LEONARDO

Leonardo Electronics

Space and Astronomy 2023

ESA Detector workshop

CNES Toulouse

7 June 23


Electronics


Helicopters


Aircraft


Cyber & Security


Space


Uncrewed Systems


Aerostructures

Infrared Detectors Southampton UK

World leader in design, development and manufacture of high performance infrared detectors

- 70 year heritage in R&D and manufacture of IR Detectors
- Fully integrated capability from material growth to volume manufacture
- 200 employees including world leading scientists
- 3000m^2 clean rooms (including class 100)
- Infrared sensitive material growth specialising in 2 detector technologies
- Supplying a diverse range of markets and applications

High performance cooled Mercury Cadmium Telluride (MCT) Focal Plane Array detectors

- Thermal imaging
- Missile guidance
- Space and Astronomy

Single element Deuterated L-AlanineTriglycene Sulphate (DLATGS) pyroelectric detectors

- Infrared spectroscopy
- Space and Astronomy

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Current Space flight programmes using TGS and MCT detector technologies:

2016 OSIRIS-REx thermal emission spectrometer (OTES) NASA asteroid sample return mission

2018 GOSAT 2 - Greenhouse Gas Observing Satellite-2 FTIR – JAXA mission

2020 UAE Planetary Science Mission – Study of climate and atmosphere

2021 NASA LUCY mission to Jupiter's Trojan asteroids

2023 SSTL Darkcarb High resolution mid-wave infra-red (MWIR) imager using SuperHawk

2024 PACE Earth science Ocean Colour Instrument for NASA

2024 IASI NG Meteorological and atmospheric science mission for CNES

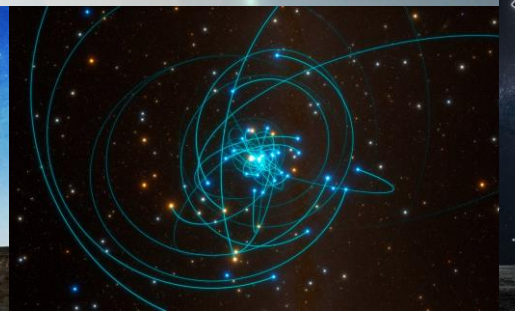
2027 ESA FORUM Far-infrared Outgoing Radiation Understanding and Monitoring FTIR

Detector pre-development programmes:

- Large area and large format arrays up to 2k x 2k, high speed arrays, APD arrays
- Range of applications Scientific imaging, Optical comms, FTIR

Astronomy:

Saphira detector is currently being used in 15 giant telescopes around the world



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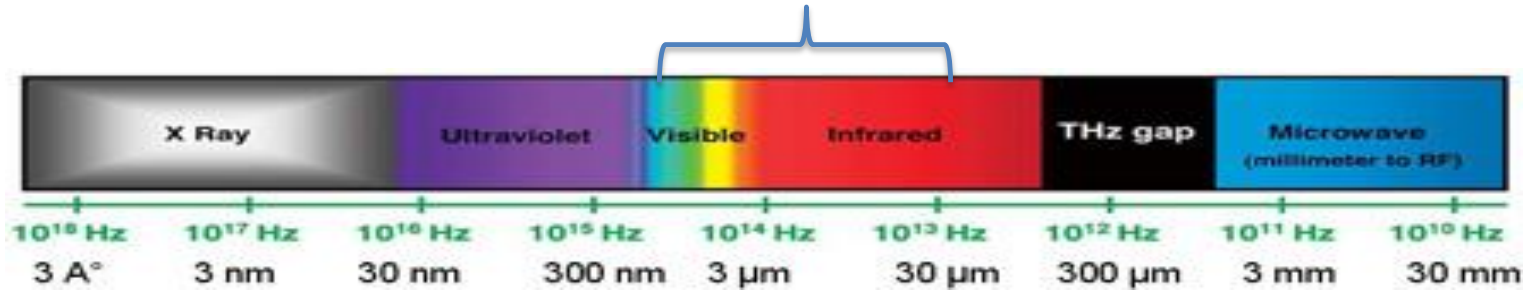
Wavelength ranges

