Selex ES

Latest IR Detector Developments for Scientific Instruments

Peter Knowles, Ian Baker, Keith Barnes

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Selex ES

New MOVPE processes for scientific FPAs and large area FPAs

Important steps forward in 2015

1 New FC300 bump bonder to be installed Q3, taking capability from 2 megapixels to >4 megapixels

2 Thicker CdTe buffer to eliminate poor quality in the first few microns of MCT. A new growth technique has been developed for CdTe using an alternative tellurium alkyl that allows thick layer growth at a higher temperature to turn over misfit dislocations. This replaces the function of the previous 1.3 um buffer.

3 Additional process step to improve electron transport in the NIR/SWIR absorber layers.

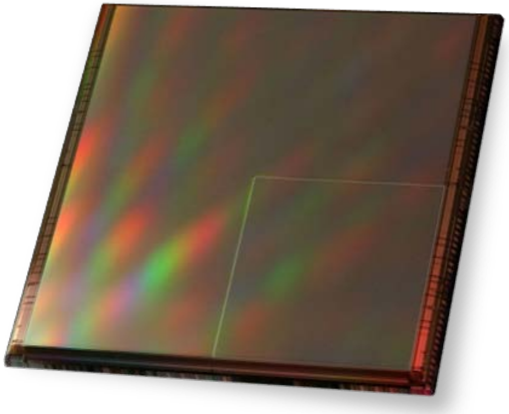
4 Low dark current measurements on APDs

5 First on-sky measurements with APD arrays

Large Format NIR ROIC

ESA contract 22948 for European alternative to Teledyne Hawaii 2RG arrays

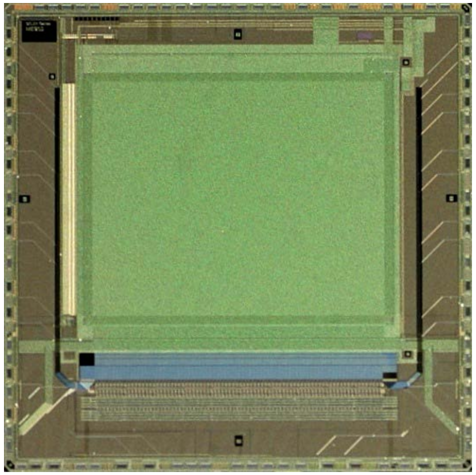
- **0.35 micron CMOS ROIC design for low photon flux and radiation hardness**
- **Development of 1280x1032, 15µm pitch format NIR (0.8 – 2.1 µm)**
- **Source Follower in the Detector (SFD) pixels**
- **Non-destructive reads (NDR) to reduce read noise**
- **100ke- full well**
- **Power consumption 34mW with 4 outputs, 54mW with 32 outputs**

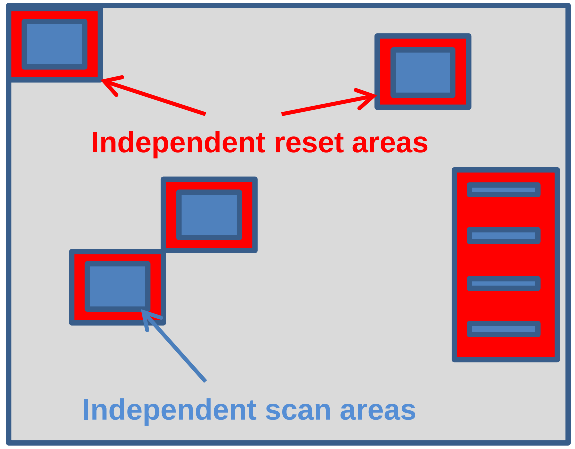


SAPHIRA with MCT eAPDs

A new infrared detector for scientific applications

Full Custom ROIC - SAPHIRA



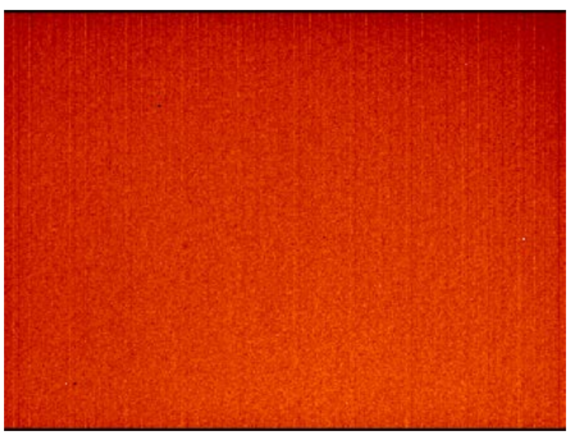


- Fully flexible ‘Region of Interest’ architecture
- 32 outputs and optimum pixel mapping for high frame rate in multiple windows
- Non-destructive readout
- Very low noise
- Designed for MCT APDs

Target market:

Wavefront sensing
Astronomy
Spectroscopy
Interferometry
Photon counting

Breakthrough in MOVPE avalanche photodiode arrays (eAPDs)

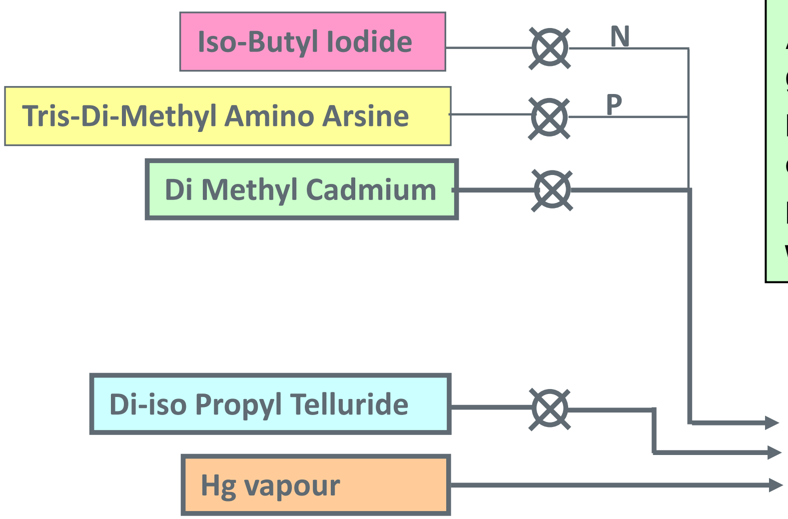


Best LPE arrays: x30 at 40K with 2% defects
Current MOVPE: x60 at 85K with few defects

New record readout noise of 0.26 e rms
Suitable for single photon imaging and photon counting at LN2+ temperatures

- Downselected for the ESO GRAVITY Project (wavefront sensors and fringe trackers)
- Demonstrated on Mount Palomar 60” and 3m NASA IRTF telescopes

MOVPE growth of MCT

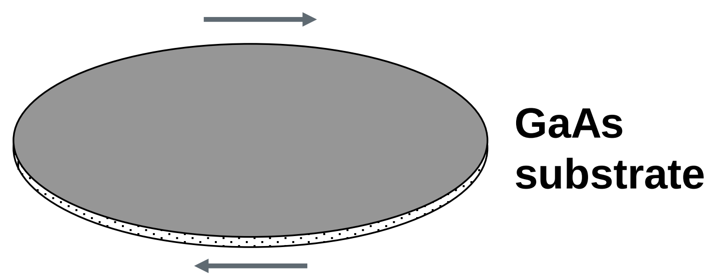


Metal Organic Vapour Phase Epitaxy

Alternate HgTe and CdTe growth for optimum growth conditions and easy control of wavelength

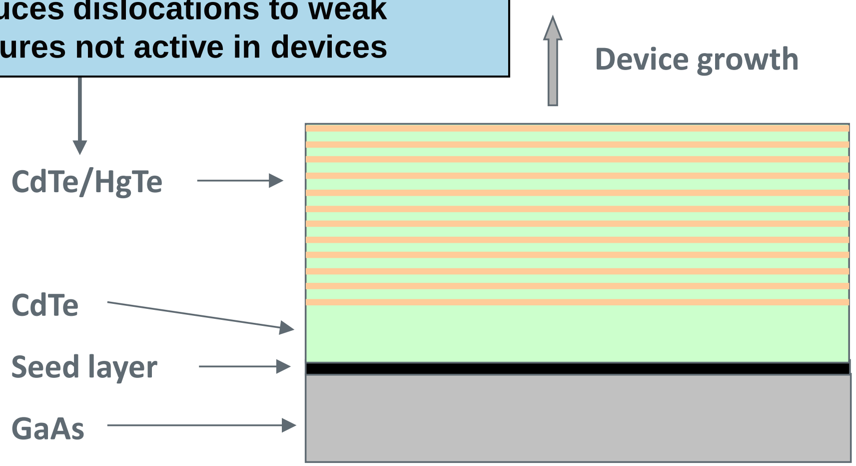
P and N doping on CdTe cycle only so independent of wavelength

