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High Performance SWIR HgCdTe 320x256/30µm FPAs at Teledyne Judson Technologies

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SPIE-OP, Infrared Sensors, Devices, and Applications VIII, San Diego, CA, paper 10766-34

August 23, 2018

Outline

- Introduction
- Detector and FPA fabrication and Characterization
- 2.5µm cutoff FPA performance
- 2.9µm cutoff FPA performance
- Summary

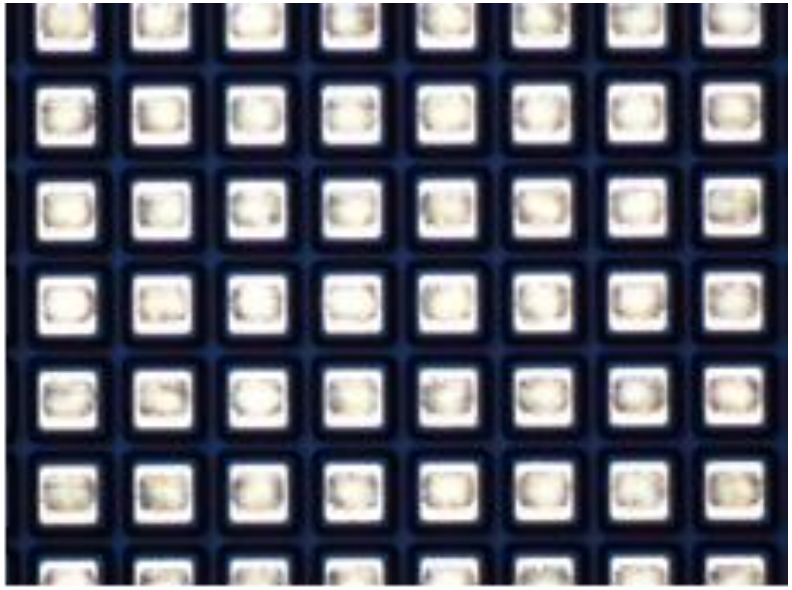
SWIR FPAs, 2-3µm Cutoff

- **HgCdTe is still the primary material choice for SWIR FPA at present**
  - Over Ex-InGaAs, SLS/nBn
- **Advanced FPA technologies developed by a number of companies over decades**
  - Large format, small pixel
  - Military applications
  - Space astronomy applications
- **In recent years, increasing demands in**
  - Commercial markets
  - Commercial space applications
- **Requirements**
  - Low cost
  - High operating temperature
  - High performance
  - Small format

320x256/30µm FPA Fab

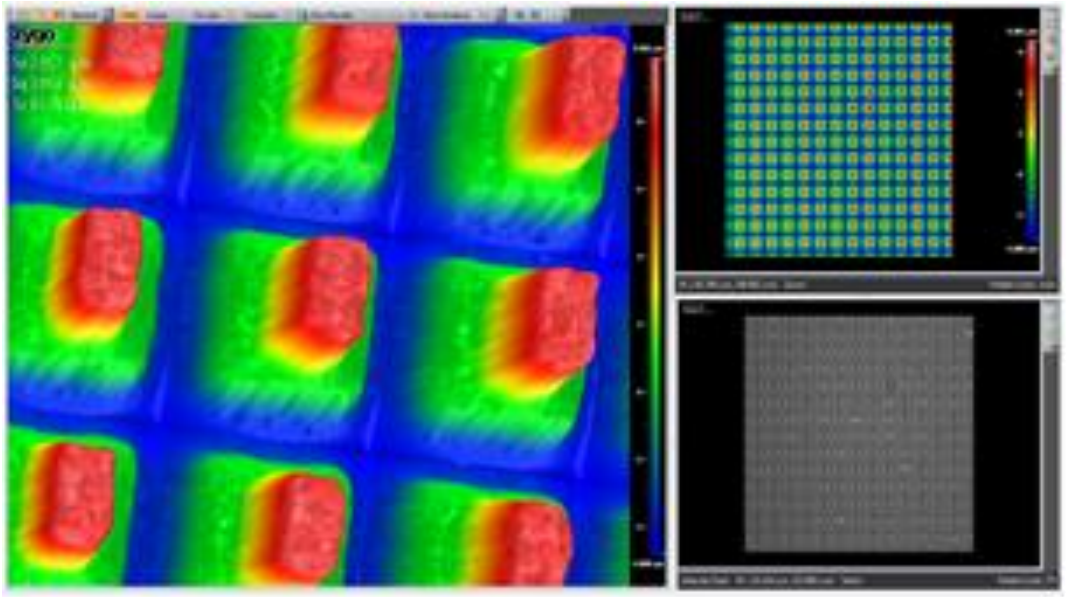
- LPE wafers, as grown P-on-n on CdZnTe, used in early time
- MBE wafers, N-on-n on CZT, As^+ ion-implantation → P-on-n, grown within Teledyne, used now
- Mesa structure with wet etch
- FLIR ISC9809 ROIC, CTIA input, 2 gains (wells), 170K e^- & 3.5M e^-

Nikkon Microscope



In-bumped array, top view

Zygo profilometer



In-bumped array, 3D topography

FPA Characterization

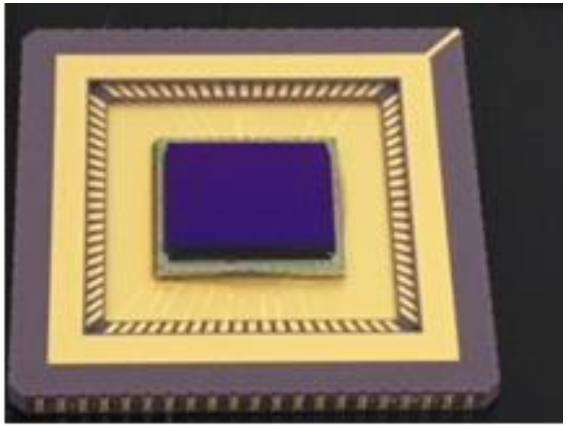
- **2 cutoff wavelengths in general**
  - 2.5µm and 2.9µm
- **4 temperatures**
  - ~23ºC, ~5ºC, -70ºC, LN_2
- **Detector "dark" current**
  - With and without cold shield
- **NEI (noise equivalent irradiance)**
- **Bad pixel map, operability**
- **IR imaging**

