Selex ES
A Finmeccanica Company

Infrared detectors for Space and Astronomy

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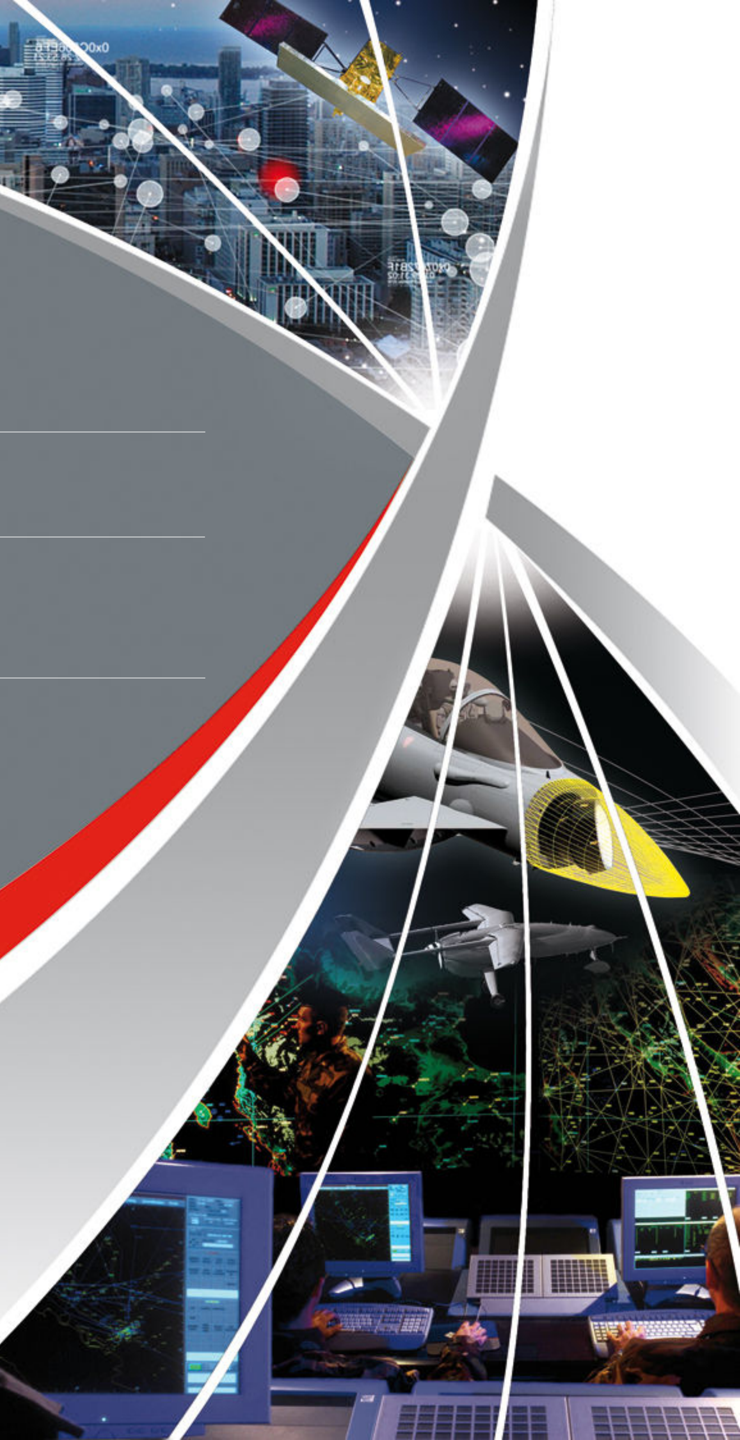
Selex ES - Southampton

CEOI ST Workshop May 1st 2014



Our divisions

Airborne and Space Systems Division

- Airborne radar
- Sensors
- Electronic warfare systems
- Avionics
- Integrated mission systems
- Airborne surveillance systems
- Tactical UAS
- Target drones
- Simulation systems
- Space sensors and equipment

Land and Naval Systems Division

- Integrated command land and naval command and control systems
- Land and naval radar
- Electro-optical sensors
- Tactical communication systems and equipment
- Battlefield protection systems and equipment

Security and Smart Systems Division

- Homeland and critical infrastructures' protection and security architectures
- Secure communications systems
- Information technology
- Information management and automation systems
- Airport systems
- Air traffic and vessel management and control systems

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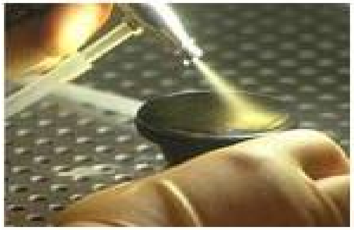
Overview

- 50 Year heritage in detector development and manufacture
- World leader in the development and manufacture of infrared detectors for applications such as:
  - Thermal Imaging for land, airborne and naval systems
  - Missile Guidance
  - Infrared spectroscopy
  - Space and Astronomy
- 180 employees – 70 educated to degree level or above
- 9500m^2 facility
- 3000m^2 clean rooms including Class 100 areas
- Dedicated space assembly and test facilities



Space Flight Programmes 1972 - 2005

Selective chopper radiometer - Nimbus 5

Horizon sensor – X4 Earth Satellite.

IR spin scan radiometer – Synchronous meteorological satellite for Hughes Corporation

ATSR (Along track scanning radiometer) – UARS for RAL

PMIRR (Pressure modulated infra red radiometer) – Mars Mariner for Oxford University

MIPAS (Michelson interferometer for passive atmospheric sounding) – Envisat for ESA

