INFRA RED DETECTION AT THALES ALENIA SPACE: ON GOING SWIR TO VLWIR DETECTION SUBSYSTEM DEVELOPMENTS

WORKSHOP ON IR DETECTION FOR SPACE APPLICATIONS

ON GOING AND FUTURE MISSION TECHNOLOGY REVIEW SESSION

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Toulouse, 7th June 2023

Date: 07/06/2023
Ref: Not referenced
Template: 83230347-DOC-TAS-EN-011

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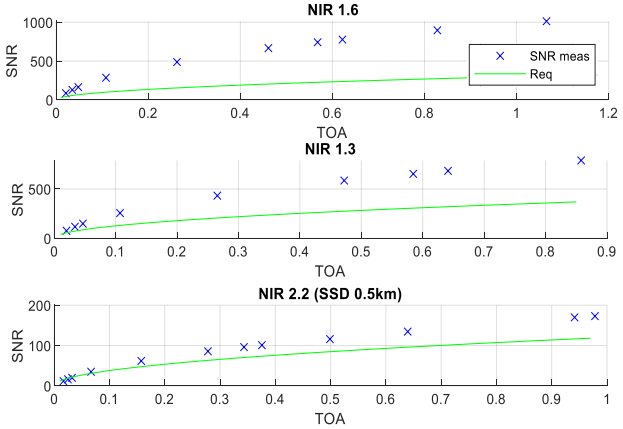
SWIR BAND : PANORAMA OF ACTIVITIES

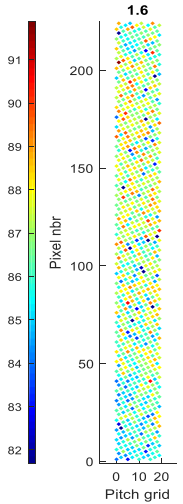
/// MTG FCI NIR Detector is the pioneer

- Linear array from Lynred with 224 to 448 rhombus pixels: 3 spectral bands from 1.3 to 2.2 µm, developed for MTG FCI.
- Low flux requiring CTIA input stage
- The NIR detector is part of an overall focal plane including 3 other IR detectors, all being integrated in a cryostat designed and developed by TAS.
- One Front End Electronic per detector, and a common Video equipment.

/// FCI PFM with very good results

SNR on a full disc image:
in line with expectation and requirement, on the 3 NIR spectral bands





Cartography of SNR at low flux: homogeneous, almost no defective pixel.

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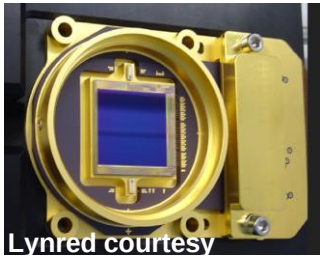
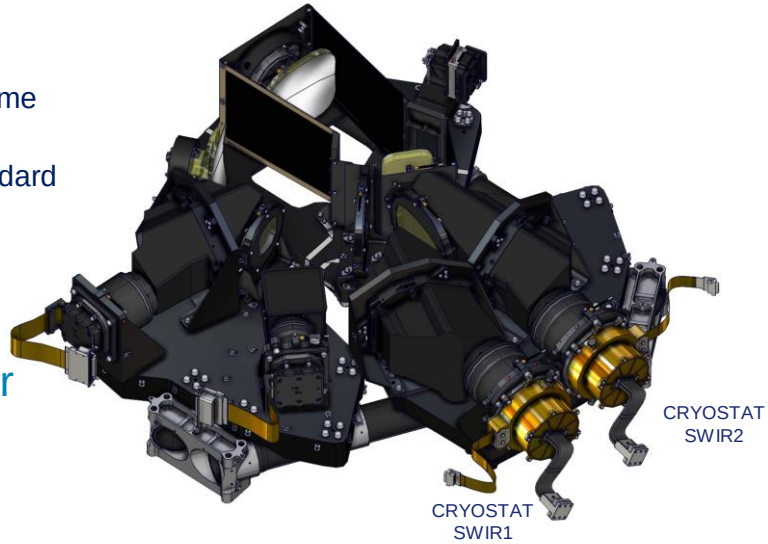
SWIR BAND : PANORAMA OF ACTIVITIES

/// CO2M: a challenging program for ESA

- Use of the well known Lynred NGP detector with some adaptations to comply with the stringent CO2M specifications,
- Two NGP detectors in the system with direct connection of the detector to the FEE through a long flex (> 25 cm),
- The main challenge comes from the accuracy requirement which requires a very low remanence level compared to imagery needs:
  - Reduction of dark current with passive cooling,
  - Reduction of background : no window,
  - Specific acquisition mode with several acquisitions during the frame time ➔ higher video frequency (> 7 MHz),
  - Improvement of the photodiode lag performance : modification of standard PV module technology (solution and process),
  - Processing for residual Lag correction which requires knowledge and dedicated test bench.



