Bolometer cameras for submillimeter wavelength at DOME C

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Why large bolometer cameras in Antarctica?

Low level of pwv => Opening of atmospheric windows specially the 200 µm window very marginally opened elsewhere in the world.

BUT submillimeter science frequently:

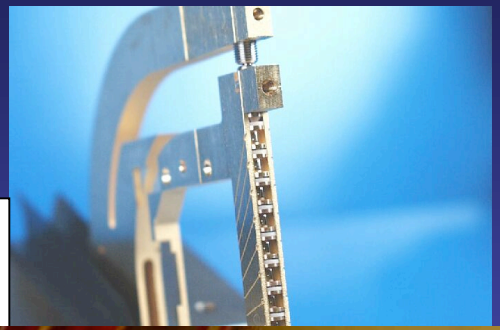
- implies large telescope (10 m class or greater).
- large arrays => larger FOV at highest resolution,
  => filled arrays,
  => atmospheric corrections .

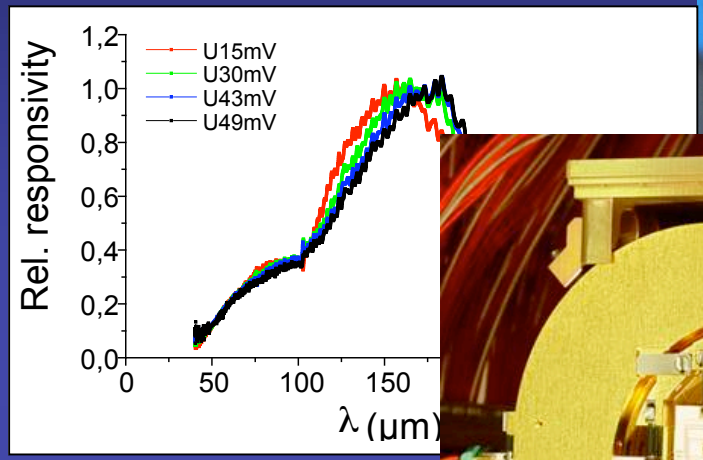
Consequence:

- autonomous operations (closed cycle cryo.)
- Develop technologies working in south pole conditions
- remote control operations (space observatories heritage)

Why bolometers ?

Photoconductors : Ge:Ga under stress





Ball segment

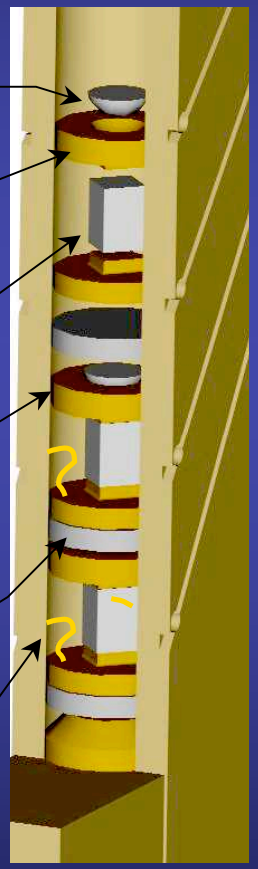
Detector contact

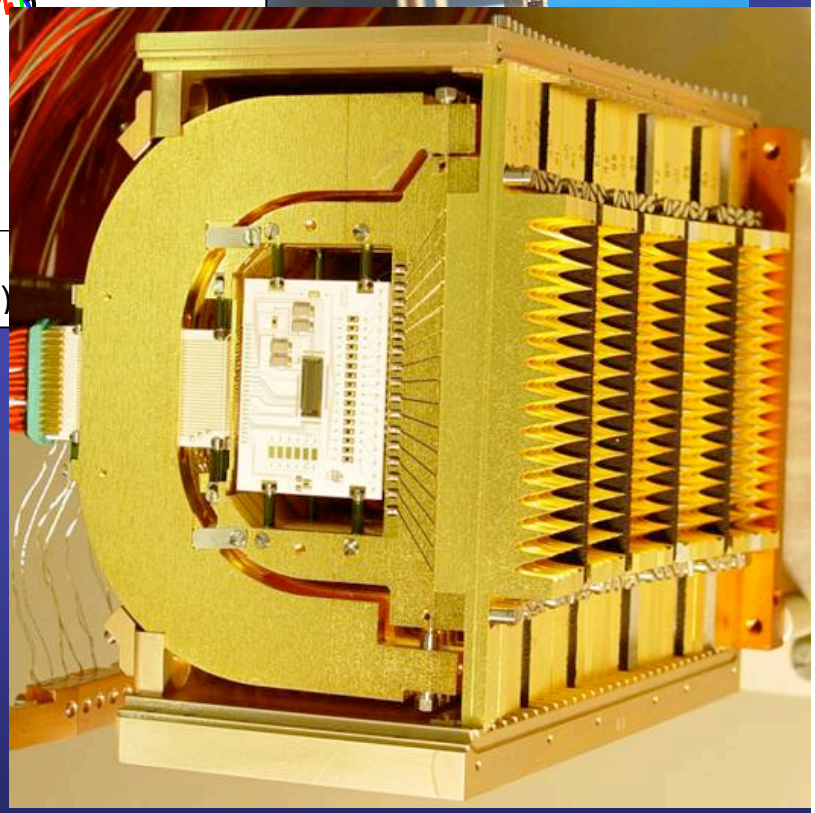
Ge:Ga crystal

Detector contact

Insulator

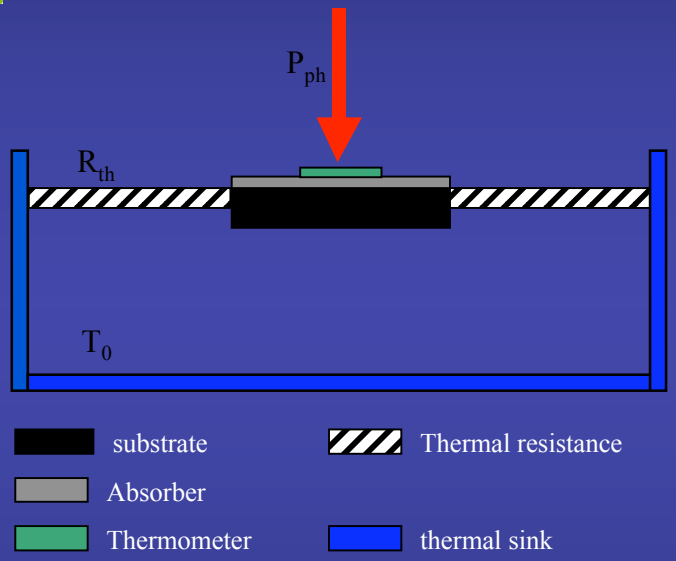
Gold wire 25 µm





For longer wavelength you need an other kind of detectors

Blometers? How it works!