DLATGS covers 0.2µm to >100µm

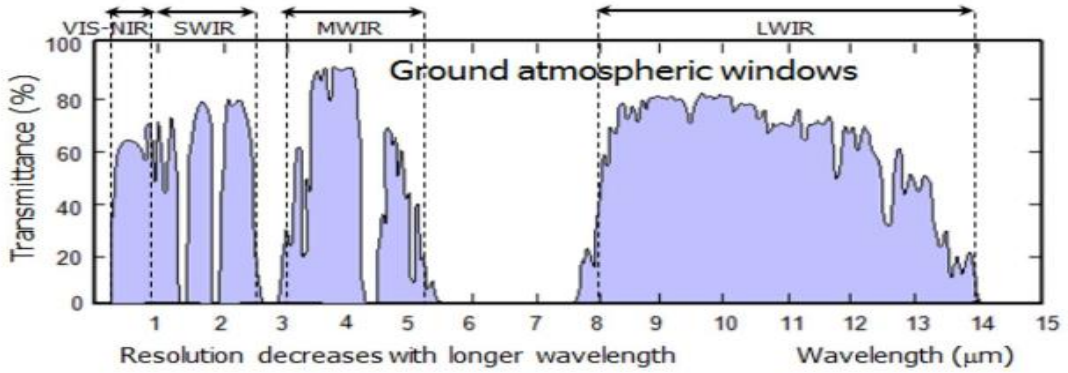


MCT

APD 2D detectors

PV 2D detectors

PC detectors



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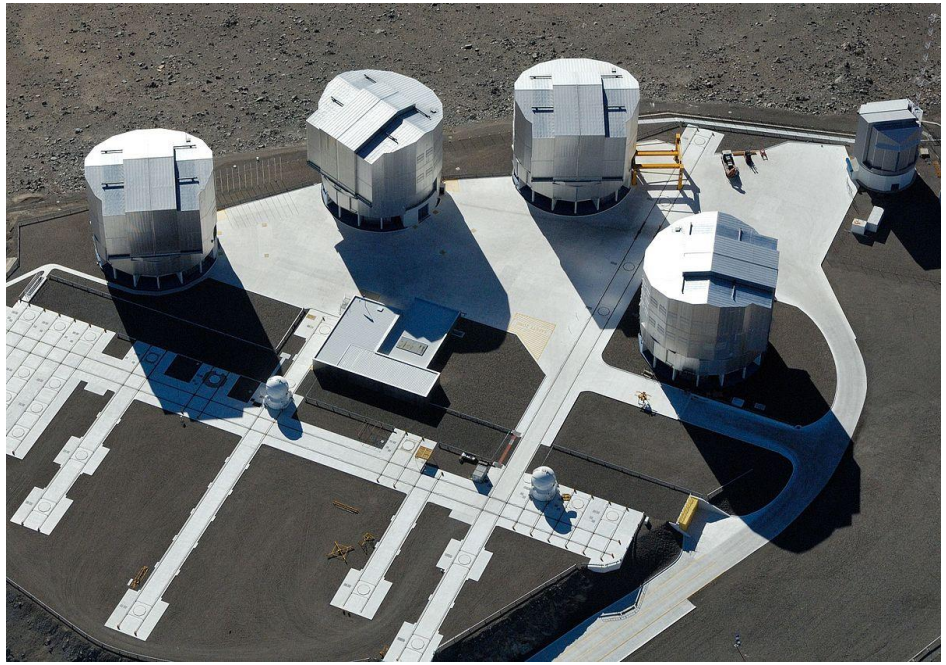
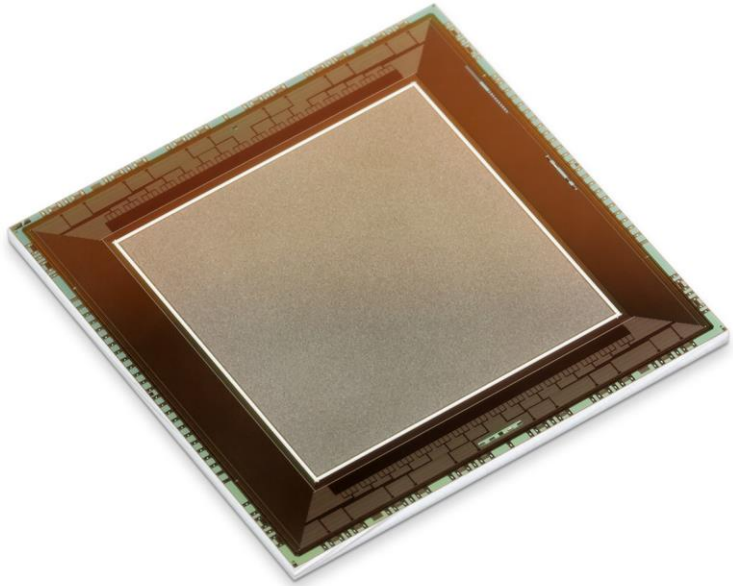
APD – wavefront sensing

- 320 x 256 – Saphira >20 arrays manufactured with zero defects. Used on 15 of the largest telescopes as a wavefront sensor
- 512 x 512 - Saphira QM, used as a pyramid wavefront sensor – Preliminary science grade devices have been supplied to ESO, results awaited





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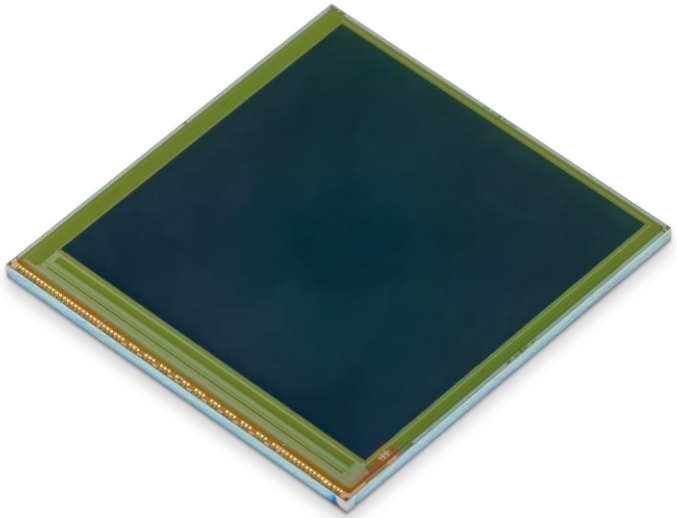
APD low flux imaging

