Detectors for Wide Field Imaging

Gavin Dalton

With input from Paul Jorden, Peter Poole, Peter Dennis, David Hall, David Lees, John Cairns, Keith Barnes, Ian Baker, Les Hipwood, Gert Finger, Jim Beletic

Overview

- Current status of CCDs
- Current IR detectors
- Developments in IR detectors
- Prospects

CCDs

- Fairchild
- LBNL (Hamamatsu)
- e2V

CCDs

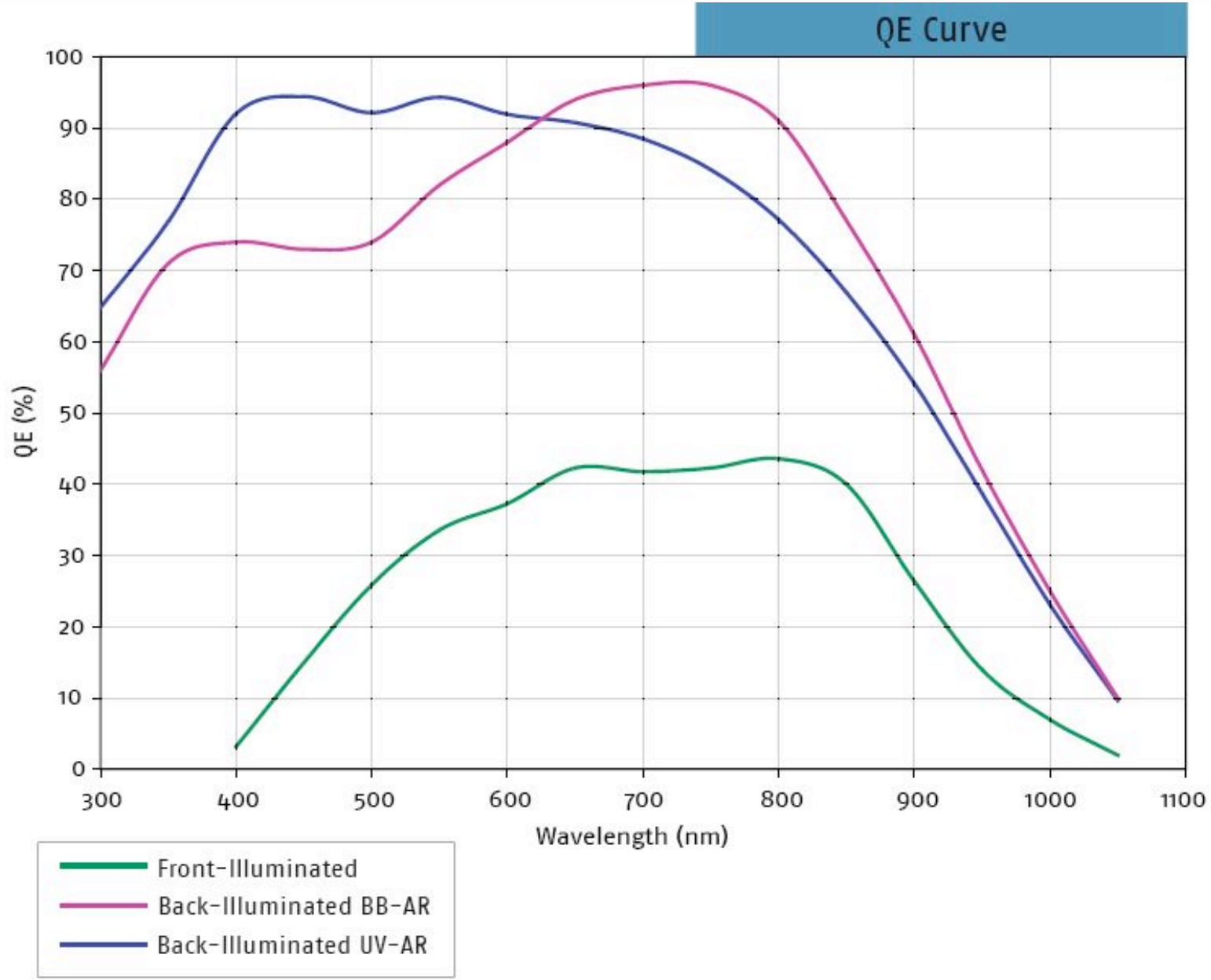
- Fairchild

CCD486, 4kx4kx15μm

Better q.e. and slightly lower dark current than e2V CCD231 due to multi-phase pinning, but also higher readout noise

In recent discussions, Fairchild appeared to have no interest in developing larger format CCDs

Fairchild q.e. curve



CCDs

- LBNL Hi-rho

Extremely red sensitive chips developed at LBNL, now also available from Hamamatsu(S10892-01) or e2V

Requires high voltage (100V) bias board, but can be incorporated into a standard controller

Some devices have been found to be extremely sensitive to ESD damage

CCDs

- e2V

Stable production process based on building blocks

Blue, Red and High-rho devices available

Anti-fringing options (variable pixel heights)

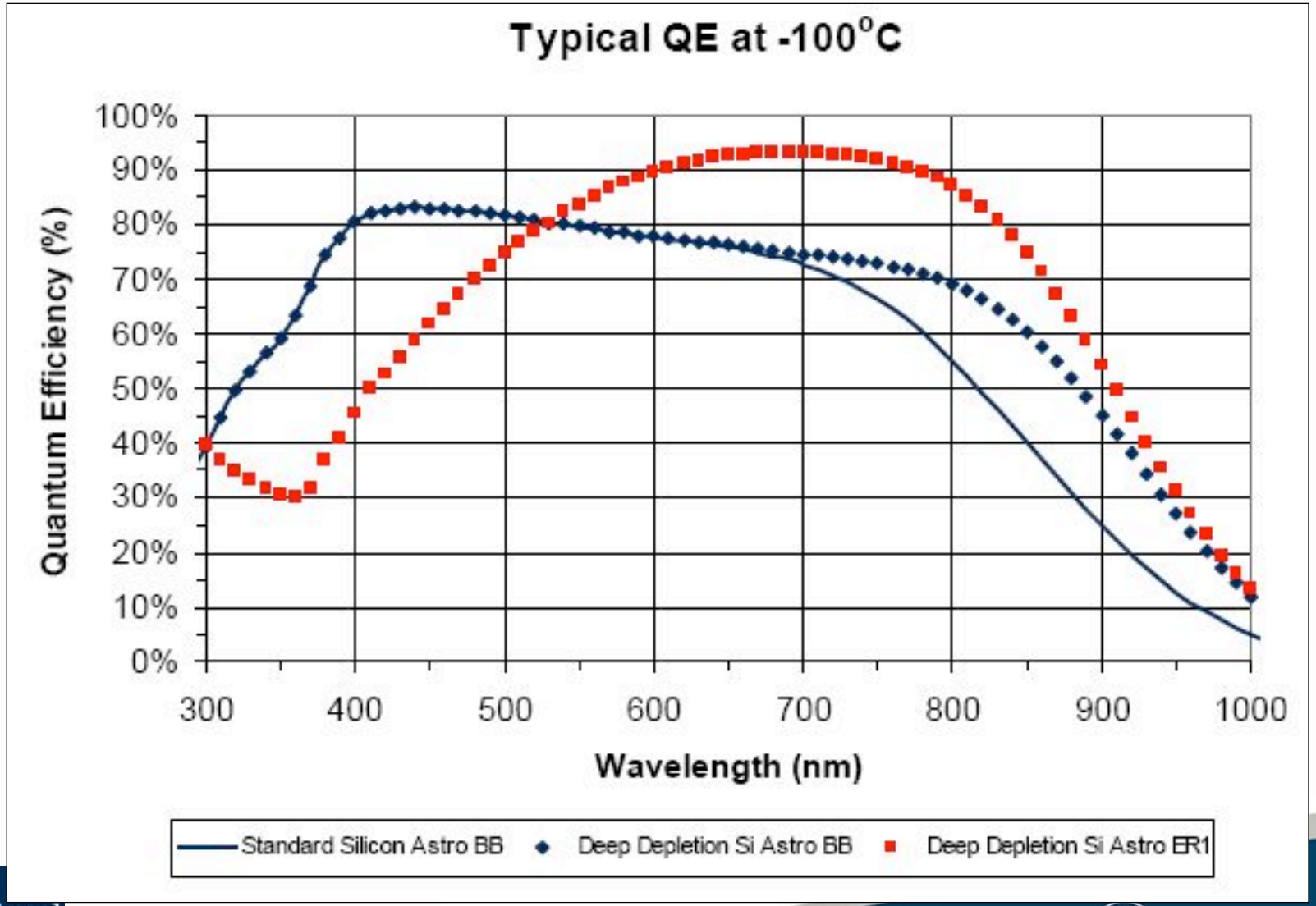
Provides a simplified controller interface

