1024x1024 Format Pixel Co-Located Simultaneously Readable Dual-band QWIP Focal Plane

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Team

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  - Brian Simolon – FLIR
- FPA Hybridization
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- Packaging and Mounting Detectors & FPAs
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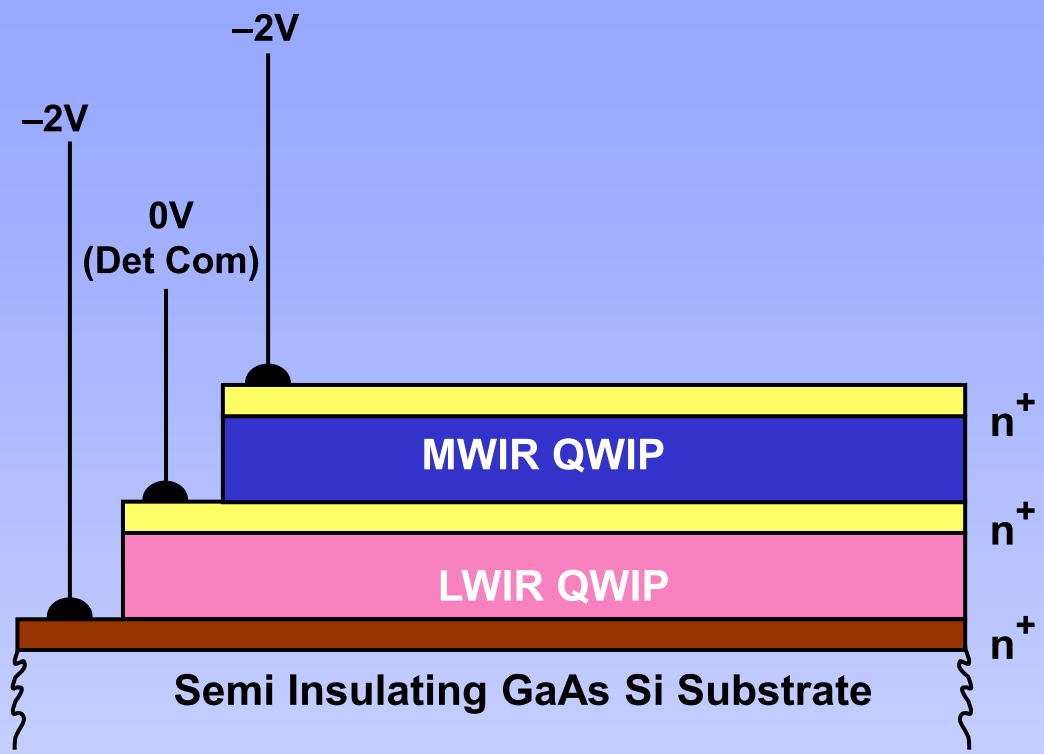
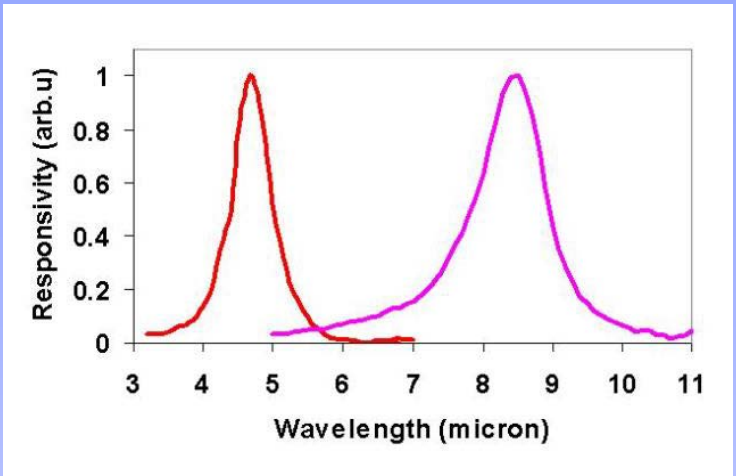
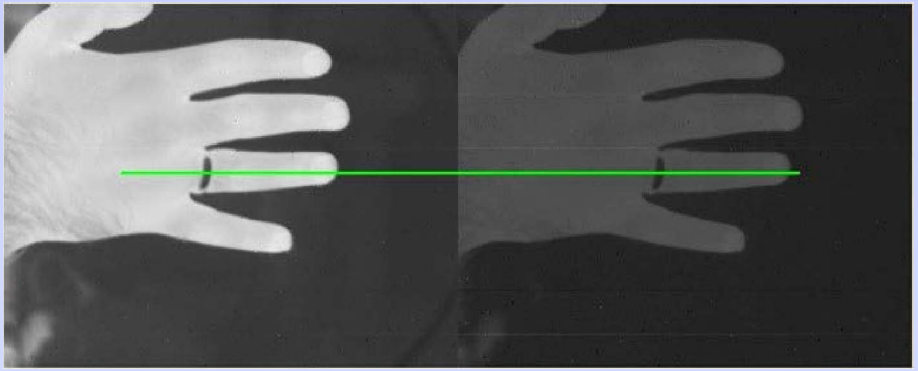
- Test Device Characterization
  - Jason Mumolo
- Data Analysis
  - Sumith Bandara
  - Jason Mumolo
- FPA Characterization
  - Jason Mumolo
- Electronics
  - Mark Stegal - SEIR
- Camera Integration & Testing
  - Jason Mumolo

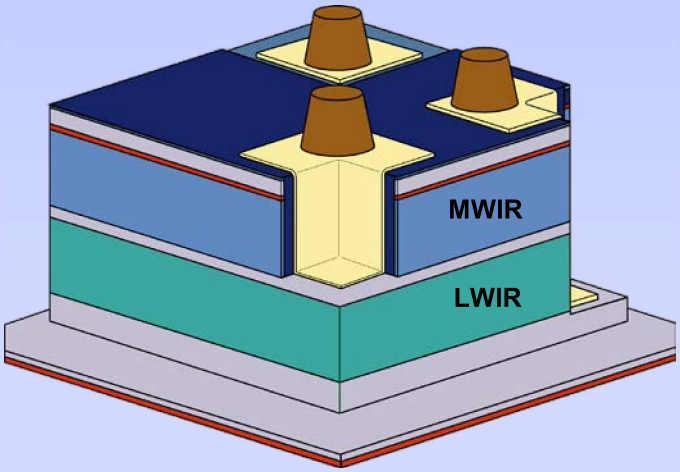
Pixel Co-Registered Simultaneously Readable Dualband (MWIR & LWIR) QWIP Pixel



