

IRS Detector

The large infrared staring array for FTS MWIR up to VLWIR
space sounding applications

N. Jamin¹ & MTG IRS Detector team¹

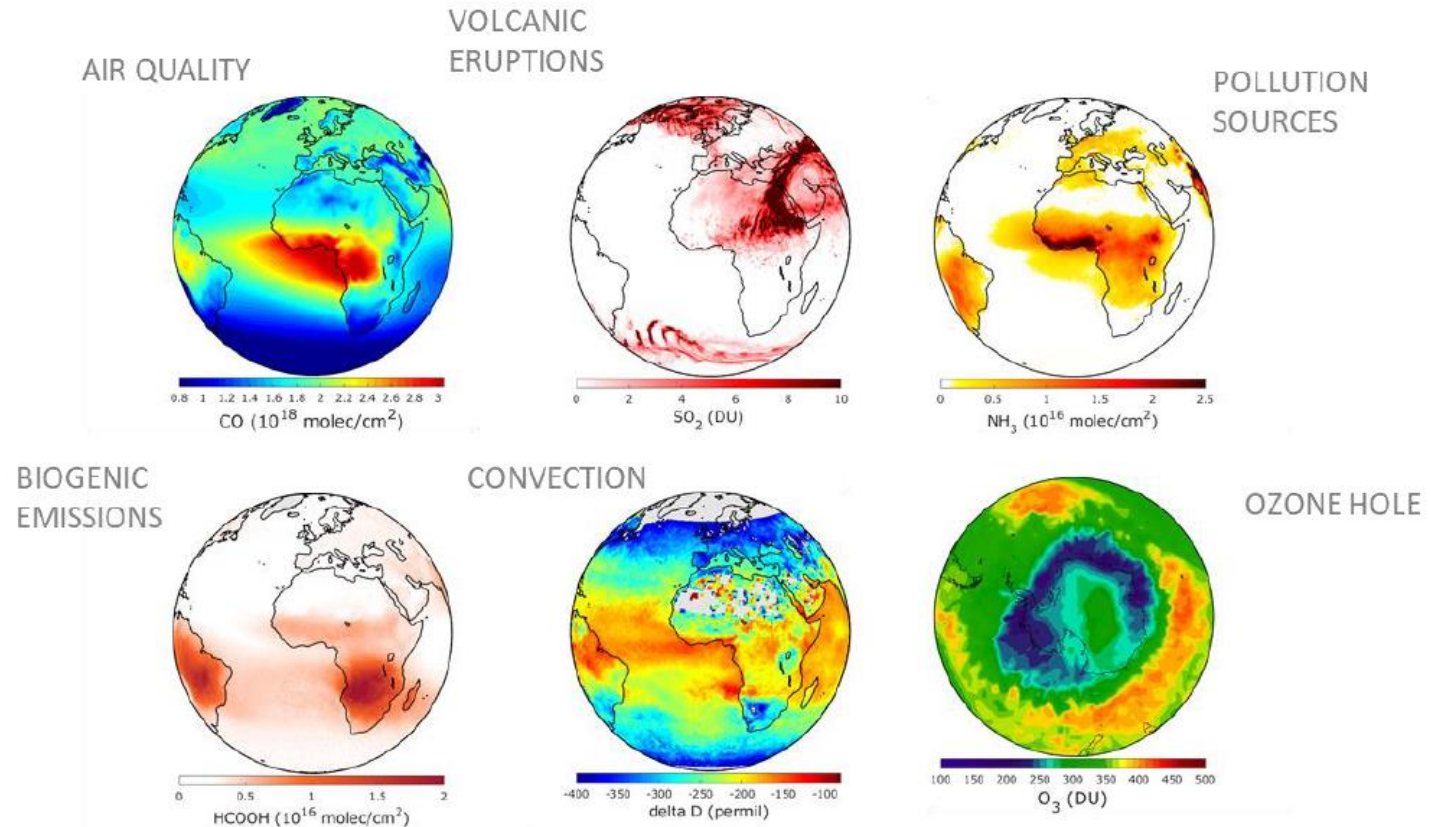
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CNES – COMET • Infrared detection for space applications Workshop • 7th – 9th June 2023



Why infrared sounding space instruments?

- ❑ **Goal: To monitor temperature, moisture and gas composition of earth surface and atmosphere**
- ❑ **2 main applications:**
 - Atmosphere chemistry
 - Meteorology
- ❑ **2 instrument concept families:**
 - Dispersive spectrometers (DS)
 - Fourier Transform Spectrometers (FTS)



Courtesy - P. Coheur (ULB - LATMOS) - GTEO Air-Atmosphère - Nov. 2020



Focus on FTS sounding instruments

Two generations of FTS :

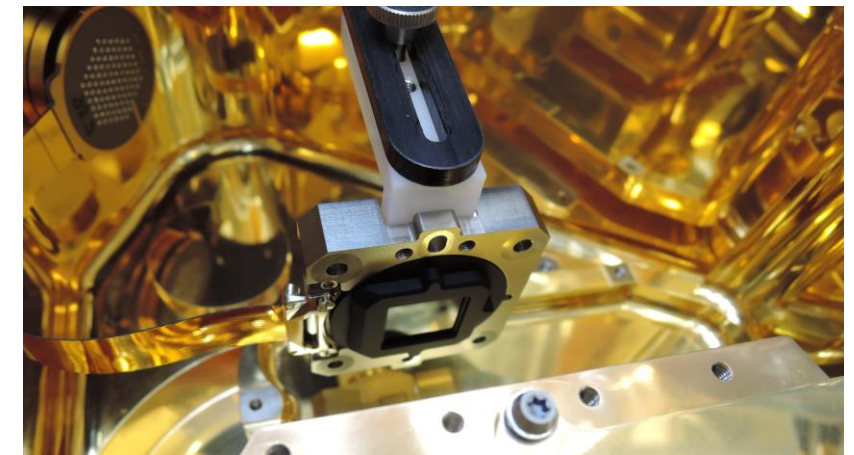
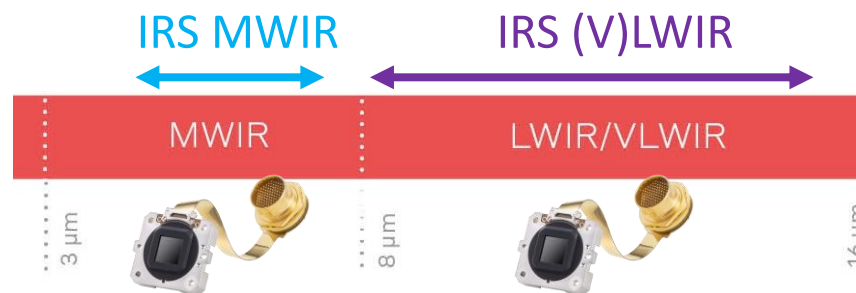
FTS sounding instruments	Orbit	SSD	Detector Format	Examples
1 st generation	LEO	12-14km	From 2 x 2 up to 4 x 4 pixels	IASI, CrIS, IASI NG
2 nd generation	GEO	4km	480 x 480 pixels	MTG IRS



Artist impression of MTG-S satellite, courtesy EUMETSAT

Increase of SSD has required increase of detector format for FTS applications

- Fundamental purpose of IRS detector(s) developed in the scope of MTG program (ESA/EUMETSAT) with TAS as prime