BIRD (Bispectral integrated detector cooler assembly) – DLR

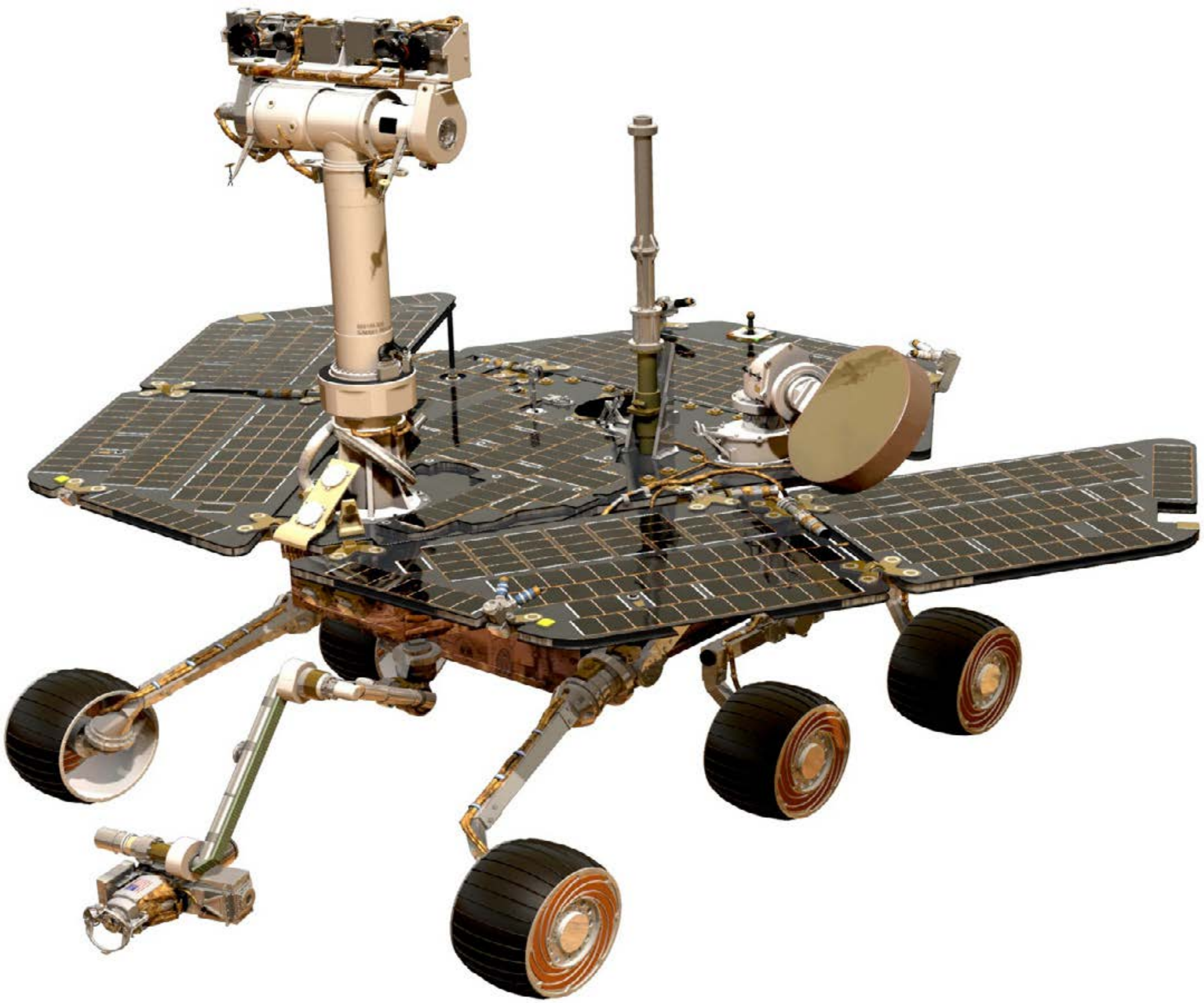
STRV2 – 2 colour PV array for DERA/BMDO

Meteosat 1st generation – for Astrium

Mini TES –Raytheon instrument on Mars Spirit and Opportunity Rovers

Meteosat 2nd generation (MSG) – for Astrium

Miniature Thermal Emission spectrometer (Mini-TES) using DLATGS



Current Space flight programmes

IASI NG (Astrium/CNES/Eumetsat)

- Phase B in progress
- PV and PC devices
- IASI NG is included in the bilateral agreement between UK Space and CNES

4 bands covering 3 – 16um wavelength range for the FTIR sounder

Weather prediction, land and sea surface temperature, and atmospheric science

Successor to IASI on METOP A launch 2006, 2012, 2015

Airbus (Astrium) will deliver 3 instruments in 2018, 2019, and 2020

Launch commences 2021

Current Space flight programmes

OTES (Arizona State University)

- OSIRIS Rex (mini) thermal emission spectrometer
- NASA asteroid sample return mission
- DLATGS uncooled pyroelectric detector
- 4 – 50μm spectral response

OTES

The OSIRIS-Rex mission, developed by the University of Arizona's Lunar and Planetary Laboratory, is planned for launch in September 2016. After traveling for approximately two years, the spacecraft will rendezvous with asteroid 101955 Bennu (1999 RQ36), and begin 505 days of surface mapping at a distance of approximately 3 miles (4.8 km). Results of that study will be used by the mission team to select the sample site and ultimately extend a robotic arm to gather the sample.

The OSIRIS-REx Thermal Emission Spectrometer (OTES) provides mineral and thermal emission spectral maps and local spectral information of candidate sample sites by collecting thermal infrared data from 4 - 50 μm.

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Completed Developments since 2009

MTG (Meteosat 3rd Generation)

- Predevelopment of PV detectors for ESA – VLWIR (up to ~14µm)

IASI NG

- Predevelopment of PV and PC detectors for Astrium in the range 3.6 -16 µm

METimage

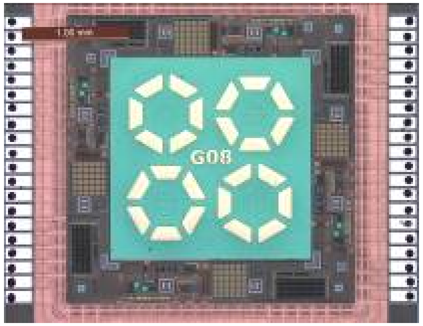
- Predevelopment of PV detectors for Jenoptronik in the range 2.2 -13 µm

LFNIR ARRAY (ESA)

- Phase 1 development of European alternative to Teledyne Hawaii 2RG for ESA

DIAL detector (ESA)

- Large area (Ø150µm)
- SWIR avalanche photodiode (APD) MCT detector with TEC and TIA for ESA
- Possibility of joint ESA/NASA mission dependent on availability of suitable space qualified laser



NSTP (UK National Space Technology Programme)

- SWIR APD characterisation for space missions

QDIP (ESA)

