



Anthology of spatio-temporal artefacts in infrared sensors

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Infrared detection for space application
7th-9th June 2023

TLASFR-23-00040501_000



Thales assessments of IR sensors

During the last decade, we have been monitoring the infrared imager market for Thales needs by conducting extended electro-optical characterisations of more than 35 sensors. The panel of sensors includes:

- SWIR, MWIR blue band, MWIR, LWIR and VLWIR
- 14 different materials / technologies
- Resolution from QVGA up to multi-millions pixels
- Manufacturers from EU, US and Asia

A standard characterisation span over 3-4 months during which we focus on the radiometric, image quality, climatic/cryogenics and specific functions.

- The evaluations are mainly done in Thales labs, but can also be done at the manufacturer facility.

This presentation only focus on the correlated defects, either along the FPA (spatial crosstalk) or/and along the time (temporal crosstalk) on quantum sensors

■ Introduction

■ Spatial cross-talk (blooming-like effect)

- Horizontal
- Vertical

■ Temporal cross-talk (latency)

- Short term
- Long term

■ Spatio-temporal artefacts

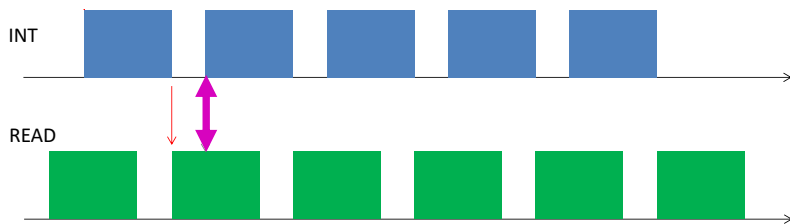
- Microphony
- Local pattern defect

■ Summary

Spatial cross-talk (blooming-like effect)

Vertical cross-talk in IWR mode

- On the row corresponding to the overlap of the INTEGRATION of frame N+1 and the READ of frame N



- Transfert of signal all along the column with the width of the « hot » source →
- X-talk of about -55 dB or 4xNETD

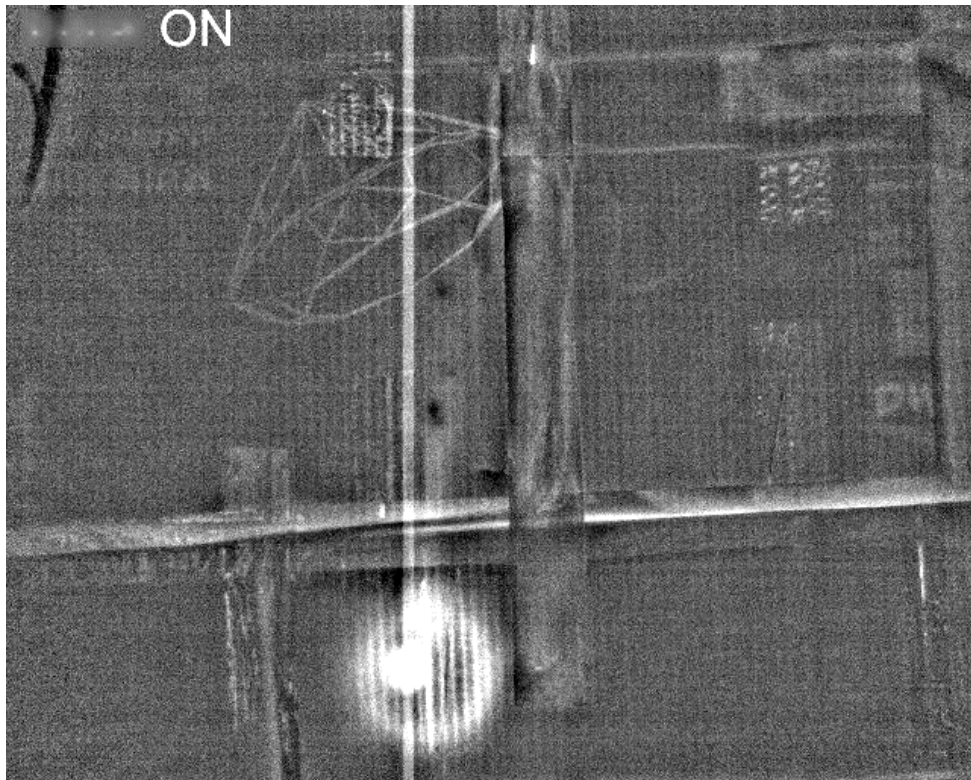


Spatial cross-talk (blooming-like effect)

Vertical cross-talk in IWR mode

Can be compensate with an additional delay during the read sequence

- Normal sequence : **ON**
- Corrected sequence : **OFF**

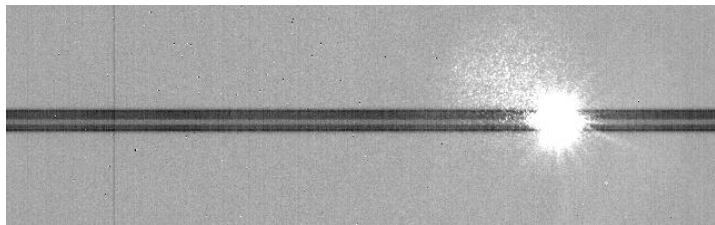


Spatial cross-talk (blooming-like effect)

