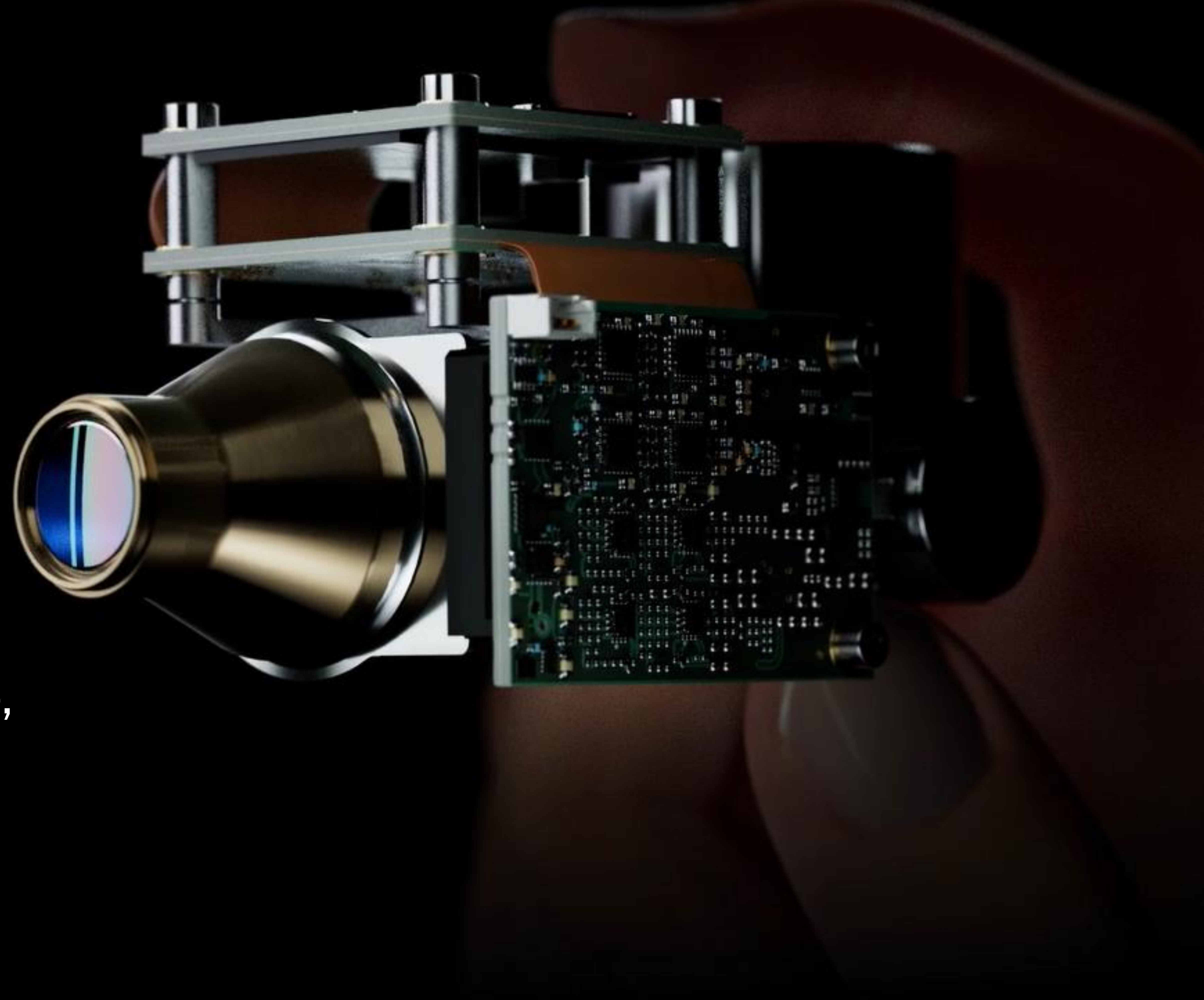
Mature T2SL technology for affordable HOT HD detectors and reduced SWaP system

Infrared Detection For Space Applications Workshop

7th to 9th June 2023, Toulouse, France

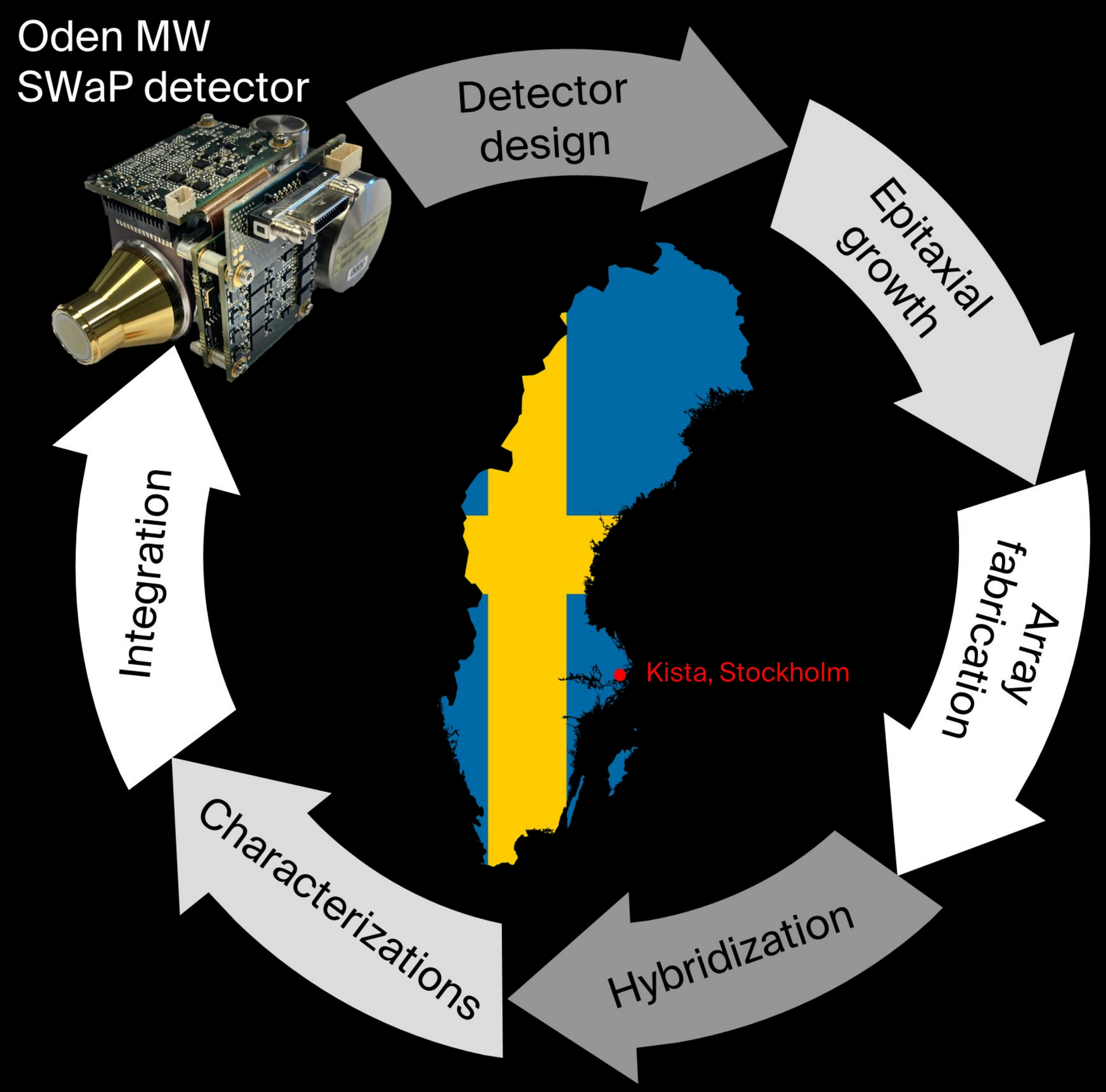


M. Delmas, L. Höglund, D. Ramos, R. Ivanov, L. Žurauskaitė, S. Högnadóttir, , D. Evans, D. Rihtnesberg, L. Bendrot, S. Smuk, A. Smuk, S. Becanovic, S. Almqvist, P. Tinghag, S. Fattala, E. Costard

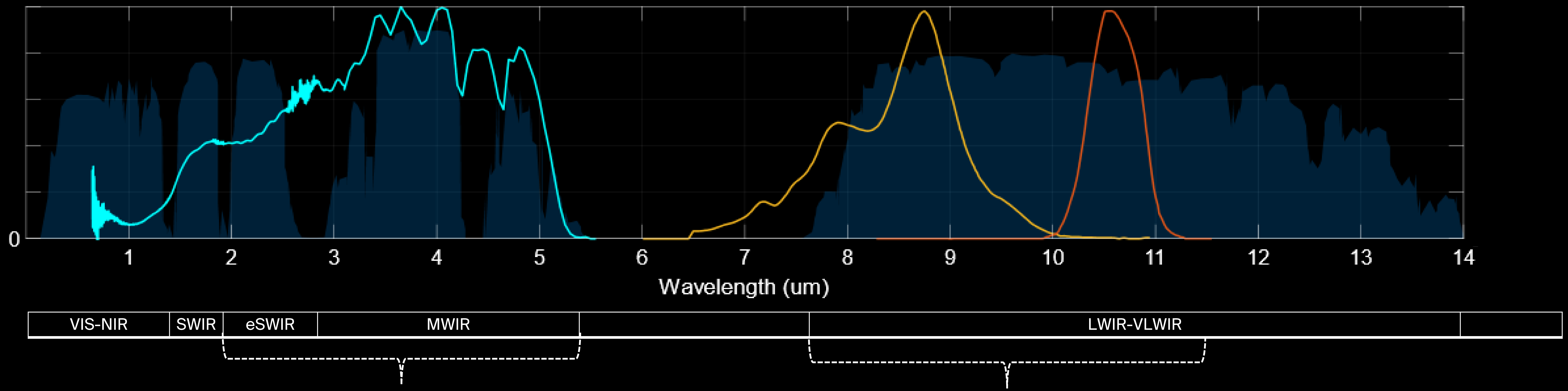
www.ir-nova.se

About IRnova

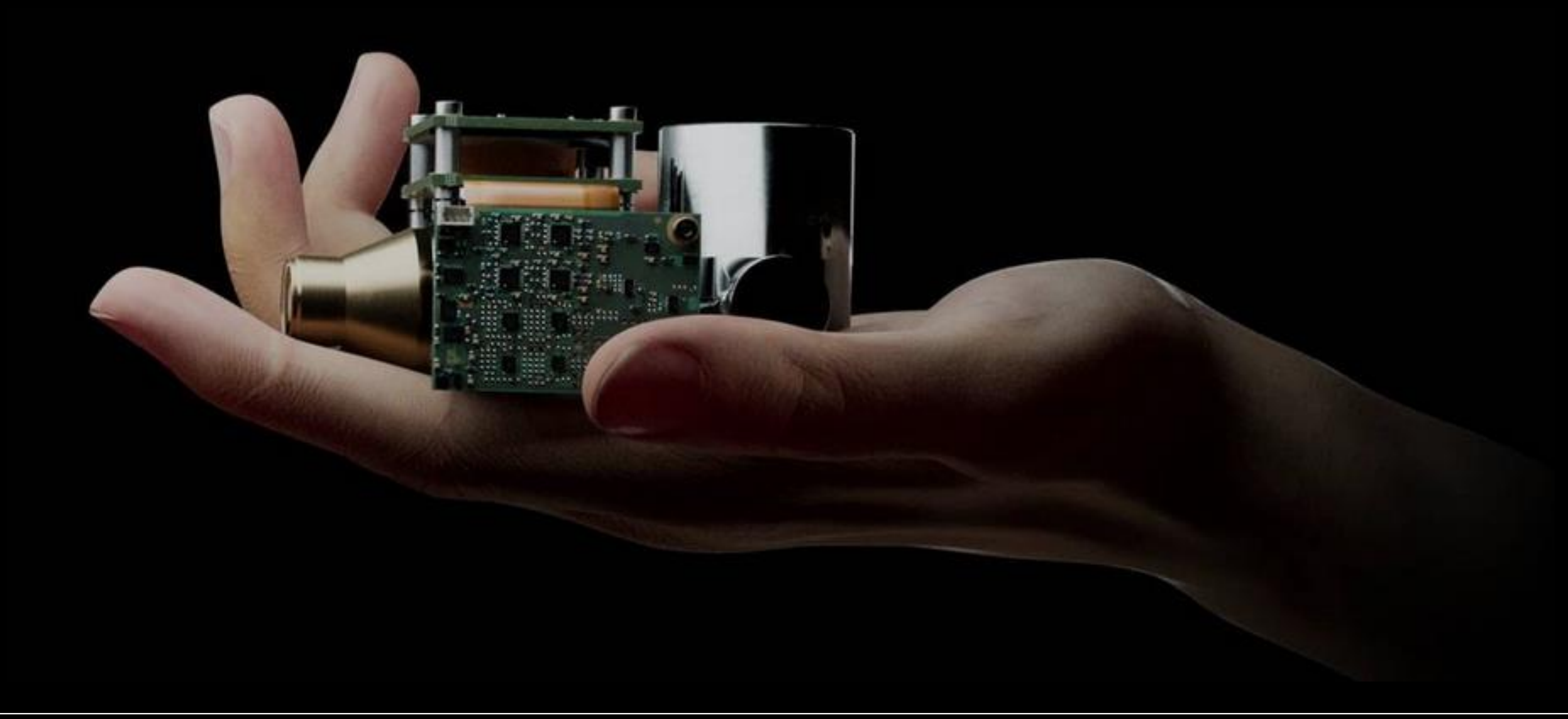
- **EU based IR detectors OEM Supplier**
  - Started in 1986 as a governmental research laboratory
  - Independent and Privately owned since 2007
- **30+ years of IR sensor R&D and Manufacturing**
  - Leading QWIP and T2SL detectors (eSWIR, MWIR, LWIR, VLWIR)
  - Several 1000's of QWIP & T2SL detectors fielded
  - Contract manufacturing for III-V material
- **Pioneers in Optical Gas Imaging**
  - MWIR and LWIR solutions for all addressable gases
  - QVGA (320x256) and VGA (640x512) solutions available
- **Strong Team and Excellent Facilities**
  - 70% staff share of PhD's and MSc's
  - 2500 m^2 manufacturing facilities including 1300 m^2 of clean room
  - ISO9001 : 2015 certified



Revolutionary technologies T2SL and small pitch QWIP



T2SL



Small pitch QWIP

“QWIP for dual-band LWIR radiometry in Earth Observation”
presented by Eric Costard today at 3.30 pm !