NGP detector Integrated in TAS cryostat



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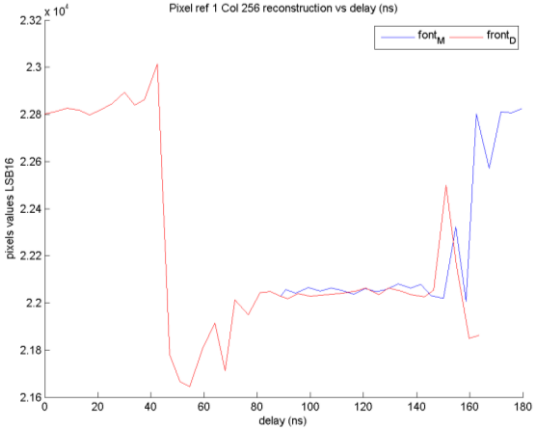
SWIR BAND : PANORAMA OF ACTIVITIES

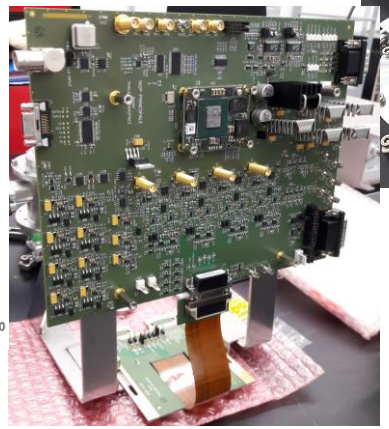
/// For CO2M, TAS has developed specific tools : electronic breadboard and remanence test bench

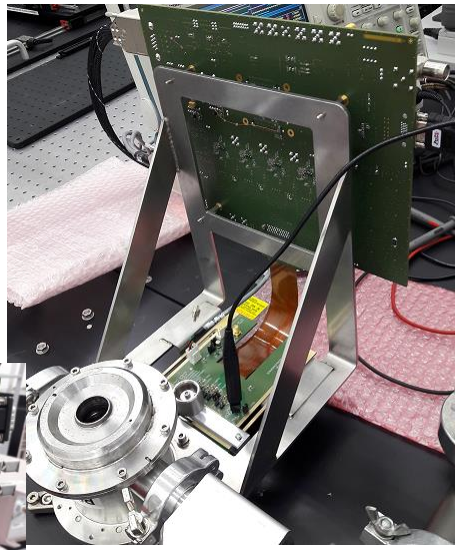
/// Video electronic board with simulation of the long flex to prove the working at high frequency,

- Compact video board with all functions and short development cycle (< 1 year),
- Low noise biases and supplies adjustable through USB interface,
- 18 bits A/D convertors,
- Camera link interface,
- Video plateau reconstruction capability (more than 100 samples),

/// Working at frequency higher than 7,3 MHz demonstrated early thanks to this type of test tool.







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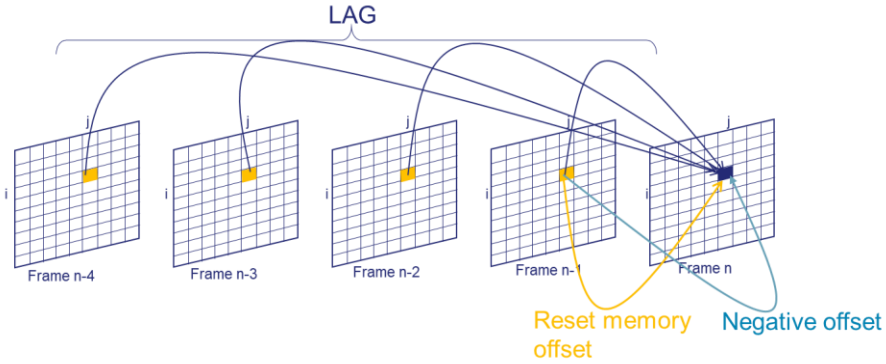
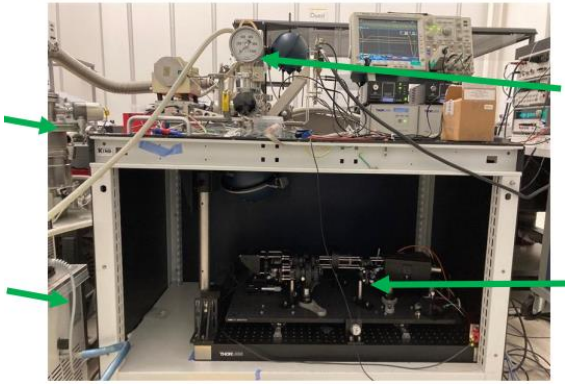
SWIR BAND : PANORAMA OF ACTIVITIES