- 1024 x 1024 Ike Pono
- 2048 x 2048 IBEX 4M

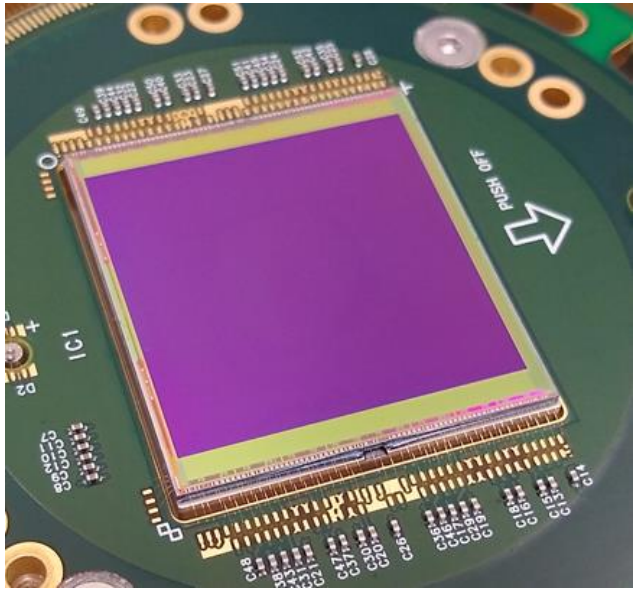


Key specifications:

- APD MCT, cut on ≤0.8 µm cut off ≥2.5 µm
- Read noise <10 e/p/s, Dark current 3 e/p/s
- CHC >100 ke-, non-linearity <1%
- 80K operating temperature

Ike Pono – results from University of Hawaii

- Dark current 0.1e-/pixel/ksecs @ 50K
- QE 100% from 4-15 volts array bias
- ROIC currently being modified to reduce glow from the output stage currently 1 electron / pixel /1800 seconds



IBEX 4M – preliminary results from Leonardo

- Measured gain curve matches prediction - ~ 40 @ 15Volts
- Both versions include reference pixels in the Si for improved performance in low flux conditions

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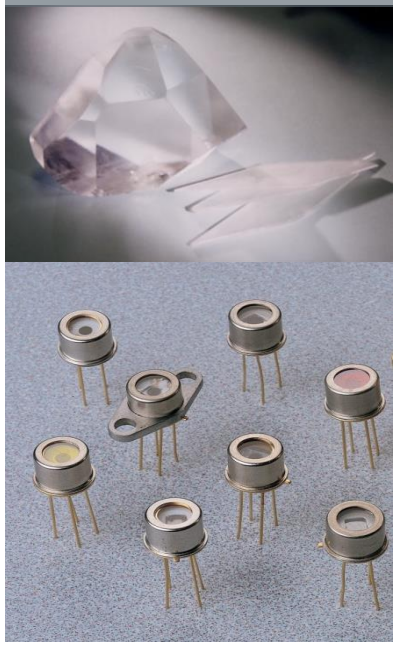
Pyroelectric Detector Capabilities

Single element, low cost detectors for Infrared Spectroscopy

- 70 years experience in the design and manufacture of pyroelectric detectors using DLATGS
- DLATGS is a high performance pyroelectric material
- Leading supplier to major Infrared Spectrometer manufacturers world-wide
- Fully integrated capability from growth of DLATGS crystal material to environmental test of encapsulated detector
- Broad spectral response from 0.2µm to >100µm
- Room temperature operation
- Standard industry (TO) transistor outline packages
- High volume manufacture
- Wide range of detector variants
- Integral temperature stabilisation using thermo-electric cooler available for demanding environments
- Low cost, high reliability
- Custom designs available
- Space heritage

DLATGS Crystal & Slices



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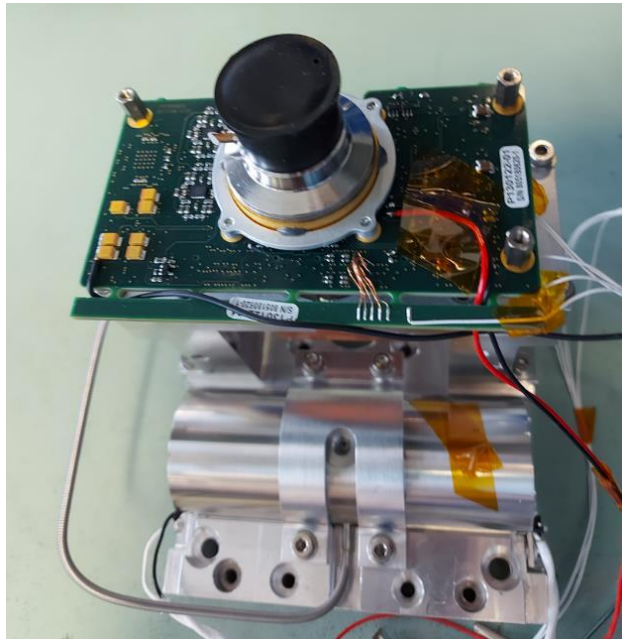
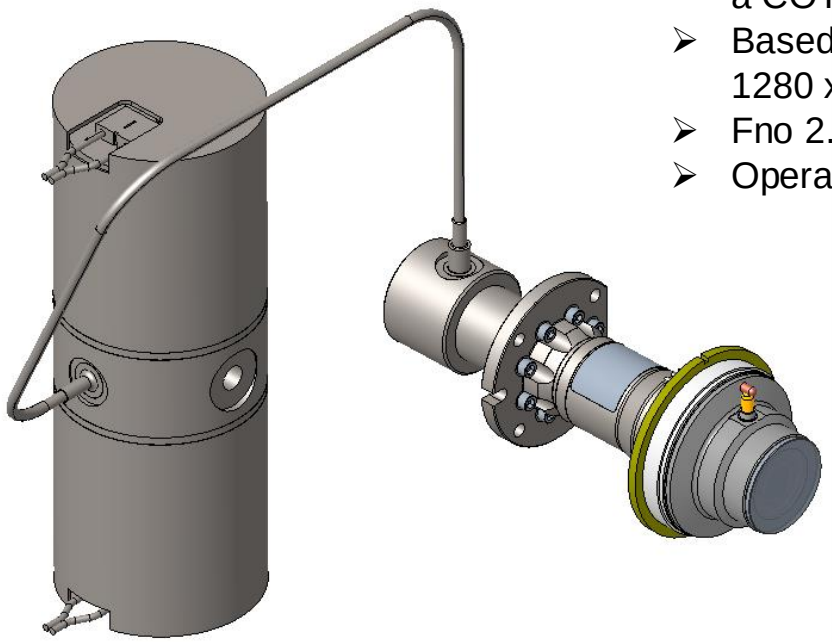
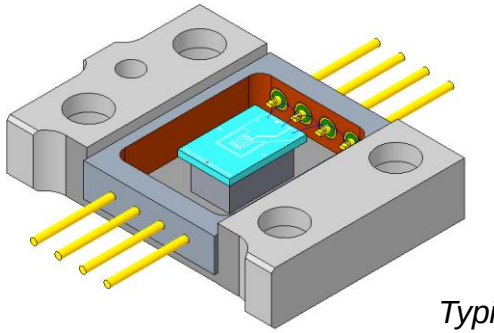
Package design / manufacture