IRS detector integrated in cold box, courtesy Thales Alenia Space

IRS Detector

1. Design & Interfaces

2. Environment robustness

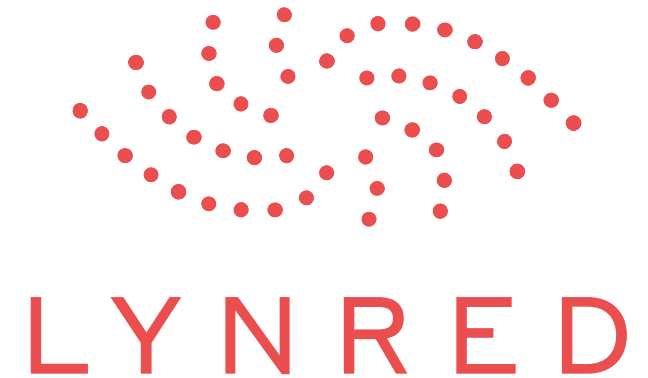


3. Performance

4. Beyond the design limits



IRS Detector



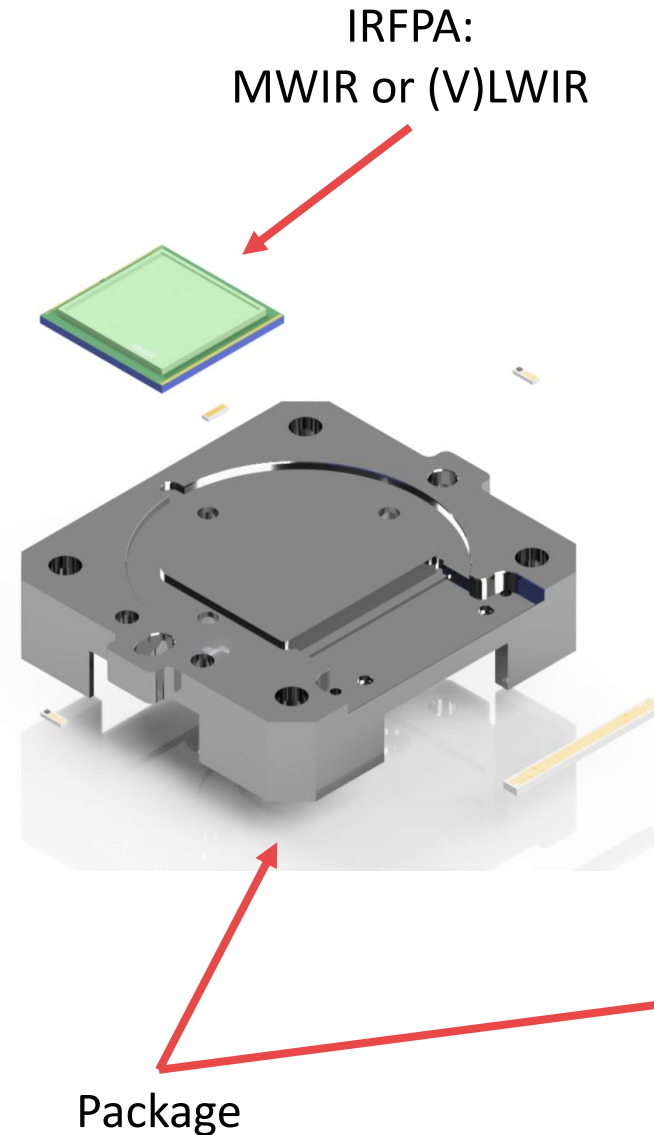
1. Design & Interfaces



IRS Detector(s) Architecture

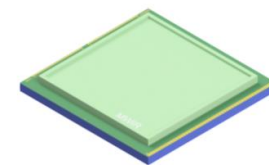
- ❑ 2 available configurations → MWIR or (V)LWIR based on 2 main sub-assemblies:

- IRFPA → Specific for each configuration but with a common ROIC
- Package (Baseplate and Interconnection) → Common for both configuration



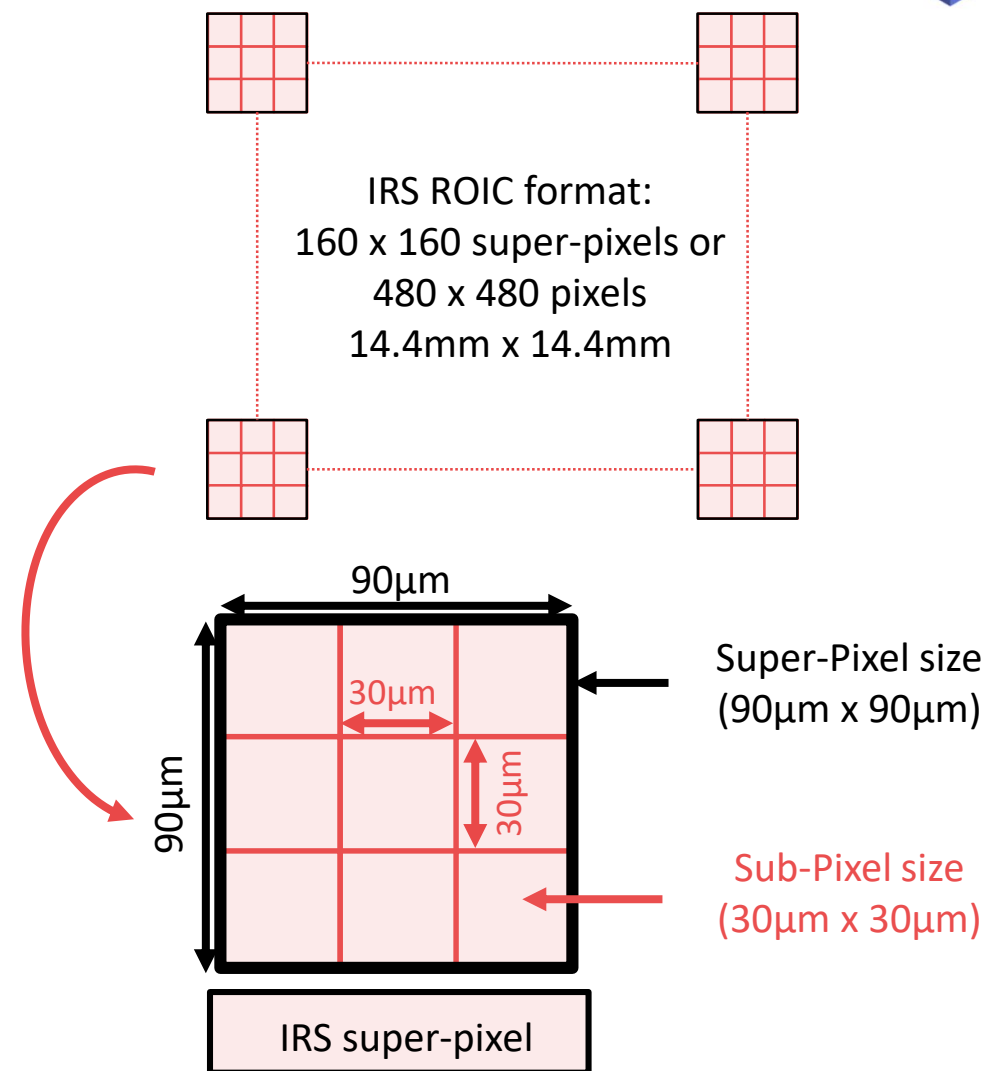


Focus on IRS Detector IRFPAs: MWIR and (V)LWIR

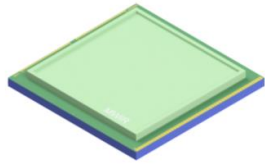


IRS ROIC main characteristics

- Modes & Format
 - Normal Mode: 160 x 160 super-pixels
 - Imager Mode: 480 x 480 pixels
- Snapshot integration type (IWR & ITR mode)
- Nominal Frame rate: 2.4 kHz in Normal Mode
 - 16 analog outputs
- High dynamic range with 2 available gains/CHC:
 - Gain 1: ≈ 37 Me-
 - Gain 2: ≈ 520 Me-
- Skimming function
- On-chip binning and sub-pixel deselection function to optimize operability