- Feasibility study for use of nanotechnology (incl T2SL) to improve TIR satellite imagers
- Led by Cardiff University with contributions from Sheffield University and Selex ES

Ground based astronomy (ESO)

- SWIR APD wavefront sensors and fringe tracker (Saphira) for ESO GRAVITY instrument on VLT

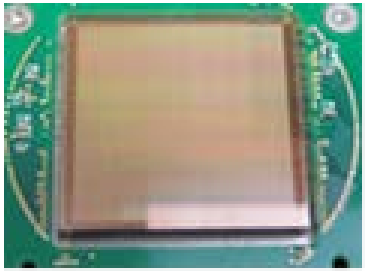
Current Space & Astronomy Developments

NIR LFA phase 2 and ASIC interface electronics (ESA)

- Alternatives to Teledyne Hawaii 2RG and Sidecar chip
- Current phase deliverable of 1032 x 1280, 15 μm pitch
- Selex provide consultancy and test facility to Caeleste on ASIC development
- APD enabled

SWIR LFA (ESA)

- 24 month contract for ESA
- 2k x 2k, 17 μm pitch
- Required for earth observation instruments
- APD enabled
- Stitched reticle
- Largest cooled detector in Europe



VLWIR development (ESA)

- 24 month contract
- Low dark current
- Up to 14.5 μm cut-off wavelength

NSTP (UK National Space Technology Programme)

- Buttable package development for NIR LFA in cooperation with e2v

Ground based astronomy (ESO, University of Hawaii, UK ATC)

- MOVPE version of SWIR APD wavefront sensors and fringe tracker (Saphira) for ESO

Microcarb with Leicester University

NIR LFA ROIC Performance Summary

Phase 2 chip is ~ 1kx1k   Phase 3 goal is 2kx2k

PARAMETER	VALUE	COMMENTS/CONDITIONS
Active array size	1032 x 1280	4 reference rows top and bottom 2 reference columns left and right
Power	<55mW	32 output mode
Linearity *	<3% up to 75ke-	99ke- full well capacity
Noise *	22e$^-$ rms (single CDS) ≤5e$^-$ rms (for 40 non-destructive reads and including dark current)	
Conversion gain	6µV/e$^-$ (typical)	Saphira ROIC 6.5 µV/e$^-$
Transfer gain	0.85	Single Source Follower on readout chain

* Linearity and noise are measured on hybridised devices

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MOVPE REACTORS

SELEX ES operates two 3” MOVPE reactors :

- New reactor installed in purpose built cleanroom
- Gas train capable of growth on 6” substrates for large array sizes 2k x 2k