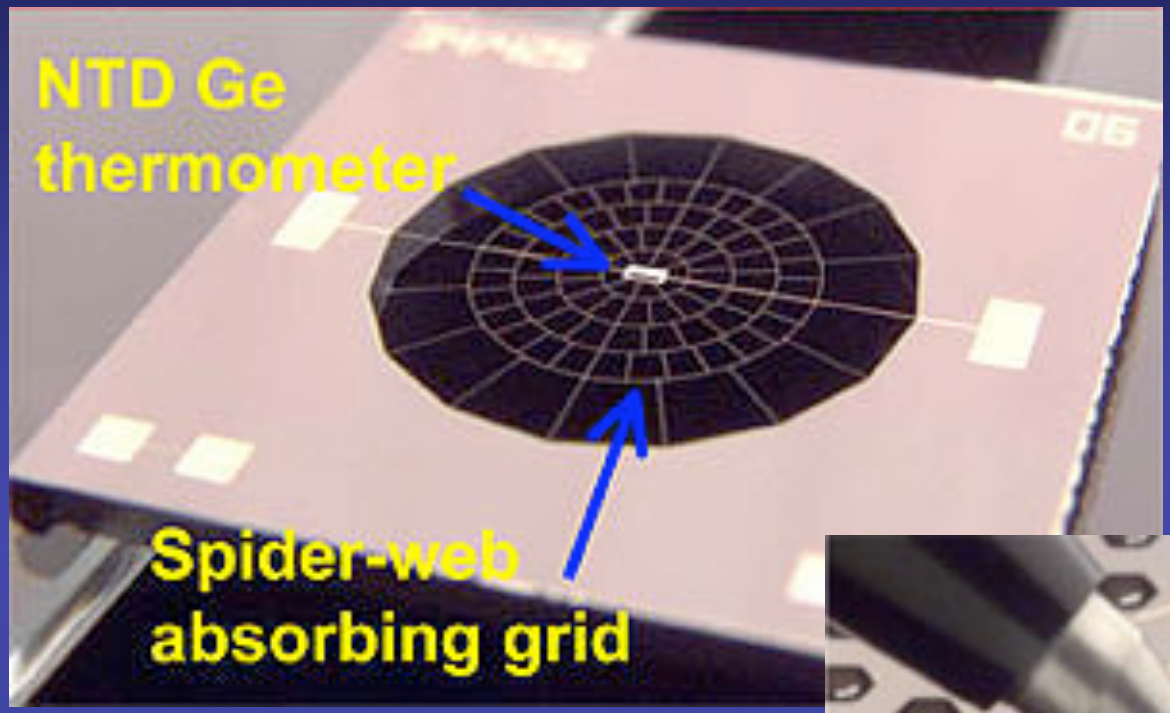


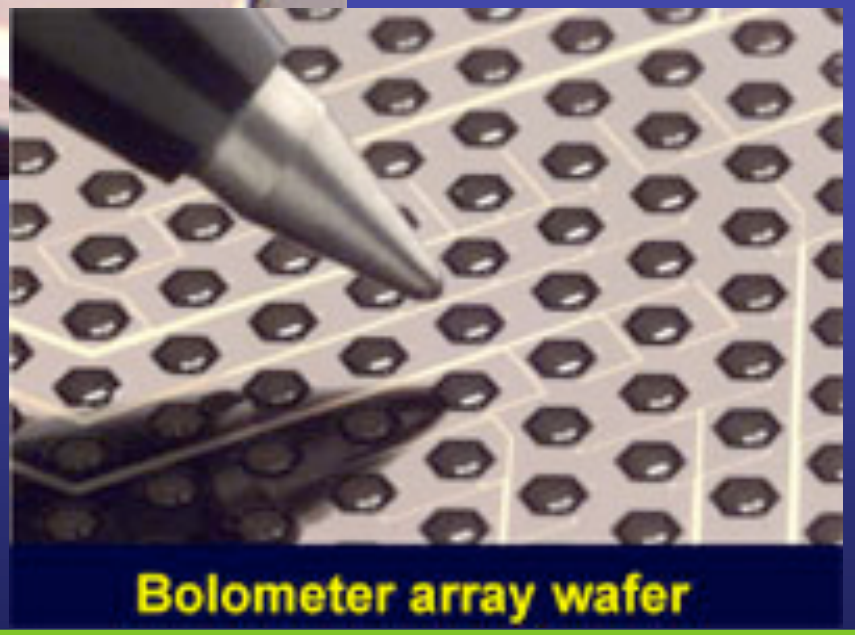
- Sensitive part :
- Good sensitivity ⇒low C_{th}
- low C_{th} ⇒ decrease mass,
  ⇒ select materials,
  ⇒ low Temperature

- High thermal resistance for high sensitivity (bandwidth).
- Absorber transforms radiant energy in heat. The thermometer resistance varies with temperature.

Main difficulty : to compete with Photoconductors sub kelvin temperature needed!