Horizontal cross-talk at column #500

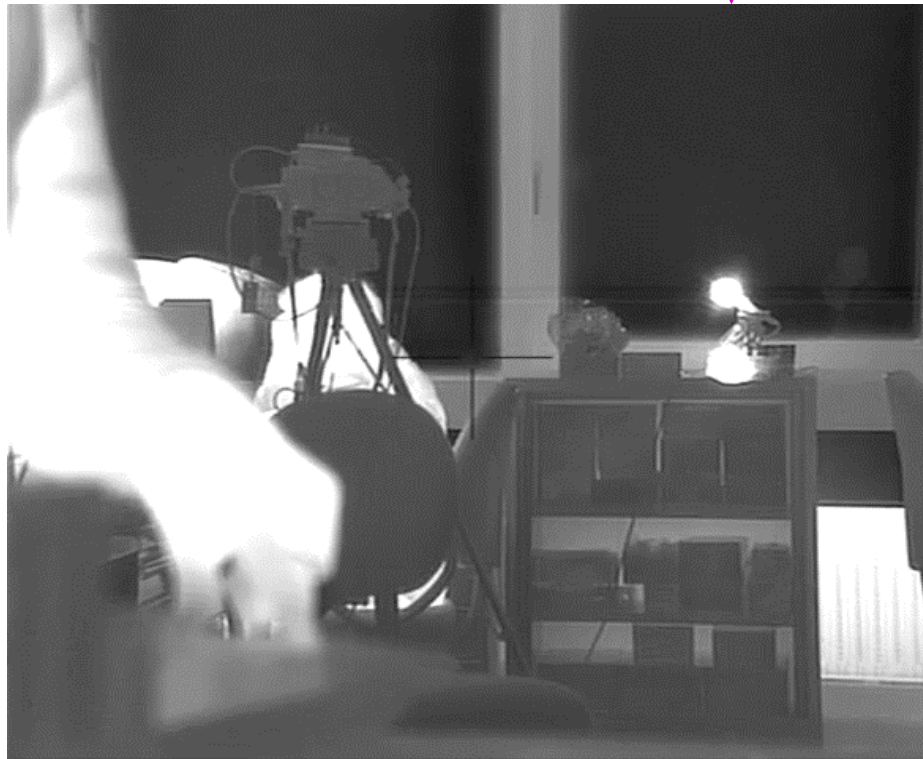
- From the column ~500 and the row number M to every column on row number $M+1$
- Parasitic coupling between the video and the column amplifiers
- Sampling row number $M+1$ (through the column amplifiers) when the video readout the pixel ~500 of the previous row (number M)

The cross-talk can be positive or negative



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Spatial cross-talk (blooming-like effect)

Transfer can be positive or negative depending on the exact column.

- Transfer rate of about -50 dB
- ITR and IWR modes
- Rate (value and contrast) influence by the pixel clock frequency

Can be limited by a modification of the timing

- For each row, we should decrease or stop the pixel clock when the column ~500 is readout.
- With a modified timing the cross-talk is reduced down to -63 dB

Laser spot scan

Column 503

Column 501

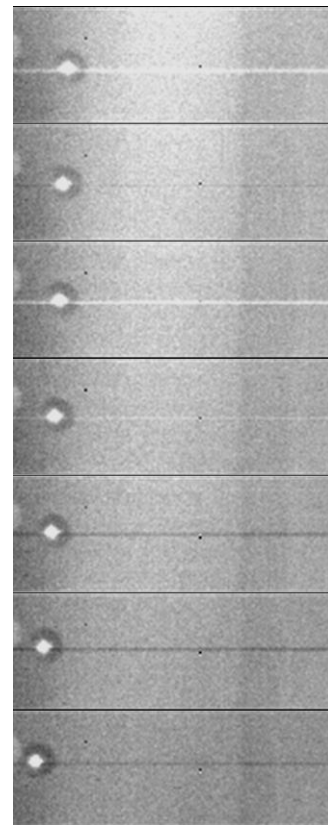
Column 499

Column 497

Column 496

Column 491

Column 487



Introduction

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Temporal cross-talk (latency)

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Spatio-temporal artefacts

- Microphony
- Local pattern defect

Summary

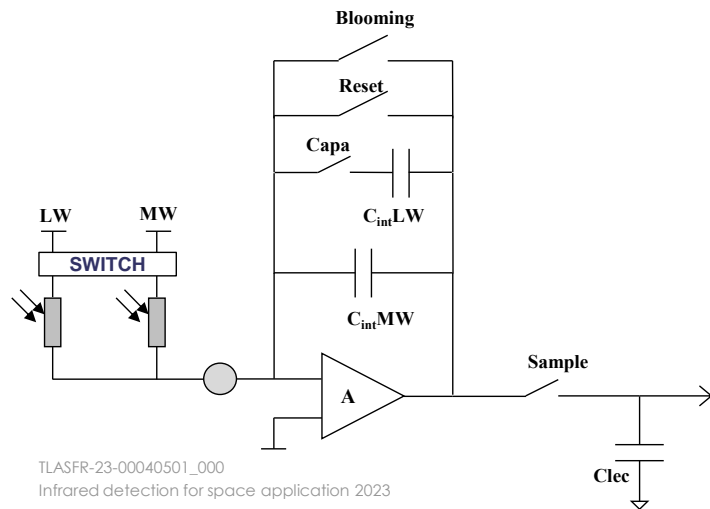
Short term temporal cross-talk (latency)

Latency (or persistance)

- Inverted contrast

“Spectral” cross-talk

- Dual band sensor MW/LW
- Residual polarization on the disable stage and RC filter of the supply