/// Different remanence inter frame effects of the detector have been characterized



/// High accuracy remanence test bench working at different wavelengths and different min/max levels has been developed in a short delay

- Based on commercial components and TAS internal know-how
- This test bench can also be used for linearity measurement in SWIR band
- An accuracy of about 2 electrons has been demonstrated for the light to dark transition



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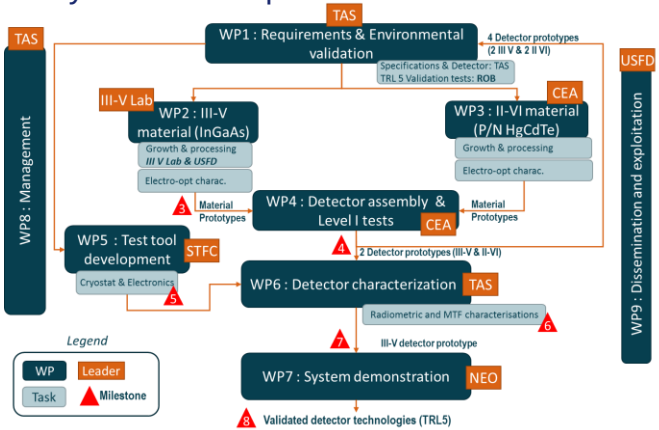
SWIR BAND : THE SWIRUP R&D PROJECT

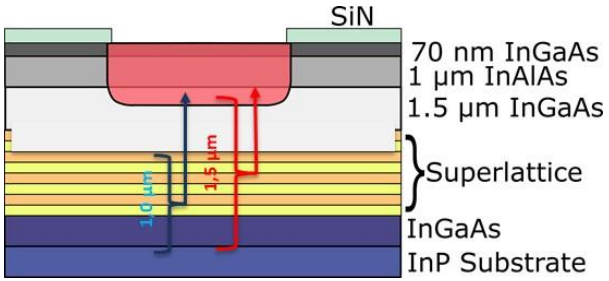
/// SWIRUP is a H2020 program granted by the European Commission initiated in June 2018,

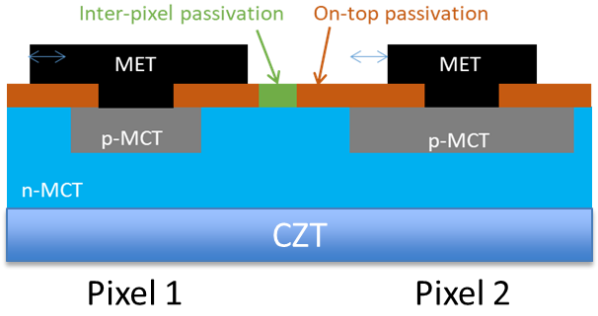
/// The goal was to develop SWIR detector technologies with cut off wavelength higher than InGaAs lattice matched one (>2,1 µm and up to 2,5 µm) and compatible with passive cooling,

- 2 detector technologies :
  - Low TRL technology : III V T2SL technology
  - Higher TRL technology : MCT P/N optimised for λc=2,45 µm
- A challenging temperature range : 230-250 K
- A complementary team with 7 partners:

TAS
III V Lab
CEA
USFD
STFC
NEO
ROB







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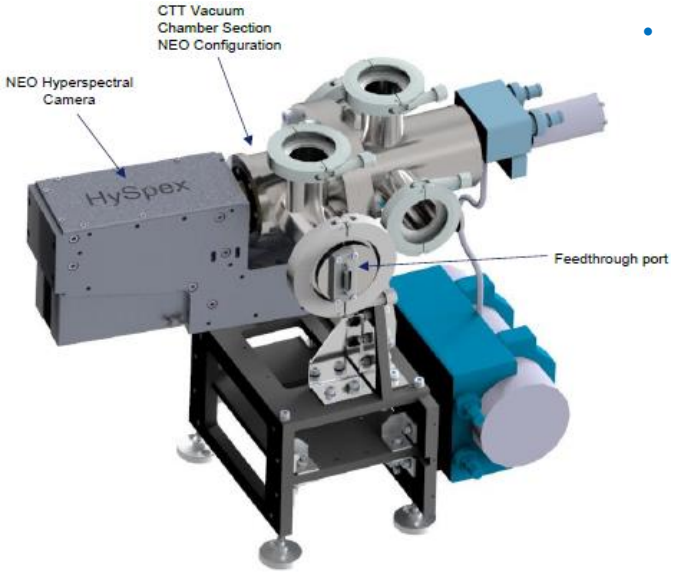
SWIR BAND : THE SWIRUP R&D PROJECT