Integrated lab camera/dewar

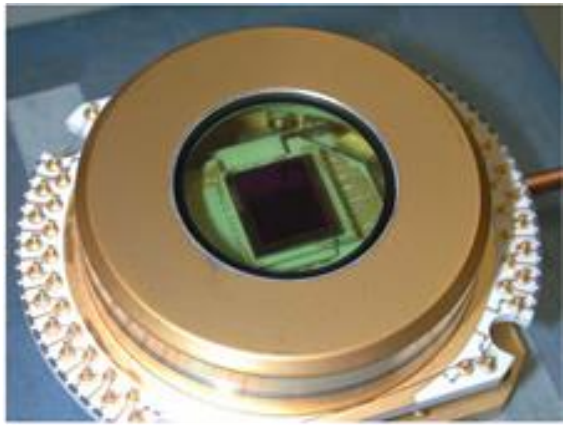
- **Spectral responsivity/QE**
  - On PEC (performance evaluation chip) diodes with backside illumination
- **Pixel capacitance**
  - Measured with a prober (fF limit)
- **Bakeability test**

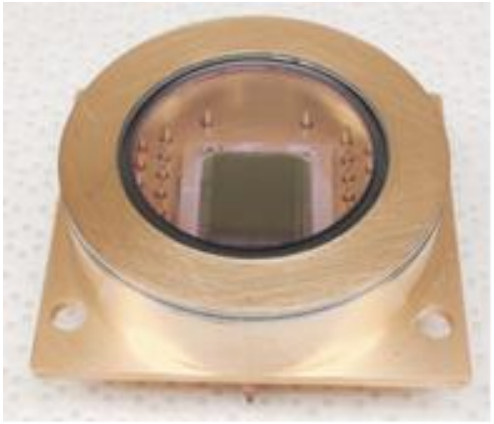
FPA in Various Packages

84-pin LCC



MC-50 with 4-stage TEC (-85ºC)

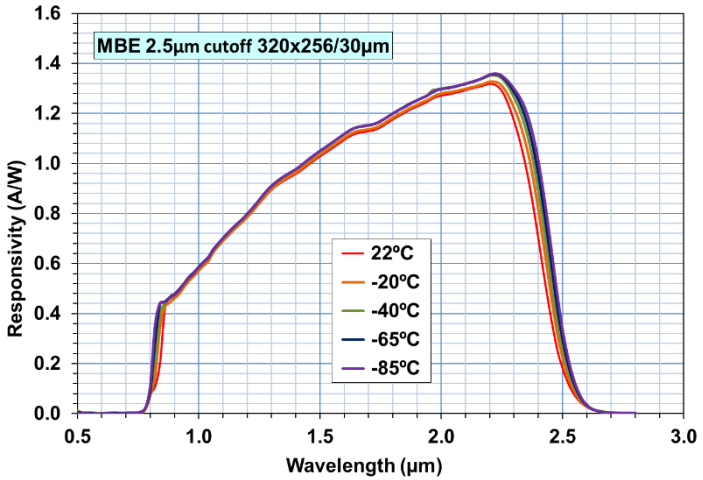


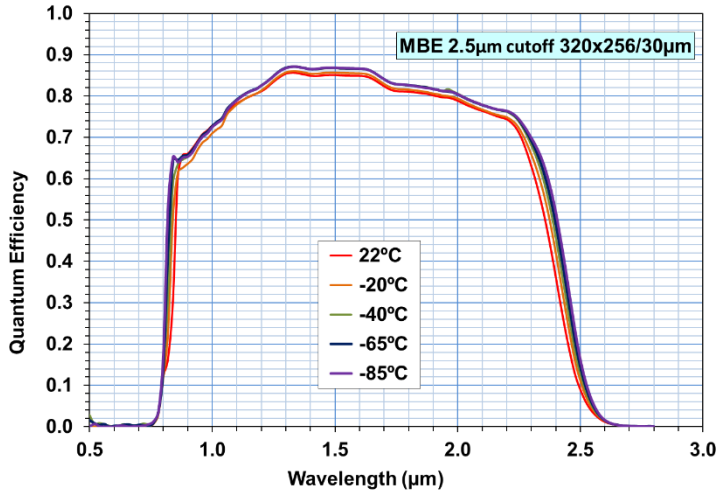


P34DIP with 1-stage TEC (-25ºC)

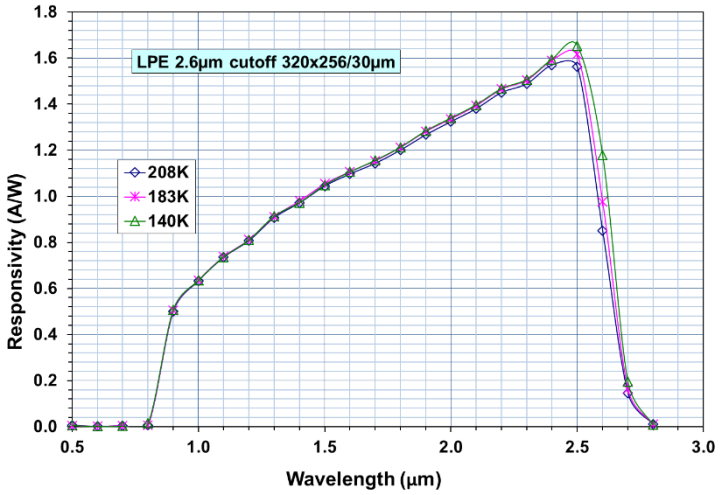
J508 with RICOR micro-cooler (LN_2)