Slow motion video x 6



Long term temporal cross-talk (latency)

Latency (or persistance)

- SWIR band
- Flickering due to the aliasing of the 220V/50Hz

Inverted contrast

Residual level depend on fluence

- Brightness of the spot
- Duration of the illumination



Long term temporal cross-talk (latency)

Residual level depend on fluence

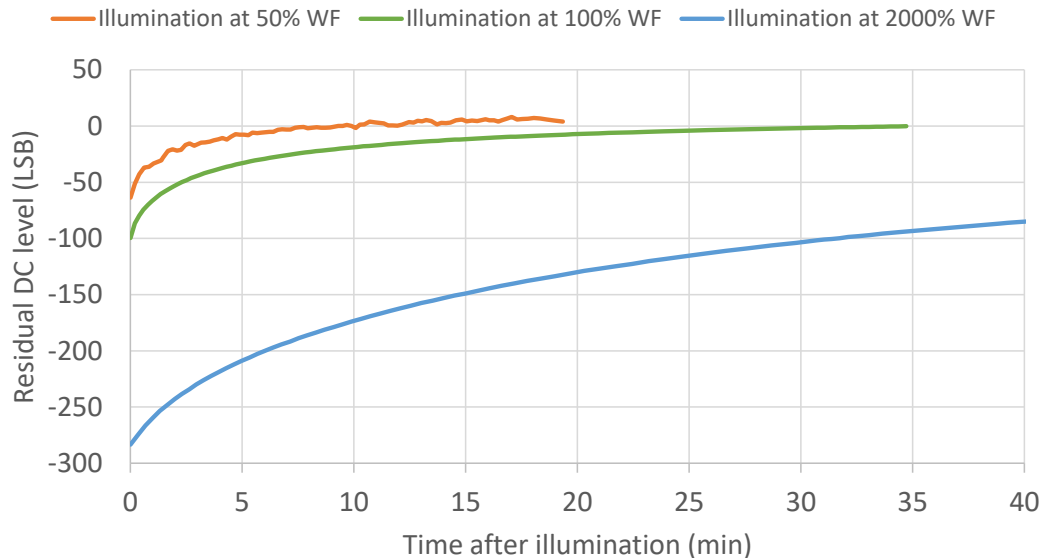
- Brightness of the spot
- Duration of the illumination

Very long time constant

Illumination (% of Well Fill)	Time constant (min)
50	15
100	30
2000	150

- No explanation (yet...)

Latency vs illumination



Long term temporal cross-talk (latency)

Long term latency after exposure to a bright source

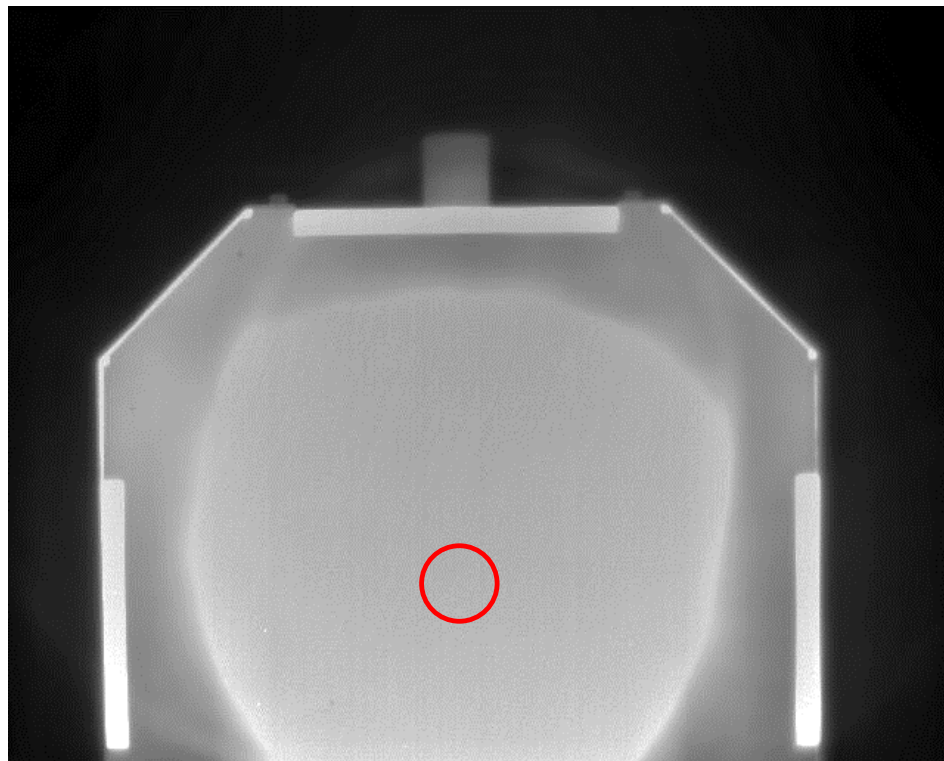
- MWIR band
- Example with a 1000°C blackbody exposed during 30 secondes
 - Output encircled in red

It remains as long as the sensor is not warm-up

- + 40 K above the cryogenic temperature

The latency value depends on:

- Brightness of the spot
- Duration of the illumination



Long term temporal cross-talk (latency)