Avalanche gain, not yet mapped to larger formats

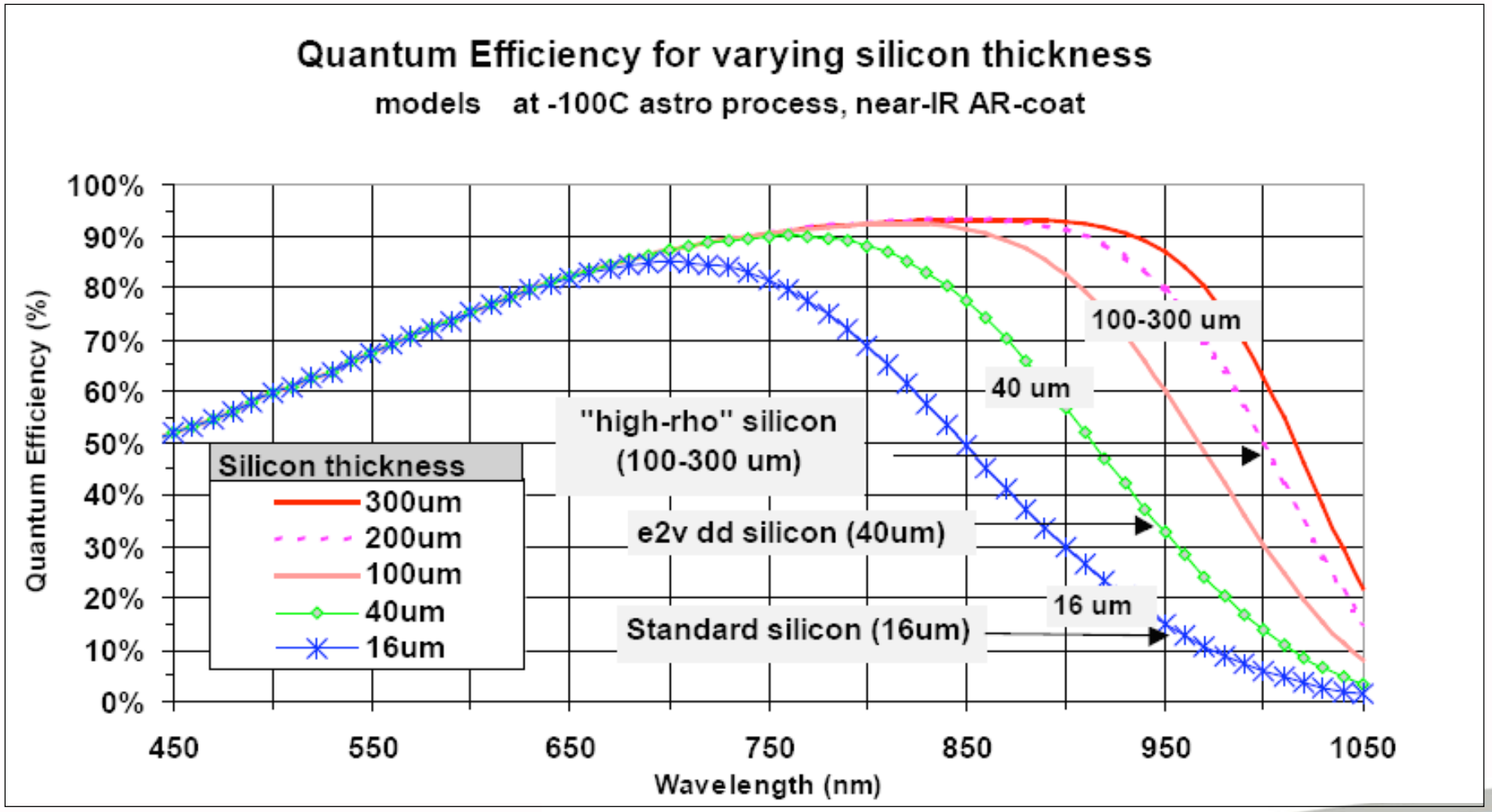
Formats up to 8kx3k have been manufactured (larger than 4kx4k is probably lower cost for large systems)

Also making 10μm pixel high-rho devices for LSST

e2V q.e. curves



e2V q.e. curves



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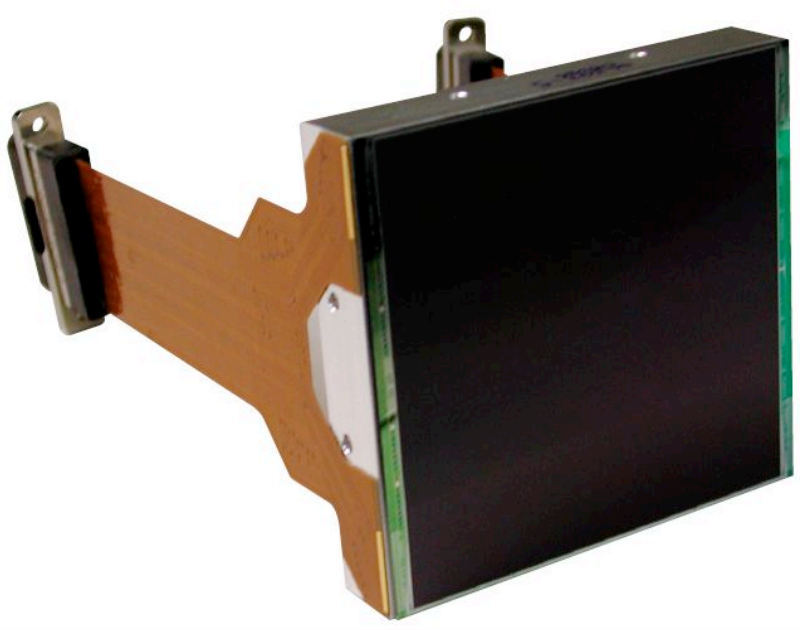
e2V package



CCD231-84 package

15μm pixels

2e- noise at 50kHz readout

5e- noise at 1MHz readout

SiC package provides 20μm flatness

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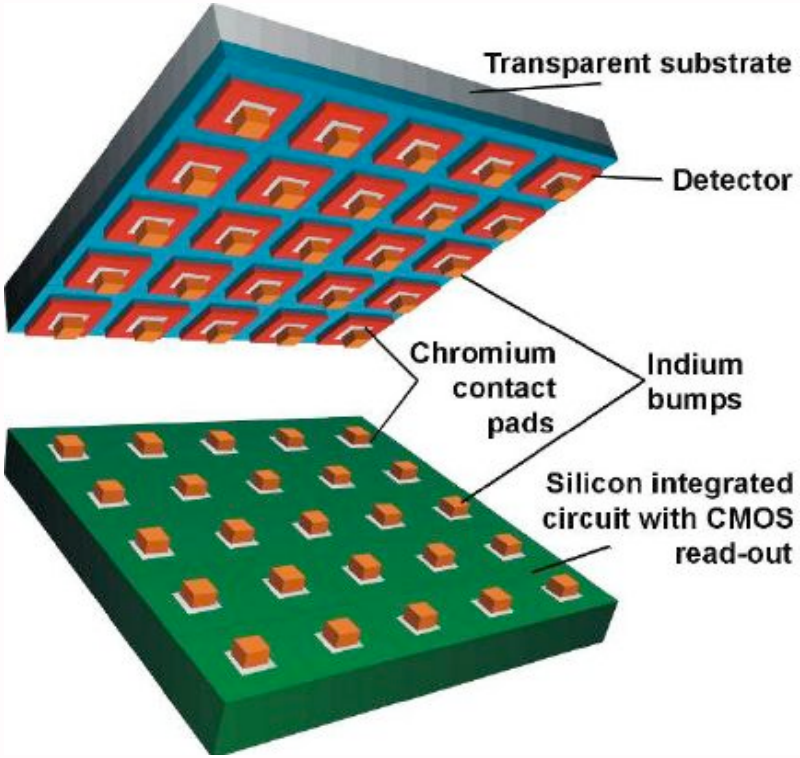
Current IR arrays

- Raytheon
  - 2kx2kx20μm VIRGO chips (VISTA)
  - 2.5μm cut-off, good q.e, poor cosmetics
    - Low cost option, mixed experience from VISTA
    - 3-edge-buttable
- Teledyne
  - 2kx2kx18μm HAWAII-2RG
  - 2.5 or 1.7μm cut-off, substrate removed
  - 3-edge buttable
  - Highly functional ROIC with option for multiple fast readout windows to prevent saturation and persistence
  - SIDECAR integrated ASIC controller