Produces all Selex products: MWIR, LWIR, dual waveband, HOT and eAPDs



Overcoming 14% mismatch

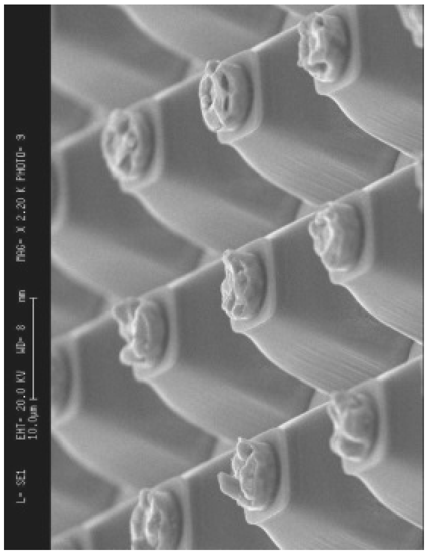
Buffer of CdTe and thick CdTe/HgTe reduces dislocations to weak features not active in devices

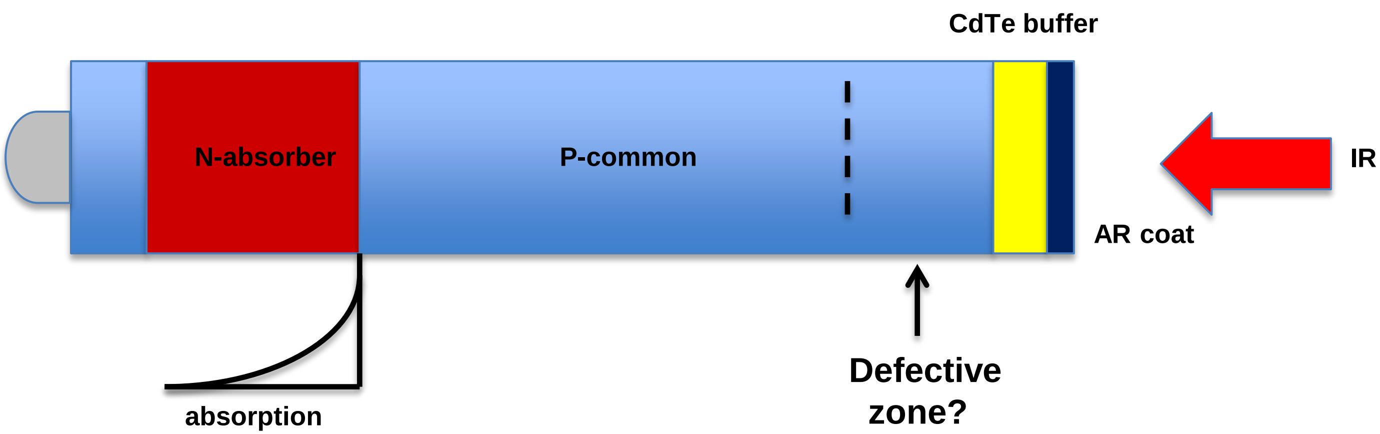


Why GaAs?

- High quality, epi-ready single crystals
- Multiple suppliers of 75 to 150 mm diameter wafers
- Low cost ~ $2.5 /cm^2 (vs ~ $200 /cm^2 for CdZnTe)
- Much greater mechanical strength than CdZnTe
- Free of trace element contamination
- Much easier surface to nucleate on than silicon
- Easily removed by selective etch after hybridization to remove thermal stresses and internal reflections
- Cadmium utilisation reduced by >100x

