DEVELOPMENT OF « INSTRUMENT ON CHIP » DETECTOR ARRAYS FOR FAR-IR ASTRONOMY

L. Rodriguez et al.

INSTRUMENTATION IN PIXEL : WHY ?

Space Instrumentation means 3 goals

- Prepare observations that cannot be done from ground or other means (balloon, aircrafts,..), to date or during the (long) duration of the mission preparation.

- Use only technologies that are available and confirmed at the mission selection date, with constraints on **Mass, Power, Volume**, …, **affordability**.

- **For a scientific goal gathering a large scientific community* or wide topics covering from Solar System planetology to Cosmology (OBSERVATORY).**

(* Exceptions for some eminent scientists prof. Ting or Prof Cohen-Tannoudji)

B: A POORLY INVESTIGATED SCIENTIFIC DOMAIN

Today in Astrophysics :

Many features concerning Magnetic field (B) are poorly or not at all established:

- **What is the origin of magnetic field. (at very large scale, in the galaxies or in the filaments in the star forming regions) ?**
- **In return, how the B field structures the galactic medium (ISM) and the evolution of the structures ?**

In mind:

One third of the stored energy in our galaxy is in the **magnetic field**. The two other components at (~) the same level are the **kinetic energy** (turbulence) and the **gravitational energy**. Models of structures evolution must take into account the B field !

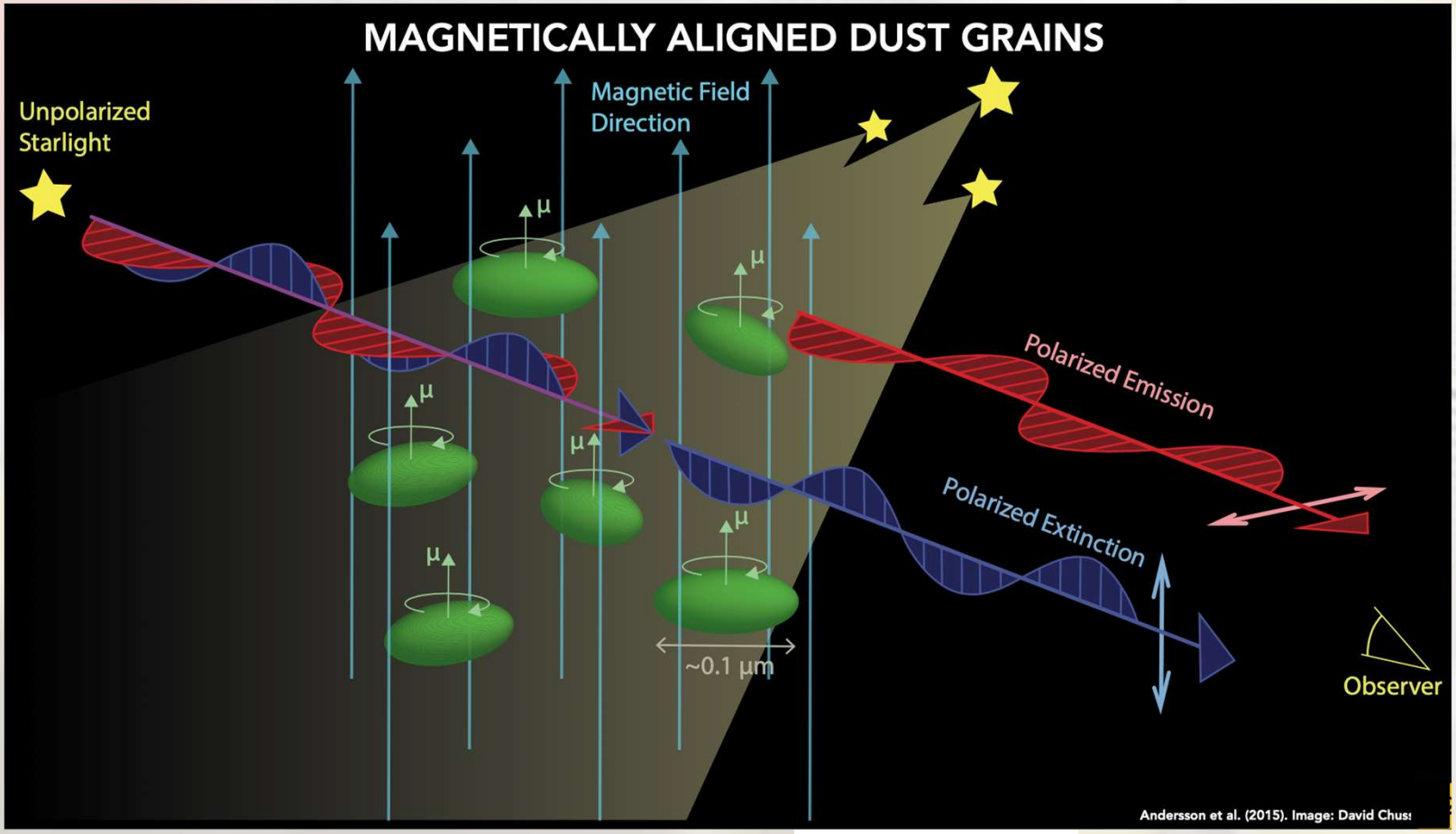
For this we need to get information by observation means.

BUT B field, even if not well understood, can be used to explore other components.

(The B field spans between few tens of nanoTeslas, in the Intergalactic medium, to fractions of GigaTeslas in the largest magnetars identified.)

