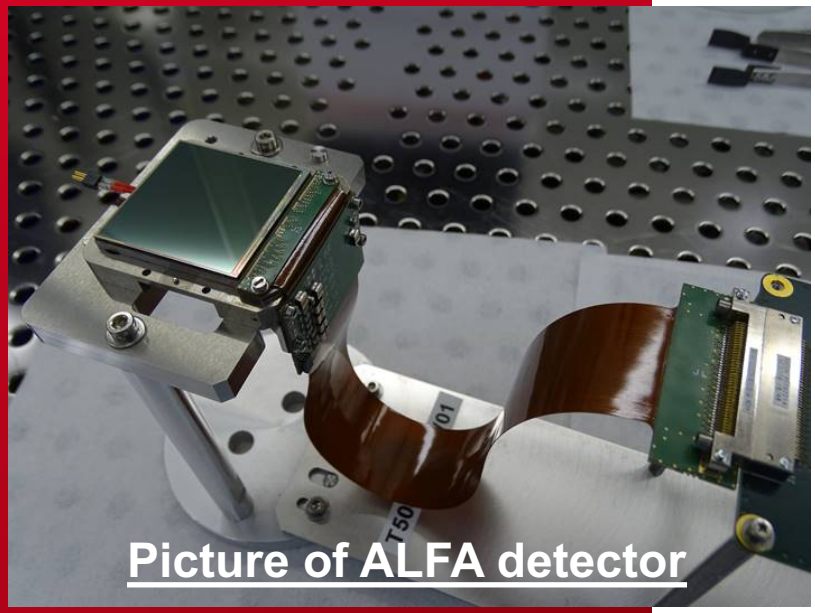
DE LA RECHERCHE À L'INDUSTRIE

ALFA and ASTEROID detectors characterization results and status of Quantix and Intrapix test benches



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AG FOCUS – LAM 20-21 Juin 2022

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PLAN

1. ALFA
   1. Presentation of ALFA program
   2. Summary of characterization results
2. ASTEROID program
   1. Presentation of ASTEROID program
   2. Summary of characterization results
3. Quantix test bench
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   4. ALFA and ASTEROID quantum efficiency measurement
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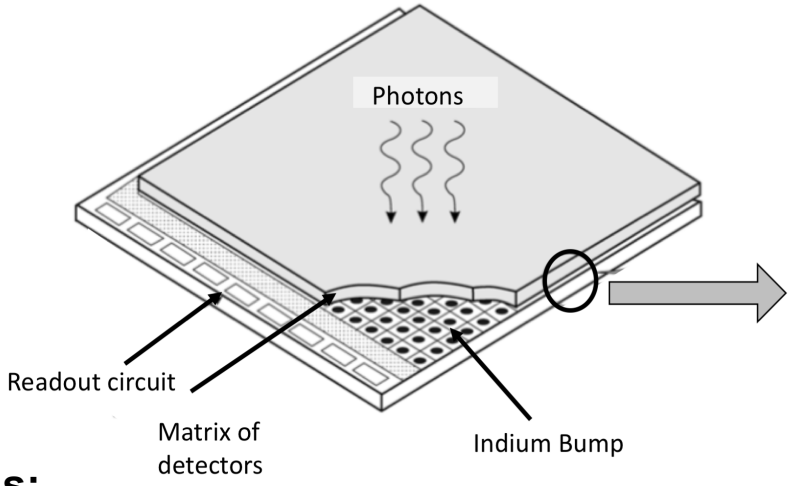
1. ALFA (ASTRONOMICAL LARGE FORMAT ARRAY)
1. PRESENTATION OF ALFA PROGRAM

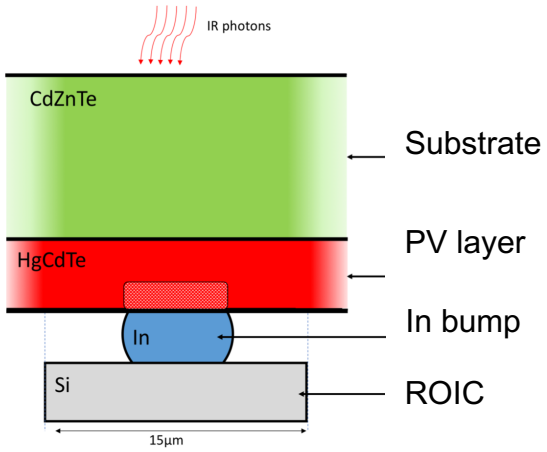
Goal: equip Europe with high performance IR detectors for space applications and astrophysics

- **Development :**
  - Lynred (ROIC + Hybridization) + CEA-Leti (PV)
- **Characterisation :**
  - Astrophysics Department, CEA
- **Funding :**
  - ESA, FOCUS

ALFA Specifications:

- HgCdTe
- 2048x2048 with a pixel pitch of 15µm.
- **Spectral domain 0.8µm to 2.1µm.**
- **Dark <0.1 e-/s/pix at 100 K**





ALFA status:

- 2 operationals detectors are at ESA (not in spec.)
- 2 detectors are under test at CEA-DAp (in spec.)