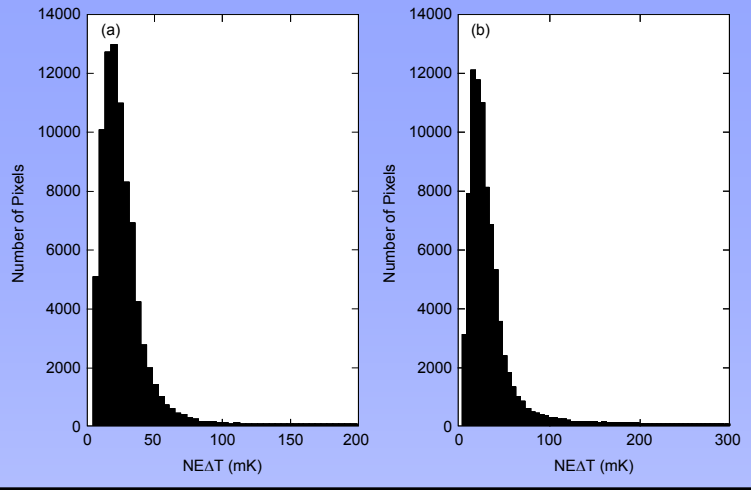




LWIR MWIR



Imagery with Dual-band QWIP Pathfinder Array



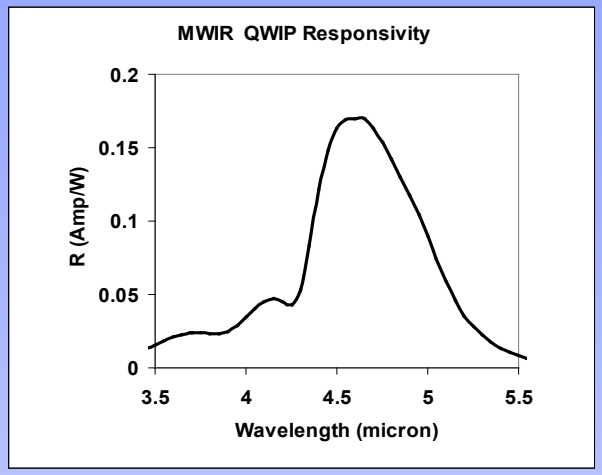
The experimentally measured NEΔT of MWIR and LWIR detectors at 65 K are 28 and 38 mK, respectively.

LWIR **MWIR**

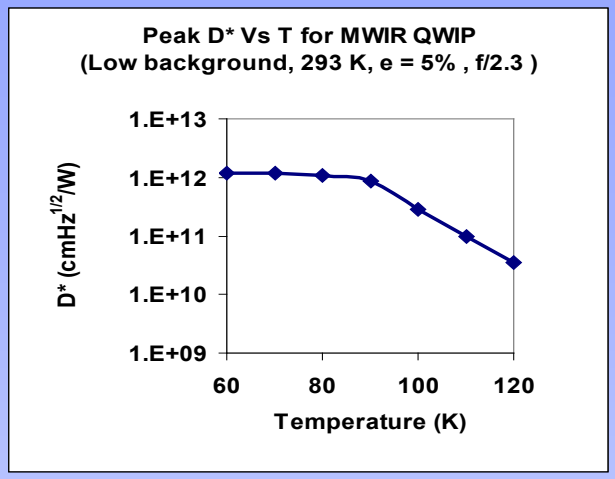
Features to look for,
The cigarette lighter produce lots of hot CO2 gas. So, flare is broader MWIR due to CO2 emission, where as LWIR (8-9 microns) doesn't have any emission (just the heat).
The hot cigarette lighter flame produce so much MWIR signal, it reflects off from the lens and Jason's face.
The plastic piece Jason is holding is opaque in LWIR, but transparent in MWIR.

Format	- 320x256 pixels, dualband & pixel co-registered
Wavebands	- 4.4-5.1 & 8-9 μm
NEDT	- 28 & 38 mK for 300K background with f/2 optics
QE	- 19% & 15%
Photoconductive gain	- 0.2 & 0.3
Detectivity	- > $2x10^{11}$ & $1x10^{11}$Jones
Operating temp.	- 65 K
Fill factor	- > 81%

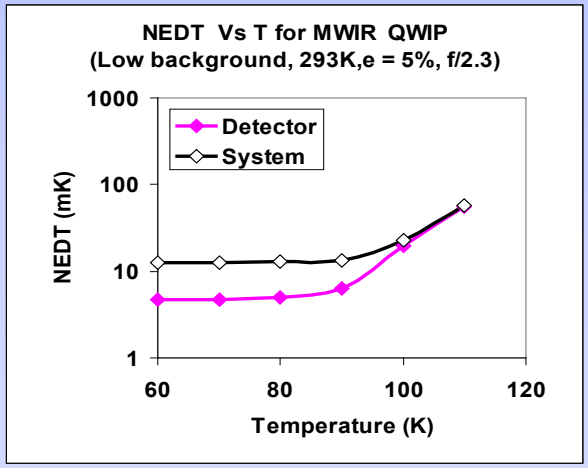
DUALBAND QWIP – MWIR DATA FROM TEST DETECTORS