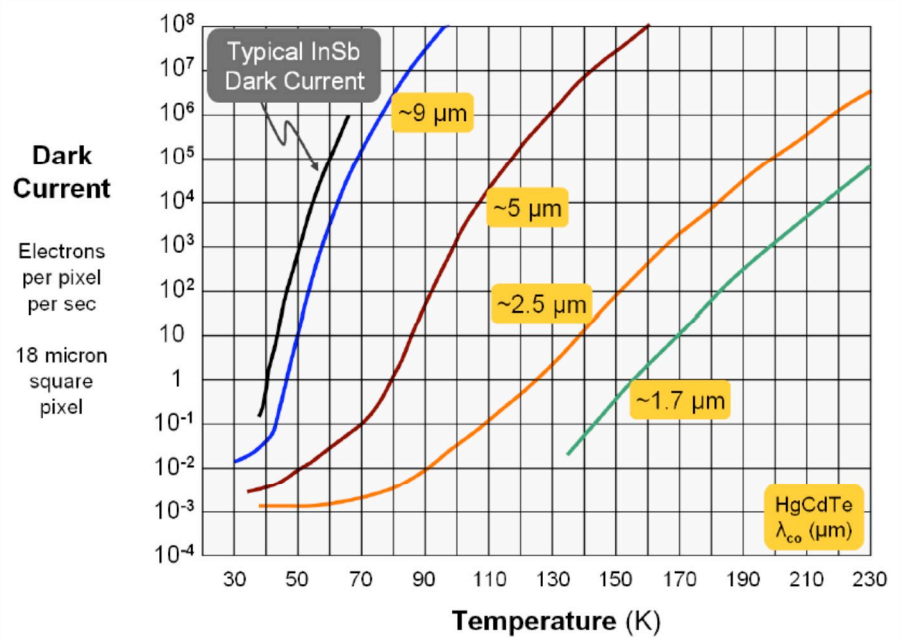
Array Fabrication Technology

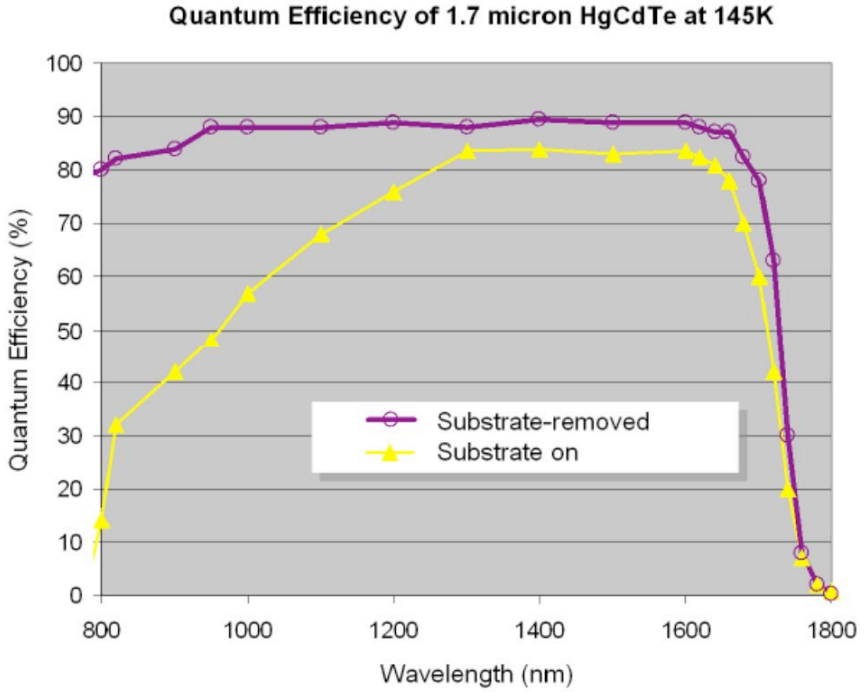
- HgCdTe layer grown on ZnCdTe substrates (good lattice match) using MBE (RVS still using LPE)
- Detector layer hybridised to Si CMOS ROIC
- Limitations on array size, performance and yield/lifetime (-> cost)

