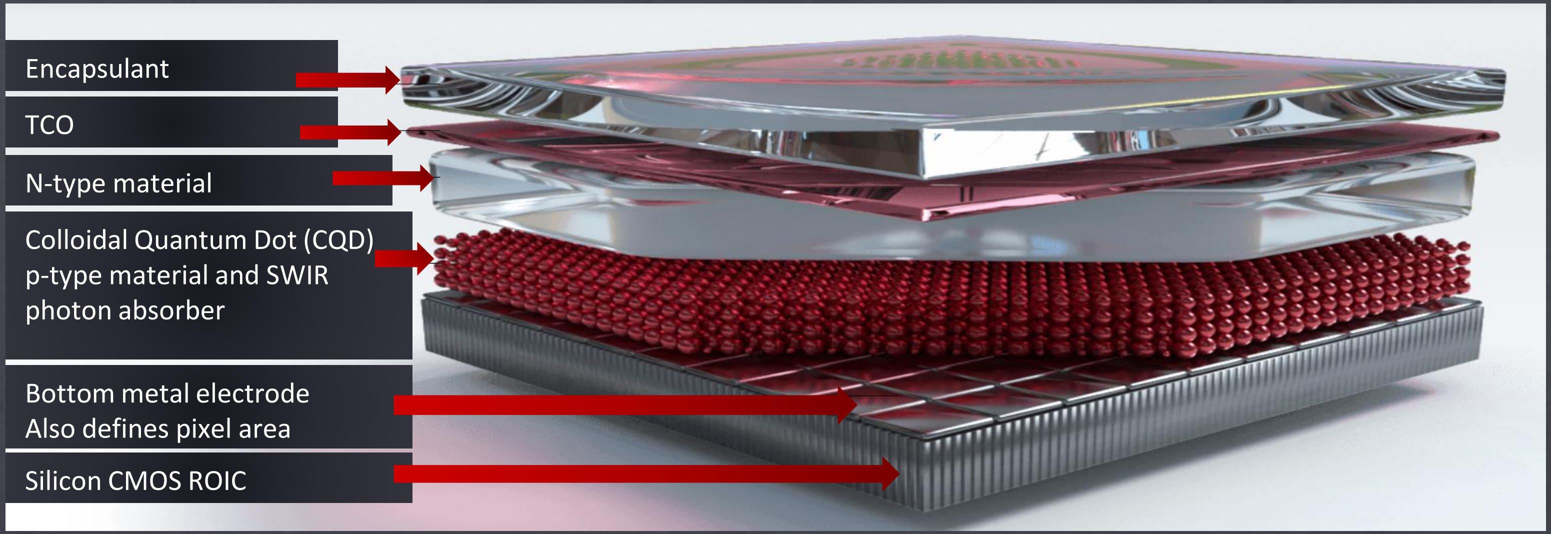
SWIR VISION SYSTEMS

High definition, low cost, CQD sensor technology demonstrated in laser marking / designating application(s)

Defense and Commercial Sensing
May 2023

Colloidal Quantum Dot CQD® Detector Overview



- ✓ Novel SWIR sensor fabrication method. Monolithic fabrication directly on 8” or 12” CMOS ROIC wafers. No flip chip bonding. Low-cost materials.
- ✓ High-resolution - 12MP demonstrated
- ✓ Small pixel pitch - 3 um demonstrated, capable of sub 2 um
- ✓ Simple fabrication process expected to scale to front-side CMOS prices at corresponding scale
- ✓ Low noise. High dark current doubling temperature. Uncooled.
- ✓ Best-in-class uncooled E-SWIR sensitivity
- ✓ Tunable bandgap which can be paired with wavelengths of interest (e.g. 940, 1380, 1550, 2100 nm)
- ✓ Broadband response from ~250 nm to 2.0 um

Acuros® CQD® SWIR Cameras Products

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Standard SWIR Cameras (-001s)

Acuros CQD SWIR 640
Acuros CQD SWIR 1280
Acuros CQD SWIR 1920

Extended SWIR Cameras (-002s)

Acuros CQD eSWIR 640
Acuros CQD eSWIR 1280
Acuros CQD eSWIR 1920

Laser Inspection SWIR Cameras (-003s)

Acuros CQD SWIR 640L
Acuros CQD SWIR 1280L
Acuros CQD SWIR 1920L

Lasers Inspection Extended SWIR Cameras (-004s)

Acuros CQD eSWIR 640L
Acuros CQD eSWIR 1280L
Acuros CQD eSWIR 1920L

400 to 1600nm

350 to 2000nm

CQD Image Example - DVI

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CMOS Visible camera

Acuros 1920 eSWIR camera

Why Use CQD Detectors in Laser Pulse Detection (LPD) Systems?