Radiation Hardened Standard Cells

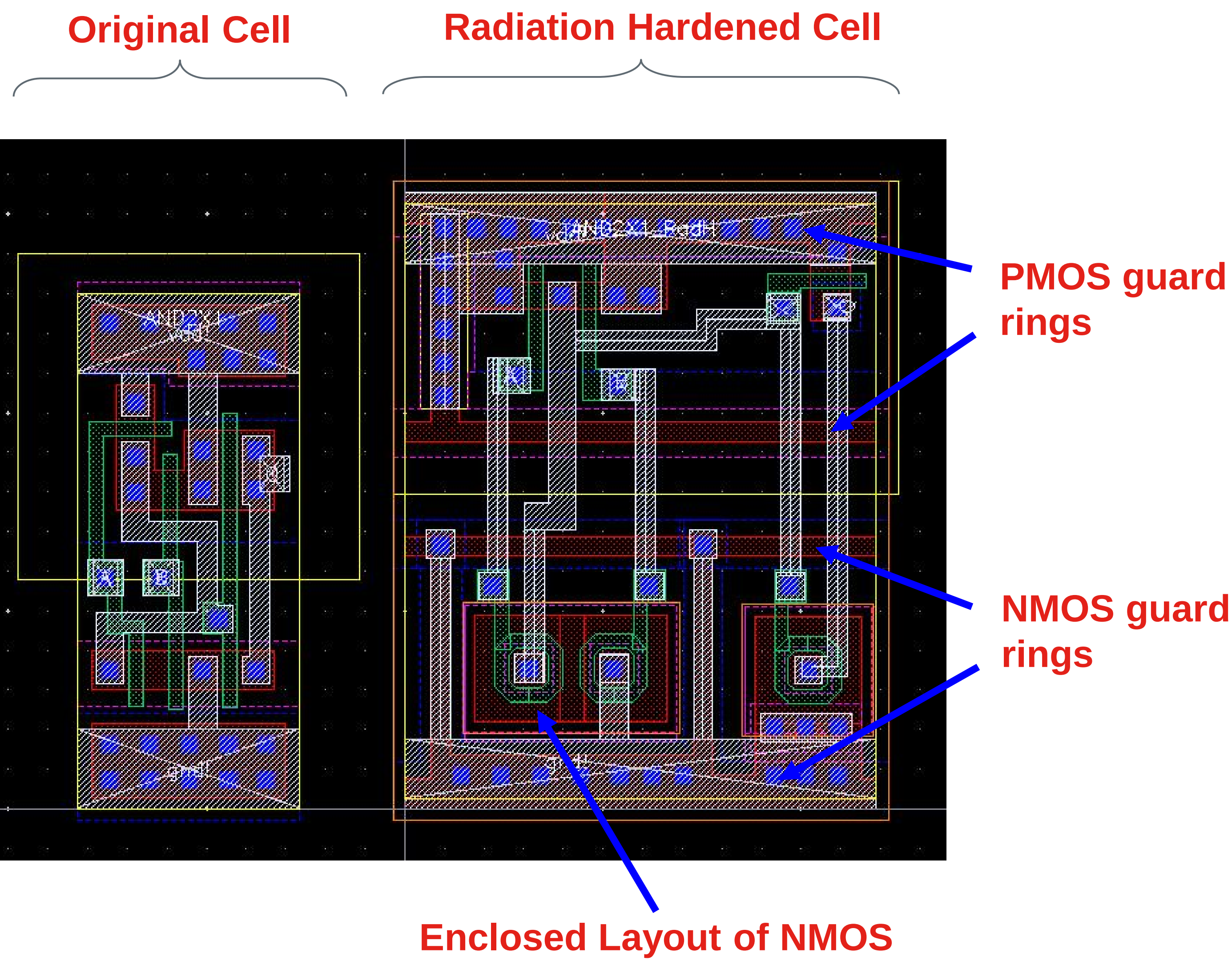
PMOS Transistors

- Surrounded by NWELL contacts to form continuous guard ring

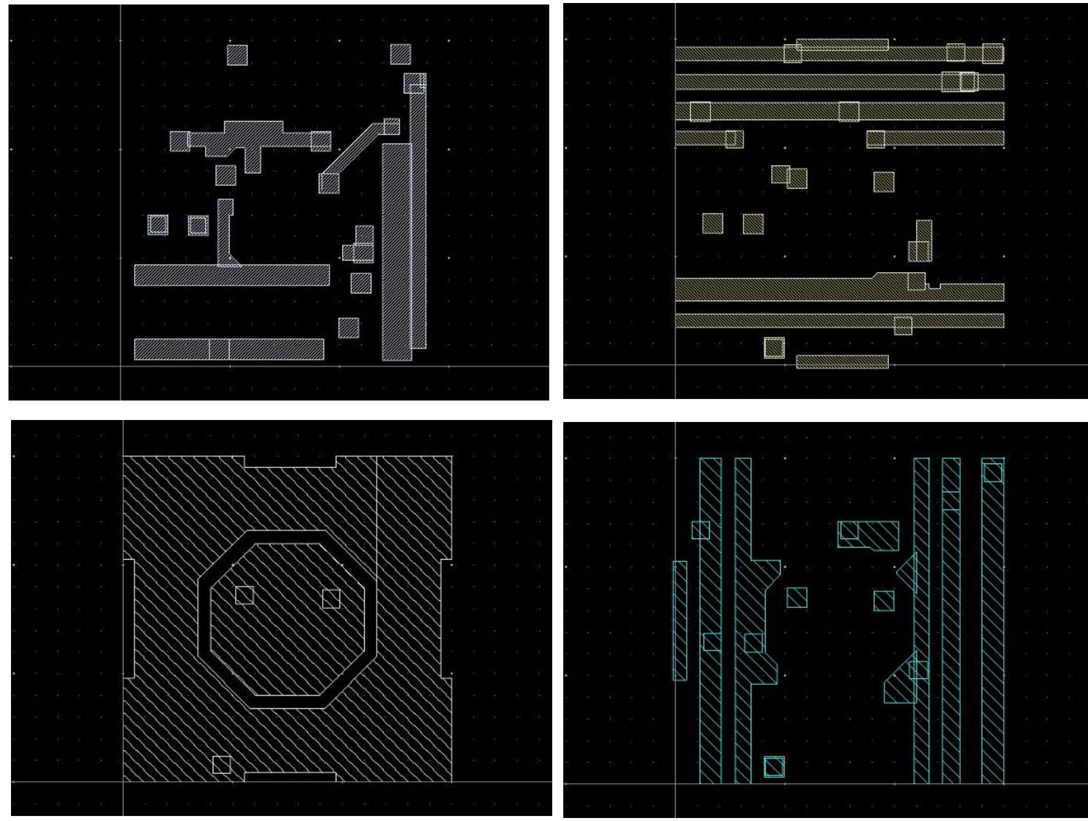
NMOS Transistors

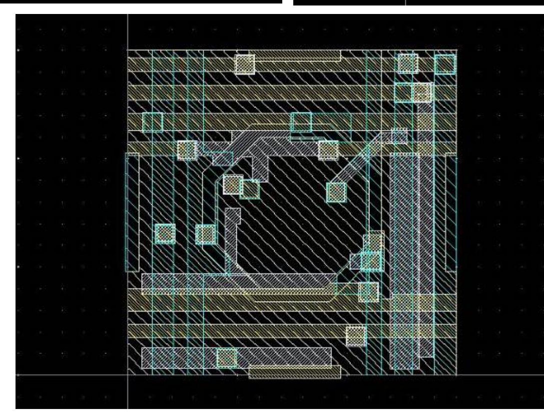
- Enclosed Layout to prevent SE latch-up
- Surrounded by substrate contacts to form continuous guard ring

Radiation Hardened Standard Cells
AND Gate example



Pixel Design – Metal Shielding





Metal shielding to prevent glow effect:

- Metal1 to Metal4 (clockwise)
- Metal layers combine to provide 100% coverage between transistors and photodiode

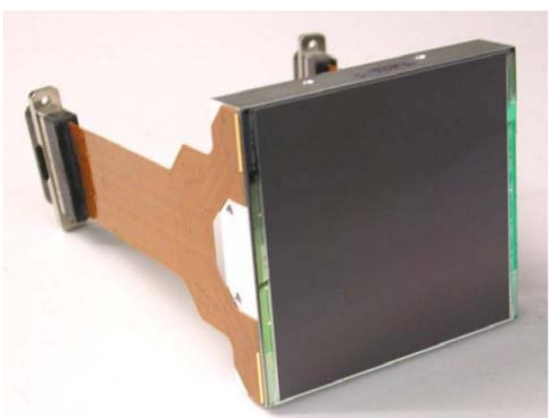
Large format array packaging

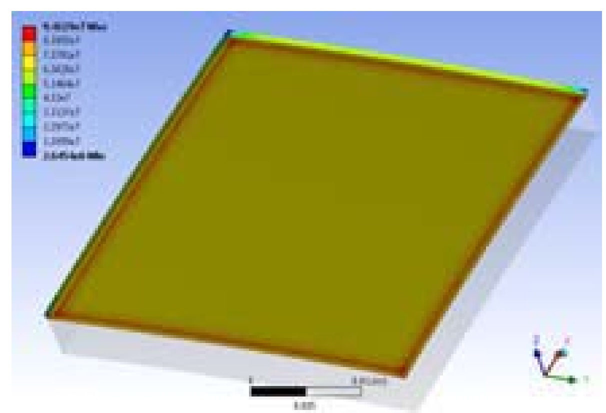
Builds upon e2v experience of close buttable packages

Expansion matched header (molybdenum)