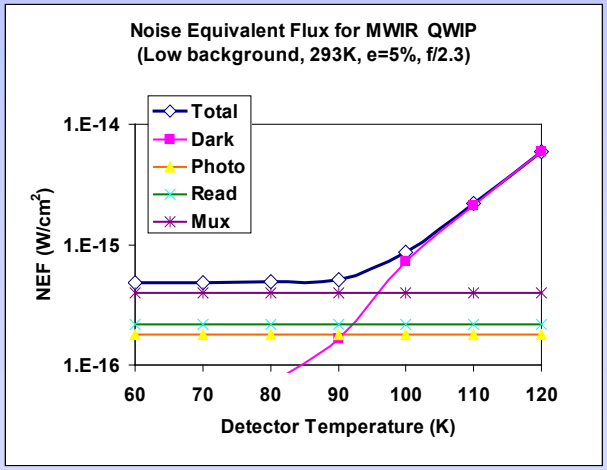
RESPONSIVITY



DETECTIVITY

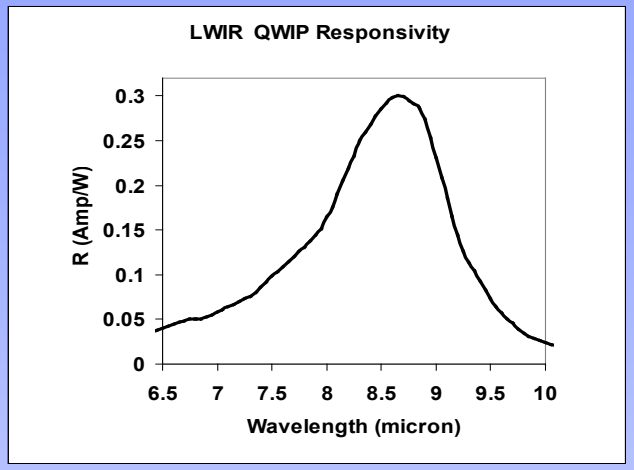


NEDT

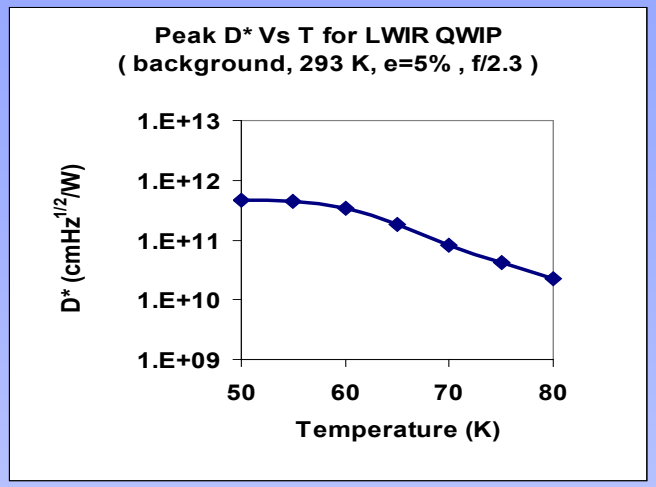


NEF

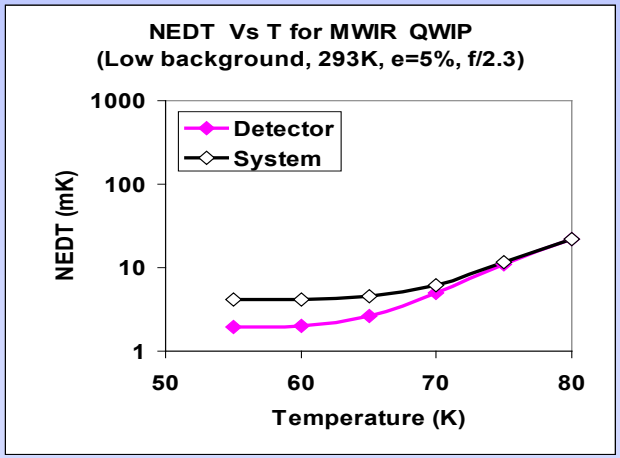
DUALBAND QWIP – LWIR DATA FROM TEST DETECTORS



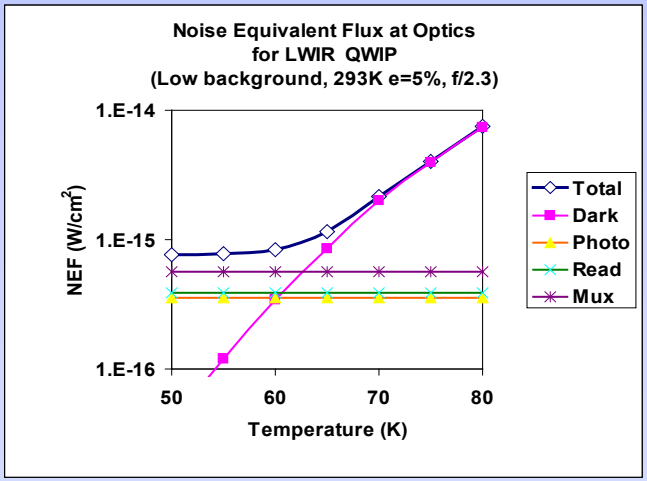
RESPONSIVITY



DETECTIVITY



NEDT



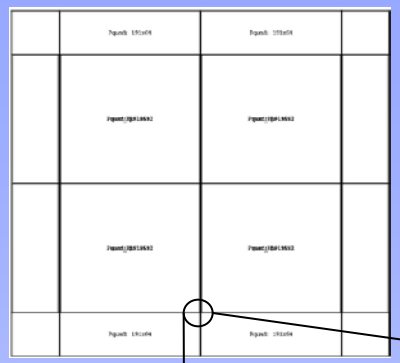
NEF

Challenges of 1024 x 1024 Pixel Dualband QWIP FPA Development

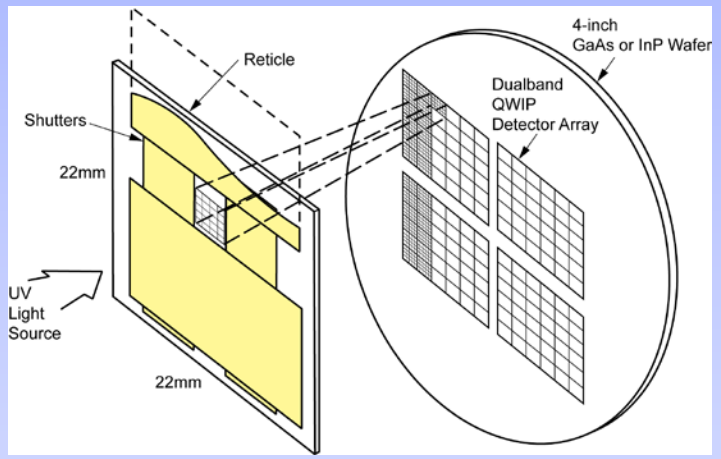
- Stitched ROIC & detector array development
- Leadless chip carrier (LCC)
- Array hybridization
- Substrate removal

Array Stitching

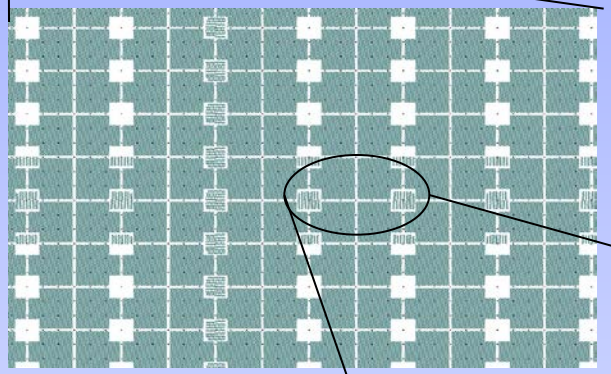
- Contact lithography
- Stepper lithography