MAGNETIC FIELD IN THE INTERSTELLAR MEDIUM

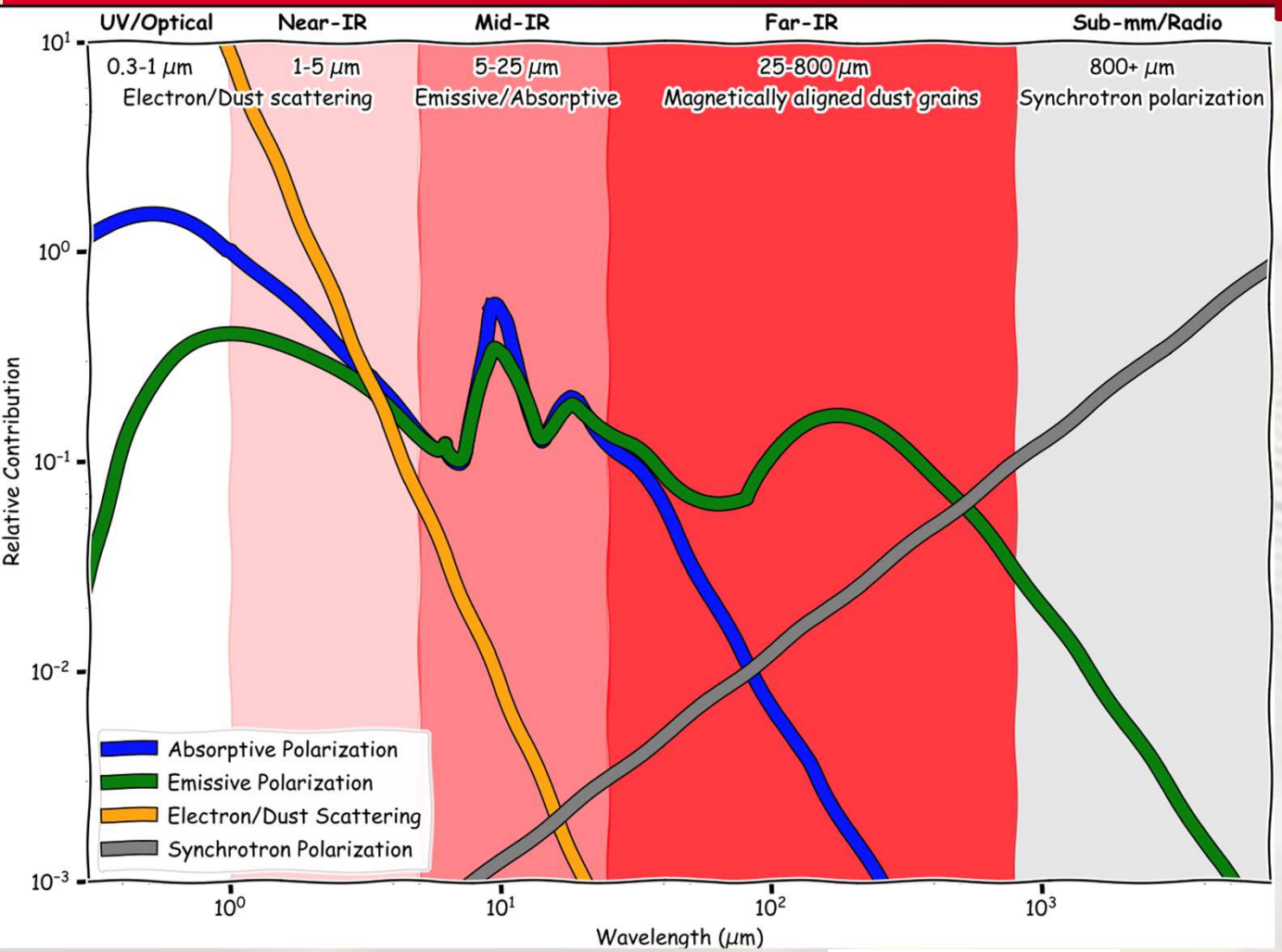
The magnetic field can also be a way to reveal the dust ISM component behaviour by means of light polarization measurements. Hereafter, figures stolen to E. Lopez-Rodriguez from a **SOFIA** tele talk in January 23.



Non spherical grains will absorb or emit light in different spectral regimes, because of grain spinning, and will result in alignment of the magnetic dipole with the B field direction. The unpolarised starlight passing through the grains will be polarized by absorption of one polarization component.

The Grain emission will be polarized in the orthogonal direction but at longer wavelength.

SPECTRAL DEPENDENCE OF LIGHT POLARIZATION



The **Blue** (absorption) and **Green** (emission) curves depend on the nature and sizes of the grains.

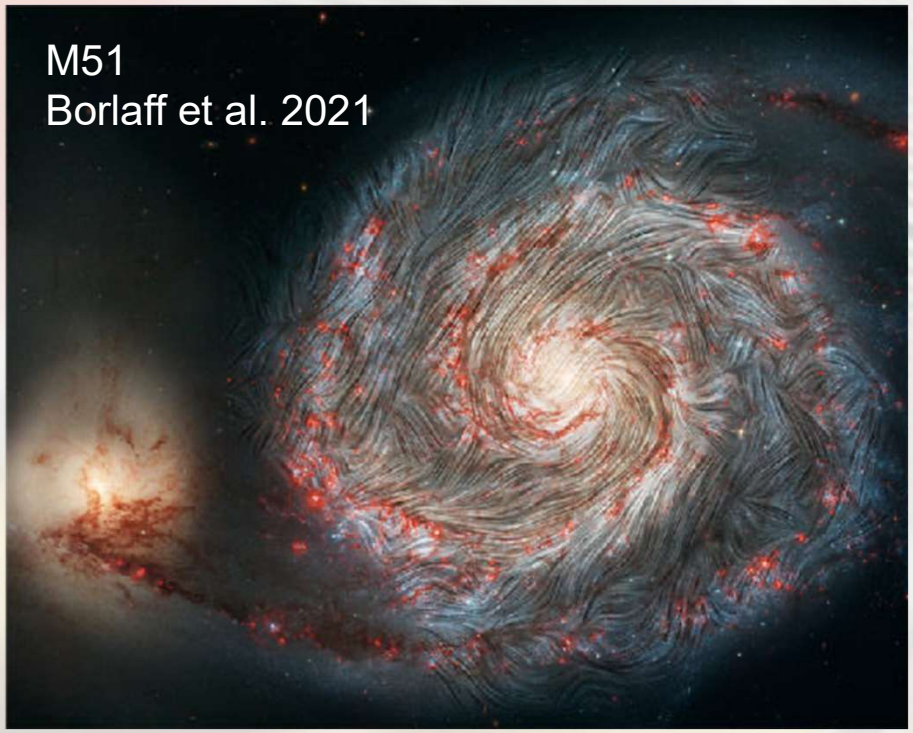
A wavelength discrimination (spectroscopy) can determine the species involved in the polarization processes.

Grains identification procedure will be similar to the molecule determination in Relative Amplitude, but in polarization Relative Contribution.