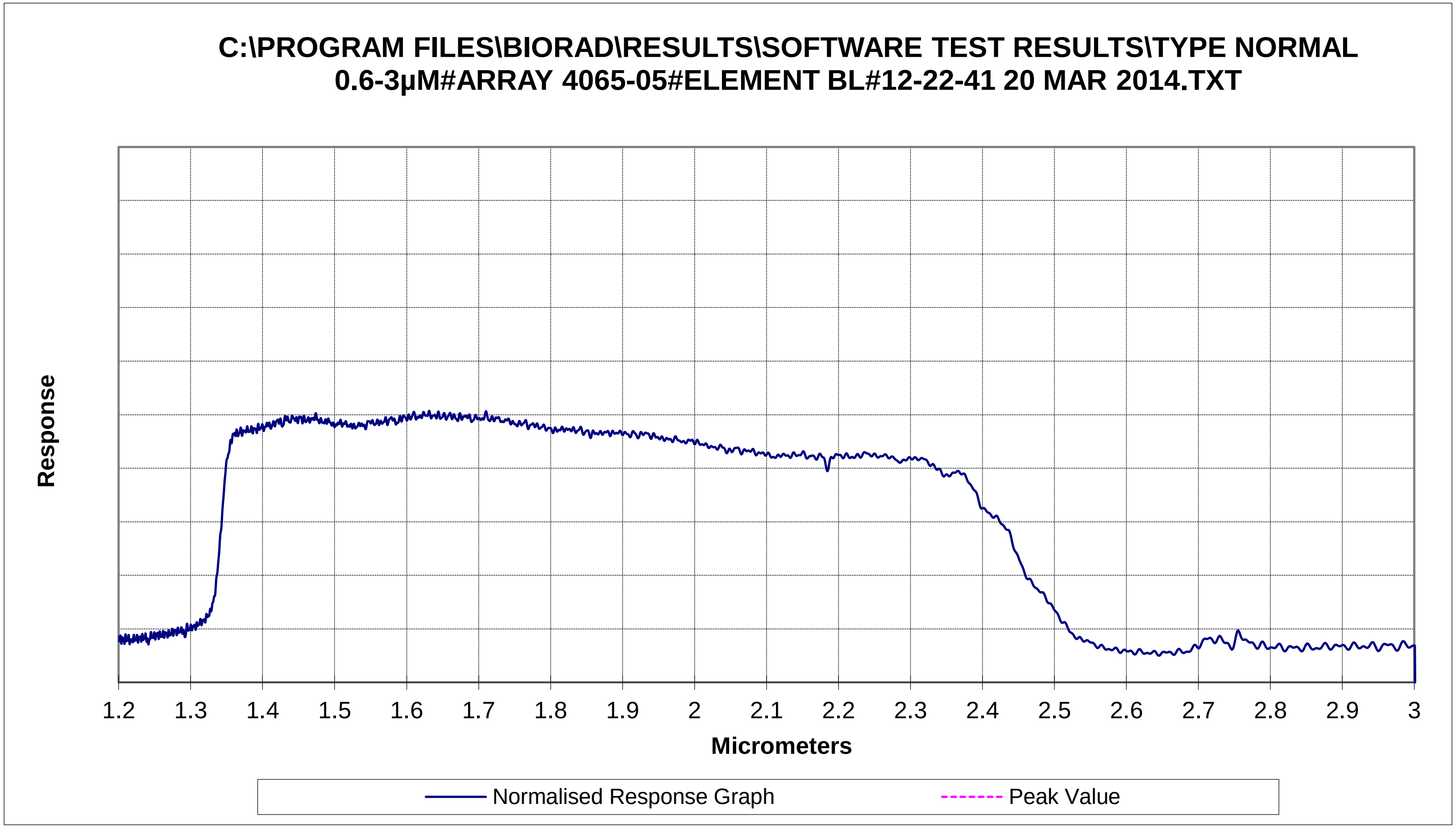
NIR / SWIR design





Standard device structure

Spectral response from 2.5um absorber, 1.35um common



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