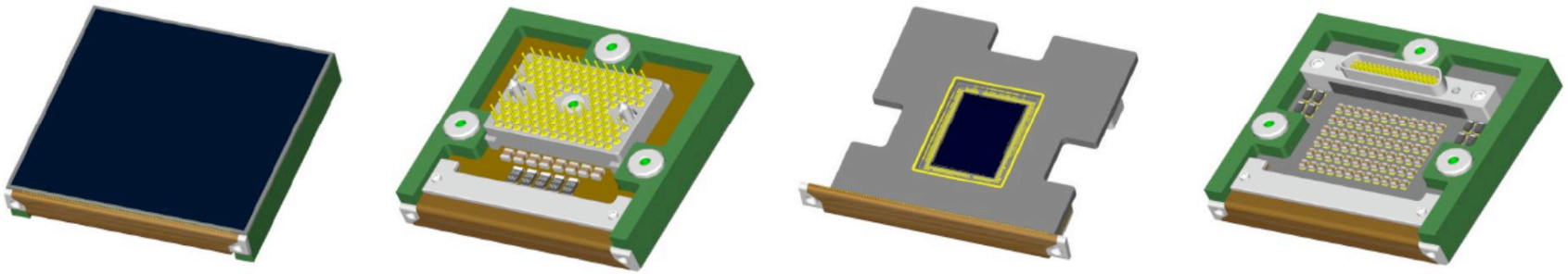


Teledyne developments

- Developing 2kx2kx30µm array as precursor to 4kx4kx15µm HAWAII-4RG

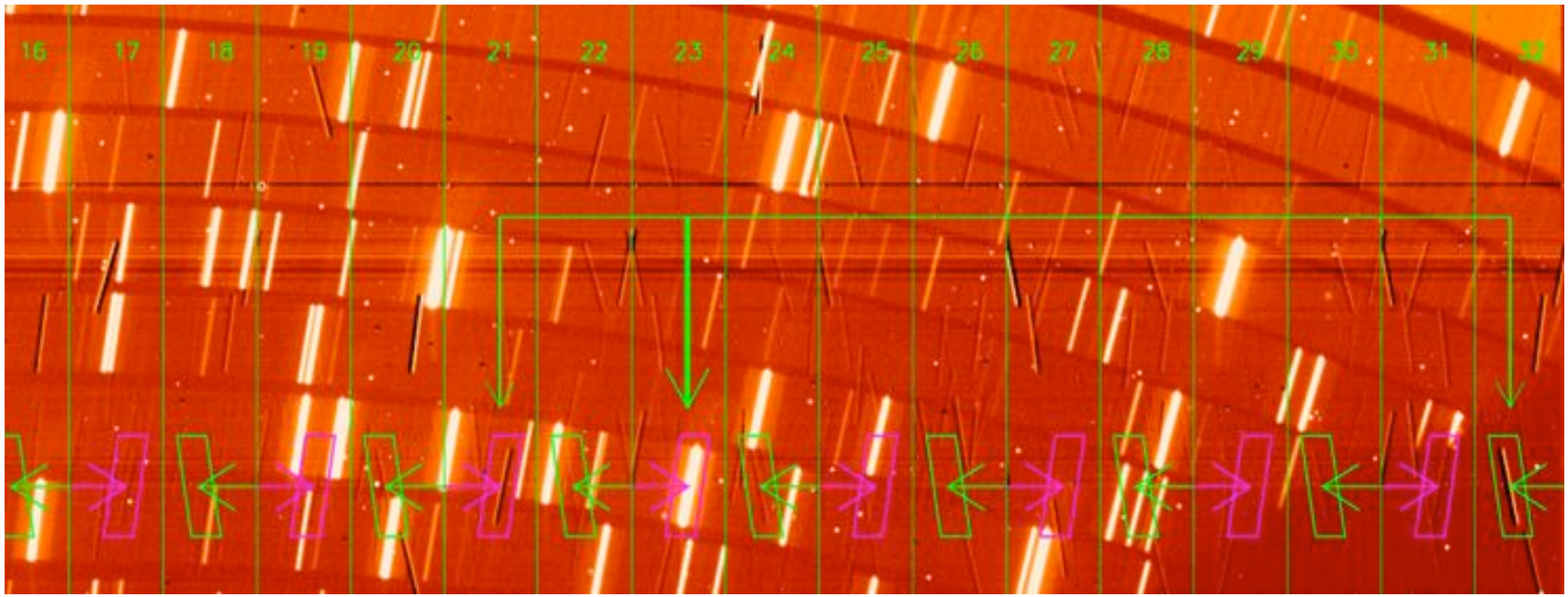






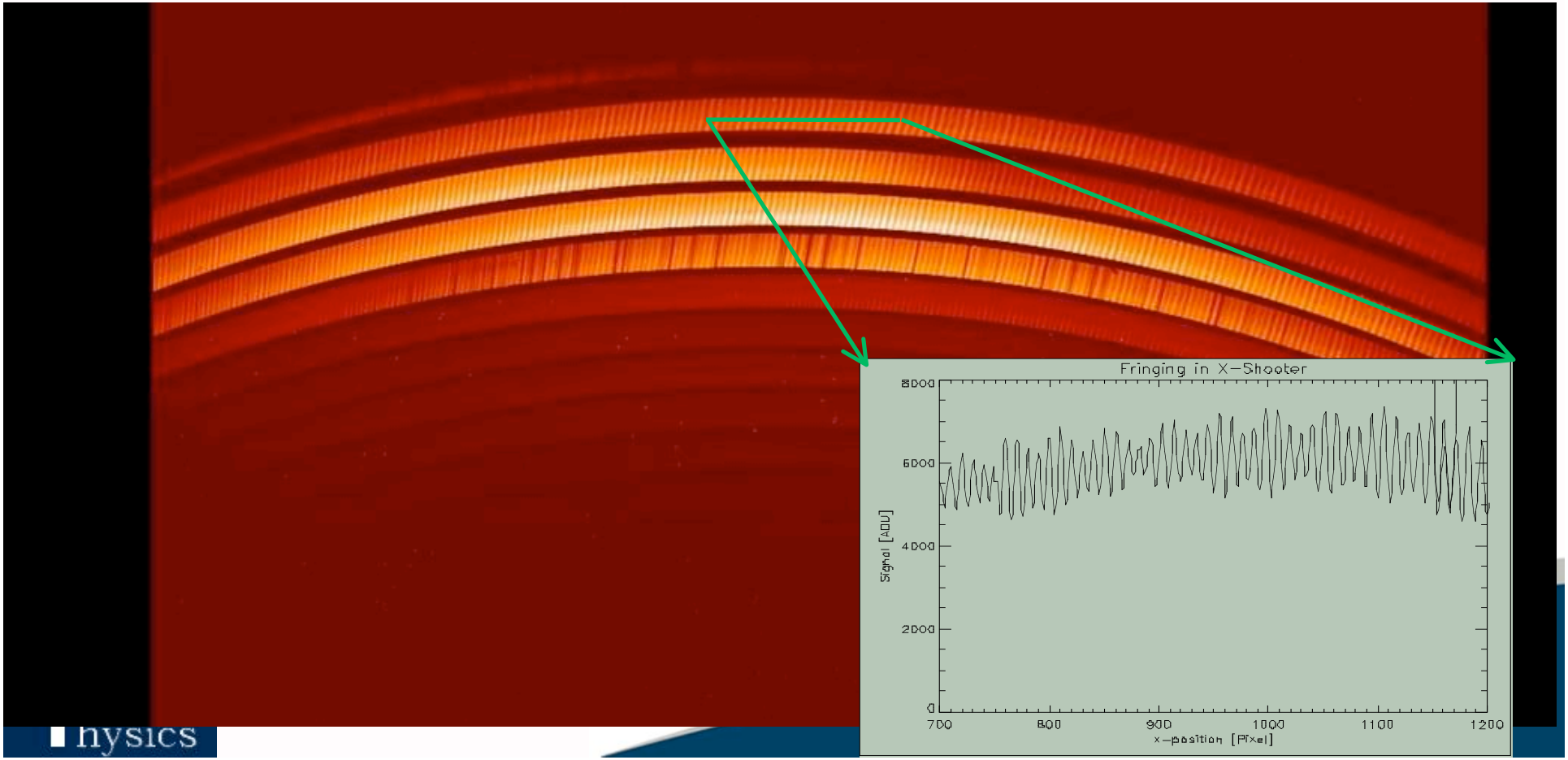
Performance Issues

- Channel cross-talk (from ESO's X-Shooter, courtesy G. Finger)



Performance Issues

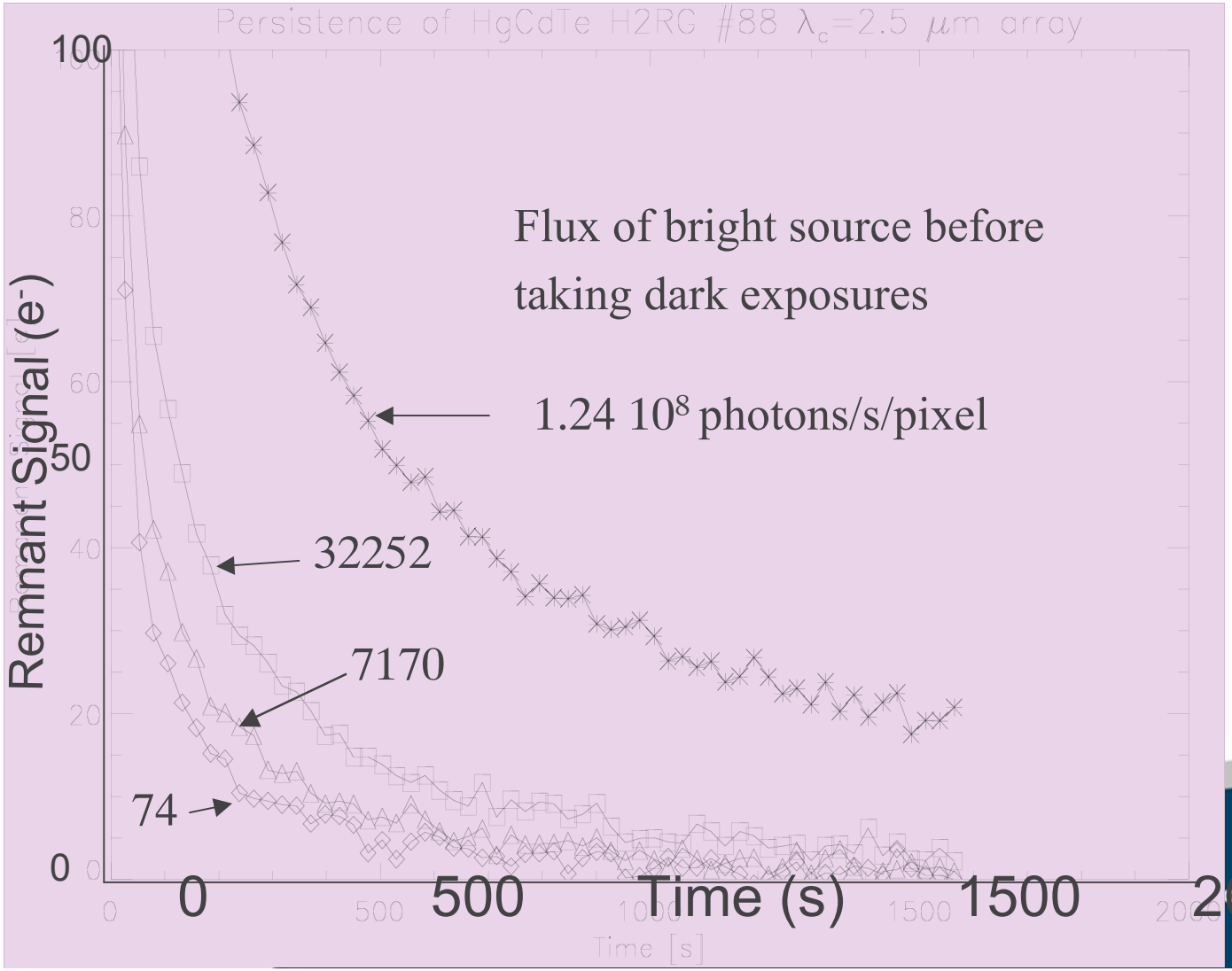
- Fringing due to substrate…



Performance Issues

- Persistence…

Remnant image of bright source in preceding exposure sometimes visible for hours after event.



Performance Issues

- Inter-pixel capacitance
  - Leads to over-estimation of system gain, and hence quantum efficiency
- Photo-emission defects
  - Occasionally individual pixels seen to act as bright IR LEDs
- Catastrophic failures…
  - A large number of early arrays have now been observed to delaminate after repeated cold cycling

New developments in IR

- ESA TRP for Cosmic Visions
  - Promote development of EU competitor to Teledyne for next generation space missions
- SELEX-Galileo
- QinetiQ