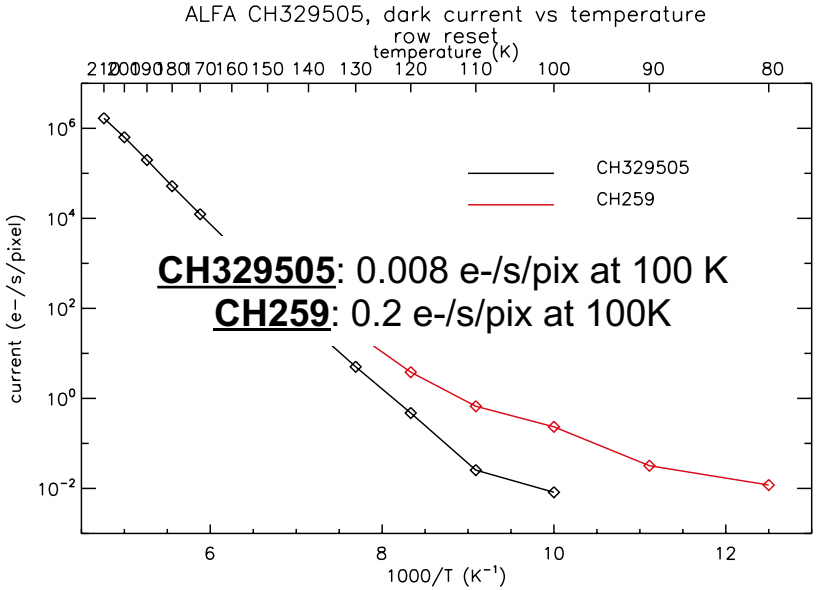
1. ALFA (ASTRONOMICAL LARGE FORMAT ARRAY)
2. SUMMARY OF CHARACTERIZATION RESULTS

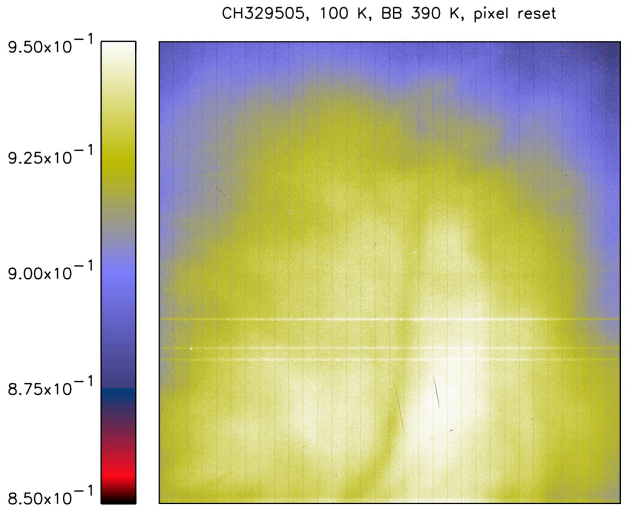
ALFA detectors characterized at CEA with NGC control electronics in light tight test bench.

ref. LETI	General performance	Location
329505 (Batch 3)	Very good	CEA Dap
259 (Batch 1)	Good	CEA Dap
260 (Batch 2)	Bad	ESA
331064 (Batch 2)	Non usable	ESA

Conclusion regarding detector 329505

- ✓Very good cosmetics
- ✓Very good operability under illumination
- ✓Extremely good linearity
- ✓Extremely low dark current
- ✓Low cross talk
- ✗Reference pixels not useable
- ✗Excess noise





ASTEROID: **AST**ronomy **E**u**RO**pean **I**nfrared **D**etection

- **Goal:** Developpment of large wafer foundry that can be used to manufacture high performance IR detectors for scientifiifc and astronomical applications. Start: May 2017. End: Nov. 2021

- **Funding** :
  - European Commission
- **Development**:
  - Lynred (PV, 1st SWIR PV layer dedicated to very low flux applications) and CEA-Leti (ROIC)
- **Characterisation :**
  - Astrophysics Department, CEA

ASTEROID Specifications:

- ALFA like technology, HgCdTe-based IR detectors
- 640x512 with a pixel pitch of 15µm.
- **Spectral domain 0.8µm to 2.1µm.**
- **Dark <0.1 e-/s/pix at 100 K**