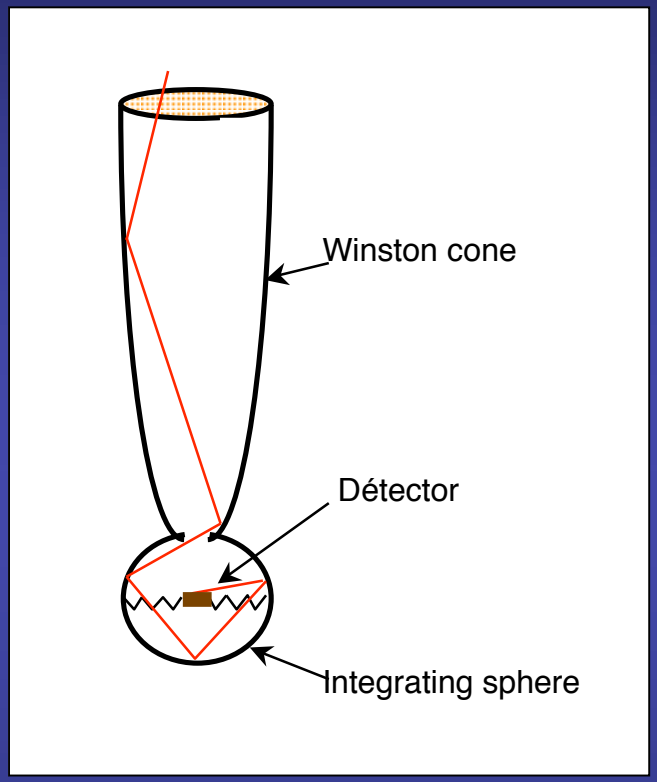
In the 90's: the spider web bolometers



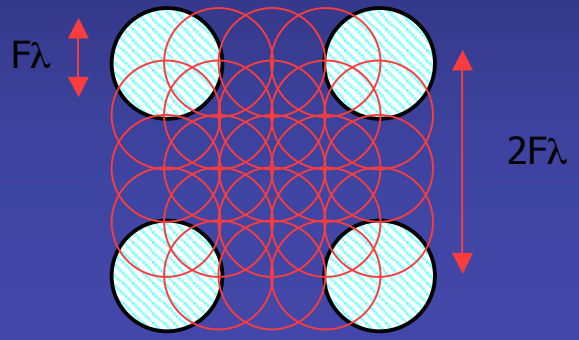


Two kind of bolometer detectors

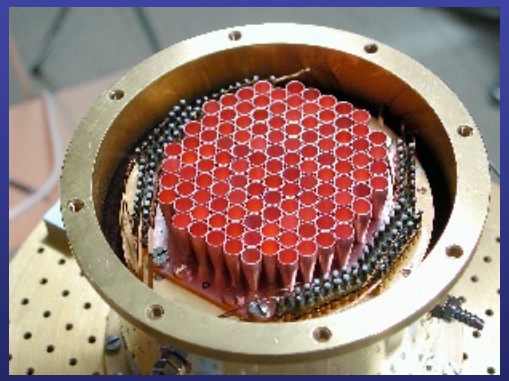
Horn arrays:



4 close packed pixels (cones) in the focal plane, couple to distant angular regions in the sky.



You need to jiggle the image to fill the focal plane.



Mambo (30 m Iram)

Very efficient for point sources

Two kind of bolometer detectors

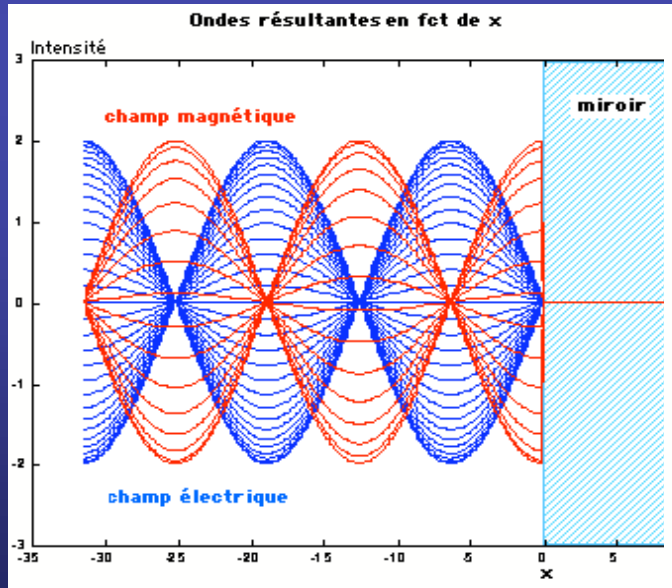
Filled arrays.

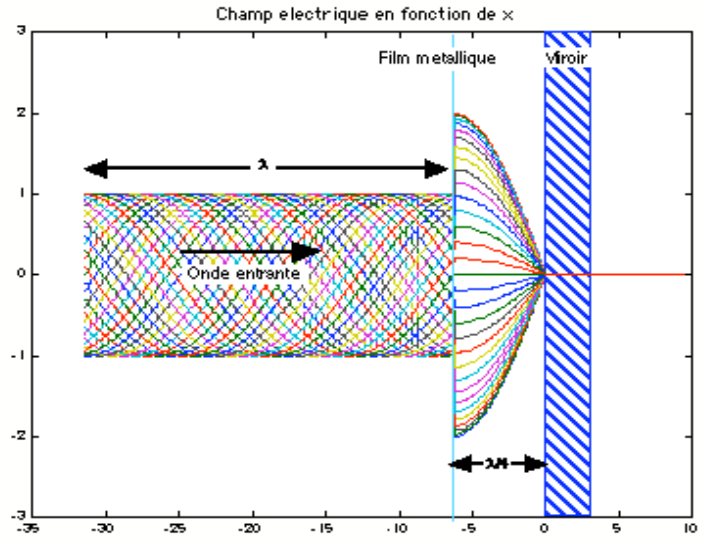
We have to solve some problems:

- absorption
- thermometer built collectively with high α
- multiplexing
- and some physical problems : Gth, Cth, absorbers …

Absorption of radiant energy.

Effect discovered in the 40's but introduced by us for detection in 1997





Two kind of bolometer thermometers

Resistive:

A semiconductor have exponential resistance dependence with temperature.

NTD Germanium crystals are the best current thermometers because homogeneity of doping species.
Not usable in collective manufacture process.

⇒Si thermometers needed for CM but it is difficult to obtain a good homogeneity !
⇒Solved by thermal diffusion on double SOI wafers.

Consequence :
⇒ Thermal sensors suited to conventional electronics for readouts (even if used at very low temperature).

Two kind of bolometer thermometers

superconductive:

To improve the “gain”, TES detectors use the superconductive sharp transition.

Consequences:

- use of exotic components for readouts (squids…)
- dynamic range limited by the technology.
- Multiplexing partly solved.

A matrix of solutions

	horn	filled
superconductive	ESZca	SCUBA2 gismo
Resistive	SPIRE MAMBO LABOCA BOLOCAM	PACS Ph. SHARC

Many types of bolometer arrays available to manufacture bolometer cameras. The prize to pay is the cryogenic system.

All detectors (PhC & Bolo.) =

Closed cycle cryo-system (PT ~ few kW) -> 1W @ 4K

Bolometers =

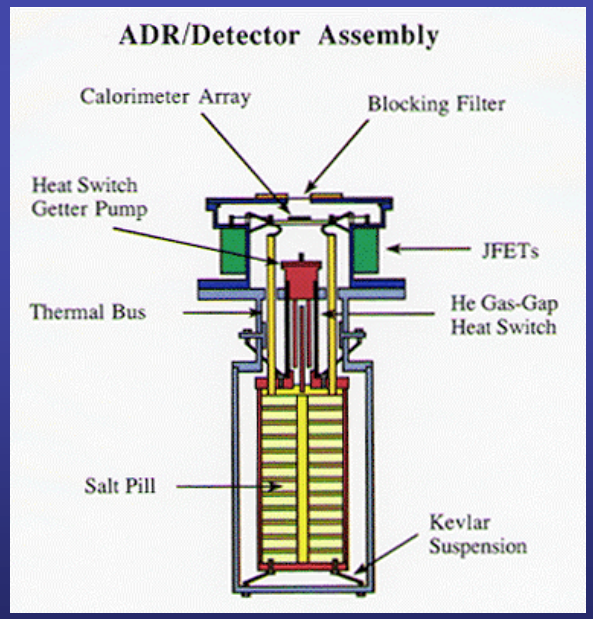
Closed cycle cryo-coolers -sorption coolers (300 mK)
-dilution coolers (20-300 mK)
-ADR coolers (20-300 mK)