NEEDS

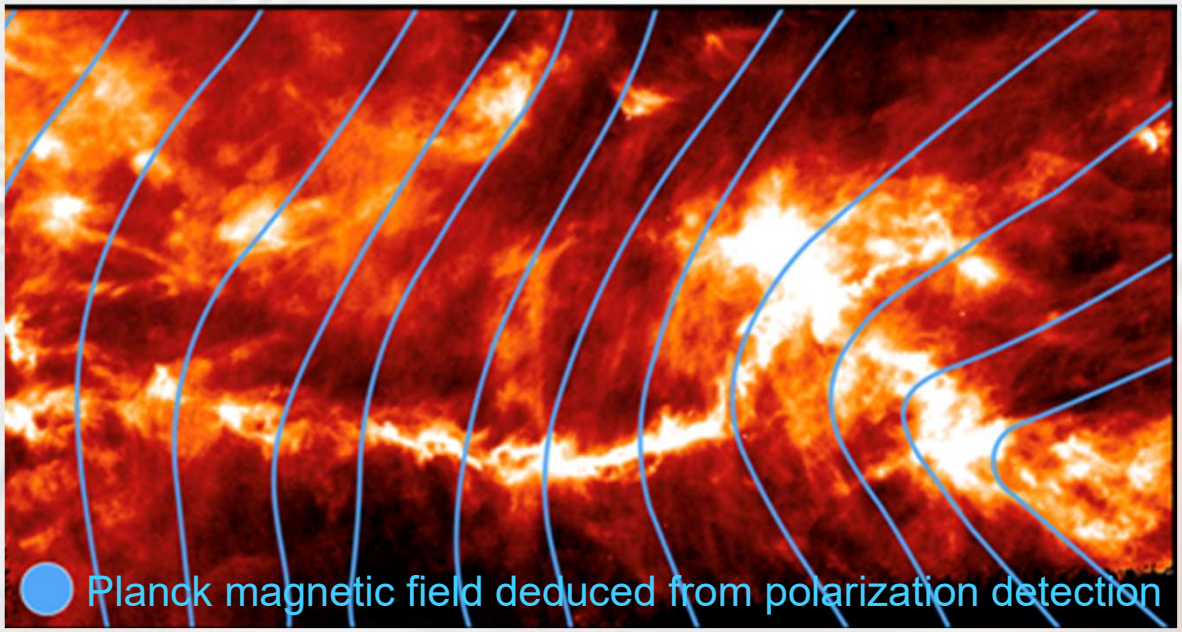
Two cases (… out of many)

Galactic case: induced Dynamo in galaxy



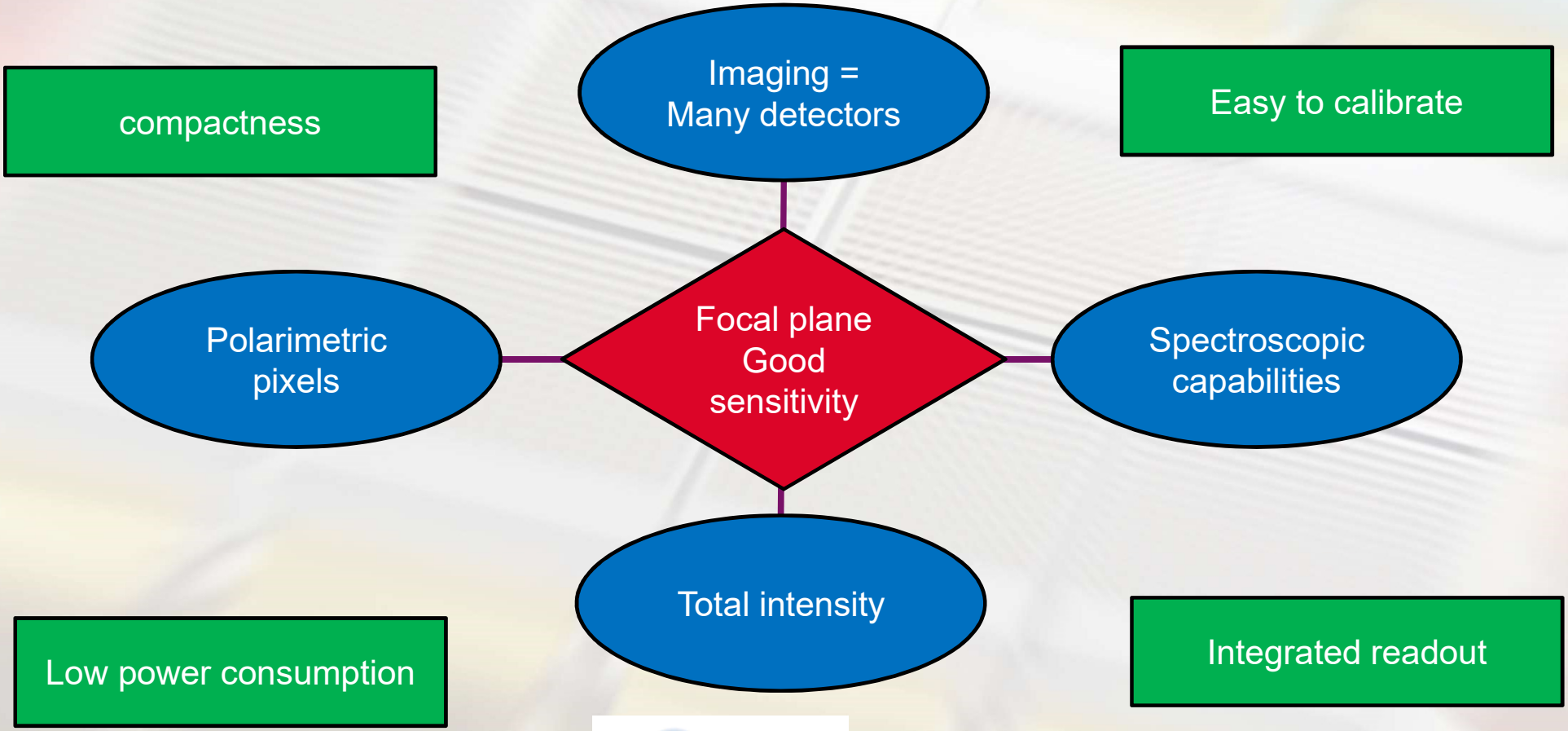
Star forming regions

Filament in Taurus



Polarimetry Sensitivity Spatial resolution Spectroscopy to identify the dust species

