IPCEI on Microelectronics

GRENOBLE 2020 ESSDERC ESSCIRC

LYNRED Advanced Developments in the Field of Infra Red Imaging technology

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September 14-18, 2020

LYNRED BY SOFRADIR & ULIS

IEEE SSCS Electron Devices Society leti ceatech ST life.augmented Grenoble INP soitec UGA Université Grenoble Alpes

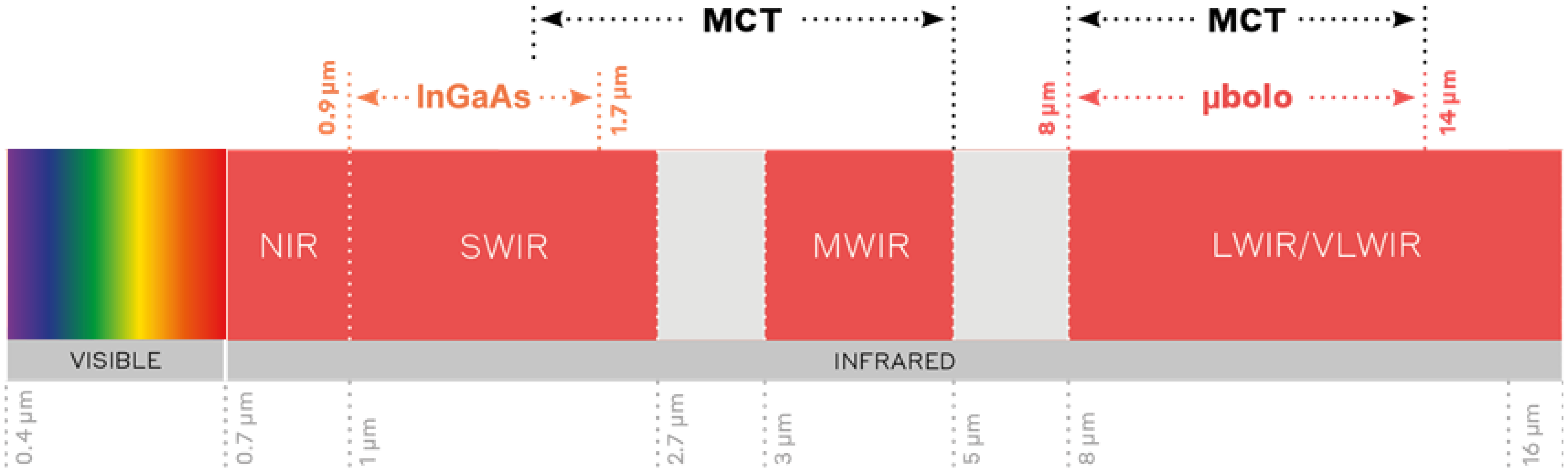
Outline

- LYNRED presentation
- Very Large dimension, Very high performance IR sensors for Science and Space Applications
- Micro-bolometer sensors for thermal sensing

LYNRED

We Are

- SOFRADIR and ULIS merged to become LYNRED
- #2 worldwide IR detector manufacturer offering the largest product portfolio