Both ROIC and pcb glued to header

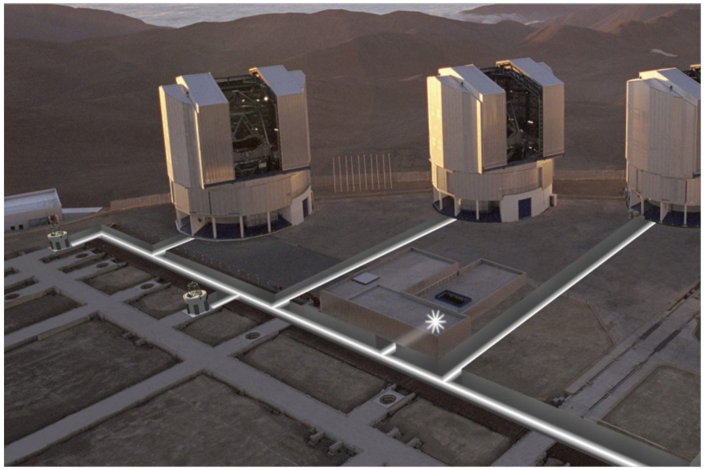
Initial trials indicate that edge effects dominate and the expected stress is not size sensitive





Sensors for the VLT Interferometer

European Southern Observatories, ESO
Very Large Telescope, VLT – cluster of four 8.2m unit telescopes



The VLT Interferometer and GRAVITY instrument

- GRAVITY will combine the signals of four 8.2 metre telescopes to achieve the sensitivity and resolution of a 200 m telescope.
- Narrow angle astrometry with an accuracy of < 10 micro-arcseconds.
- Interferometric imaging for objects as faint as K = 11.
- Pioneering research at the event horizon of black holes, resolution of exo-planets and the origin of protostellar jets.

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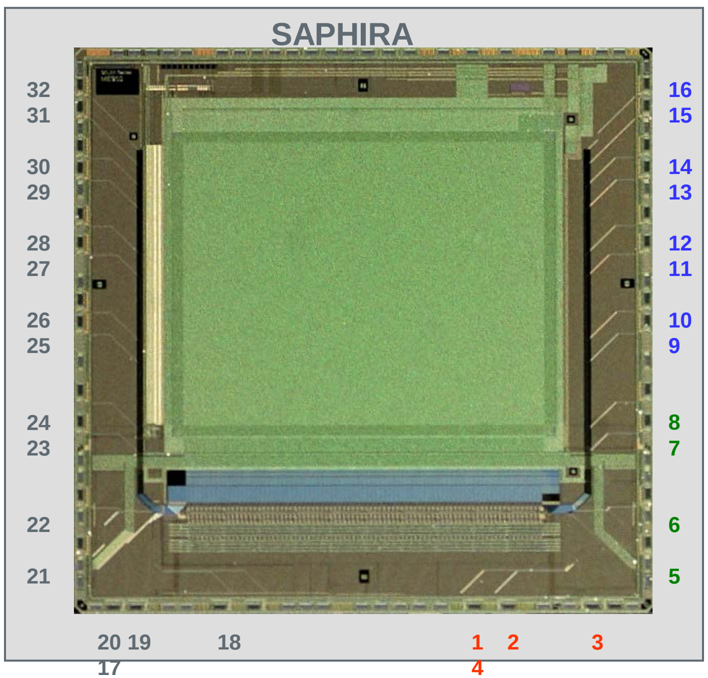
SAPHIRA - full custom ROIC for ESO's GRAVITY Project