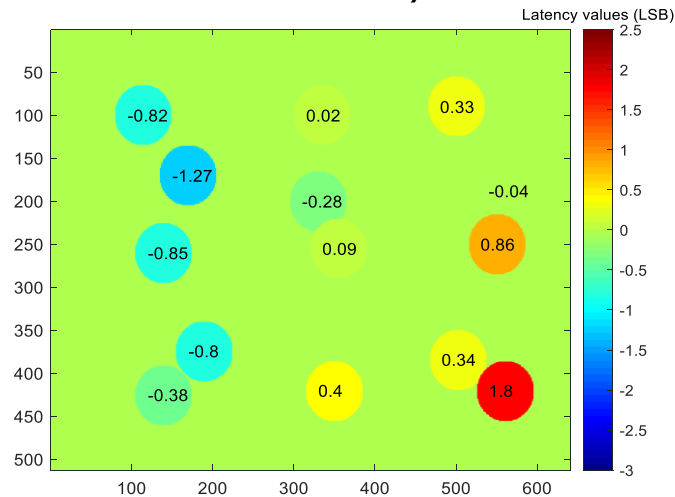
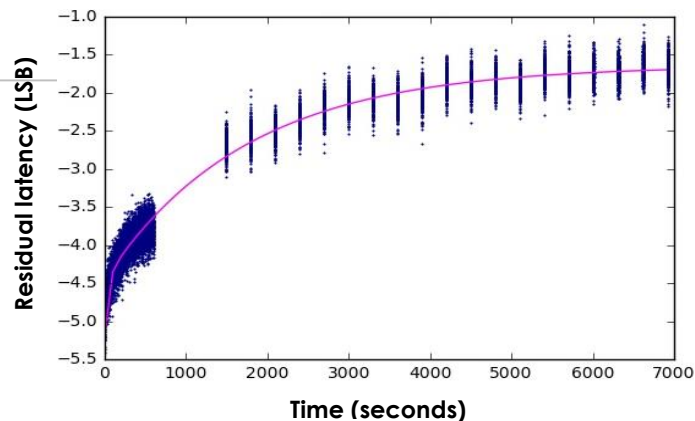
The latency occurs with very short illumination (<50 ms) and last for long

➤ 3 time constants :

- A few seconds
- A few tens of seconds
- A few hundreds of seconds

The contrast of the latency can be dark or white

- The latency depends on the position of the spot
- The process variant
- The spectral content of the illumination



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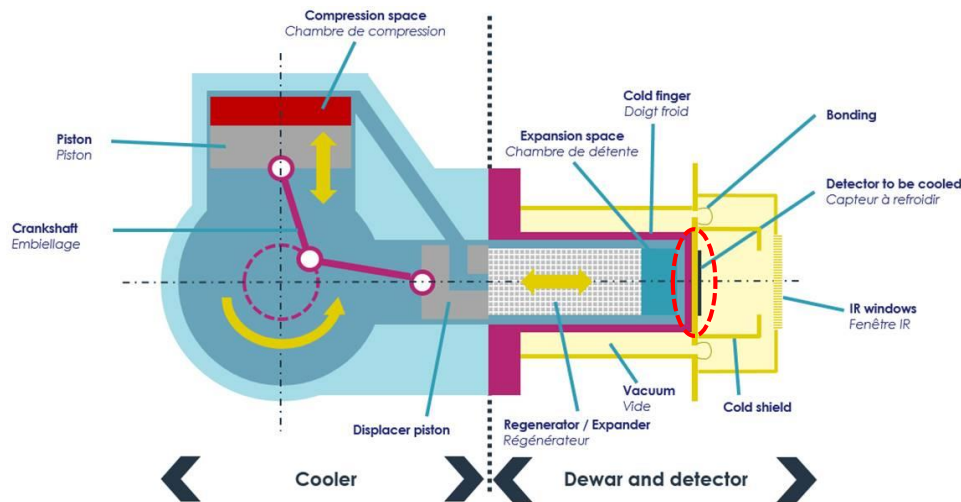
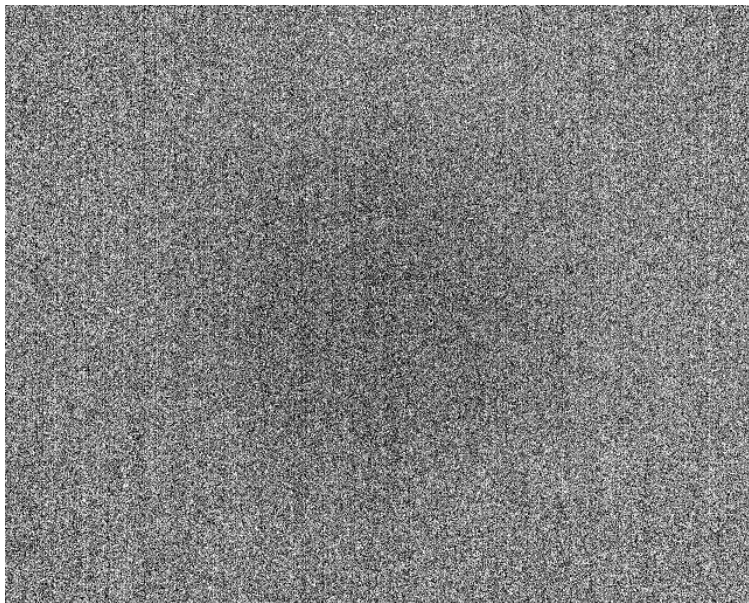
- Microphony
- Local pattern defect