IPCEI on Microelectronics

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We Are

950 EMPLOYEES
2017 REVENUE: €227 MILLION

LYNRED USA
BY SOFRADIR & ULIS

SOFRADIR-EC
2008 / 20 employees /
2017 REVENUE: €9 MILLION

LYNRED
BY SOFRADIR & ULIS

SOFRADIR
Seeing your future
1986 / 730 employees
2017 REVENUE:
€142 MILLION

ULIS
Infrared for you
2002 / 200 employees
2017 REVENUE:
€76 MILLION

80% EXPORT

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We Are

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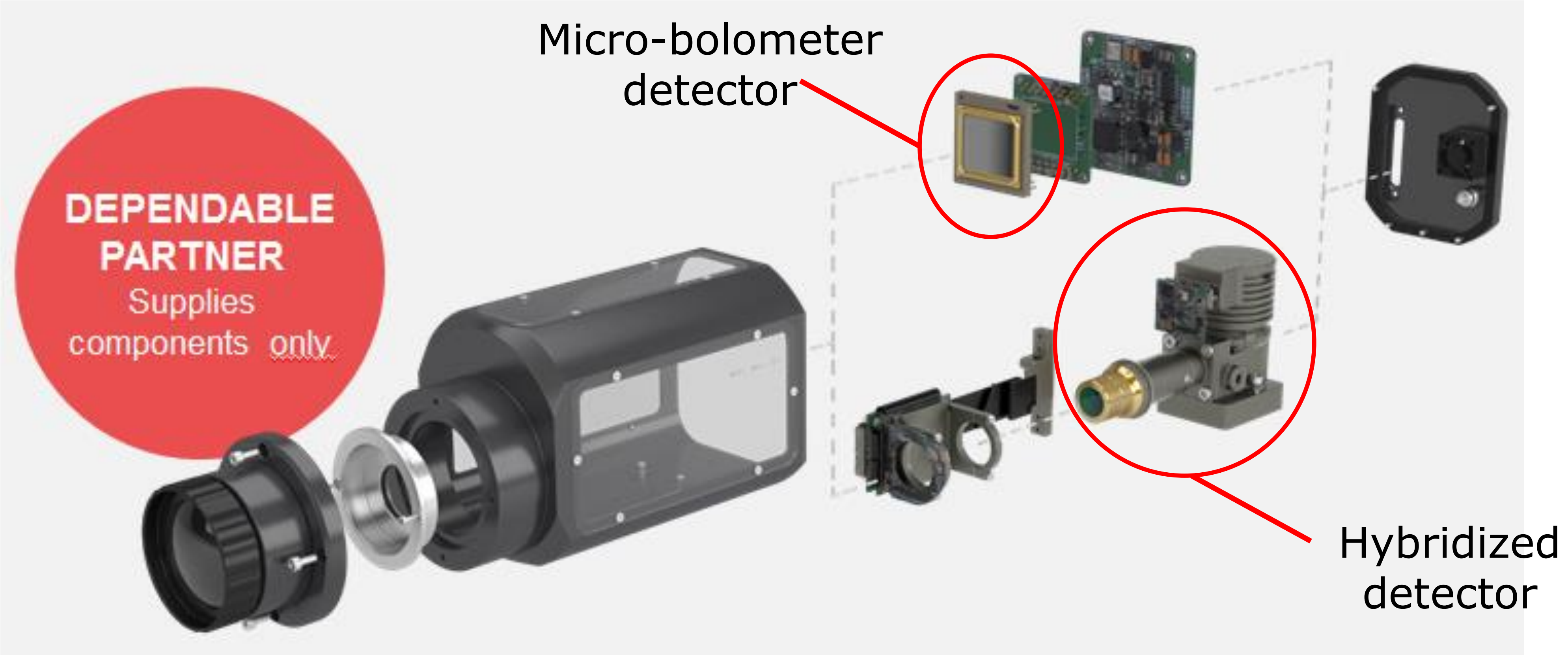
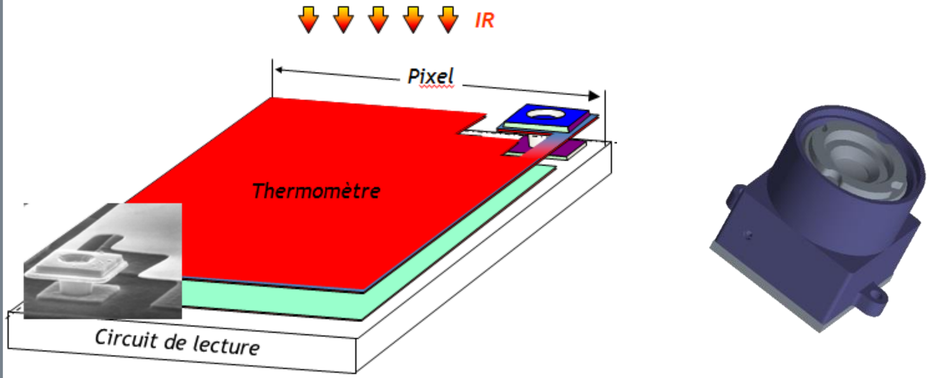
IEEE SSCS Electron Devices Society

LYNRED BY SOFRADIR & ULIS

We Do


DEPENDABLE PARTNER
Supplies components only
Micro-bolometer detector
Hybridized detector