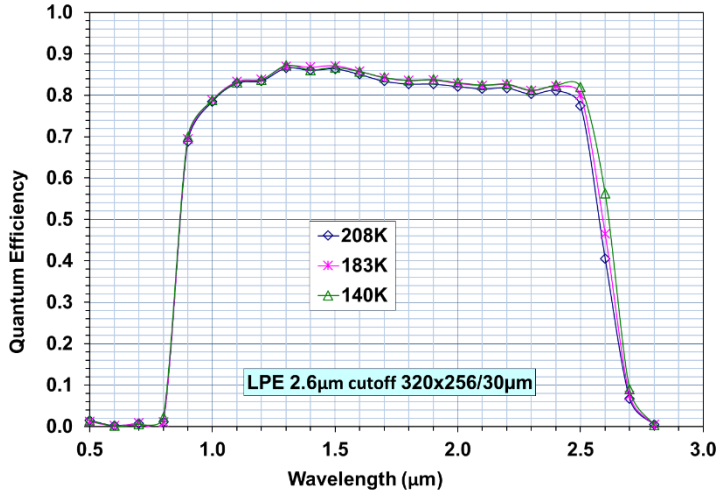
2.5µm FPAs, Spectral Responsivity & QE





2.45µm MBE



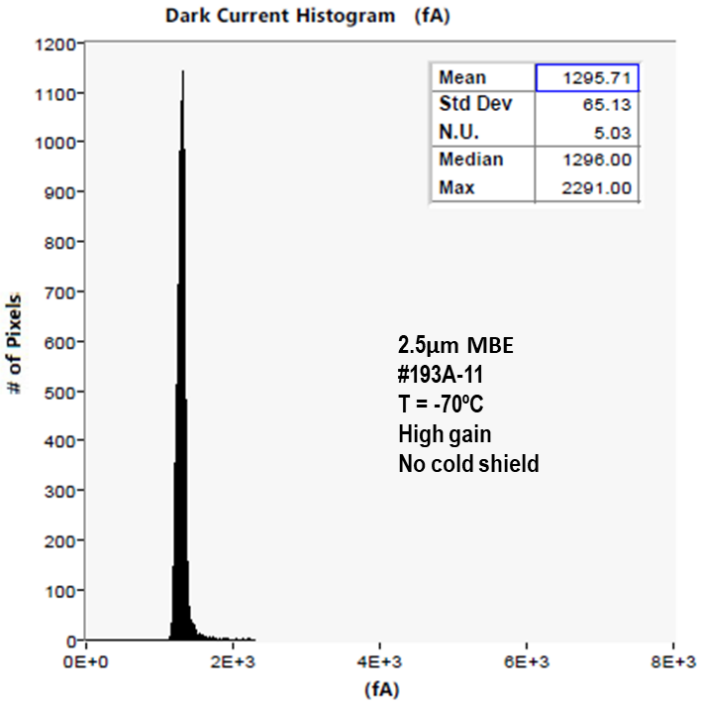


2.6µm LPE

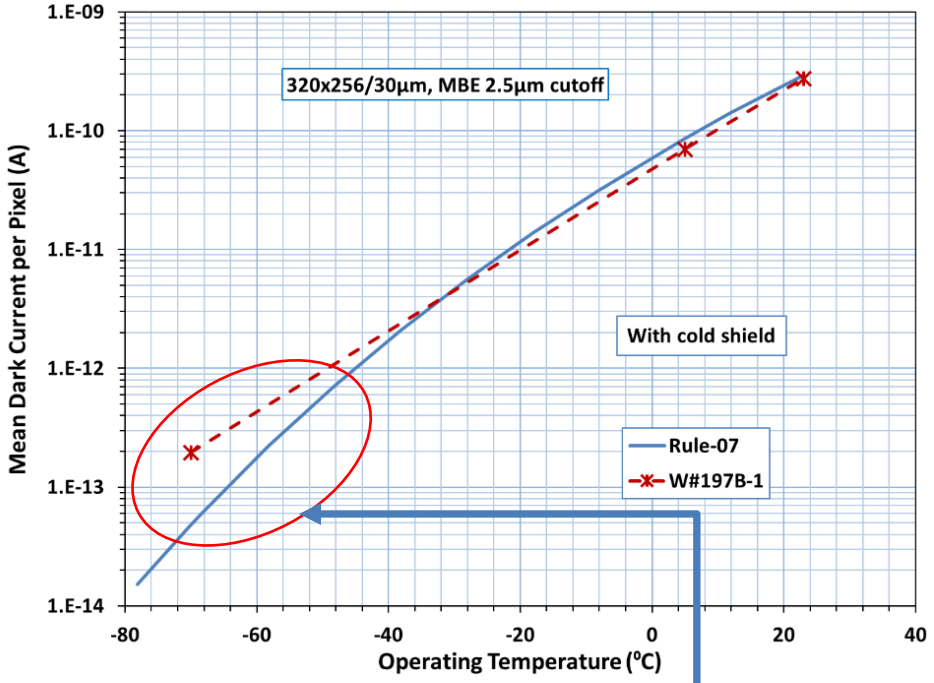
- **Peak QE ~85%, single layer ARC**

“Dark” Current Histogram and Temperature Dependence

-70ºC, no cold shield



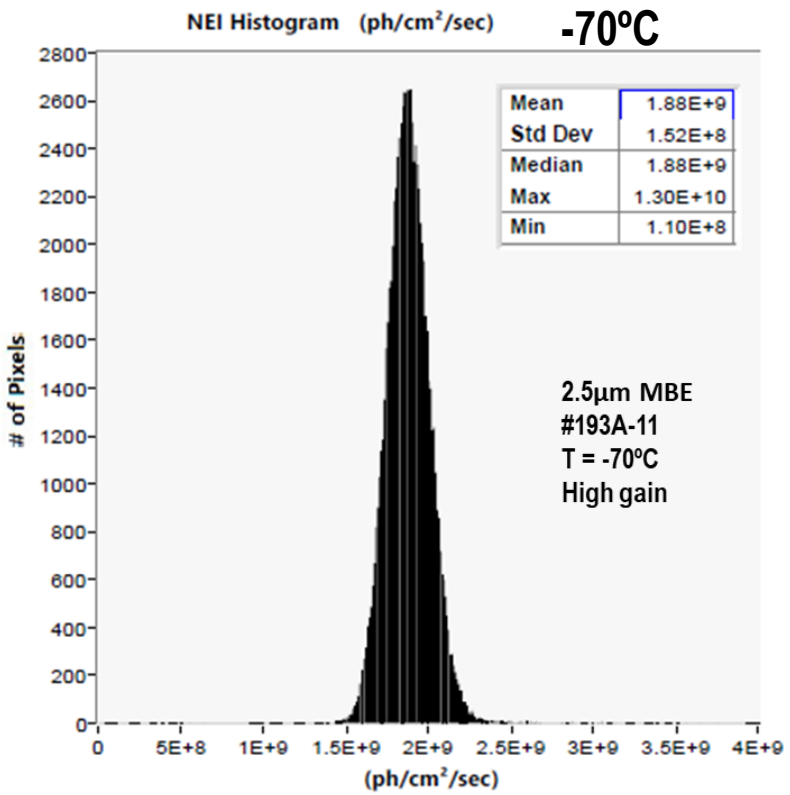
With cold shield

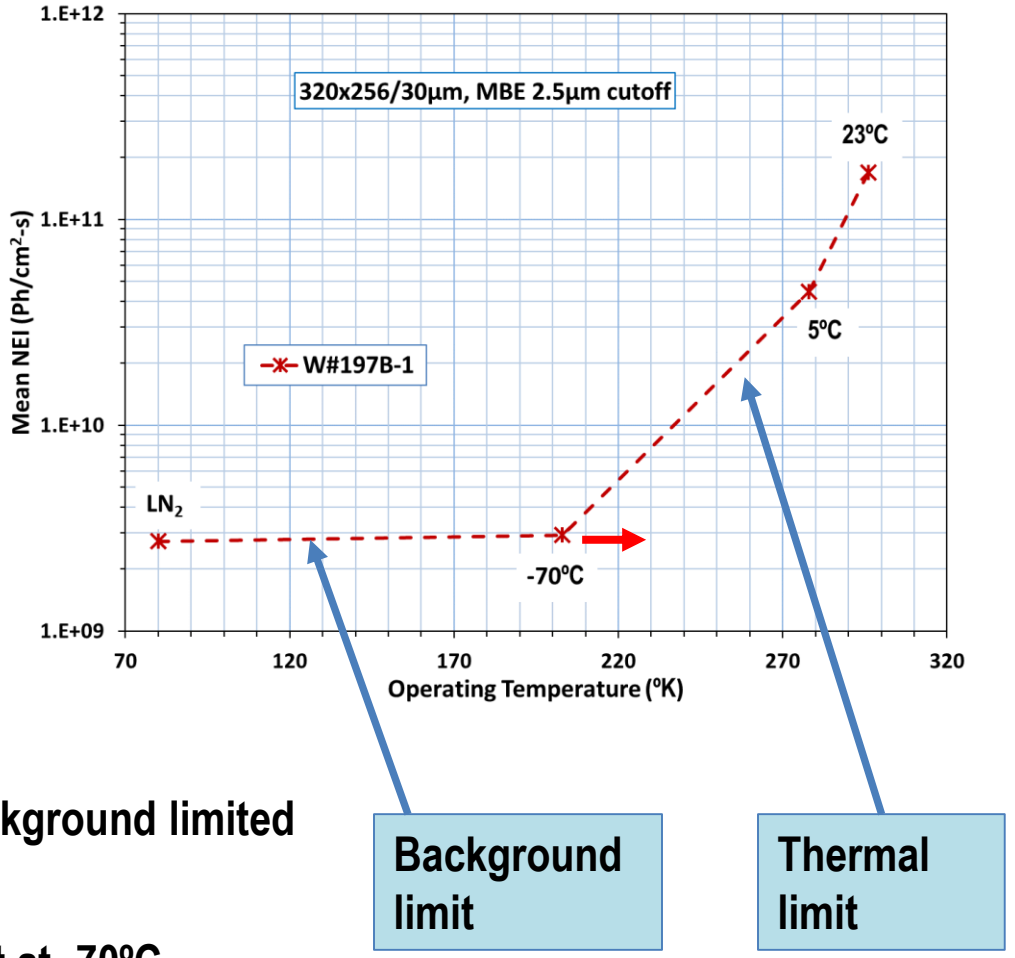


- **Background photocurrent dominant at -70ºC with FOV ~ 100º, 6.7X higher than dark current (1.3pA vs. 195fA)**