WHISH LIST : SUMMARY



OTHER SYSTEM IMPLICATIONS

Evolution

Exotic cryogenic detectors are needed to reach NEP ~ 10^{-18}, 10^{-19} or 10^{-20} W/√Hz

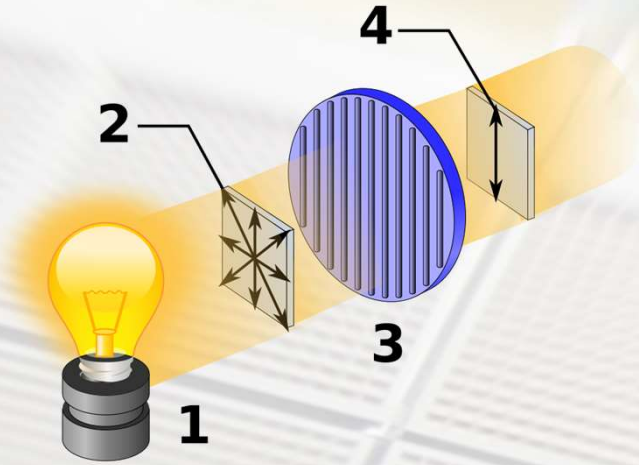
Candidates are TES (Transition Edge Sensors), KIDs (Kinetic Inductance Devices), but today limited above 100 µm, …, SNSPD

or Semiconductors in the hopping range regime (Germanium, Silicon)

The price to pay is **Cryogeny below 100 mK.**

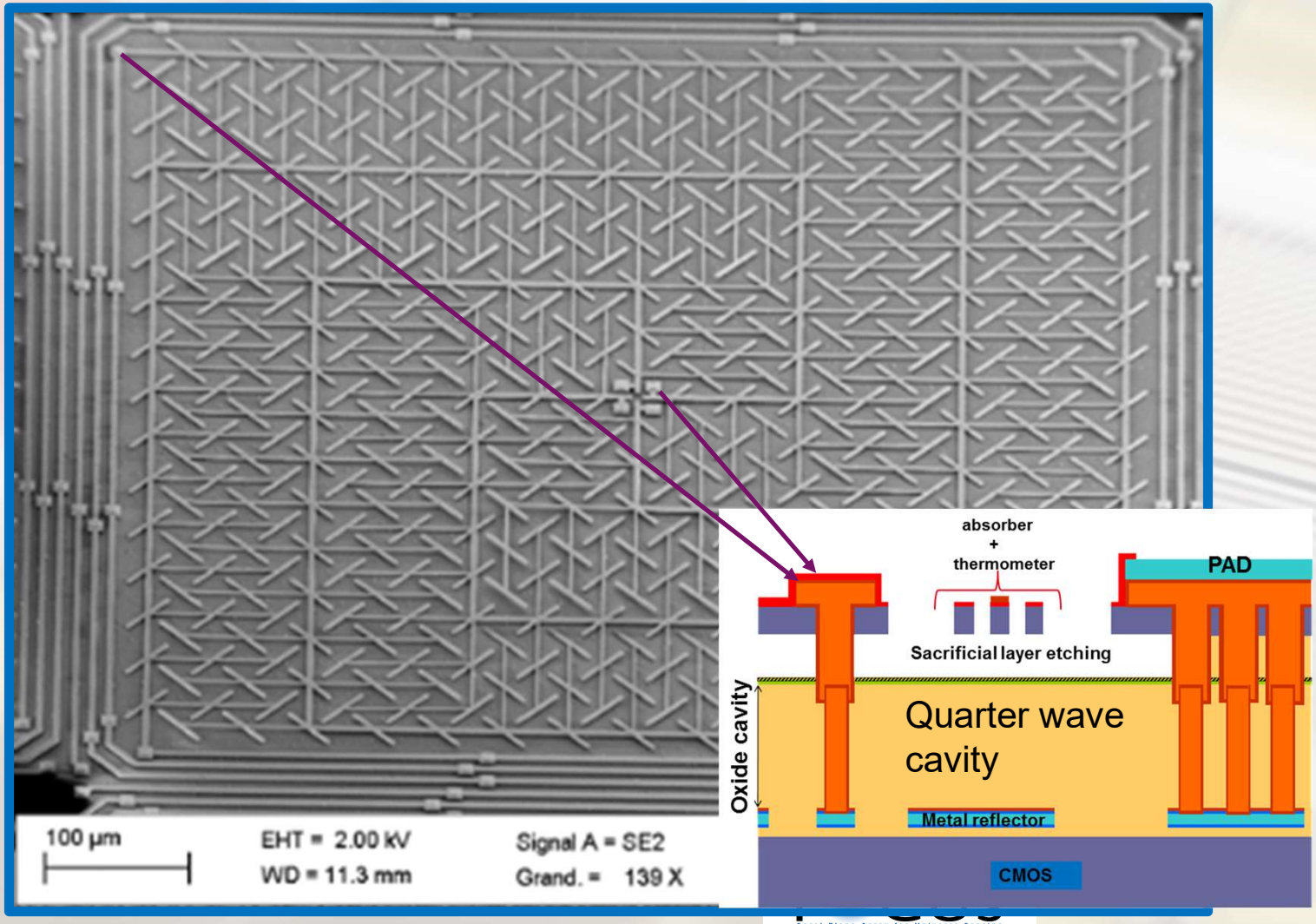
Various candidates : ADR, Dilution, Hybrid (ADR + sorption)

Here, Si Semiconductor detector principle was selected because it can be easily tailored for instrumentation in pixel.



Polarimetry

INSTRUMENTAL FUNCTION #1: POLARIMETRY IN THE 70-100 UM PIXEL



Two networks of orthogonal dipole absorbers at ~λ/3.
--> 2 x 240 dipoles

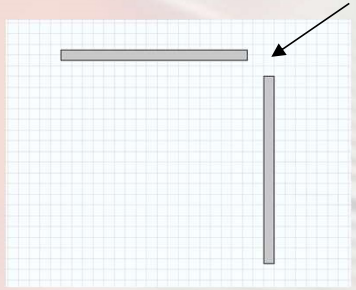
All the absorbers in one orientation are linked to one spiral arm.