We Do

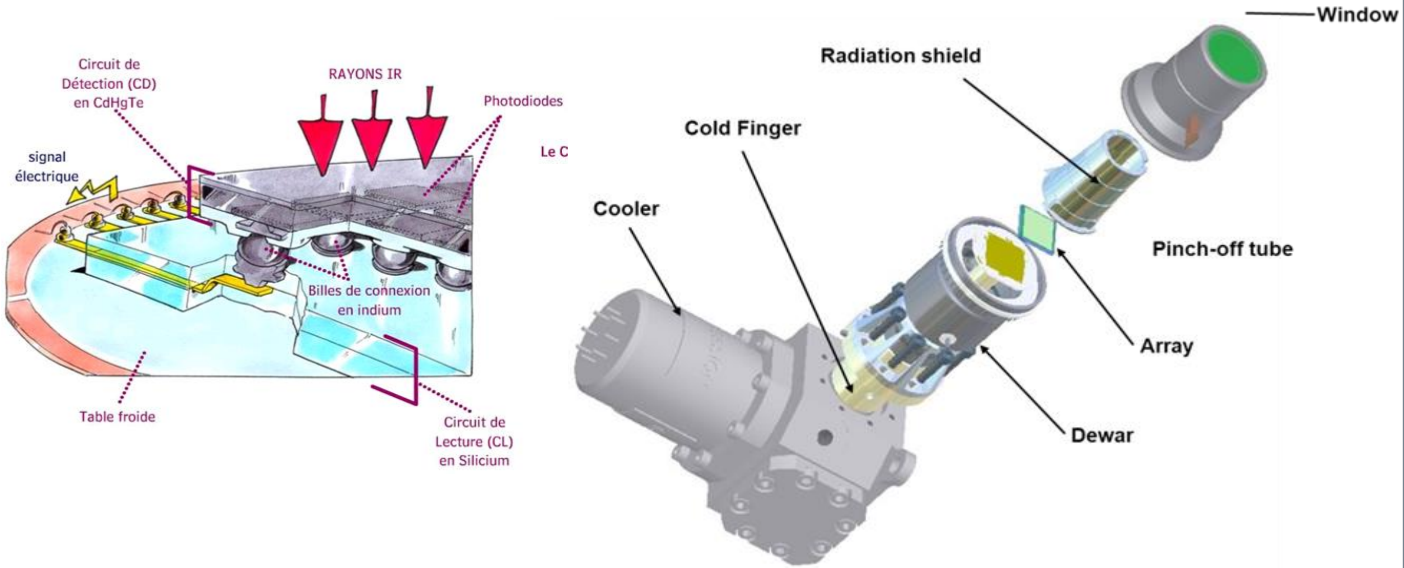


Micro-bolometer IR detector

Operating T°: Room T°

Performance: Range ~ 1km

Technology: MEMs above IC



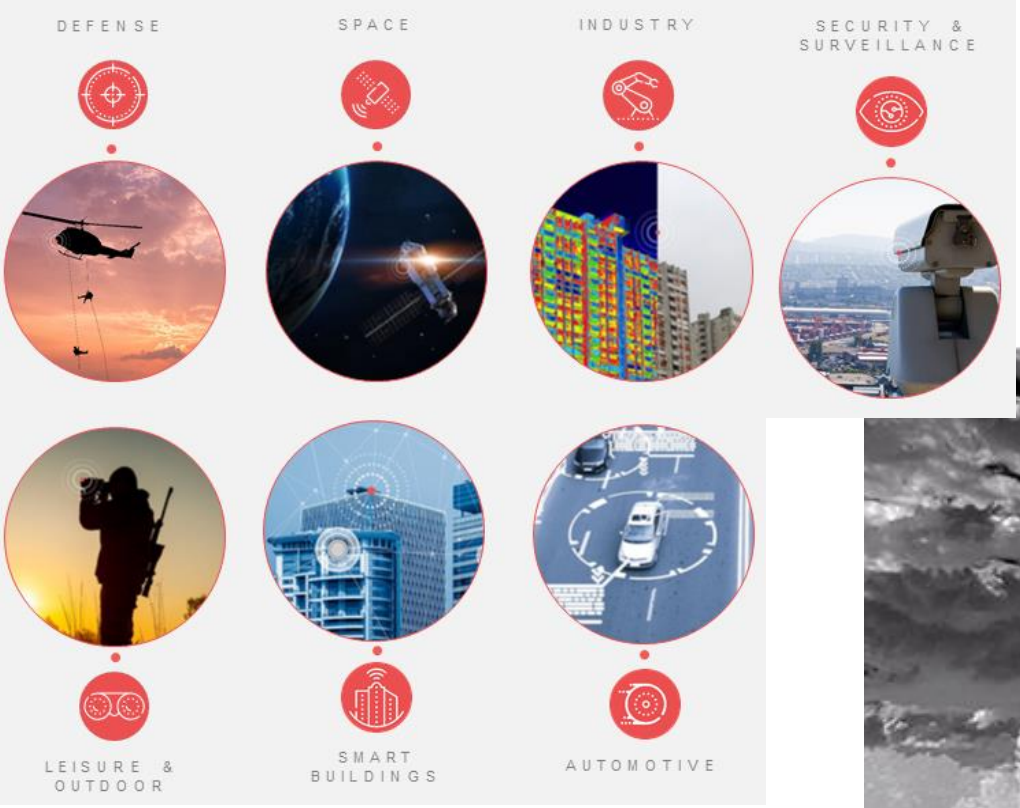
Hybridized IR detector

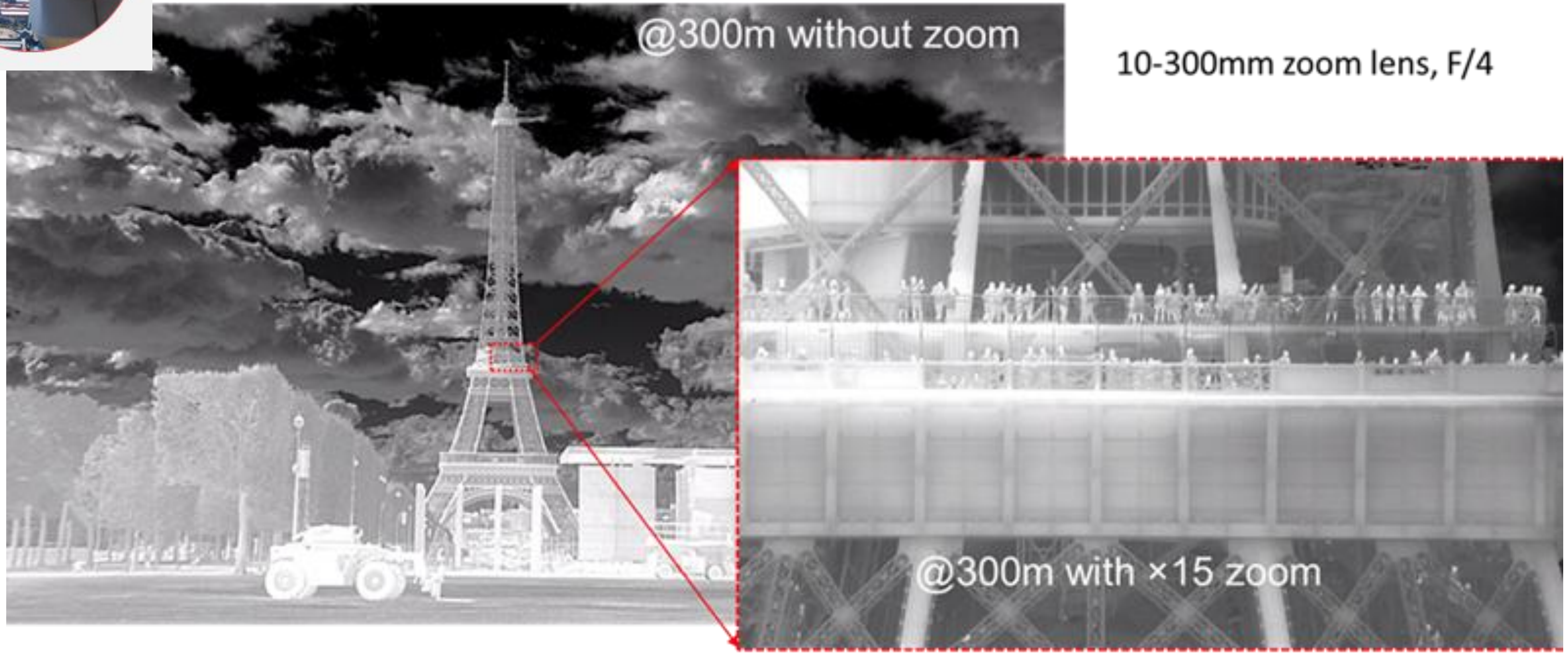
Operating T°: - 200°C

Performance: Range ~ 10km

Technology: II-VI /III-V semiconductors hybridized on CMOS ASIC