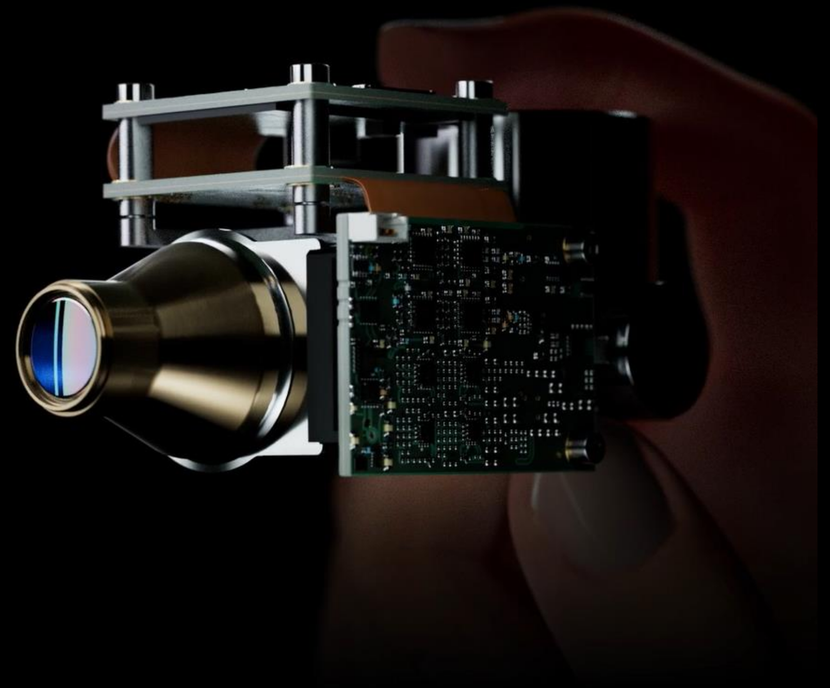
T2SL history at IRnova

HOT HD T2SL
10 µm pitch
Njord MW

T2SL in production for gas sensing since 2013

Full scale production of VGA MWIR T2SL

First European SWaP T2SL detector



HOT T2SL 15 µm pitch
Oden MW

7.5 µm pitch
Skade MW

T2SL R&D

2004 – 2013 – 2019 – 2020 – 2022 – 2024 – 2026

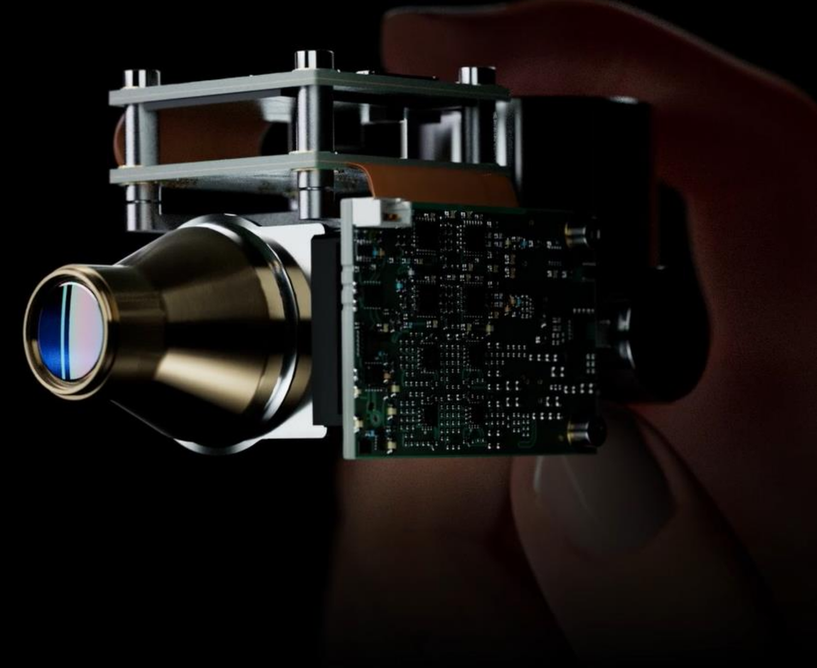
2024: VGA eSWIR

2026: HD eSWIR

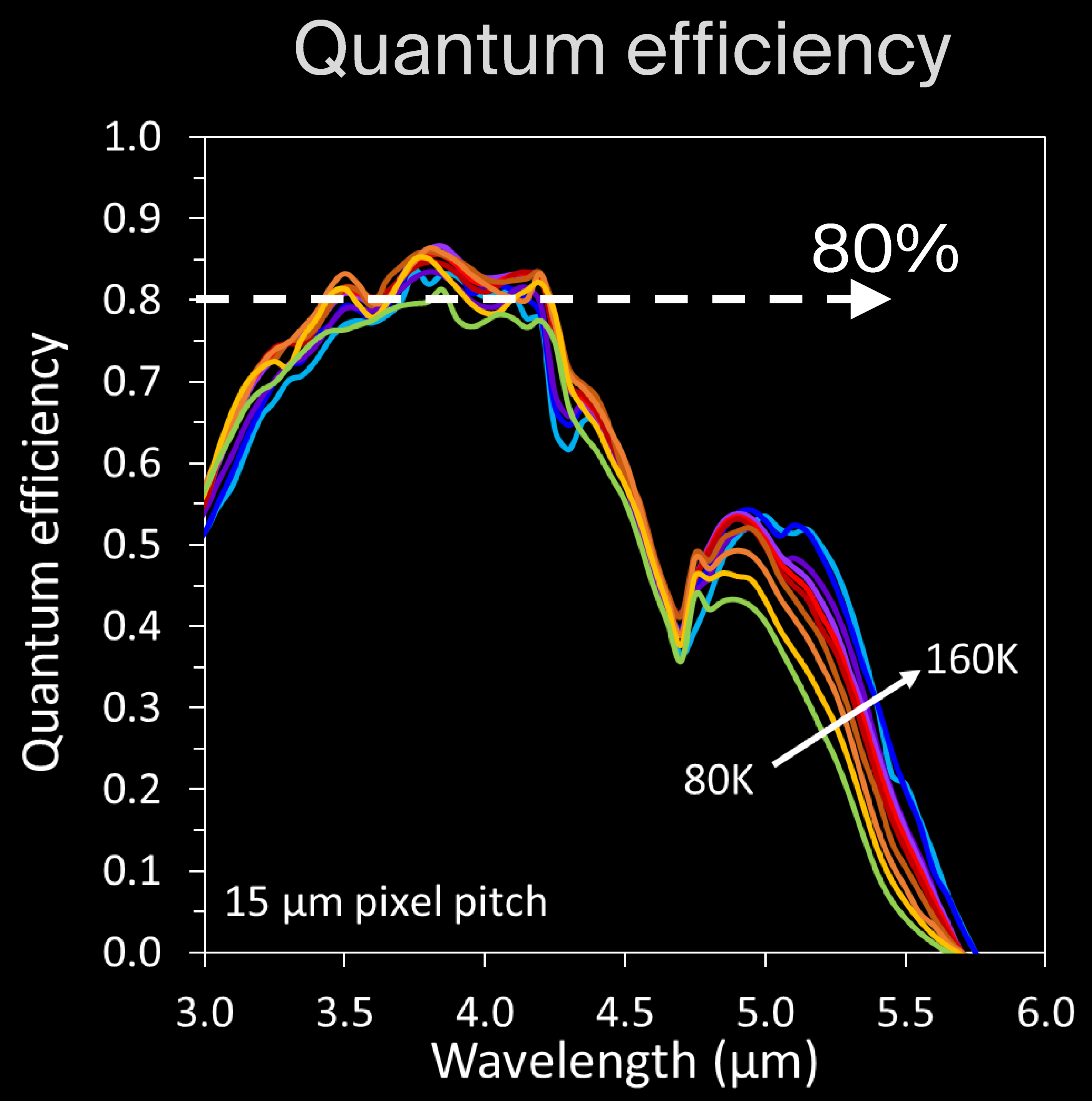
Agenda

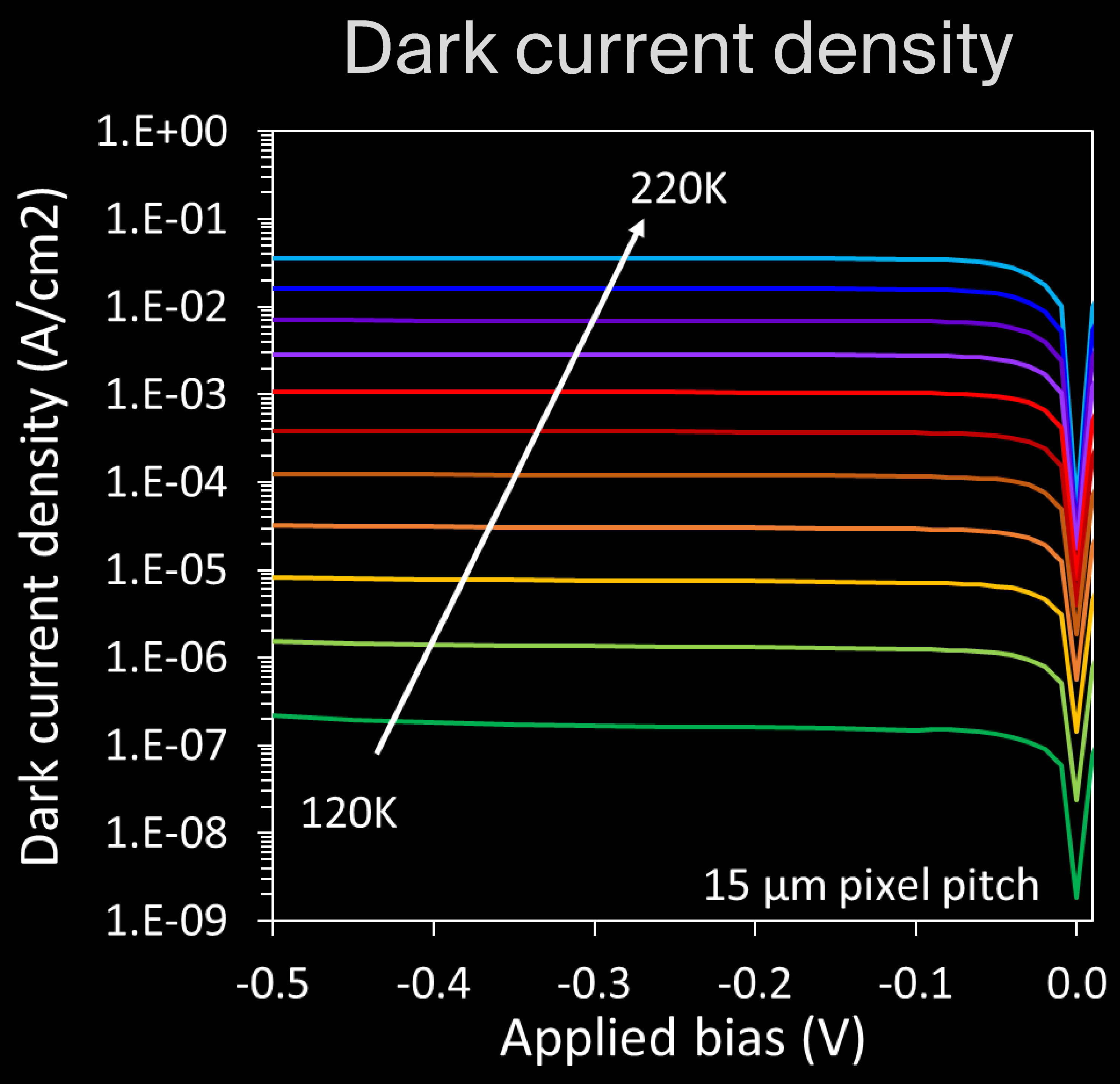
- Oden MW detectors for HOT SWaP
- Njord MW for HOT HD
- Skade MW 7.5 µm pitch T2SL detector
- HD eSWIR for T = 200K

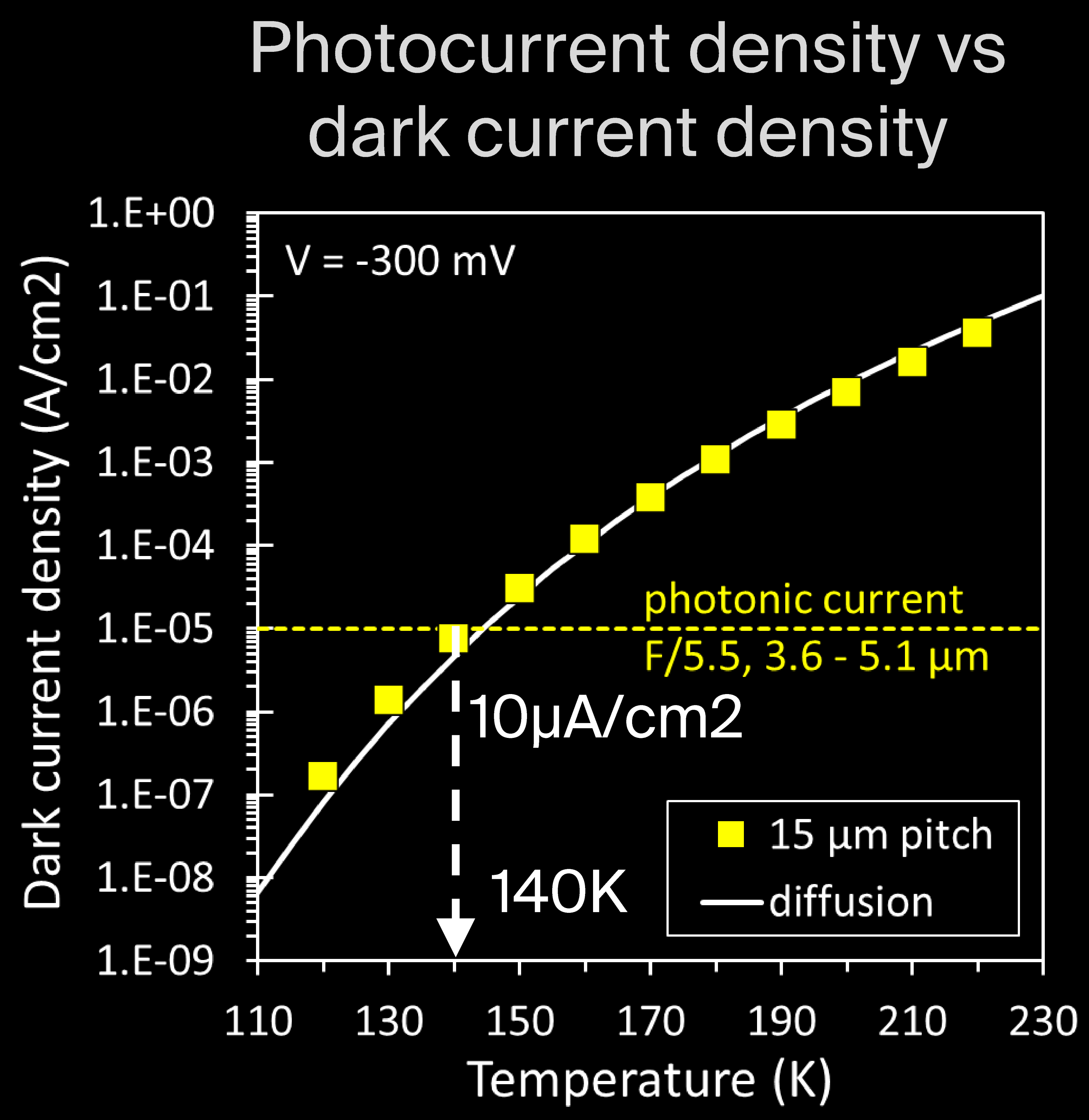
Oden MW - Photocurrent vs dark current @15 µm pitch



- Full coverage of MWIR band with cut-off wavelength ~5.2 µm @120 K
- High quantum efficiency (~80%@4µm) and low turn on bias
- Diffusion limited dark current density with lower level than photocurrent up to 140K

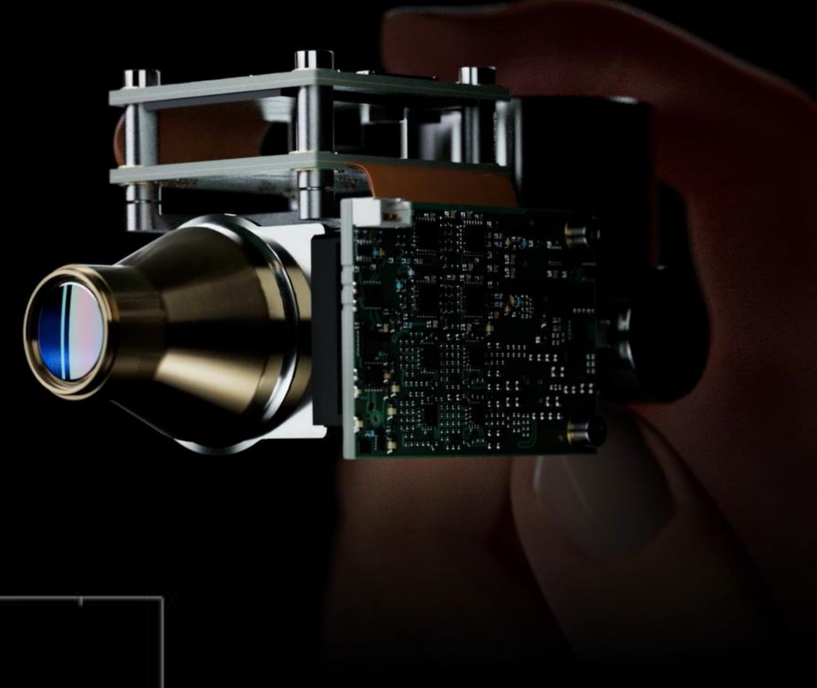


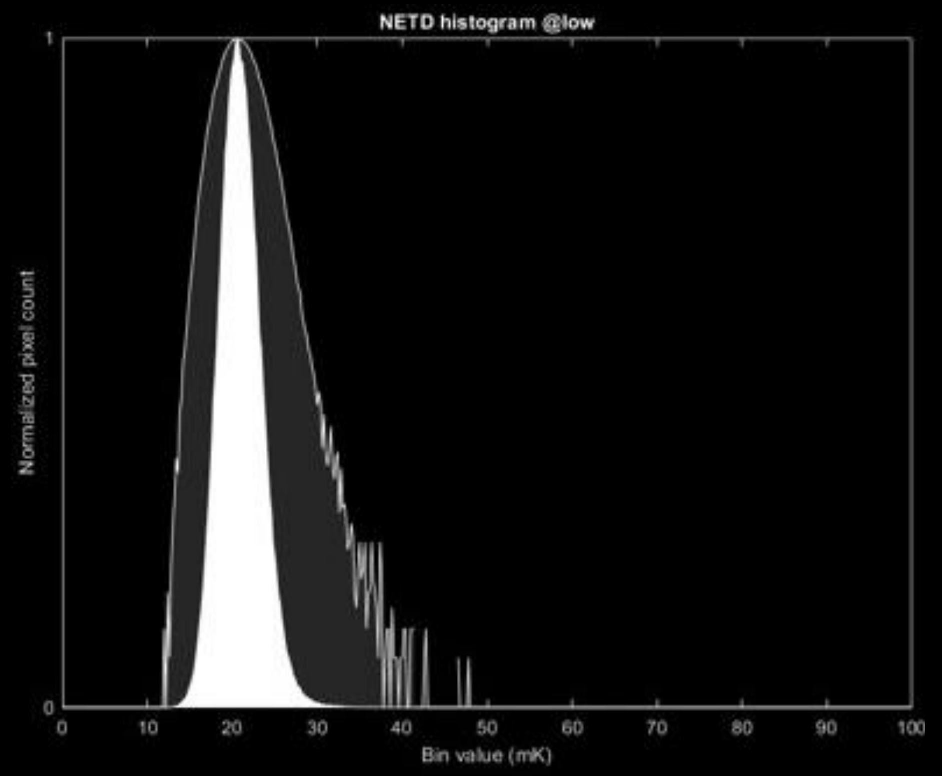
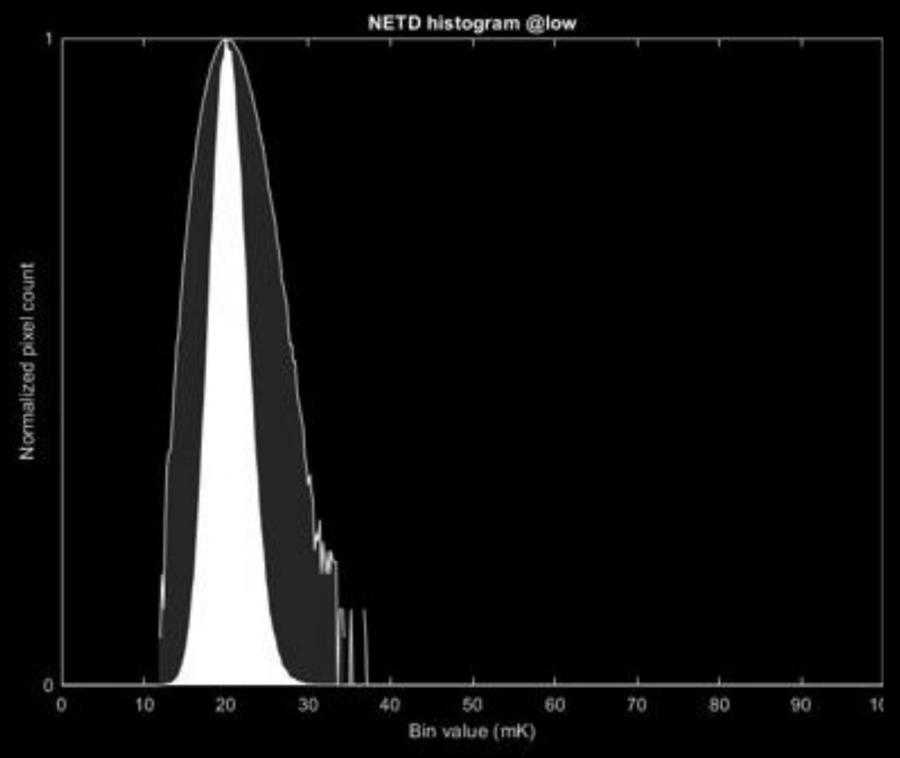
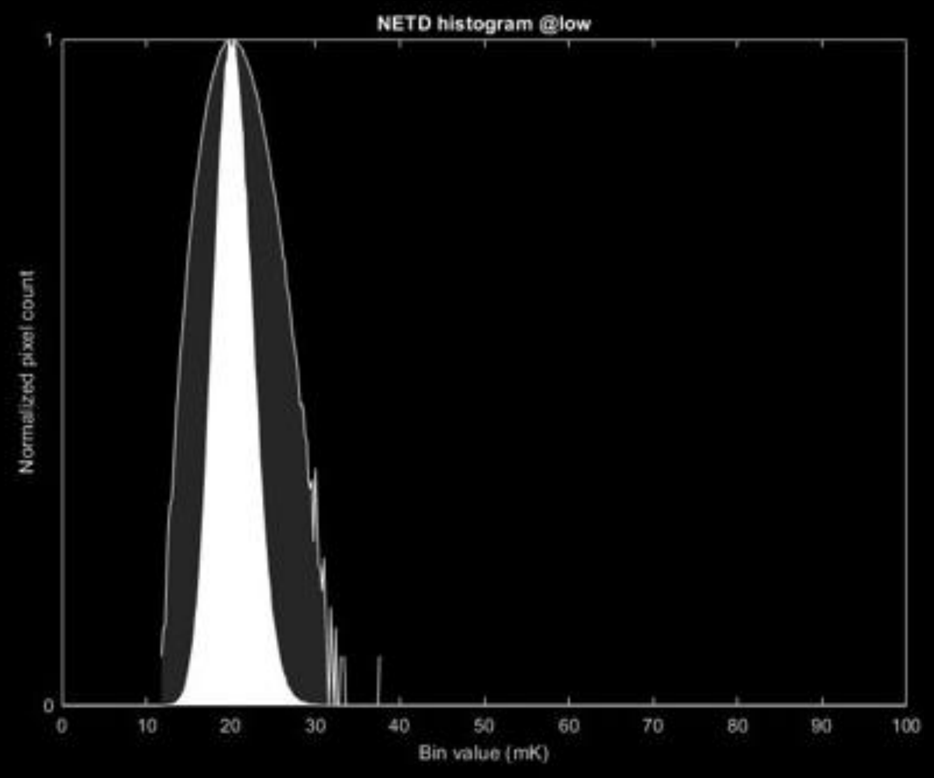
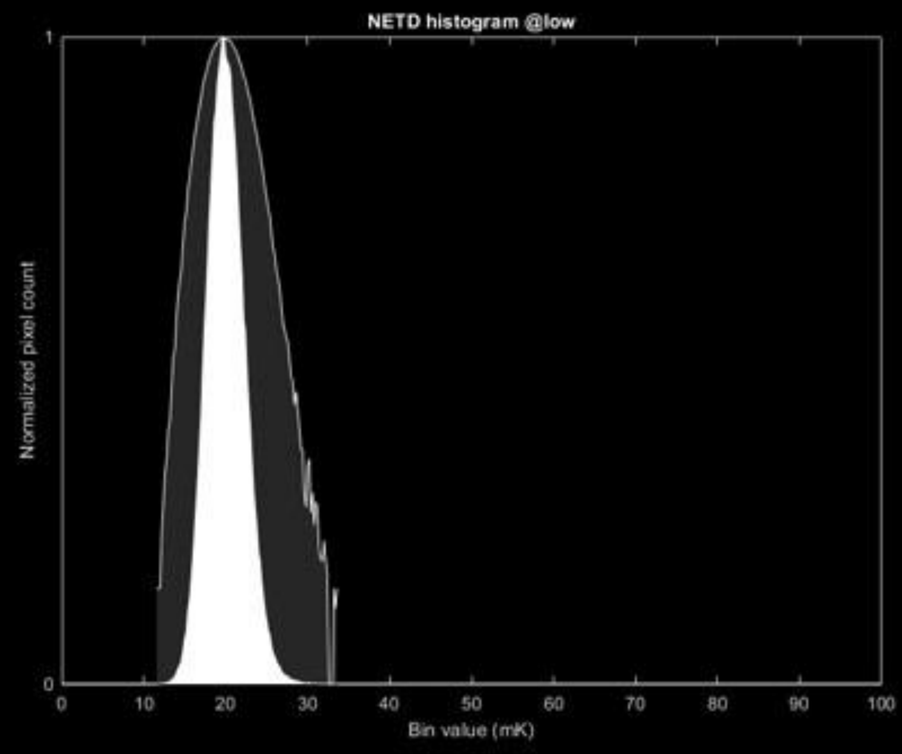
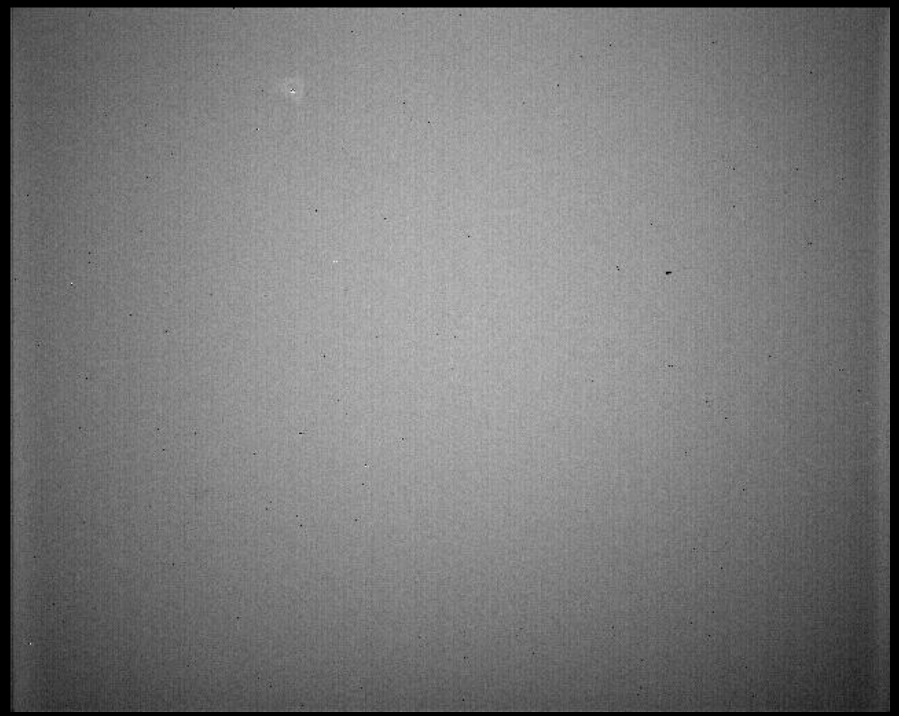