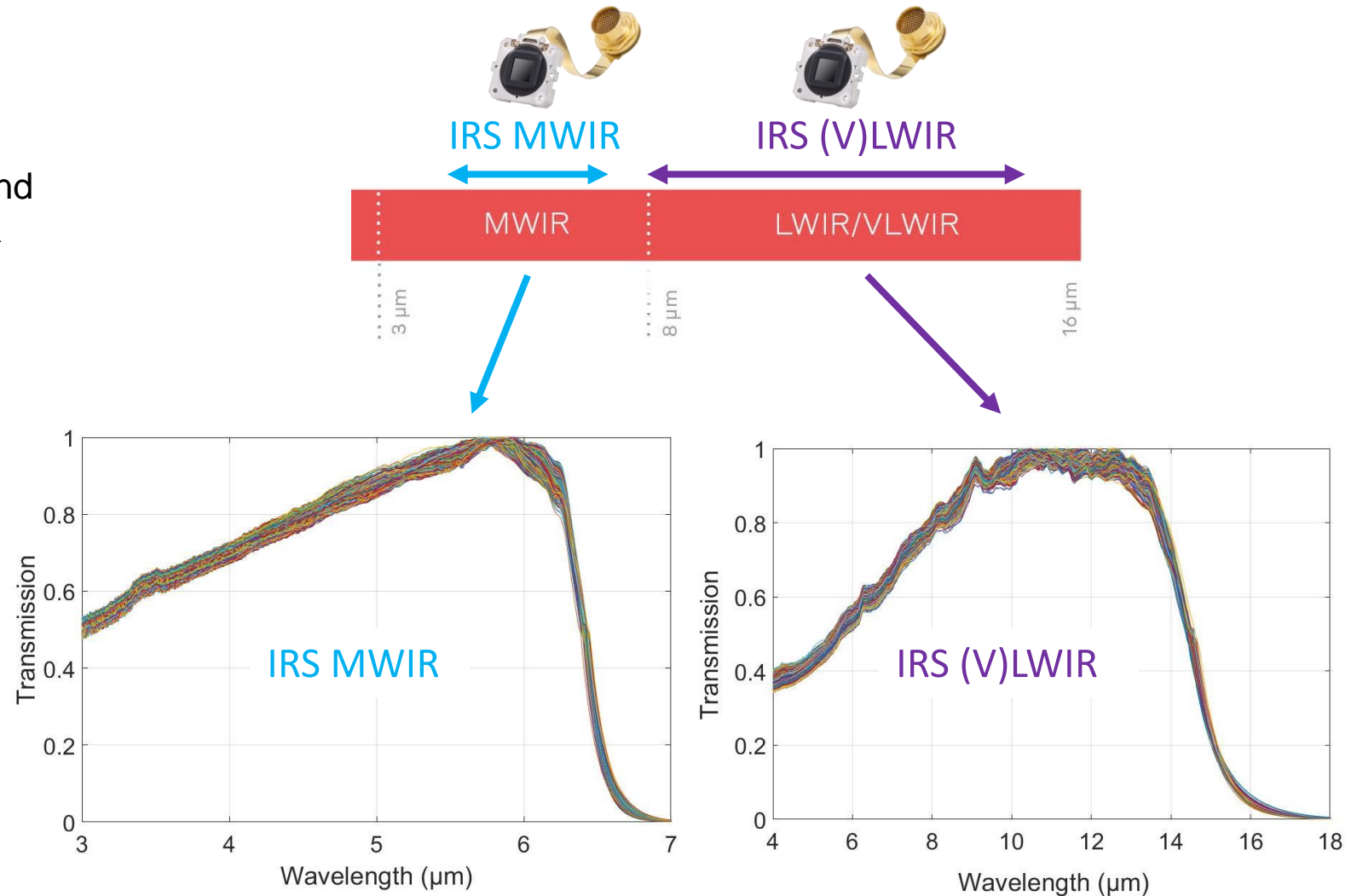


Focus on IRS Detector IRFPAs: MWIR and (V)LWIR



❑ MWIR & (V)LWIR Detection Circuit main characteristics

- FPA temperature: [55-57K]
 - Driven by (V)LWIR detector and adjustable depending on SNR requirements
- n-on-p photodiode technology
- Spectral bands:
 - MWIR: 4.44 – 6.25 μm
 - (V)LWIR: 8 – 14.5 μm
 - Adjustable thanks to HgCdTe material cut-off wavelength tuning



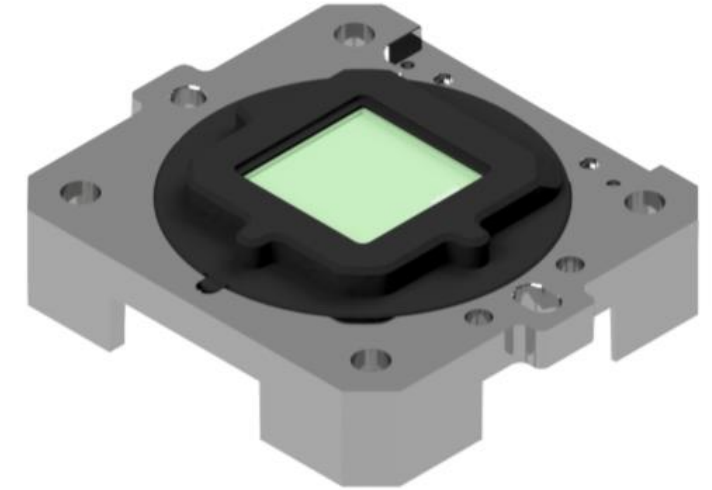


Focus on IRS Detector Package & Flex/Connector



❑ Package main characteristics

- Common open package design for both MWIR & (V)LWIR IRS detector
- Cold shield in order to limit parasitic fluxes and to protect wire bonding area
- High precision IRFPA positioning $< 10\mu\text{m}$
- Interconnection ceramic between ROIC and flex/connector sub-assembly
- Thermal sensors



❑ Flex/Connector main characteristics

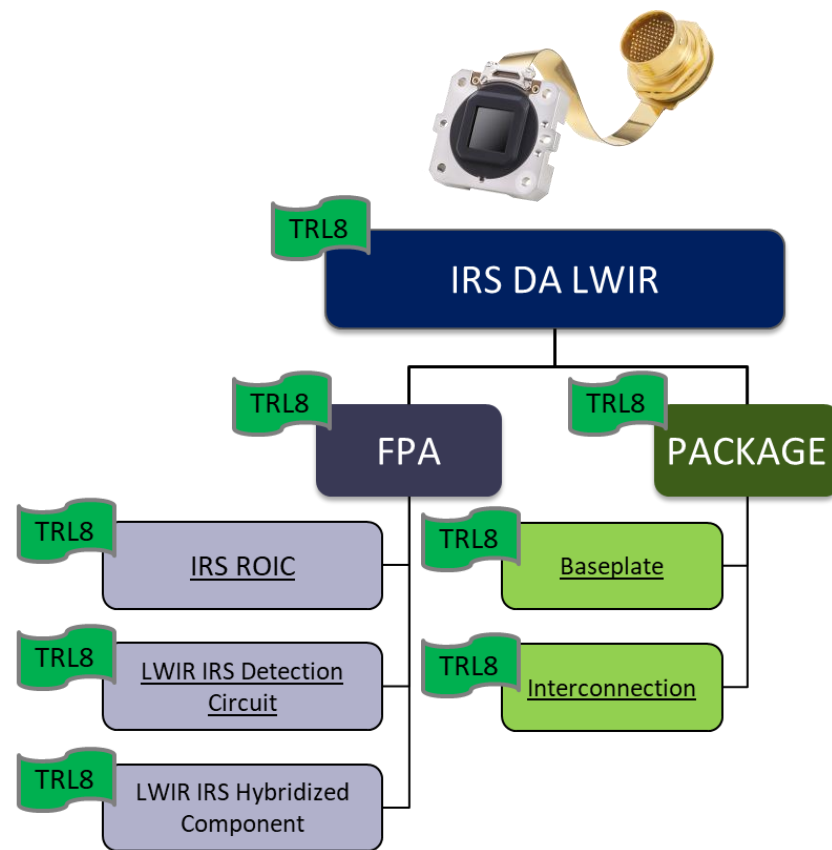
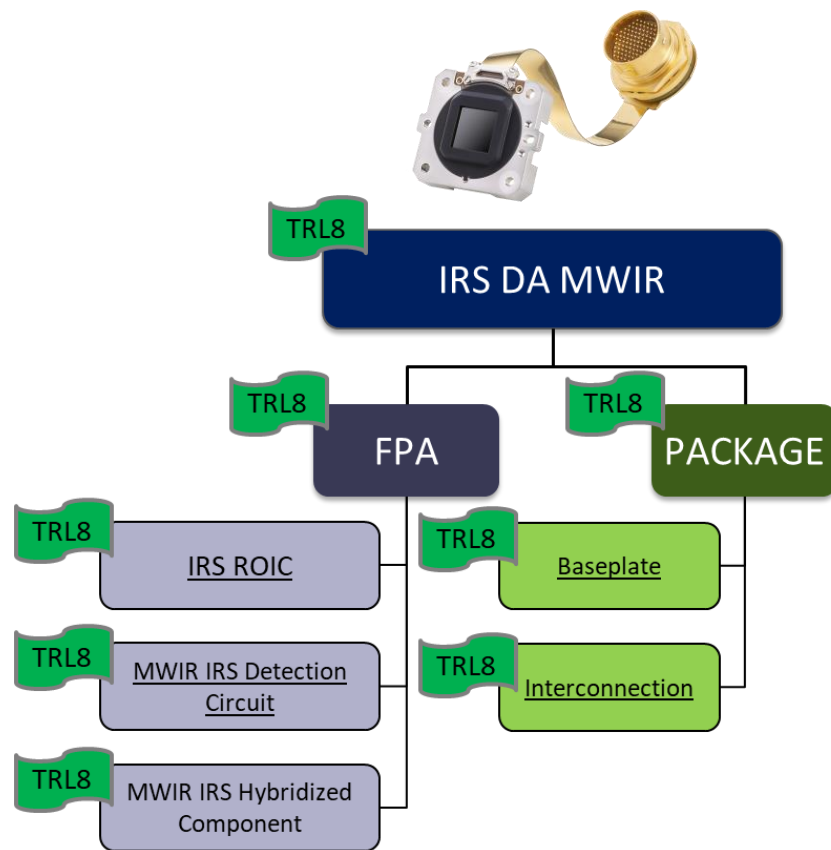
- Specific flex design:
 - Low emissivity/conductivity for thermal losses optimization (radiative and conductive)
 - High electrical signal integrity (required due to low ROIC noise performance)
- Standard 91 points connector