Sub Kelvin cryocooler solutions

Dilution fridge
> 400µW

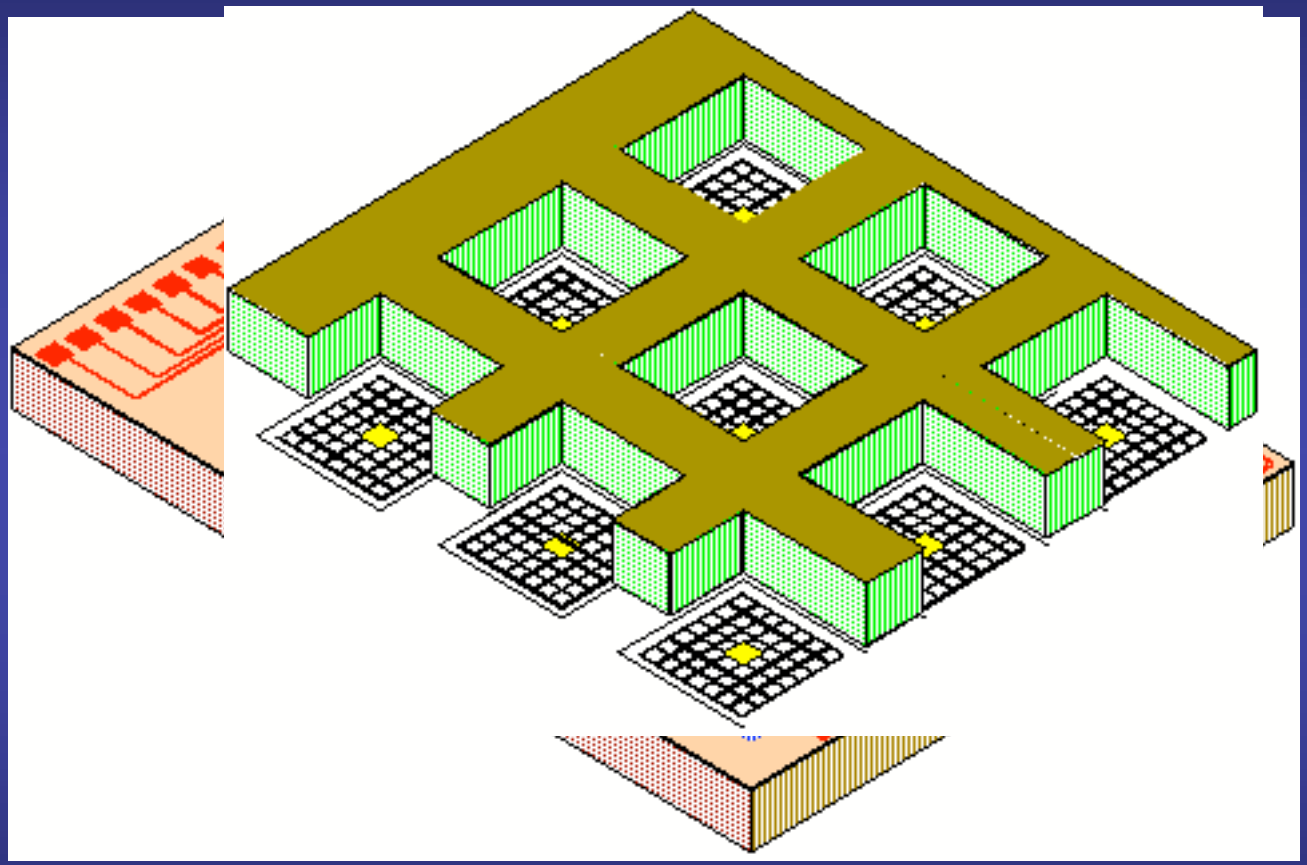
Sorption cooler
used on Herschel

ADR developed @
GSFC for space
Applications (XRS)