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	SWIR Vision CQD		InGaAs		SWIR Vision Advantage
Quantum Efficiency	✗	10-15% in commercial products Demonstrated 50%	✓✓	> 70%	None
Read noise	✓	60e- read noise for 15 um pitch (high gain)	✓	Varies but similar	None
Dark Current at RT	✓	~ 5 nA/cm^2, 25C	✓	~ 5 nA/cm^2, 20C	None
Dark Current at the handset and auto operating temps	✓	Doubling temperature = 10.5C Jd (85C) = 190 nA/cm2 Jd (105C) = 700 nA/cm2	✗	Doubling temperature = 7.5C Jd (85C) = 2,000 nA/cm2 Jd (105C) = 12,000 nA/cm2	Lower dark current at elevated operating temps
Pixel Size	✓	Sub- 2μm	✗	Best in class = 5μm < 5μm not expected	Reduced SWAP-C. Enables very high resolution at low cost
Spectral range	✓✓	~ 250 nm – 2.0 um	✓✓	TBD-Expected to be good	Best in class uncooled e-SWIR SNR. e-SWIR more covert
Thermal Reliability	✓	Demonstrating MIL-STD	✓	Fielded	
Volume Scalable	✓	Scaling to 8/12" wafers	✗		Si substrate = large wafers = low cost
Low Cost Scalable	✓✓	Low materials and processes	✗	Does not easily scale to unmounted price requirements	Very low cost. Plans to enter consumer market

CQD detectors are cheaper, smaller, and uncooled eSWIR even more covert

Are CQD Detectors Fast Enough for LPD Applications?

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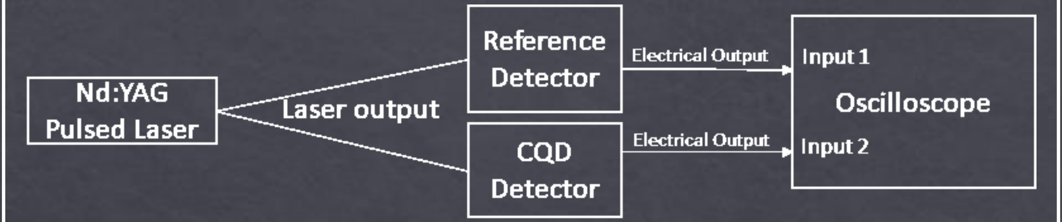
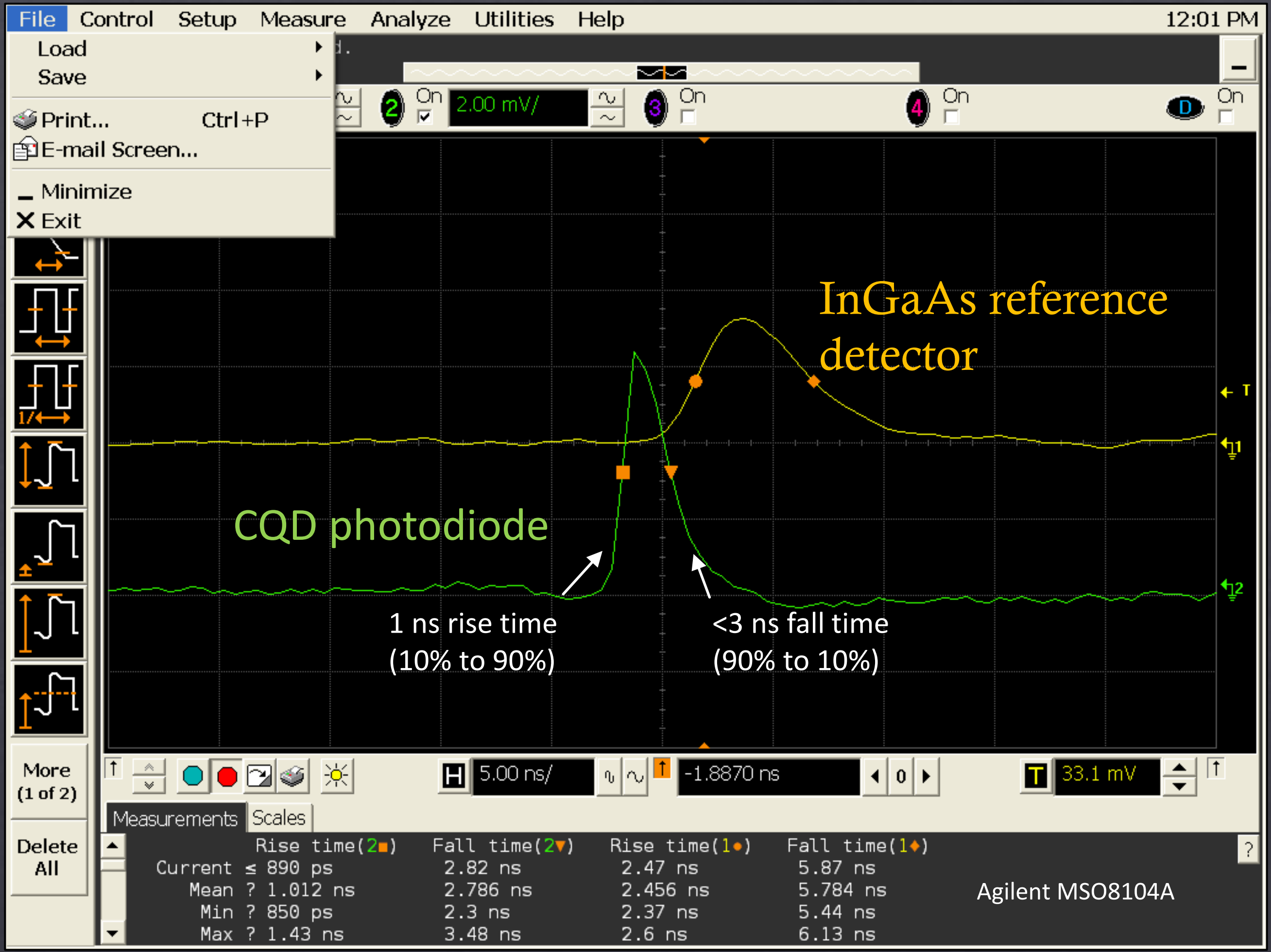
Response time measurement setup