Oden MW IDDCAs - Temperature dependence

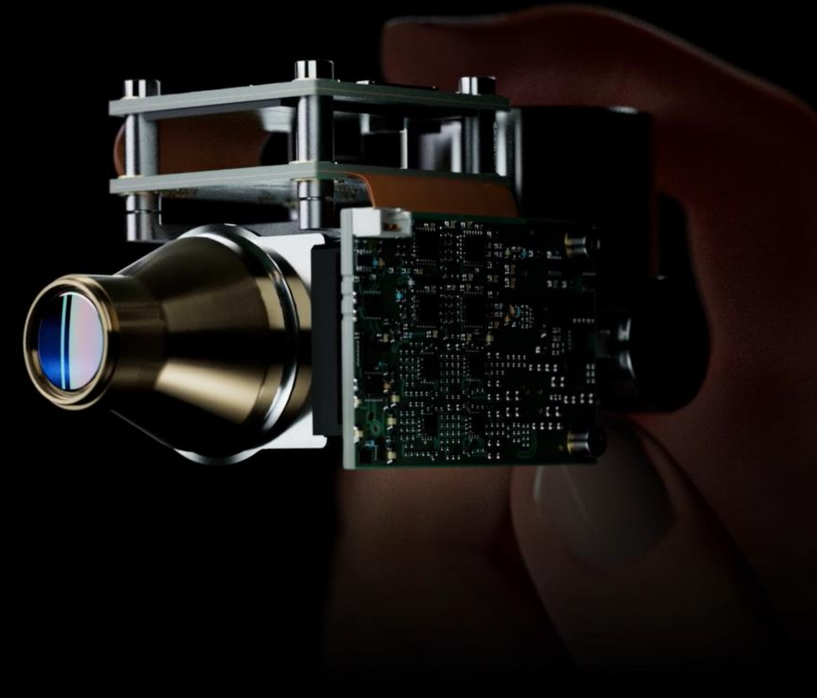
F/5.5
60 Hz
3.6-5.1µm filter



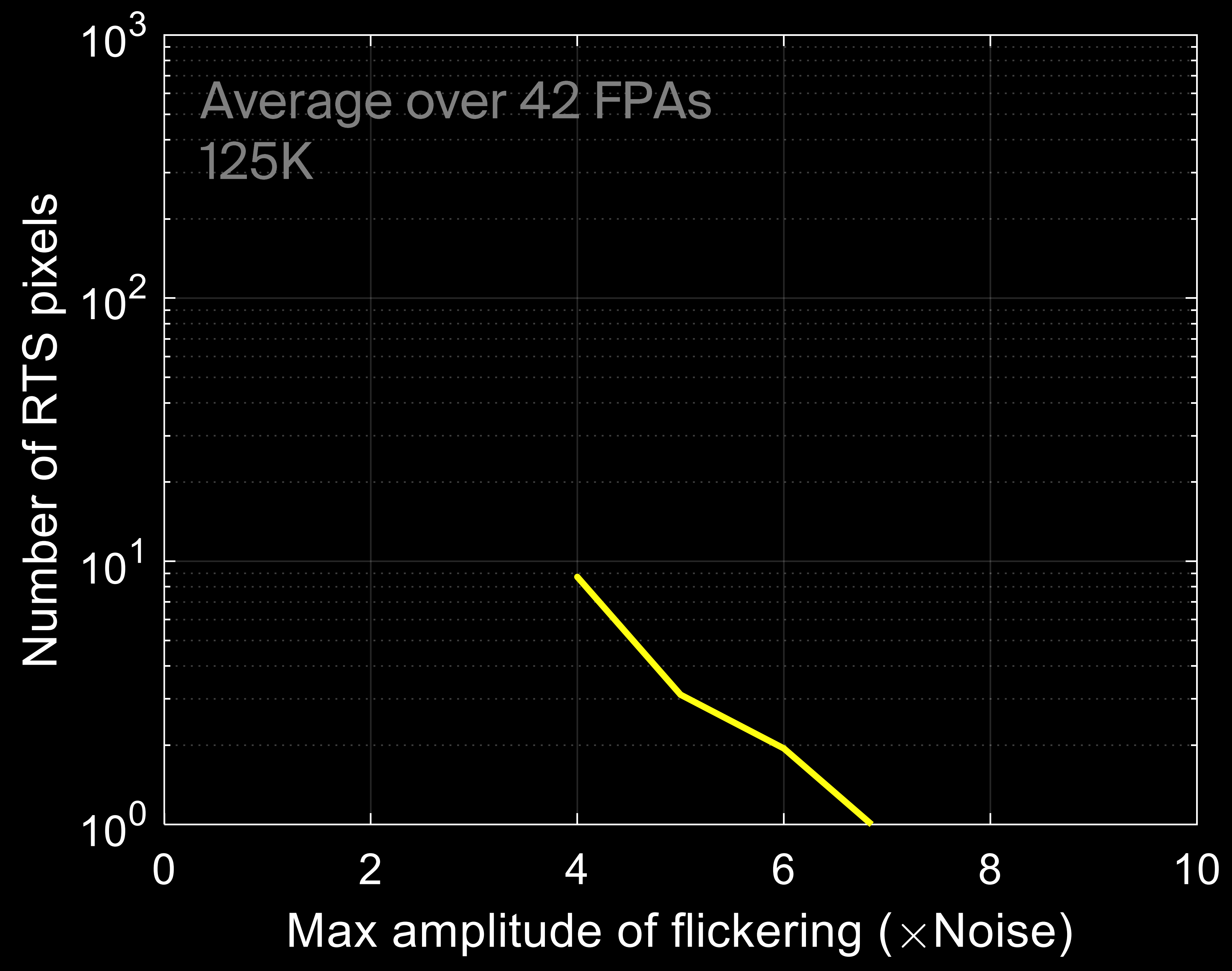
	110 K	120 K	125 K	130 K
NETD histogram				
	NETD_temp: 18.9mK NETD_spat: 6.9 mK Operability: 99.89%	NETD_temp: 18.5mK NETD_spat: 6.6 mK Operability: 99.94%	NETD_temp: 18.5mK NETD_spat: 6.6 mK Operability: 99.94%	NETD_temp: 18.35 mK NETD_spat: 5.1 mK Operability: 99.97%
Response map				

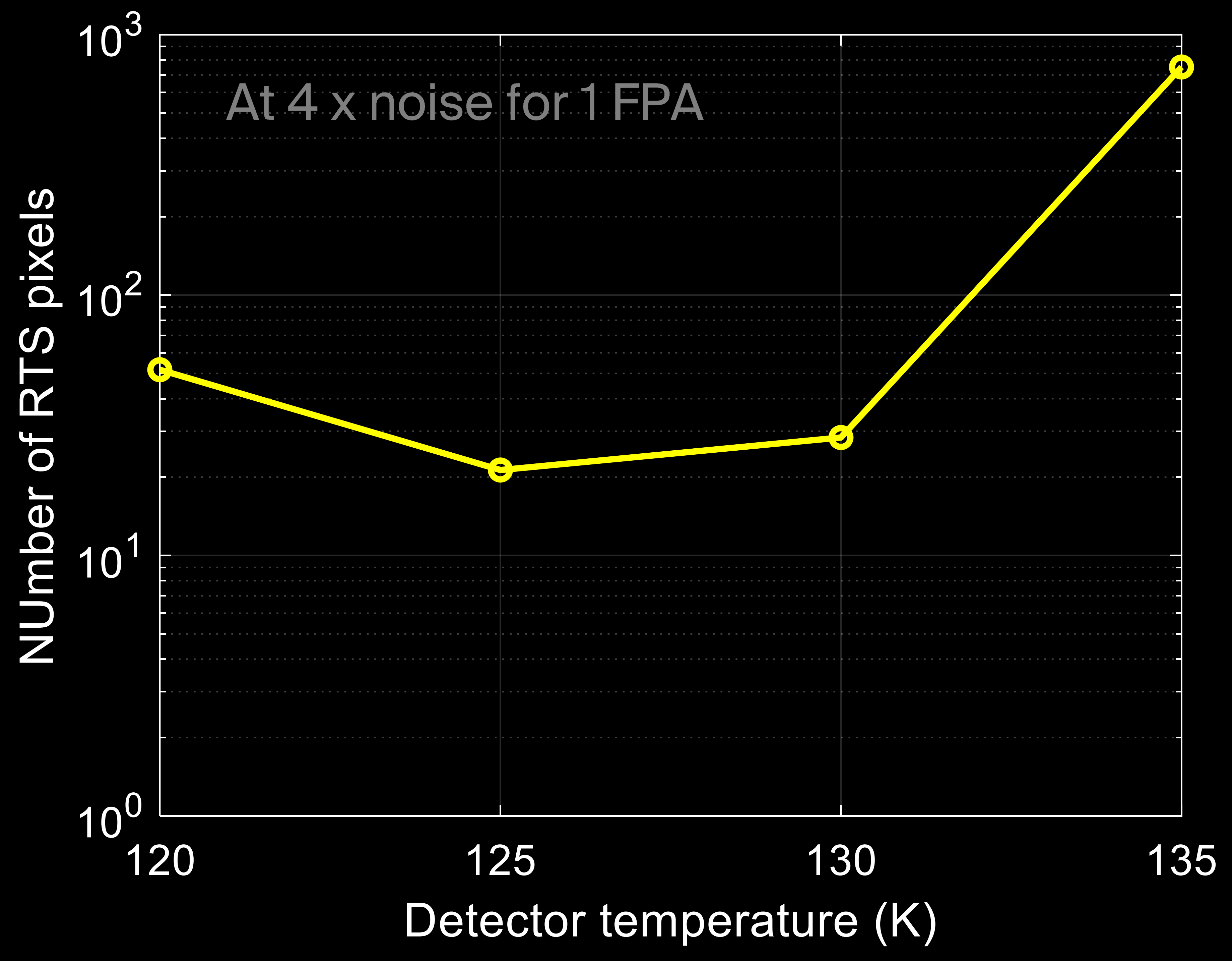
No tail, very few noisy outliers. Operability higher than 99.9 %.
Excellent uniformity maintained up to 130K !

Oden MW IDDCAs – Low flickering rate

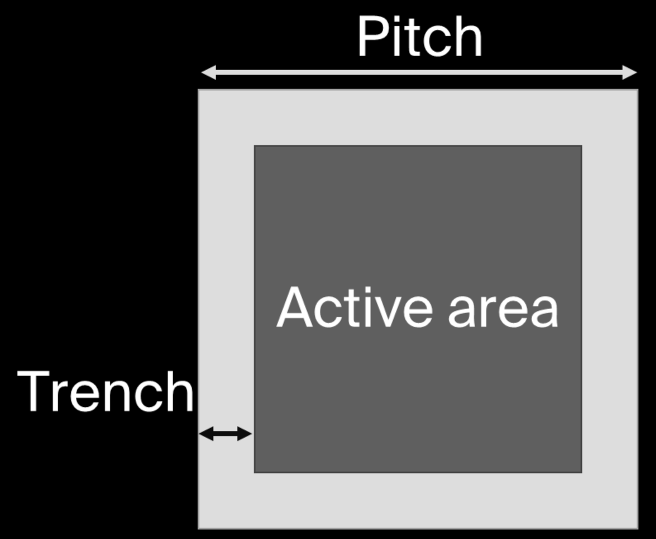


- Statistics of RTS in 42 FPAs at 125 K validate the very low flickering rates in Oden MW
- Average number of RTS ~10 (with max. 4 x noise)
- Low flickering rate maintained up to 130K

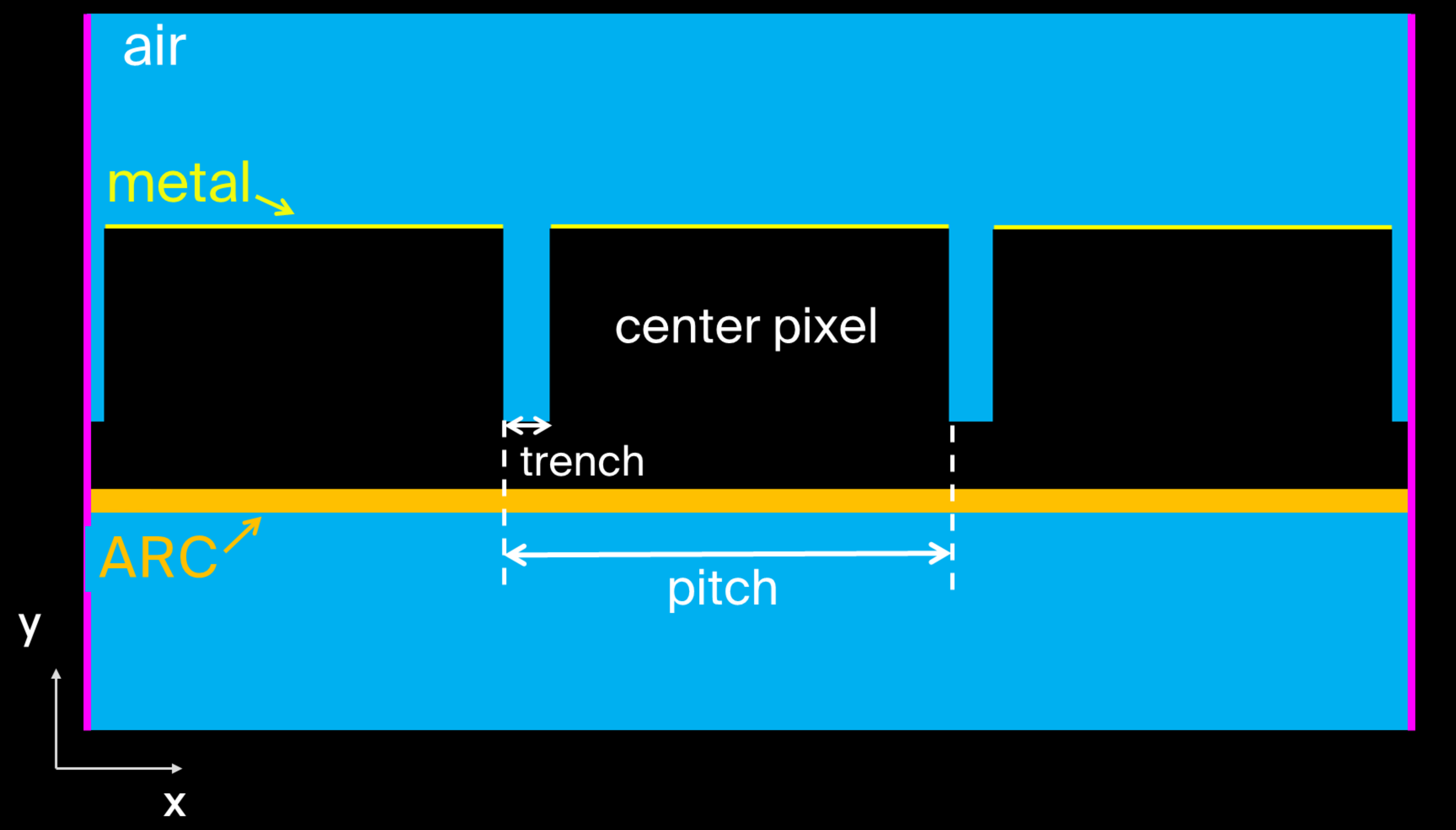




MTF simulations on T2SL detector @15 µm pitch

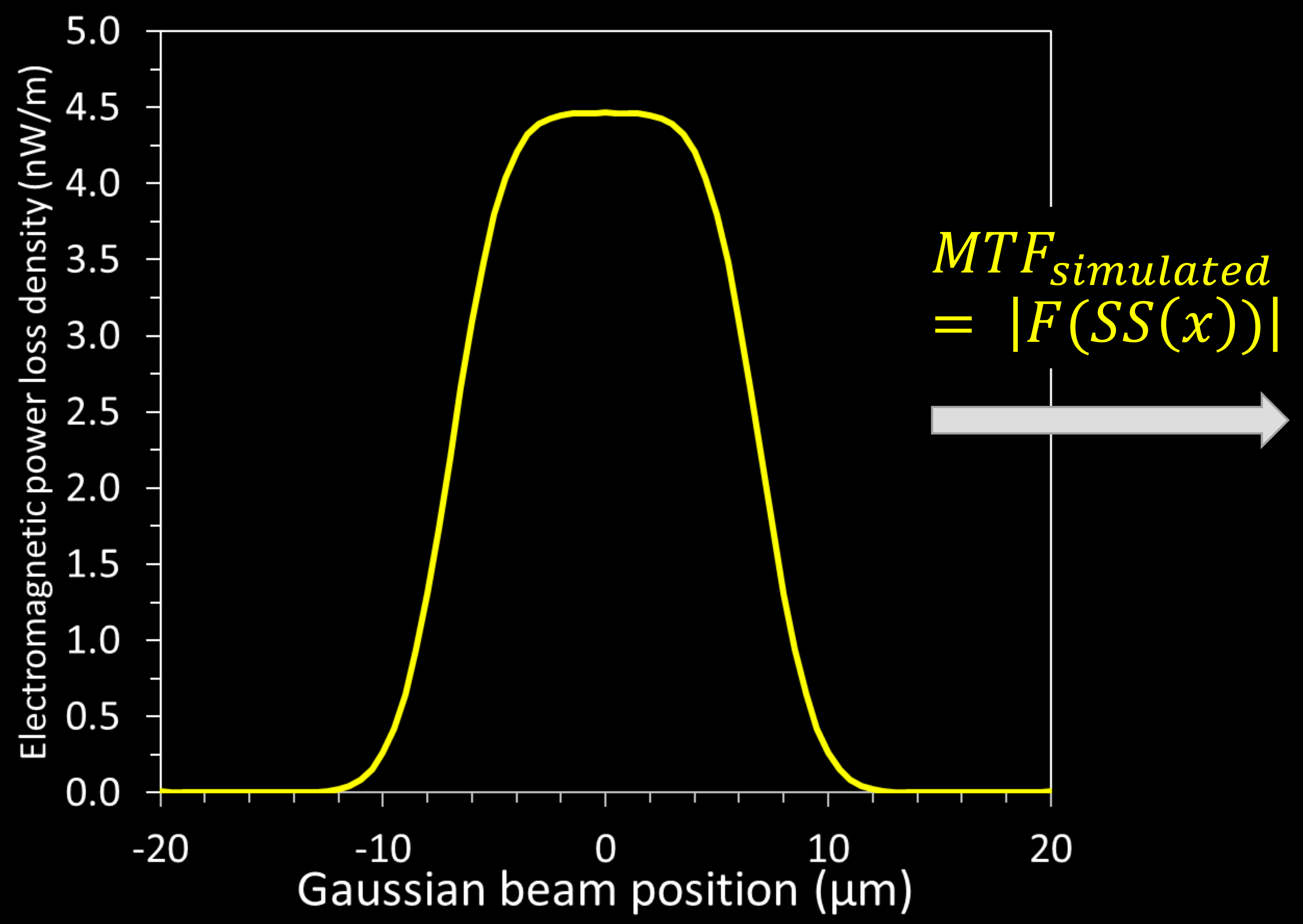


Geometry



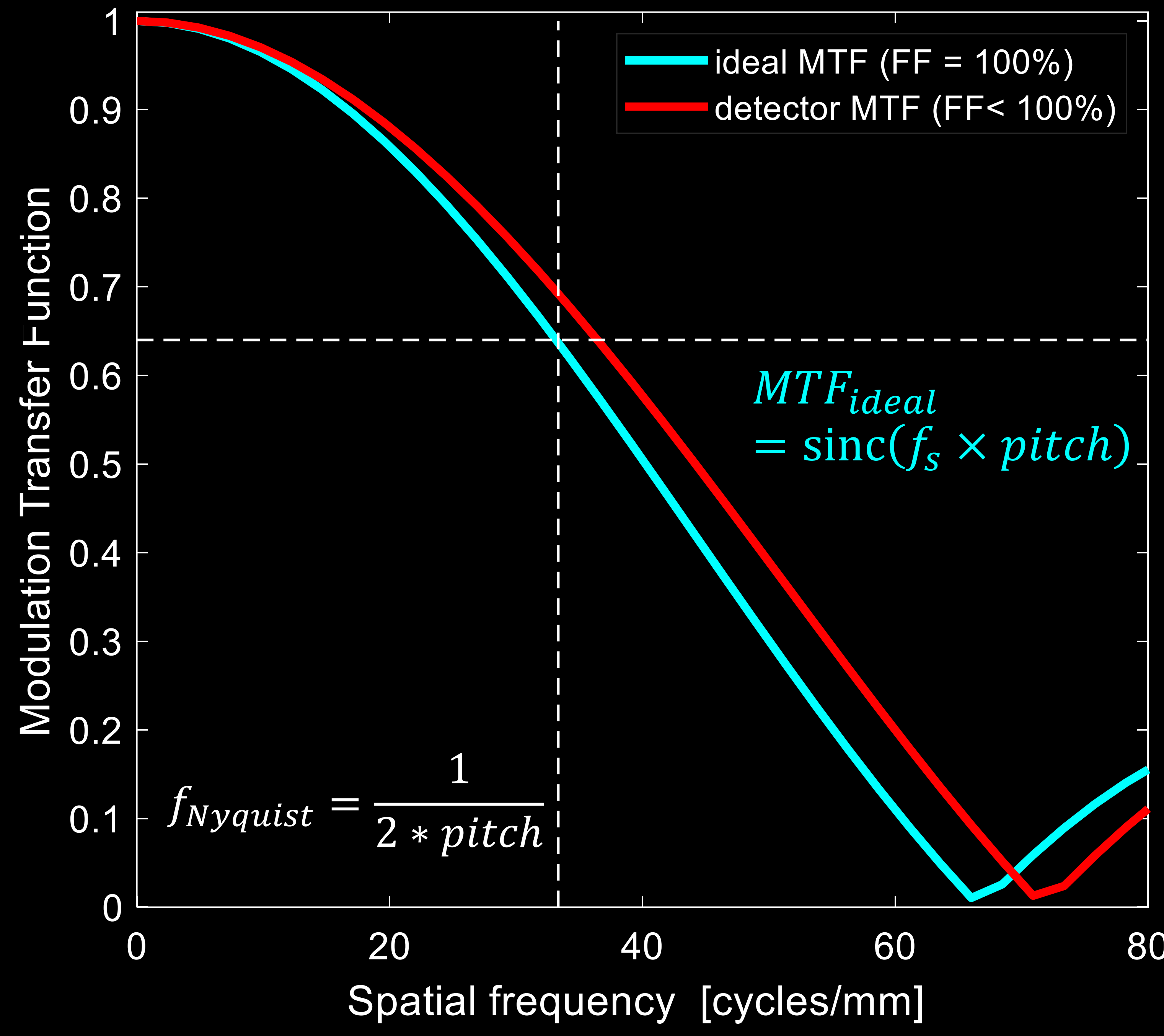
- Geometry and optical properties considered same as in our T2SL detector
- Gaussian beam is incident to the pixel and moving in the x-direction