General architecture
: 320x256 on 24μm pitch with either 32, 16, 8 or 4 outputs

Windowing
: Multiple windows each independently resettable

Readout
: Non-destructive readout for Fowler sampling

Performance
: Frame rate up to 100K frames per second



Selected for wavefront sensors and interferometers in VLT

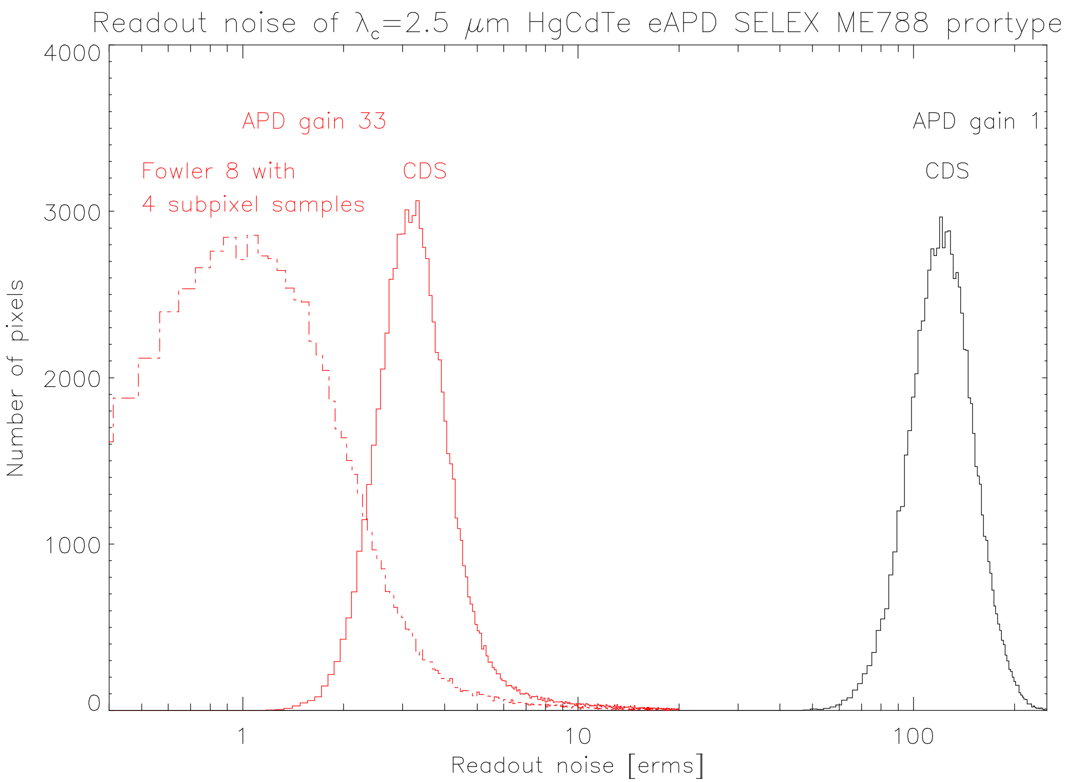
LPE APDs

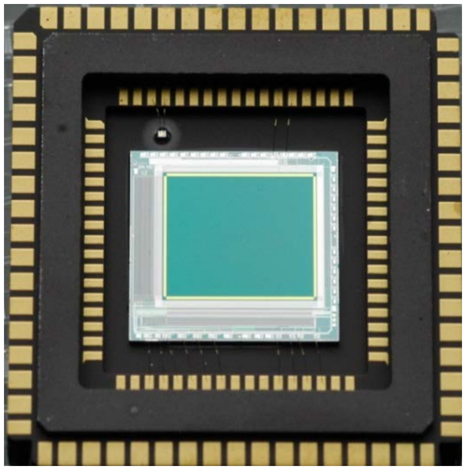
Typically 45K operation

E-APDs in HgCdTe

Usually give pro-rata improvement in sensitivity

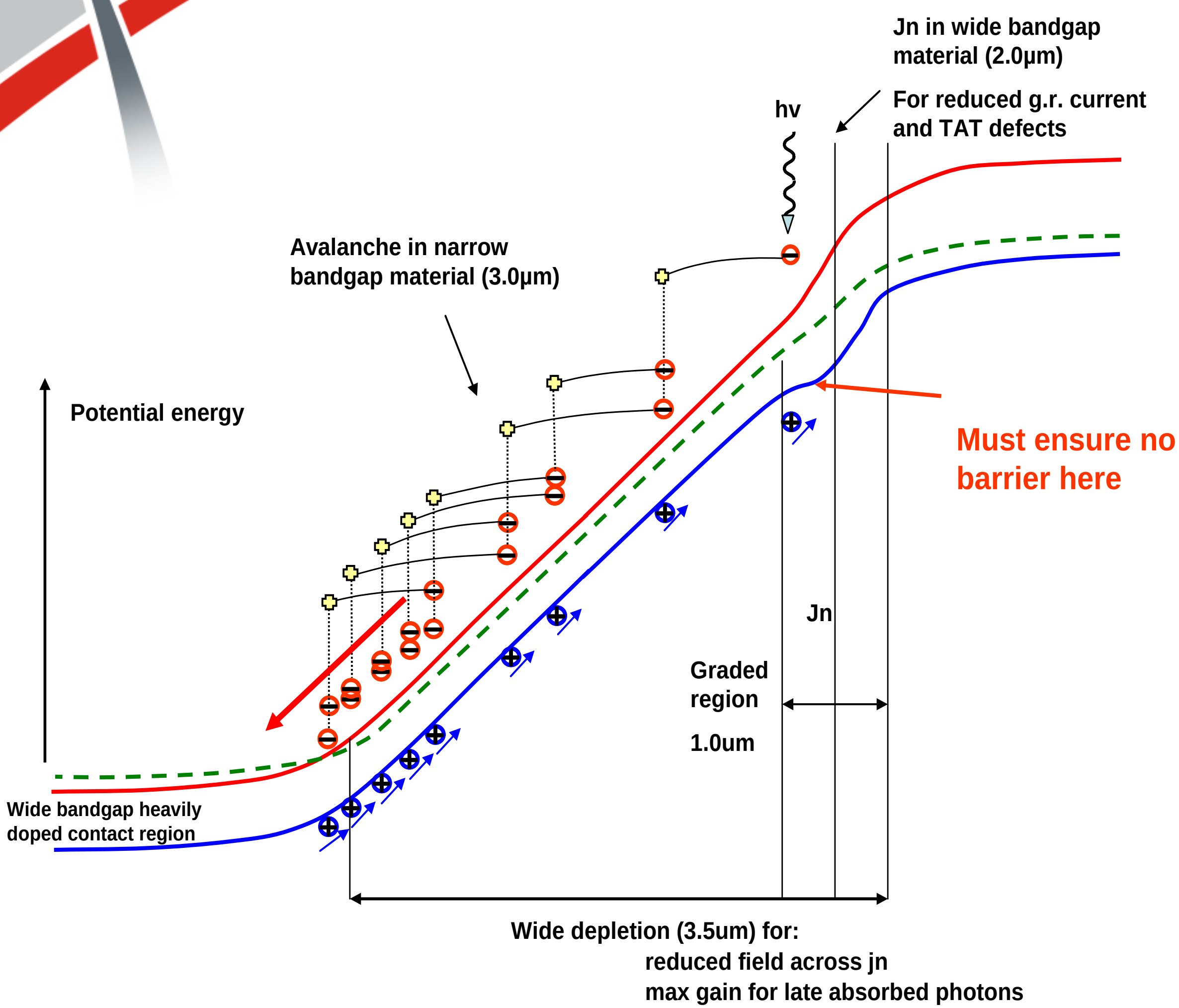
Earth observation
Astronomy
Wavefront sensors
Spectroscopy
Interferometry
Photon counting
Ultra-fast imaging