All the other orthogonal absorbers are linked to the second arm.

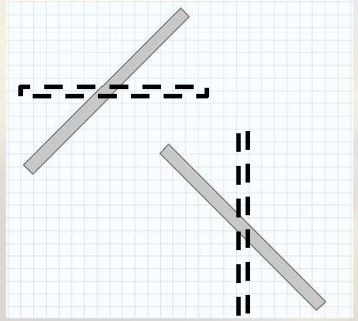
The two spiral arms are suspended over a λ/4 cavity to improve the detector efficiency above 90%.

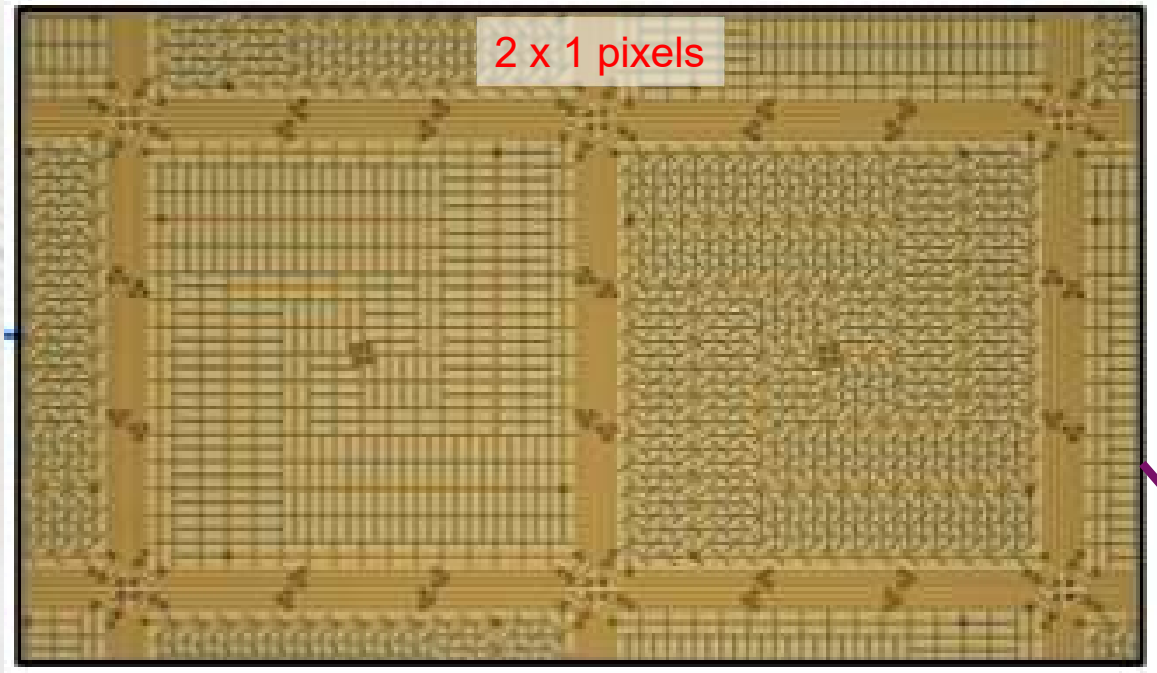
Of course, if phase is not recorded, we need a third direction to Retrieve the Stokes Parameters.

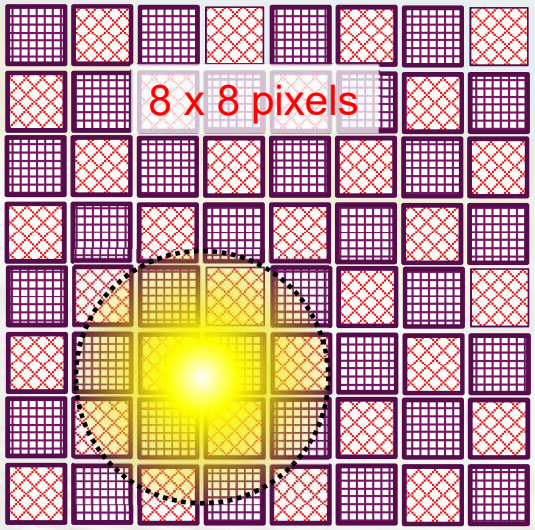
STOKES PIXELS

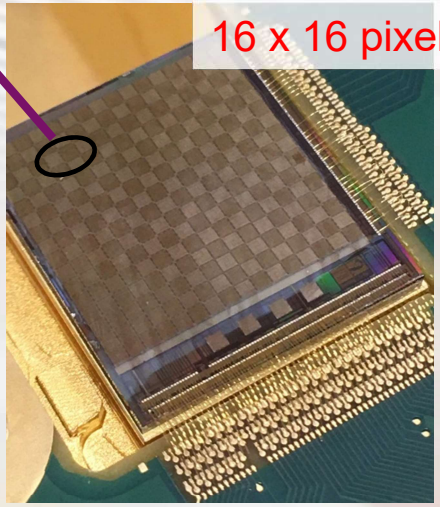


Rotation by 45°

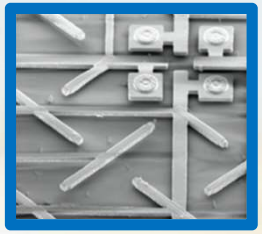




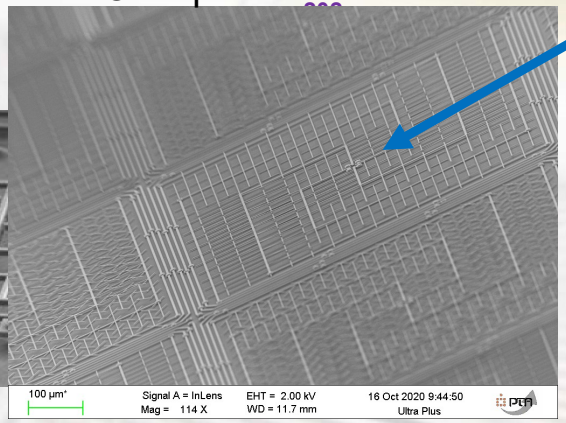


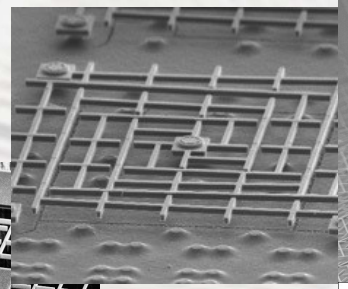


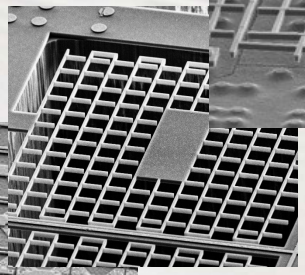
EVOLUTION : FROM PACS BOLOMETERS TO BBOP