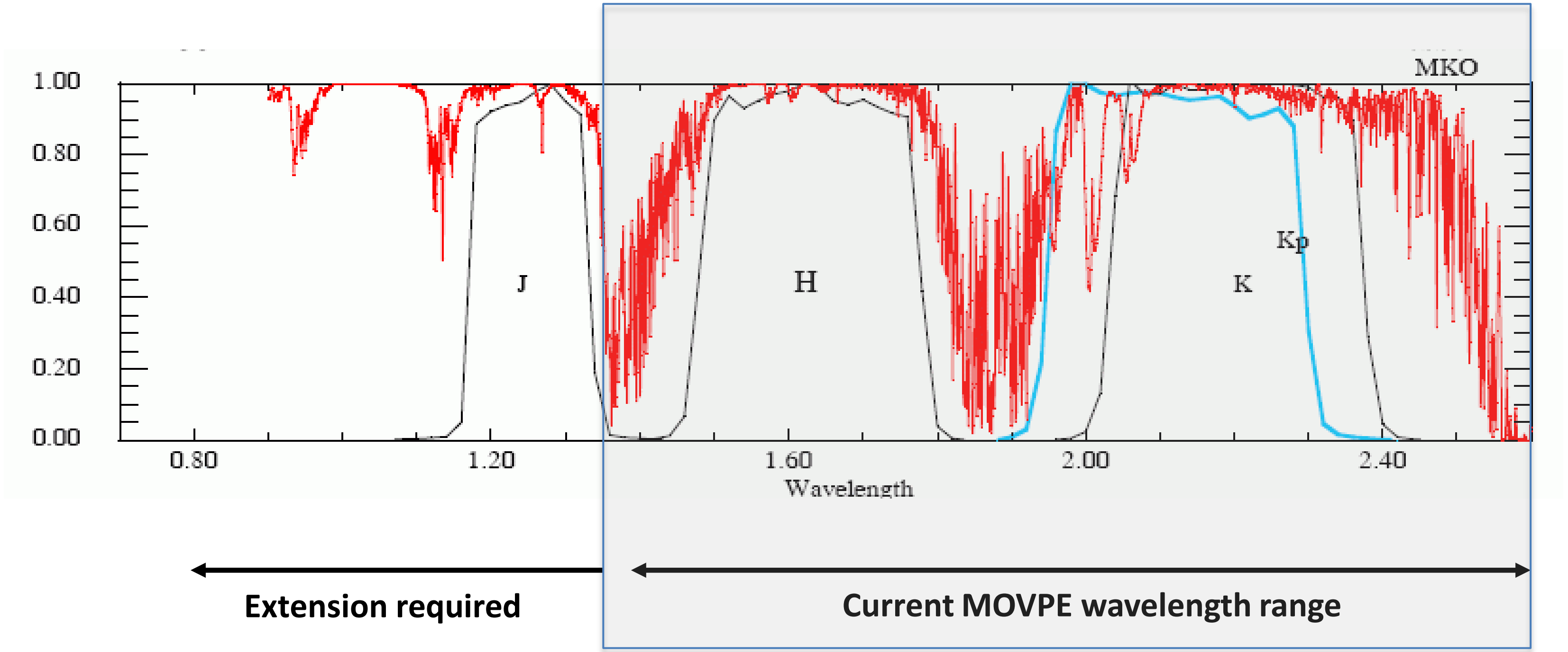
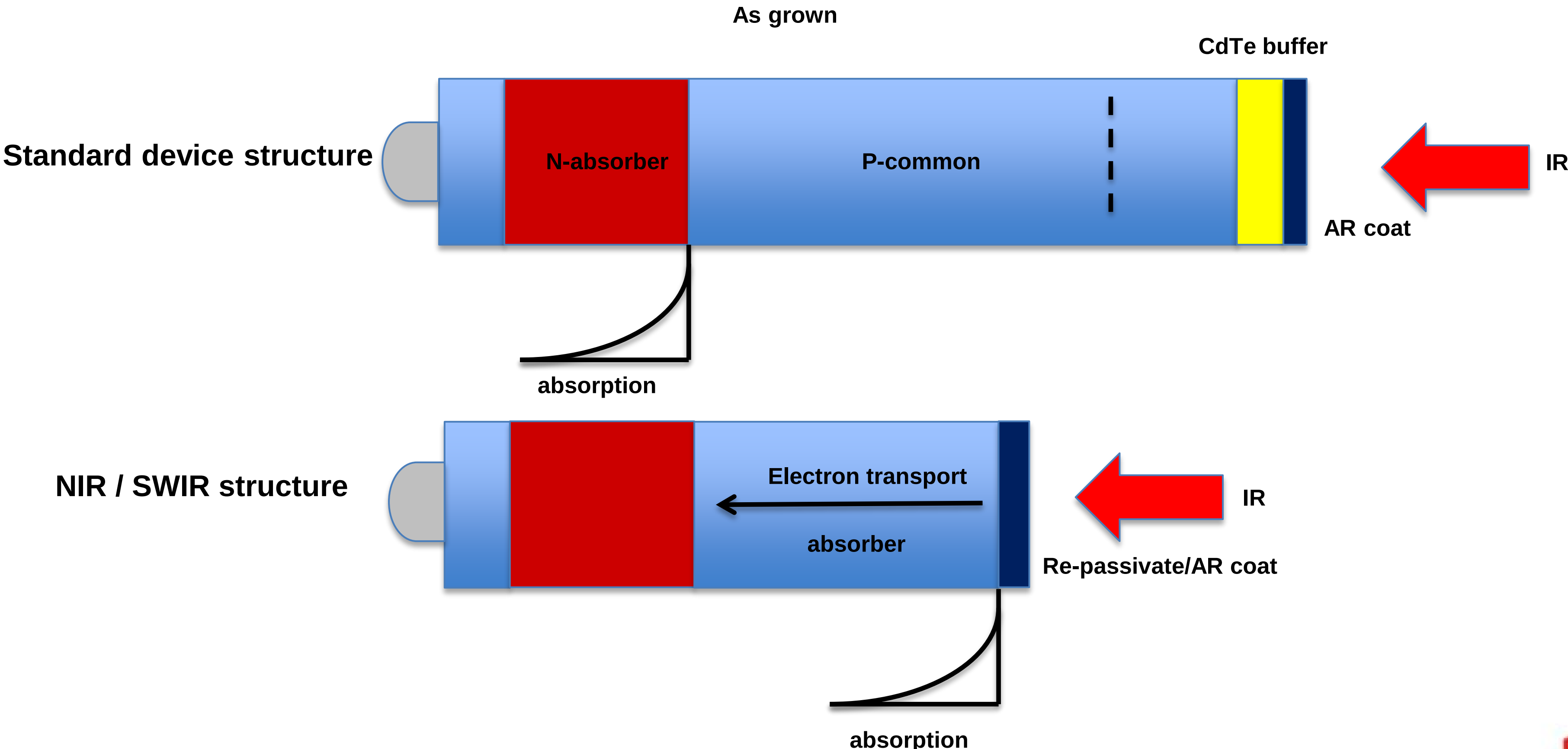
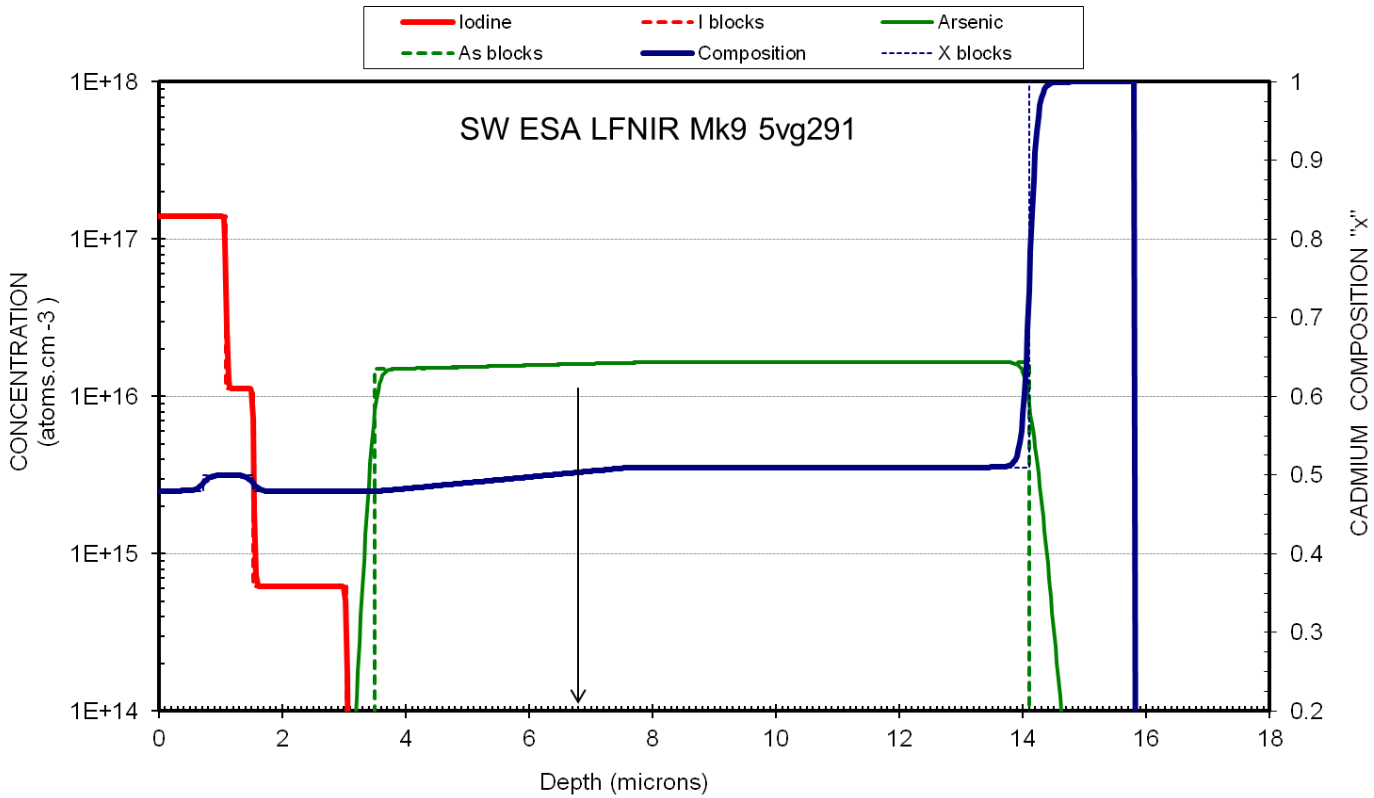
SWIR MOVPE FPAs – current spectral response