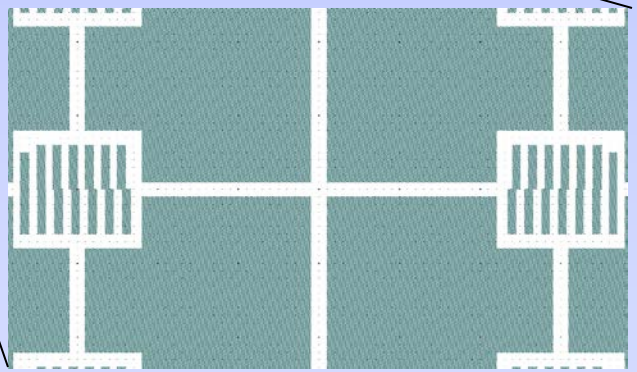
Stitched together to form a larger array



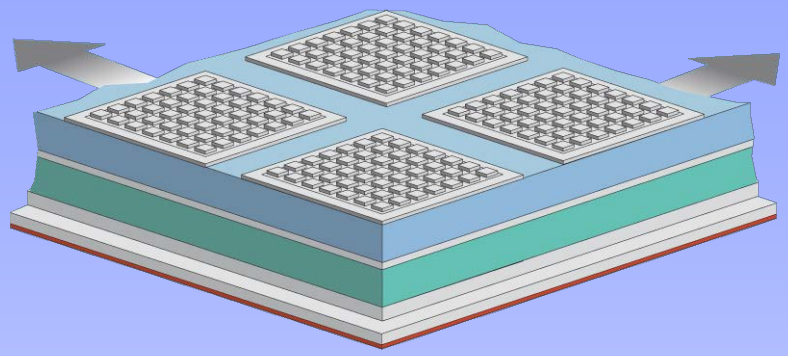
Max reticle exposure area ~ 22 mm^2



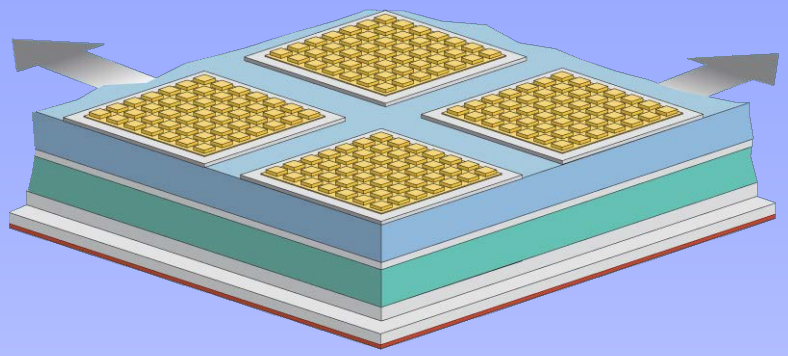
Vernier marks on vertical and horizontal edges.



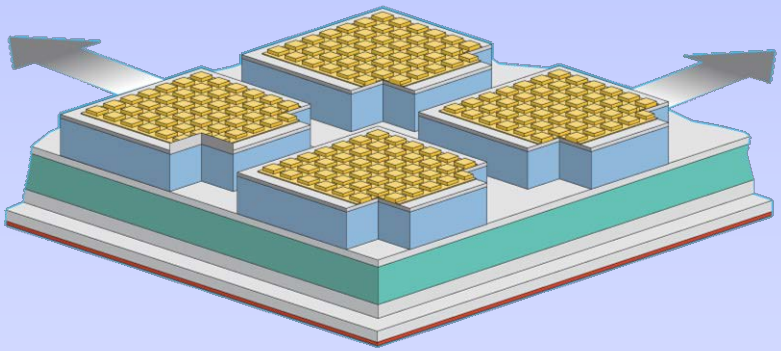
To guarantee accuracy of no less than 100nm