/// Specific test tools have been developed by STFC on the base of TAS preliminary designs

A detector packaging

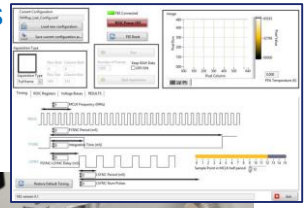
A versatile cryostat

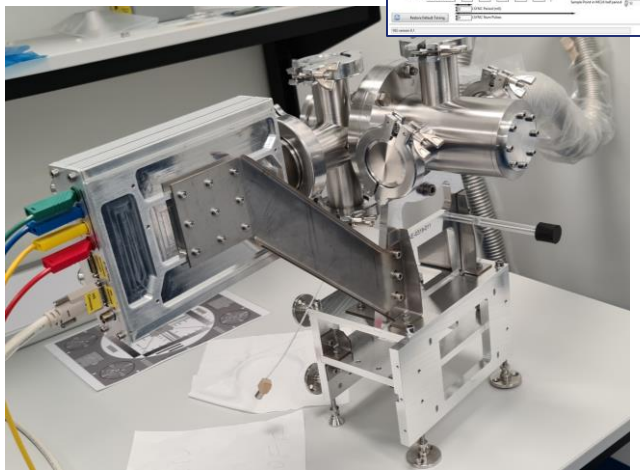
- Used for fine E-O tests
- Compatible with System demonstration at NEO



A complete Video Acquisition System

- 4 video chains with 18 bits ADC,
- FEE integrated inside the cryostat,
- Adjustable supply/biases and timing diagram
- Camera link interface





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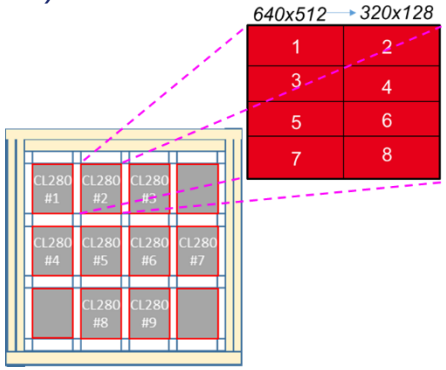
SWIR BAND : THE SWIRUP R&D PROJECT

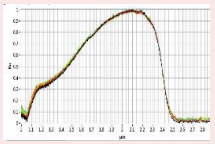
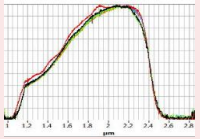
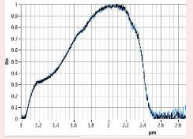
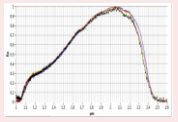
/// HgCdTe P/N results : use of a common ROIC (640 x 512 – 15 µm pitch)

- Different technology variants have been tested on 3 wafers (doping level) and 8 variants per array (≠ diode geometries)



	1	2	3	4	5	6	7	8
P-box size	STD	STD	STD	STD	H	H++	H	H+
MET size	H	L	H	L	L	L	L	L
Inter-pixel passivation	WO	WO	W	W	WO	WO	W	WO

- Cut off wavelength in the target

Wafer	3614		3615			3616		3617
Die	C02	N08	C02	N08	V02	N09	C02	N08
Cut-off (µm)	**2.39**	**2.39**	**2.41**	**2.40**	**2.39**	**2.39**	**2.395**	**2.35**
curves								

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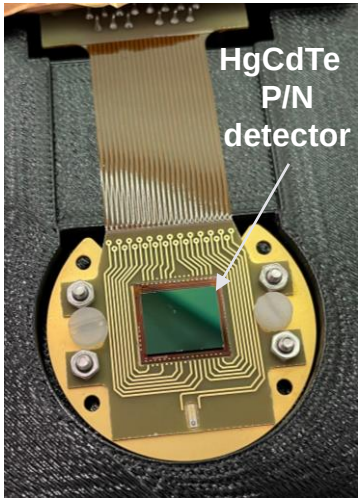
SWIR BAND : THE SWIRUP R&D PROJECT