9 detectors manufactured
→ 7 delivered at CEA-Dap
→ 6 characterized

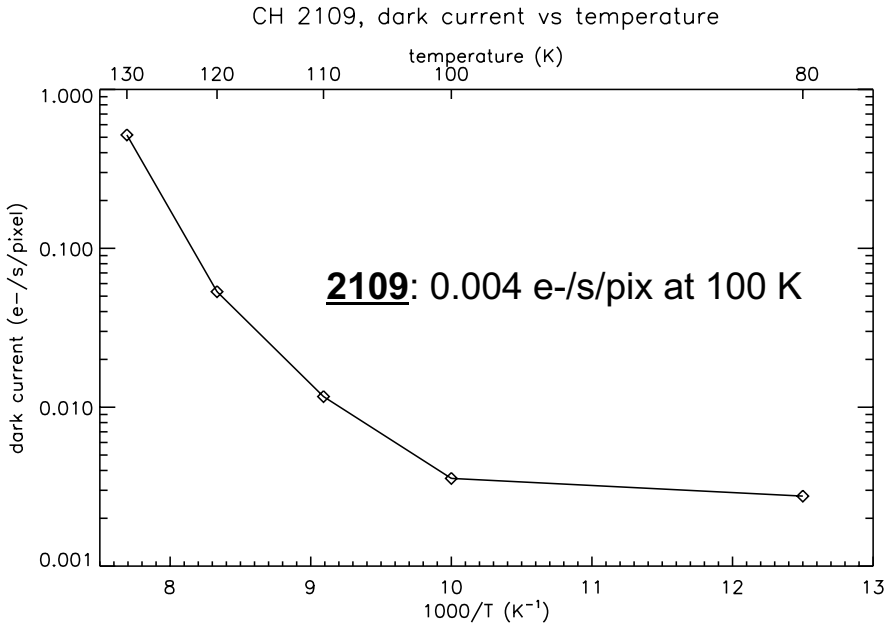
ref. LETI	Type	Characterized at DAP
21-01	étude2	Delivered but non operable
21-03	étude2	
21-05	étude2	Not delivered to DAp
21-08	étude2	
21-02	étude1	
21-04	étude1	
21-06	étude1	
21-07	étude1	Not delievred to DAp
21-09	Monovariante	

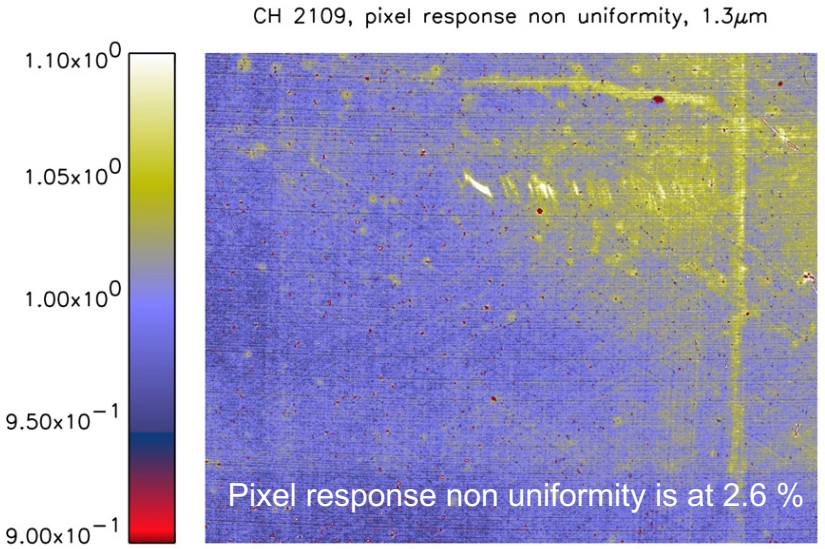
ASTEROID detectors characterized at CEA with in-house control electronics in light tight test bench.

ref. LETI	General performance
21-03	Very good
21-08	Very good
21-09	Very good
21-02	Polluted by glow
21-04	Polluted by glow
21-06	Bad