- DarkCarb is high resolution MW IDCA, featuring a COTS detector and split cycle cooler
- Based on the existing SuperHawk detector ;- 1280 x 1024, 8µm pitch
- Fno 2.8
- Operating at 90 Kelvin

- Several packages designed in coordination with customer to meet system requirements, for space applications. IASI-NG, GOSAT, PACE, Dark Carb
- Include open and encapsulated arrays, as well as full IDCA product with cooling engines [Dark Carb]
- Space qualified PCB's designed and procured to support system design [IASI-NG]
- CCB and glass-to-metal seal technologies used for electrical interface
- Bespoke and customer supplied packages used
- High precision manufacturing and array placement to the packages datum features achieved.



Typical header assy

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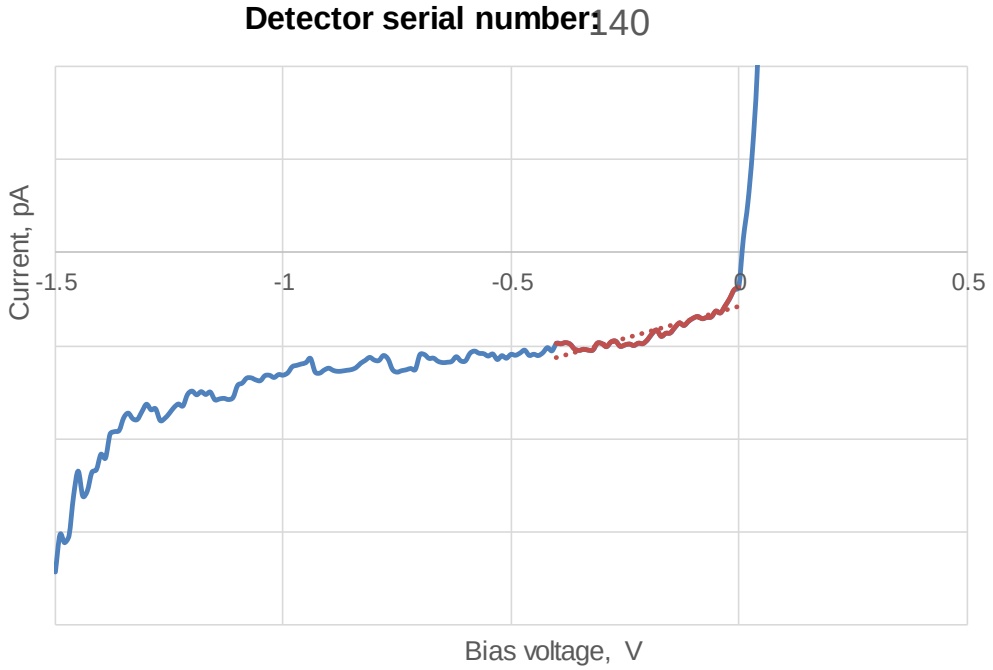
Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission - Ocean Color Instrument (OCI)

- PACE Consisted of a single element, 300µm in diameter
- Short wave, around 2.2µm cut off
- Operating at around 200K
- Electronic components mounted on the cold plane
- *14 flight units delivered + engineering samples*



Typical blind IV @ 208K

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Leonardo DLATGS IR Detector NASA's OSIRIS-Rex Mission

In 2016 NASA launched it's OSIRIS-REx an Asteroid sample return mission.

The mission objectives were to travel to Bennu, a carbonaceous asteroid whose regolith may reveal the molecular precursors to the origin of life and the Earth's oceans.

The spacecraft travelled to Bennu where the thermal emissions spectrometer (OTES), designed and supplied by Arizona State University, mapped the surface of the asteroid to help determine a suitable site on its surface to hover whist a TAG-arm reached out and during a dramatic few minutes, grabbed a sample of soil for return to earth.

Leonardo designed and supplied the single element DLATGS detector used in the OTES instrument.

The mission was a success and the spacecraft is scheduled to deliver the sample to Earth on Sep 24, 2023.