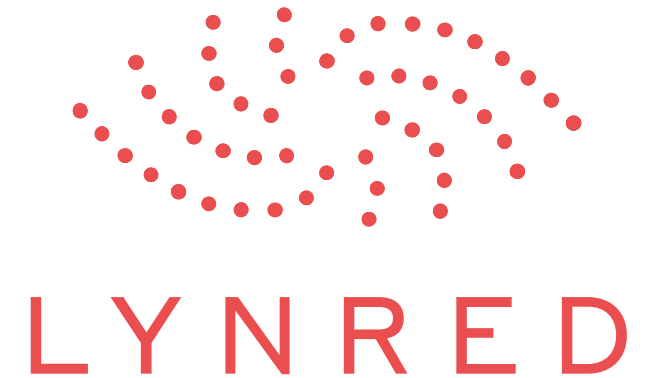
PBS IRS & TRL assessment

- IRS detector flight qualified → TRL8





IRS Detector



2. Environment robustness



Environment Robustness

❑ IRS flight qualified and no failure has been observed considering for:

■ Thermal Environment:

- Up to 225 thermal cycles between cold and ambient temperature
- Moisture: 2500h, 60%, 25°C
- Storage Environment: ~ 15 years, ambient temperature, under vacuum or dry nitrogen

■ Mechanical Environment:

- Sine vibrations:

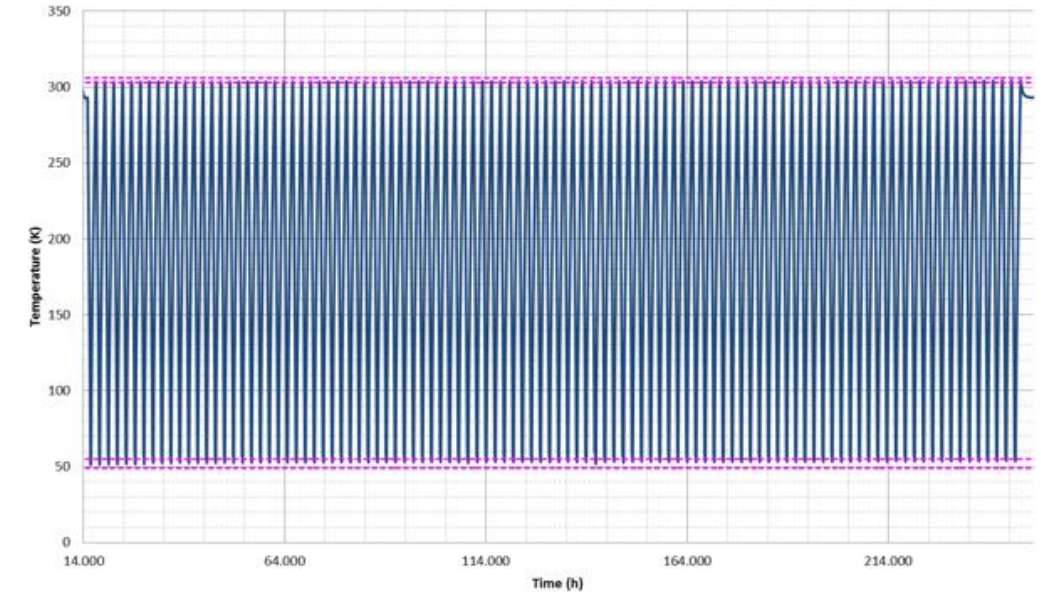
Frequency	Qualifications
5 to 25 Hz	± 20 mm
25 to 100 Hz	50 g

- Random vibrations: Up to ≈ 45 gRMS

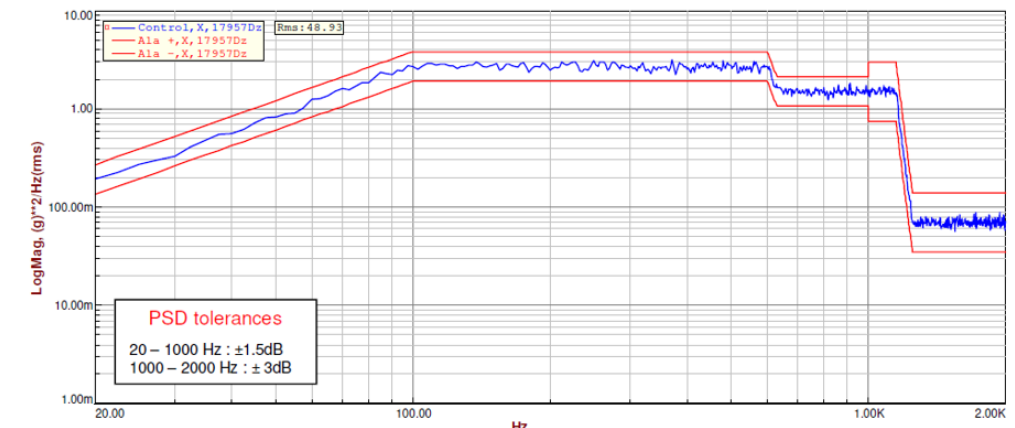
- Shocks:

Frequency (Hz)	SRC Level (Q=10)
100	5g
1000	200g
10000	200g

Thermal cycles



Random vibrations



Environment Robustness

❑ IRS flight qualified and no failure has been observed considering for:

■ Electrical Environment:

- ESD class: 3B (> 8 kV)
- Life-test: ~ 9 years ON operating
- On-Off: > 6400 on-off cycles

■ Radiation environment

- TID: up to 28 krad
- TNID: up to $5,2 \cdot 10^{10}$ protons/cm² @41.6 MeV
- SEE robustness: SEL free up to 62 MeV.cm²/mg @ room temperature / Low SEU & SEFI rate

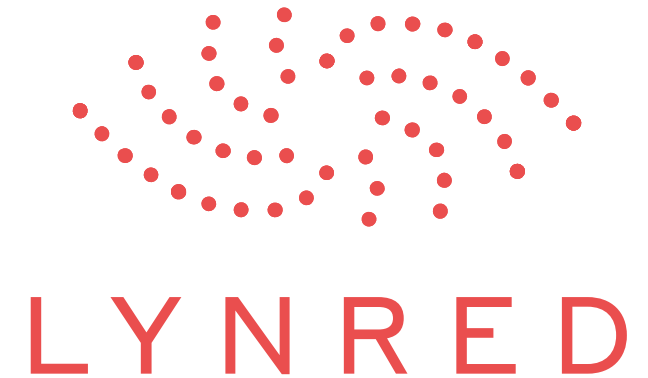
→ Heritage of space proven technologies (MCT, ROIC... building blocks) confirmed