Evolution of 2D arrays at SELEX

by Merlin MWIR

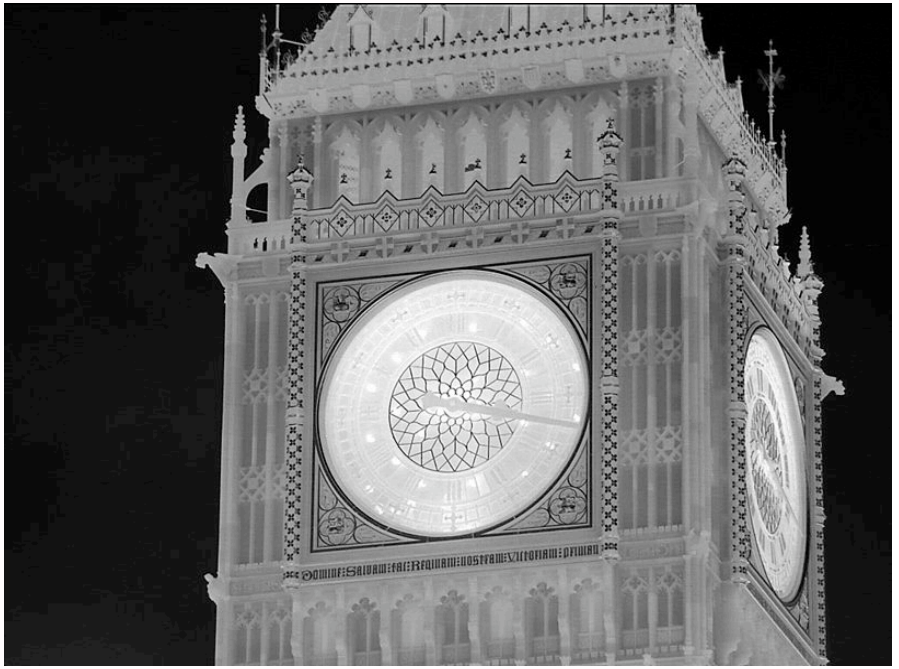
OSPREY 384 x 288
- 24µm pitch MW and LW

EAGLE 640 x 512
- 24µm pitch MW and LW

HAWK 640 X 512
- 16µm pitch MW and LW
- Dry etched mesas

MERLIN 1024 x 768
- 16µm pitch MW and LW
- Dry etched mesas

CONDOR 640 x 512
- 24µm pitch Two Colour
- Dry etched mesas



Larger area
Smaller pixels
Multicolour detectors

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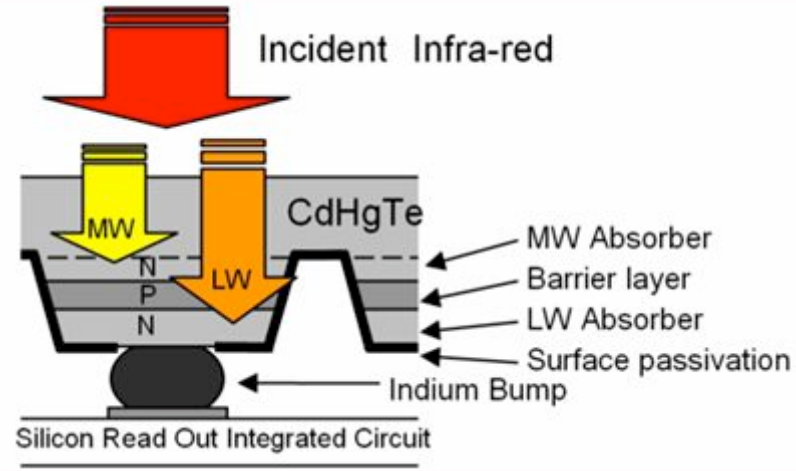
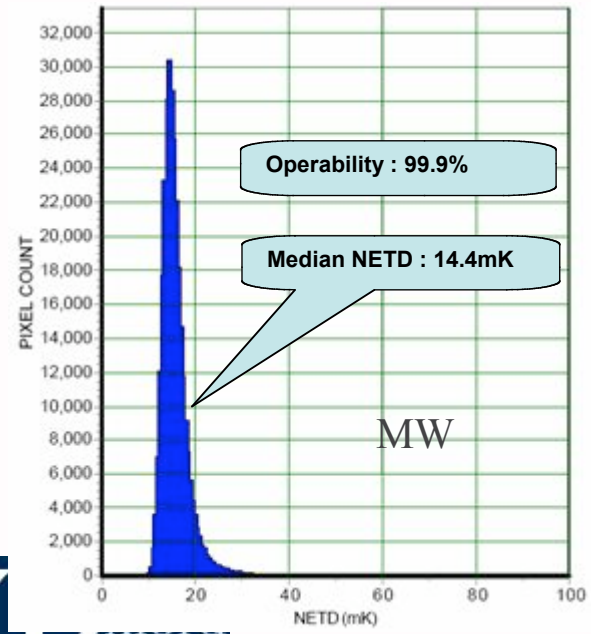
SELEX Capabilities

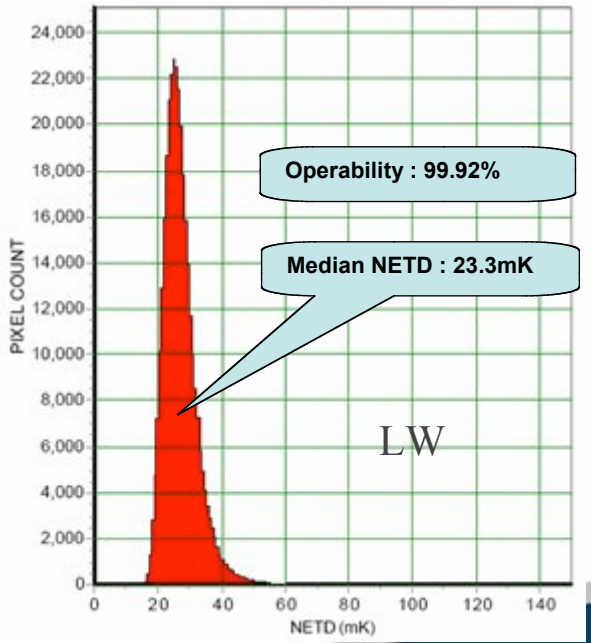
- HgCdTe grown by MOVPE on GaAs substrates then hybridised
- GaAs 100x less expensive than lattice matched CdZnTe
- Multiple suppliers (CZT has limited no. of commercial suppliers)
- Wafer scale (150mm) processing using standard semiconductor equipment
- Few mask stages
- New bump bonder being installed. 150mm array end-end capability
- Should be able to produce low-cost equivalent of HAWAII-2RG devices

Two-Colour Detectors

- N-P-N diode structure
  - Spatially coincident MW/LW pixels







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Evolution of 2D arrays at QinetiQ

HgCdTe as IR detector invented at Malvern in 1959

128 x 128 HgCdTe hybridised on Si
55µm pitch LW (10µm)
1024 x 768 HgCdTe hybridised on Si
26µm pitch LW (9.6µm)
Dual band arrays
30µm pitch MW and LW
two capacitors/pixel

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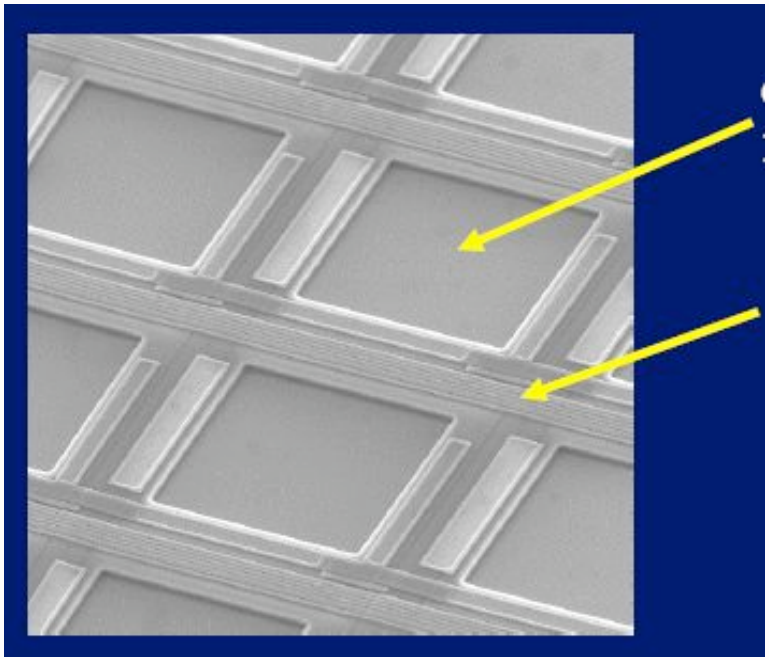
Developments - QinetiQ

- MOVPE growth at high T gives much more control of growth environment than MBE process
- Direct growth onto ROIC mesas - no substrate
- Si substrates ultimately available up to 300mm
- Key technology is the survivability of the ROIC structure in the MOVPE growth environment

MCT Island Growth on ROICS

Optical micrograph showing ROIC pixels



Crystalline Si surface growth window

Integrated circuits surrounding growth window

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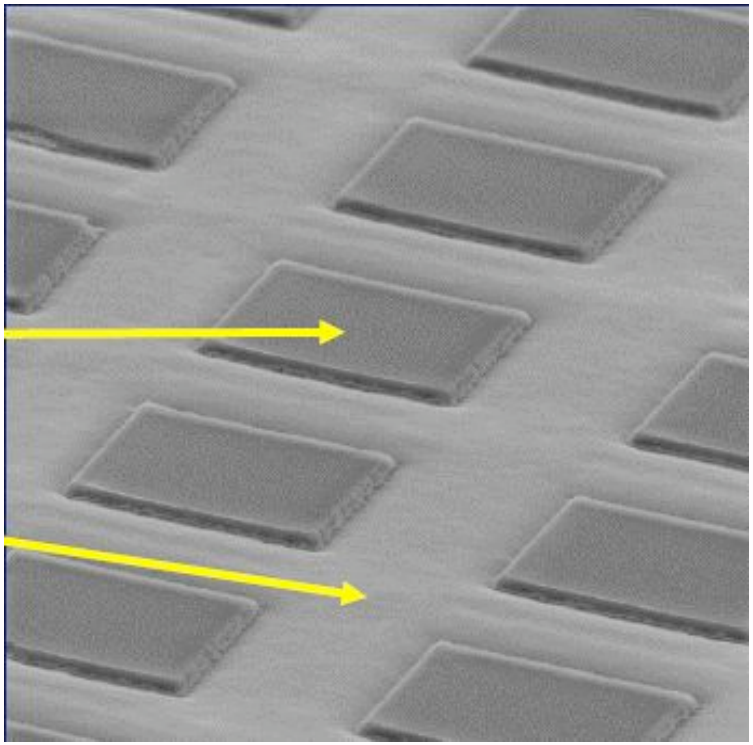
MCT Island Growth on ROICS