We Serve





10-300mm zoom lens, F/4

Very Large dimension

Very high performance

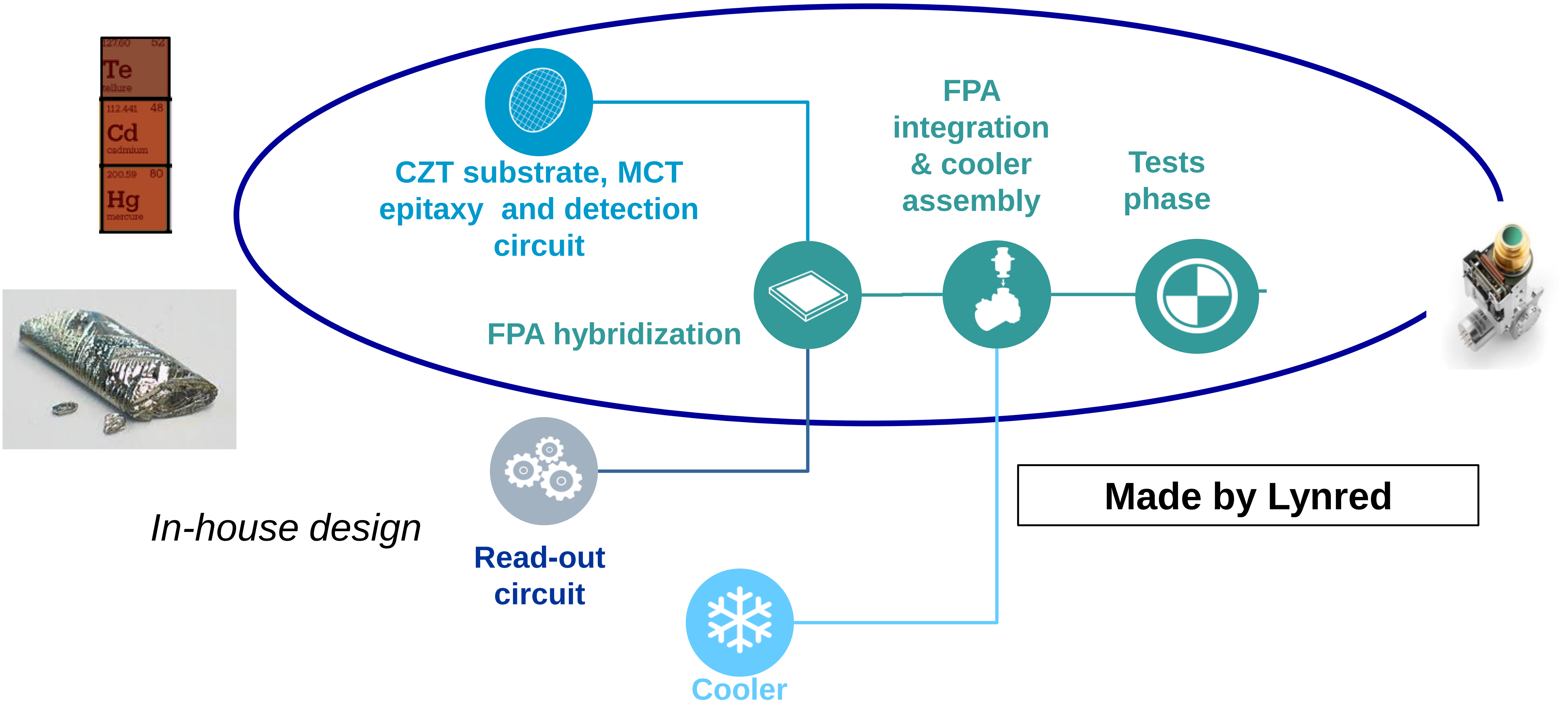
IR sensors for Science and Space Applications

$2K^2$ FPA for EELT new generation of telescope

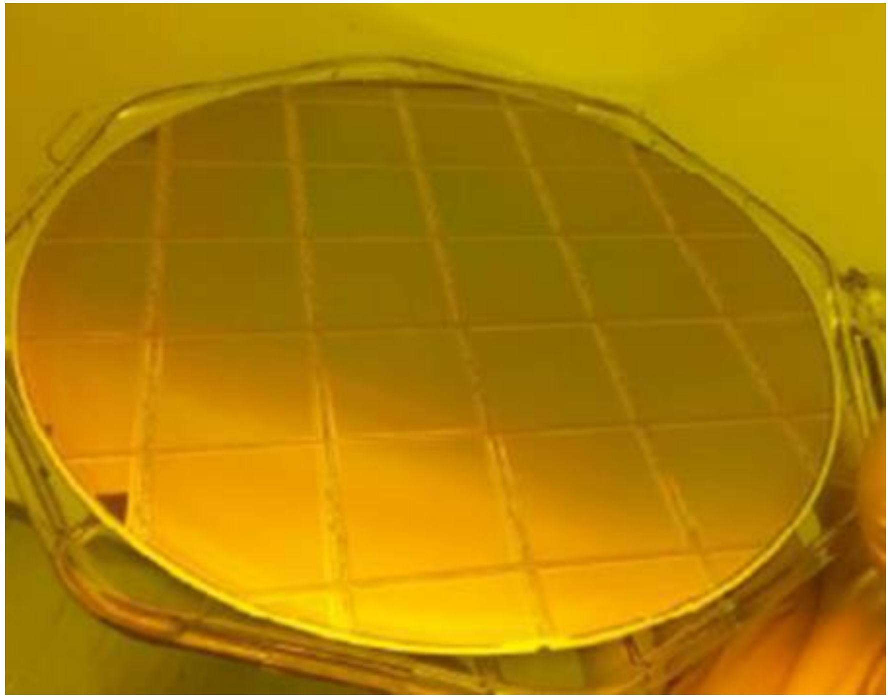
Earth observation and Science (astronomy…) need very large dimension and high performance Focal Plane Array