- **Dark current matches Rule-07 model at high temperatures (> -30ºC)**
  - –Low temperature I_d data affected by background leak and/or camera electronics
- **2.5µm MBE**

Background and/or camera limit

NEI Histogram and Temperature Dependence

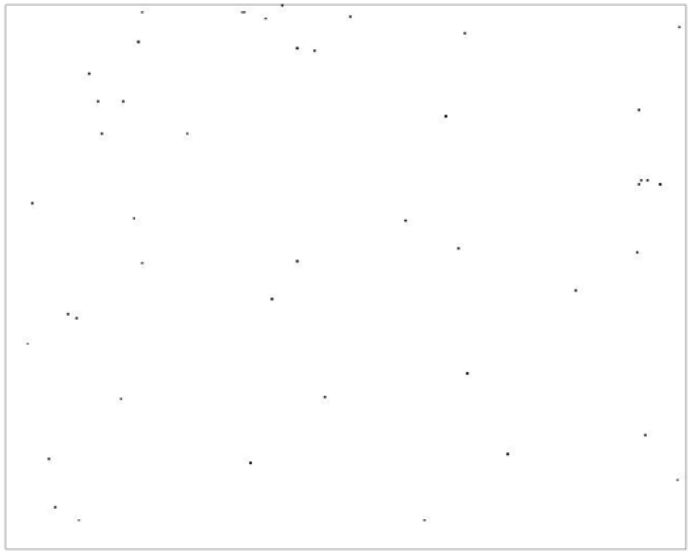




- FOV ~100º, BPF = 1850-2400nm. NEI is background limited near and below -70ºC
- NEI = 1.9E9 ph/cm^2-s achieved on best unit at -70ºC
- Lower NEI could be achieved under smaller FOV, or similar NEI value could be achieved at up to -55ºC