/// HgCdTe P/N results : use of a common ROIC (640 x 512 – 15 µm pitch)

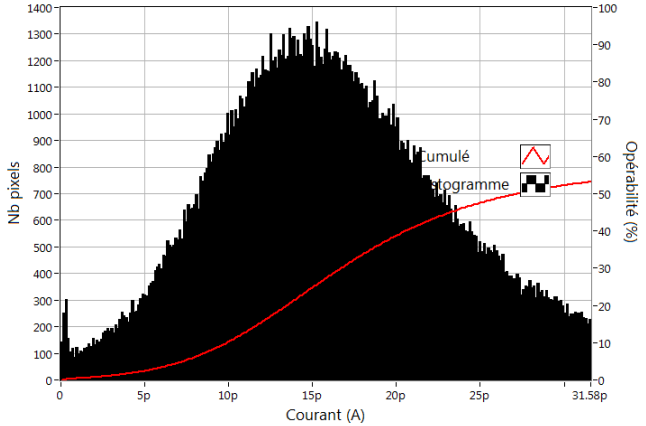
- Batch affected by inter pixels leakages due to a defective on top passivation ➔ crosstalk between pixels

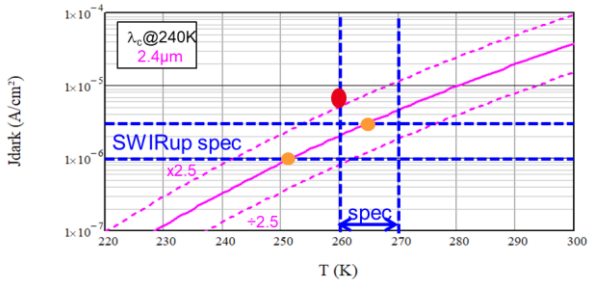


Dark current density at 260 K :
5.10^{-6}A/cm²
close to program specification :
< 3.10^{-6} A/cm²

Dispersion (DSNU): 41%

Qe on test chip > 80 %





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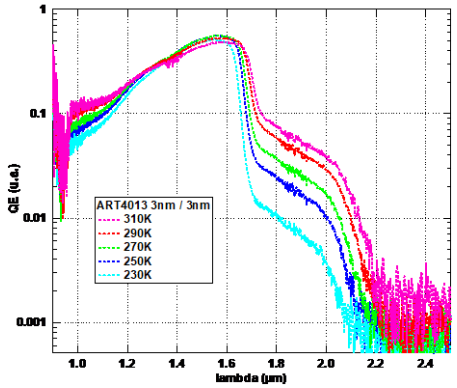
SWIR BAND : THE SWIRUP R&D PROJECT

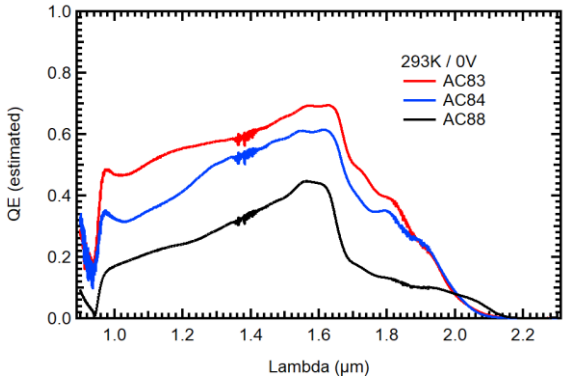
/// III V T2SL technology: developed in Jean Luc REVERCHON dedicated paper

- Different technology variants obtained in different steps, but no hybrid realized during the time allocated to the program

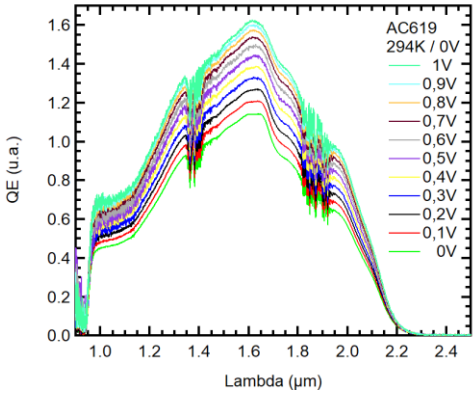
Exploratory batch at the beginning



Improved batch
Introduction of InAs & Strain compensation



Optimized batch at the end of the program



Considering acceptable Qe and dark current spec, this technology is difficult to promote for space at λ >2,1 µm