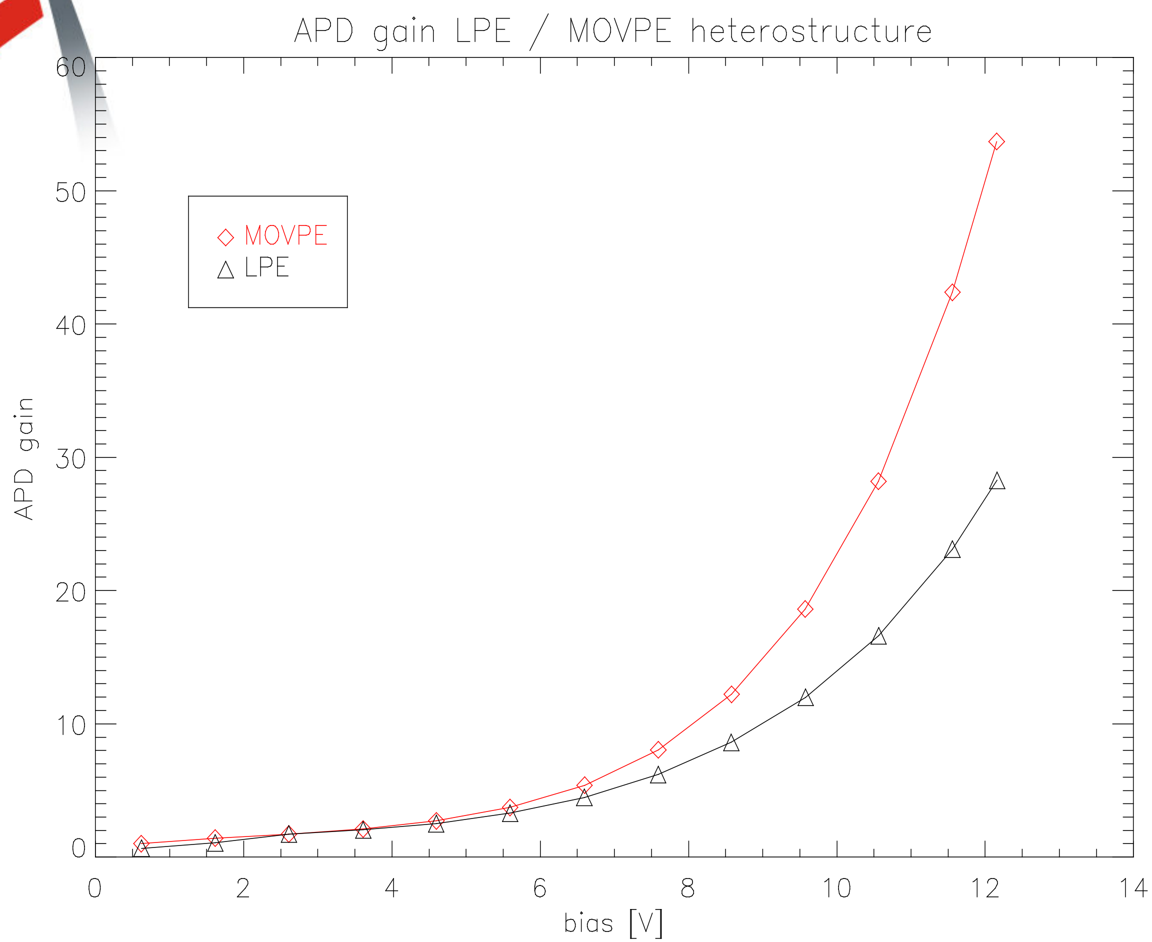
Courtesy of European Southern Observatories, ESO, with special thanks to Dr Gert Finger

Change of crystal growth from LPE to MOVPE



- heterojunction
  wider bandgap at junction
- photons absorbed and
  amplified in n-type region
- better breakdown voltage
  yields higher APD gain
- higher operating temperature
  better cosmetics

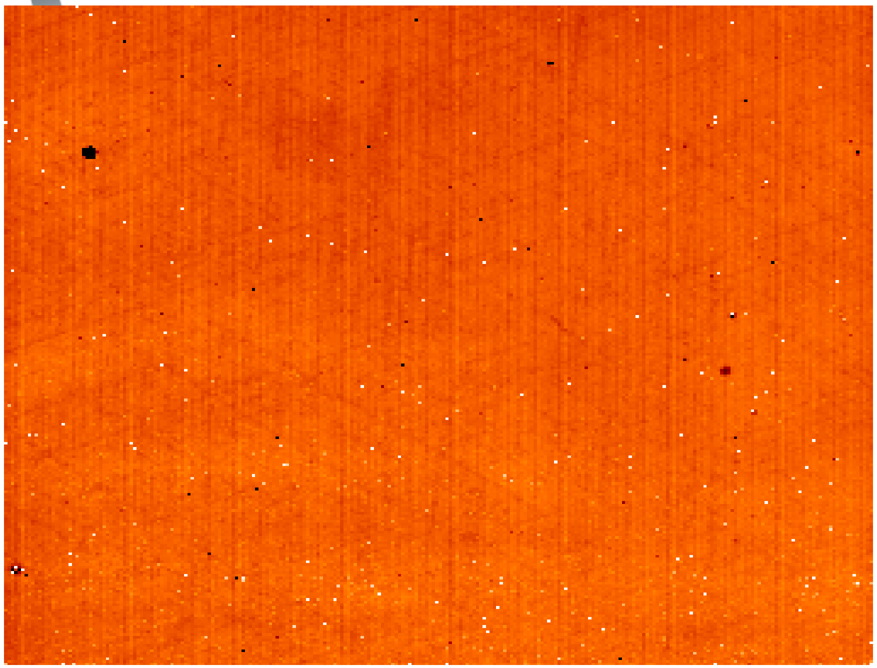
APD gain MOVPE / LPE



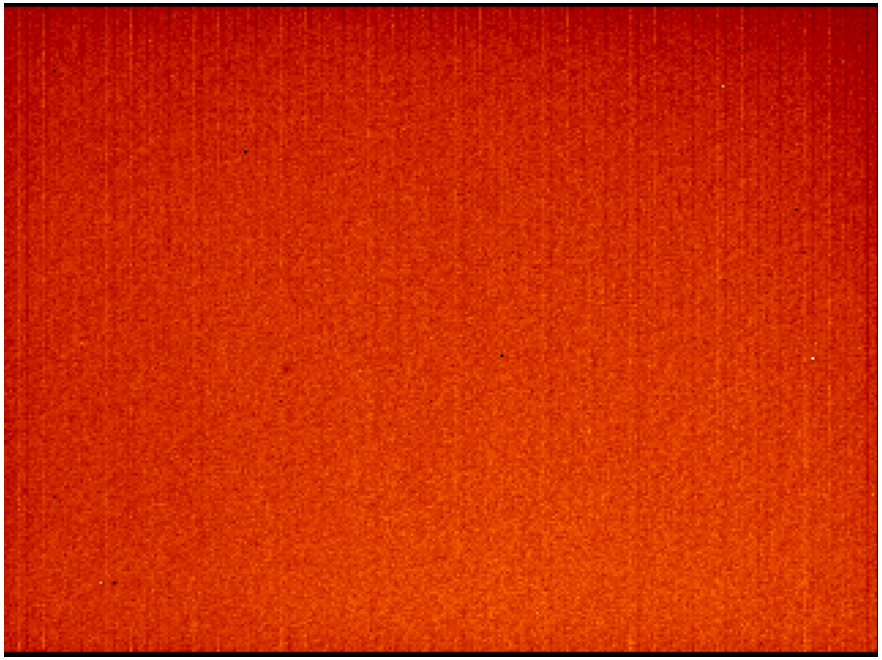
- LPE gain measured on GRAVITY FT science array
- APD gain of MOVPE heterostructure is a factor of 2 larger
- Increased gain of MOVPE heterostructure because of narrow bandgap gain region (3.5 microns cut-off)