NIR / SWIR design

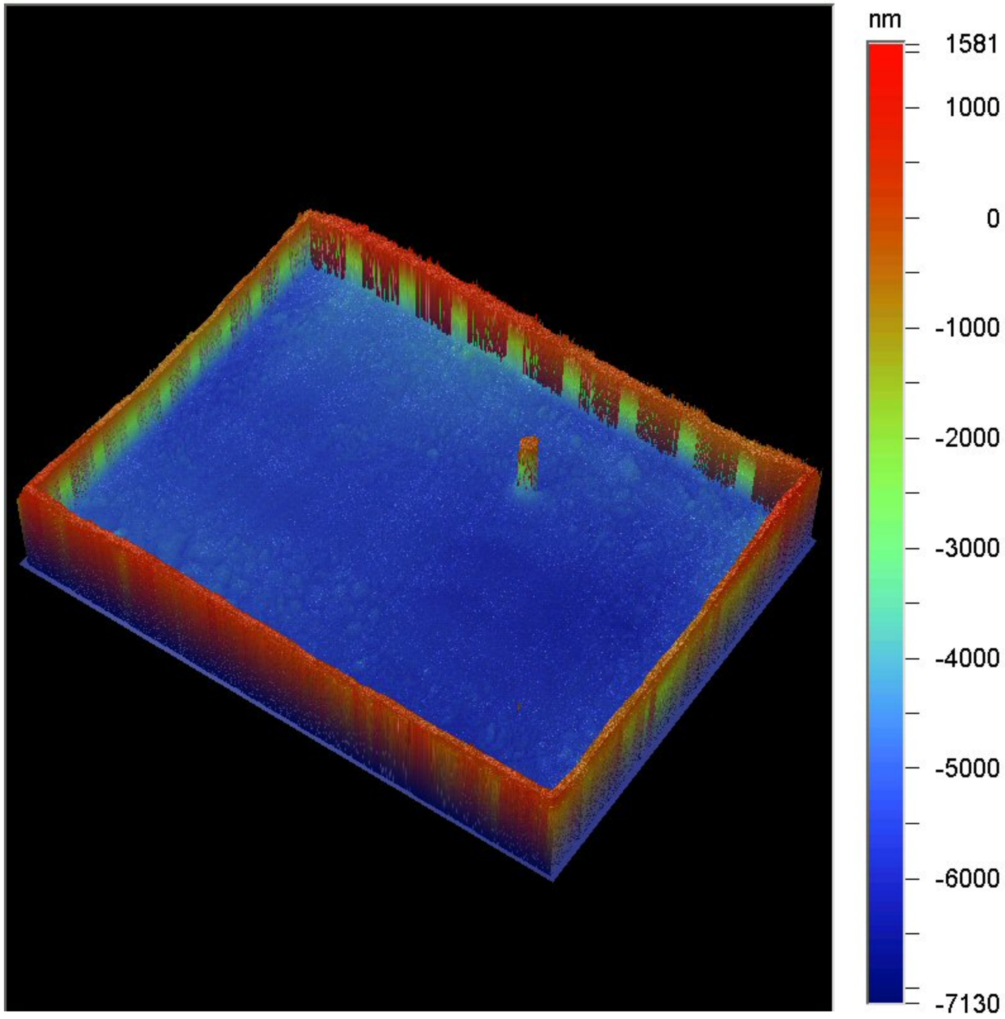


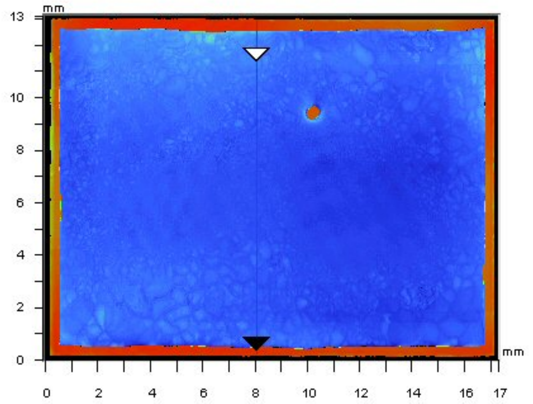
5vg291 growth structure

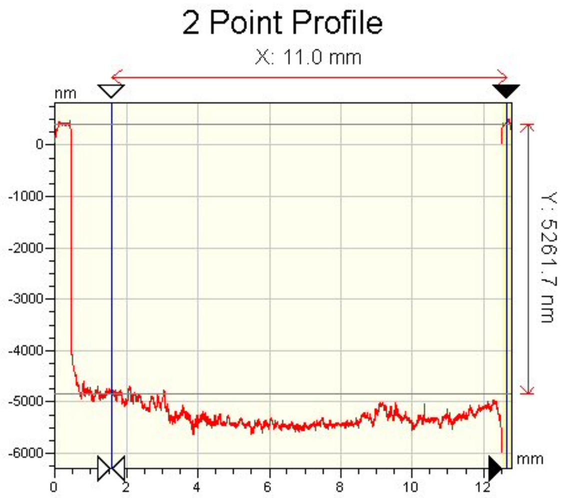


This structure is designed to respond to 0.8um radiation after thinning

Large format thinning trials







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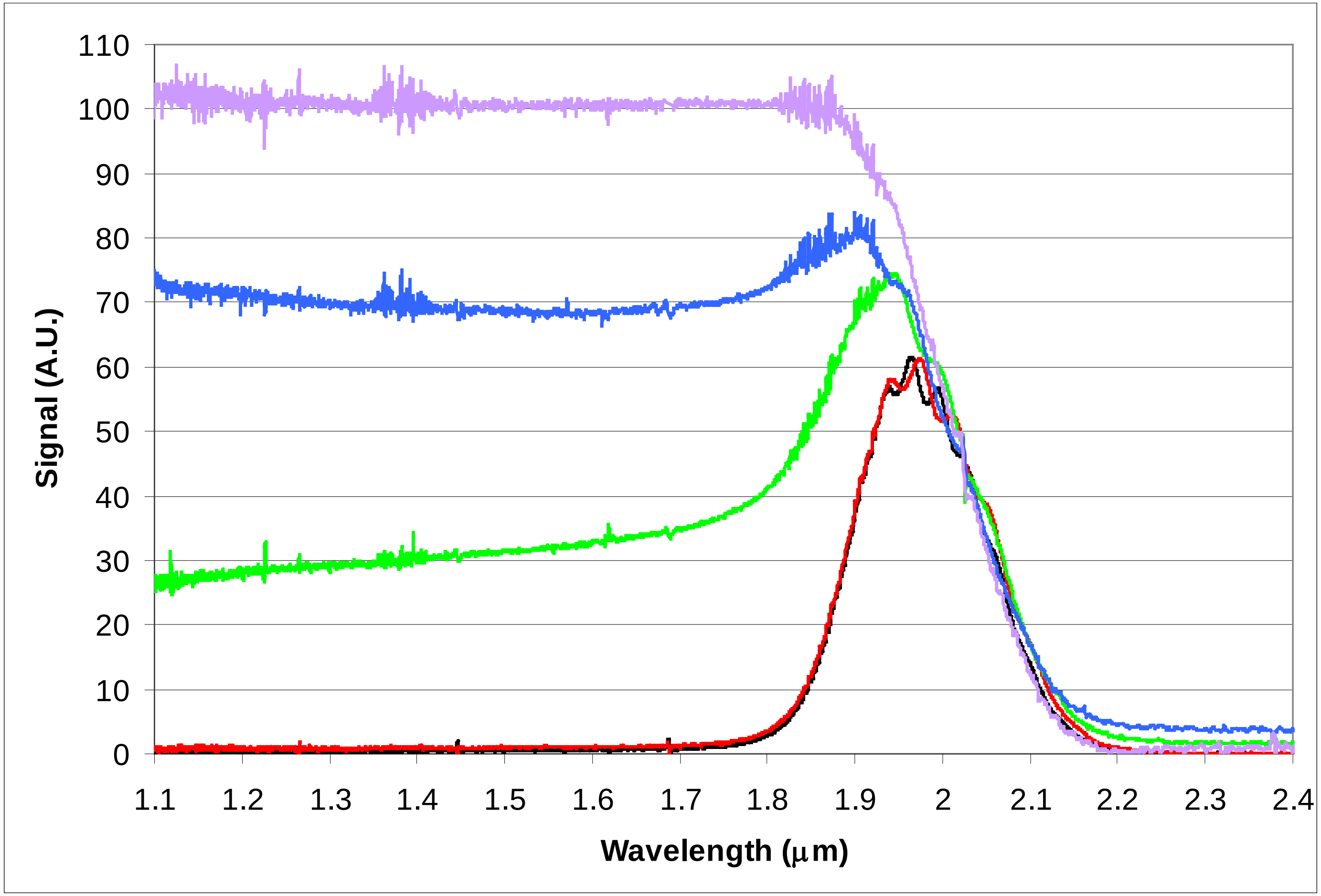
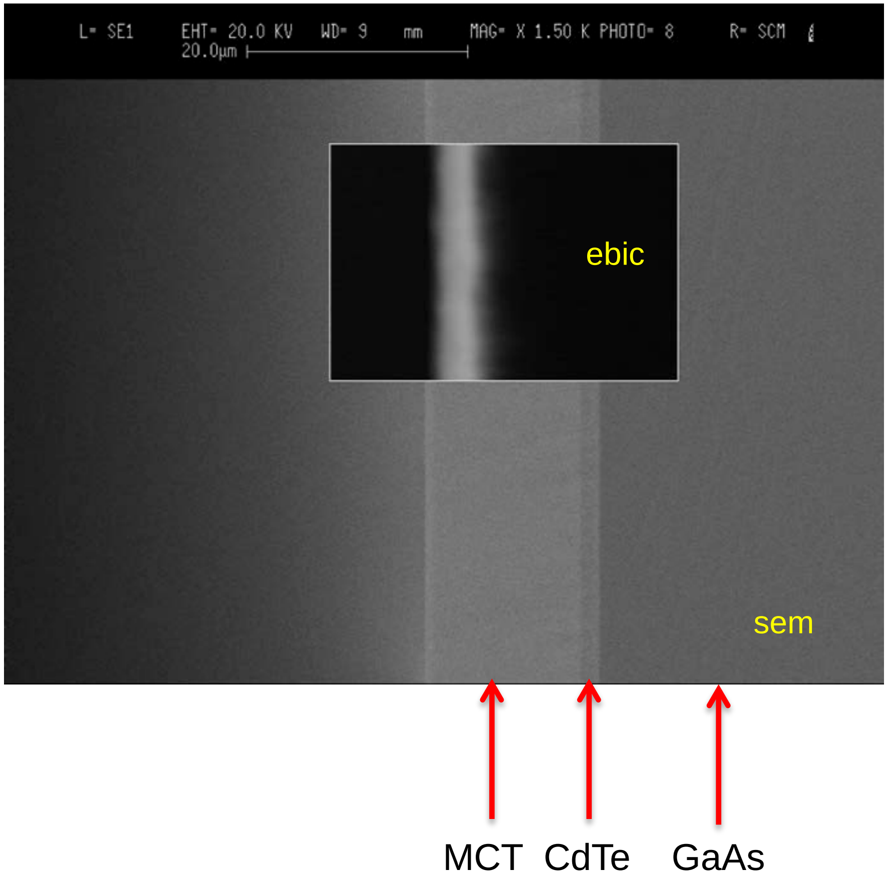
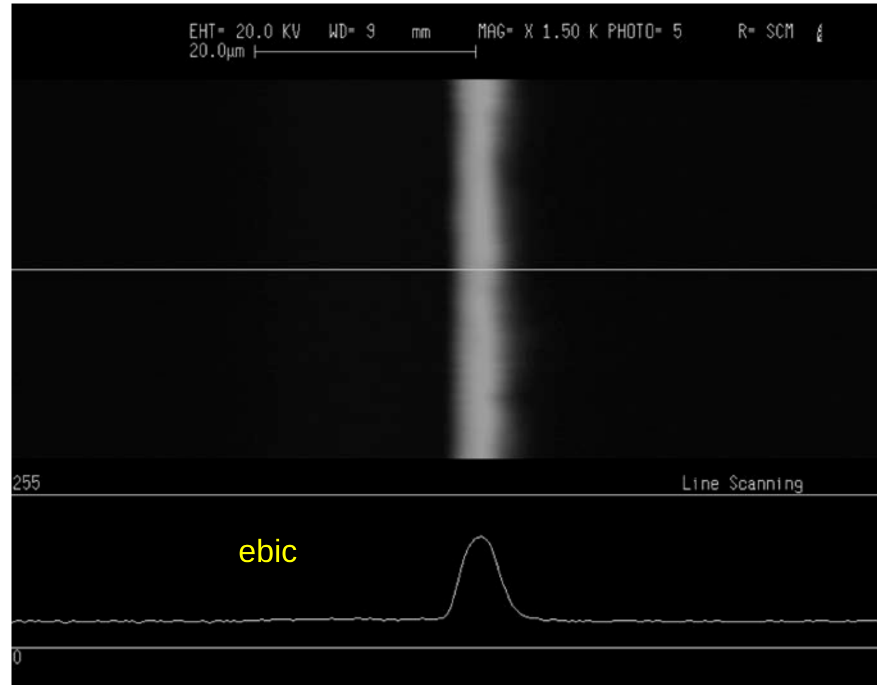
Etch time - effect on spectral response