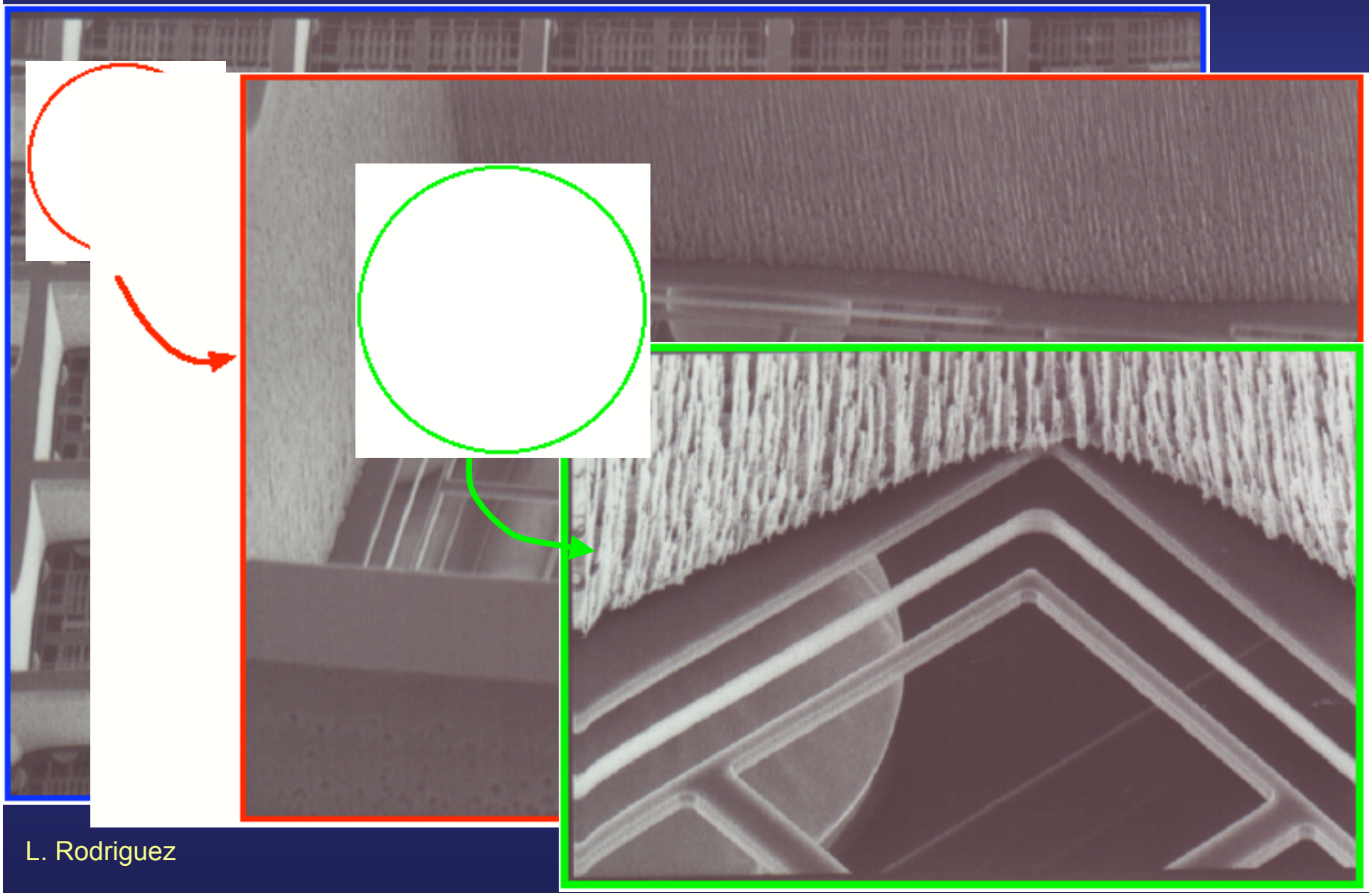


Cea developments: PACS BOLOMETERS and Beyond

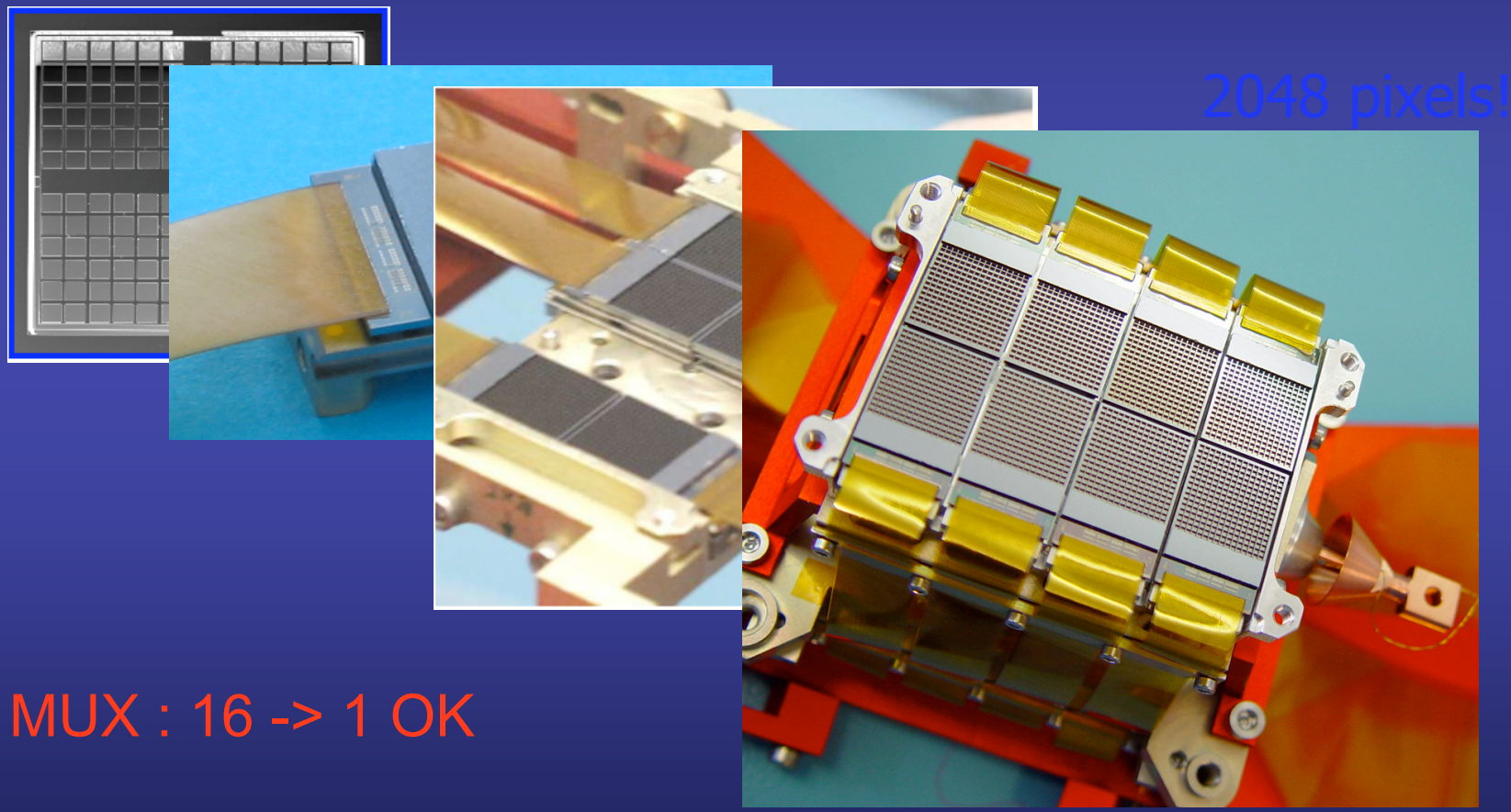
CEA bolometer an overview: on PACS (i)



CEA bolometer overview: On PACS (ii)