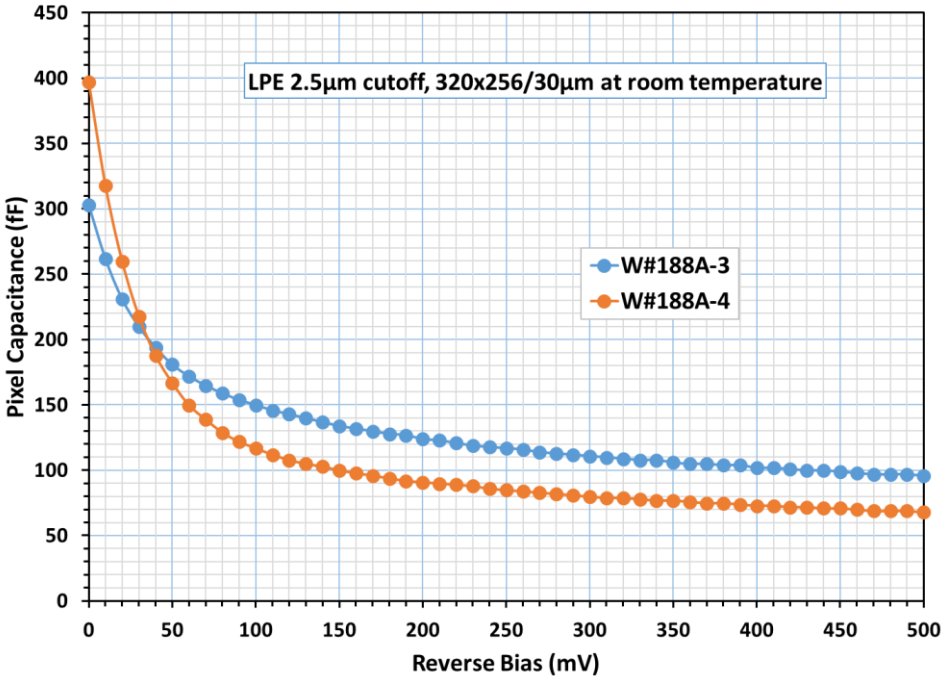
Bad Pixel Map and Pixel Capacitance

-70ºC



2.5µm MBE, #193A-11, -70ºC, High Gain,
Operability = 99.95%

Room Temperature



- Excellent operability, no bad pixel cluster
- C_d ~ 100fF at reverse biases

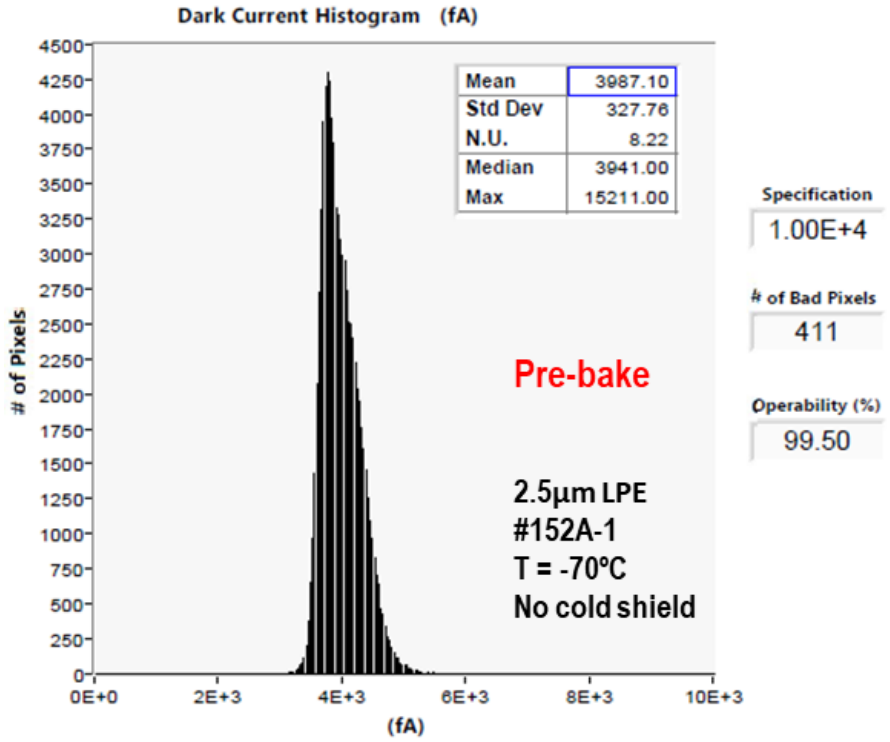
2.5µm FPA Imaging at -70ºC

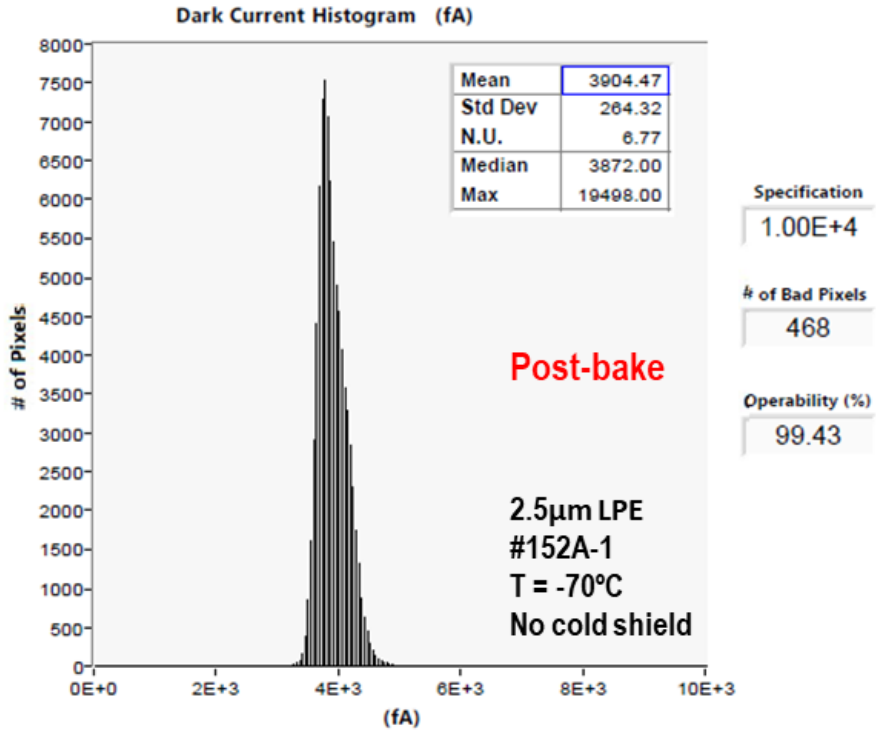
Reflective image under bright room light