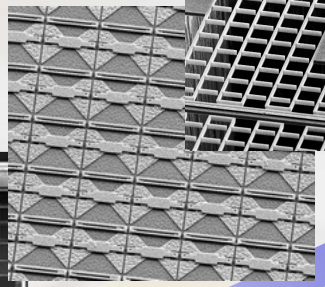


B-BOP's polarimetric bolometers

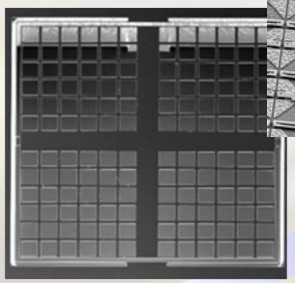








~2000



CoRe+

Does it work ?
Yes , but first we must describe the front-end readout electronics in the detector array

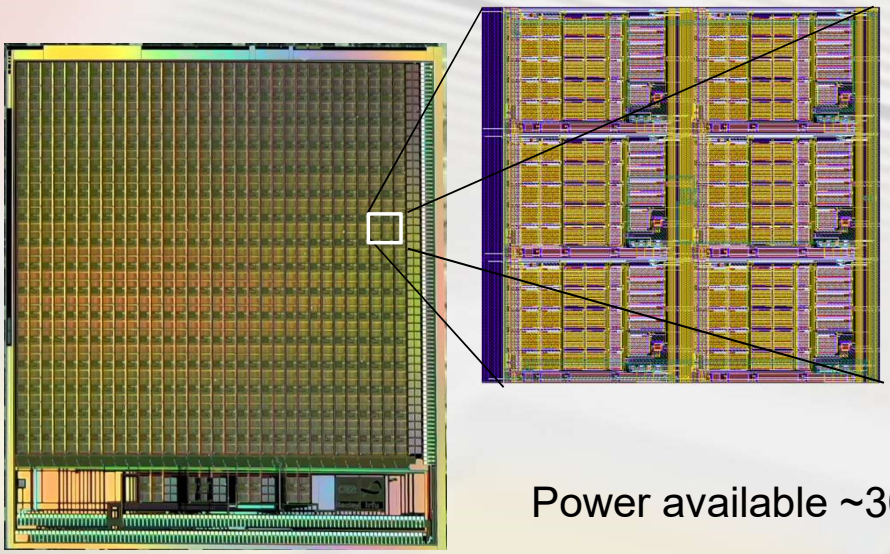
ROIC @ 50 mK

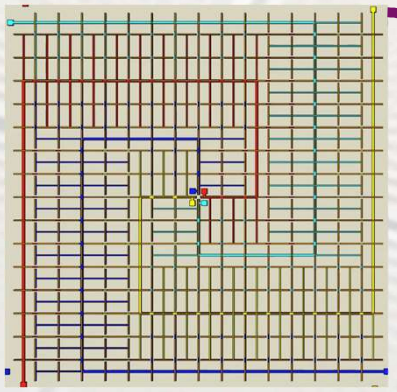
INSTRUMENTAL FUNCTION #2 : INTEGRATED FRONT END ELECTRONICS @ 50 MILLI-K

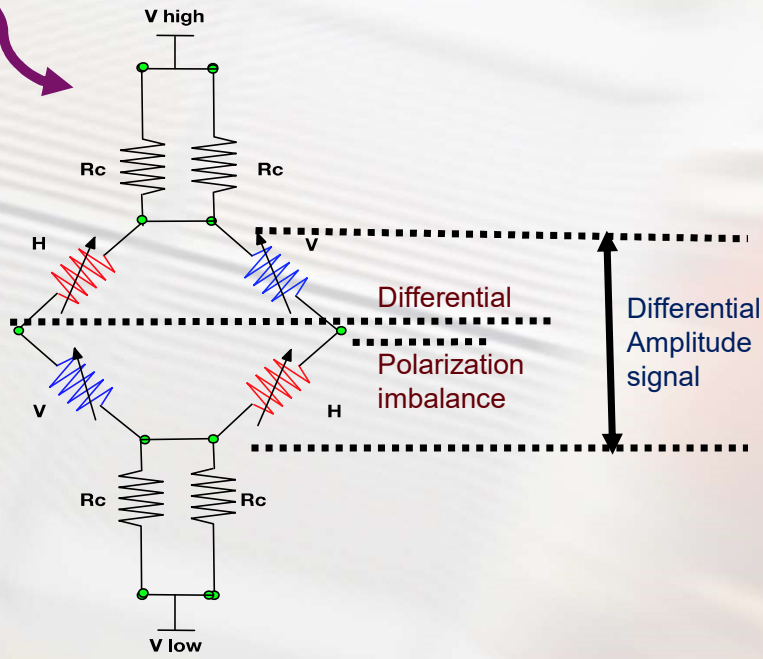
Functions required:

- **Buffering (for impedance adaptation GΩ (sensor) →MΩ (line to the second level)),**
- **Multiplexing 16 →1.**

the four branches of the spirals can be combined in a fully symmetrical Wheatstone Bridge