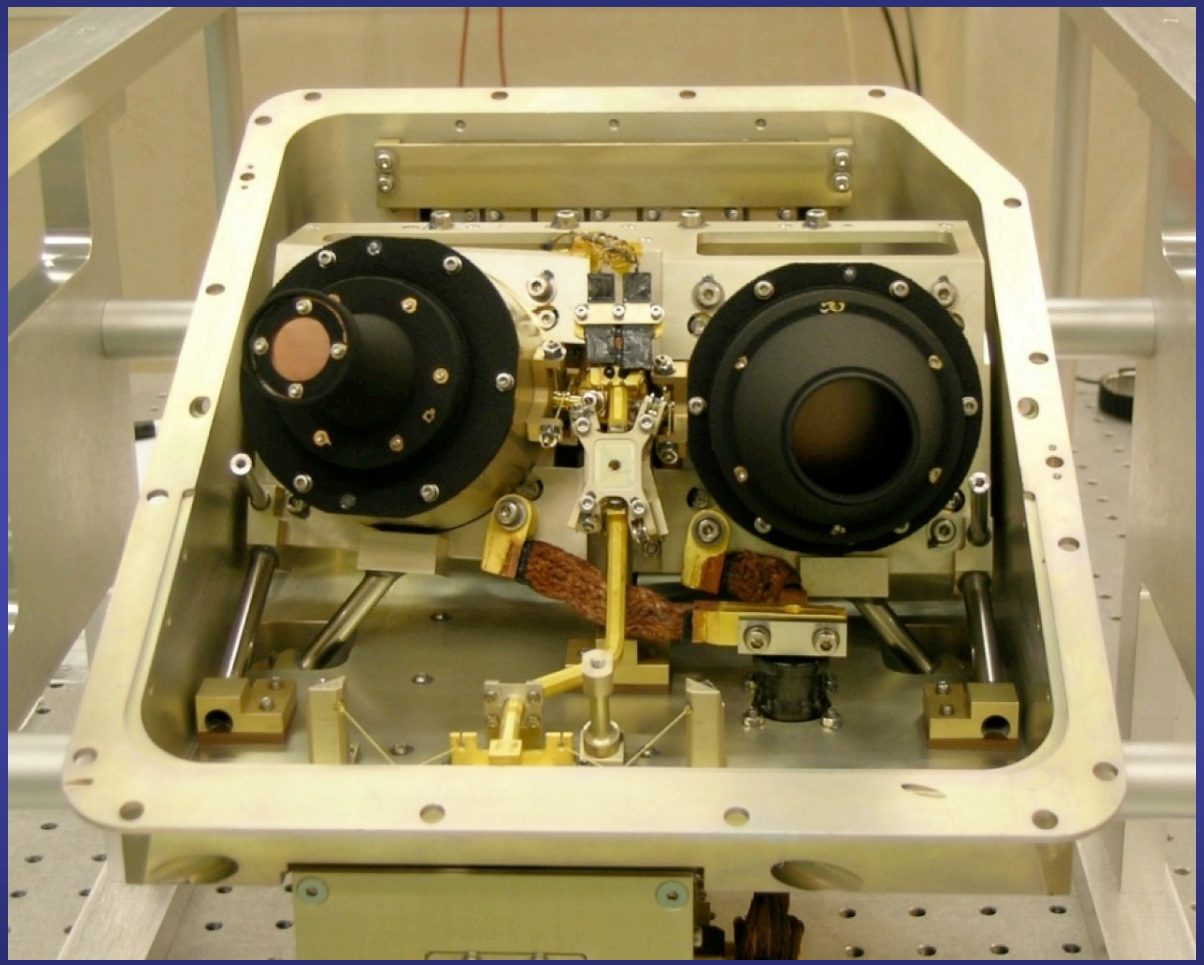
CEA bolometer overview: On PACS (iii)



2048 pixels!

MUX : 16 -> 1 OK

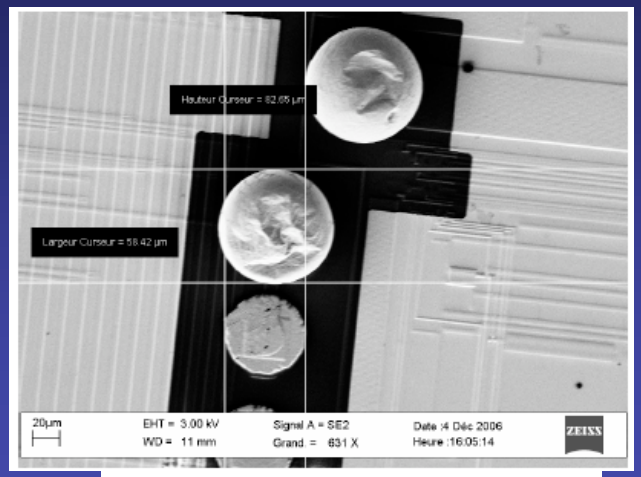
CEA bolometer overview: On PACS (iv)



Toward longer wavelength (i)

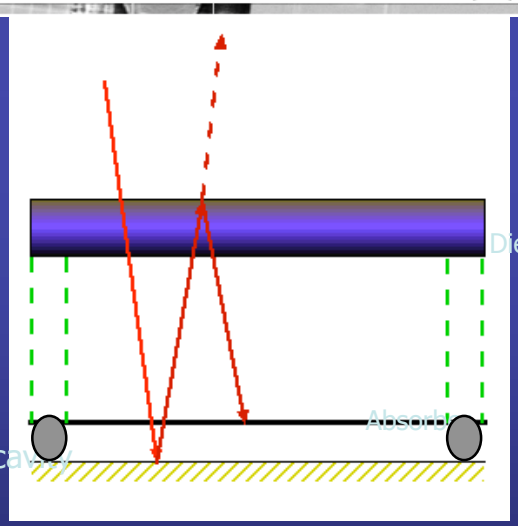
1) Adapt the quarter wave cavity.

By increasing the Indium Bumps or inserting a dielectric layer.