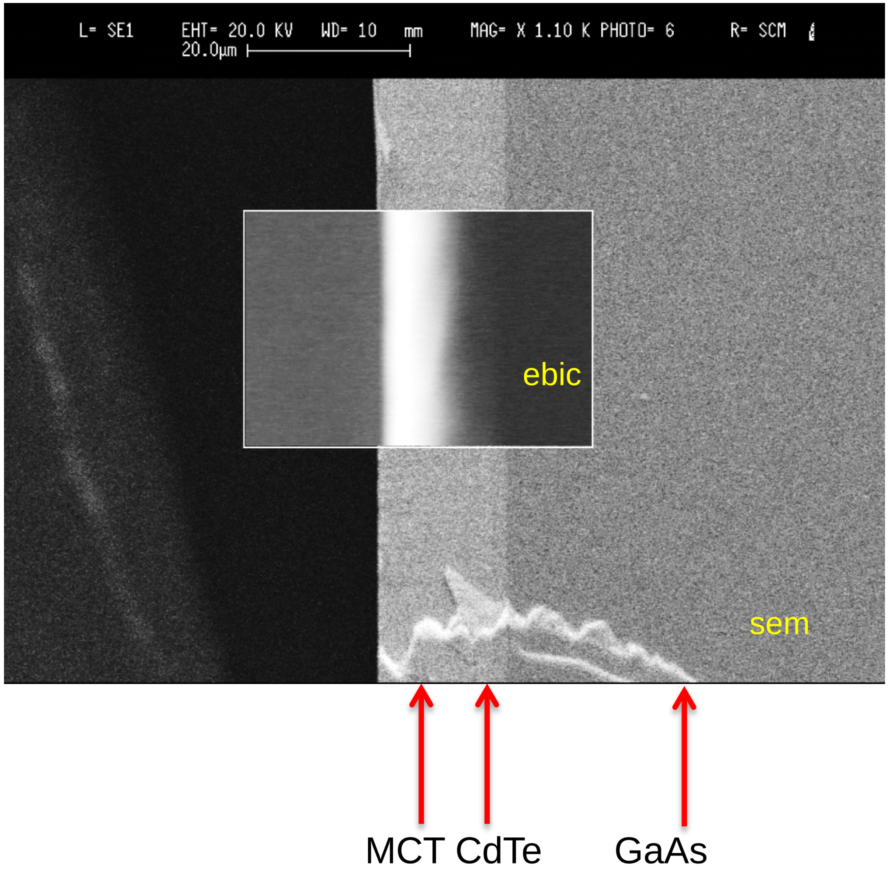


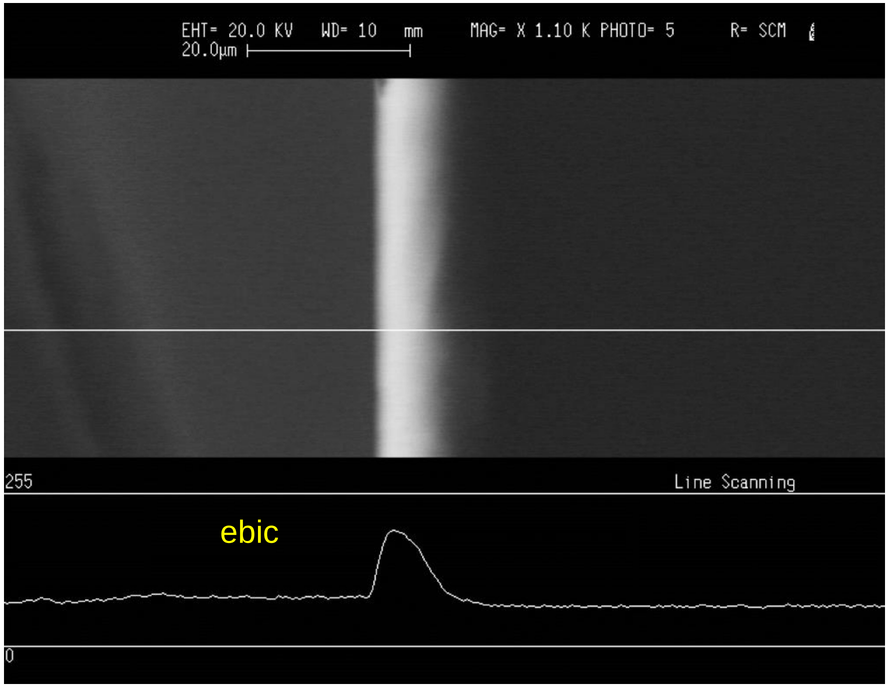
5vg291/c2b liquid nitrogen ebic/sem





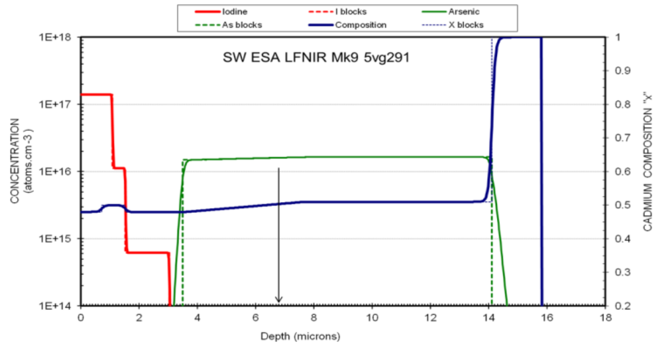
5vg291/c4b liquid nitrogen ebic/sem



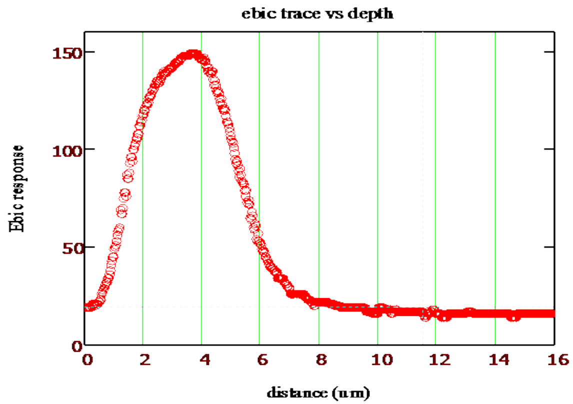


At 80K, ebic response from ~half the MCT layer thickness

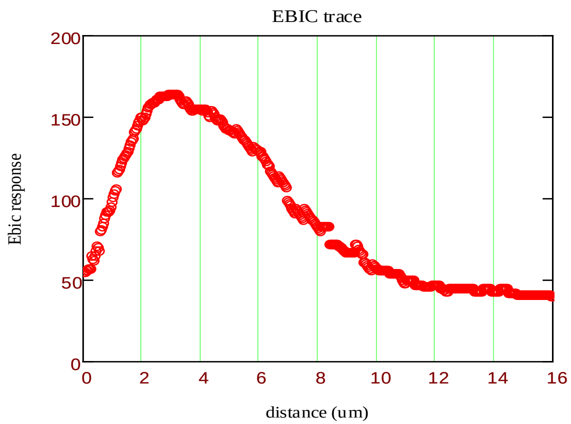
Cold ebic trace compared to SIMS profile



BEFORE



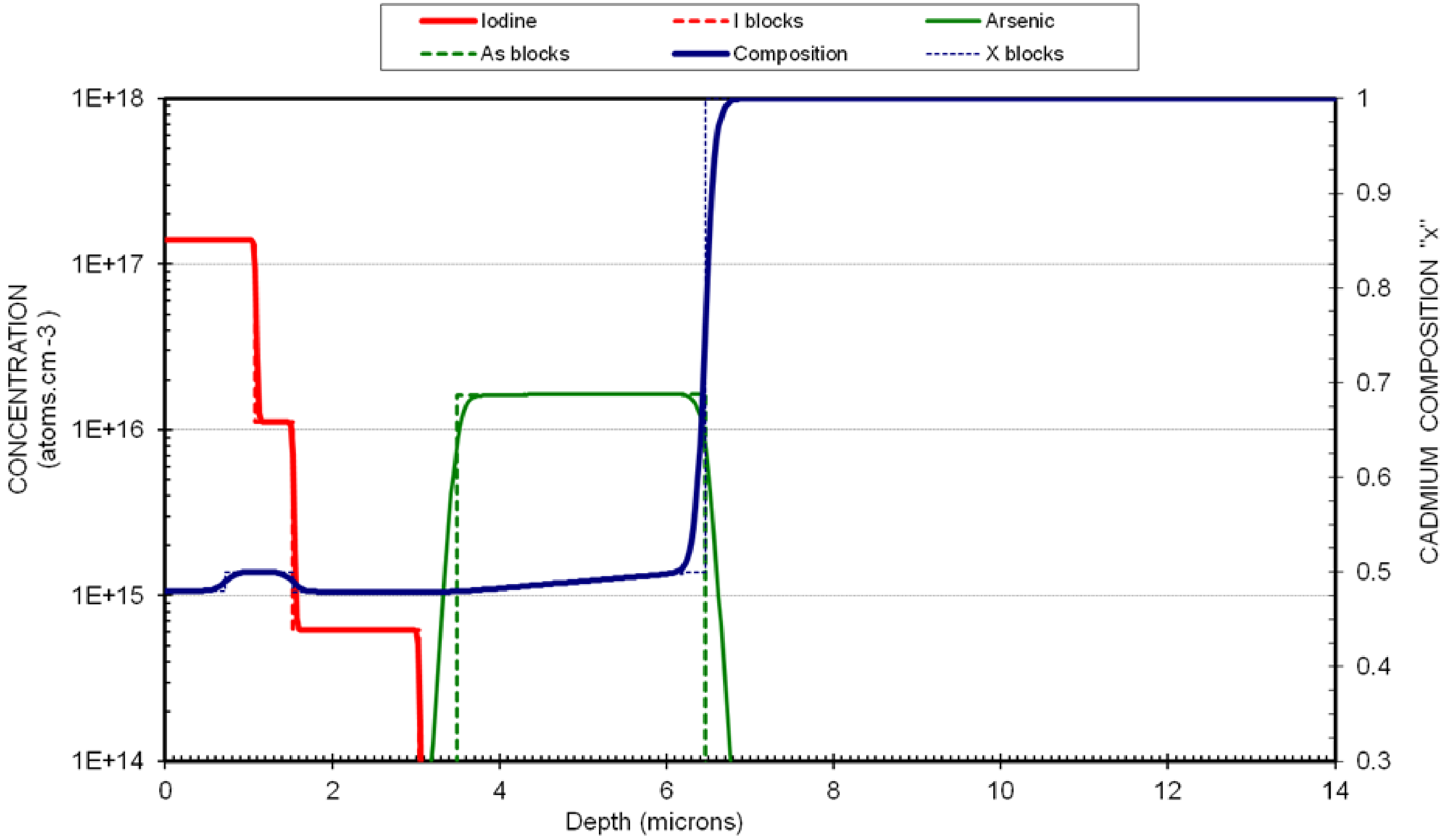
AFTER



This sample has a longer diffusion length compared to the sample above from the same layer

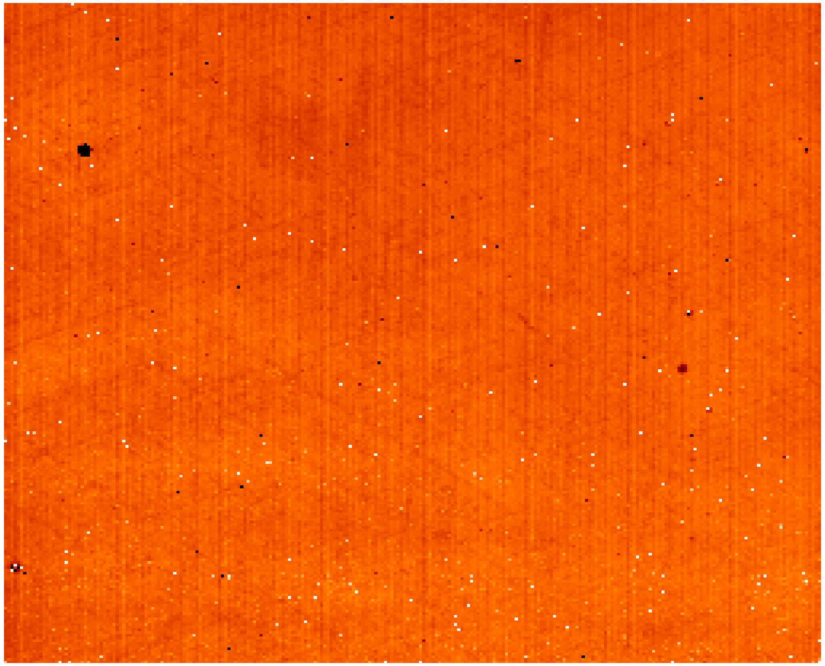
The ebic profile suggests that thinning the structure to ~7um should result in a SW q.e. of >70%