Spot scan profile



Signal in center pixel as function of the gaussian beam position

MTF extraction

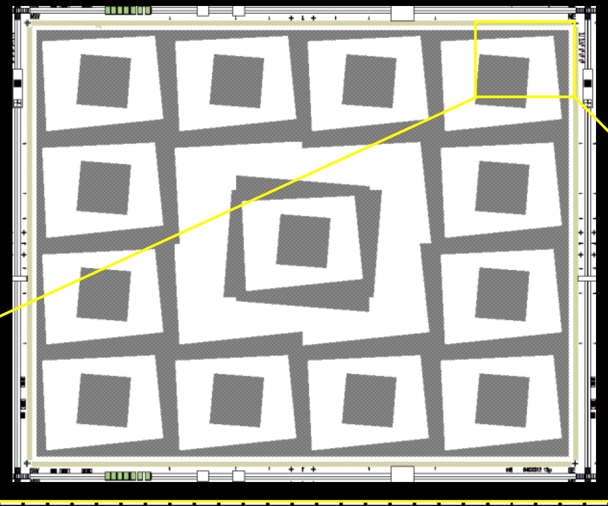


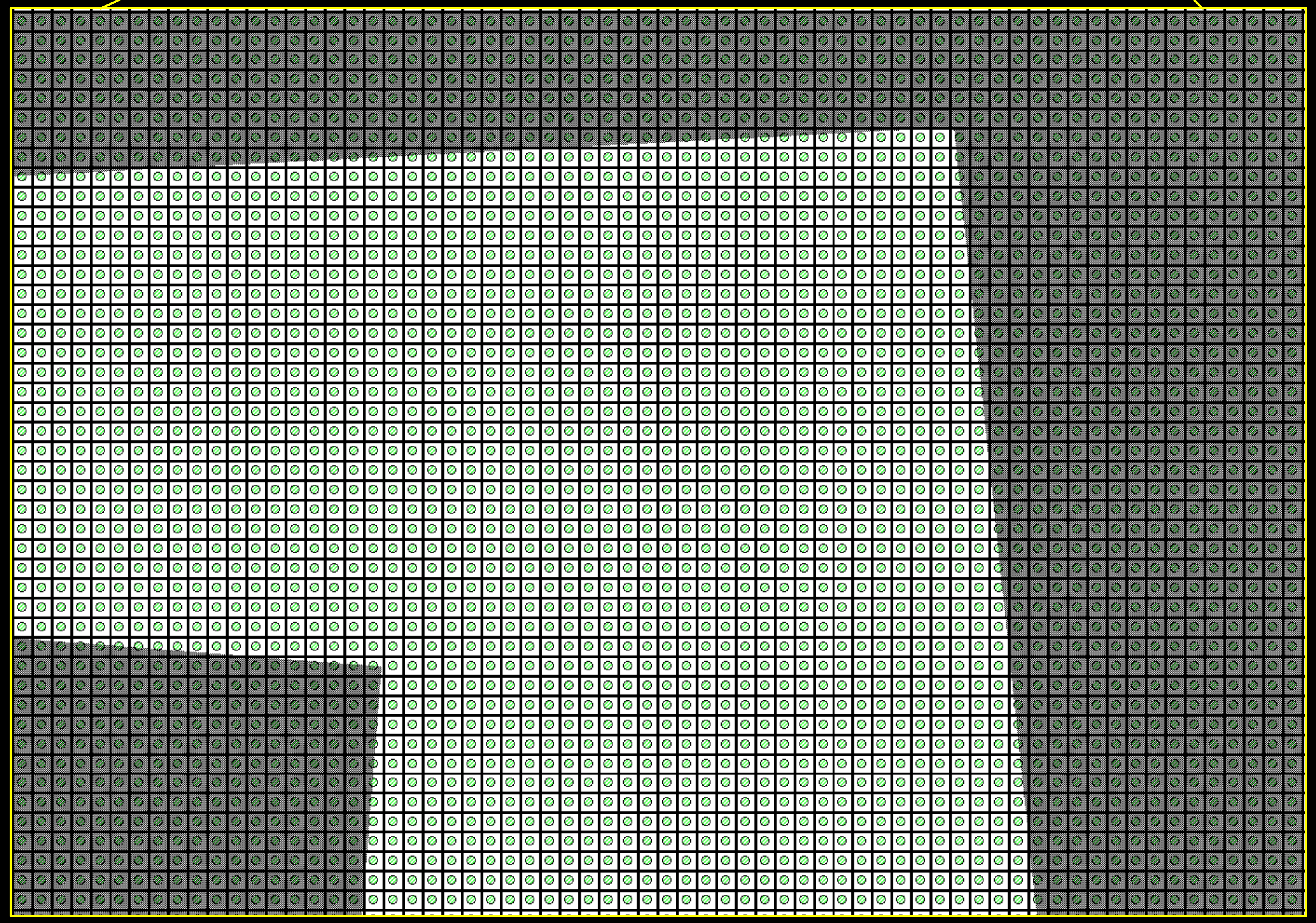
MTF @ Nyquist frequency close to ideal

MTF measurements on T2SL VGA FPAs

Mask design

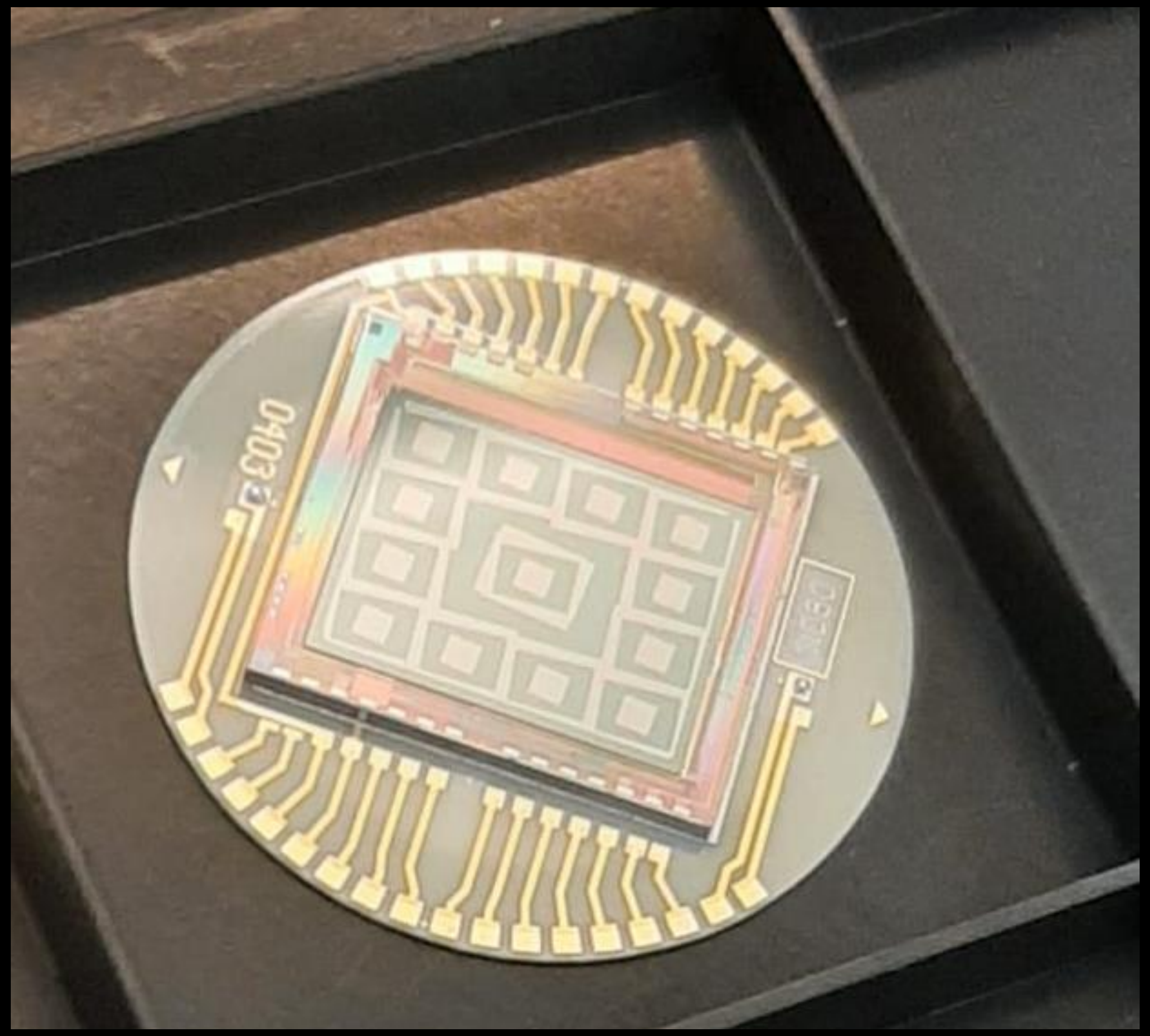
Different angles
Edge span over large number of pixels





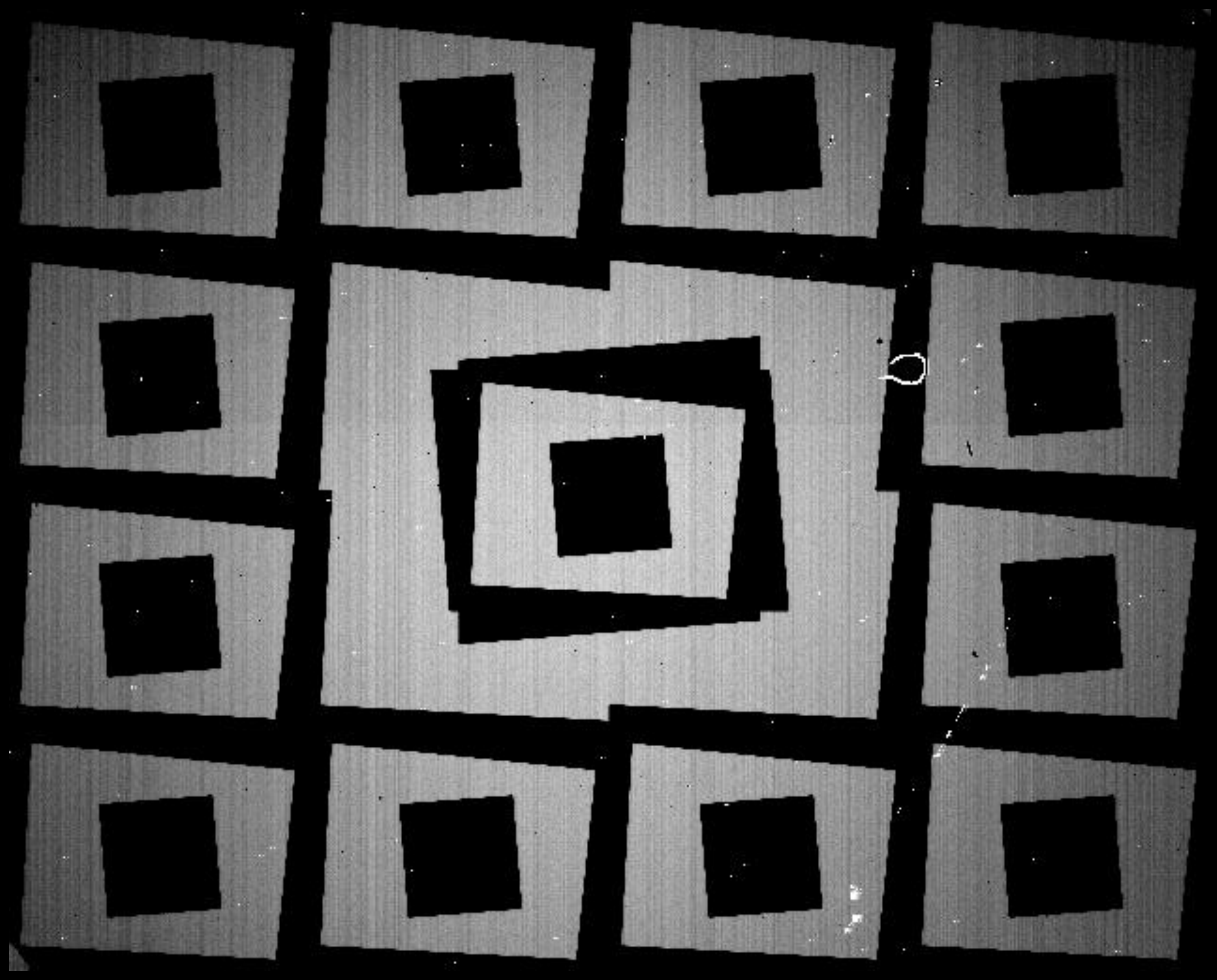
In-house fabrication on VGA FPAs

Only 0.007° rotation misalignment
Very sharp metal edge



FPA measurements

(FPA signal, ±10 %)

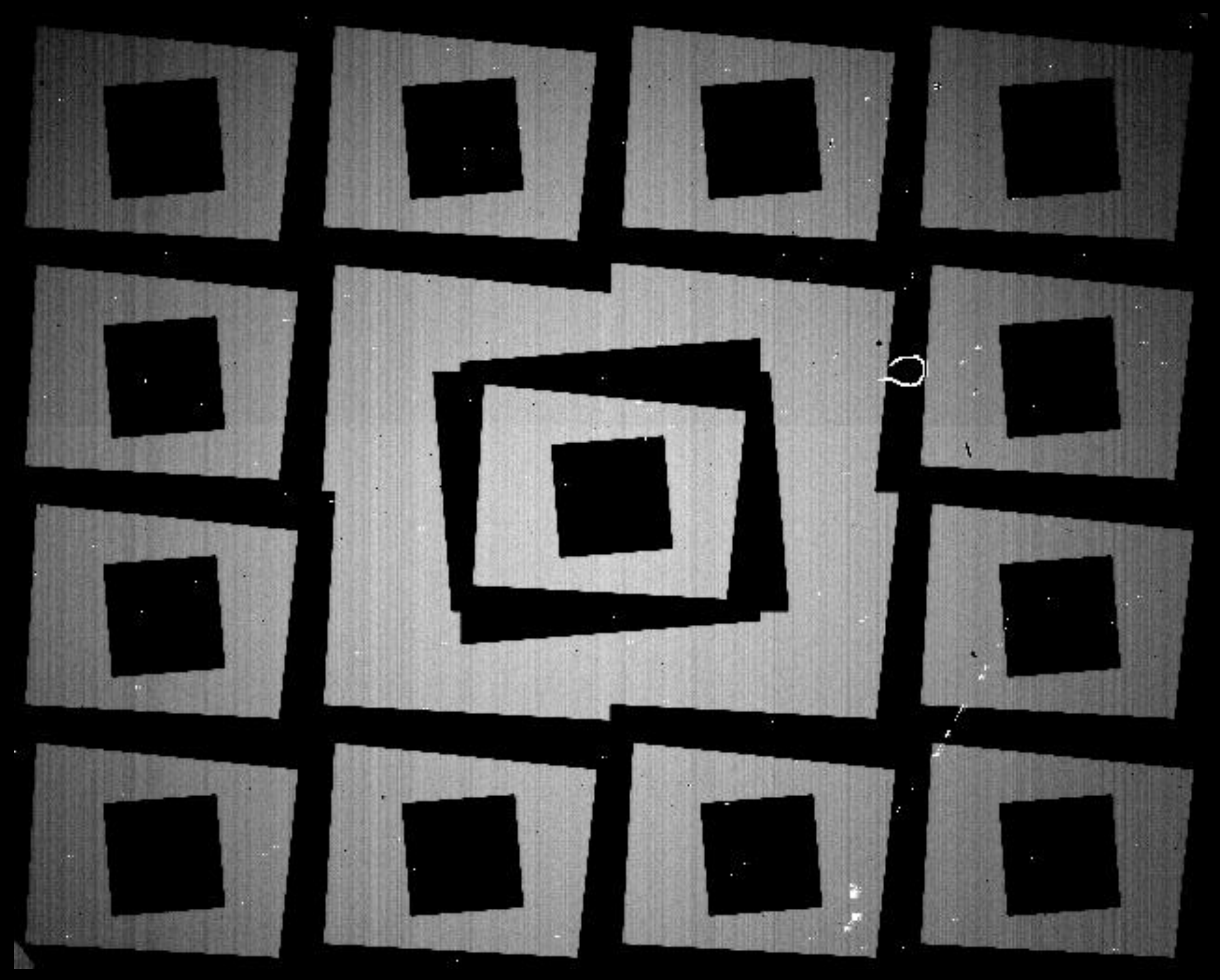


MTF measurements on T2SL VGA FPAs

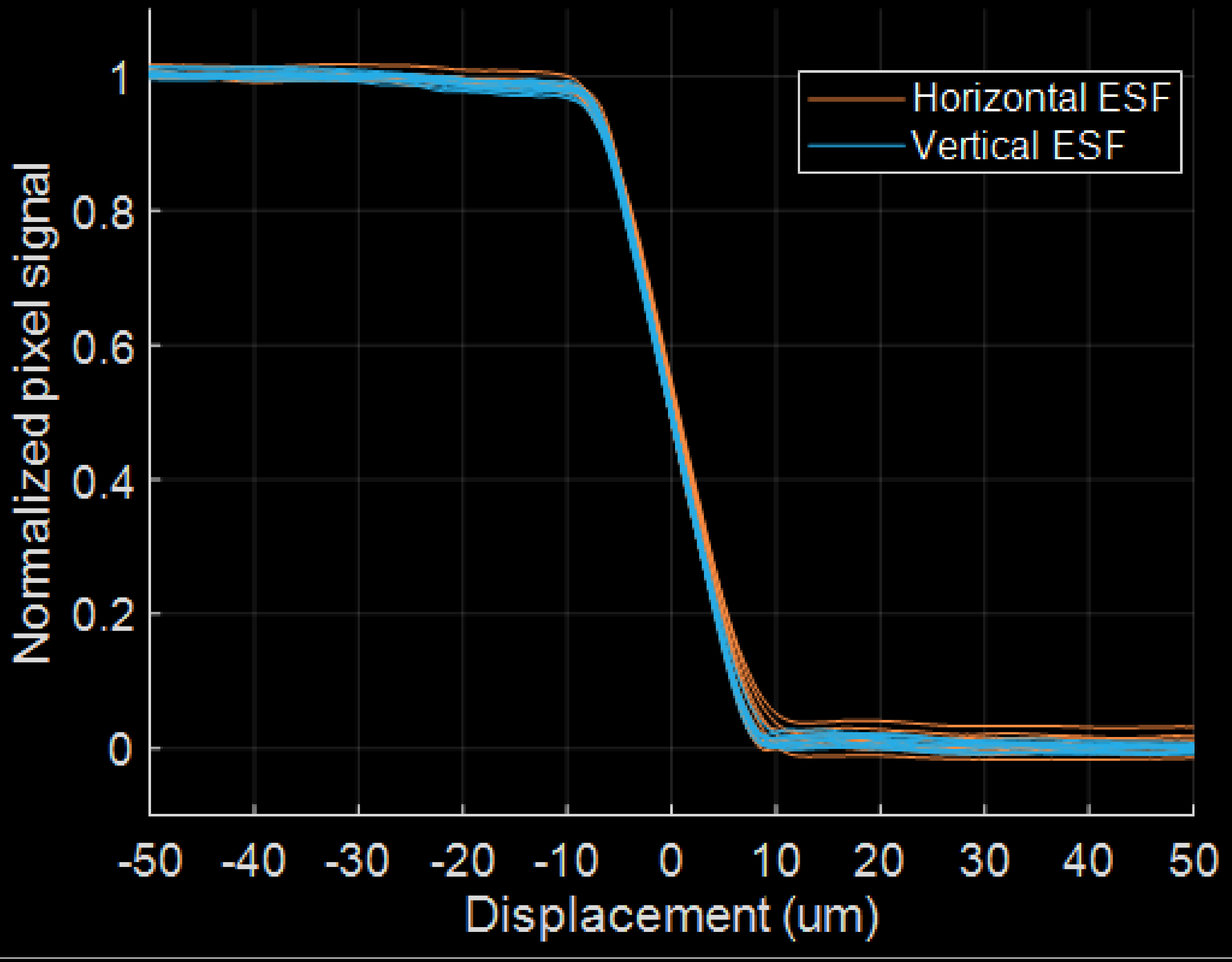
- Very uniform edge spread function across the array
- MTF close to ideal along both x- and y- directions
- MTF @ Nyquist frequency ~ 0.6

Measured MTF @ Nyquist frequency close to ideal !