European Extremely Large Telescope (EELT)

Vertical Industrial Model for II-VI Technology

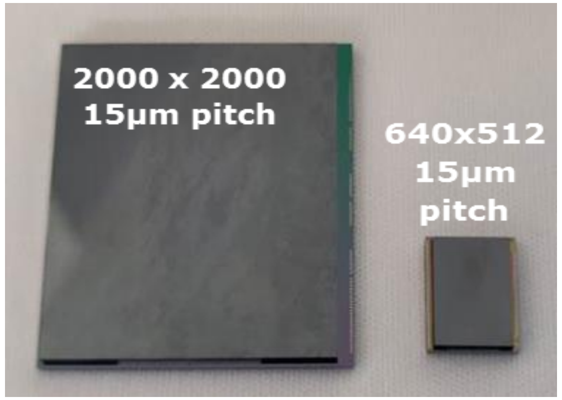


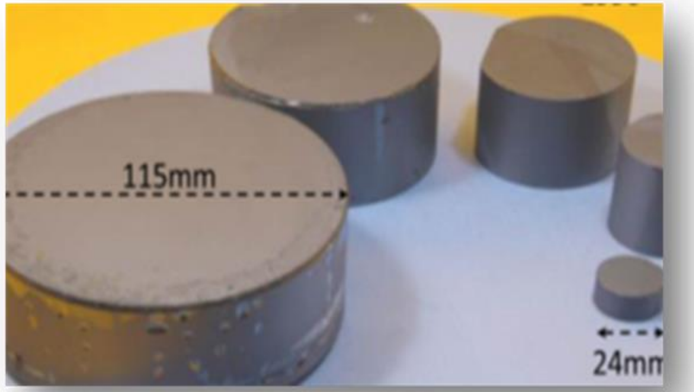
ROIC CMOS Technology



- Very large components with ROIC dimensions larger than 200 mm CMOS maximum reticule size
- Development of specific stitching process for LYNRED
- Development of CMOS wafer post process for hybridization of very large components

Increase CZT Substrate Size



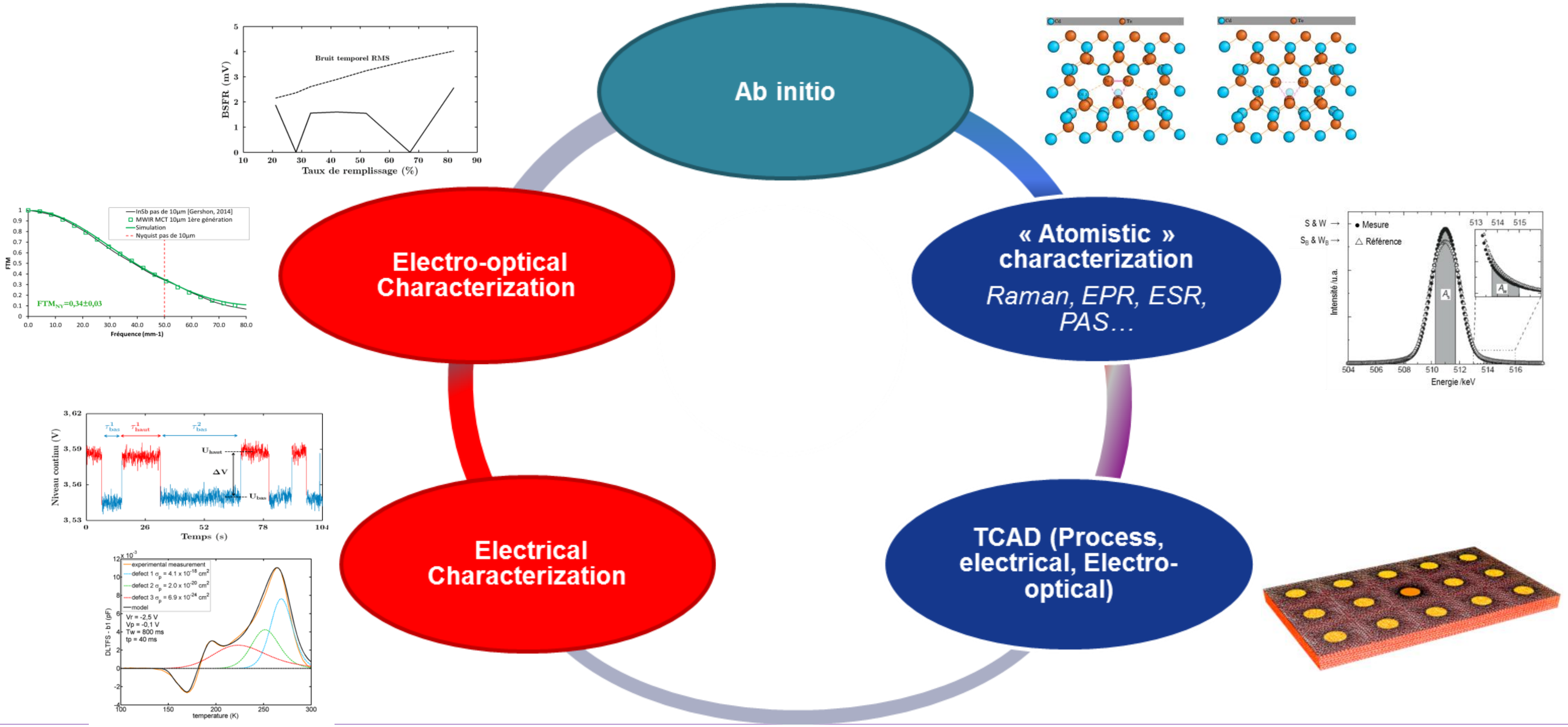


- CZT wafer manufacturing and MCT epitaxy:
  - 5x5cm² CZT : industrial standard for the production of 640x512 MWIR Scorpio FPAs.
- Increase of CZT wafer size up to 4" In-house CZT bulk manufacturing and epitaxy:
  - On-going developments for CZT ingot diameter > 4.5''.
  - Increase of CZT ingot diameter from 0.9'' (late 70's) to 4.5'' (today).