- Scanning electron micrograph

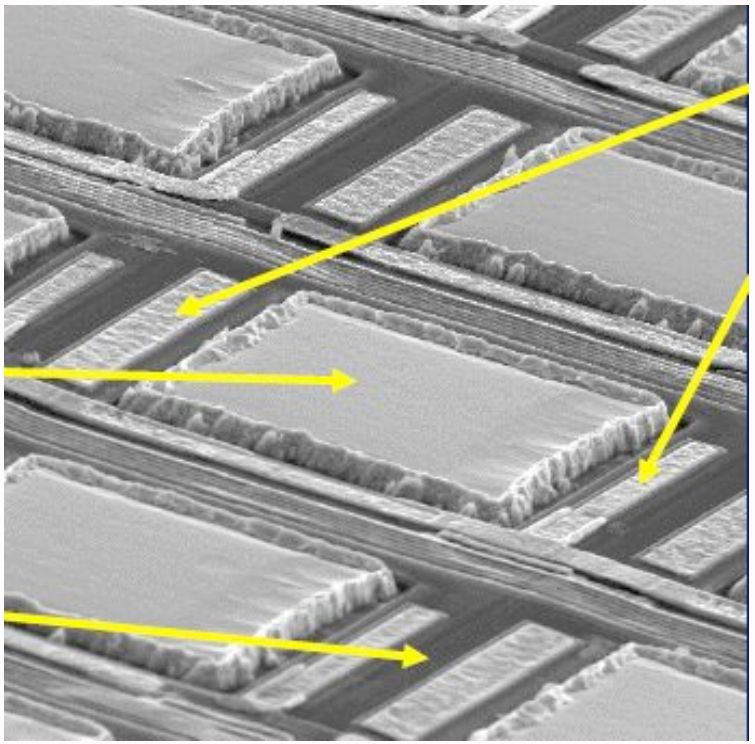
Crystalline MCT in window areas

Polycrystalline MCT



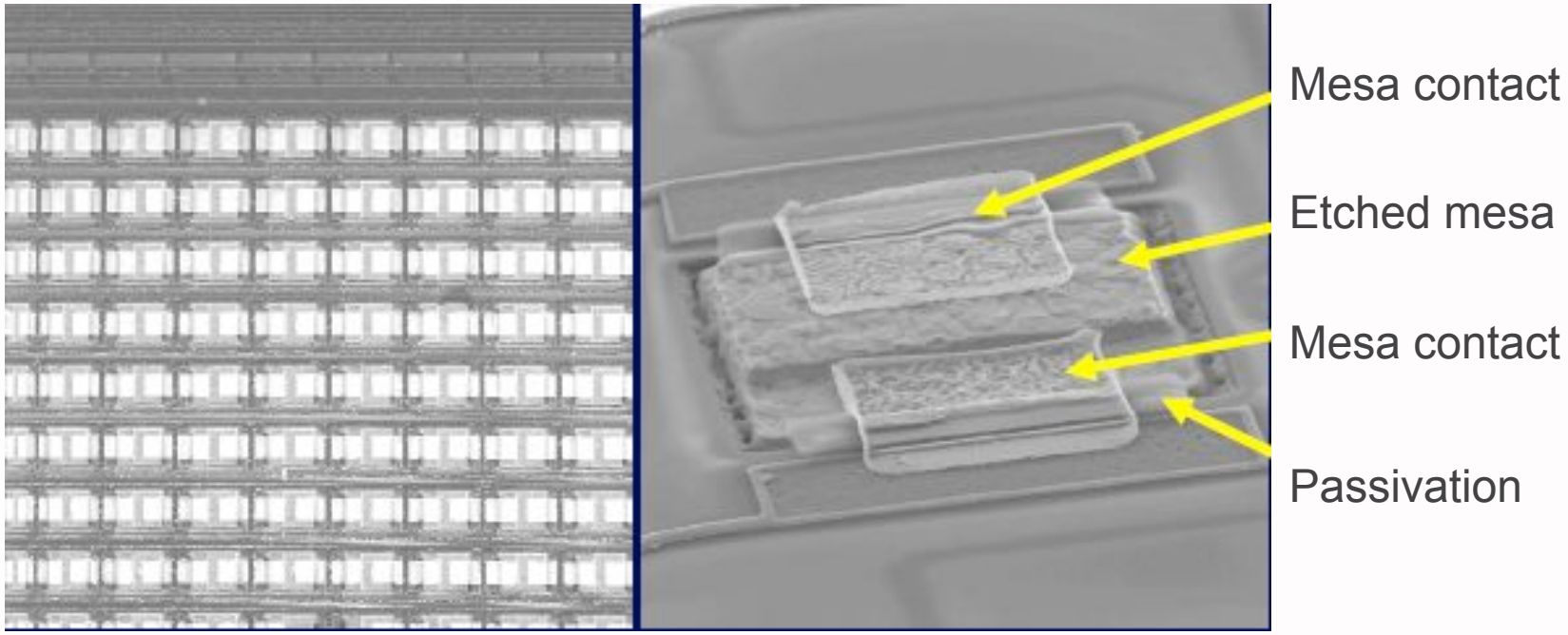
MCT Island Growth on ROICS

•Scanning electron micrograph of part of processed FPA

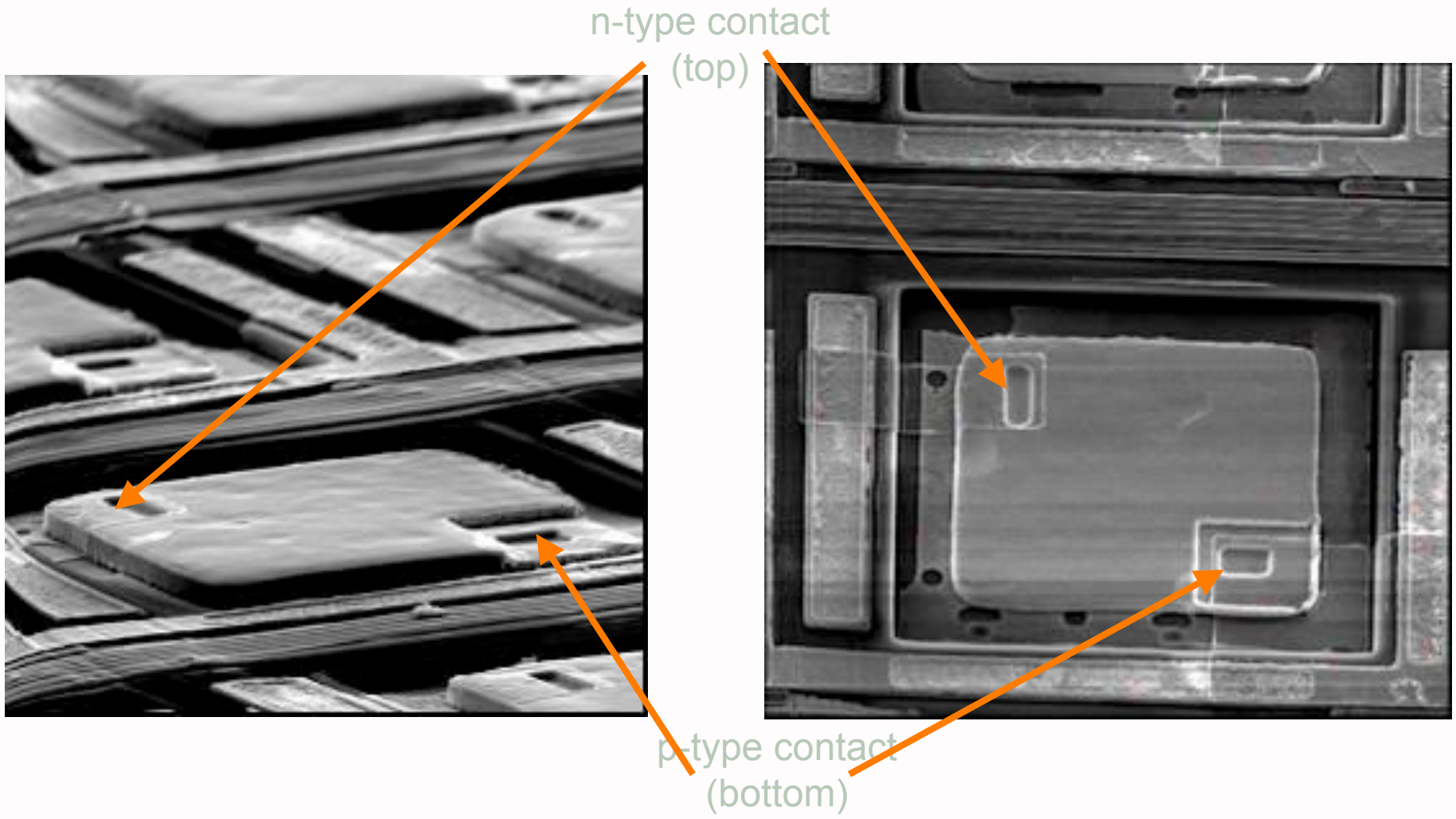


MCT Island Growth on ROICS

•Example of prototype FPA



Test Pixel Growth



75μm pixel grown in 100μm growth window on a test wafer

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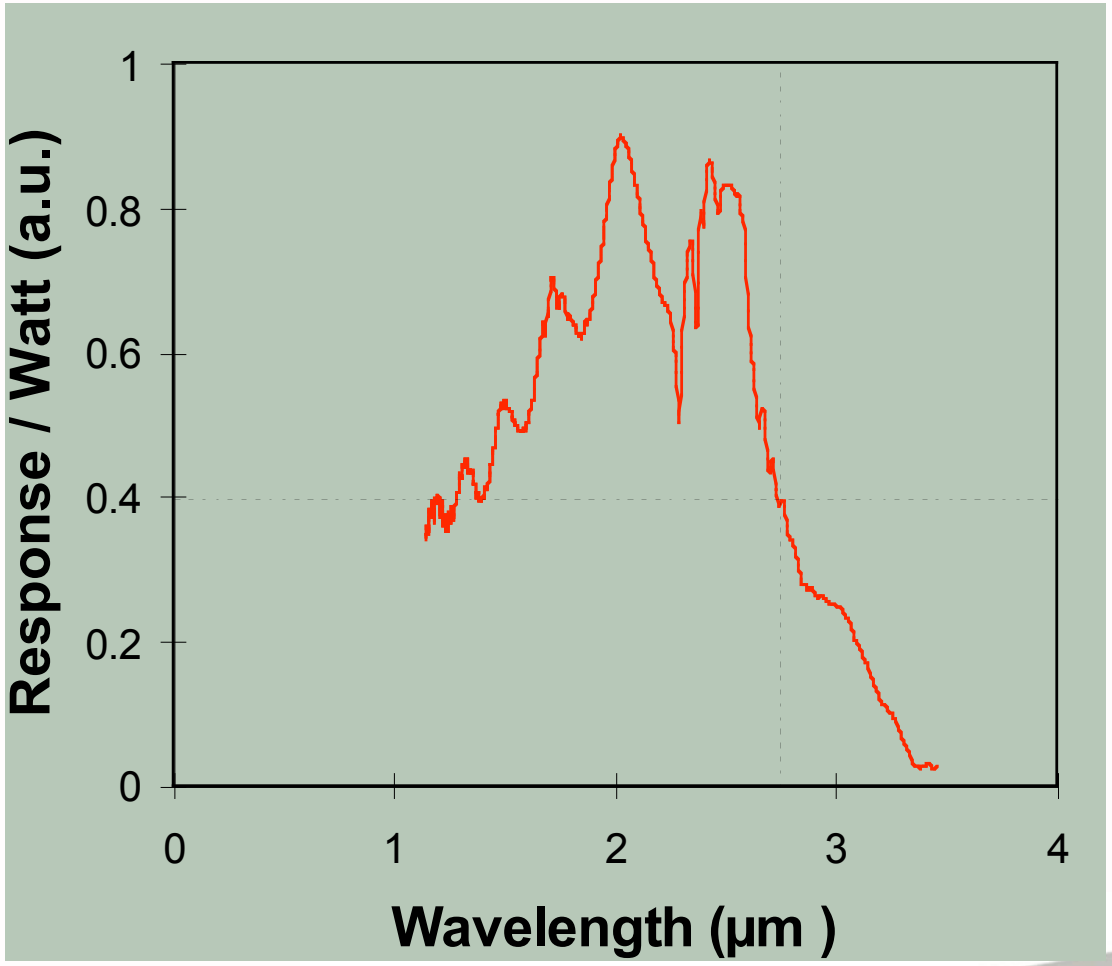
Test pixel transmission (inferred from back-illuminated test)



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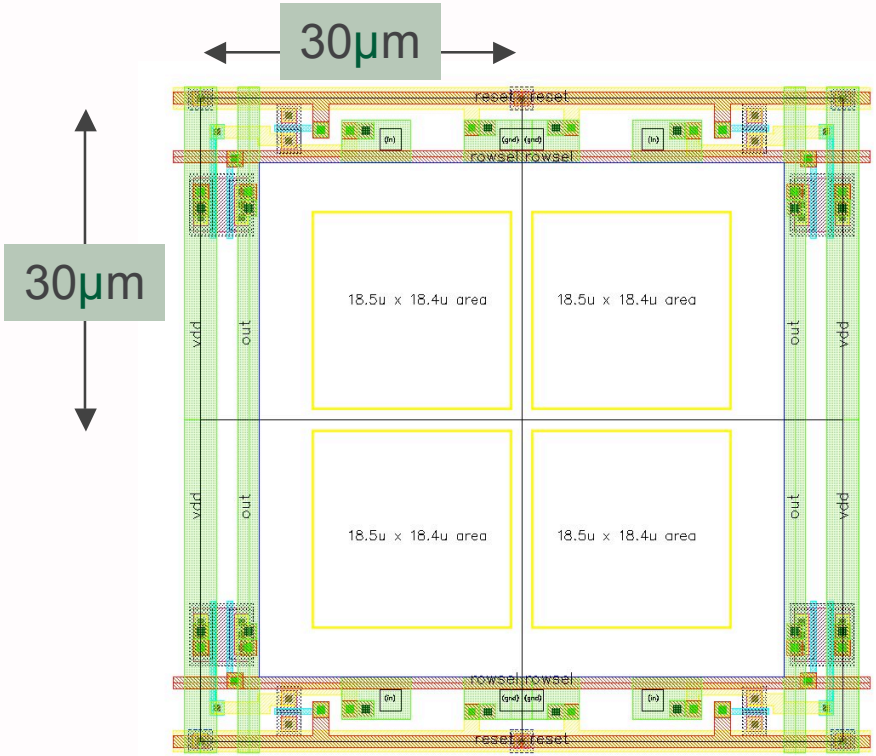
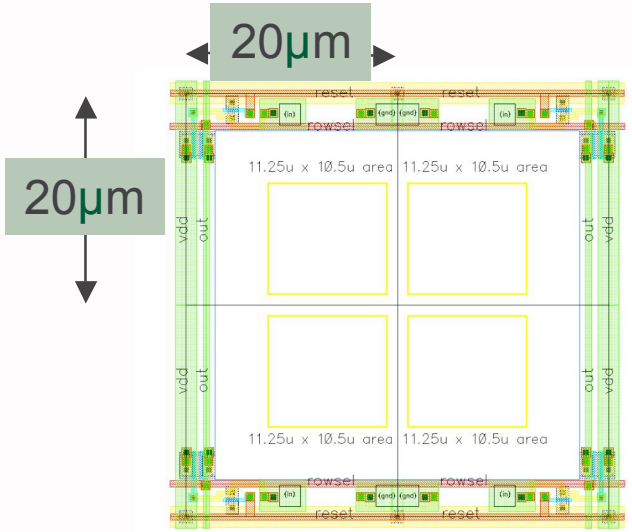
Developments - QinetiQ

- MOVPE growth at high T gives much more control of growth environment than MBE process
- Direct growth onto ROIC mesas - no substrate
- Si substrates ultimately available up to 300mm