New NIR design

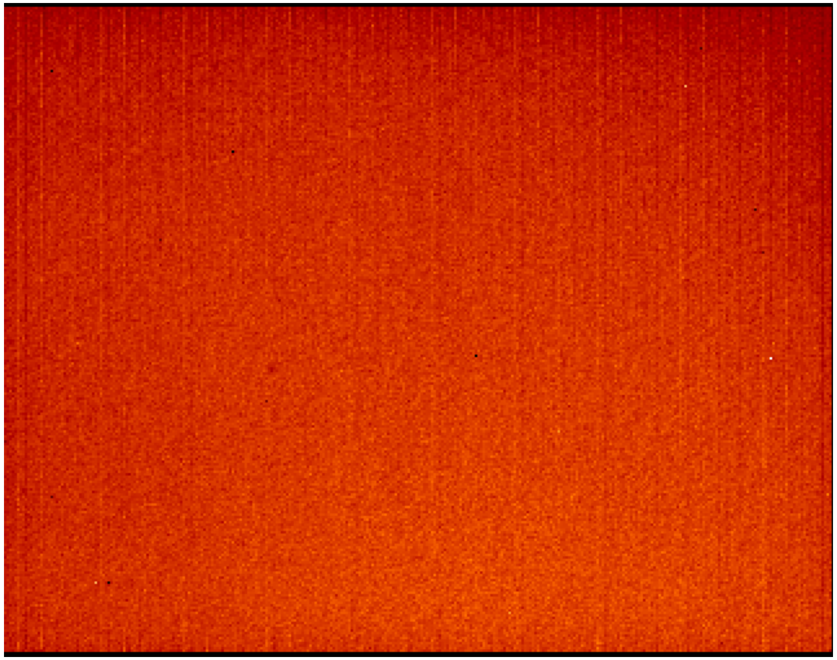


MOVPE avalanche photodiode array breakthrough

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

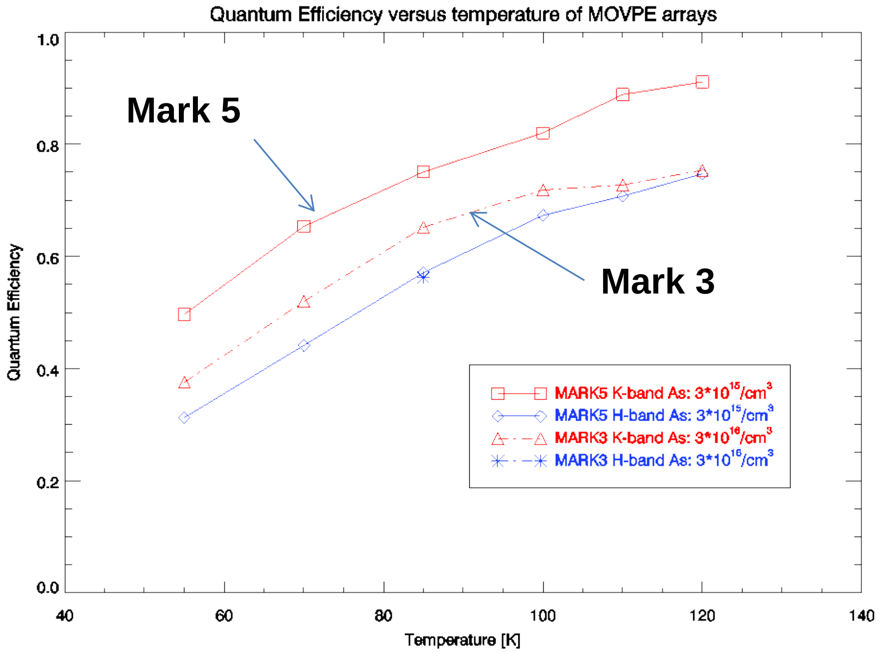


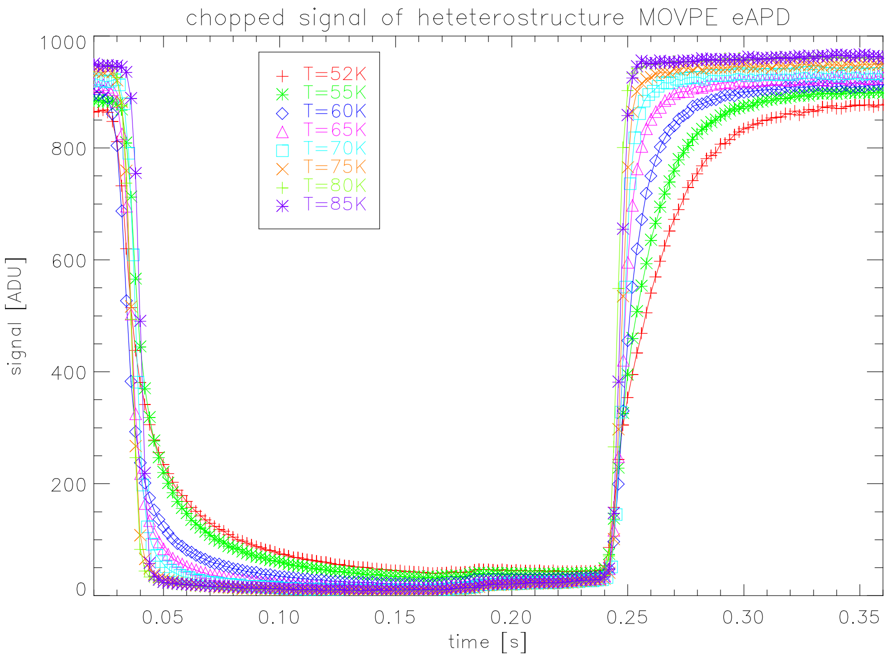
MOVPE array (H and K band)
(85 K, avalanche gain: 60x, DIT: 5 ms)



- **New MOVPE APD design gives virtually no defects at bias voltages as high as 12V and integration times of seconds**
- **Record read noise of 0.26 e- rms announced in Sept 2013 by ESO**
- **Outstanding high temperature operation**
- **Photon counting demonstrated by University of Hawaii in March 2014**
- **Conversion to MOVPE opens up the opportunity for very large arrays**

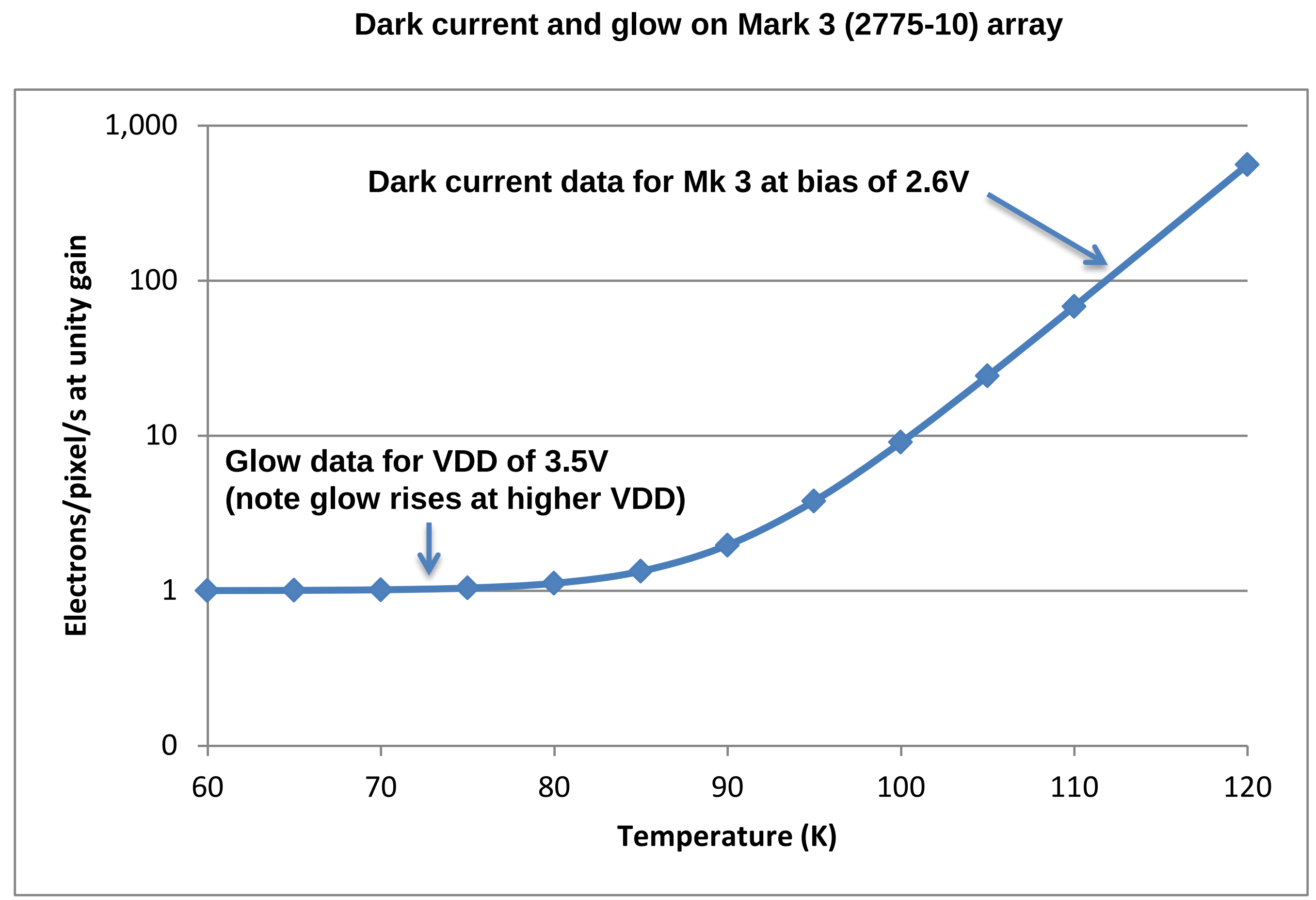
MOVPE APDs in NIR have slow response and poor QE at low temperature