IRS Detector

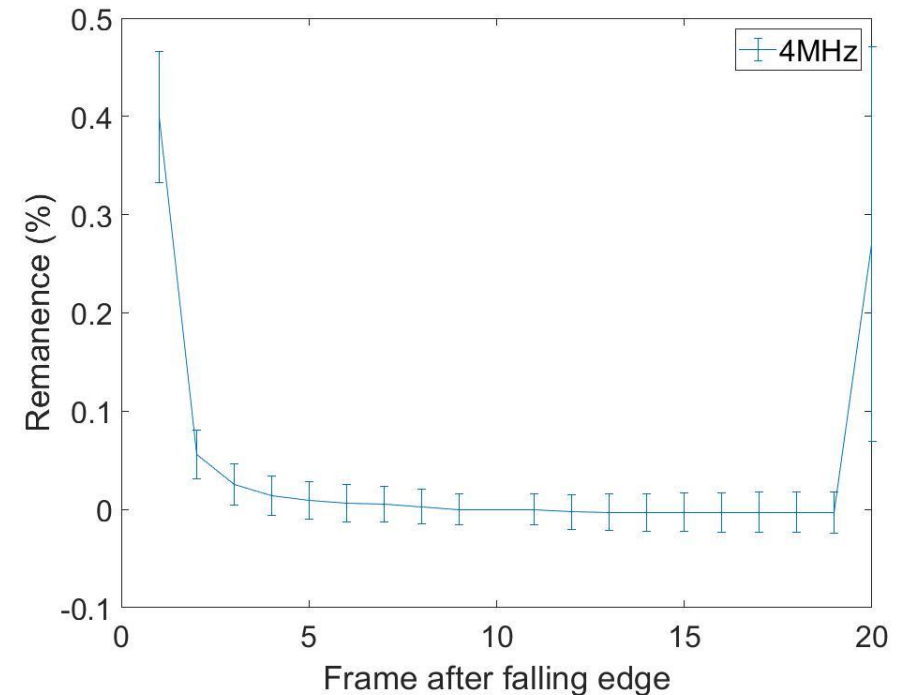


3. Performance



IRS ROIC Performance

- ❑ **Power dissipation : $\approx 100\text{-}110$ mW in Normal mode @4 MHz**
- ❑ **Readout Noise : $\approx 95\text{-}100\mu\text{V}$ RMS leading to around**
 - 1900 e- for Gain 1
 - 16900 e- for Gain 2
- ❑ **Temporal lag (Measured with $T_{\text{int}}/T_{\text{frame}}$ ratio adjustment over a total of 40 frames)**
 - $< 0.5\%$ for Frame $n + 1$
 - $< 0.1\%$ for Frame $n + 2$



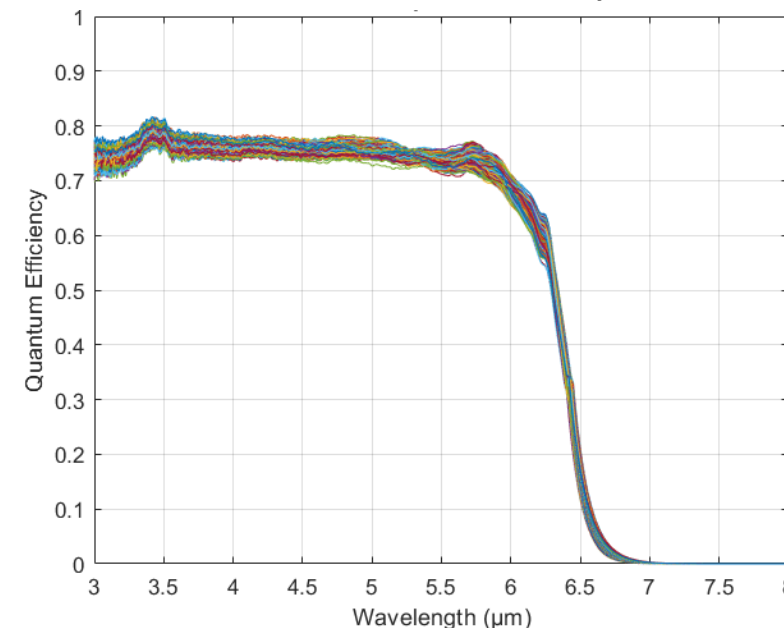


IRS MWIR Detection Circuit Performance

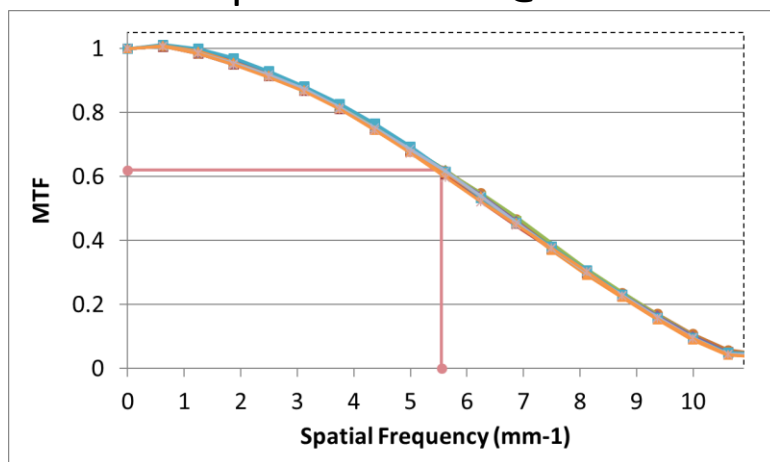
□ Typical performance

- **High Detection efficiency plateau > 0.75** →
- Dark current → Negligible considering VLWIR operating temperature
- **Very low PRNU $< 2\%$**
 - Low spectral response dispersion due to very good uniformity (material quality)
- **High MTF $> 0.62-0.63$ @Nyquist**