Thermal image in the dark

- Similar FPAs, similar camera setup

Bake-ability Test, 136h/80ºC in Vacuum Oven

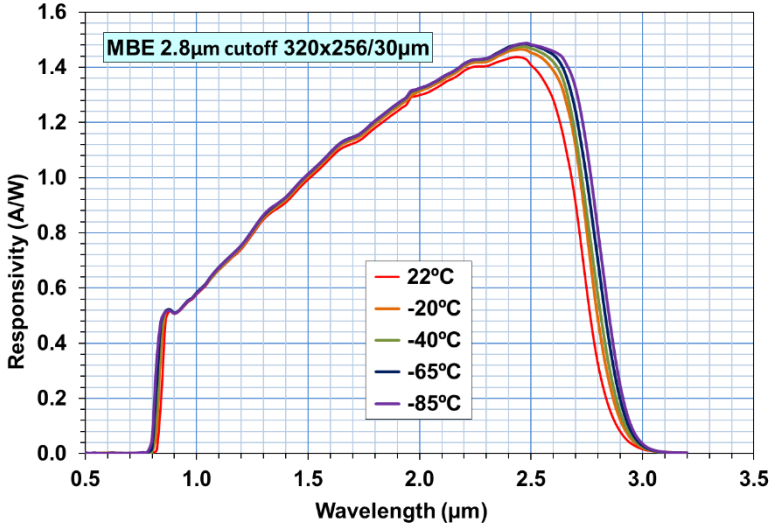


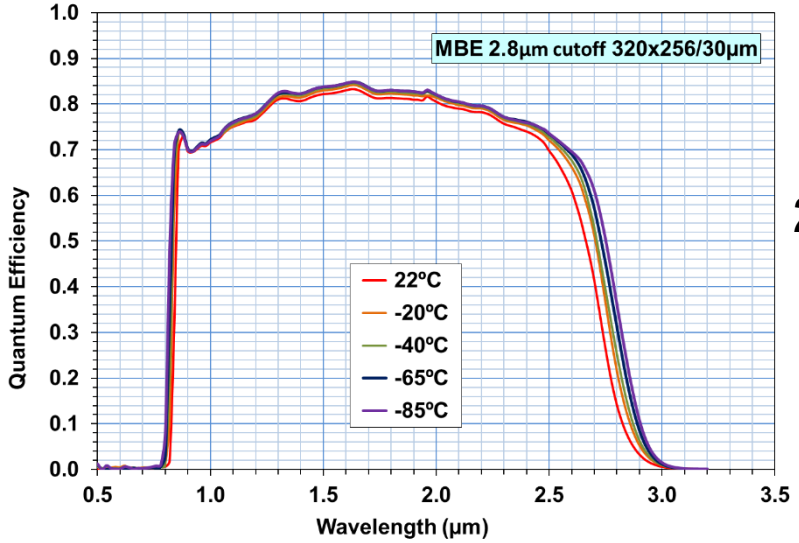


- 2.5µm LPE, -70ºC, no cold shield
- Mean I_d: 4.0pA → 3.9pA
- NU: 8.2% → 6.8%
- Bad pixel count: 411 → 468
- Operability: 99.50% → 99.43%

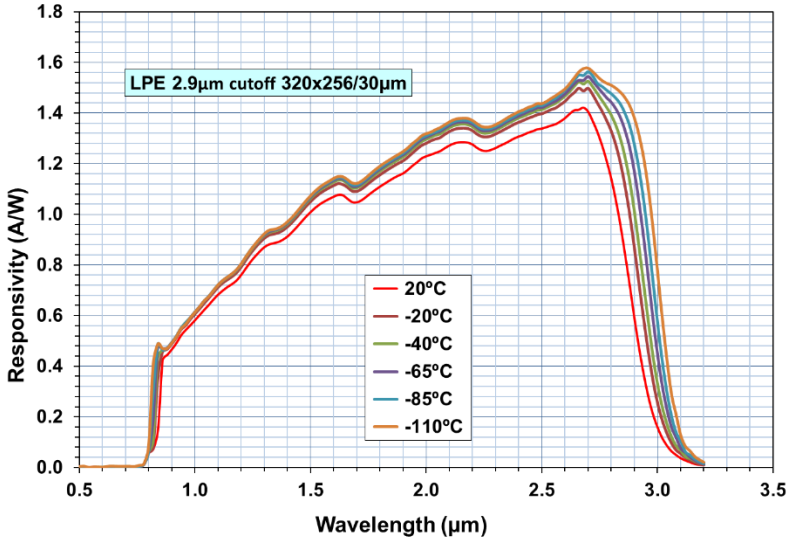
No performance degradation

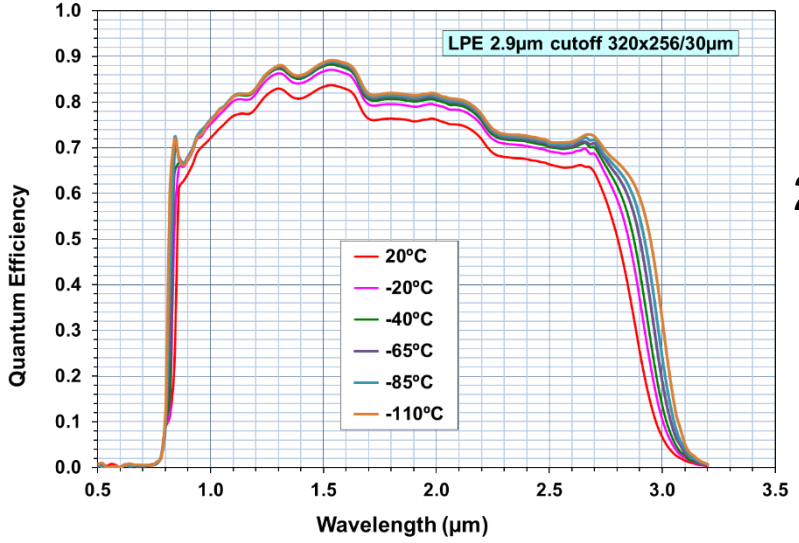
2.9µm FPAs, Spectral Responsivity & QEAs





