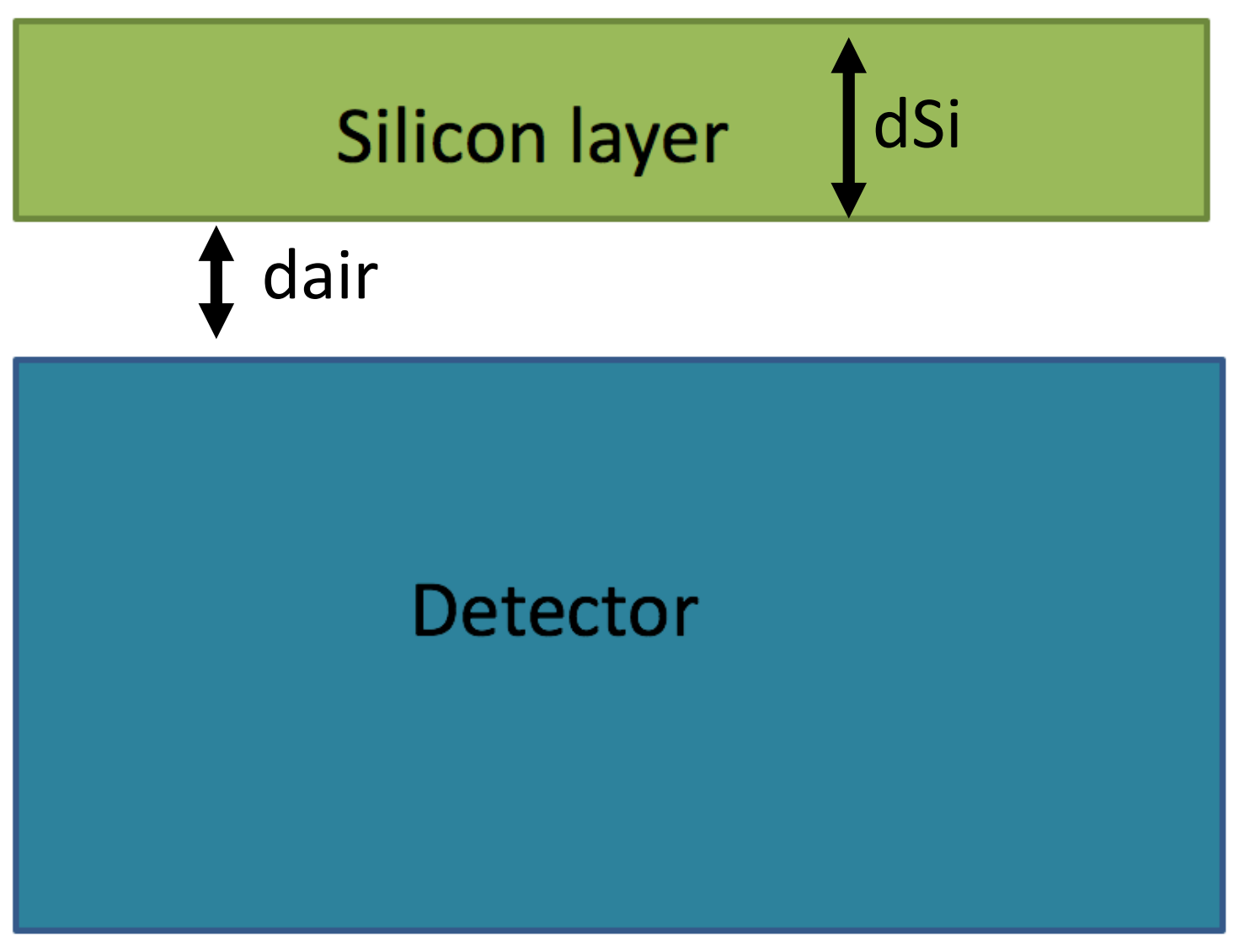
- ✓ **Up to dl = 4 µm, the cross-polarization is still <u>reasonable</u> (~ 1/100)**