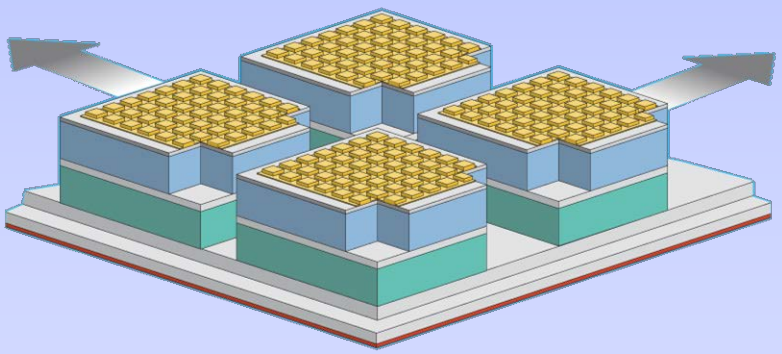
Grating Etch



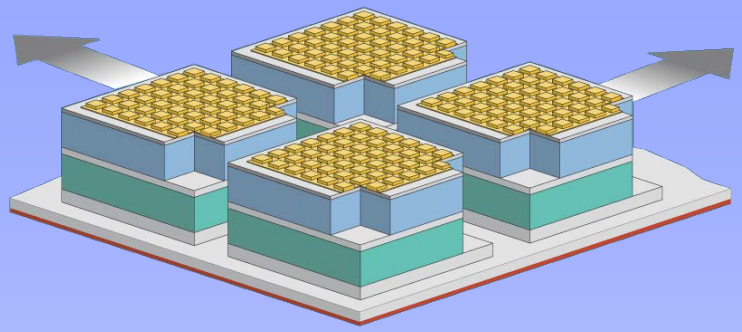
Top Metal Deposit



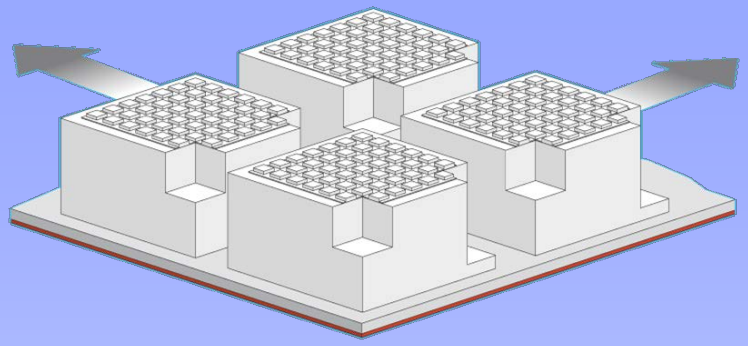
First Mesa Etch



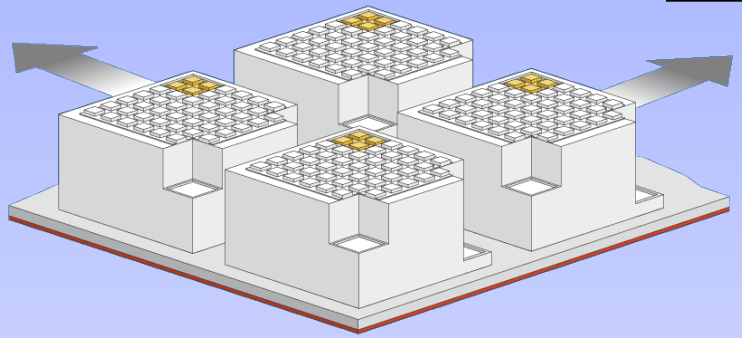
Second Mesa Etch



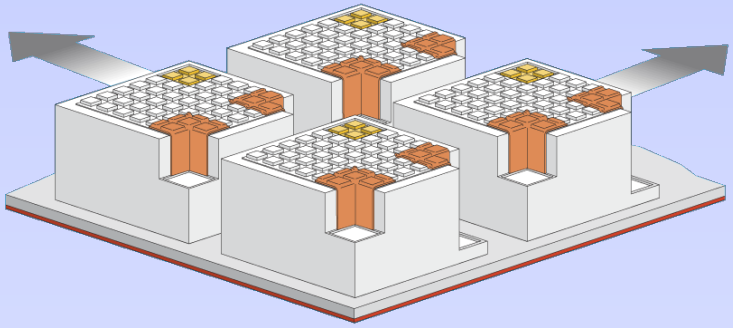
Isolation Etch



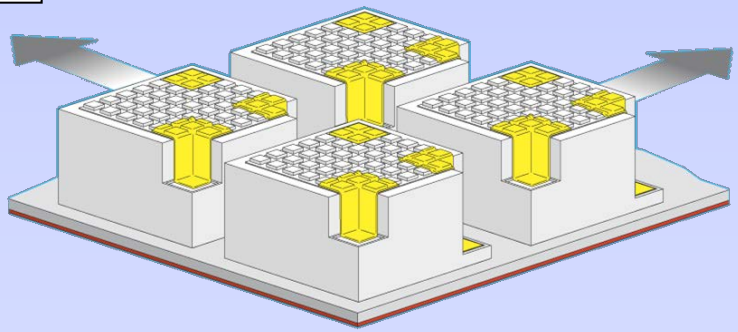
Deposit Insulation Layer



Window Opening

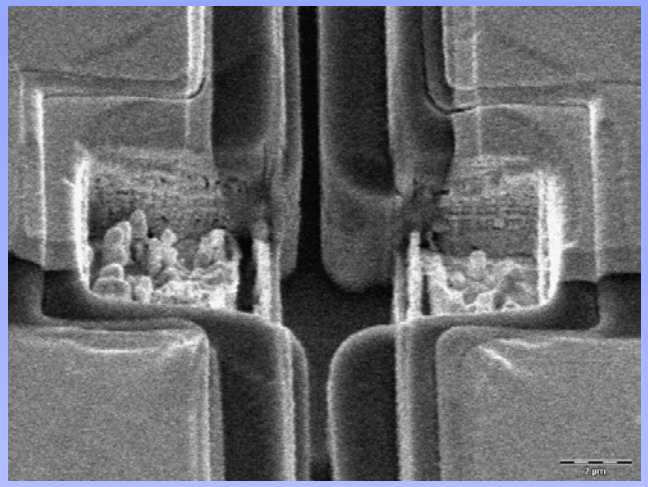


Adhesion Metal Deposit

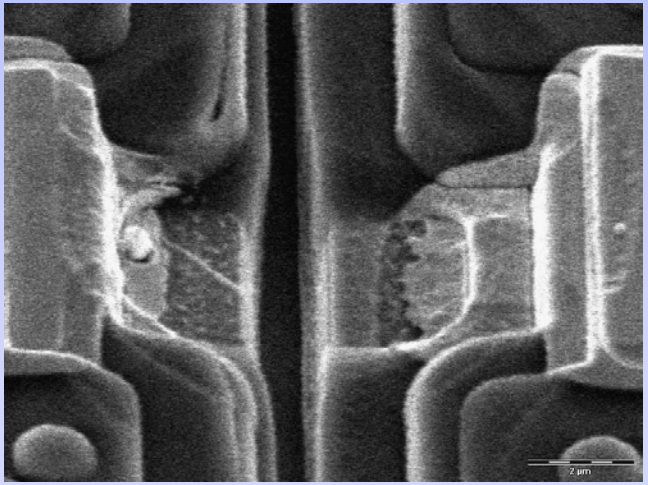


Final Metal Deposit

VIAs OF Dual-band FPAs based on Contact Lithography



Middle contact of dualband co-located first & second batches

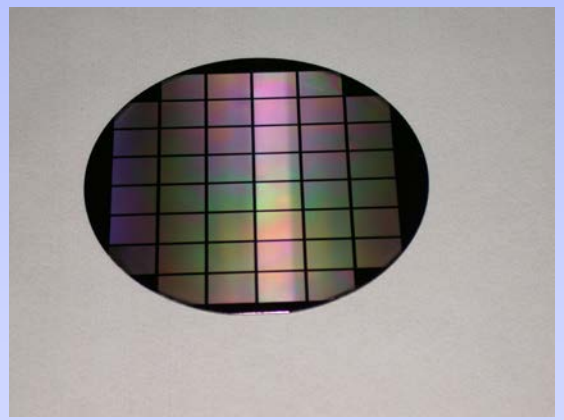


Bottom contact of dualband co-located first & second batches

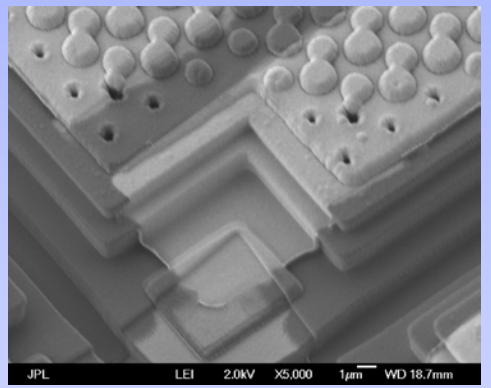
- Via processing is challenging
- Etching through InAs layers of MWIR QWIP is difficult
- High via aspect ratio (via size/via depth) reduce fill factor
- Smaller via aspect ratio reduces the removal of dry etching waste
- Resulted in a rough & uncleaned lower contact surface
- Poor Ohmic contacts
- Via insulation