The new process is expected to improve APD performance

Saphira performance in single photon sensing applications



Dark current receives less avalanche gain than photosignal effectively suppressing dark at high gain

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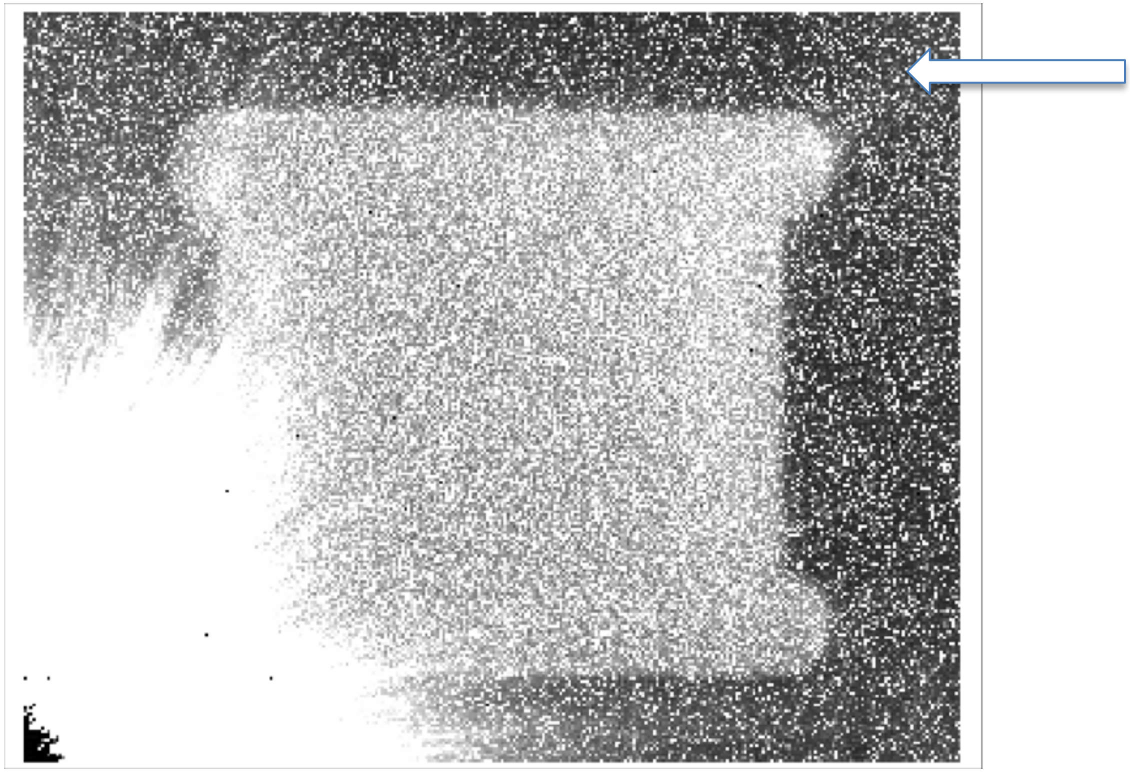
Dark current and glow

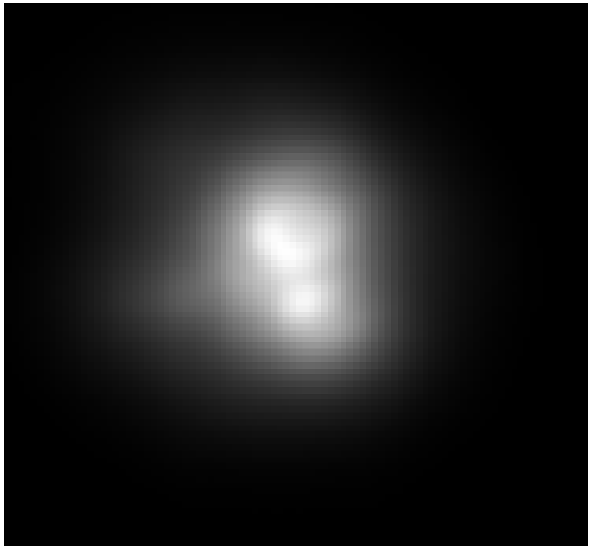


Dark current
in this area
0.005 e-/sec

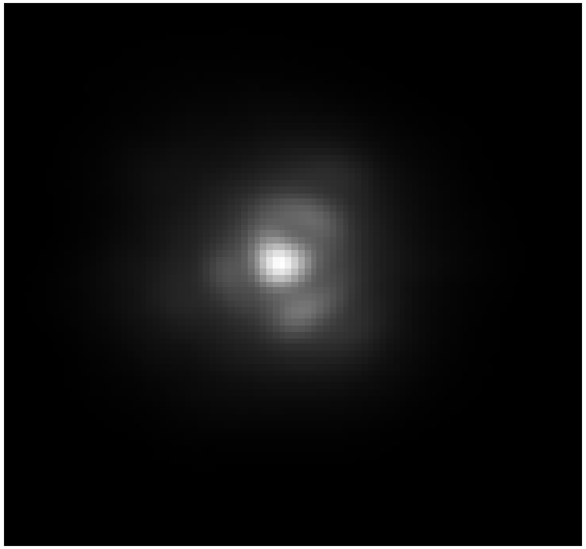
The low background dark current of the MOVPE based arrays
is comparable to the best MBE astronomy arrays - 0.005 e-/sec at 60K
(University of Hawaii)

University of Hawaii on-sky evaluation of SAPHIRA

Images from 3-m NASA IRTF telescope on Maunakea



Shifted-and-added based on centroid analysis - giving 0.3 arcseconds (similar to seeing conditions on night).

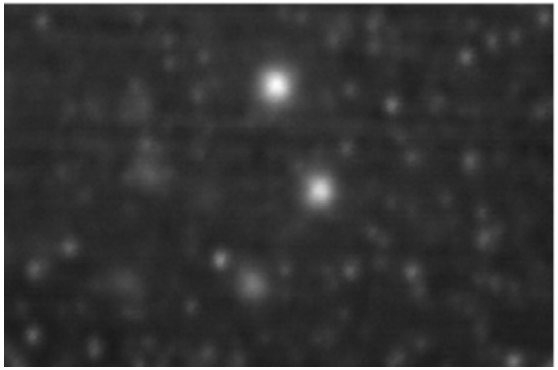


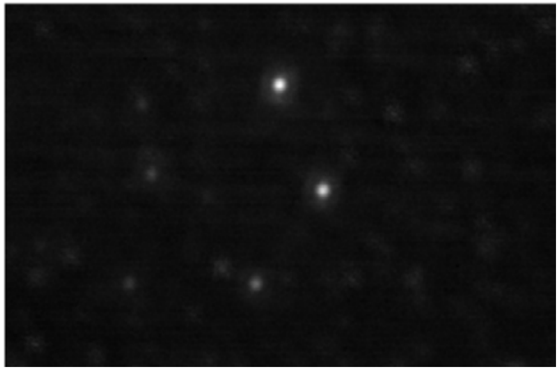
10% frame selection based on peak flux giving 0.13 arcseconds – diffraction limited performance.

These 2 seconds exposures were performed with an avalanche gain of x30 and frame rate of 1000 frames per second. By using lucky imaging, diffraction limited performance was achieved on IRTF for the first time. The trefoil pattern is due to the telescope supports.

Saphira demonstrated on-sky

Images from Mount Palomar 60 inch





Preliminary data in 2 arcsecond seeing conditions with 1% lucky imaging showing near-diffraction limited performance without an AO system

Courtesy of University of Hawaii.

- We apologise for too much astronomy

- The improvements are applicable to EO