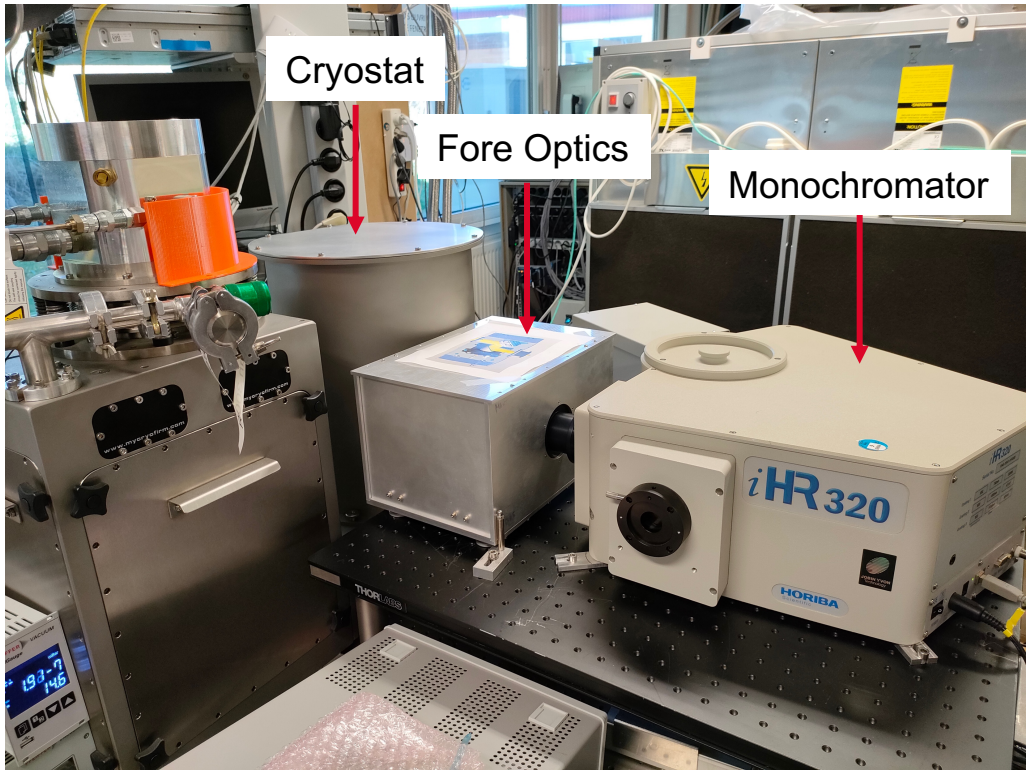
Conclusion regarding detector 2103, 2108, 2109

- ✓Very good cosmetics
- ✓Extremely low dark current
- ✓Low cross talk
- ✓Very good operability under illumination

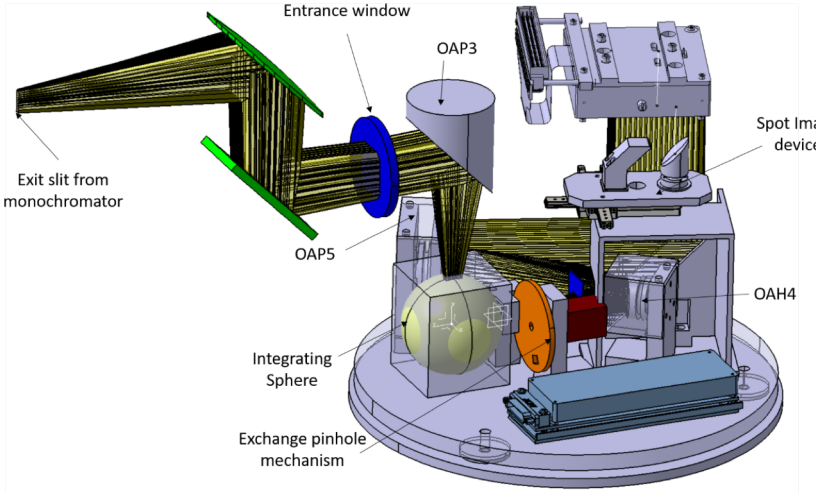




3. QUANTIX TEST BENCH
1. TEST BENCH PRESENTATION



- Three components:
  - monochromator,
  - fore-optics
  - cryostat
- Collimated beam to illuminate calibrated photodiode and detector simultaneously



Quantix and the calibrated photodiode (CEA-Leti) have been funded by FOCUS.

⚠ We only have one SWIR calibrated photodiode (no backup)

3. QUANTIX TEST BENCH
2. PRINCIPLE OF MEASUREMENT

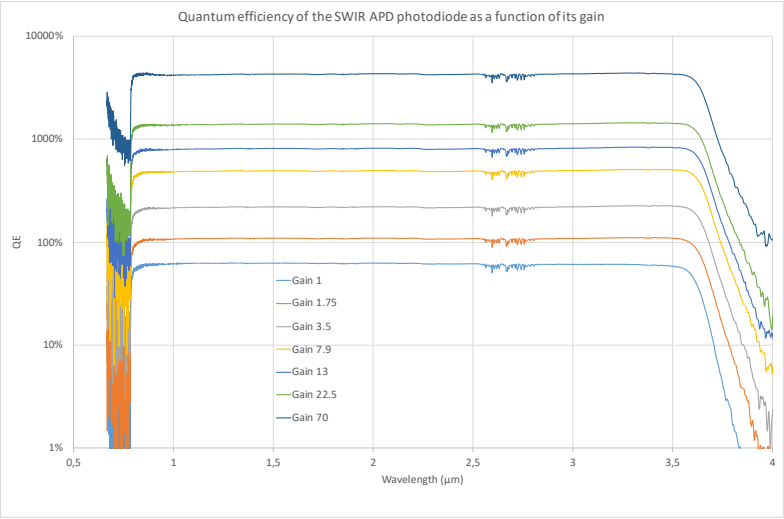
QE principle of measurement with a calibrated photodiode :