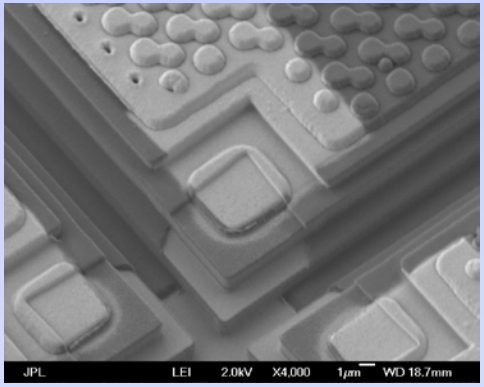
New Dualband Array Based on Stepper Process

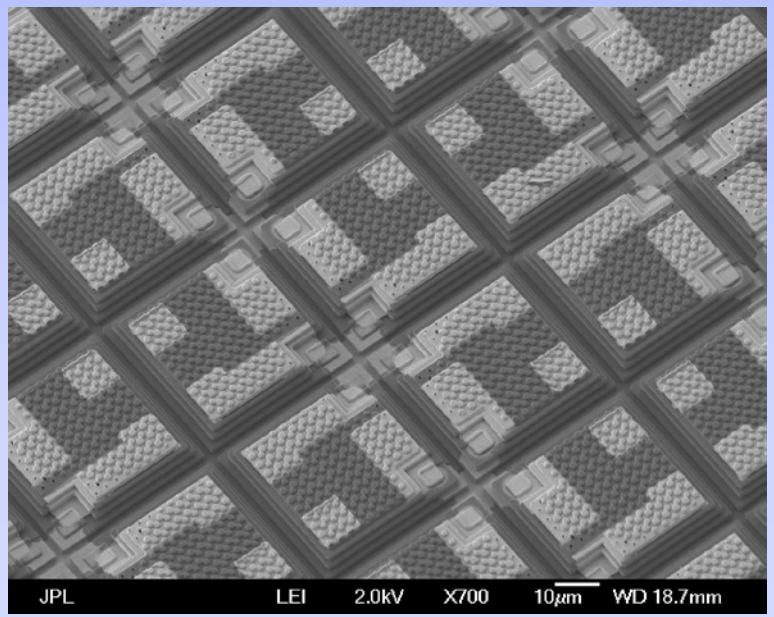
- Features well aligned
- Thin device structure
- New via architecture allows more net space in via hole
- Completely new processing scheme
- SEMs show clear via connections and pixel isolation trenches
- Pixels are electrically not shorted or open