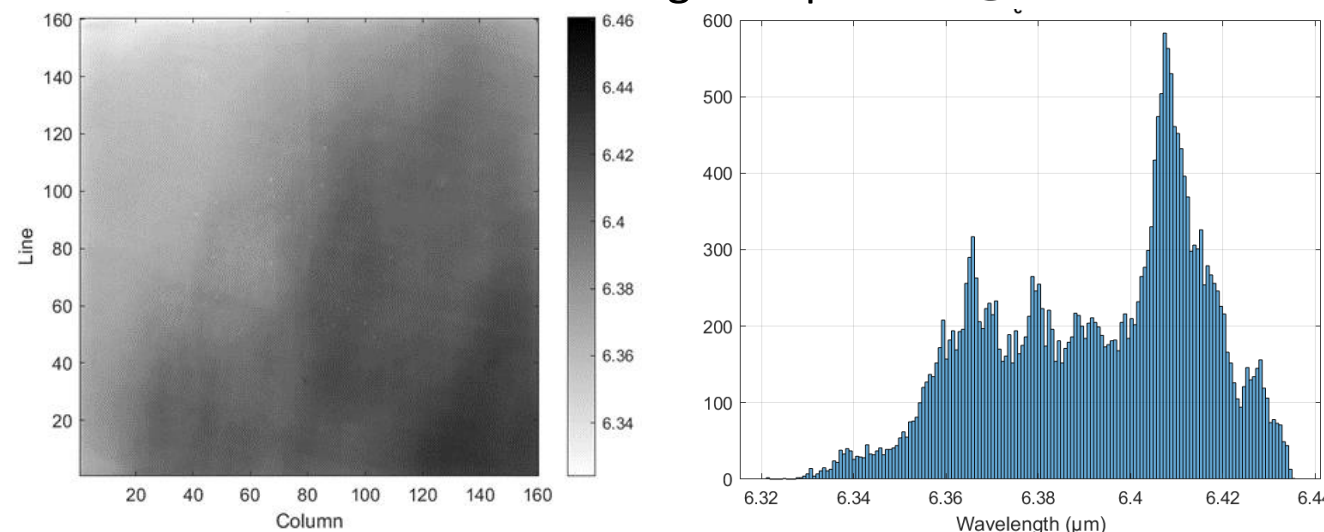
MWIR Detection efficiency @56.5K



MTF performance @56.5K



MWIR cut-off wavelength dispersion @56.5K



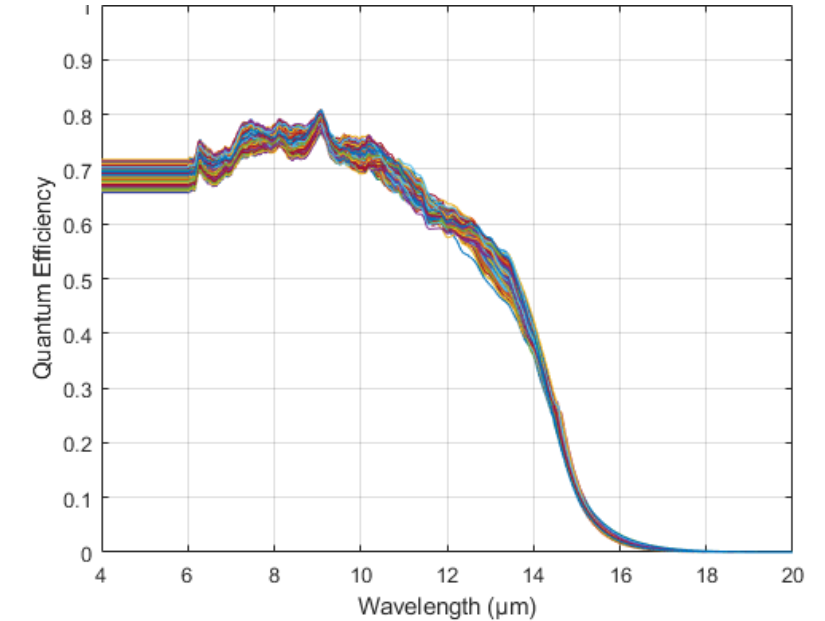


IRS VLWIR Detection Circuit Performance

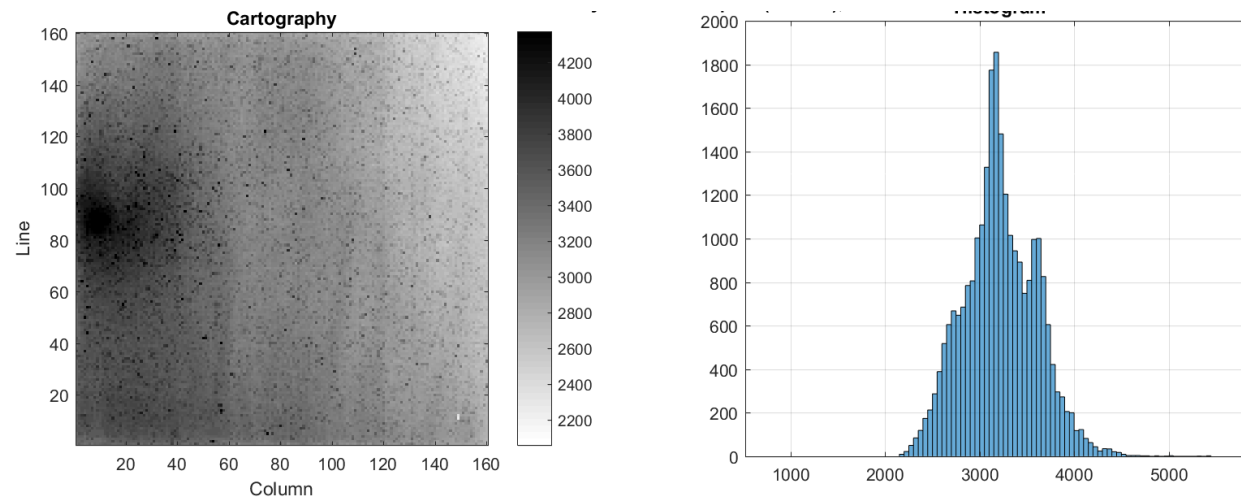
□ Typical performance

- High Detection efficiency plateau $> 0.7-0.75$ →
- High MTF $> 0.62-0.63$ (comparable to MWIR Detection Circuit)
- Reproducible Dark current density → [2500-6000] fA/ μm^2 (DSNU: $\approx 8 - 12\%$) for T_{fpa} [55K;57K]

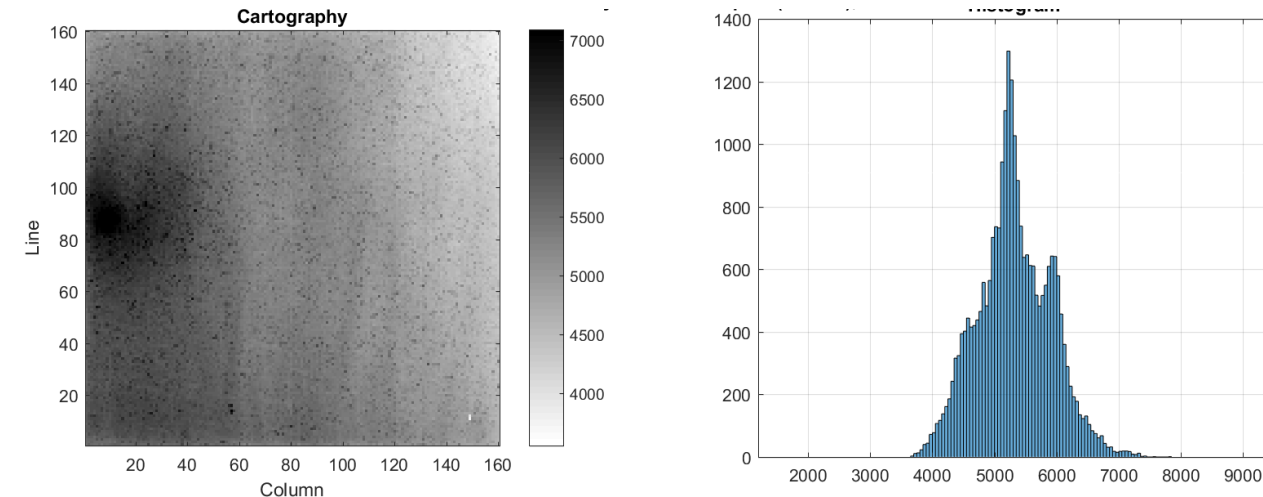
(V)LWIR Detection efficiency @56.5K



Dark current density (fA/ μm^2) @54.5K



Dark current density (fA/ μm^2) @56.5K





IRS VLWIR Detection Circuit Performance

□ Typical performance

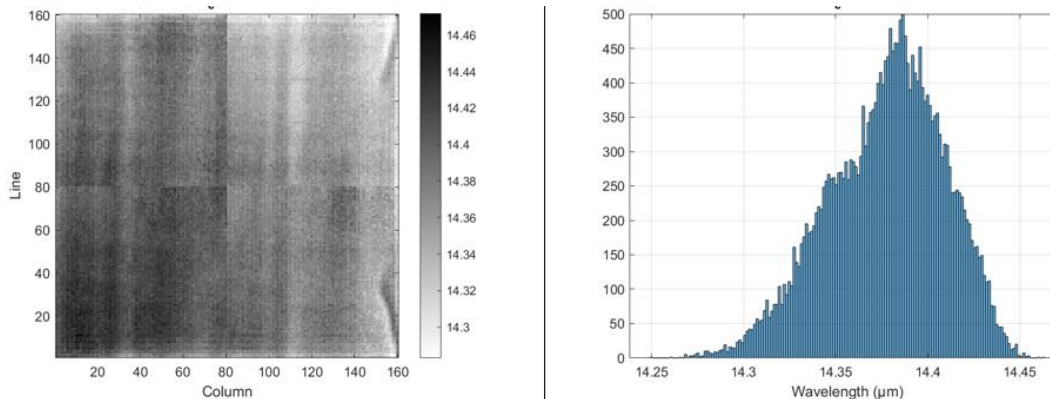
- Outstanding material quality for VLWIR range (cut-off wavelength around $14.5\mu\text{m}$ @ 55K)