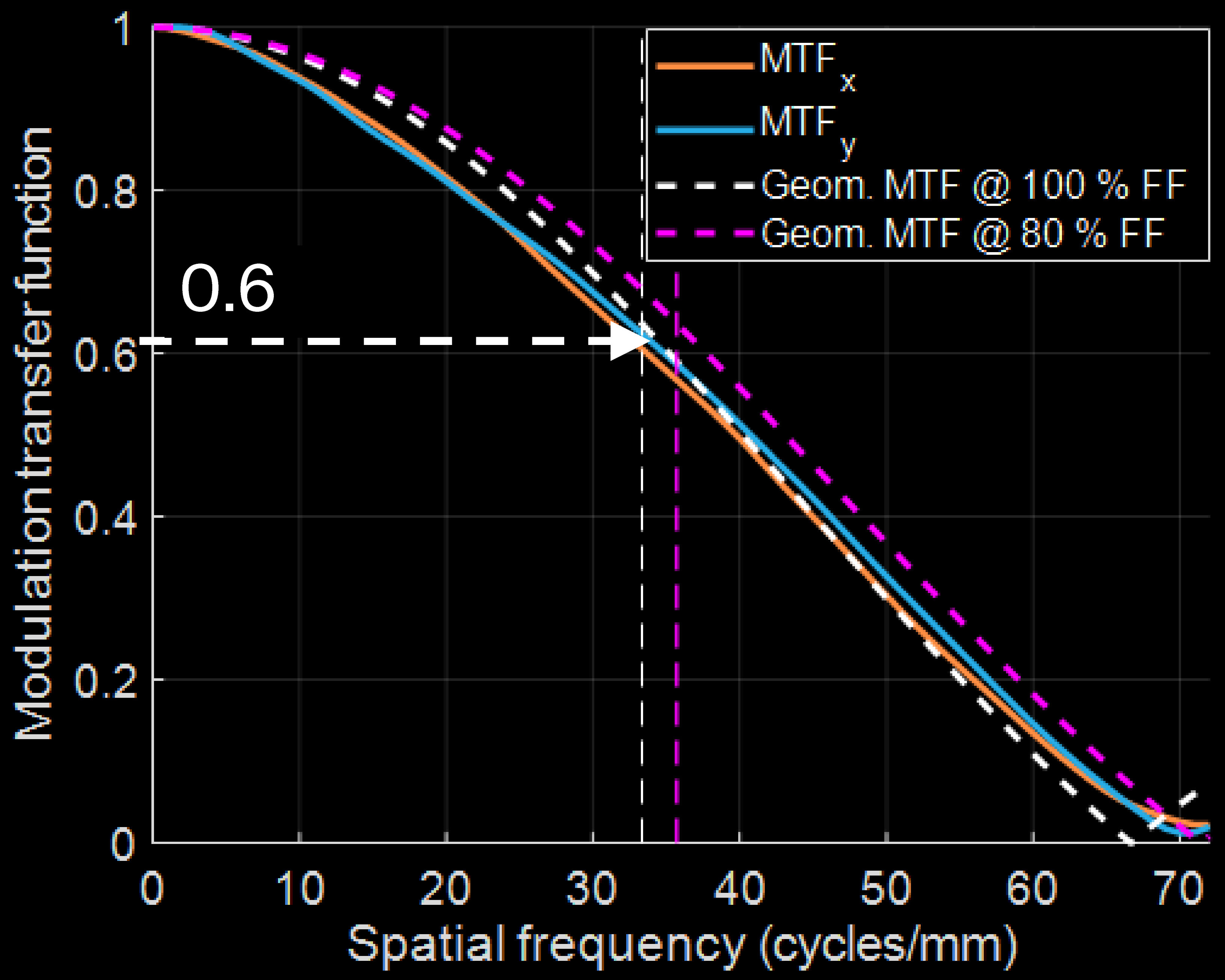
Measured signal map



Edge spread function



MTF of T2SL FPA



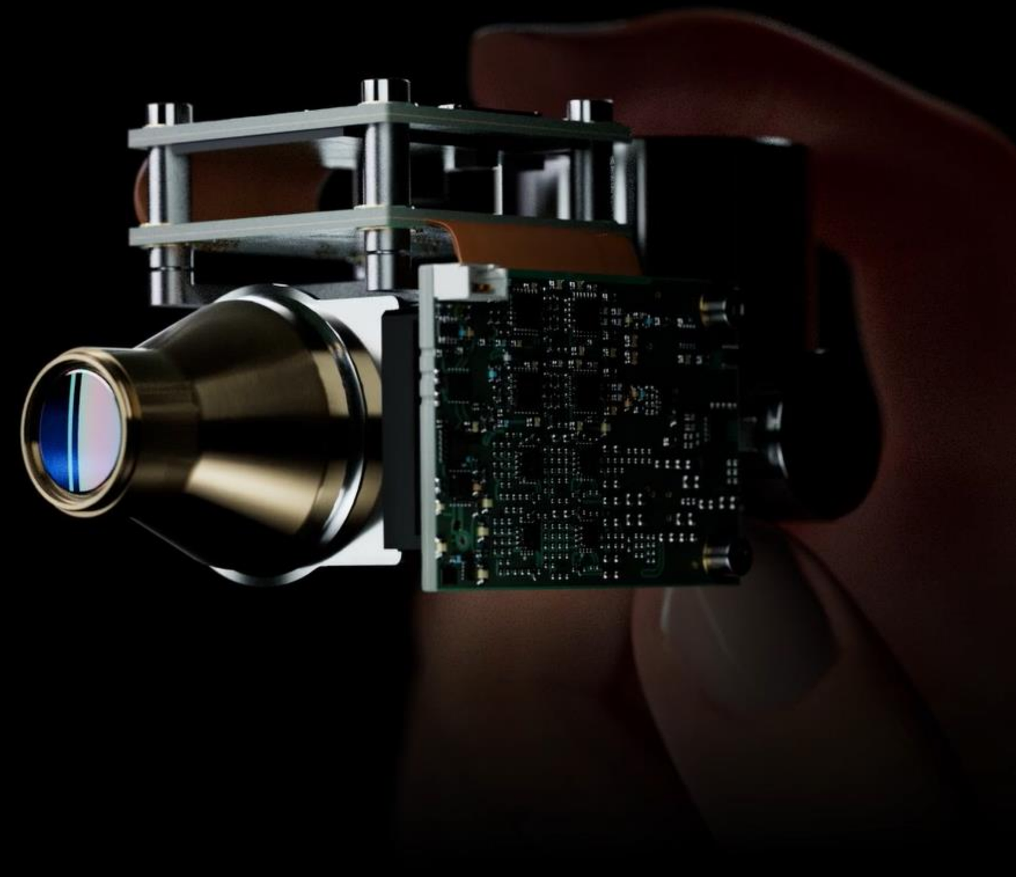
Agenda

Oden MW detectors for HOT SWaP

Excellent uniformity

Low flickering rate

MTF close to ideal value



Njord MW for HOT HD

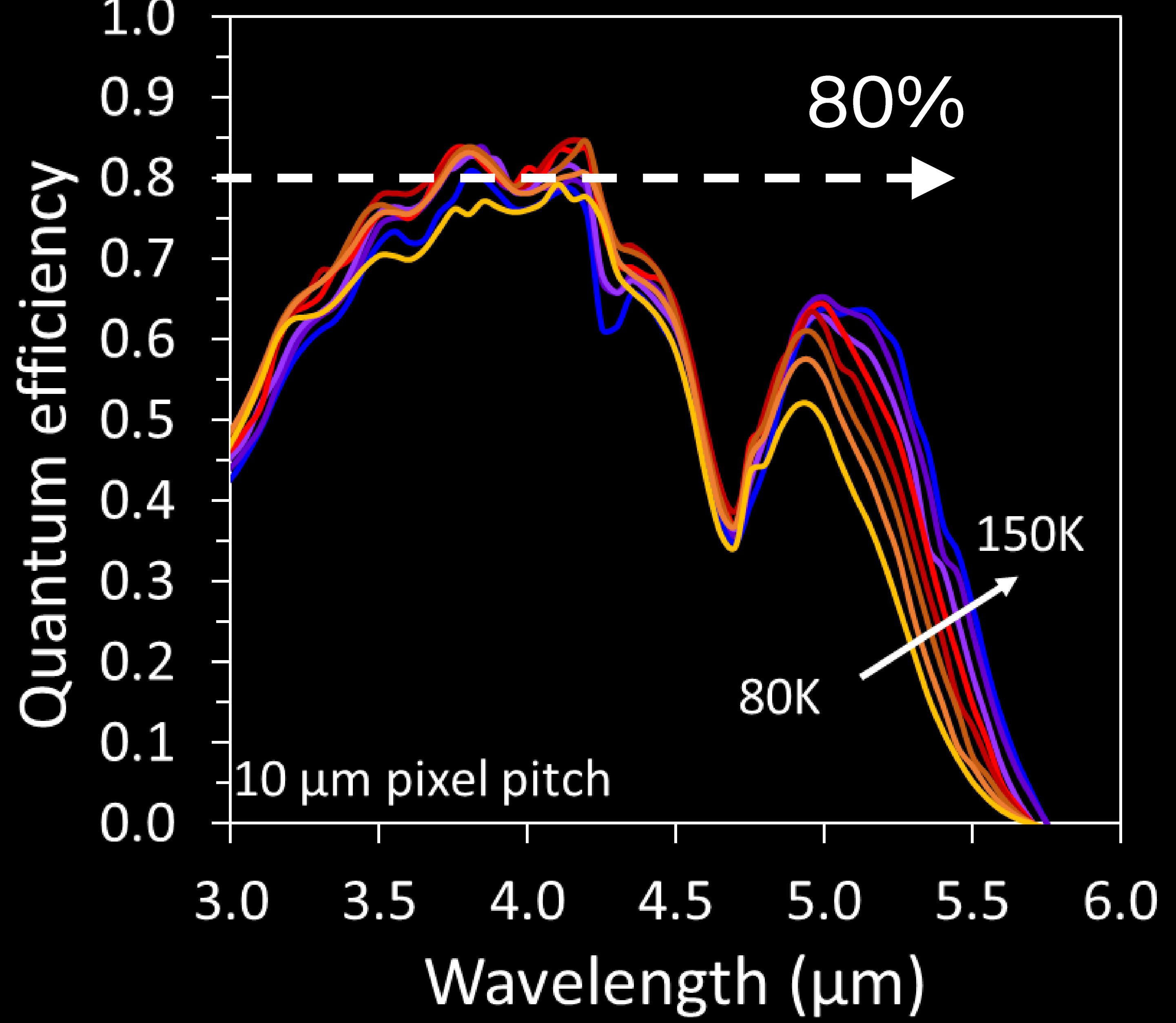
Skade MW 7.5 µm pitch T2SL detector

HD eSWIR for T = 200K

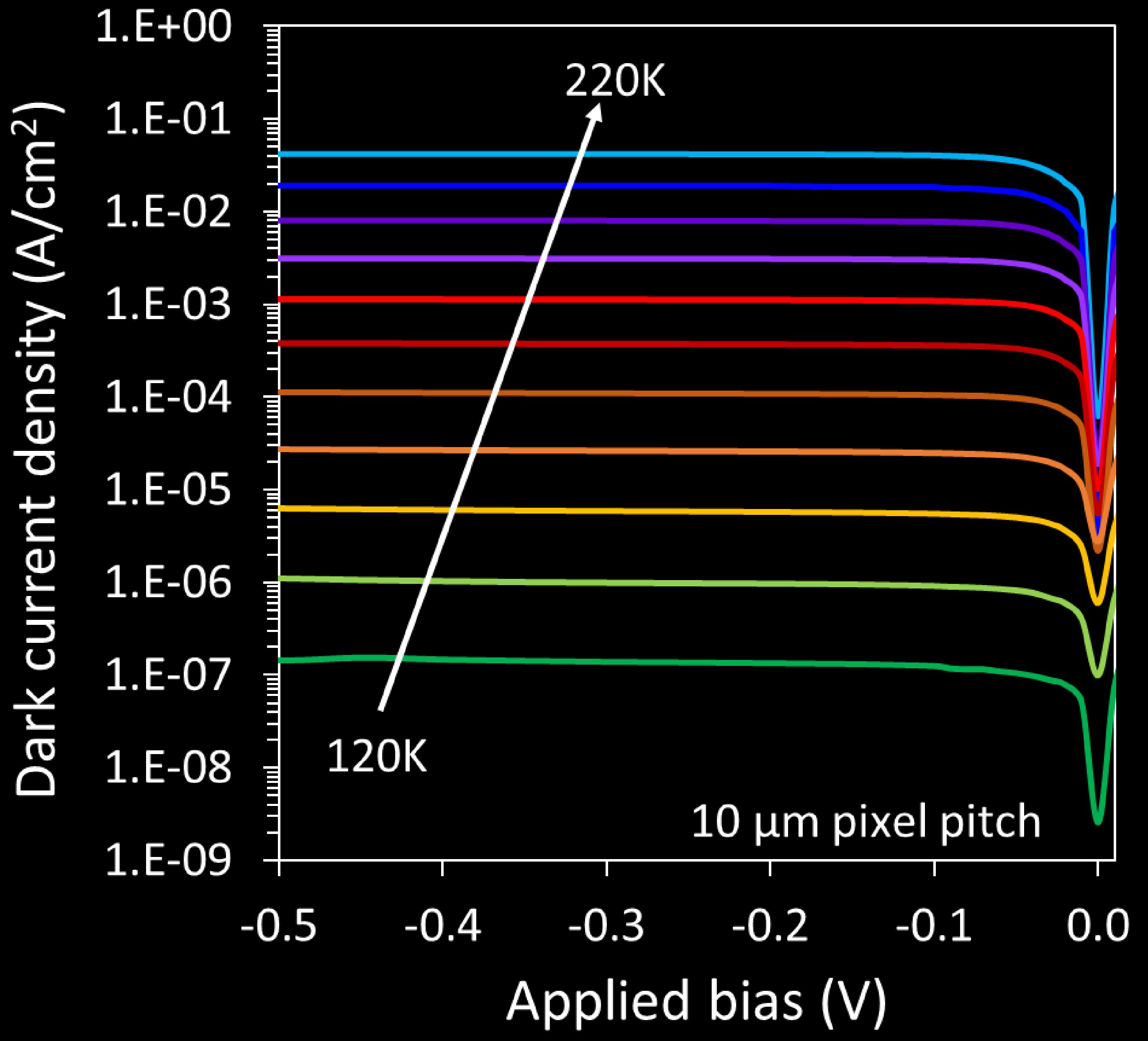
Njord MW - Photocurrent vs dark current @10 μm pitch

- Full coverage of MWIR band with cut-off wavelength ~5.3 μm @150 K
- High quantum efficiency (~80%@4μm) and low turn on bias
- Diffusion limited dark current density with lower level than photocurrent up to 150K

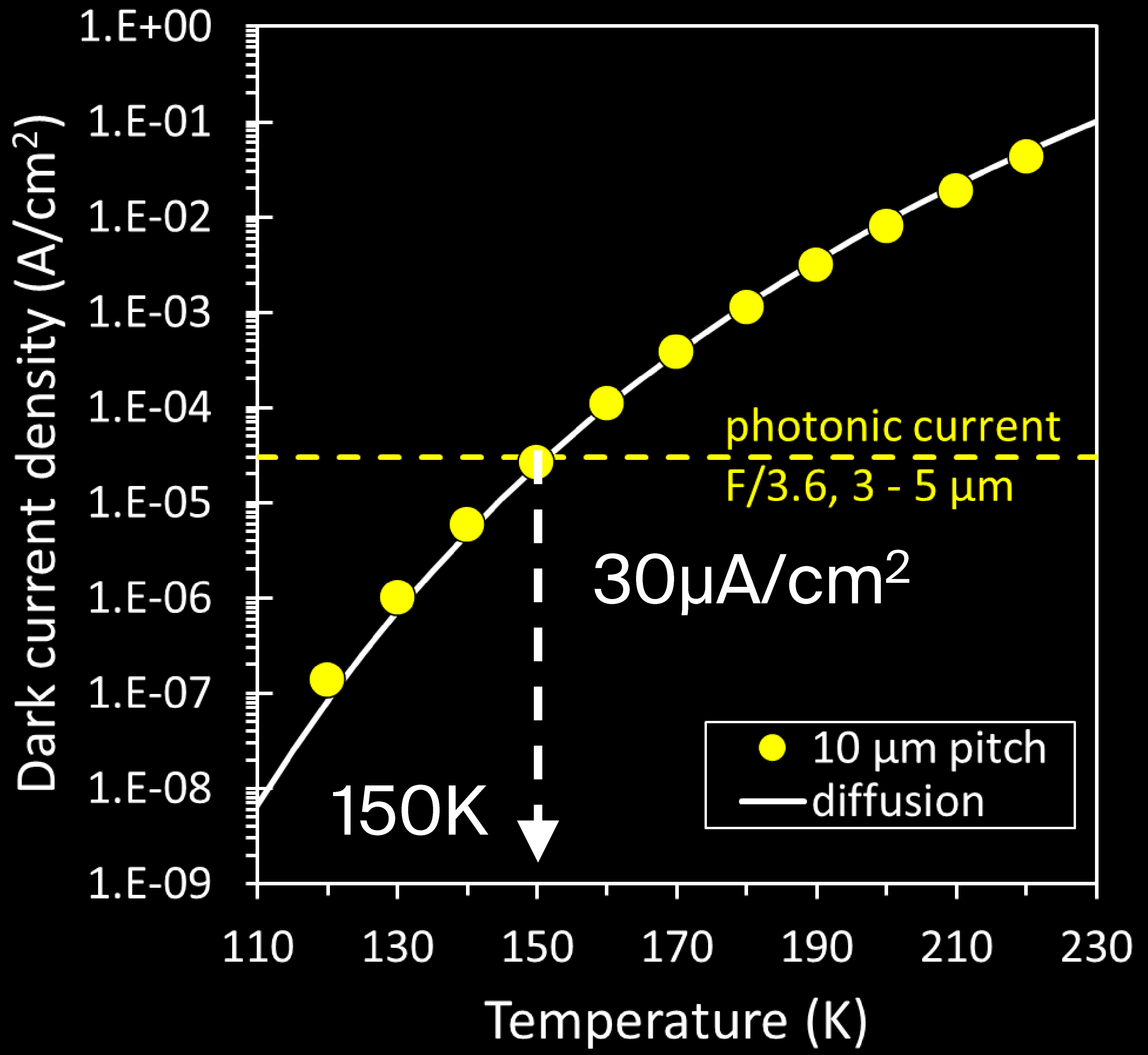
Quantum efficiency



Dark current density



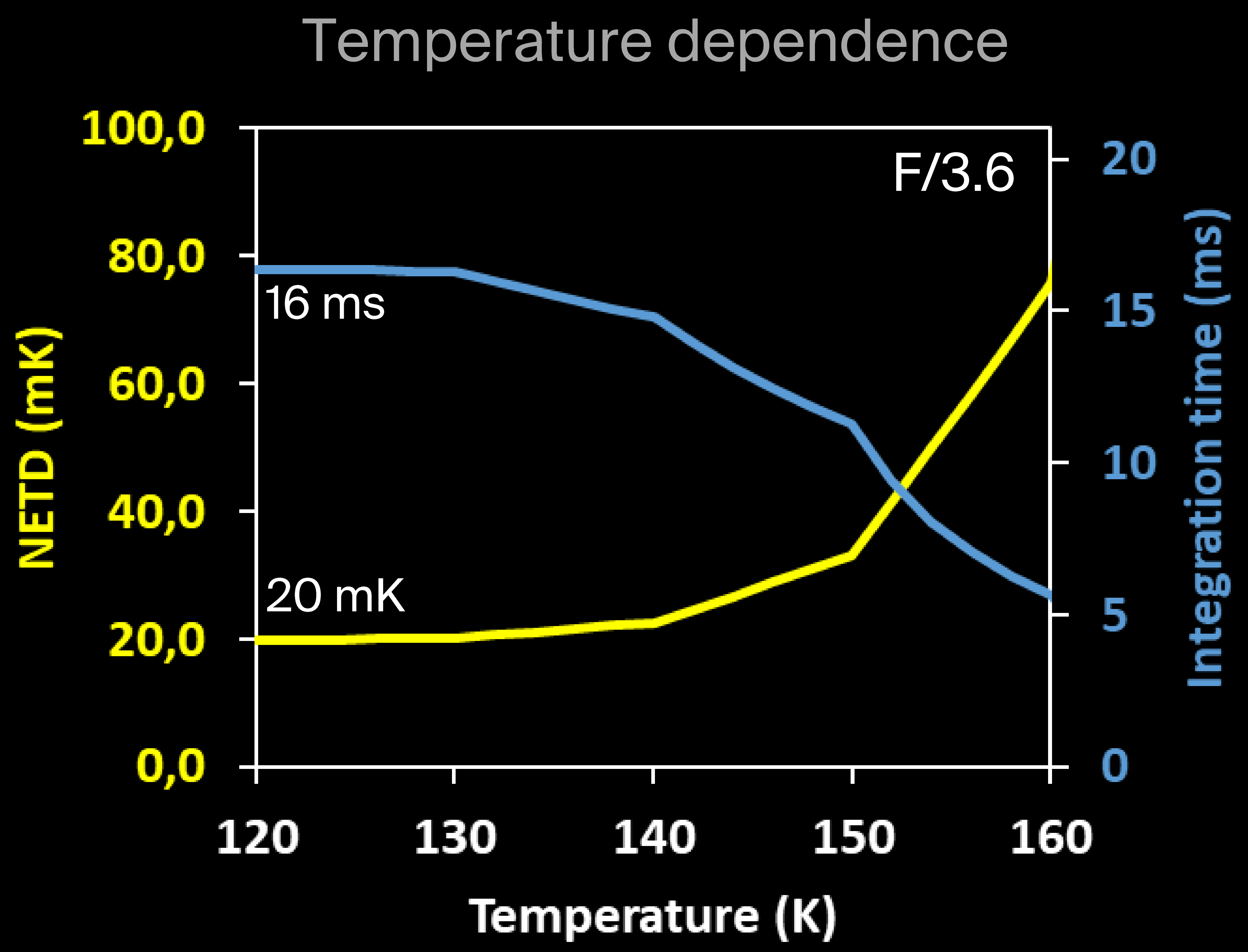
Photocurrent density vs dark current density