4-inch wafer with 48 detector dies







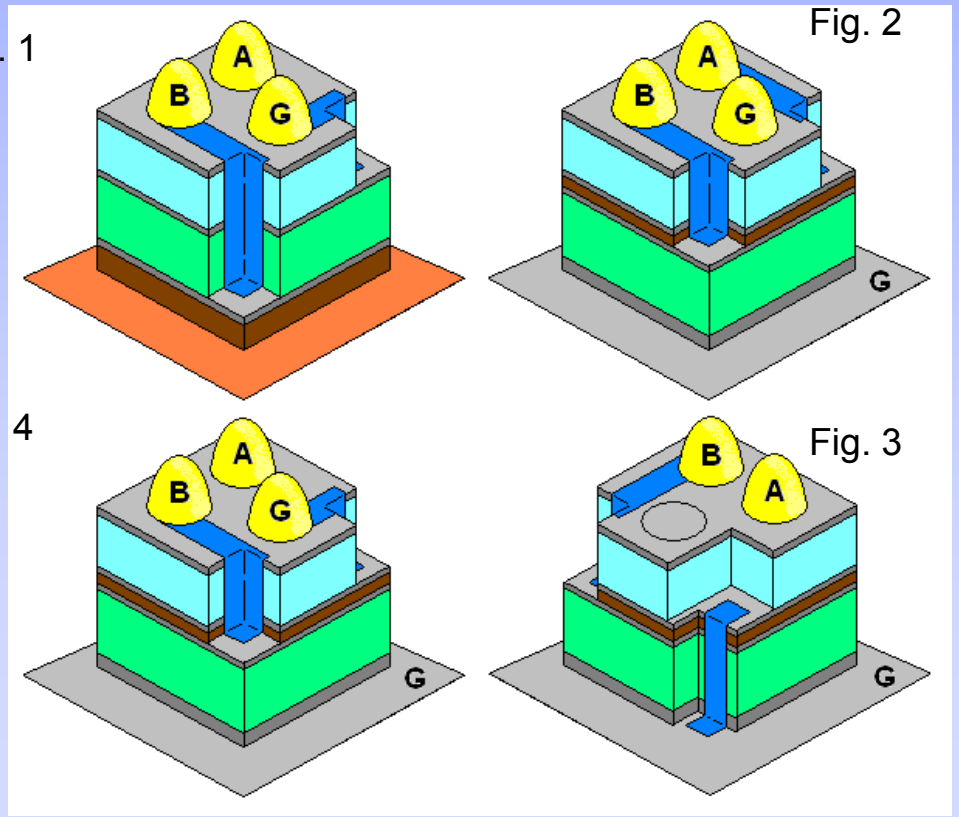
SEM of dualband QWIP array

1Kx1K Dualband structure options

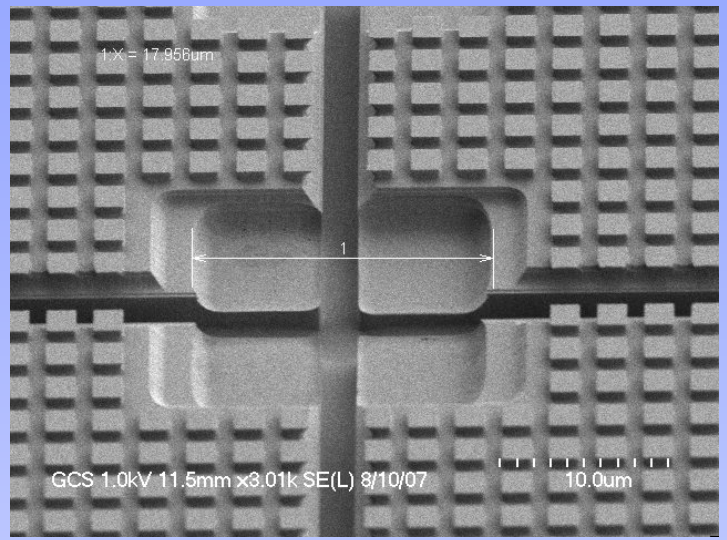
Below are four different structure options for the 1kx1k 2 color design. Top-left is the old method used for the 320x256 format, with the biases coming in the middle and data read-out at top and bottom for colors A and B; pixels are isolated from each other. Bottom-left is one new option where we have bias in the middle below color A, as well as common below all pixels; color A reverse bias, color B reverse bias. Top-right is the same structure, however A and G are flipped to switch the bias on color A to a forward bias condition. Bottom-right is a different scheme where we only require two bumps, bringing the ground up from the common plane to the middle in each pixel.

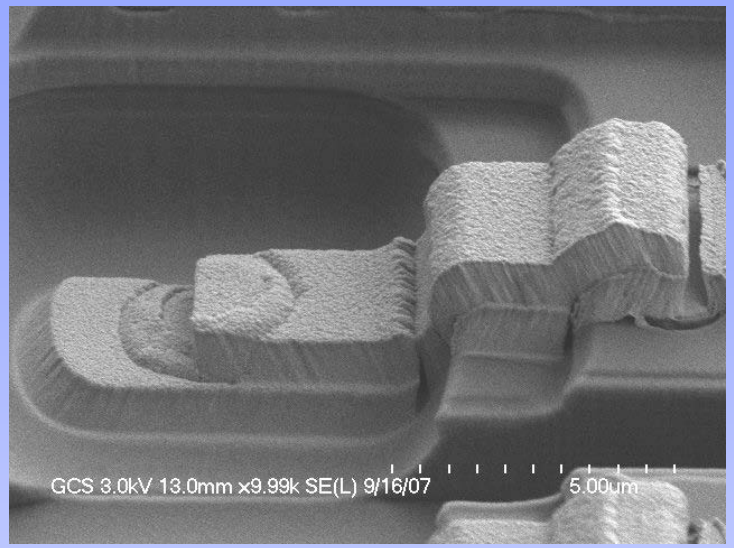
Color Legend

- **Orange** = Isolation Layer
- **Green** = Long Wavelength QWIP
- **Light Blue** = Short Wavelength QWIP
- **Grey** = Contact Layer
- **Dark Blue** = Metal shorts between layers
- **Yellow** = Indium Bumps



1Kx1K Pixel Dualband QWIP Detector Array Fabrication

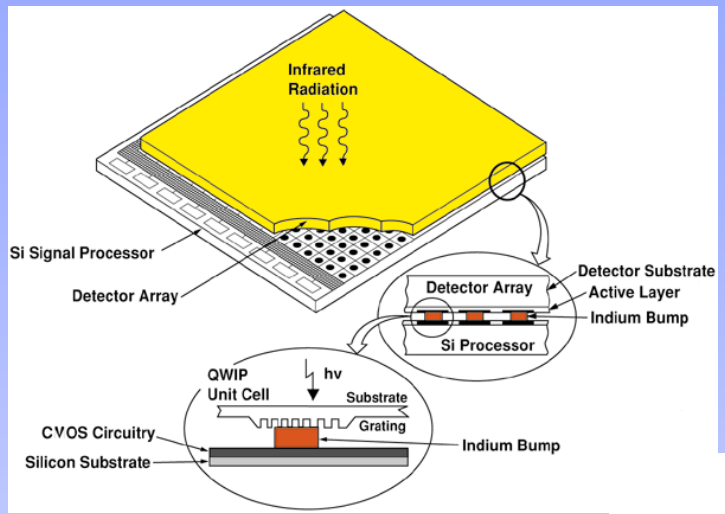




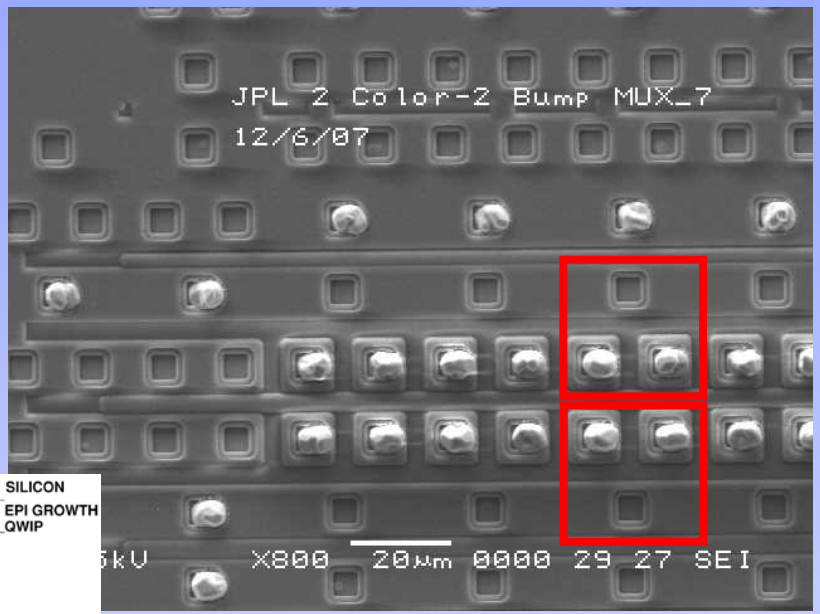
SEM Picture

1. Etch depths met the target
2. Metal bridges connected after second liftoff process
3. Preliminary detector array fabrication process completed
4. Array hybridization completed (Grade B/A)