- Key technology is the survivability of the ROIC structure in the MOVPE growth environment
- Good SW (1-2.5μm) material performance demonstrated
- Larger (36μm) pixels optimal for some ELT instruments
  - NB for 150mm wafers and 50μm pixels = 2048x2048 array (c.f. end of VISTA talk)
- Key specifications appropriate to ELT instruments can be met - Good q.e. & linearity

- Not able to measure dark current at astronomical level
- Key aims are to demonstrate modest array-scale growth of SW device on an appropriate ROIC

Small pitch IIDC





- CX06XI10 0.6µm W process
- Pixel growth area ~18.5µm x 18.4µm
- Fill factor ~ 38%

- XH035 0.35µm Al process
- Growth area ~12.25µm x 11.5µm
- Fill factor ~30%

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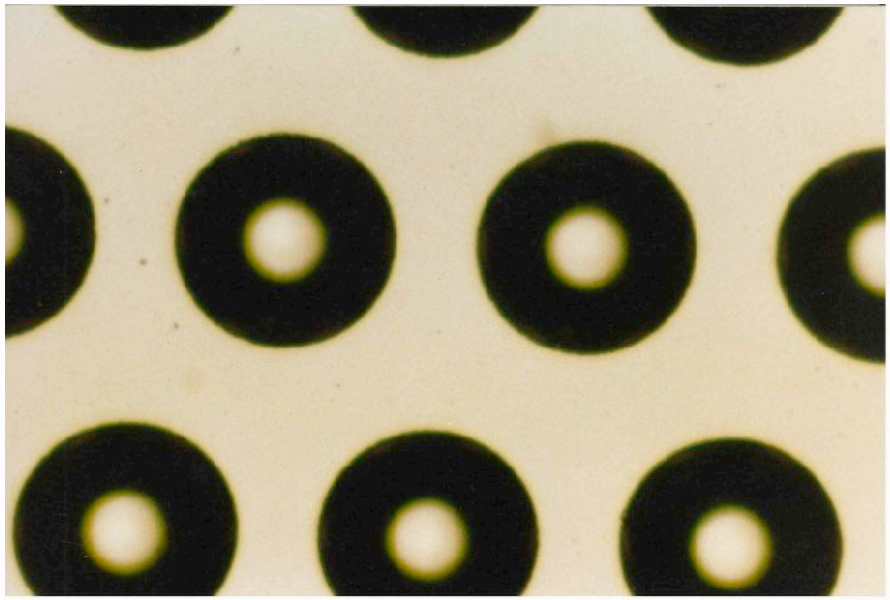
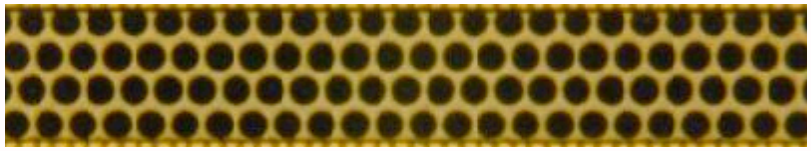
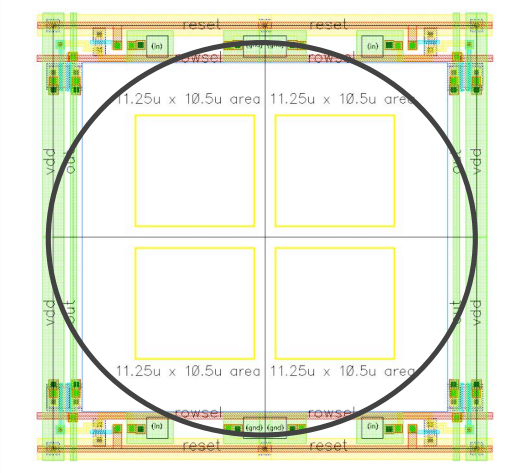
Optical concentrators – immersion lens