Conclusions for the design of the SAFARI-pol detectors in the 100 µm band

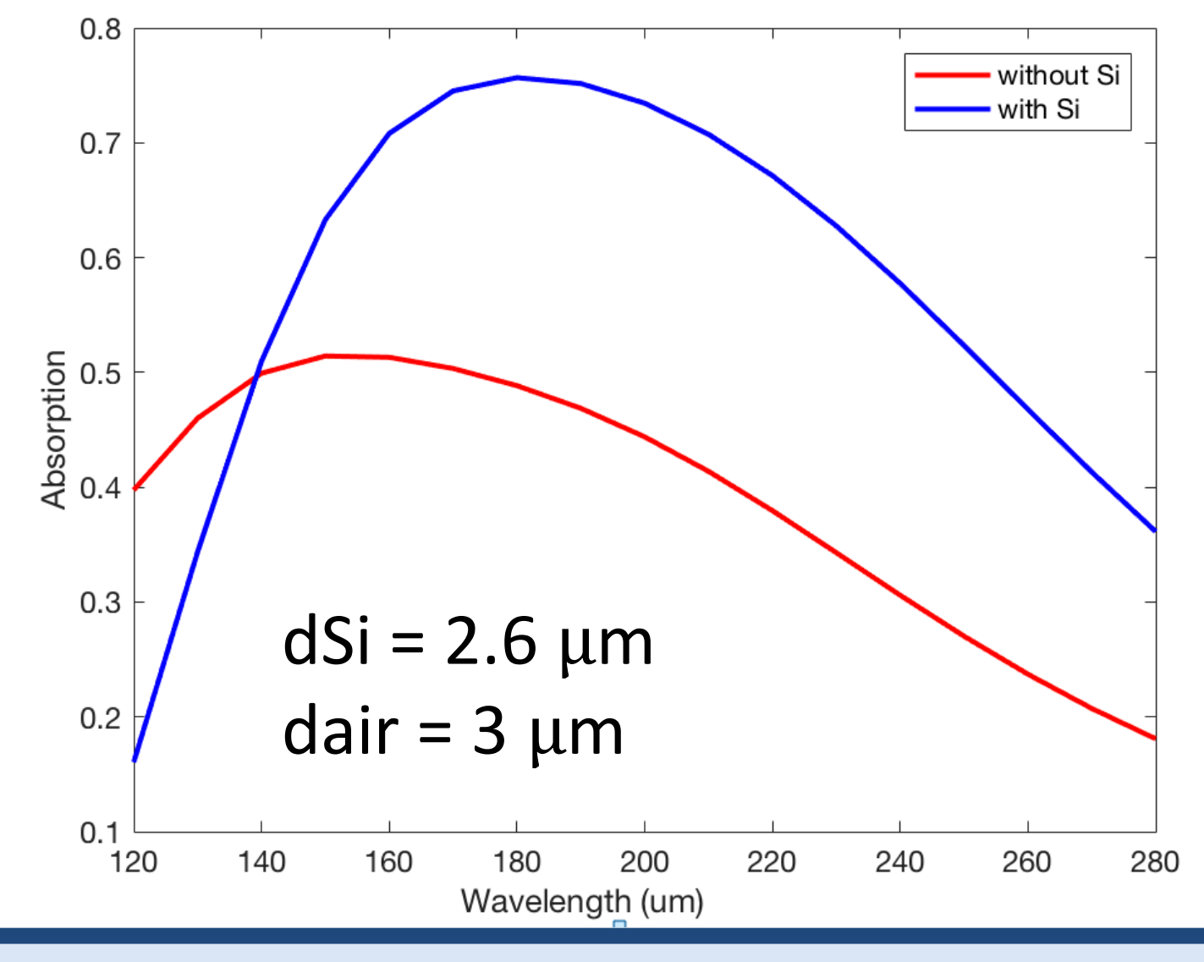
- ✓ SAFARI-pol detectors sensitive to the polarization by design
- ✓ Simulations allowed to optimize the absorption according to the length of the dipoles, and the spacing between two dipoles
- ✓ Cross-polarization can be neglected for narrow dipoles

Perspectives for the 200 µm and 350 µm detectors

- ☐ It seems complicated to make a $\lambda/4$ cavity for the 200 µm and 350µm !
- ☐ <u>BUT</u> we have another technical solution : adding a refractive (silicon) layer on top of the detector: by tuning the distance to the detector and the thickness of this refractive layer, we can address longer wavelengths.



Example of performances simulated by a 100 µm – cavity and silicon layer adjusted to the 200 µm



dSi = 2.6 µm
dair = 3 µm