- $QE_{DUT(i,j)}(\lambda) = \frac{I_{DUT(i,j)}(\lambda)}{F_{DUT(i,j)(\lambda)}}$
- $F_{DUT(i,j)}(\lambda) = F_{PHD}(\lambda) \times \frac{Irr_{DUT(i,j)}(\lambda)}{Irr_{PHD}(\lambda)}$
- $F_{PHD}(\lambda) = \frac{I_{PHD}(\lambda)}{QE_{PHD}(\lambda)}$

$$QE_{DUT(i,j)}(\lambda) = \frac{I_{DUT(i,j)}(\lambda)}{I_{PHD}(\lambda)} \times \frac{Irr_{PHD}(\lambda)}{Irr_{DUT(i,j)}(\lambda)} \times QE_{PHD}(\lambda)$$

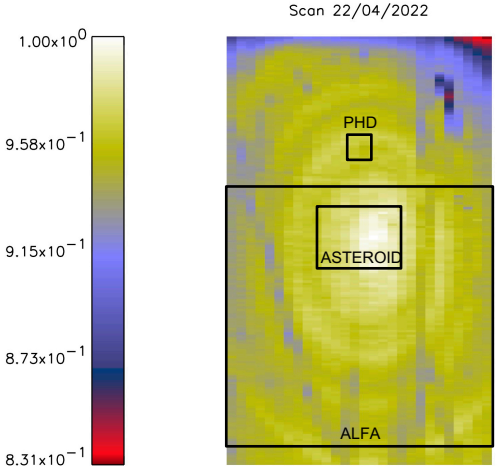
➢ **Different measurements are necessary**

- Photonic current delivered by detector under test, $I_{DUT(i,j)}(\lambda)$ ✓ Output of the detector control eletronics
- Photonic current delivered by calibrated photodiode, $I_{PHD}(\lambda)$ ✓ Photodiode electronics (HEMT based cryo-amplifier) + RT amplifier and multimeter.
- Calibrated photodiode quantum efficiency $QE_{PHD}(\lambda)$ ✓ Measurements + calibration
- Uniformity of illumination, $\frac{Irr_{PHD}(\lambda)}{Irr_{DUT(i,j)}(\lambda)}$ ✓ Measurements



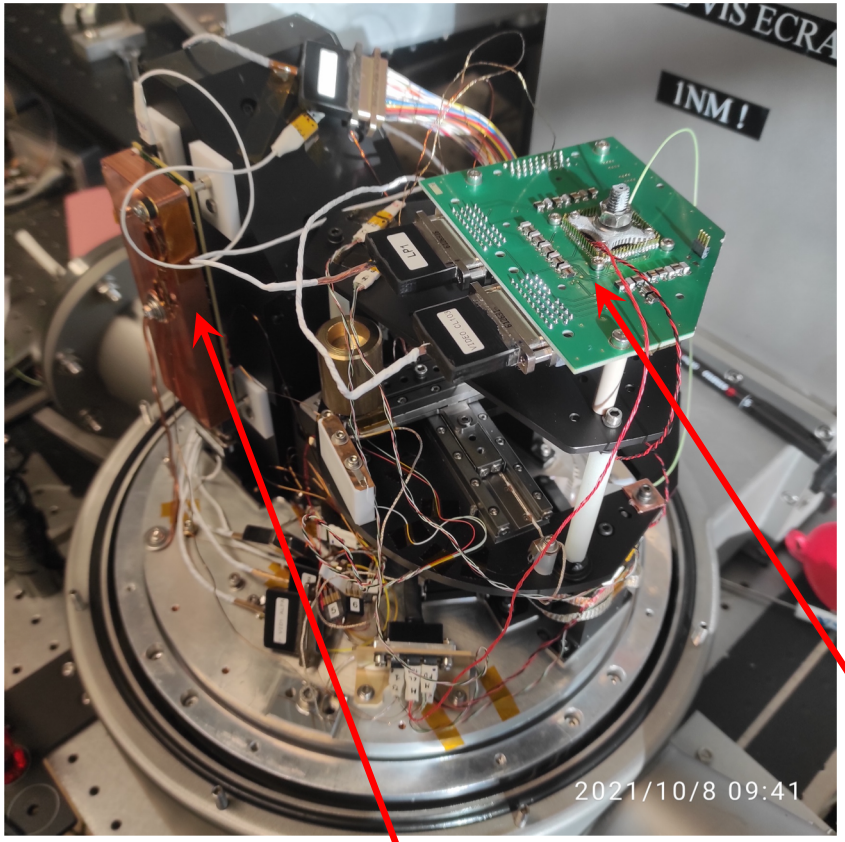
The photodiode has been installed on cryogenic stages to measure the uniformity of illumination