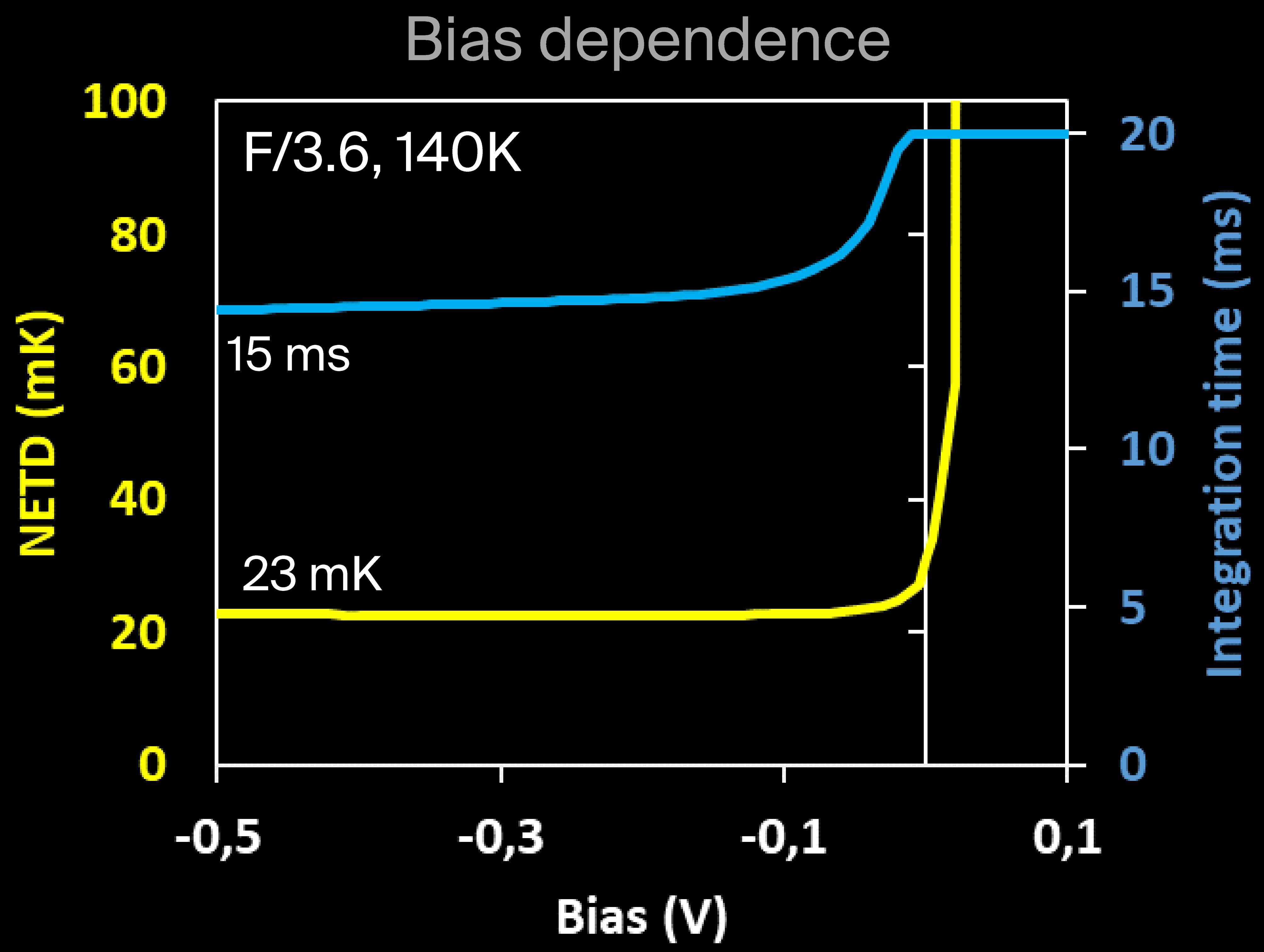


Njord MW – Anticipated performance

ROIC specifications:
- CHC: 5.5 Me-
- 60 Hz frame rate

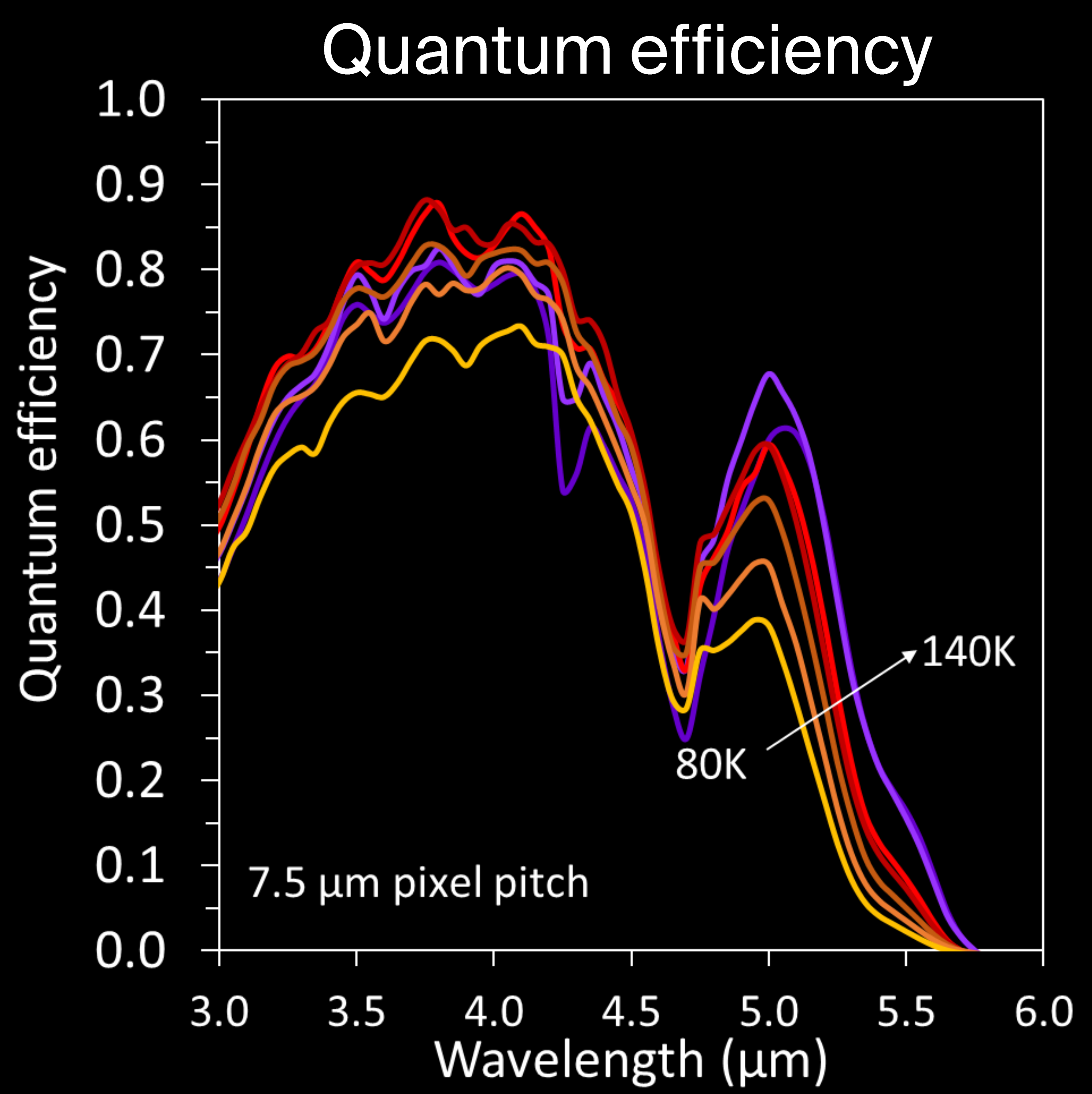
- 1280 x 1024 pixels, 10 µm pitch
- NETD lower than 25 mK up to 140 K with very little bias dependence

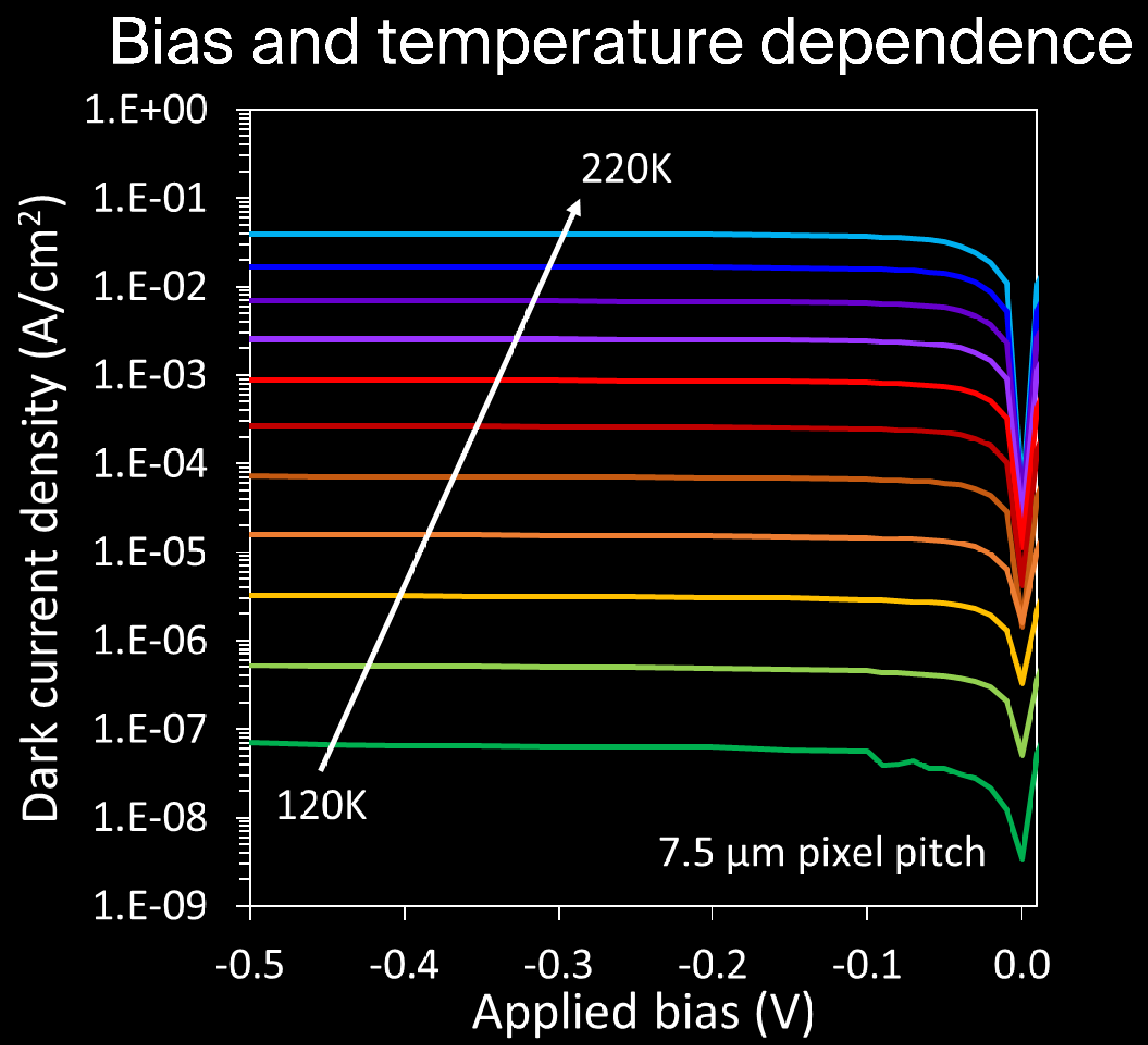


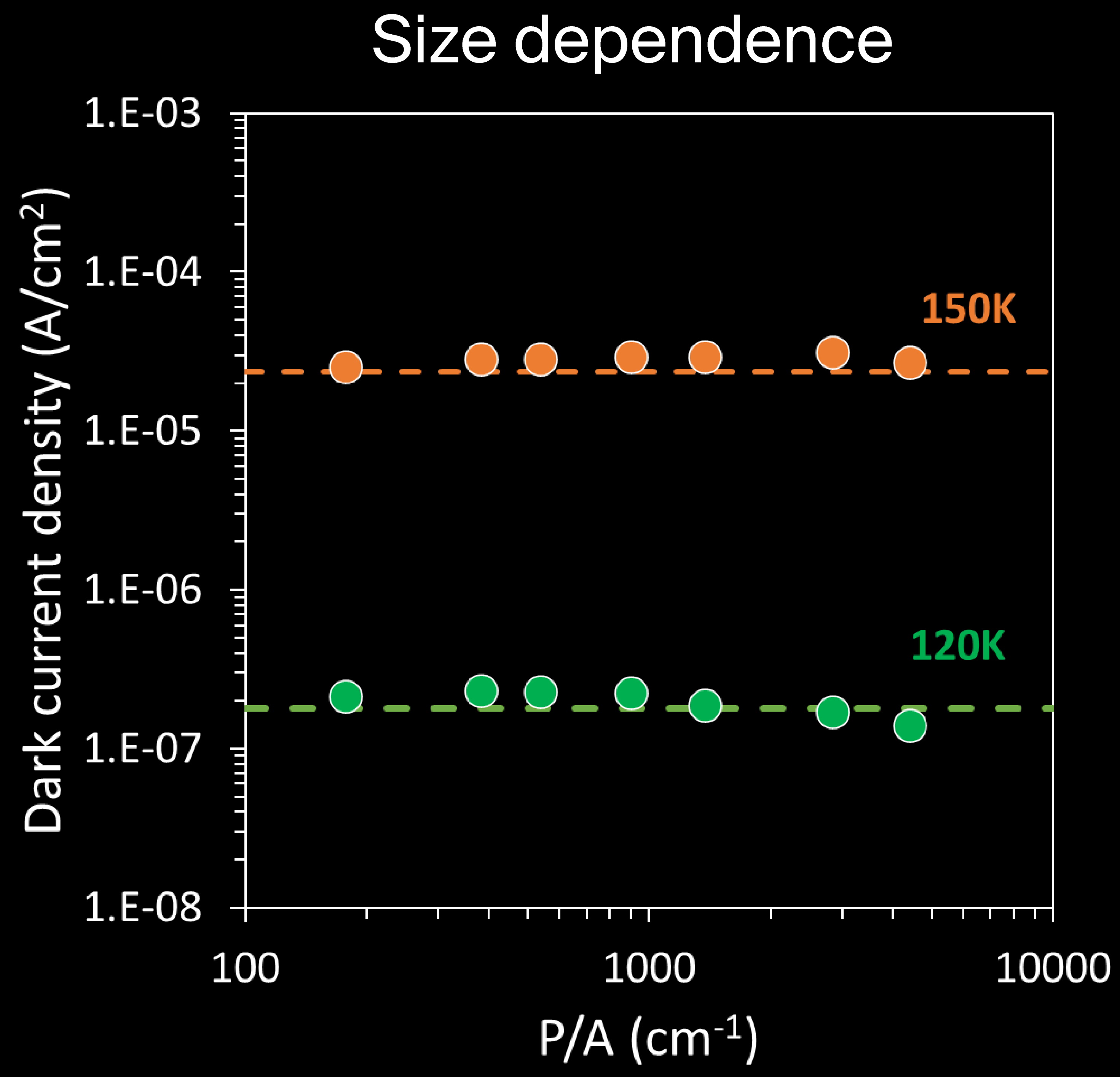


Skade MW - @7.5 µm pitch T2SL detectors

No degradation of the performances with reducing pixel pitch !







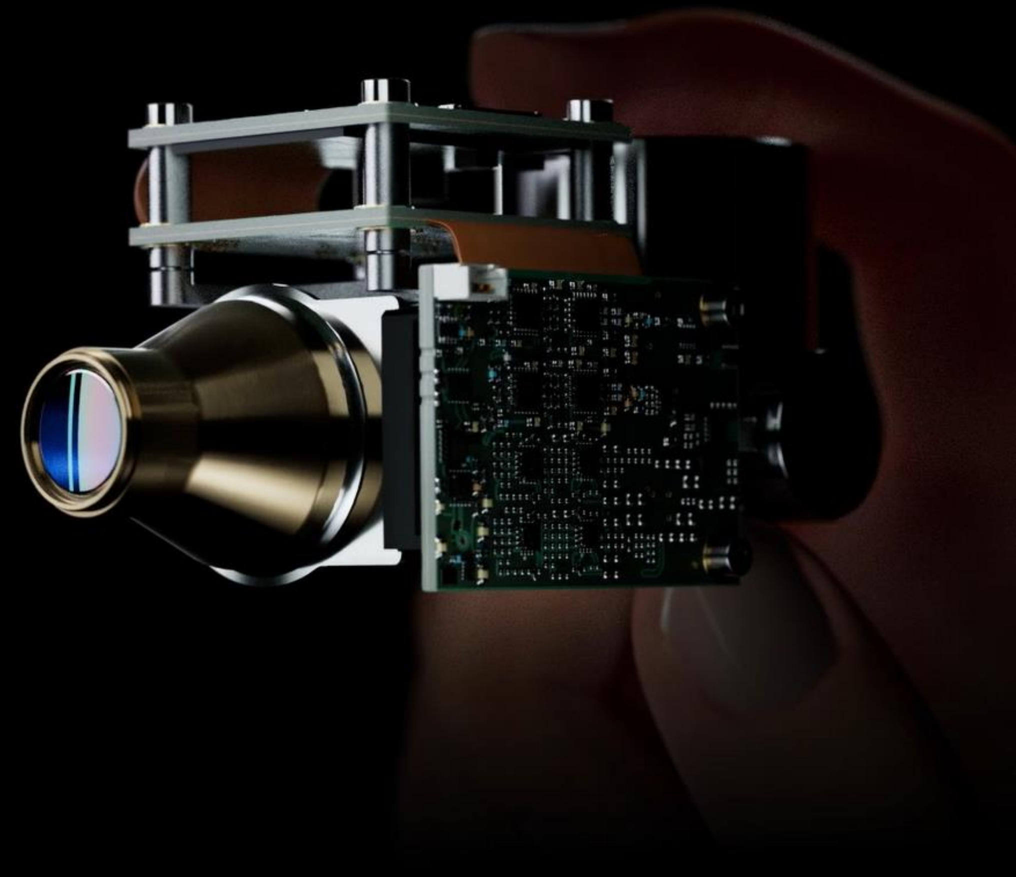
Agenda

Oden MW detectors for HOT SWaP

Excellent uniformity

Low flickering rate

MTF close to ideal value



Njord MW for HOT HD

Will be released in 2024

High performance with 10 µm pitch

Skade MW 7.5 µm pitch T2SL detector

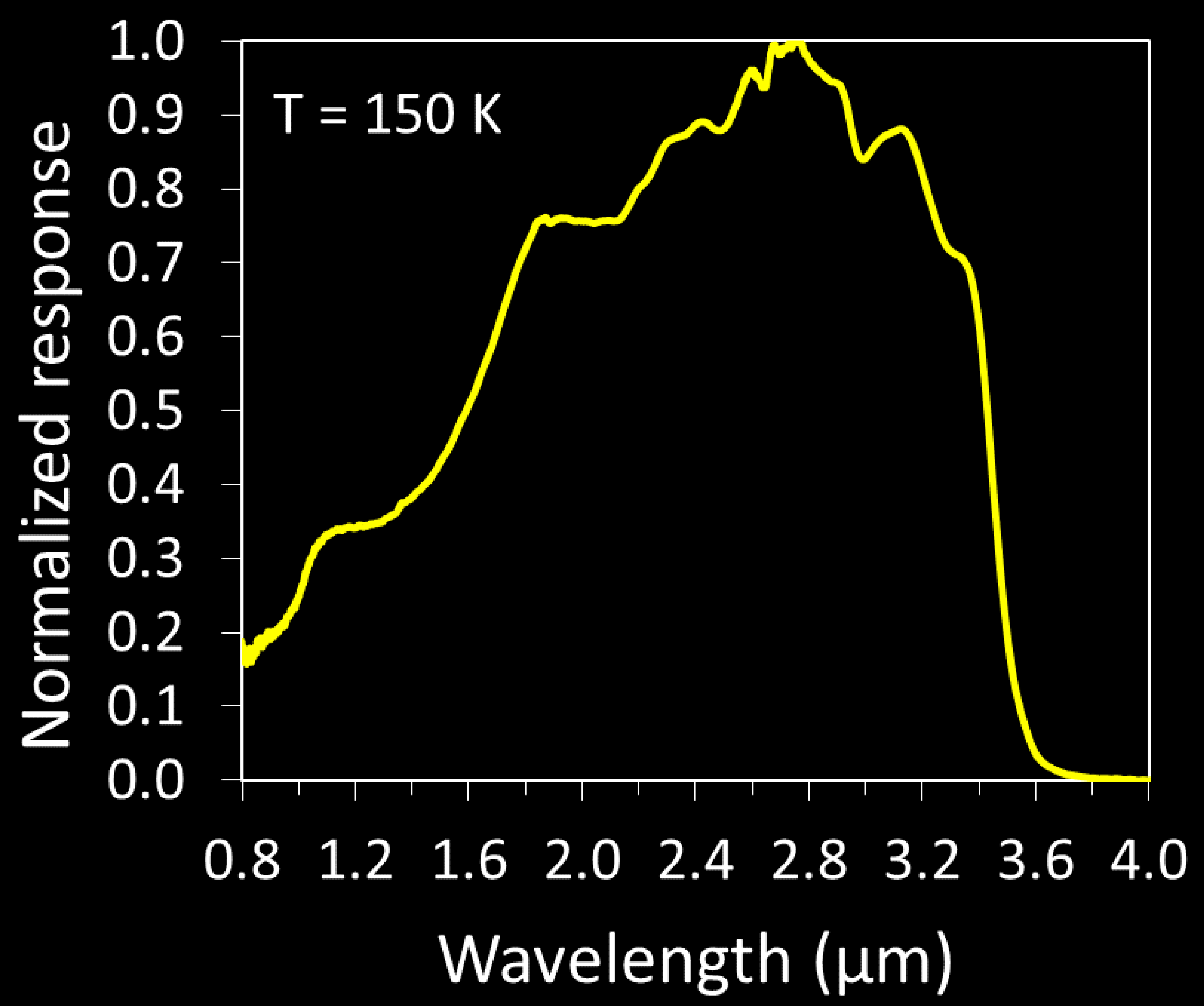
No degradation of the performances when reducing pixel pitch !