SWIR Vision Systems CQD photodiode:
- 200 um x 200 um pixel size
- 15 pF measured capacitance (using LCR meter)
- 400 nm to 1600 nm spectral response
- Dark current density: 5 nA/cm^2 @25 C

Reference photodiode:
- Thorlabs FGA015 InGaAs
- 150 um diameter
- 2 pF capacitance (from datasheet)

Nd:YAG pulsed Laser, 1064 nm, 5 Hz rep rate



CQD's sub 5 ns rise/fall times are more than sufficient for typical laser pulse detection (LPD) applications

Are CQD Detectors Reliable Enough for Field Use?

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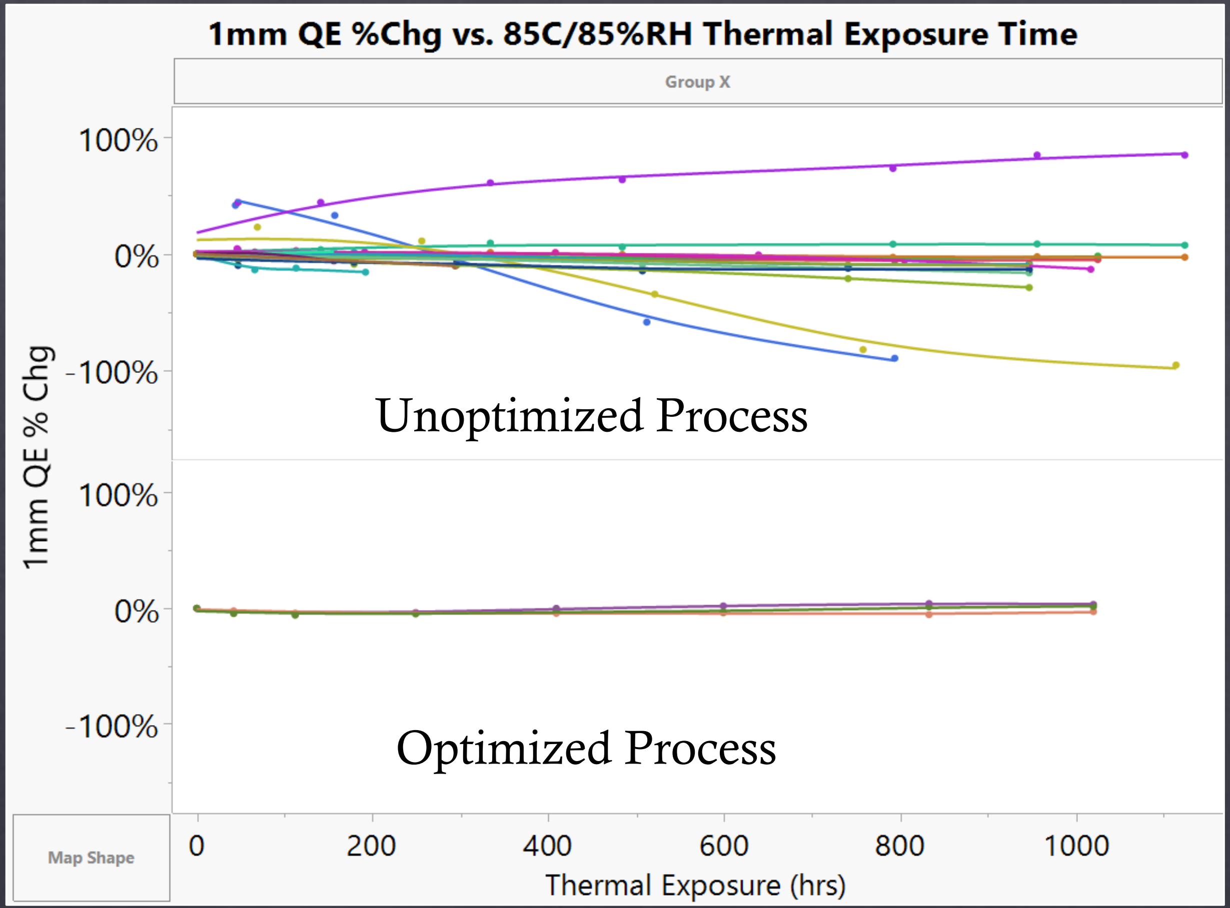
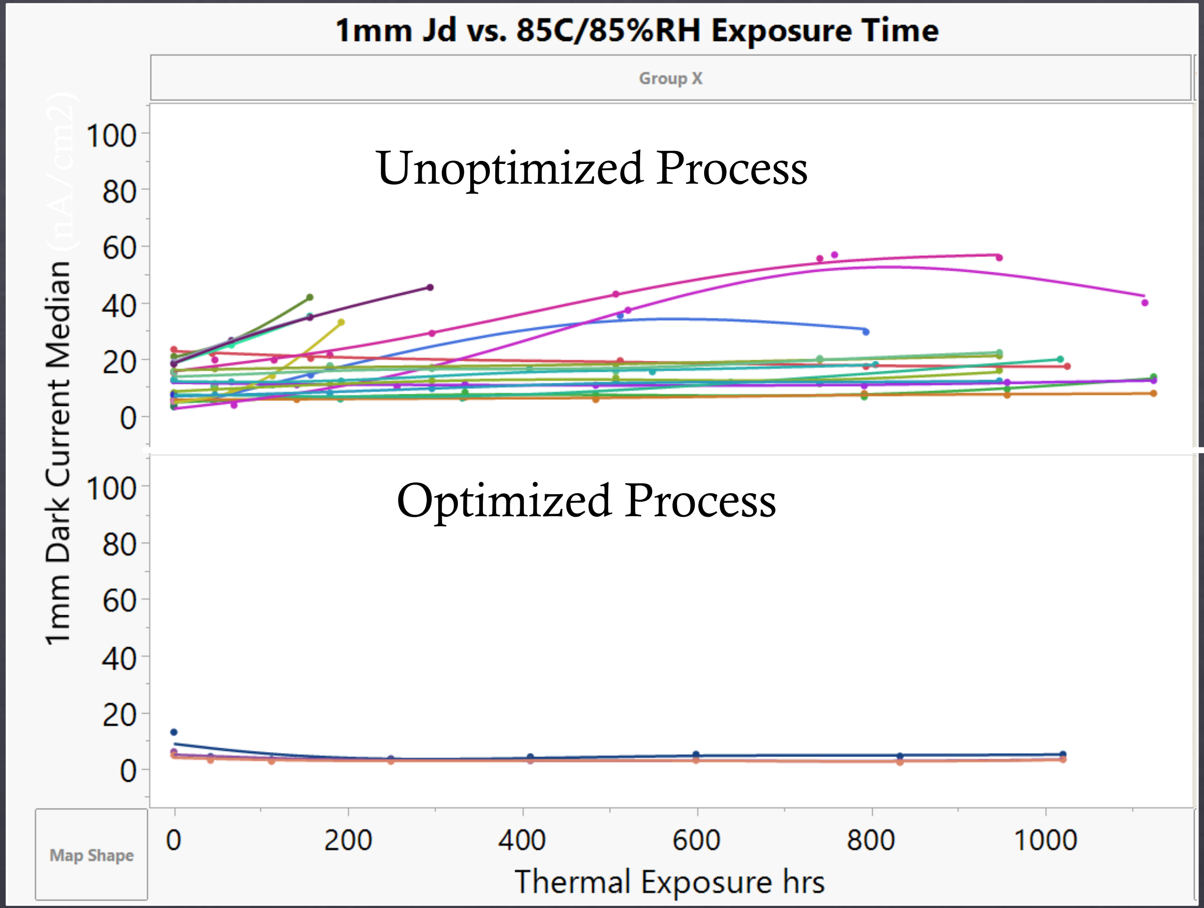
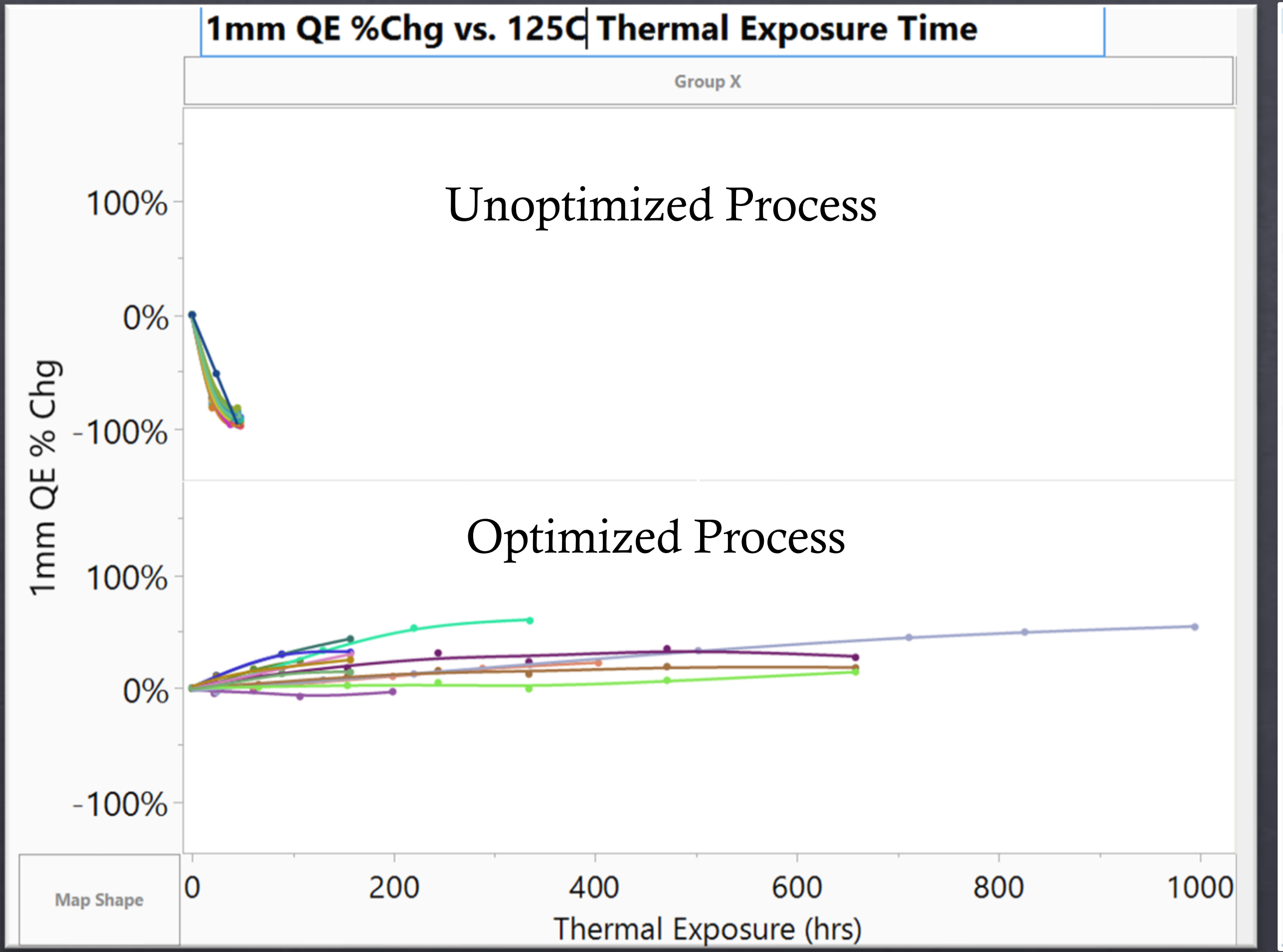