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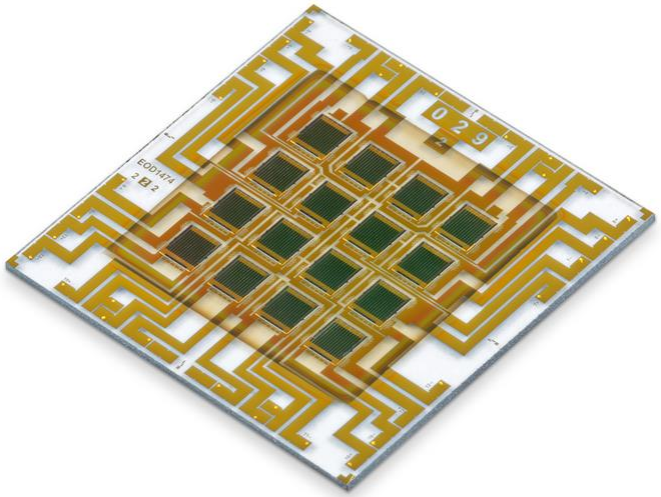
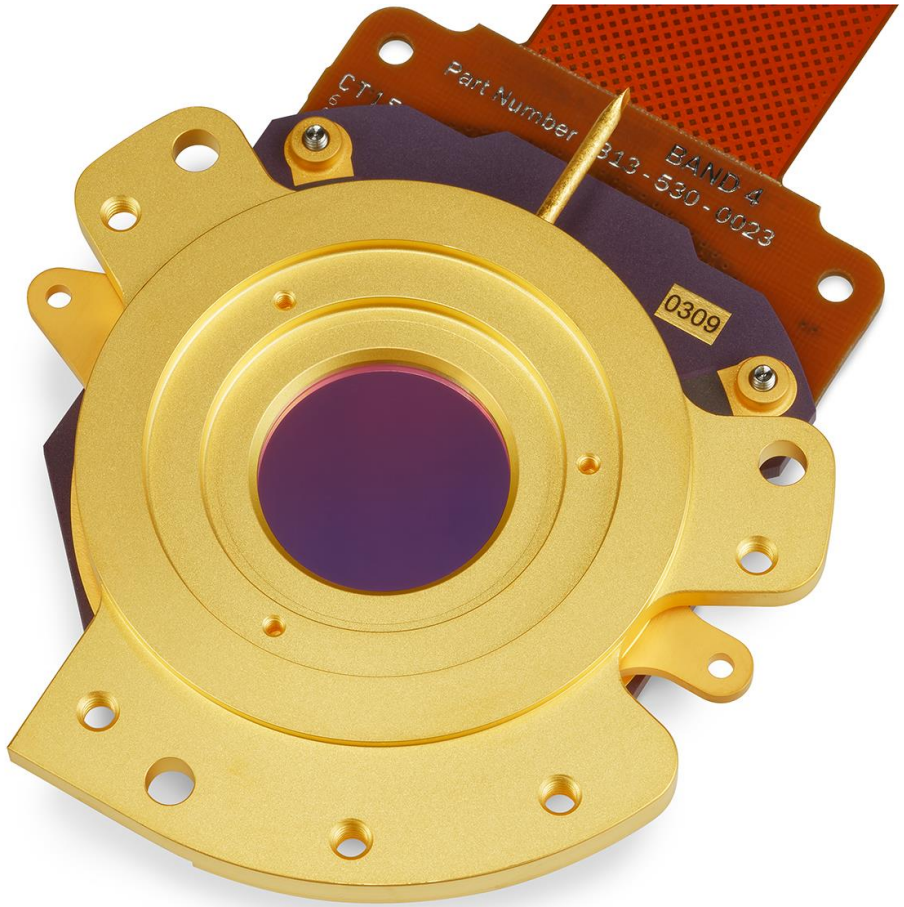
IASI NG

- All flight models & flight spares delivered to ADS
- All LAT and qualification activities have been successfully completed
- 4 channels – 1 PC VLW, 3 PV MW & LW
- Five flight samples delivered per band
- All 4 channels operate at around 80 Kelvin
- Each device consists of 4 x 4 large area pixels – 1.32 x 1.32mm
- The PV channels include a patented sub pixel de-selection process, whereby sub optimal sub pixels can be deselected





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IASI NG

- 4 channels – 1 PC VLW, 3 PV MW & LW
- All at around 80K
- PV channels include patented sub pixel de-selection
  - Allows individual sub pixels to be deselected, either on the ground or in flight
- Radiation stressed – Gamma, Heavy Ion & Proton
  - Silicon (ROIC & temperature sensor)
  - PC MCT
  - PV MCT