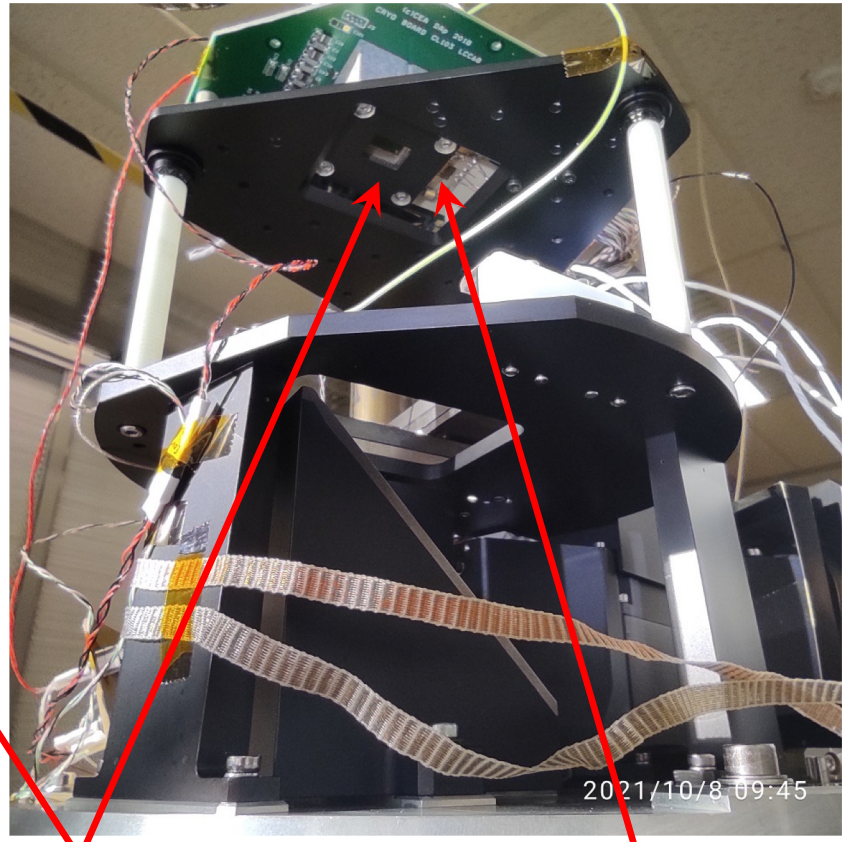
Relative standard deviation of illumination is 2%



3. QUANTIX TEST BENCH
3. VALIDATION

- Views of the cryostat with ESA (manufactured at CEA/Leti) reference device installed