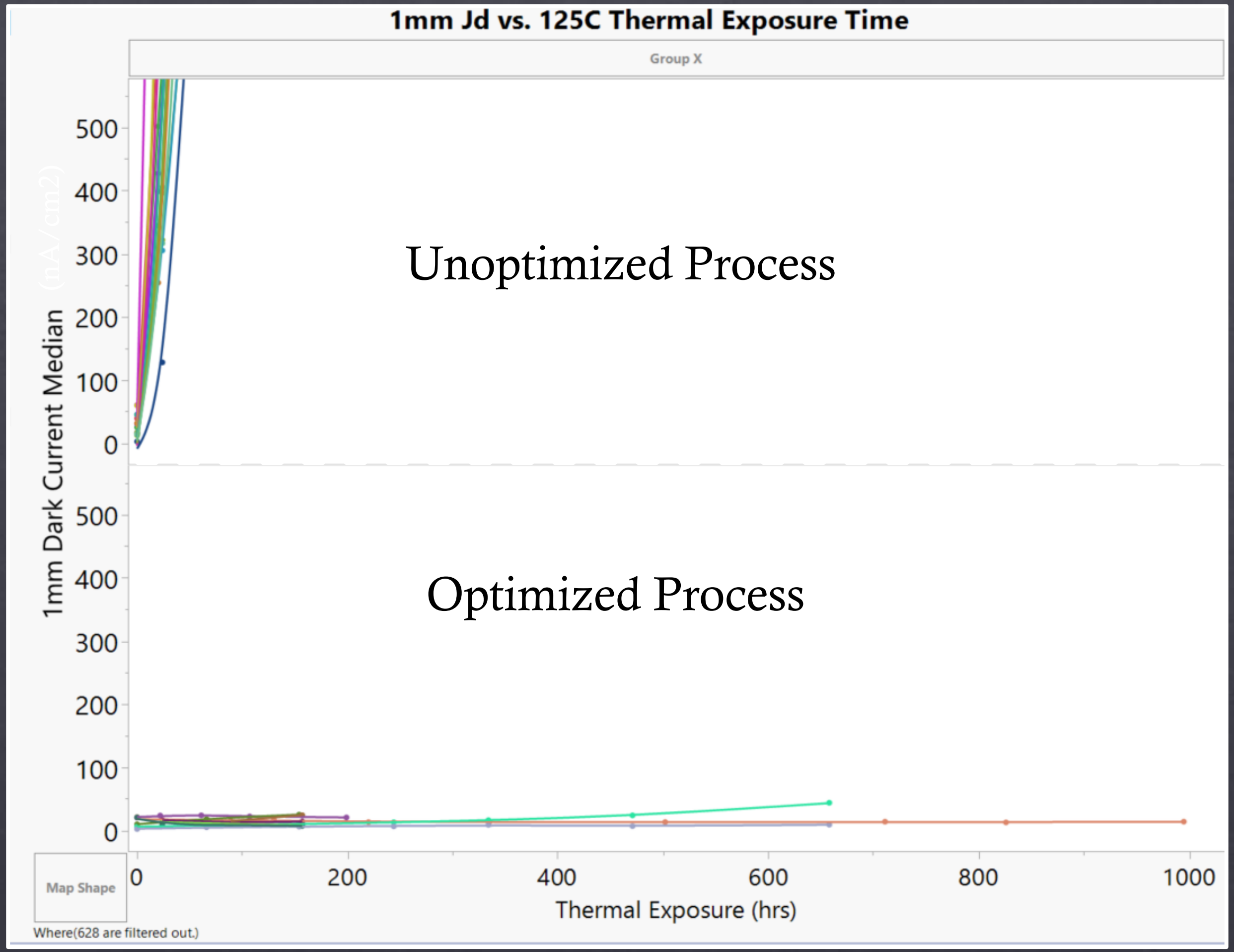


QE% change and Jd vs 85C/85%RH stress time. Each line represents a separate passive substrate. Four 1mm x 1mm diodes measured on each substrate. Median value of the four diodes is reported.

CQD Detectors now survive 85C/85%RH 1000 hr accelerated stress test

Are CQD Detectors Reliable Enough for Field Use?