2013 MOVPE APD breakthrough

LPE array (H and K band)
(45 K, avalanche gain: 17x, DIT: 5 ms)



MOVPE array (H and K band)
(85 K, avalanche gain: 60x, DIT: 5 ms)



- New MOVPE APD design gives virtually no defects at bias voltages as high as 12V and integration times of seconds
- Outstanding high temperature operation

Courtesy: Gert Finger - ESO

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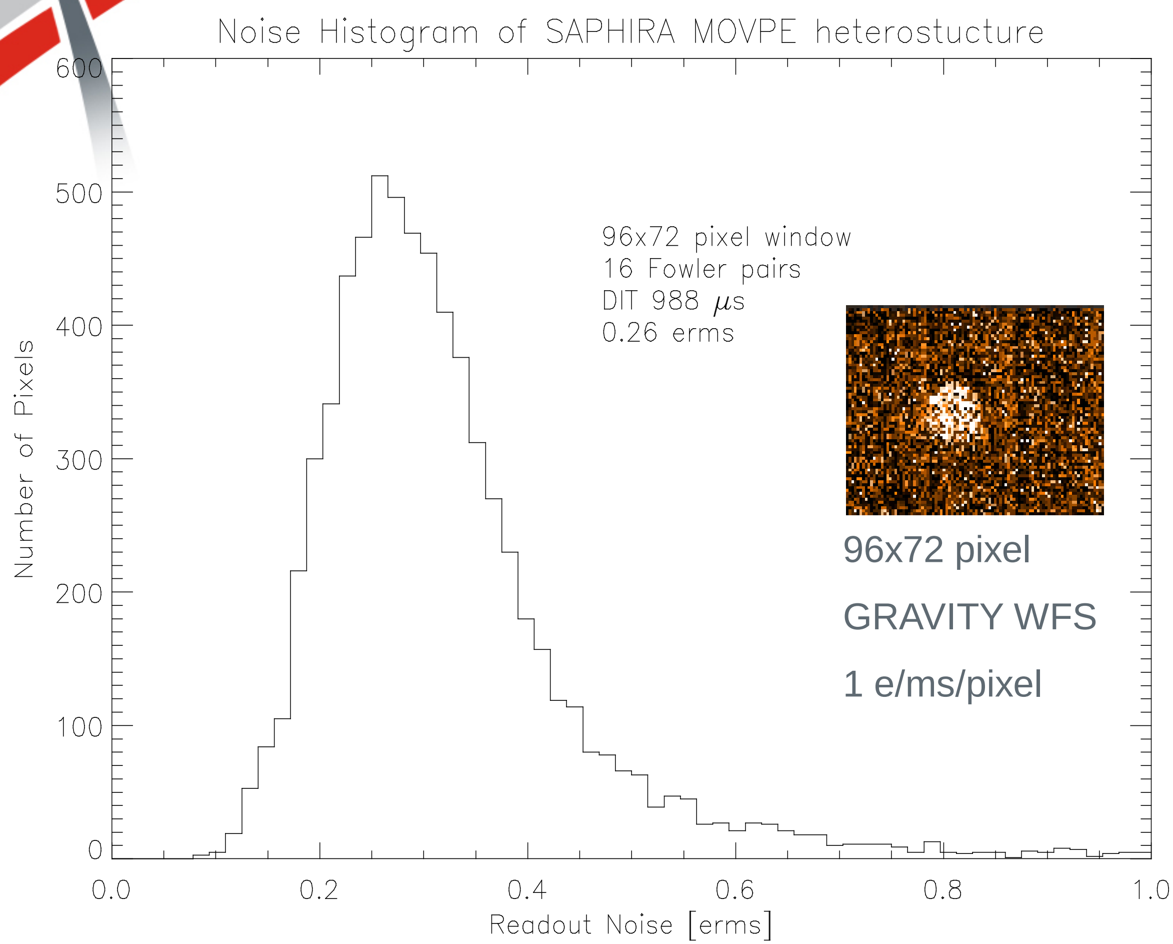
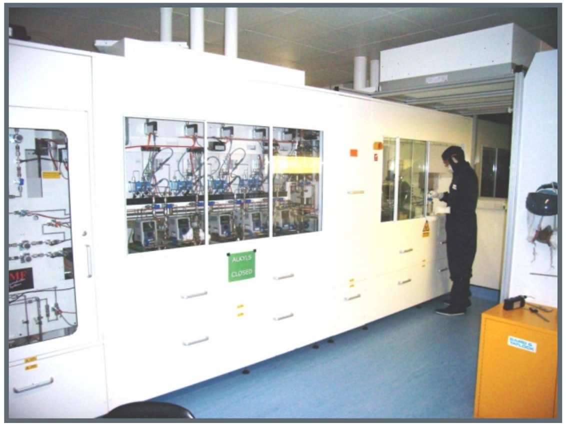
ESO results- readout noise with Fowler sampling



- APD gain 53.7
- window size 96x72 pixel
  as needed for GRAVITY WFS
- Integration time 988 μs
- 16 Fowler pairs
- 80K operation
- Readout noise **0.26 e rms**

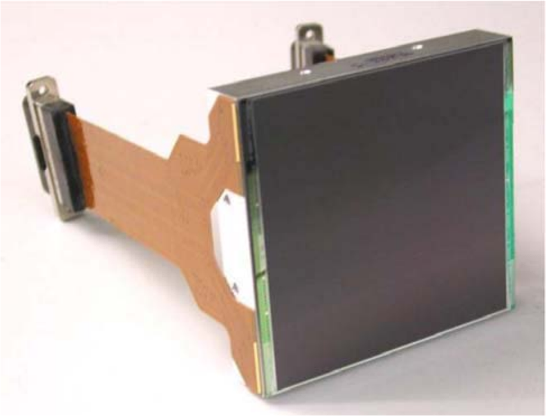
Courtesy: Gert Finger - ESO

What Next ?



Large area MOVPE growth

+



2k x 2k APD-enabled ROIC

= **APD Successor to Hawaii 2RG** ?