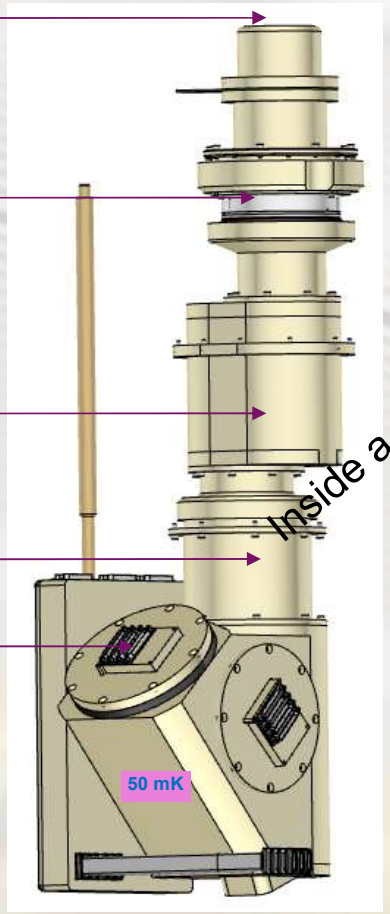


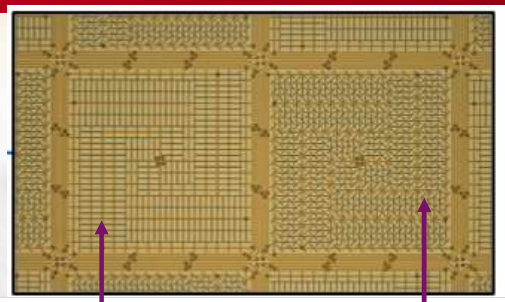




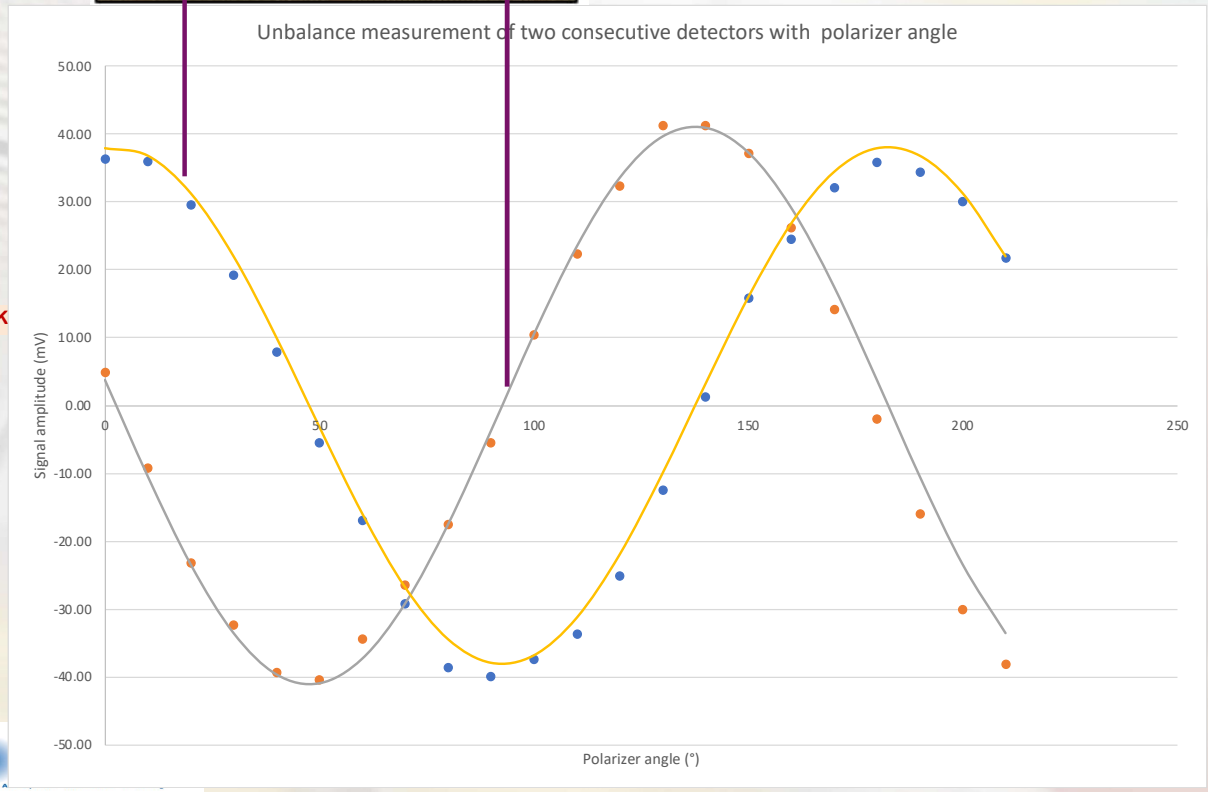
Power available ~300 nW/array @ 50mK

POLARIMETRIC MEASUREMENTS : IMBALANCE





No changes in the total power signal



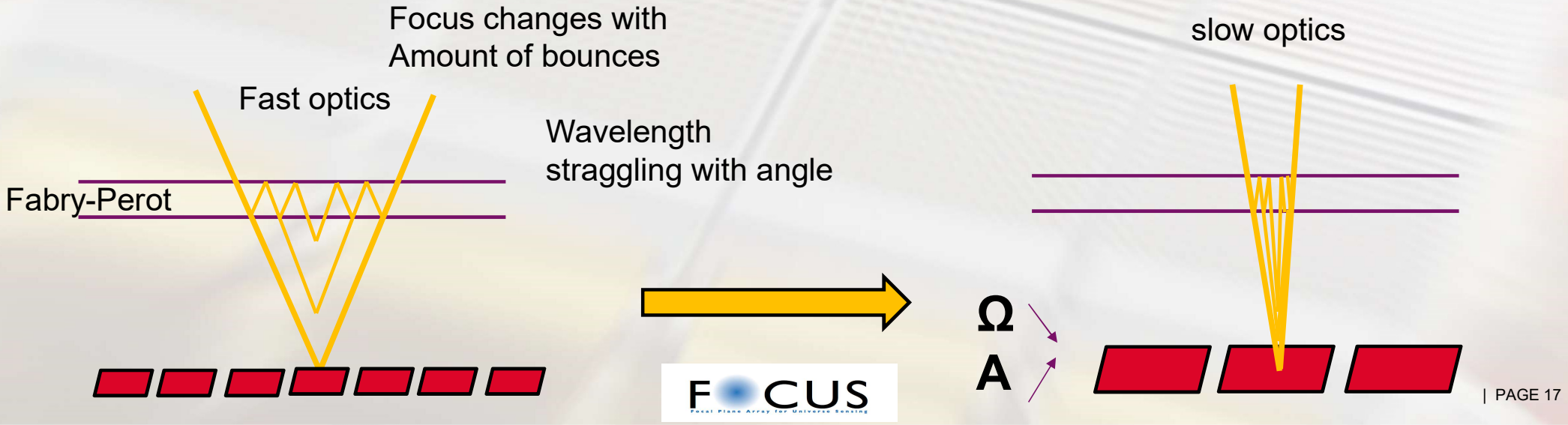
Spectroscopy

NEXT FUNCTION : SPECTROSCOPY

For this section, the presentation is mainly an introduction and advertisement for the poster by Timothée Tollet currently in thesis @ Saclay.