QE% change and Jd vs 125C stress time. Each line represents a separate passive substrate. Four 1mm x 1mm diodes measured on each substrate. Median value of the four diodes is reported.

CQD Detectors now survive 125C 1000 hr accelerated stress test

Are CQD Detectors Sensitive Enough for LPD Applications?

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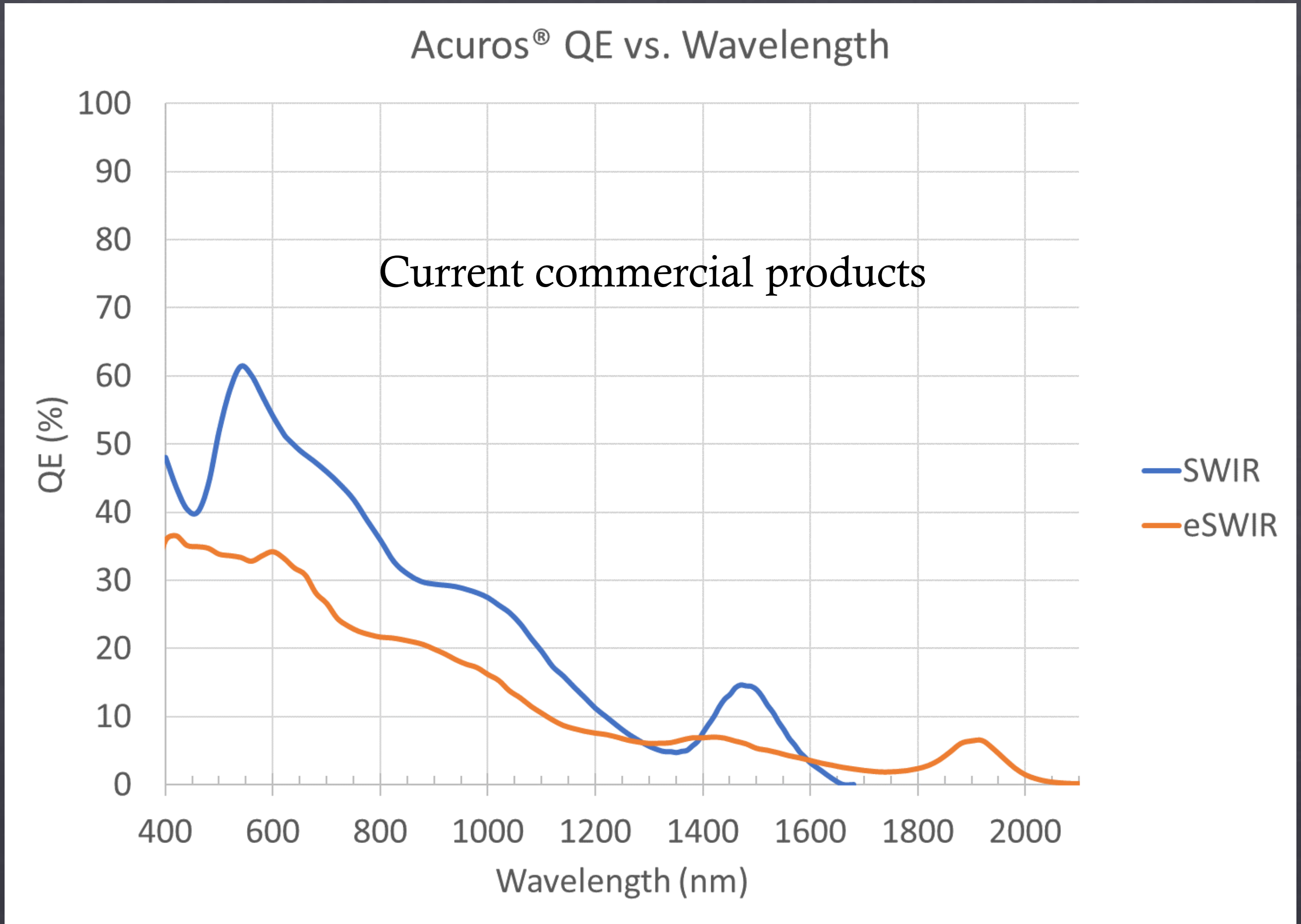