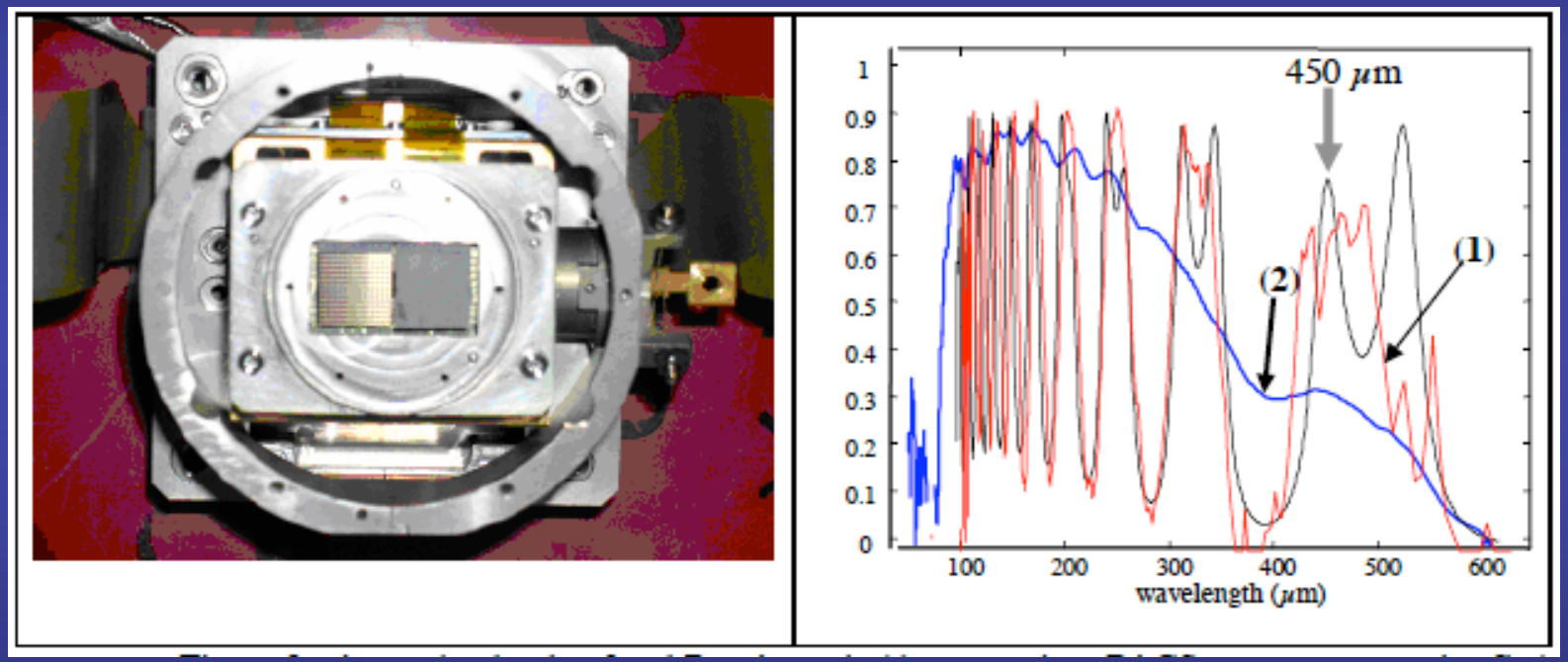


2) Use of anti reflection layer.

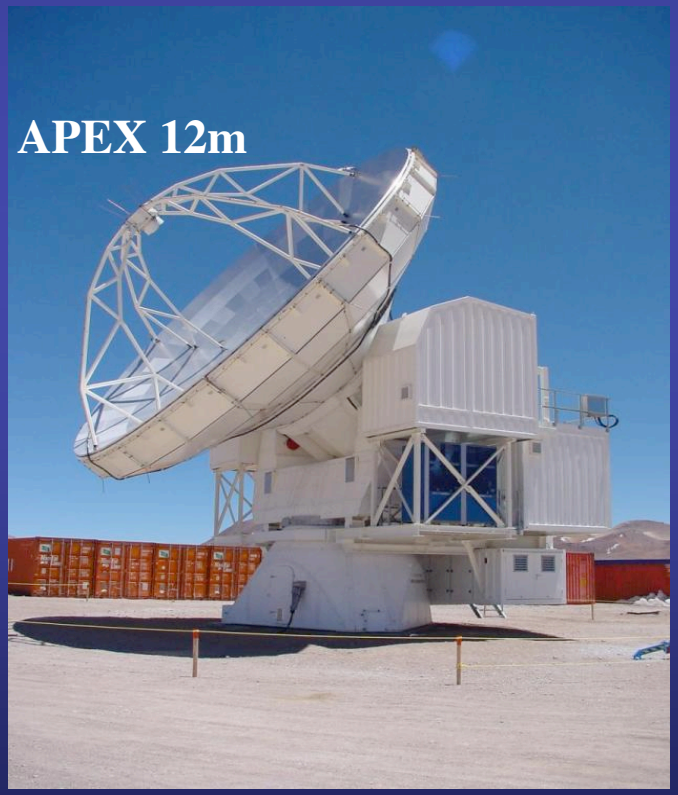
Dielectric above the existing cavity (see next slide).

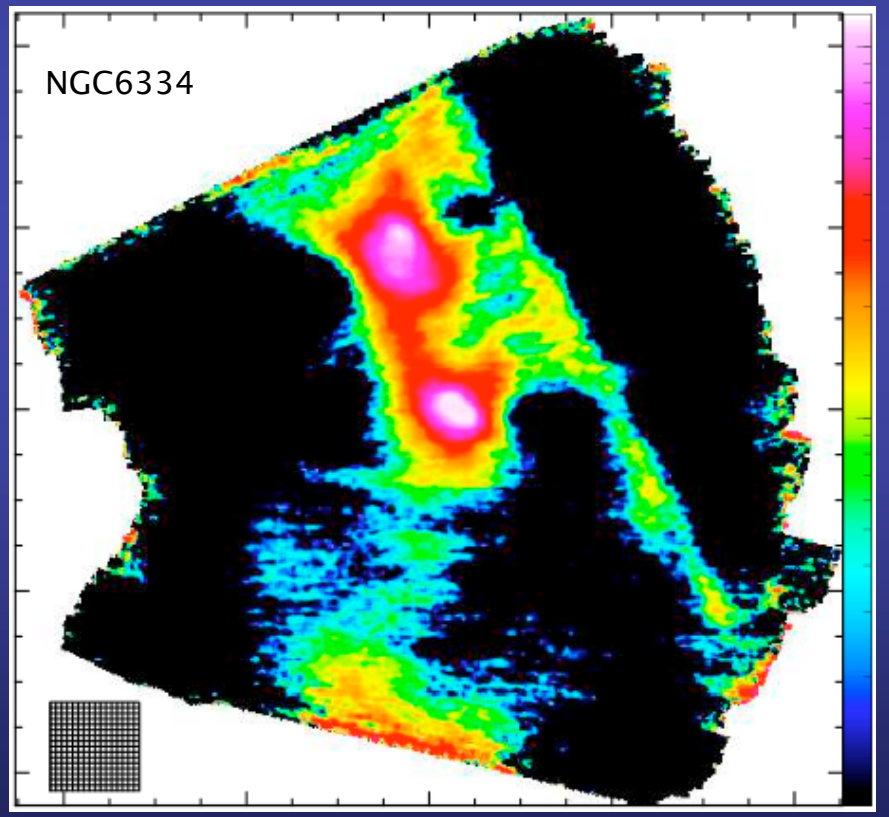


Toward longer wavelength (ii)