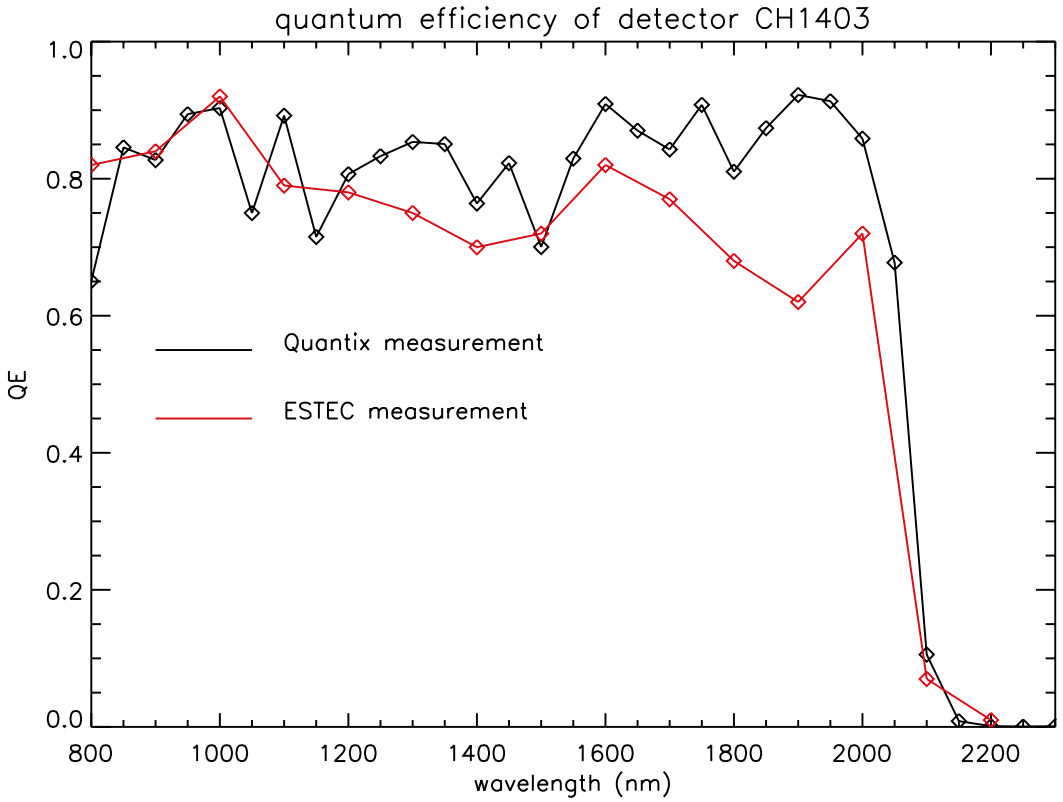
Photodiode cryogenic amplifier

Reference device

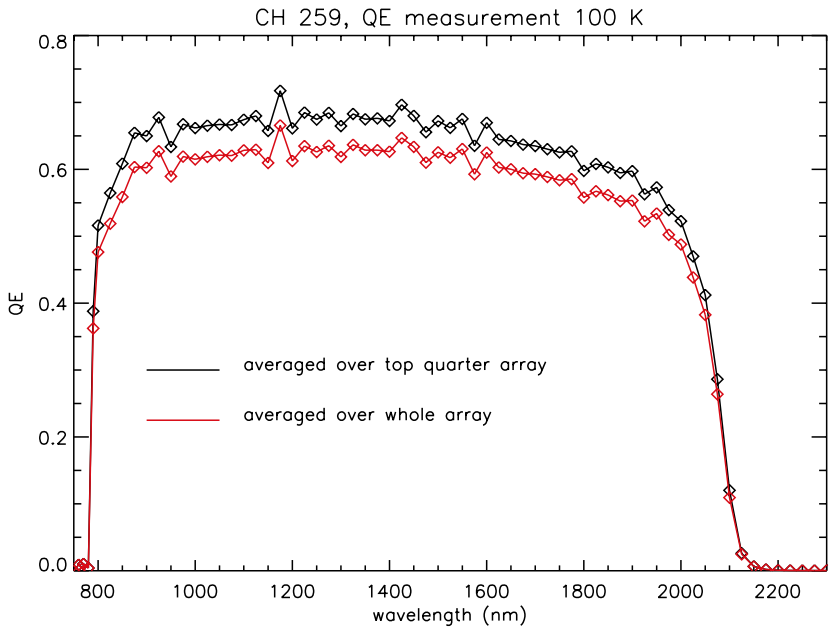
Calibrated photodiode

3. QUANTIX TEST BENCH
3. VALIDATION

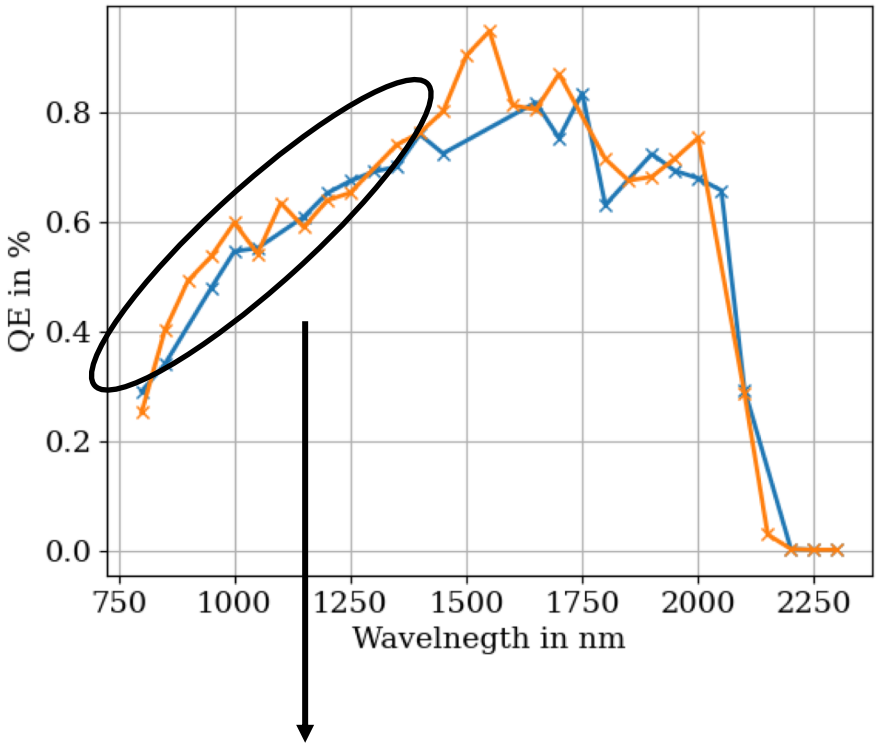
- QE measured from 0.8 to 2.3 µm: OK!
  - Uncertainty is ±12%
  - Largest contributor to uncertainty is photodiode current: ± 8%