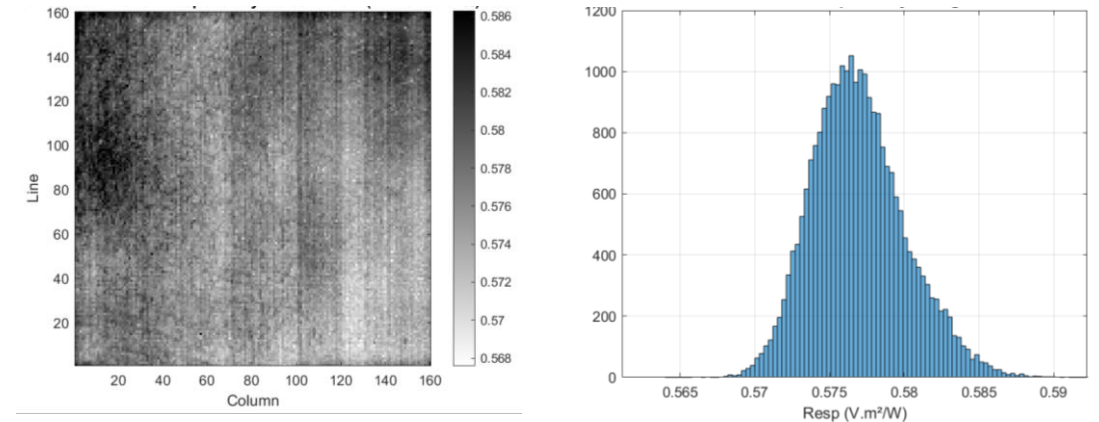
Very low spectral response dispersion $< 0.2\mu\text{m}$ P-P

Very low PRNU $< [0.5 - 2\%]$

(V)LWIR cut-off wavelength dispersion @56.5K



(V)LWIR Responsivity

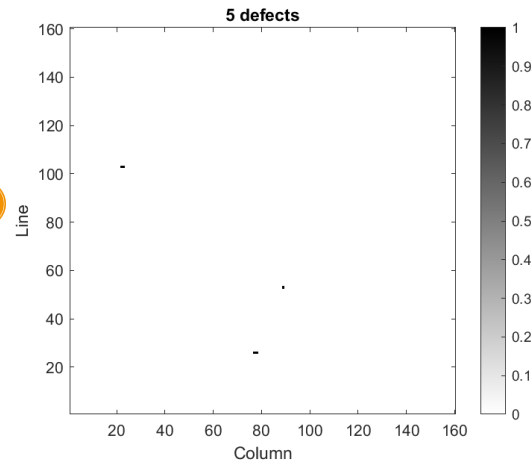




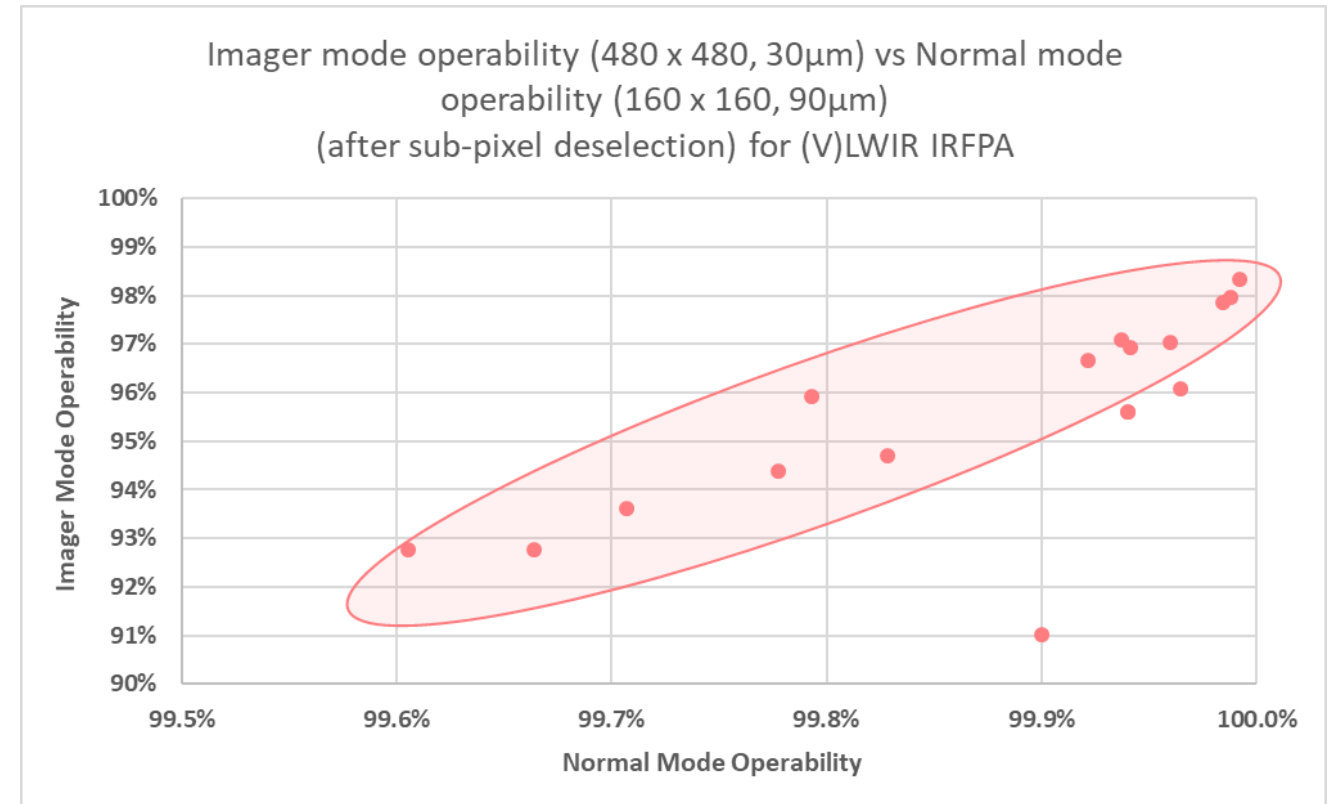
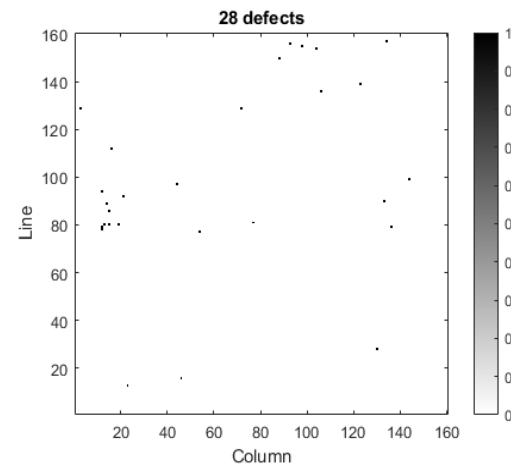
IRS MWIR & (V)LWIR IRFPAs Performance

- Outstanding Operability for both MWIR & (V)LWIR DA > 99.5% for all FMs

MWIR DA

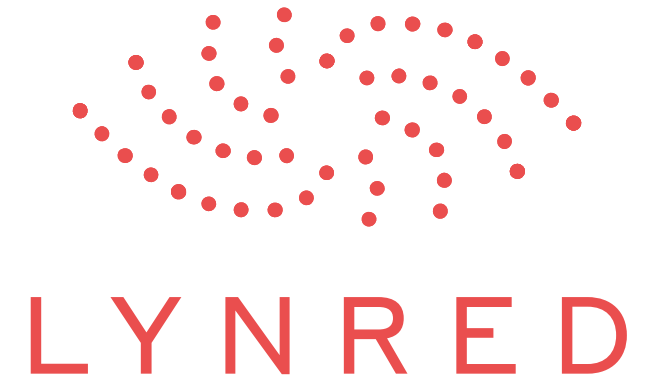


(V)LWIR DA





IRS Detector



4. Beyond the design limits



IRS latest characterizations (Higher Frame rate)

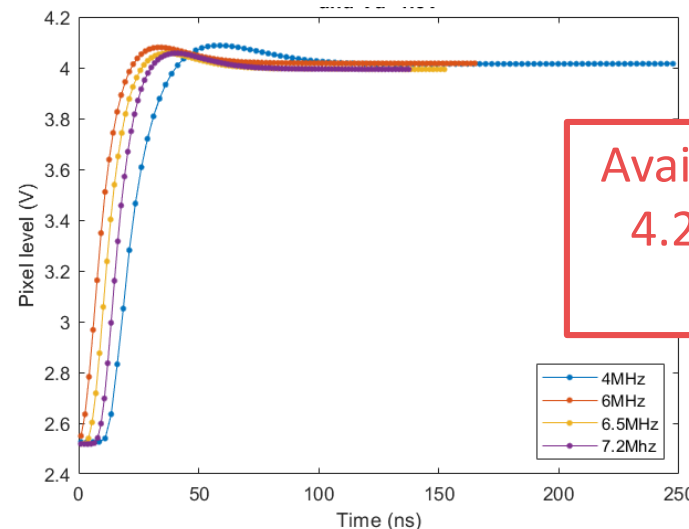
❑ Context: CAIRT Phase 0

❑ Objective: Measurements of IRS detector at higher frame rate, i.e. higher Masterclock (MCLK) frequency → 6.5 & 7.2 MHz compared to 4 MHz (reference)