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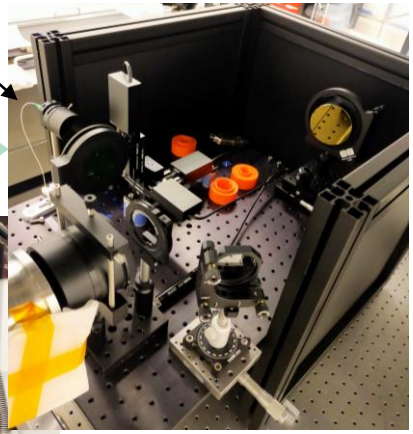
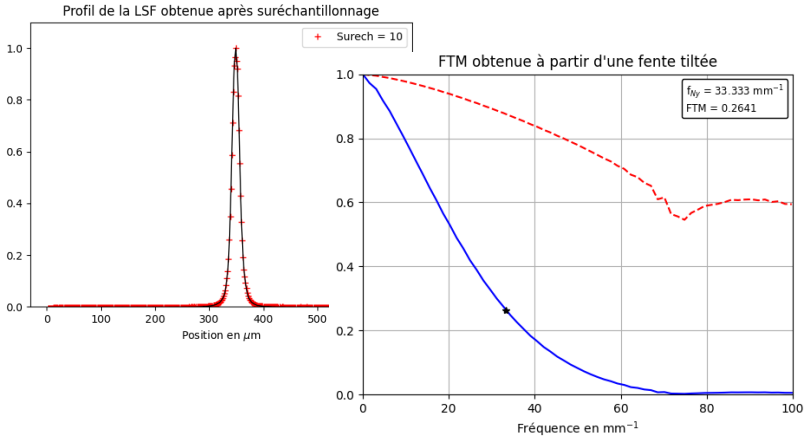
SWIR BAND : THE SWIRUP R&D PROJECT

/// SWIR MTF test bench developed by TAS : global measurement method

Laser source: 3 wavelengths



Example at λ= **1632 nm on SNAKE detector**



$$FTM_{pixel} = \frac{FTM_{Measured}}{FTM_{optic}} = \frac{0.2552}{0.567} = 0.45$$

- At 1632 nm, MTF = 0,45 to 0,466
- At 1309 nm, MTF = 0,6

In line with published SNAKE characteristics

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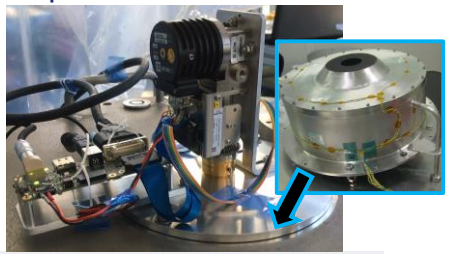
HIGH RESOLUTION EARTH OBSERVATION : IR CHANNELS

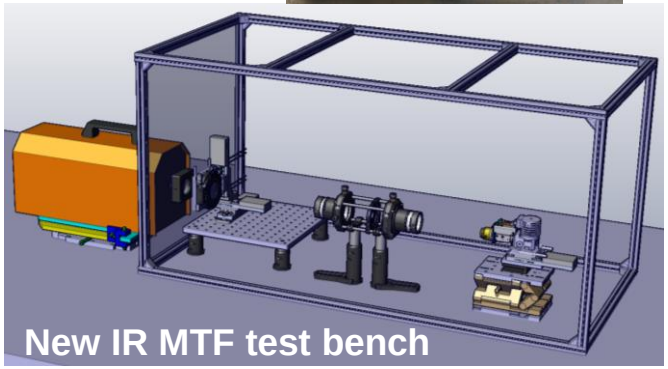
/// The current generation is mature (TRL9): first model in orbit since 2018,

/// The new generation is under preparation since a few years with a lot of innovations through R&D and pre-developpement actions:

- Some technological breakdown on cooling system : more cryogenic power, less power consumption, no micro-vibration in the sensitive bandwidth ➔ simplification of cooler drive electronics
- New generation of IR focal plane to increase resolution
  - More functions in the detector chip : up to the digitization,
  - Hot MCT technology for LWIR bands,
  - Low pitch, high TDI depth, large format for multi-spectral long linear array,
  - Focal plane with independent detector modules and FEE in close proximity,
  - Very compact FEE with HSSL optical outputs.
- TRL5 level planned in 2025 for the Detection Subsystem critical technologies
- At TAS: on–going characterisation on detectors with representative technologies
  - IR MTF test bench development: global measurement method
  - Electronic board design and development adapted to digital detectors