■ Summary

Overview of spatio/temporal artefacts: Microphony

Mechanical vibrations induce an undesired electrical signal

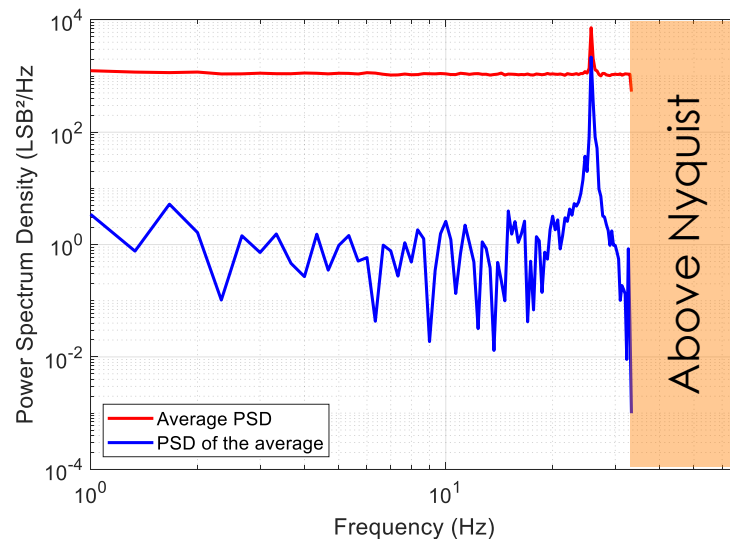
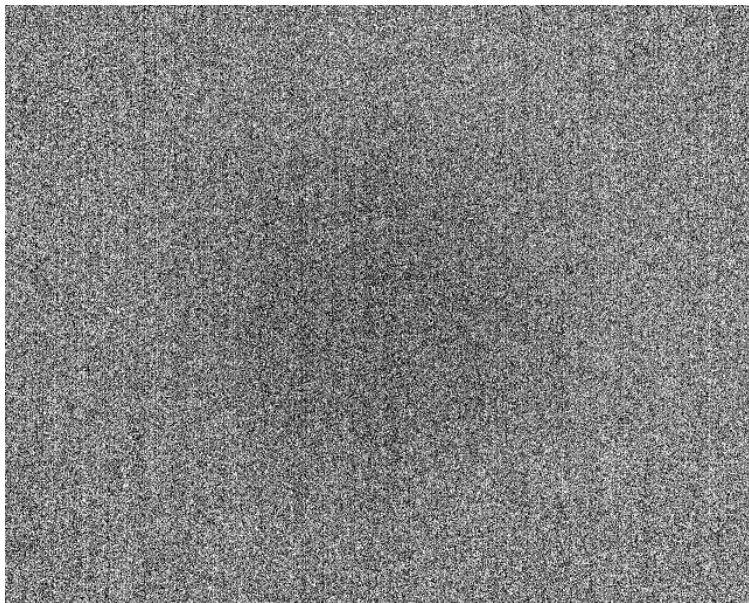
- We can “see” the vibration mode of the cold plate (encircled in red) at the end of the cold finger.



Overview of spatio/temporal artefacts: Microphony

Beat between the acquisition frequency (67 Hz) and the cooler pressure wave frequency (~25 Hz)

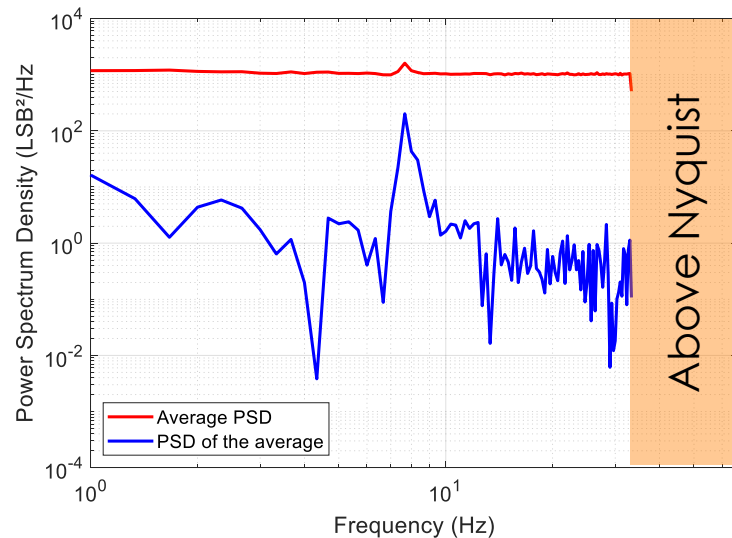
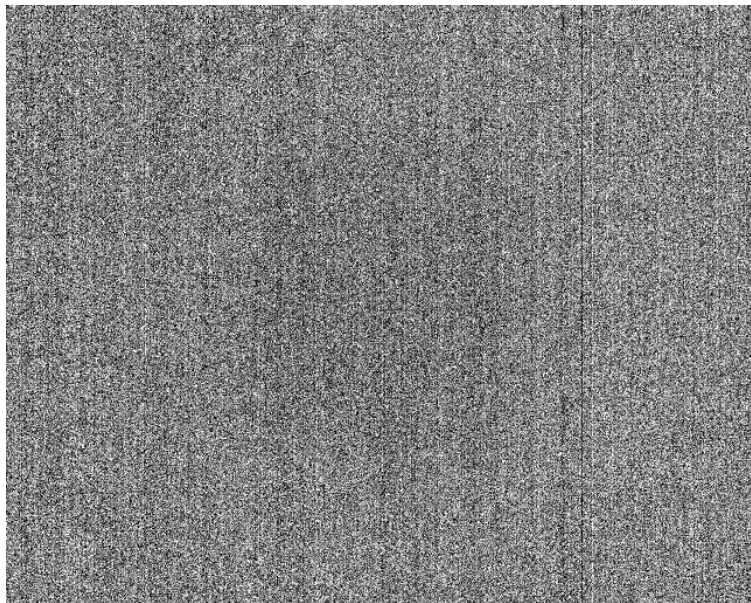
- The spike shifts depending on the cooler speed