LYNRED R&D Approach

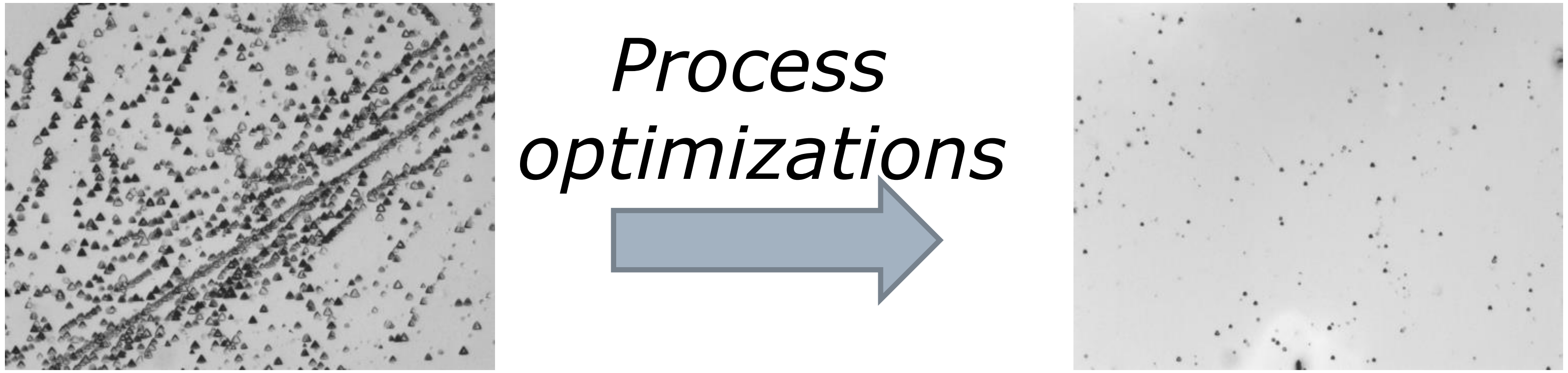
Strong Research Partners Ecosystem

cea leti, IMEP-LAHC, III-V lab, ONERA THE FRENCH AEROSPACE LAB, C2N …



Increase Substrate Quality And Affordability

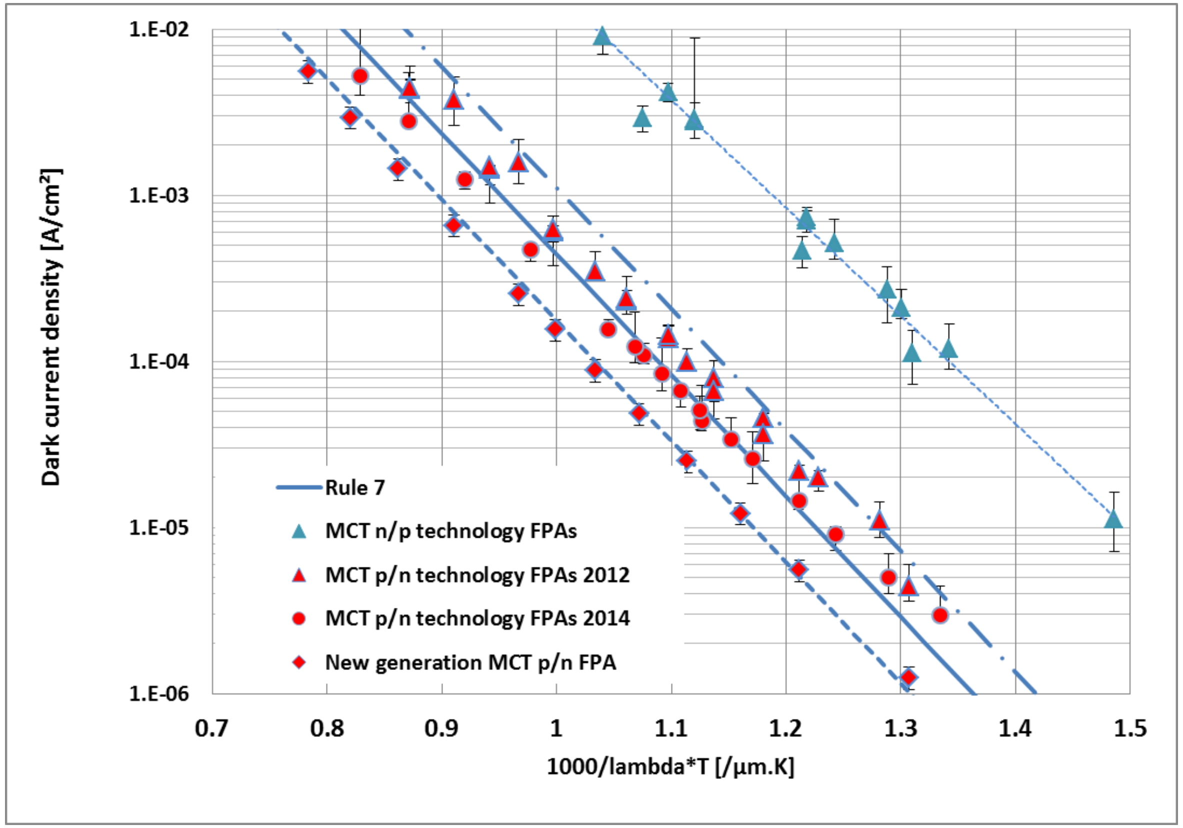
- CZT bulk process improvements:
  - Increase of single crystal yield.
- Better CZT material quality:
  - Suppression of Te-rich and Cd-rich 2nd phase defects.
  - Dislocation density reduction from mid-to-high 10^4 to low 10^3 cm^{-2}.