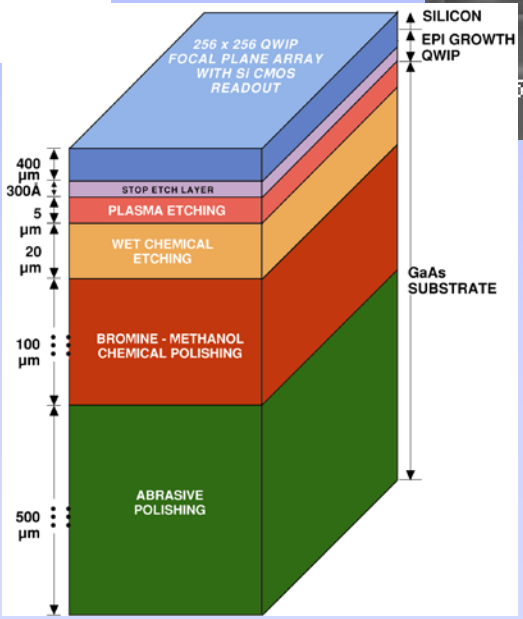
Array Hybridization & Substrate Removal Process



INDIUM BUMP BONDING PROCESS



Dual-band array has more than 2/3-million indium bumps



FPA THINNING PROCESS

Advantages of Substrate Removal

- Eliminates thermal mis-match issues
- Eliminates pixel-to-pixel optical cross talk
- Enhance light coupling

First Megapixel MWIR:LWIR Dualband QWIP Imagery

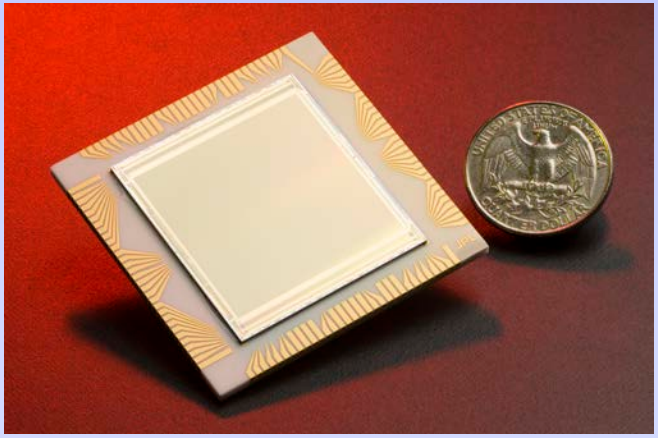
ROIC PARAMETER	SPECIFICATION REQUIREMENT
Array Configuration	1024 x 1024
Pixel Size	30um x 30um
Spectral Range	MWIR: 4.3-5.1um (Color A) LWIR: 8-9um (Color B)
Input Polarity	Hole Collection for QWIPs
Input Configuration	Direct Injection (DI)
Input Clock Rise and Fall	CLK: 10ns rise/fall for 10% to 90% FSYNC, DATA: 10ns rise/fall
Number of Outputs	8 Analog per color
Output Modes	4, and 8 Analog per color
Windowing	Row Only Windowing Minimum Window of 1 Rows
Frame Rate (1024 x 1024)	60Hz (8 outputs per color)
Total Well Capacity	$\geq$ 17 x 10^6 carriers
Well Capacity Ratio	4:1 (LWIR:MWIR)
Noise	$\leq$ 420 e^-_{RMS} at 3.4x10^6 e-MWIR (Color A) $\leq$1250 e^-_{RMS} at 13.6x10^6 e-LWIR (Color B)
Power	$\leq$ 600mW for 8 Output Mode
Integration Mode	ITR, IWR

Preliminary specifications of 1024x1024 pixel dualband ROIC

MWIR LWIR

An image taken with the first 1024x1024 pixel co-registered simultaneously readable MWIR:LWIR dualband QWIP FPA. Flame in MWIR image (left panel) looks broader due to the detection of re- emitted infrared signal from the heated CO2 gas produced by the cigarette lighter in 4.1-4.3 microns band.

MWIR LWIR



Megapixel dual-band ROIC on 124 pin LCC
Pixel pitch – 30 μm

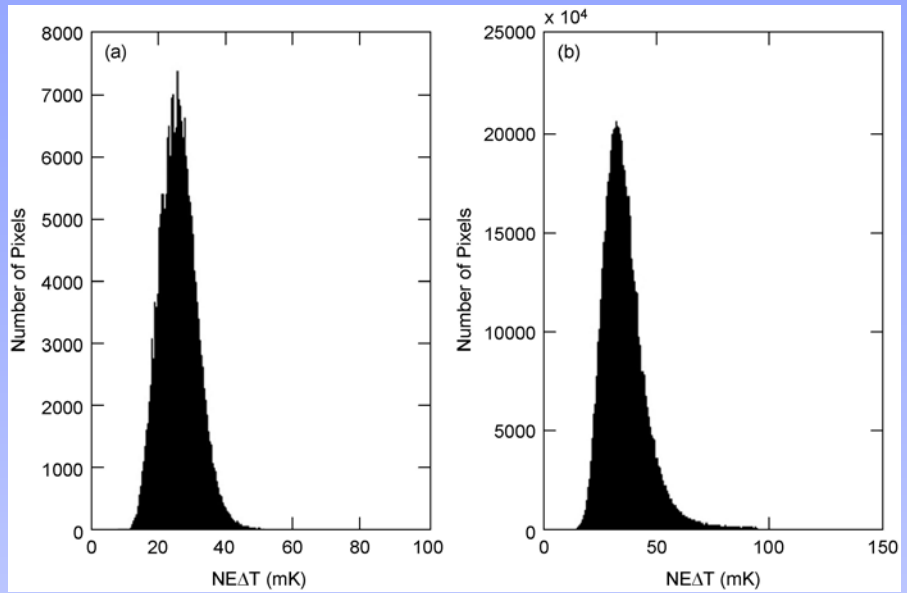
Imagery

JPL 1kx1k QWIP
Dual Color FPA
<-- MW / LW -->

JPL 1kx1k QWIP
Dual Color FPA
<-- MW / LW -->

JPL 1kx1k QWIP
Dual Color FPA
<-- MW / LW -->

Figures of Merit



NEDT	- 27 & 40 mK for MWIR & LWIR
Uniformity (uncorrected)	- 22% & 20% for MWIR & LWIR
Operability	- 90% (full frame)
Operability	- 99% & 97.5% (for 512x512 pixel ROI)
QE	- 19% & 15%
Photoconductive gain	- 0.2 & 0.3
Detectivity	- > $2x10^{11}$ & $1x10^{11}$Jones
Operating temp.	- 70 K
Fill factor	- 76% & 81%

Summary

- Demonstrated 1024x1024 pixel MW:LW dual-band pixel co-registered simultaneously readable QWIP focal plane arrays.