Overview of spatio/temporal artefacts: Microphony

Change of cooler model with the same dewar-detector assembly

- Reduction of the amplitude and apparent frequency (8 Hz due to aliasing). Cooler speed (~59 Hz)

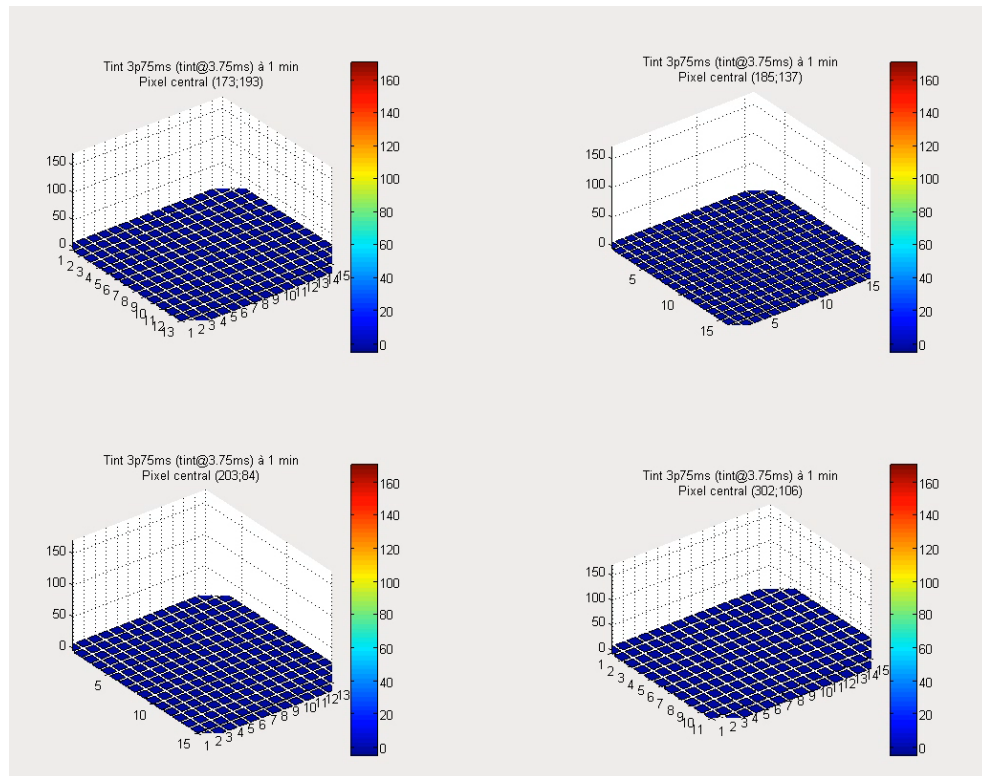
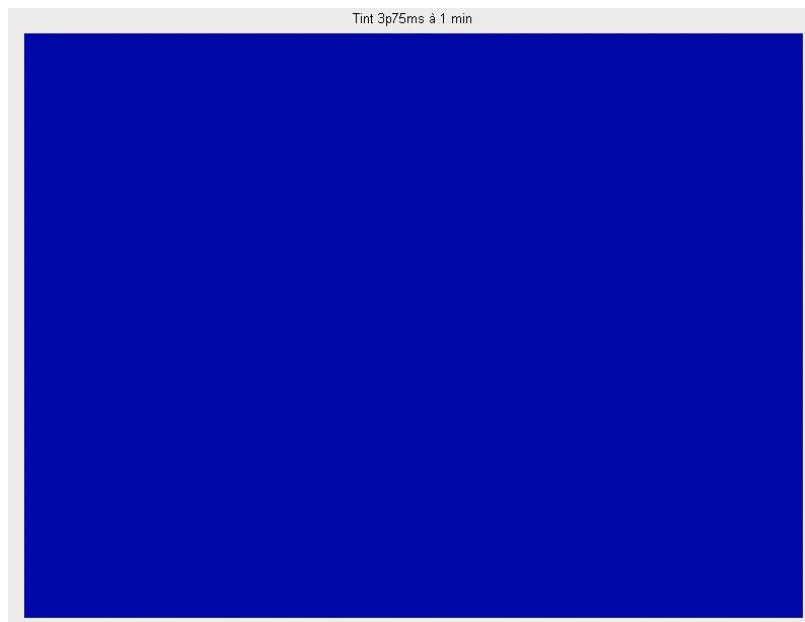


- Can be suppress by a change in the mechanical design or a change of sensitive materials

Long term spatial-temporal cross-talk (local pattern defect)

« White spots »