Very cooled BB for fine radiometric measurements as RTS, linearity, …





New IR MTF test bench

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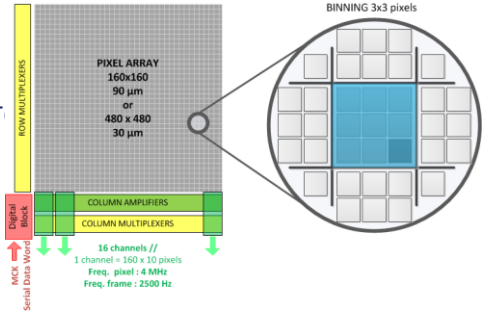
OTHER DEVELOPMENTS IN MWIR TO VLWIR: MTG IRS INSTRUMENT

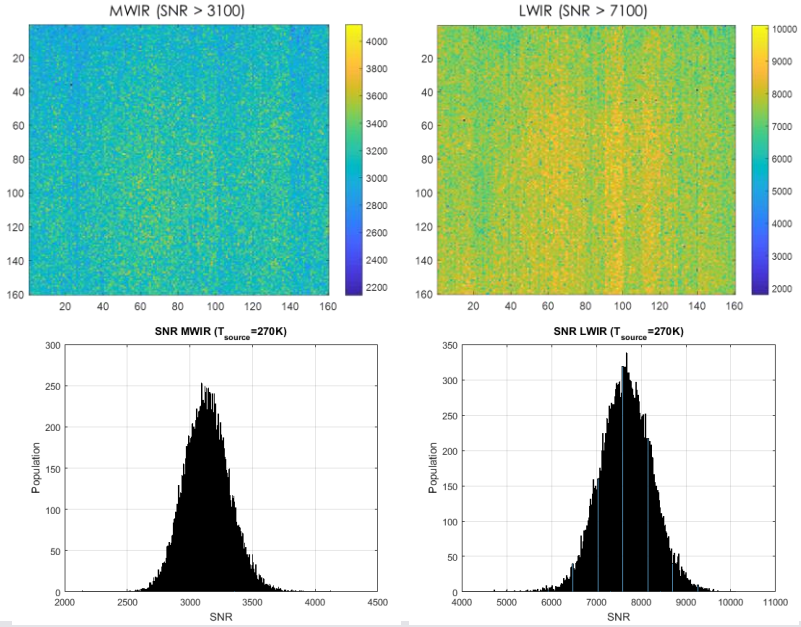
/// MTG IRS Detection Subsystem developed and tested by TAS

- 160 x 160 macro pixels for both MWIR and VLWIR 2D arrays : Lynred detector assemblies, developed for MT
- FEE+VAE with 32 video chains (16 bits - 4 Mhz) for the 2 detectors : TAS equipments
- TAS Cryostat with LPTC coolers from ALAT



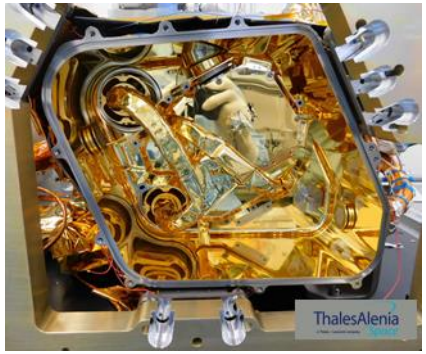
/// PFM and FM2 Detection Subsystem tested in 2022, with excellent results

- SNR @Tscene = 270 K without Non Uniformity Correction
- NeΔT compliant to requirement



/// PFM Detection Subsystem integrated in MTG IRS PFM, under test at instrument level

Cold box with 2 detectors



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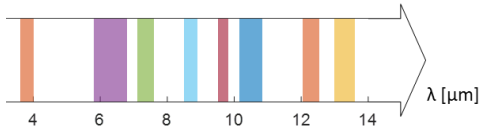
OTHER DEVELOPMENTS IN MWIR TO VLWIR: MTG FCI INSTRUMENT

/// MTG FCI IR Detection Subsystem developed, integrated and tested at instrument & satellite level

/// 3 IR detectors called IR1 to IR3, with 8 channels between 3.8 and 13.3 µm

- For each channel, linear array of 112 to 224 rhombus pixels (with 3 redundant columns).
- Cooled below 60 K
- One Front End Electronic per detector, and a common Video equipment.