P on N Technology Performances

Very low photon flux in Scientific and Space observations.

➔ Dark current has to be as low as possible



Rule 7 behavior, 15µm pitch TV format:
- **Diffusion regime**
- **Auger 1 lifetime**

$$J_{Dark}(T) = q\frac{n_i^2(T)e}{N_D \times \tau_{Auger\ 1}(T)}$$

[L. Rubaldo et al, SPIE 2017]

[L. Rubaldo et al, SPIE 2016]

Image Quality Challenges: MTF & MRTD

Minority carrier lifetime increase to decrease J_{dark}

τ ↗ for Jdark ↘ ⇒ Ldiff ↗ $L_{diff} = \sqrt{\frac{kT}{q}\mu \times \tau}$

➔ **Diffusion length increase**

But…. Diffusion length increase decreases MTF (↑cross talk) and degrades MRTD

$$MRTD = \frac{\sqrt{K_1 \times NETD^2 + K_2 \times RFPN^2}}{MTF}$$

K1 and K2: system dependent constants
MRTD: Minimum Resolvable Temperature Difference
NETD: Noise Equivalent Temperature Difference
MTF: Modulation Transfer Function
RFPN: Residual Fixe Pattern Noise

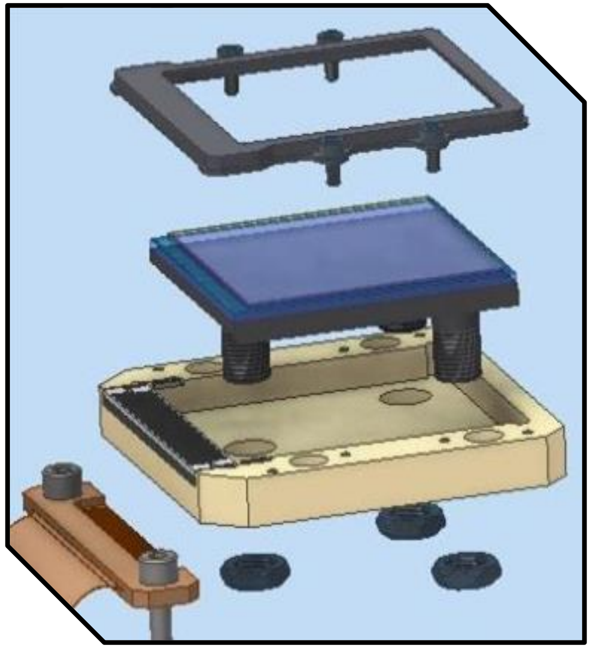
Design optimization to …

❶ **Maximize MTF**

❷ **Maximize QE**

❸ **Minimize Noise: temporal, spatial for ROIC and photodetector**

Project achievement



Selected for SVOM mission
(Gamma emission study 2020-2026)

Micro-bolometer sensors for thermal sensing

Micro-bolometer development motivations

Today’s Technological development in uncooled IR detectors

Cost reduction

- Pixel size reduction : below 12 µm … ? µm

Value addition

- System integration as close as possible to detector development
- **Improve FOM beyond NETD**

BOLOMETER THERMAL TIME CONSTANT

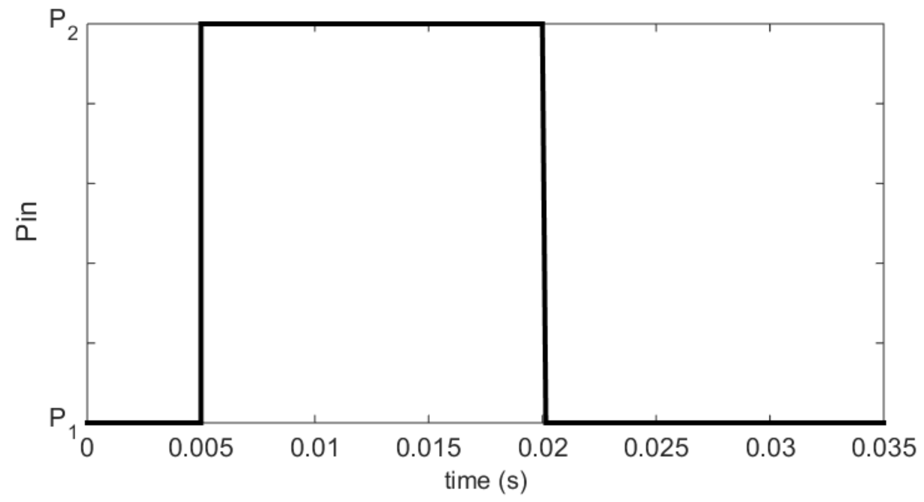
- The need of a short τ_{th}

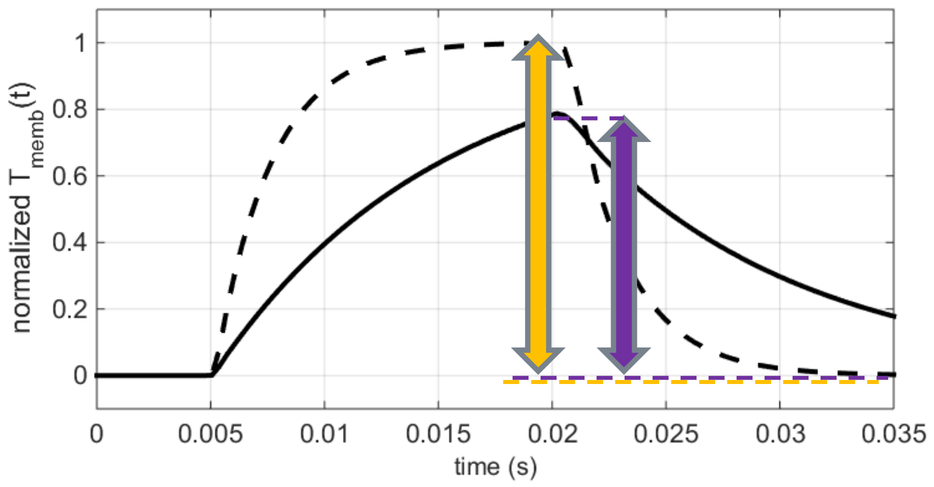
In the case of short events :