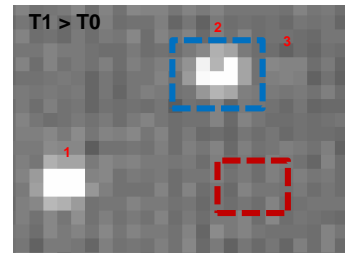
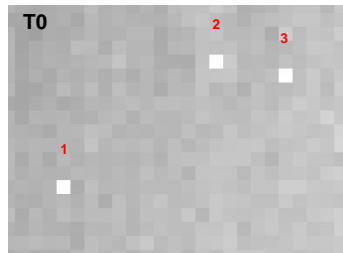
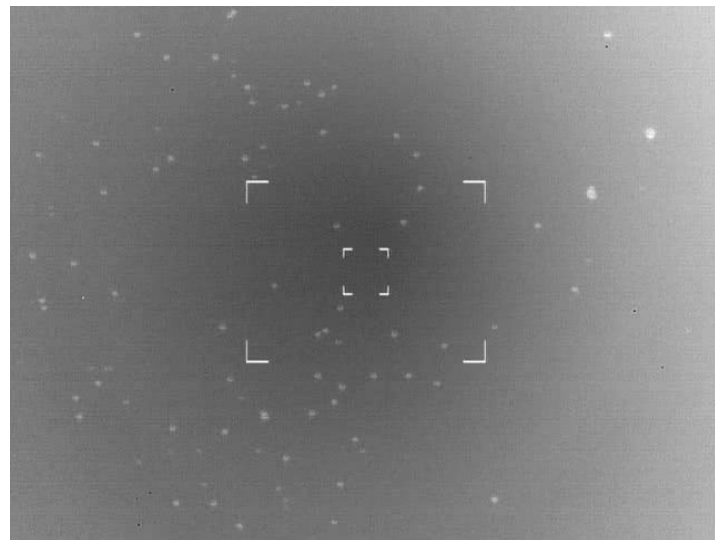
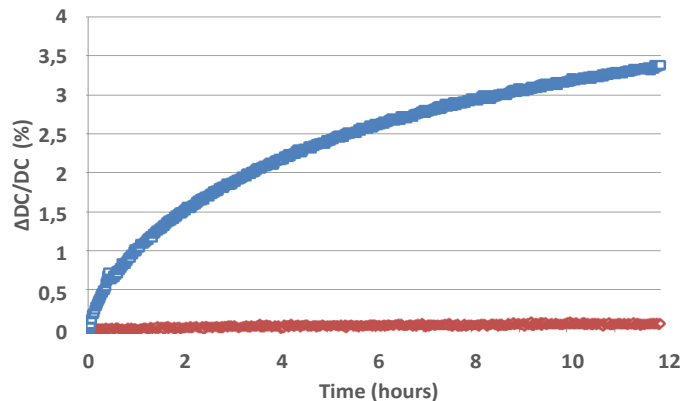
- DC map over 2 hours and 3D view of the spots (in LSB)



Long term spatial-temporal cross-talk (local pattern defect)

« White spots » in LWIR sensors

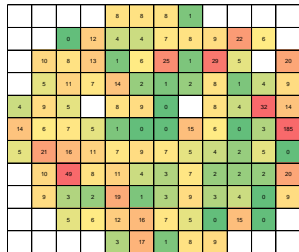
- Slowly and steady increase of the spot over the time.
 - Perceived after few minutes of use.
- Rise of the signal around saturated pixel, but not all
 - Reboot after a warm-up
- Cross-talk of few percents of the DC level
 - Repeatable behavior



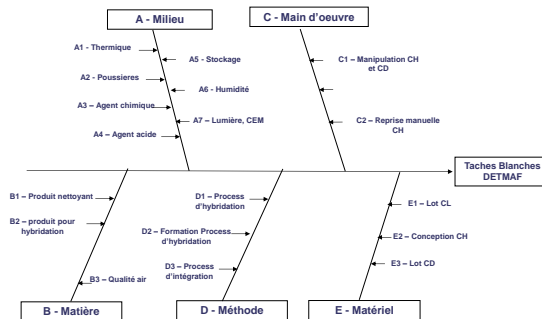
Long term spatial-temporal cross-talk (local pattern defect)

Clear root cause never identified

- Almost every tools and methods were used
- Probleme solved with a change of ROIC