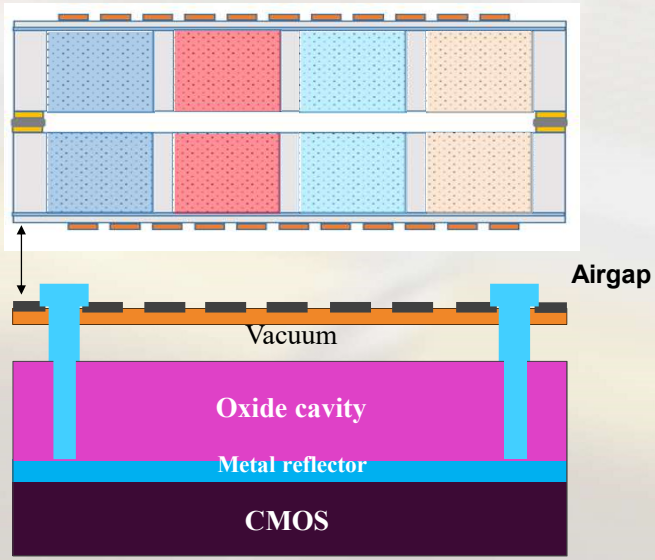
When you want to introduce spectroscopy by interference effects, you have to fight the “étendue de faisceau” : **AΩ** that must be conserved along the optical path (or degraded!)

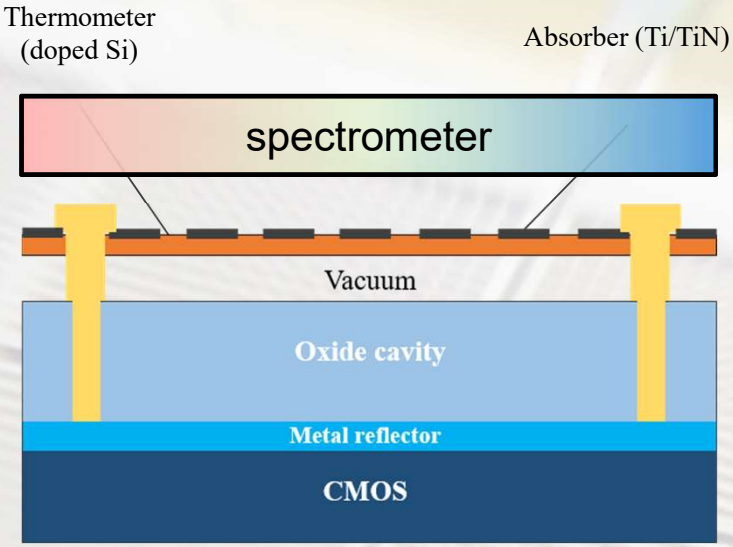
In general, if you want to keep the imaging capability it results in bulky instruments (Fourier Transform Spectrometers, Grating Spectrometers, and even Fabry-Perot that need a collimated zone in the optics. IF NOT …



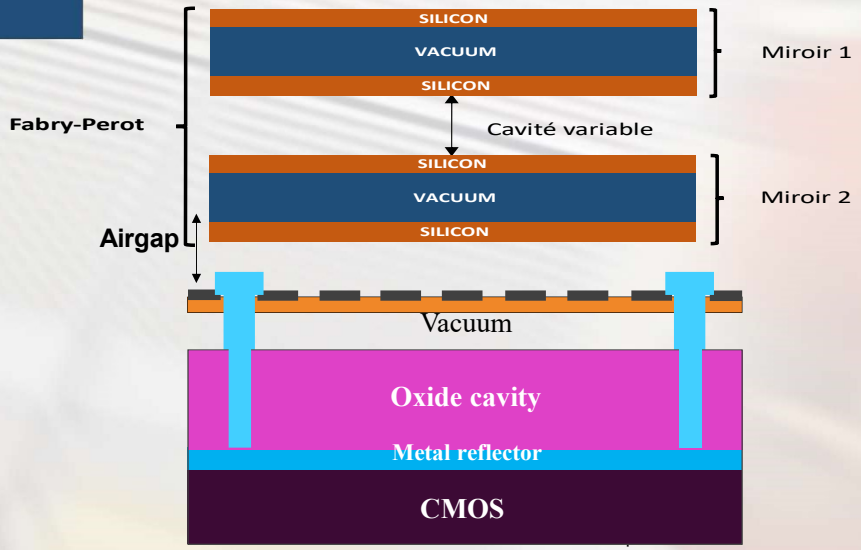
SOLUTION : PUT THE FABRY-PEROT AS CLOSE AS POSSIBLE TO THE DETECTORS

Option # 2 :
"Arlequin" F-P made by tuning the refractive index in the cavity.





Option # 1 :
scanning F-P with Bragg mirrors



FOCUS
Focal Plane Array for Universe Sensing

CONCLUSIONS

The Instrumentation in pixel (array) is now a reality, in this wavelength domain.

The first instrumental function introduced was the front end electronics.

Polarimetry in pixel is now demonstrated

Spectrometry is on its way…

Can we introduce others ?

I struggle for years to introduce the cooling inside the pixel by hot electron evaporation (NIST Boulder sells a separate system to reach 260 mK).

Non linear optics will probably change the landscape in near future

The real issue !

This type of development is pushed by scientific space programs…
and there is **NO space program** after Herschel Planck in Europe.

Cryogenic observatories seem to be banned from programs today.

THE BBOP PROJECT : CONTRIBUTORS

Saclay DAp Group

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- Détector/Instrument
- Optics
- Electronics
- System
- Project

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+ DSBT Team @ CEA Grenoble

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