2.8µm MBE

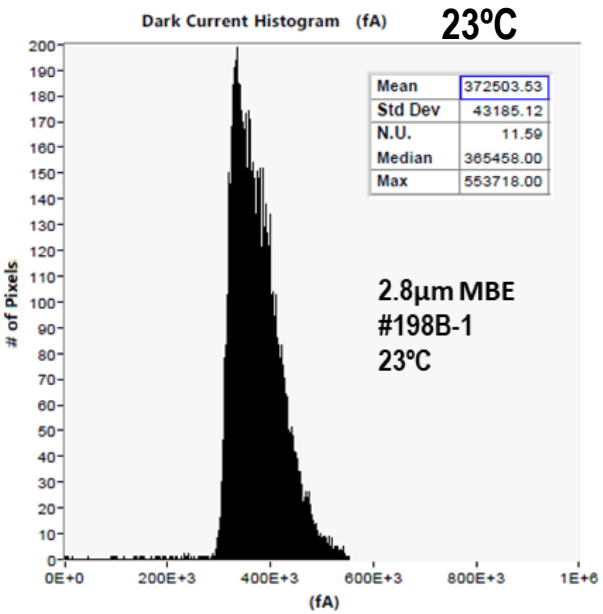


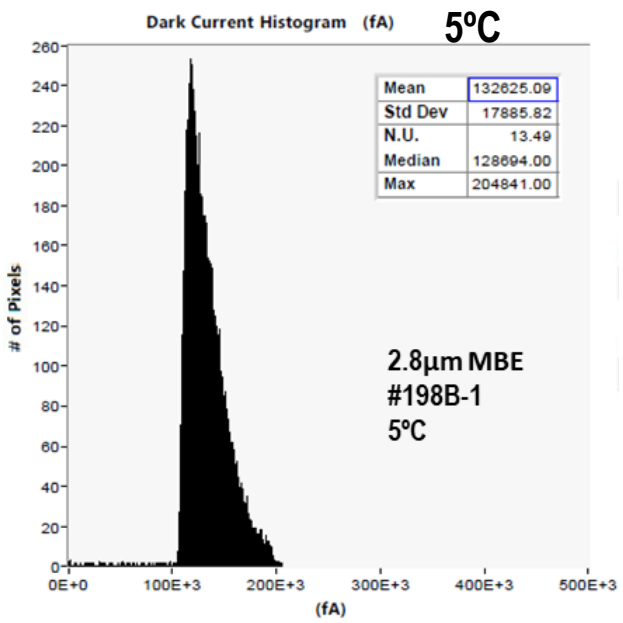


2.9µm LPE

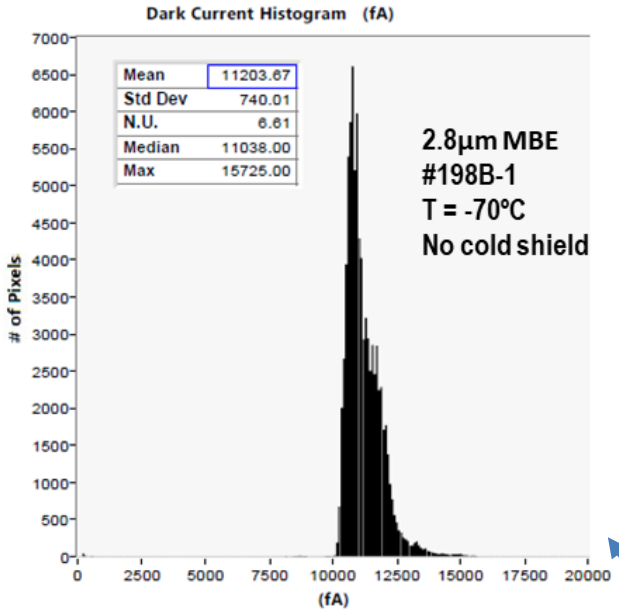
- **Peak QE ~85%, single layer ARC**

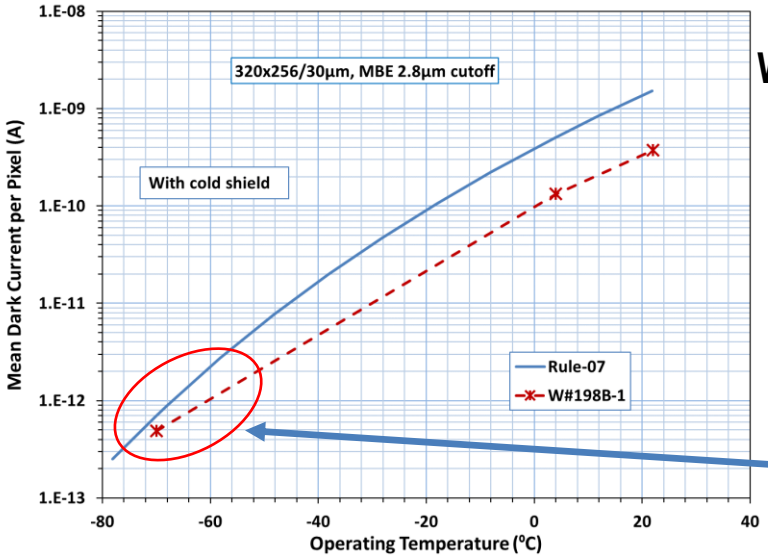
"Dark" Current Histogram and Temperature Dependence





- **Background photocurrent dominant at -70ºC with FOV ~ 100º, 23X higher than dark current (11.2pA vs. 487fA)**
- **Dark current ~4X lower than Rule-07 model at high temperatures (> -30ºC)**
  - –Low temperature I_d data affected by background leak and/or camera electronics
- **2.8µm MBE**