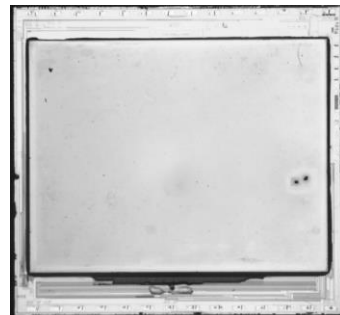


Process correlation

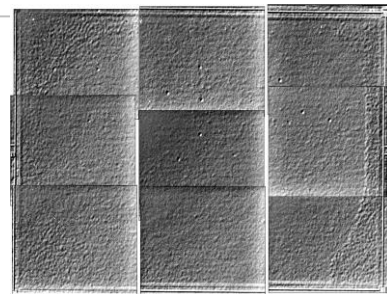


8D-ISHIKAWA

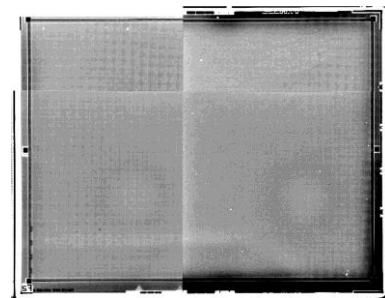
FIB-SEM



Visible microscopy



DIC microscopy



Infrared microscopy

STEM

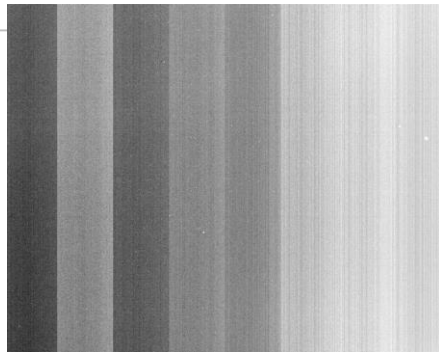
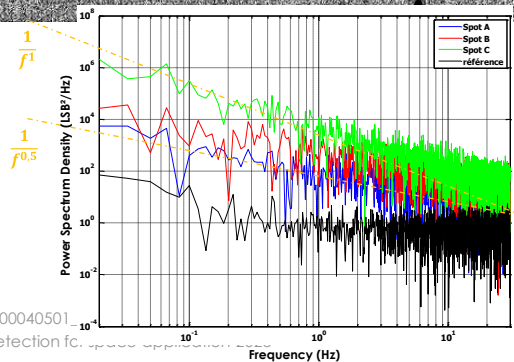
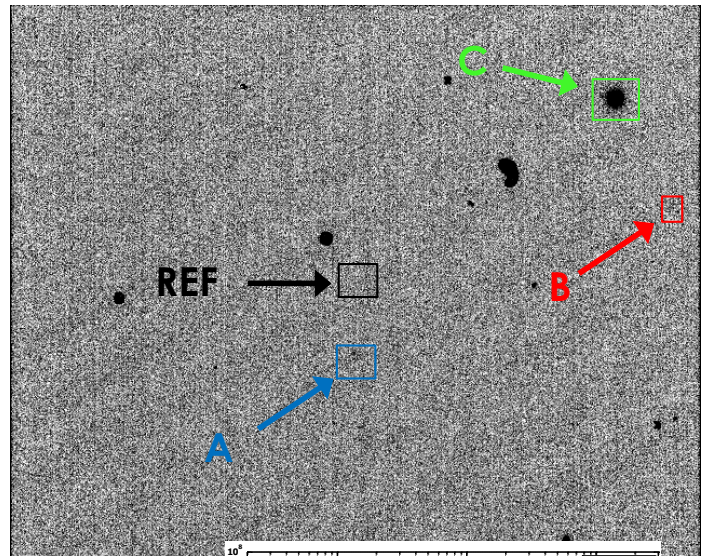


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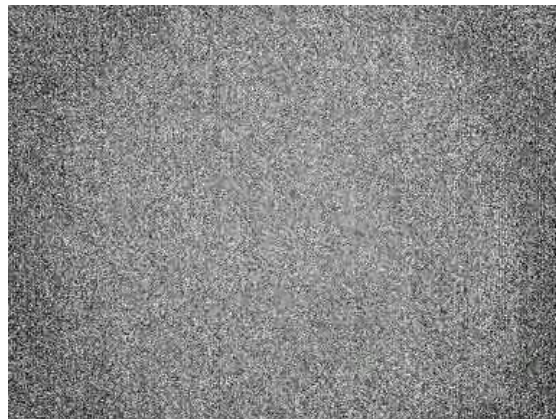
TEM (DF & HR)

Still some more..

Local pattern defects evolutive in time

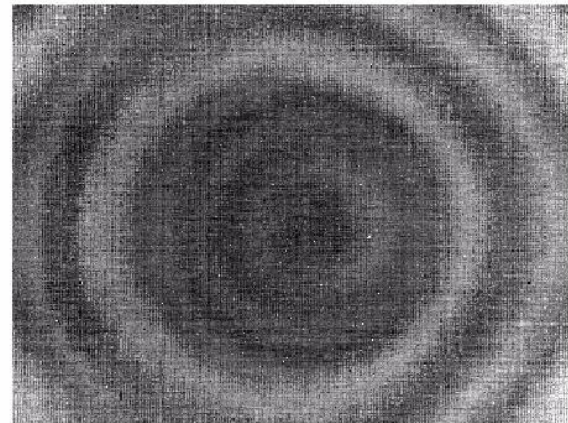


RFPN

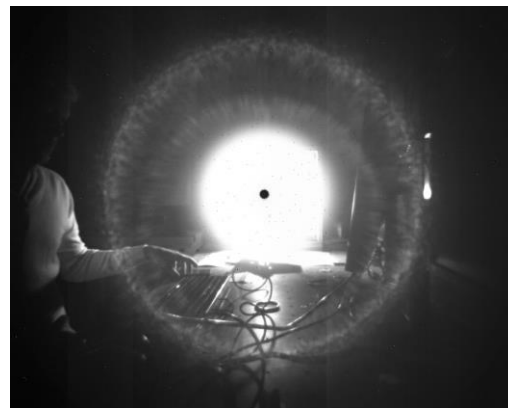


Blickering columns

CN@5°C



Ring artefact



Black sun effect

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Infrared detection fc.

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Summary

- **Almost every sensors suffer of spatio-temporal artefacts.**
- **Root cause are generally due to either the CMOS or the photosite but sometimes it can be due to interference between them or with the proximity electronic.**
 - Investigation of such issue can drain a lot of ressources
 - The root cause is not always find and palliative actions are thus necessary
- **The spatial artefacts are particulary an issue for imagery application with a human end user.**
- **The application based on image processing are more sensitive to temporal artefacts, especially in step-stare system.**
- **Set the right level of requirement is difficult and it is always tricky to find the threshold between perception and impact on the « mission ».**

Thank you for your attention.

Any questions?

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