No unexpected delta of radiometric performance at higher frame rate

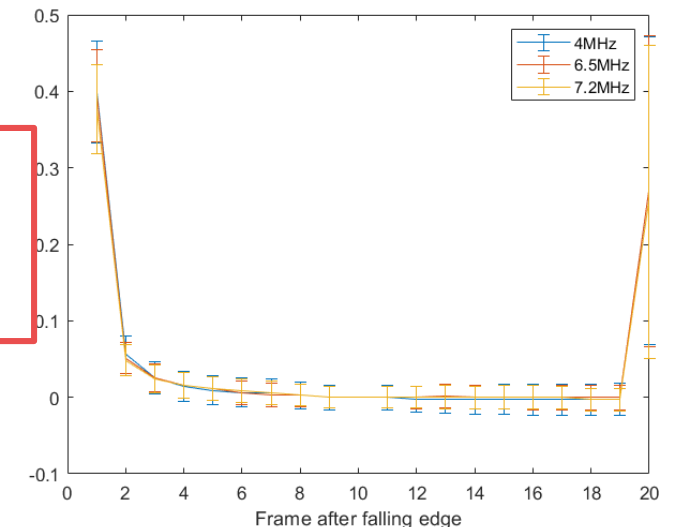
- ROIC noise, Linearity vs Flux, Responsivity and PRNU
- SNR @Emin, @Eref, @Emax & Operability based on SNR defects criteria
- Temporal lag

Settling time measurements vs MCLK frequency
(4, 6, 6.5 & 7.2 MHz)



Available operation up to 4.2 kHz (frame period) confirmed

Temporal lag vs MCLK frequency
(4, 6.5 & 7.2 MHz)





Conclusion & Perspectives

- ❑ IRS detector is now space qualified and available for future next infrared sounding missions
- ❑ **State of the art VLWIR technology (up to $\approx 14.5\mu\text{m}$ @55K)**
 - High QE, High MTF, High Operability on Large FPA (14.4 x 14.4mm)
- ❑ **What next? Alternative operating points and configurations can be considered (either higher frame rate or different packaging concept)**
 - For example → Alternative IDDCA configuration



Today
("Passive configuration")



(In collaboration with
Absolut System)

Tomorrow
("Active" configuration high reliability cryocooler > 60 000h)



Acknowledgements

❑ To all LYNRED teams/people dedicated to MTG IRS detector development

❑ MTG IRS program teams including LYNRED and all MTG industrial chain



❑ CAIRT phase 0 teams including LYNRED and ESA

LYNRED

THANK YOU
FOR YOUR ATTENTION

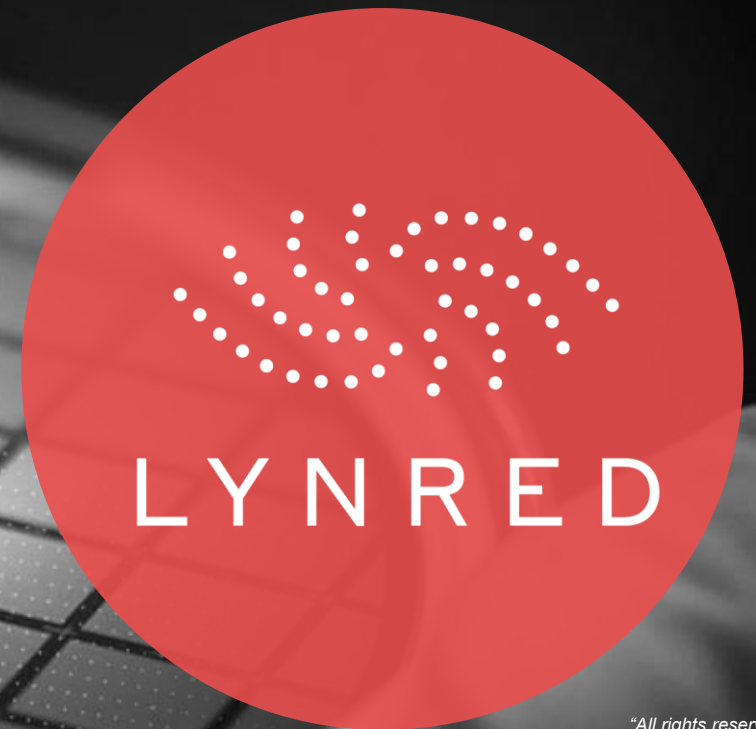
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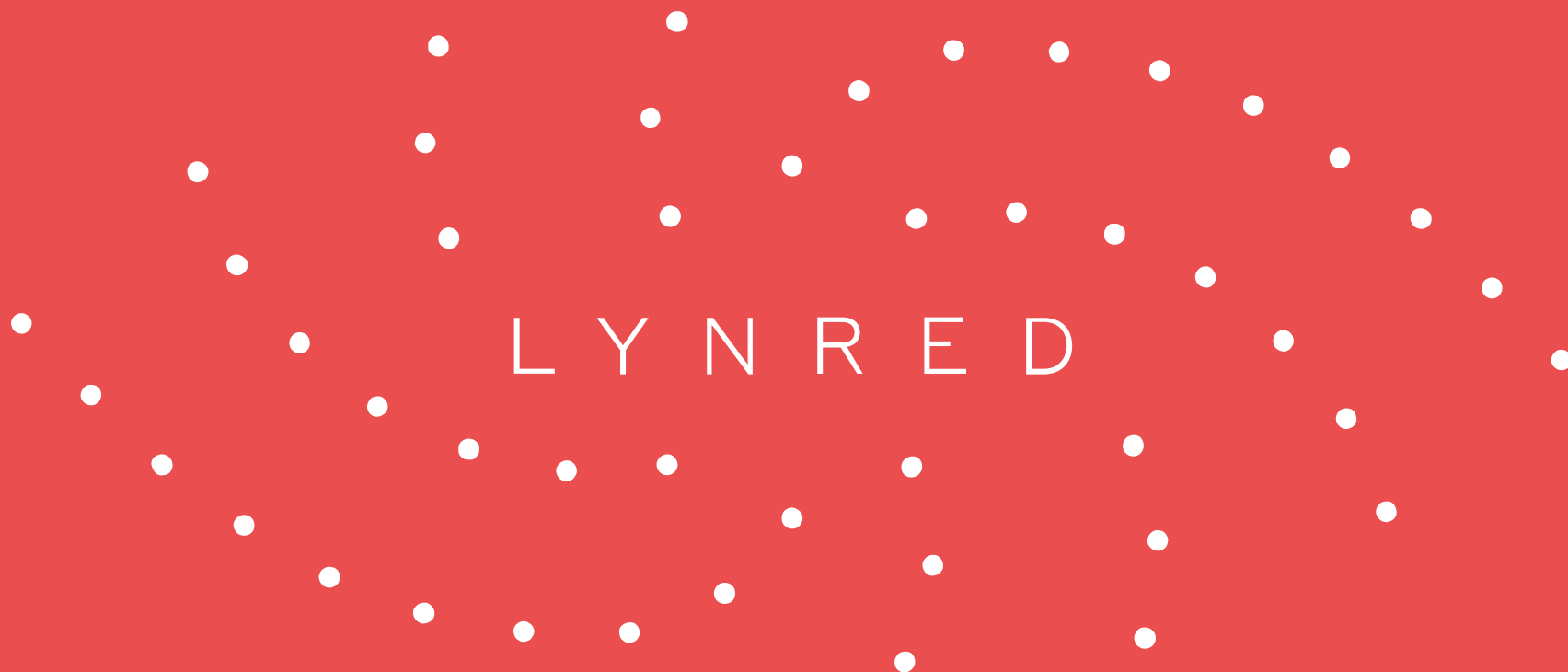
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