ALFA



ASTEROID – Detector 2108

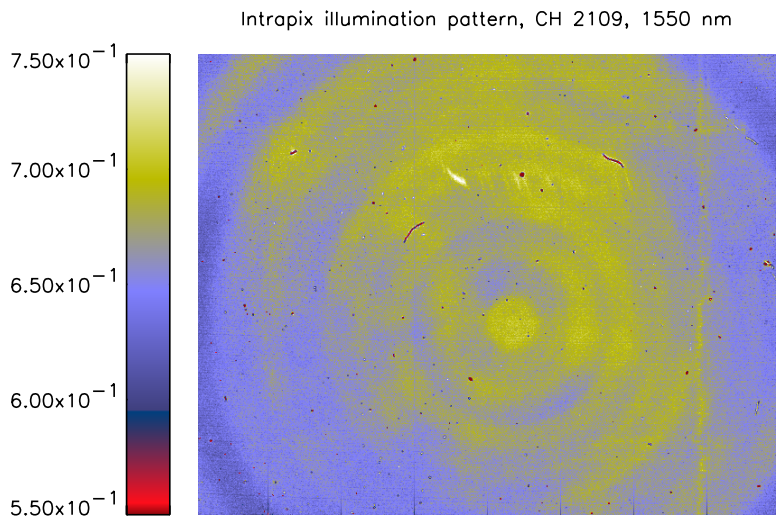


Attributed to the substrate ?

4. STATUS OF INTRAPIX

Intrapix: Test bench dedicated to the measure of the intra-pixel response based on the Talbot effect (self imaging effect).

- FOCUS has highly contributed to the funding (hardware, post-doc, CDD)
- In collaboration with ONERA
- « first light » with an ASTEROID device (without CSIG)
- Same spatial structures in illumination map as in Quantix (Diamond machined mirrors)
- C. Ketchazo will joint CEA (expected July) to work on Intrapix data processing.



First image with a CSIG expected this week !

5. CONCLUSIONS AND PERSPECTIVES

ALFA and Asteroid detectors show **very good detection** detection layers !

Detector	EUCLID H2RG detector, 2.3 µm cutoff	CEA/LETI CH1403 (ESA ref for Quantix)	ALFA: CEA/LETI CH329505 (Detector CAGIRE)	ASTEROID: Lynred CH2109	ASTEROID: Lynred CH2108 Detector with different diode geometries	ASTEROID: Lynred CH2103 Detector with different diode geometries
IPC (%)	**2.1-2.6**	2.4	2.3	2.5	2.3	To be measured
QE	**~80 %**	~80 %	To be measured	To be measured	max 80 %	To be measured
Dark current at 100 K in e-/s/pix	**0.0052 (Phd Serra B.)**	~1 (polluted by glow, to be remeasured)	0.003	0.004	0.003-0.006	0.002-0.005

Soon no more detector available at CEA-DAp. Yet:

- More measurements are needed to investigate the origin of the excess noise in these detectors
- Extra electro-optical performance measurements can also be performed to have more statistics.

→ Need for another batch.

5. CONCLUSIONS AND PERSPECTIVES

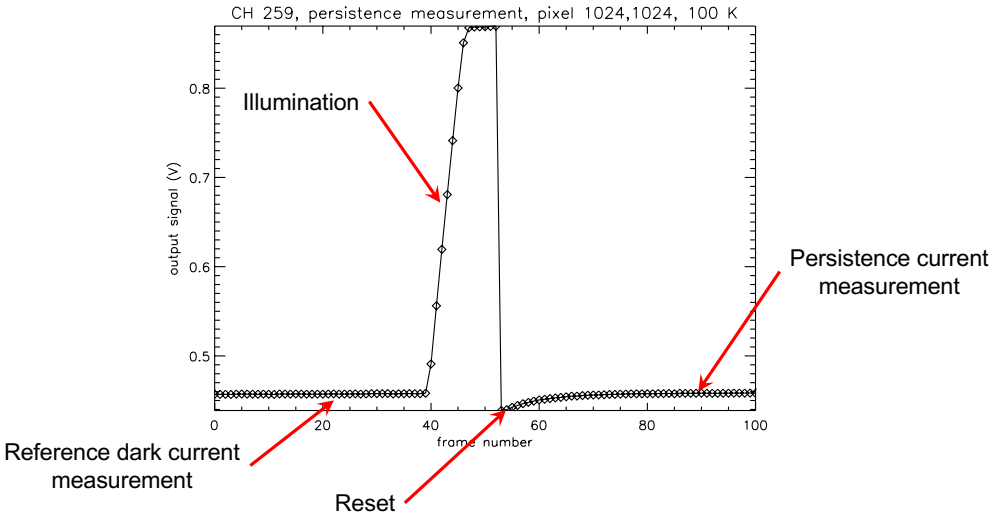
Test benches

Quantix test bench:

1. Validate test bench in the VIS and LWIR
2. Modify HEMT amplitifier (suspected to add noise)

Intrapix test bench:

1. First measurement with a TV format detector (this week)



Detector characterization:

ALFA detectors, next steps before delivery:

- Persistence (reproducing Titouan procedure, data acquired on one detector, to be analyzed)
- Intrapixel response (on one ALFA detector)
- QE of CH329505 (Det CAGIRE) detector to be measured

Asteroid detectors:

- Persistence measurement
- Plan to do an irradiation campaign (dose effects)