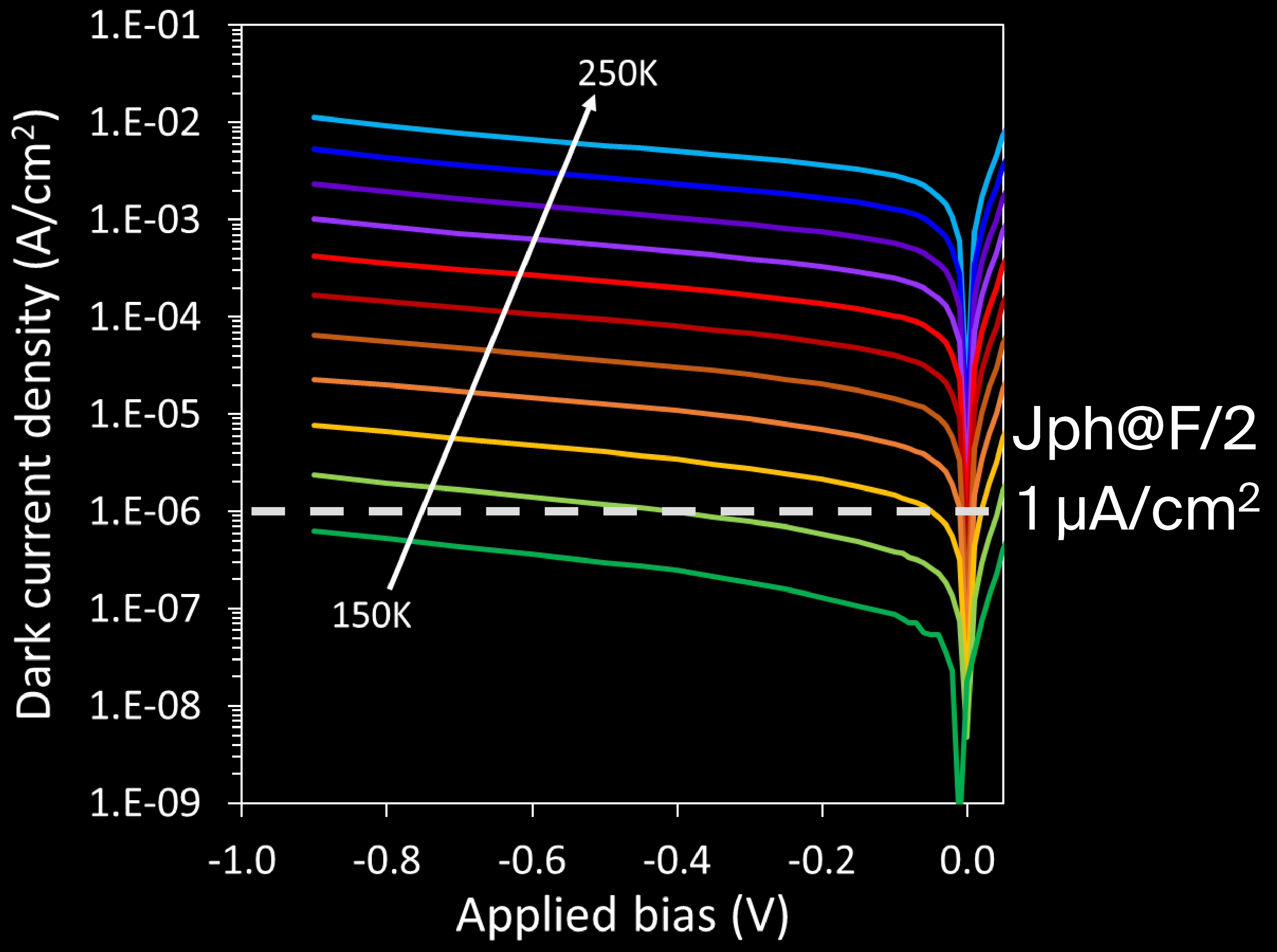
HD eSWIR for T = 200K

eSWIR development at IRnova

Proof of concept in previous eSWIR T2SL studies funded by esa, Rymdstyrelsen Swedish National Space Agency

- IRnova's T2SL designs and fabrication technology is also compatible with eSWIR
- Development of eSWIR with **3.5 µm** cut-off wavelength initiated
- Operating temperatures up to **160 K** feasible

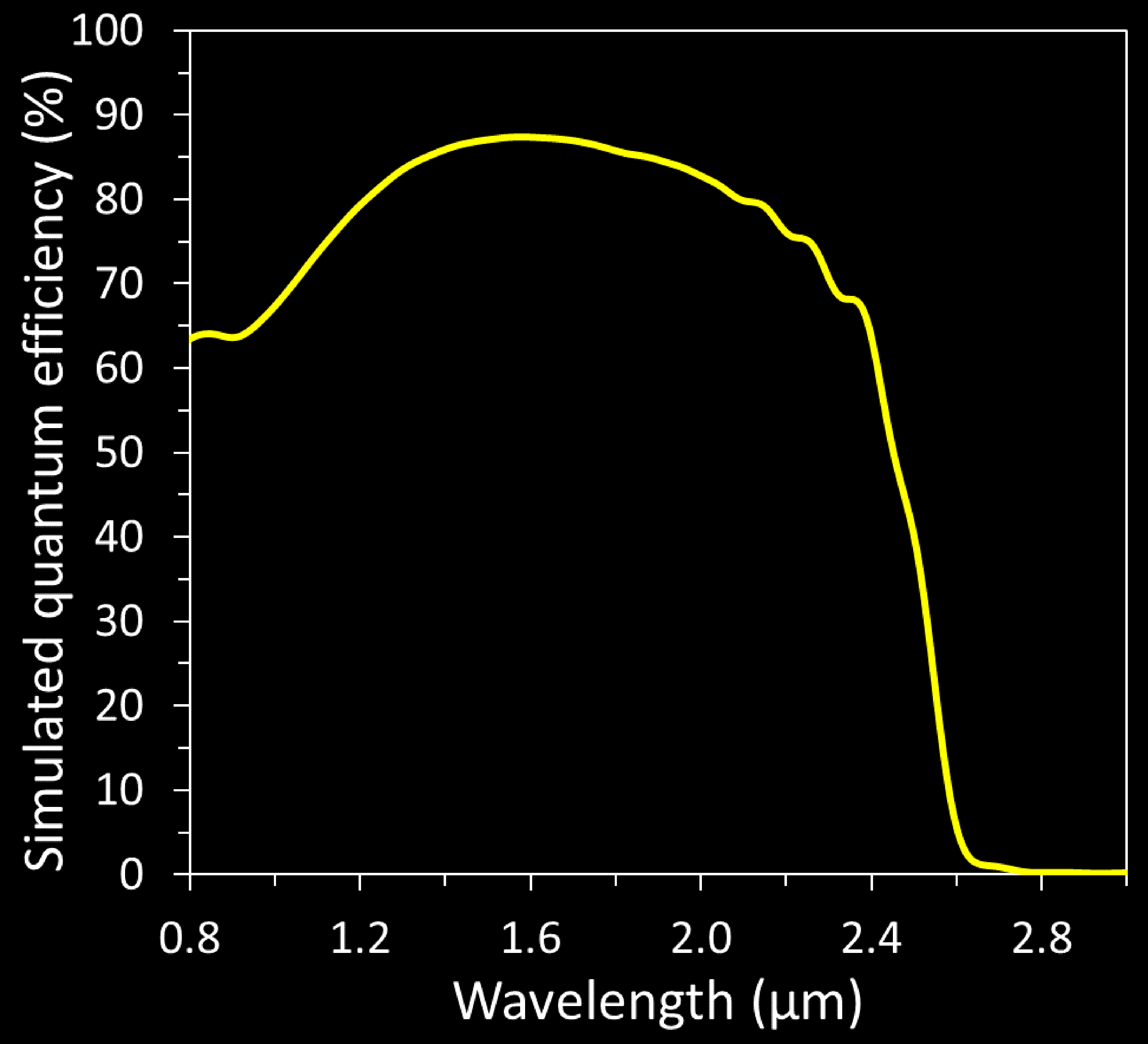


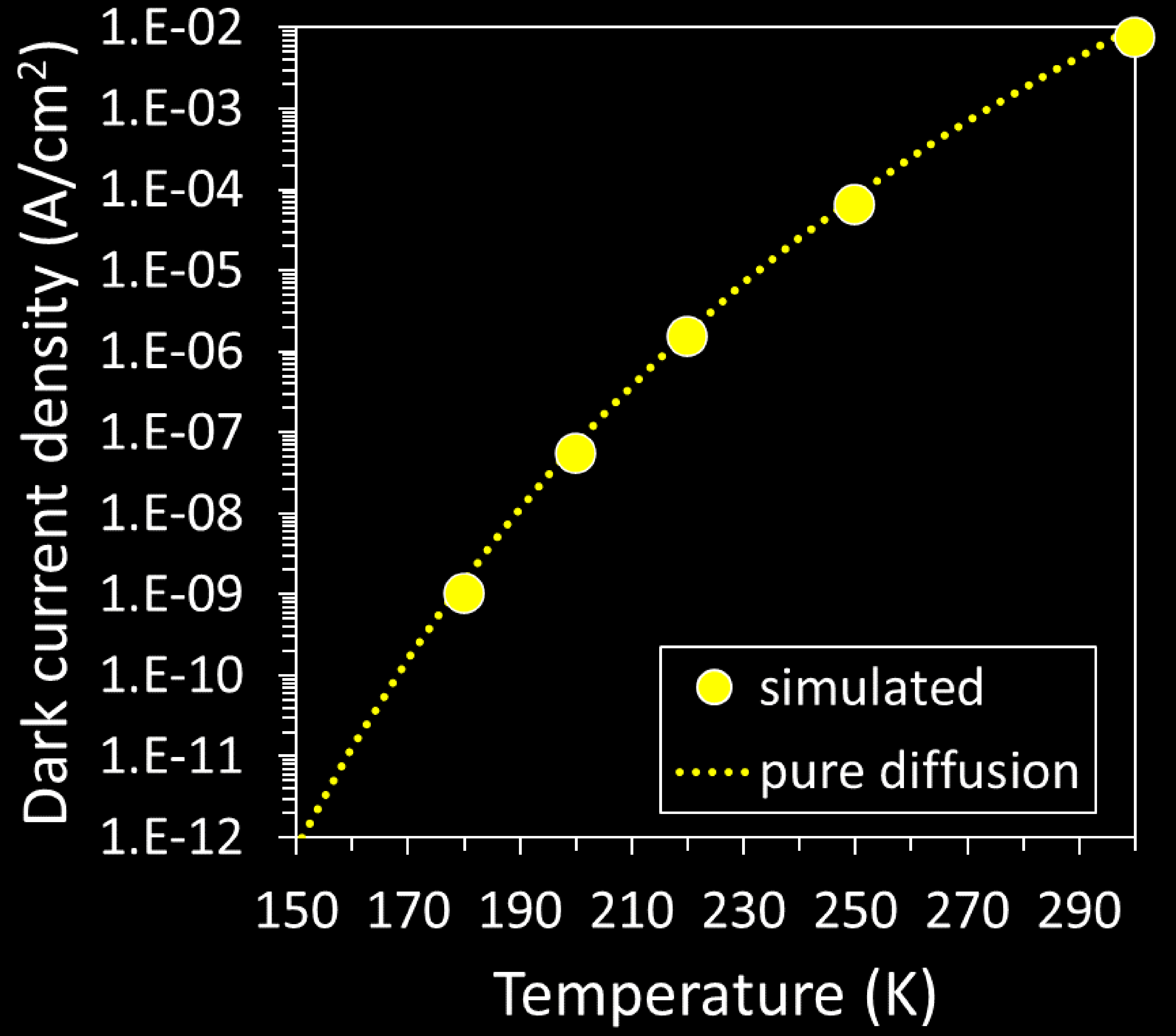


Highly uniform FPAs fabricated

Anticipated performance eSWIR 2.5 µm T2SL

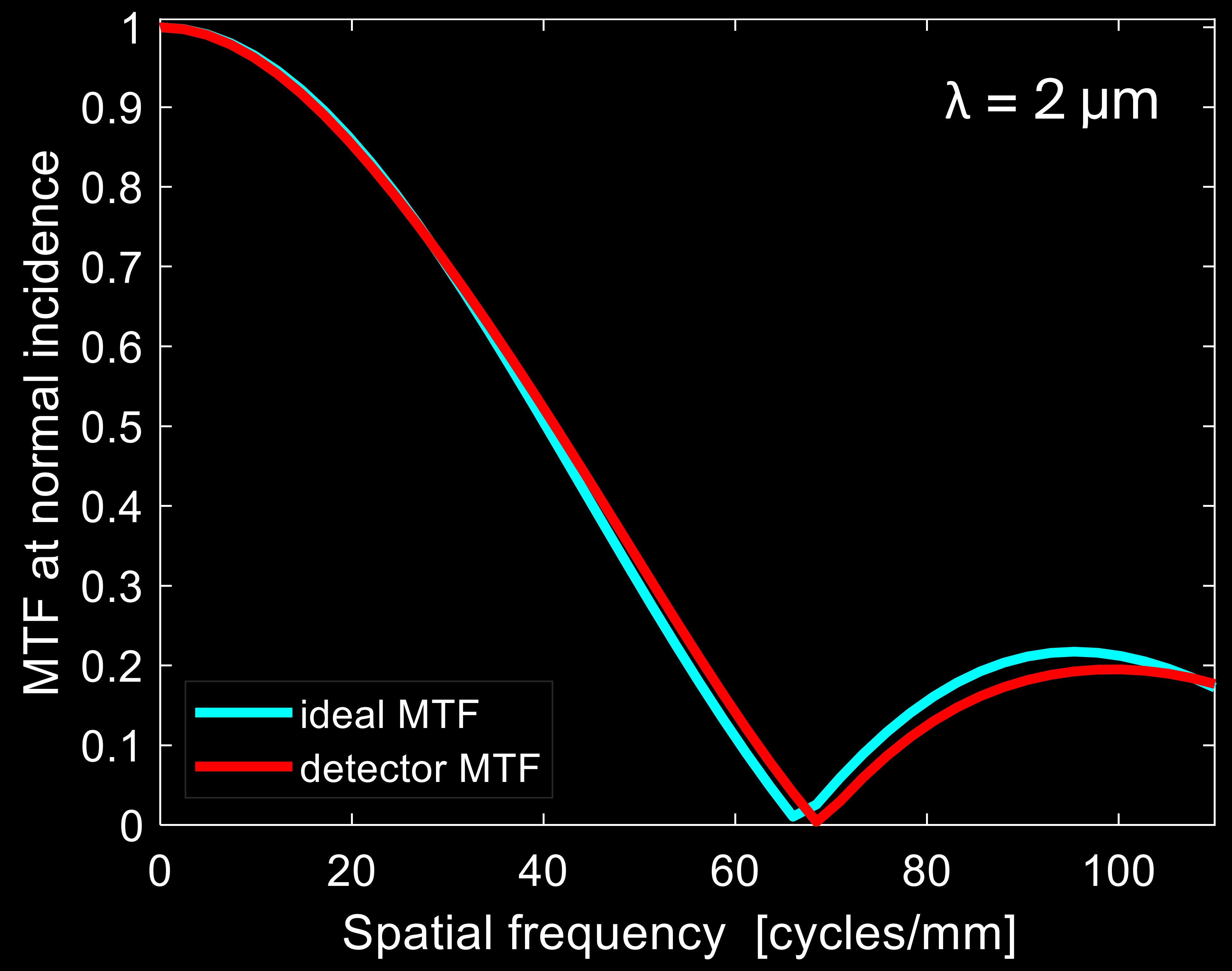
- New eSWIR design for 2.5 µm cut-off wavelength
- Quantum efficiency > 70%
- Dark current density < 5E-8 A/cm^2 at 200 K, competitive to existing technologies

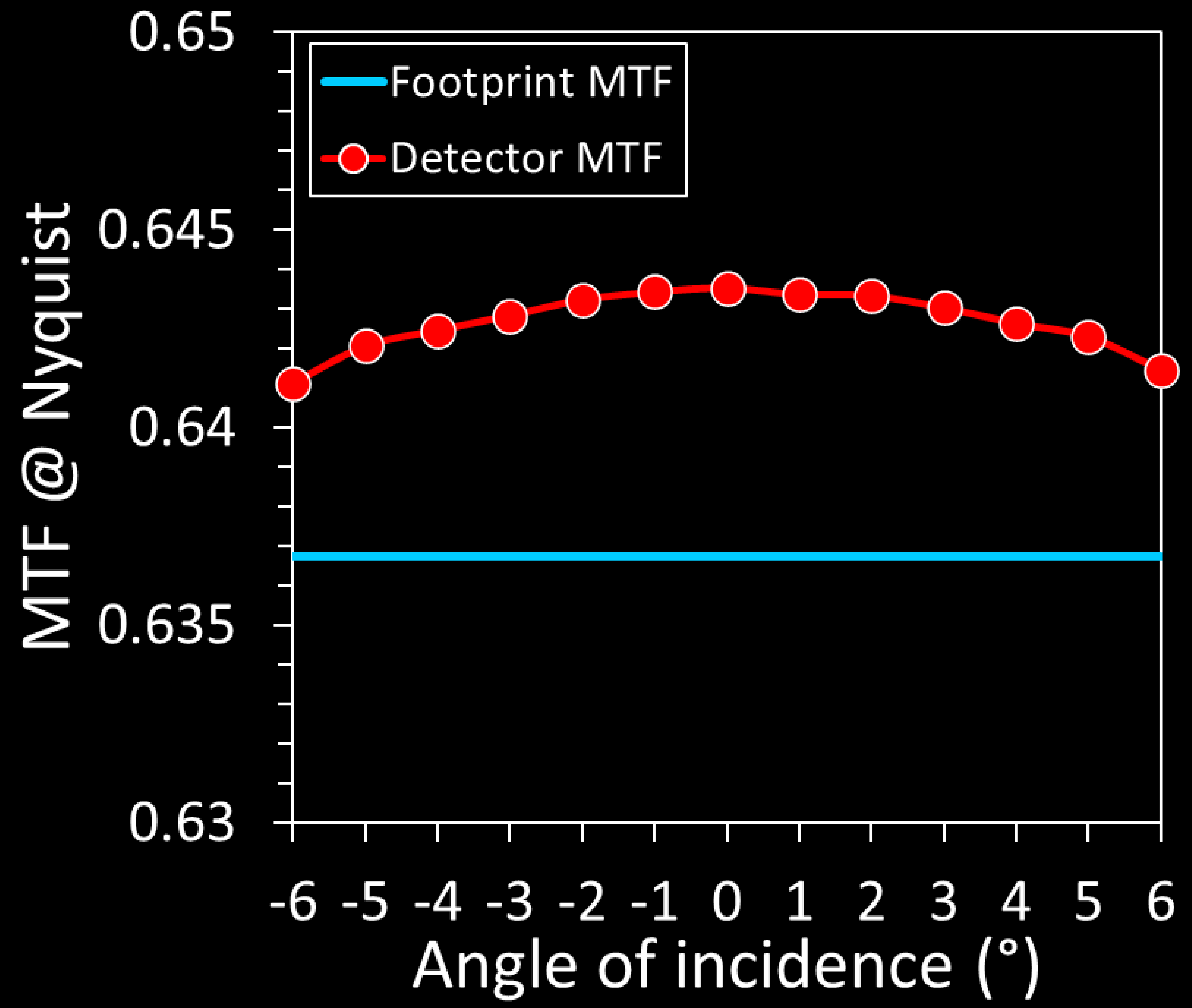




MTF simulations of eSWIR 2.5 µm T2SL @15 µm pitch

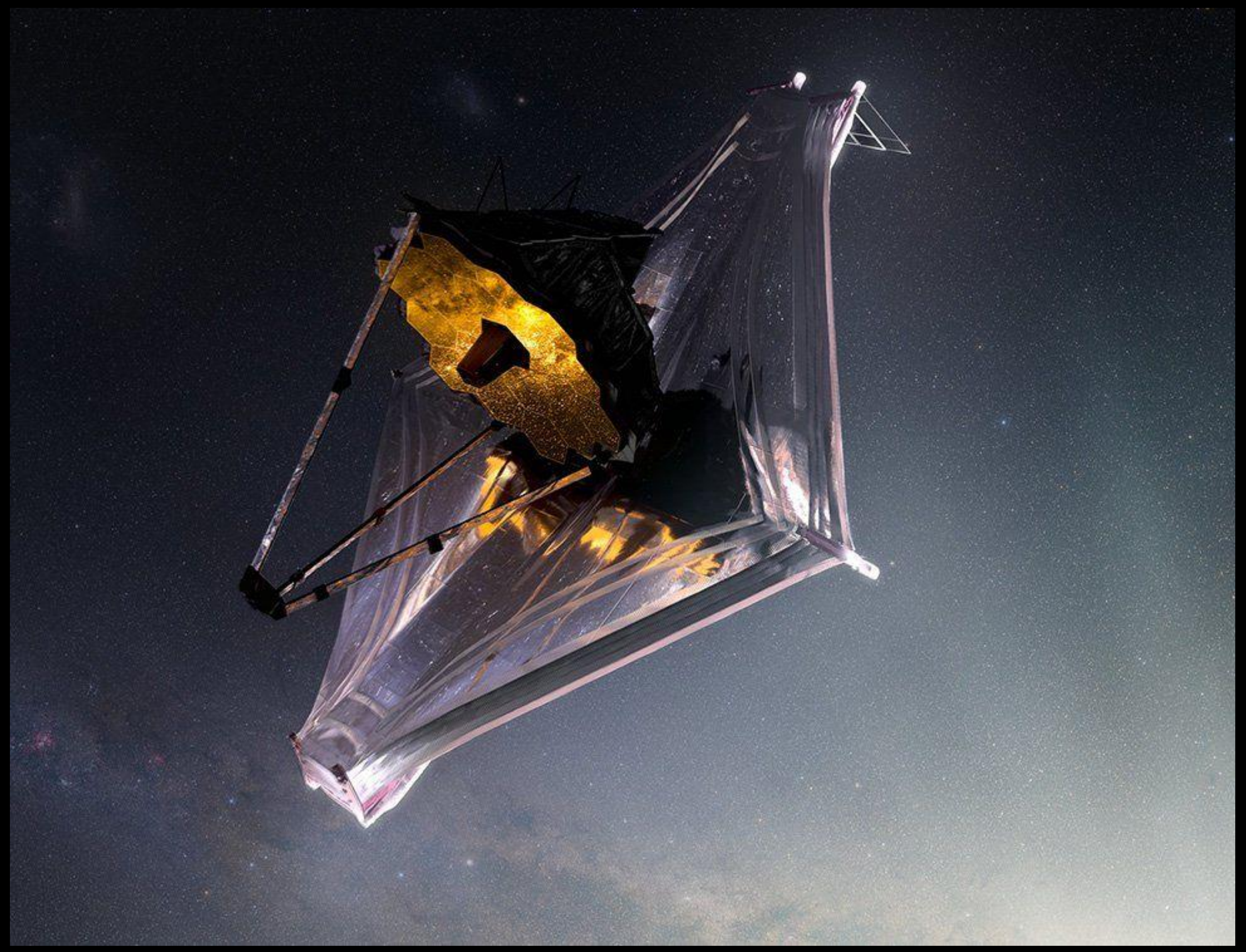
- MTF close to the ideal MTF values are predicted also for eSWIR, MTF > 0.6 @ Nyquist
- Simulated MTF within ± 6°angle of incidence : 0.642 ±0.001 !
- Next step: validation at FPA level