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Current developments

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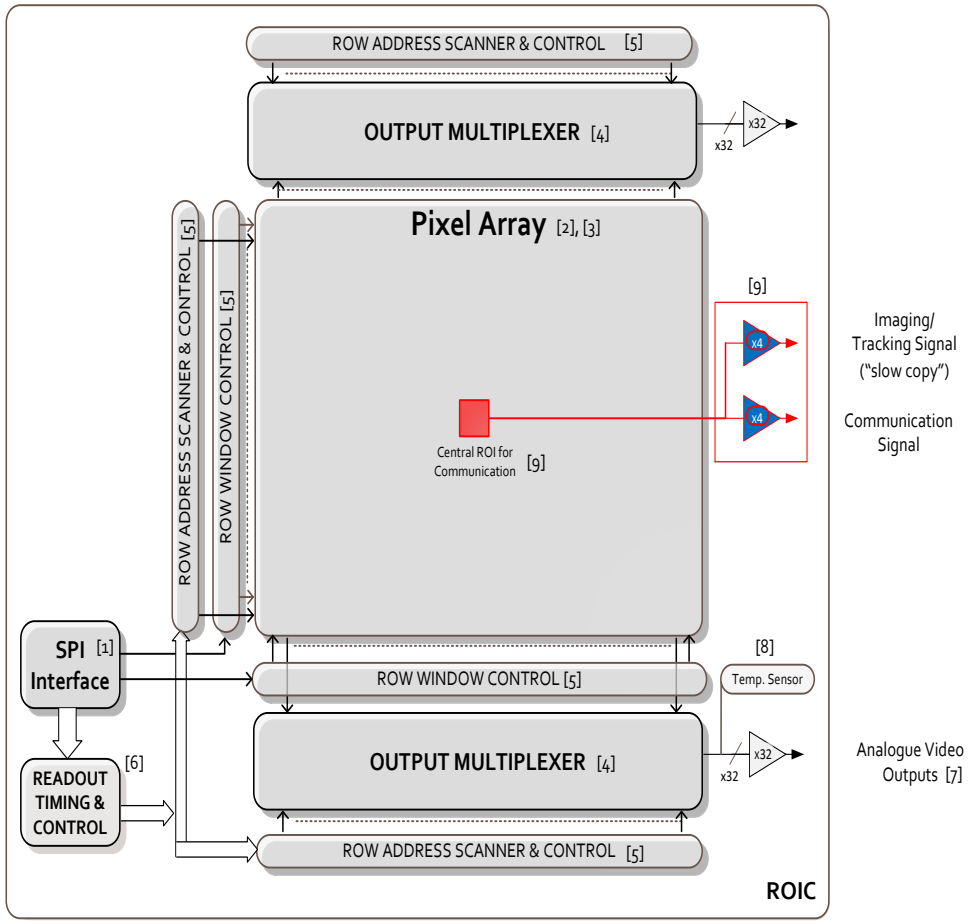
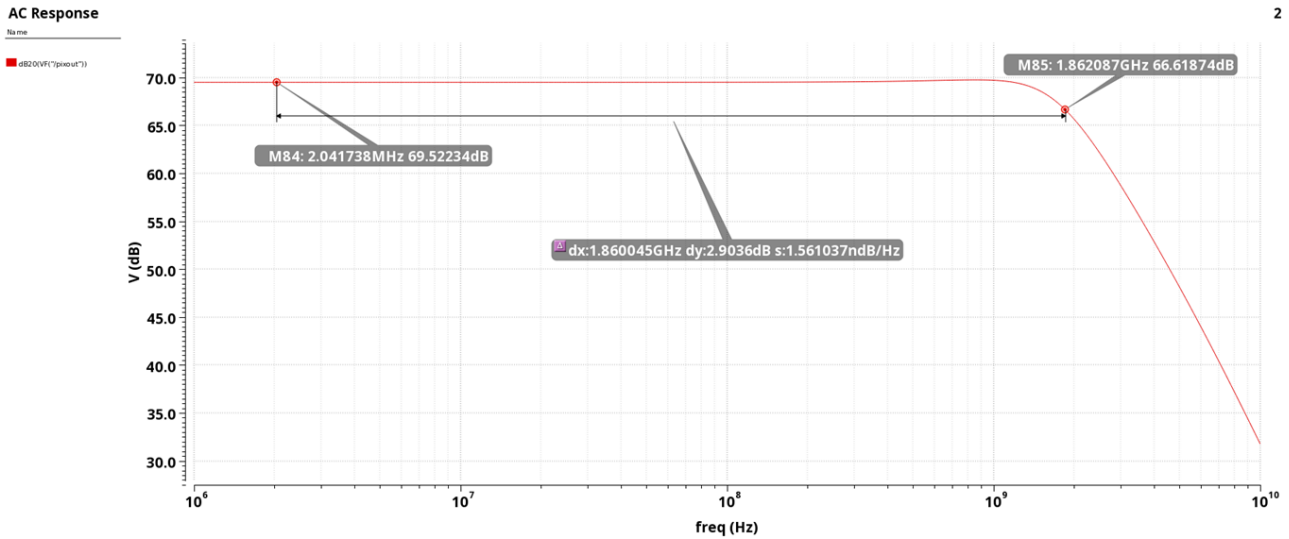
OptiTrax



- High speed APD array for optical comms. Includes 512 x 512 APD array for telescope aiming / wavefront sensing.
- Organising the ROI as a four quadrant detector, will help to operate the communication channel in sub-optimial signal conditions, facilitates operation in a tracking mode using the slow outputs, and also minimise the TIA input capacitance which is critical to achieve high-speed data rates.
- Expecting to achieve >1GHz, < 5 photons



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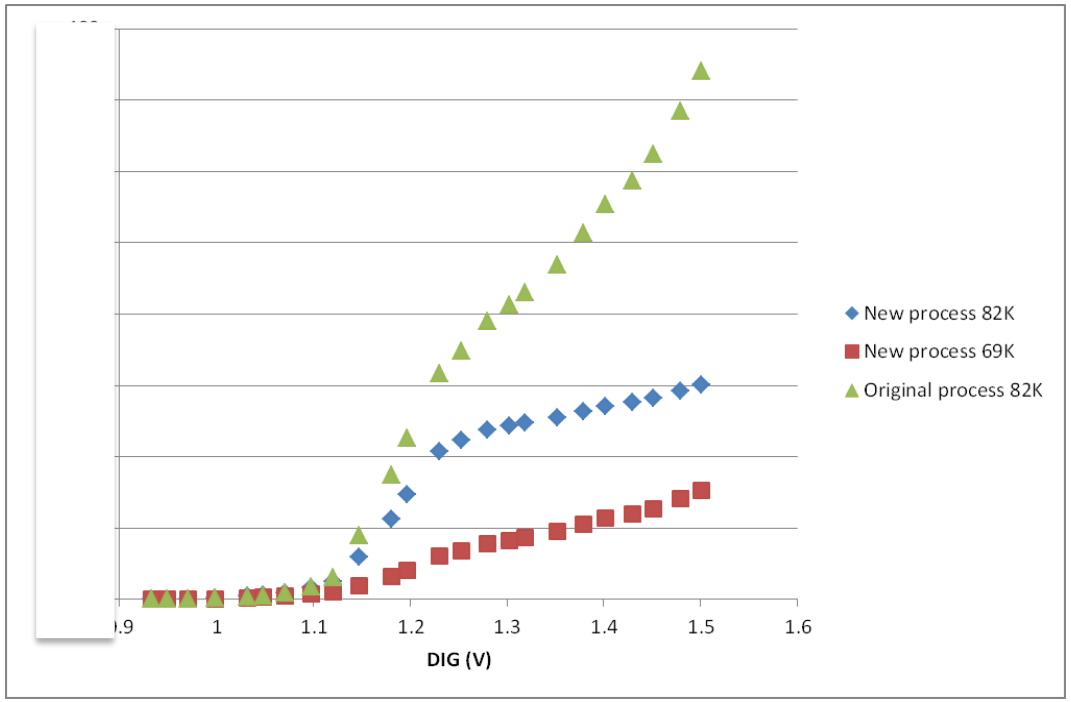
VLW & dark current