First light at APEX

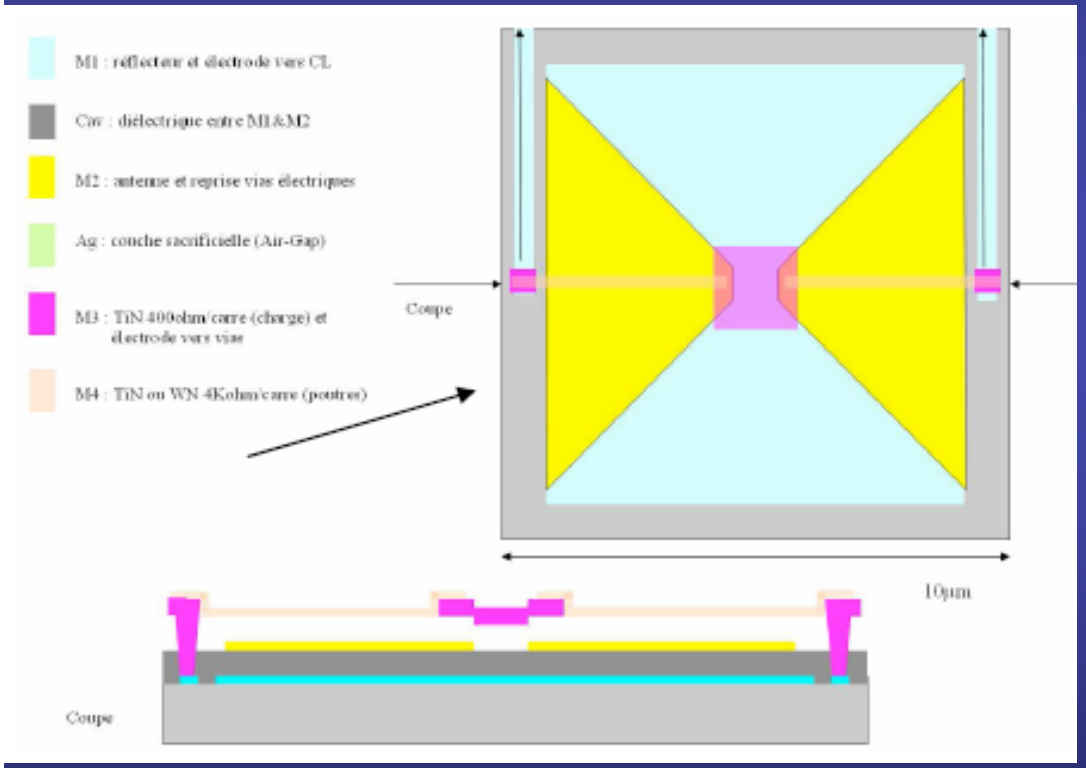


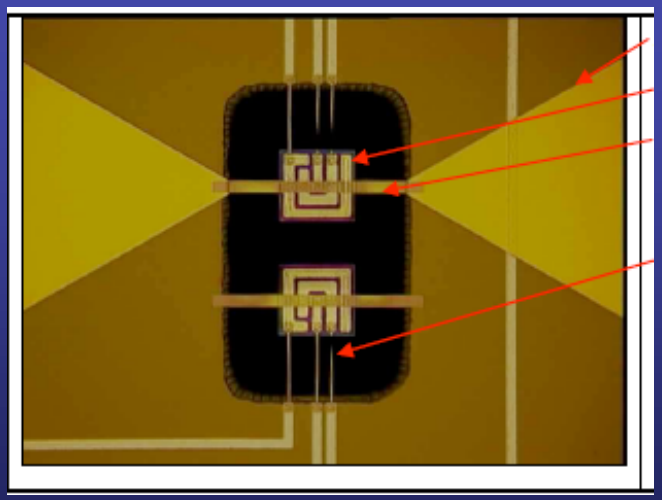


New Bolometer concept ?

Antenna coupled bolometer arrays

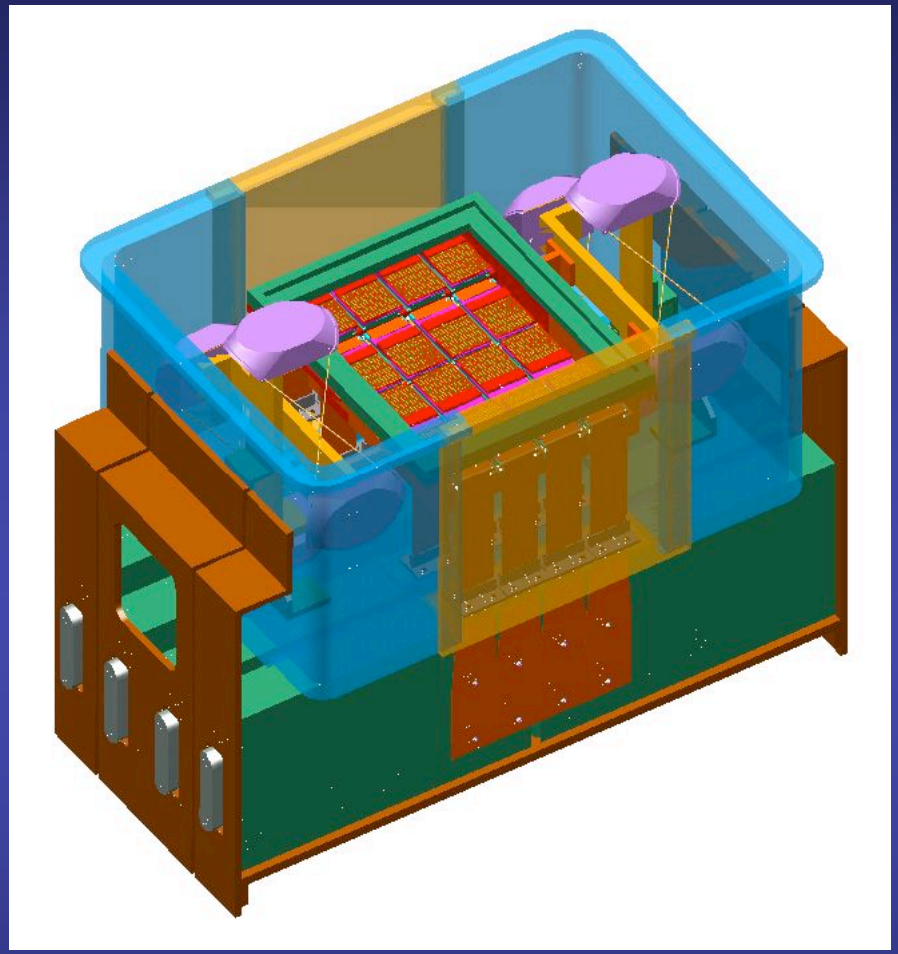
Again superconductive and resistive thermometers





How many pixels ?

The ArTeMiS 1 focal plane is 4200 pixels.



If we want to improve this number by a factor 10, we have to solve two problems:

- Sorting of sub arrays to populate large focal planes
- improve integration (multiplexing) and manufacture Yield.

Conclusions

The technology needed to manufacture large bolometer arrays is currently available.

We still have to improve our methods to build many kilo-pixel arrays!

The way to cool down from 4K to sub-kelvin temperatures is now well defined (ground or space applications).

For Antarctic developments the real issue is the cost in installed power to reach 4 K !