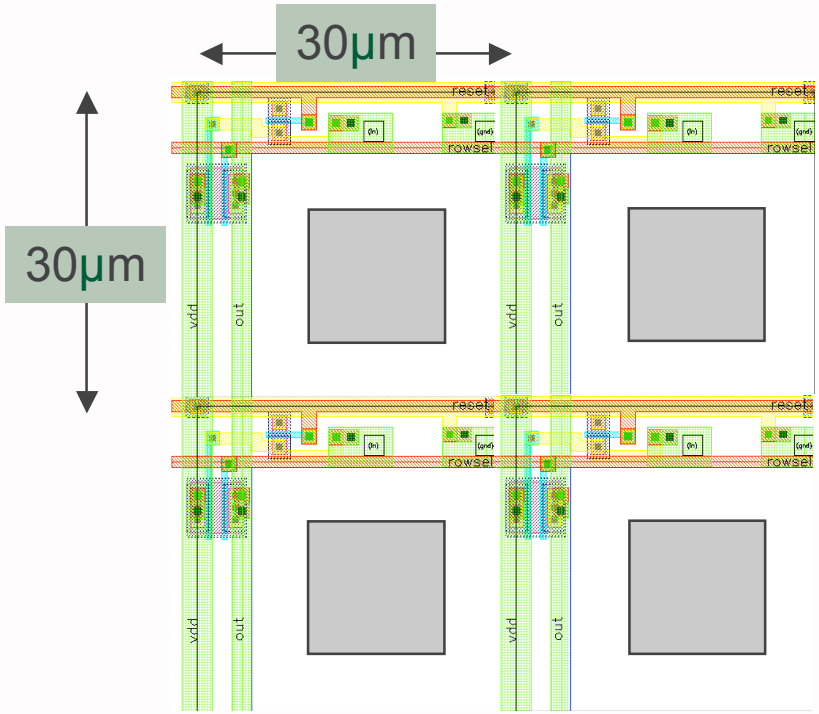






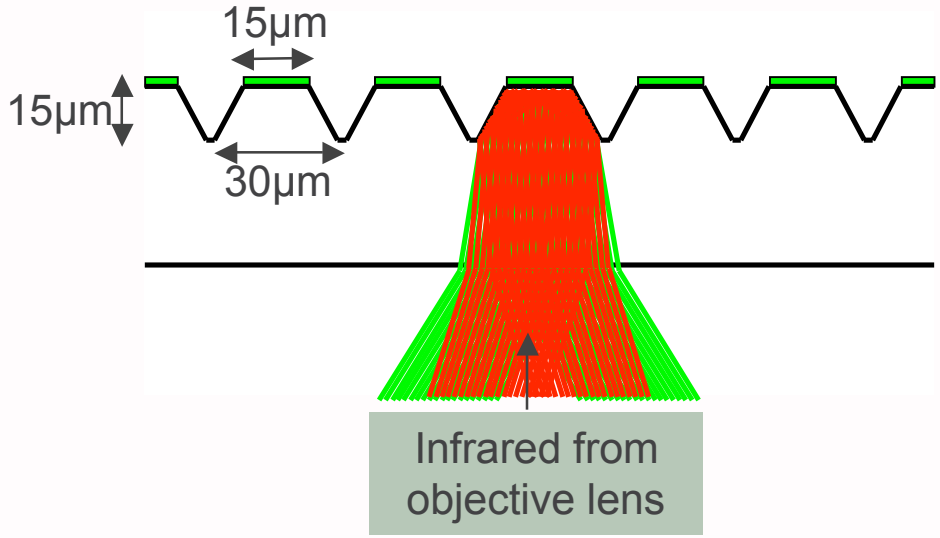
- One immersion lens / 4 pixels

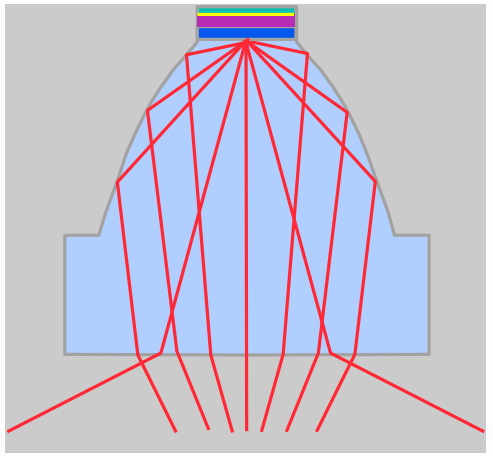
Constant pitch ROIC

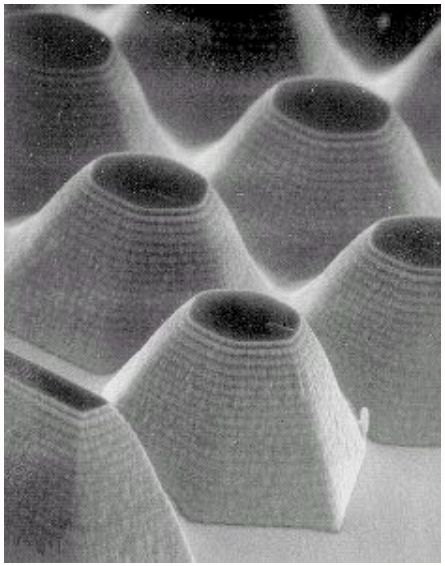


- CX06XI10 0.6µm W process
- Pixel growth area ~13µm x 13µm
- Fill factor ~ 19%

Optical concentrators - cones







- Low gain option with area gain of 4
- Substantially reduces dark current/"pixel"

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Prospects

- ESA TRP announced last week for NIR detector development
  - Terms look favourable to both SELEX and QinetiQ development routes
- SELEX probably provides the best route to a quick replacement for a H-2RG/H-4RG type device…
- QinetiQ probably more interesting for wide-field imaging considerations: possibility of migrating to 12” silicon wafer scale devices.

Longer term…?

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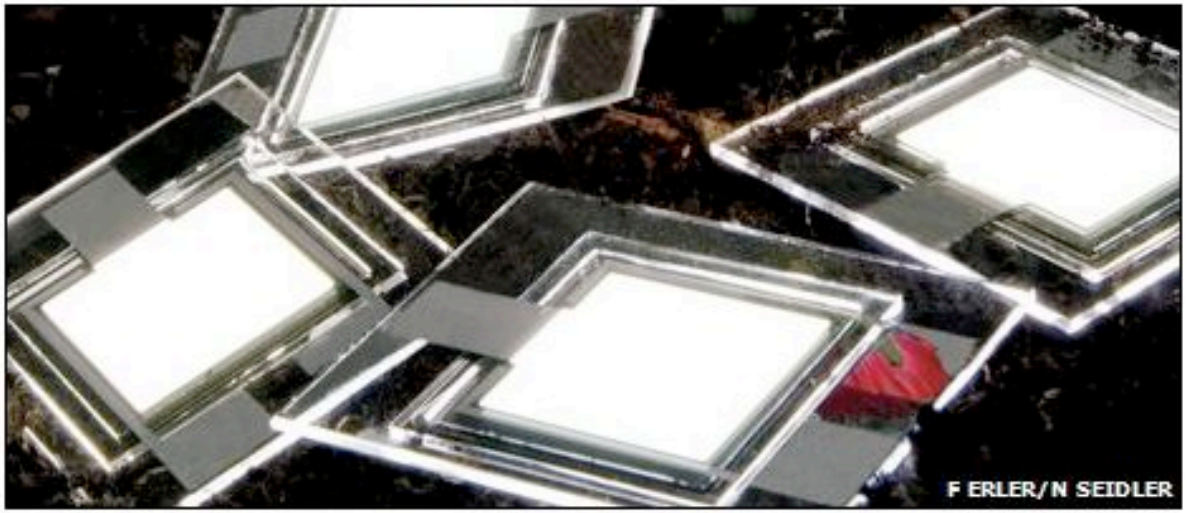
Flat-screen light bulbs switch on

By Jason Palmer
Science and technology reporter, BBC News



The devices are flat - another reason they are desirable as light sources

Researchers have demonstrated white, organic light-emitting diode (OLED) sources with the same efficiency as fluorescent light bulbs.