- Previous attempts at VLW resulted in diodes with poor leaky characteristics
- Associated with stress introduced by the contact.
  - VLW more sensitive than standard LW and MW
- Contact technology has since improved but not yet applied to VLW
- Example of improvement seen for LW arrays with new process:



- Manufacturing delayed by an upgrade to the cleanroom facilities
- Arrays have been manufactured N on P & P on N
- Planned wavelengths in the 14-15um range
- Initial results promising (N on P)
- Full results expected in a few weeks

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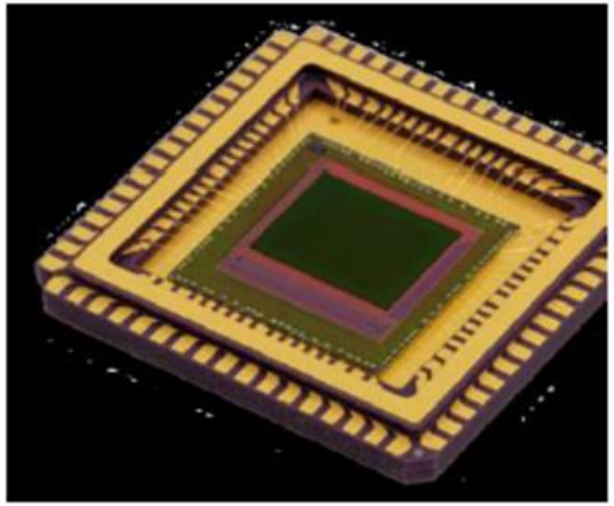
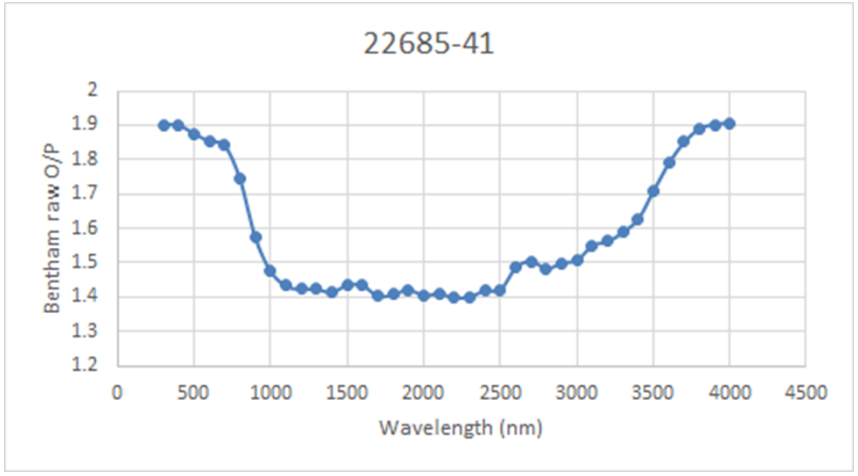
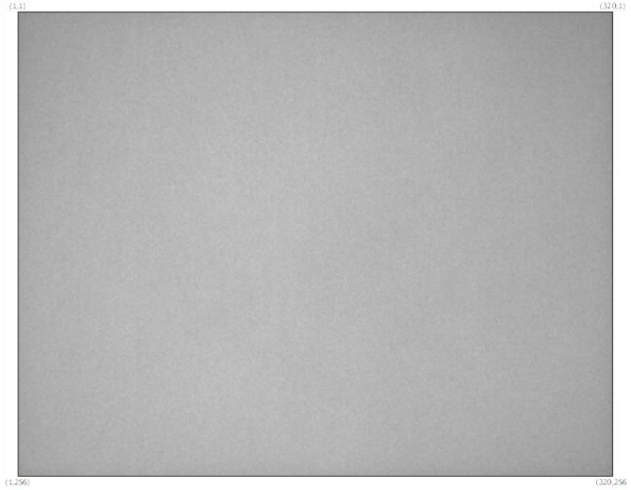
High Speed APDs for LiDAR

Leonardo are currently developing a high speed version of our APD MCT, aimed at a LiDAR requirement.
Aiming to achieve sub-photon sensitively, together with an APC gain of 300 and temporal response of 1ns. Our aim is to include both 1064 & 1550nm. Operating at 80 Kelvin.
Currently, trial parts have been successfully manufactured and tested, demonstrating gains of around 300. Deliverable parts are expected at final test in the next few weeks.