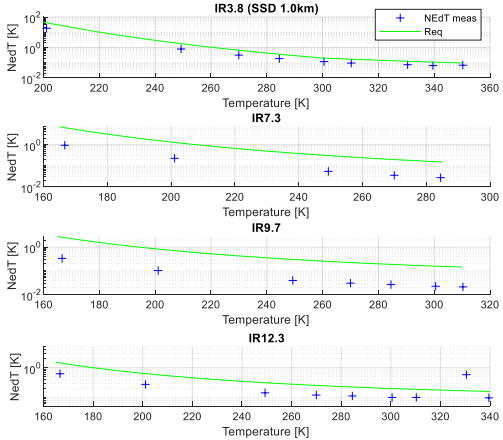


FCI IR channels

/// FCI PFM tested in 2021 with very good results

/// NEdT on a full disc image

- Performance verified, inside requirement
- NIR/IR TFPA driven by the IR3 channels NEdT (Noise dominated by dark current) ⇒ this leaves more margin for the other channels



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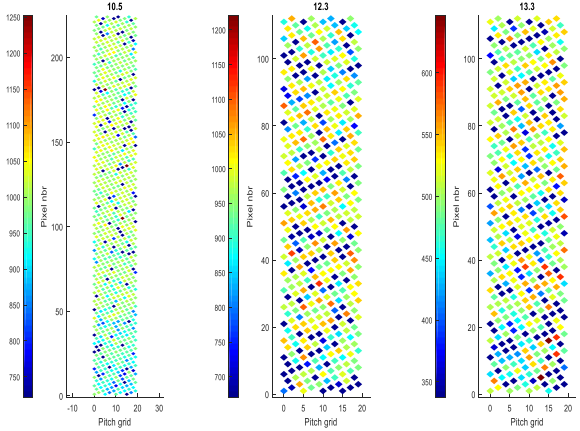
THALES ALENIA SPACE OPEN

ThalesAlenia Space
a Thales / Leonardo company

OTHER DEVELOPMENTS IN MWIR TO VLWIR: MTG FCI INSTRUMENT

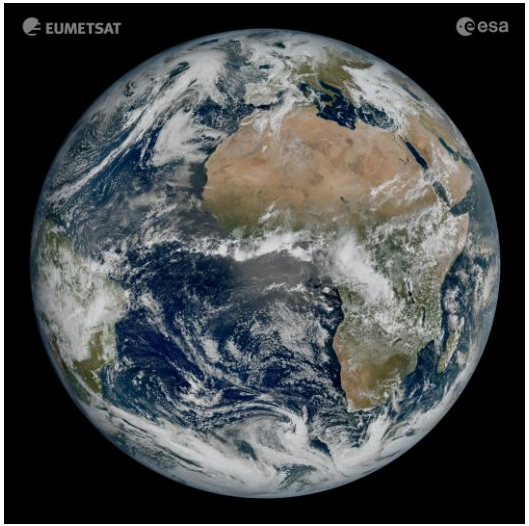
/// Cartography of SNR at Tref:

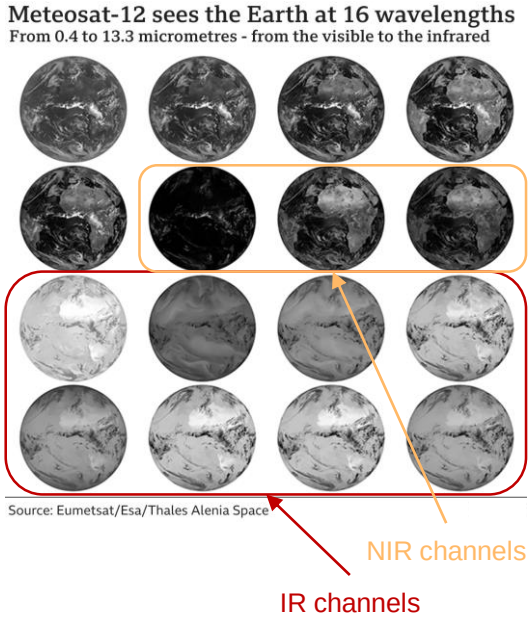
LWIR defects compensated by pixels redundancy, allowing 100% avalailability.



/// MTG-I1 satellite with FCI PFM in orbit since December 2022

→ **1st image** very satisfying in all bands





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CONCLUSIONS

/// The second generation of Thales Alenia Space IR instruments are in orbit since a few months for the most recent to several years for the oldest: recurrent models are still in preparation especially for MTG,

/// The new generation preparation of IR Detection Subsystem with solutions in technological breakdown has already started,

/// Acknowledgments to our different customers for their financial support and confidence in our successes

- CNES,
- DGA,
- ESA,
- EUMETSAT,
- The EUROPEAN COMMISSION,

/// **Thank you for your attention.**

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