- Higher signal to noise ratio

$$T_{memb}(t) = \begin{cases} T_{sub} + P_1 R_{th} & for\ \ t < t_0 \\ T_{sub} + \left(P_2 + (P_1 - P_2)exp\left(\frac{t_0 - t}{\tau_{th}}\right) * R_{th}\right) & for\ \ t > t_0 \end{cases}$$

$$with\ \ \tau_{th} = R_{th} * C_{th}$$





BOLOMETER THERMAL TIME CONSTANT

❑ The need of a short τ_{th}

In the case of short events :

- ➢ Higher signal to noise ratio
- ➢ Sharper image

$$T_{memb}(t) = \begin{cases} T_{sub} + P_1 R_{th} & for\ \ t < t_0 \\ T_{sub} + \left(P_2 + (P_1 - P_2) exp\left(\frac{t_0 - t}{\tau_{th}}\right) * R_{th}\right) & for\ \ t > t_0 \end{cases}$$

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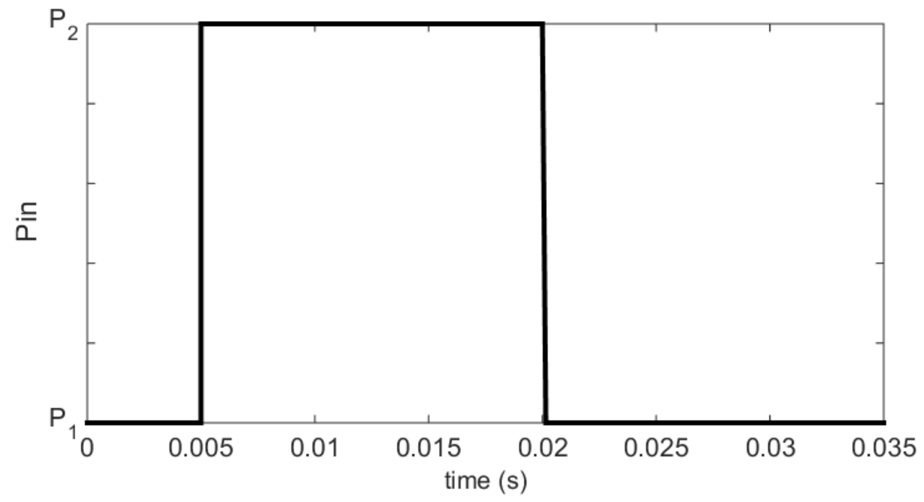

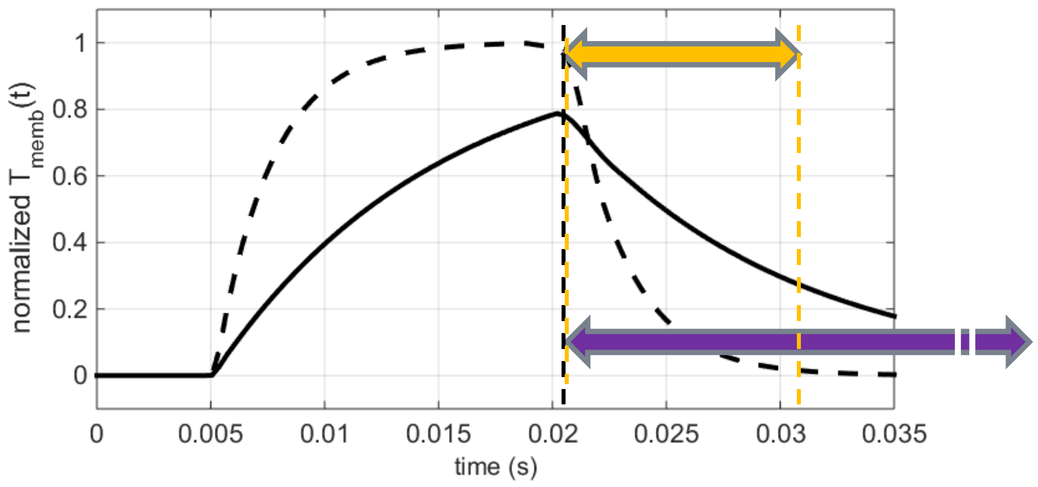

BOLOMETER THERMAL TIME CONSTANT

- Higher signal to noise ratio
- Sharper image

Summary

Material

Design

IPCEI on Microelectronics

European sovereignty in
IR sensing technologies

Process

Theoretical
Modelling

Acknowledgement

- ***People at LYNRED who made all this happen!***

Alexandre Kerlain, Diane Sam-Giao, Vincent Destefanis, Pascal Leboterf, Julien Roumegoux, Laurent Rubaldo, Nicolas Boudou, Alain Durand…

- ***This work is funded by the French Public Authorities, under the coordination of the French Ministry of Industry, in the frame of the Important Project of Common European Interest (IPCEI) on microelectronics***

The IPCEI is also funded by Public Authorities from Germany, Italy and U.K.