Signal data for one of the trial parts operating at 10.7v bias – good performance and zero defects

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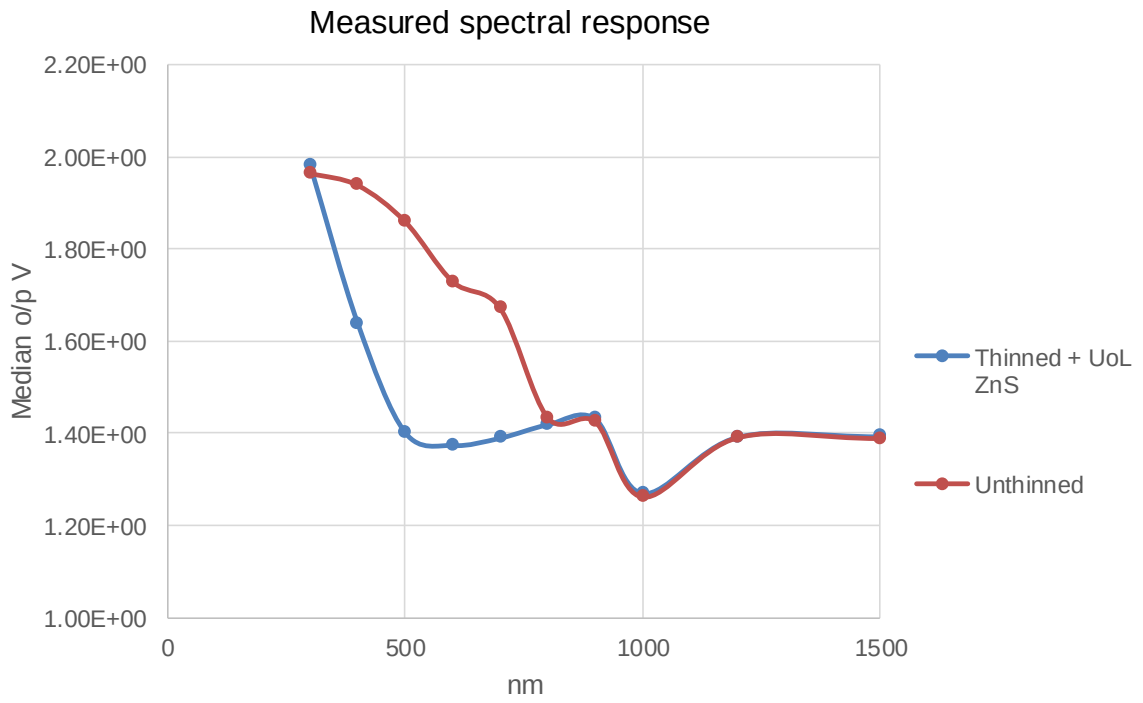
Extending MCT into the visible and beyond

Our current APD structure is sensitive from 800nm to 2.5µm, Leonardo are currently developing the MCT to allow sensitivity to the visual band to be demonstrated. Initial target requirement was < 500nm.
Future work is aimed at improving the QE in the visible part of the spectrum



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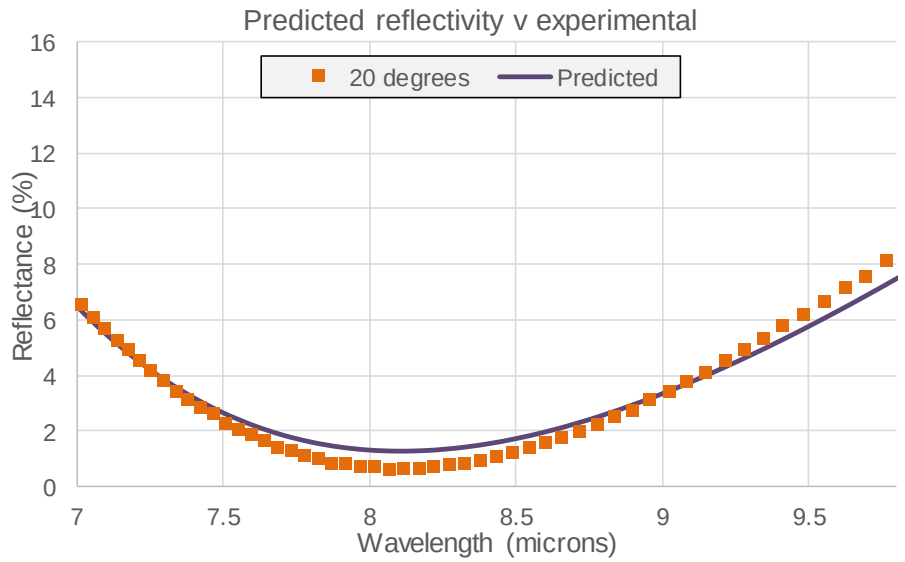
MCT reference pixels

- Masking MCT pixels would allow improved sensitivity in low flux environments by allowing drifts in operating temperature and supply voltage to be calibrated out.
- The reflectance of the applied layer needs to be minimised to prevent excessive straylight, meaning a metal masking layer is inappropriate
- A Fabry Perot structure, manufactured directly above the MCT would allow the reflectivity to be minimised at the wavelength of interest



Leonardo have manufactured samples in SW and LW wavebands. All have been subjected to typical environmental stresses and retested – no degradation has been observed.

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Summary

- APDs – low glow 1024 x 1024 ROIC expected back from the foundry next month
- OptiTrax – ROIC about to go to the foundry, MCT being piloted
- Improved VLW dark current – initial results look promising
- LiDAR Deliverible samples should reach test this month
- Visible response – good initial results – need to improve QE
- MCT reference pixels, just completing initial research contract

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FOR YOUR ATTENTION

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