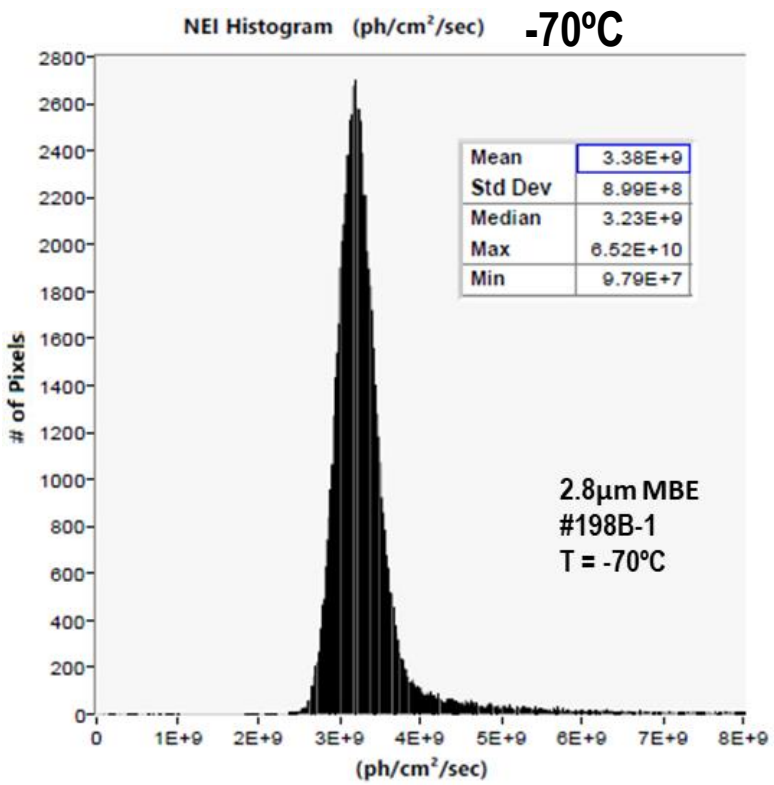


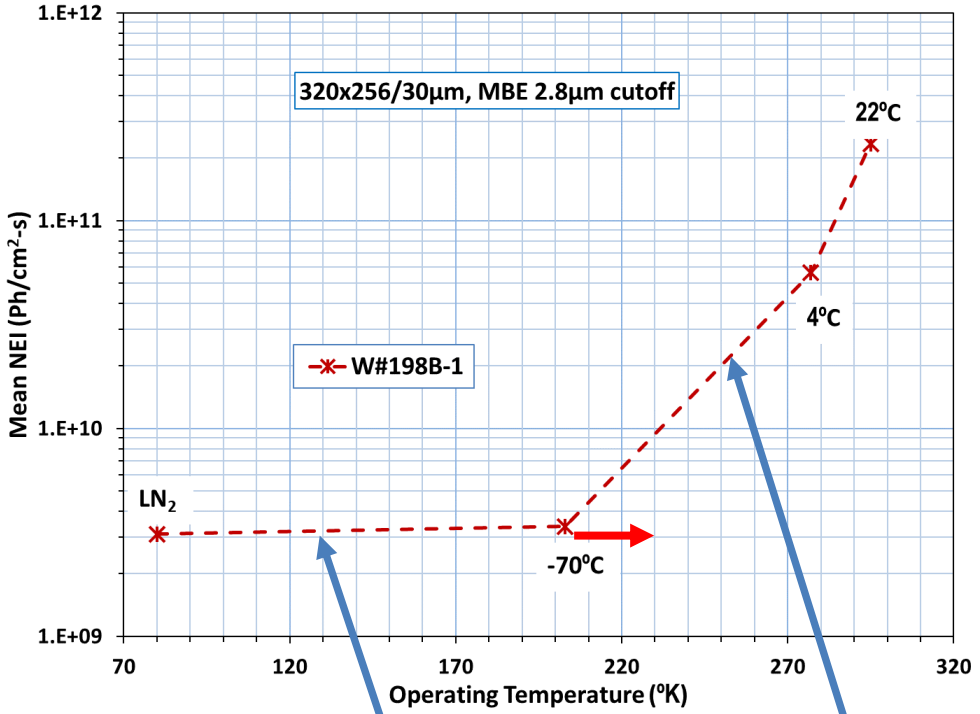
With cold shield

Background and/or camera limit

-70ºC, no cold shield

NEI Histogram and Temperature Dependence





- FOV ~100º, BPF = 1850-2400nm. NEI is background limited near and below -70ºC
- Typical NEI = 3.4E9 ph/cm²-s at -70ºC
- Lower NEI could be achieved under smaller FOV, or similar NEI value could be achieved at up to -40ºC

Background limit

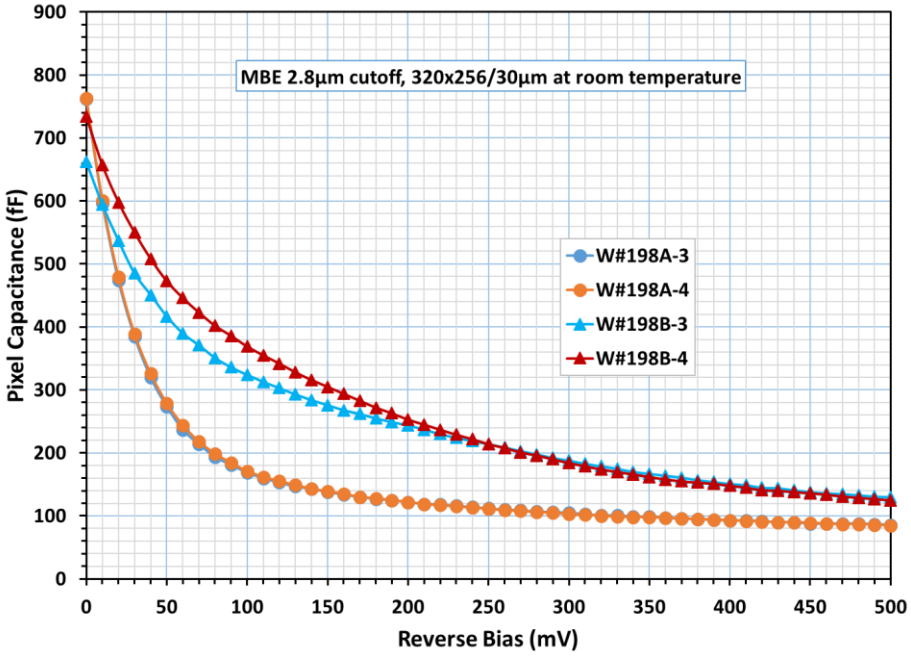
Thermal limit

Bad Pixel Map and Pixel Capacitance

-70ºC

2.8µm MBE, #198B-1, -70ºC, Low Gain,
Operability = 99.89%

Room Temperature



- Excellent operability, no bad pixel cluster
- C_d ~ 100-300fF at reverse biases

2.9µm FPA Imaging at -70ºC

Reflective image under bright room light

Thermal image in the dark

- **Same FPA, same camera setup, taken at same time, looking at same scene**

Summary

- **Excellent operability and detector yield achieved with state-of-the-art Teledyne MBE materials on CZT and a P-on-n mesa structure based process**
  - 2.5µm and 2.9µm cutoff SWIR FPAs
  - Typical operability ~99.9% with few or no bad pixel cluster
  - Low cost production
- **Dark current matches or below Rule-07 at high temperatures (> -70ºC)**
  - 275pA and 372pA at room temperature for typical 2.5µm and 2.9µm FPAs respectively
  - 195fA and 487fA at -70ºC for typical 2.5µm and 2.9µm FPAs respectively
- **NEI limited by background at -70ºC with FOV ~100º**
  - 1.9E9 Ph/cm^2-s for best 2.5µm FPA
  - 3.4E9 Ph/cm^2-s for typical 2.9µm FPAs
- **NEI would be even lower under smaller FOV**
  - Similar NEI could be achieved at higher temperatures, up to -55ºC for 2.5µm FPAs and up to -40ºC for 2.9µm FPAs
- **Peak QE ~85% with a single layer AR coating**
- **Pixel capacitance ~100-300fF at reverse bias of 100-200mV**

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