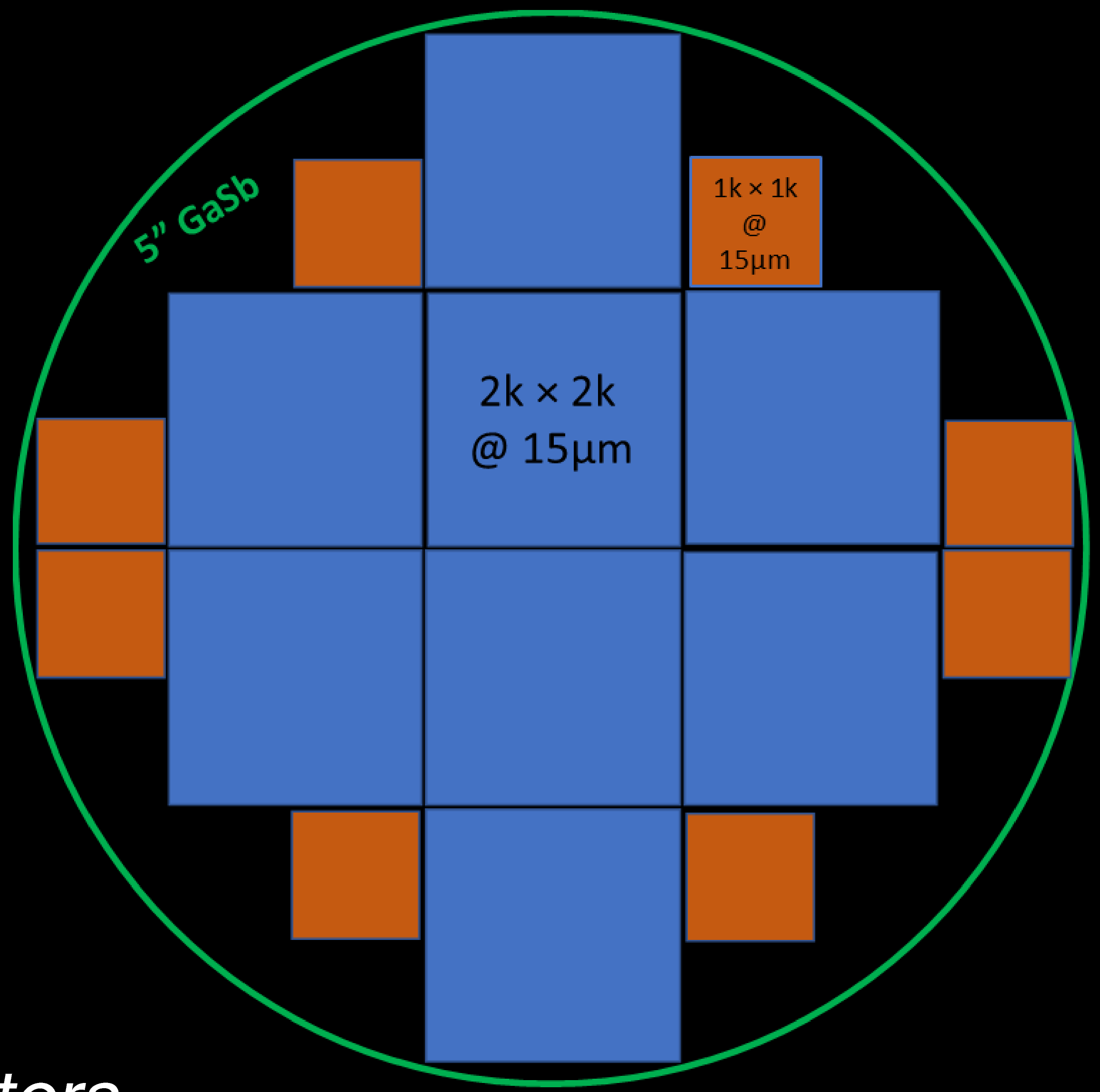
HD SWIR T2SL for future space applications

Potential development of 2k x 2k T2SL detectors for eSWIR benefiting from large high quality wafers, high uniformity, long term stability and excellent performance.

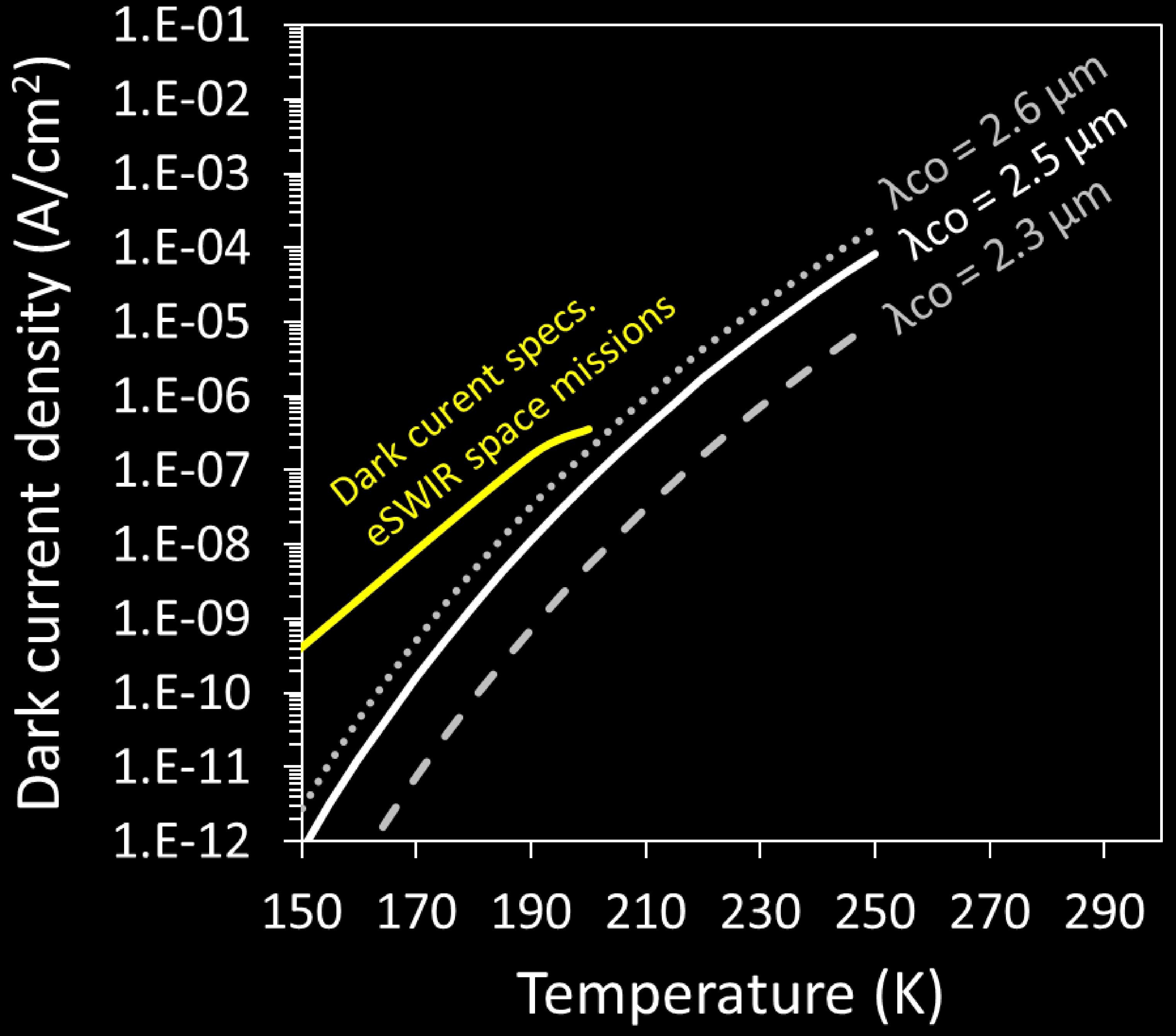


- *James Webb, including 2k × 2k MWIR detectors*
- *Nancy Grace Roman will include 4k× 4k eSWIR detectors*

Large diameter GaSb substrate enabling 8 2 k x 2 k FPAs with 15 µm pitch per wafers



Estimated dark current density of eSWIR T2SL detectors



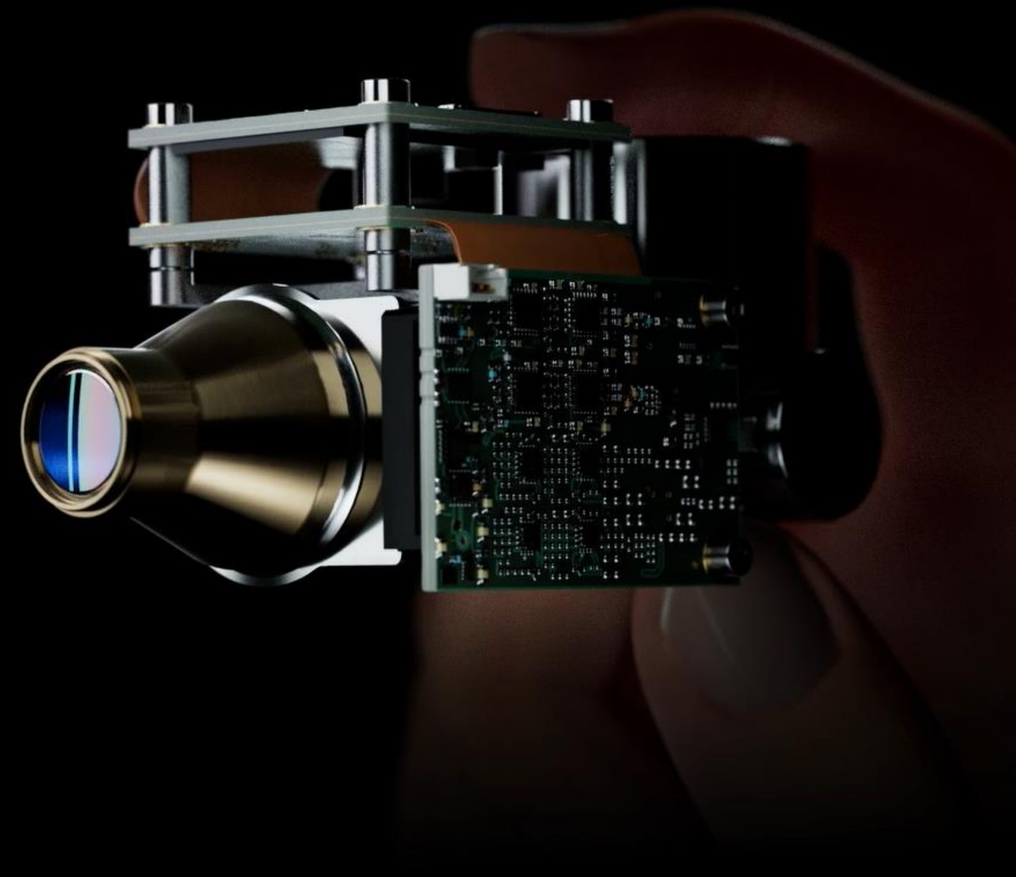
Conclusion

Oden MW detectors for HOT SWaP

Excellent uniformity

Low flickering rate

MTF close to ideal value



Njord MW for HOT HD

Will be released in 2024

High performance with 10 µm pitch

Skade MW 7.5 µm pitch T2SL detector

No degradation of the performances when reducing pixel pitch !

HD eSWIR for T = 200K

Proof of concept of eSWIR T2SL at IRnova

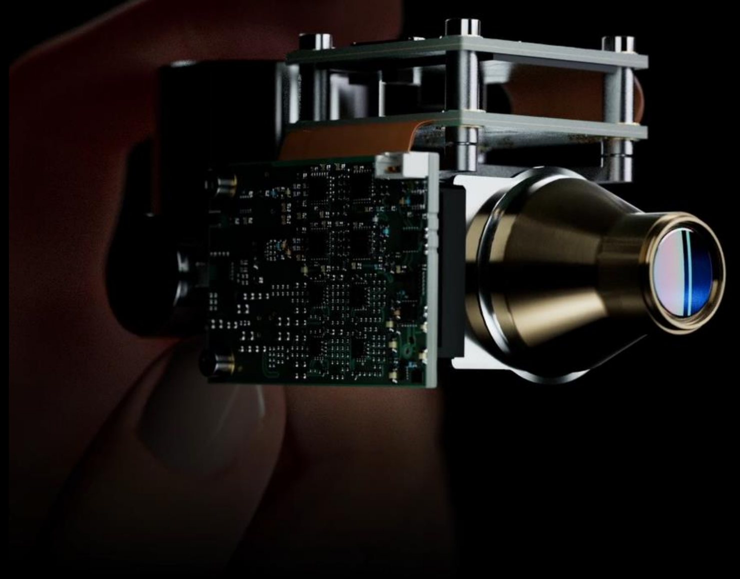
New T2SL design for 2.5 µm

Validation at FPA level 2023

"Low power infrared imaging sensors" sponsored by: VINNOVA Sweden's Innovation Agency

IRnova

Oden MW, HOT T2SL



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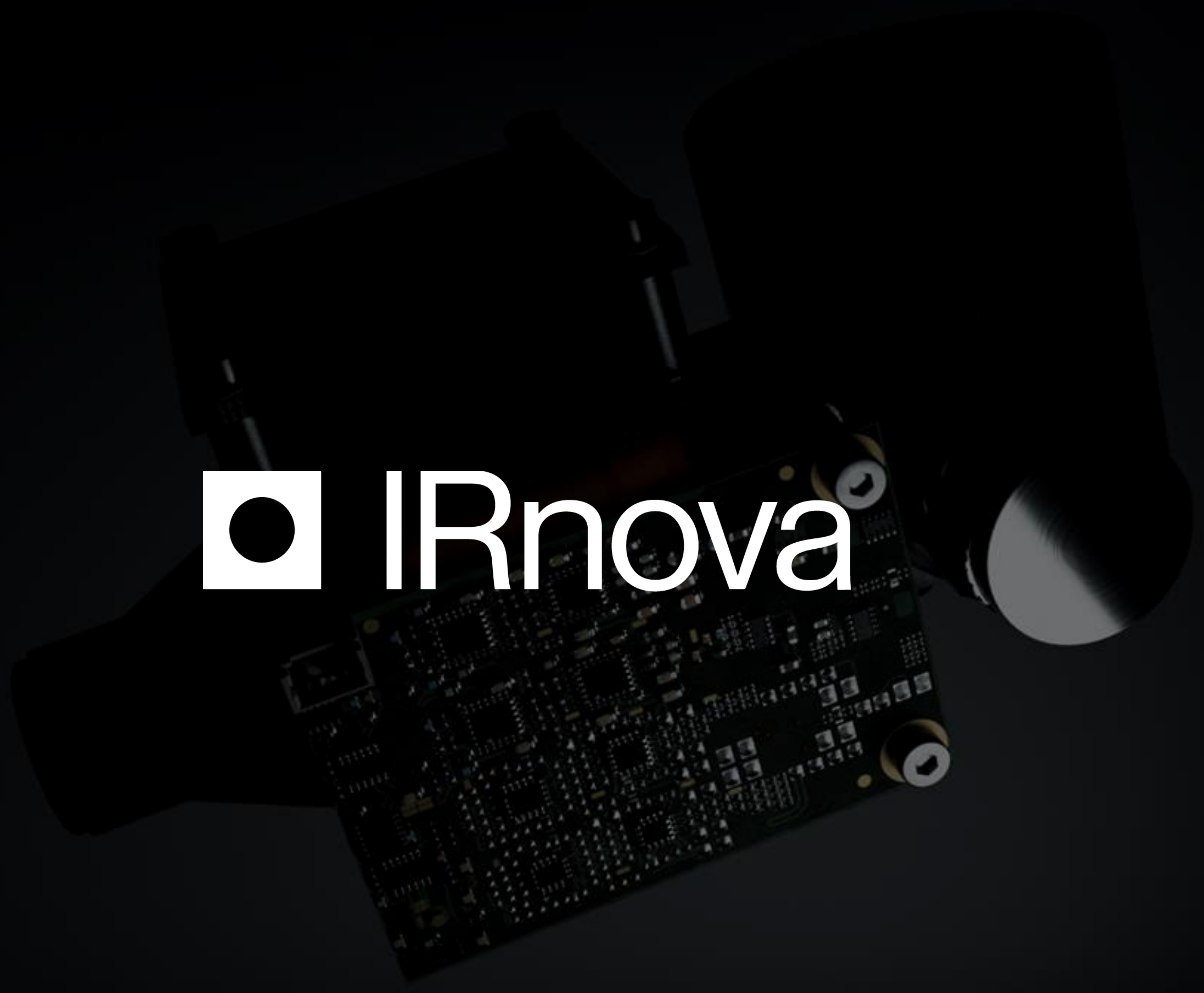
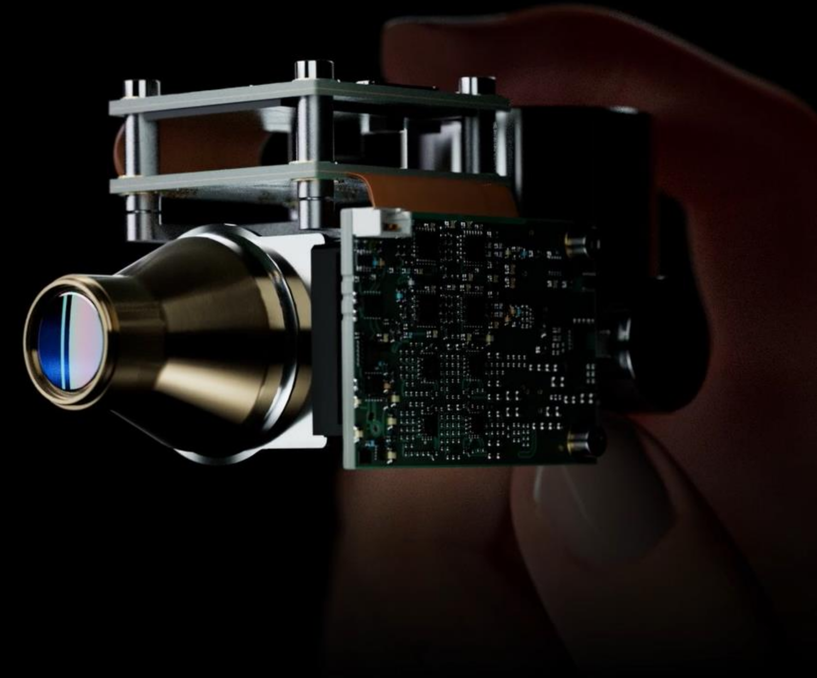

IRnova

Imaging quality with Oden MW detectors*



*IR images taken with Oden MW detectors, F/5.5 aperture, 60 Hz frame rate, bandpass filter, no image processing (2-point NUC correction only)

Njord MW - HOT HD T2SL

To be released in 2024

Detector specifications:

- Format: 1280 × 1024 pixels
- Pitch: 10 µm pitch
- Spectral range: 3.7 – 5.1 µm
- F number options: F/3.6, F/4
- Maximum frame rate: 60 Hz
- NETD: 25 mK
- Operability: 99.8 %
- Cooler options: RM2, K563

ROIC specifications:

- CHC: 1.5 Me-, 5.5 Me-
- Dual polarity
- 4 outputs
- 60 Hz frame rate
- 2x2 binning capability

MTF and crosstalk

- MTF is a measure of how well a detector reproduces the contrast and sharpness of the object's details.
- The MTF is typically affected by both
  - Electrical crosstalk
  - Optical crosstalk
- By using fully delineated detector pixels, the electrical crosstalk is avoided and only the optical crosstalk remains