CQD detectors have lower QE. Is existing QE "good enough" for LPD applications?

Experimental Setup – High Level Description

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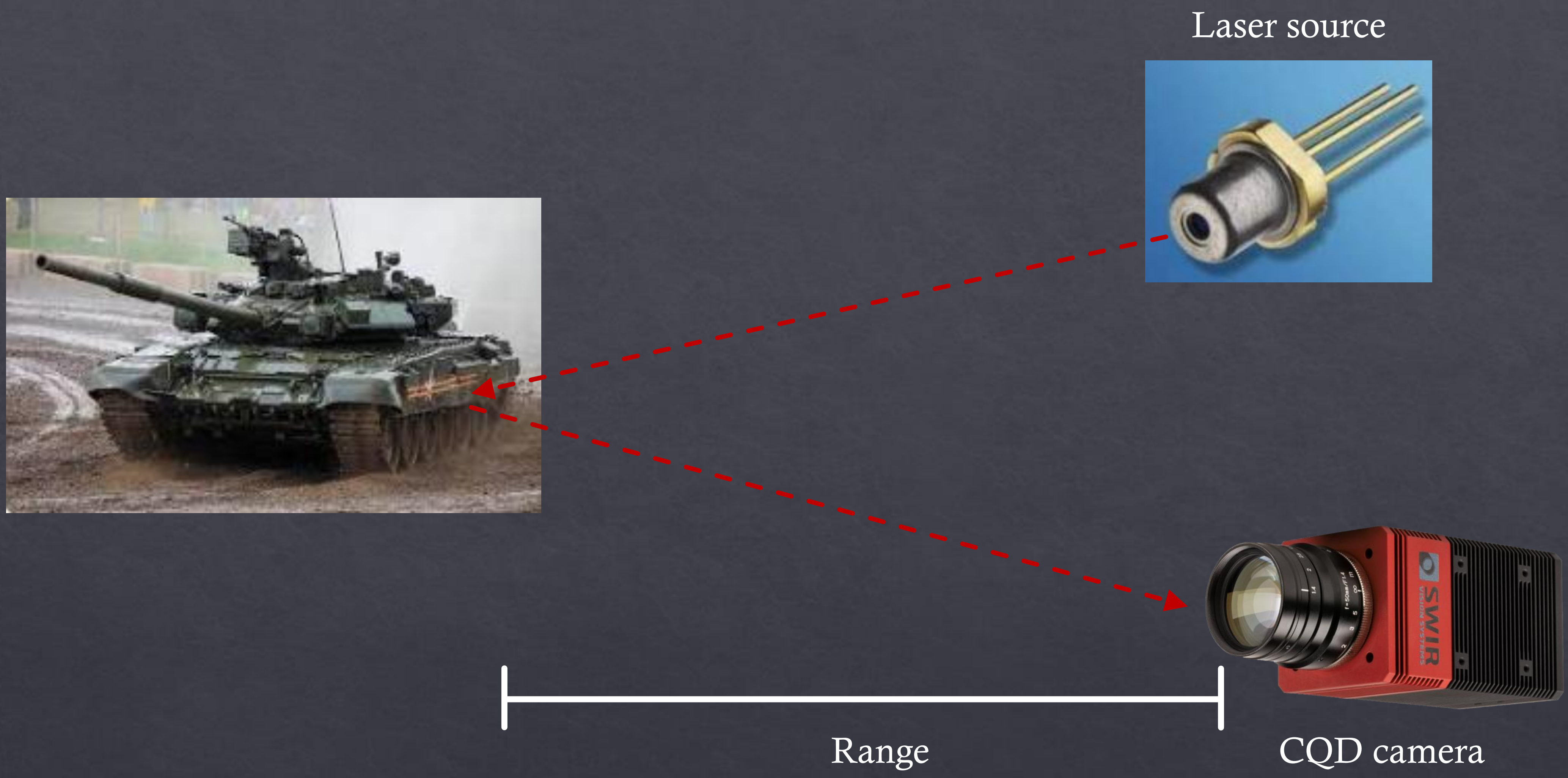
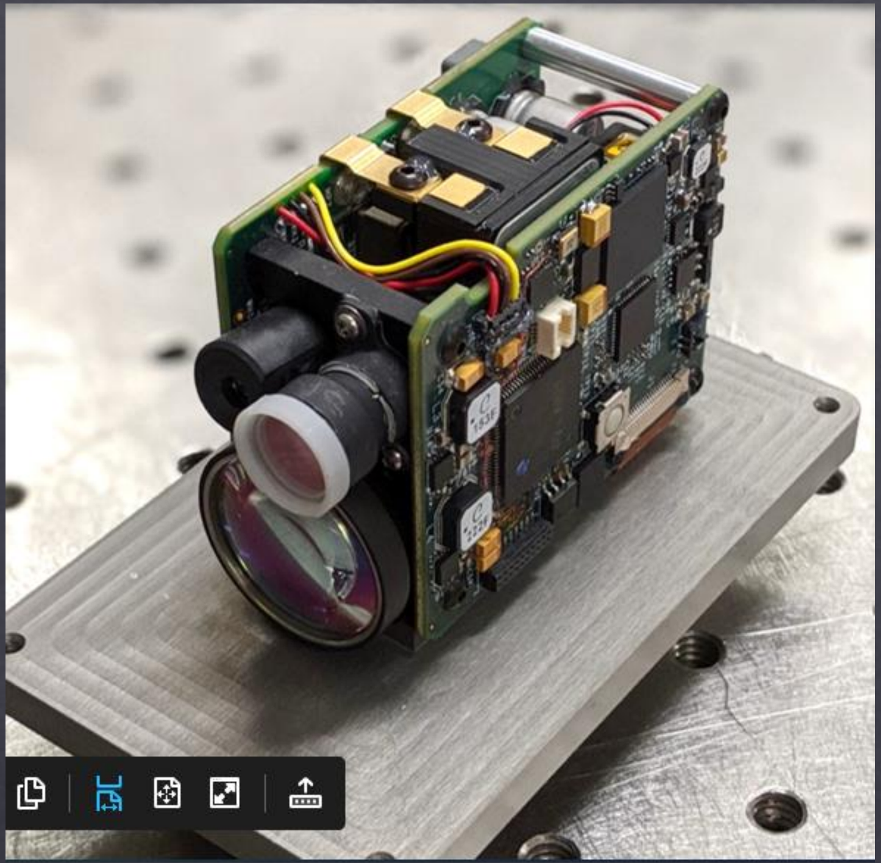


Experimental Setup – Laser and Targets



Target	Description	Range (m)	Size	Reflectivity
1	NATO target	200 m	2.4 x 2.4 m	~10%
2	NATO target	1000 m	2.4 x 2.4 m	~ 10%
3	Tank	1800 m	Tank	30-40%
4	NATO target	2000 m	2.4 x 2.4 m	~10%

- 1.535 um, 5 mJ, laser range finder / marker
- 15 ns pulse width
- 5 hz rep rate

Experimental Setup – Acuros Camera

Camera = Acuros 1920 GigE 001

Exposure time = 0.5 ms

Gain mode = high gain (25Ke-)

Lens = 100 mm f/2.1 SWIR coated

Filter = 1535 nm band-pass filter, >60% transmission, 10 nm FWHM

ALPD = No – existing ROIC does not have ALPD capability

External trigger = Yes – synched with laser

TEC Temp = 10C

Results – 200 Meter - NATO Target

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Acuros Camera can detect LRF at 200 meters

Results – 1000 Meter - NATO Target

Acuros Camera can detect LRF at 1000 meters

Results – 1800 Meter - Tank

Acuros Camera can detect LRF at 1800 meters

Results – 2000 Meter - NATO Target

Acuros Camera can detect LRF at 2000 meters

CQD and InGaAs Comparison

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Camera	Lens	Exposure time	Filter	FOV (@ 200 m)	Pixels on target
CQD Acuros (1920 x 1080)	100 mm f/2.1	0.5 ms	1535 BP filter	1.8 km2	6,400
InGaAs (640 x 512)	83 mm f/2.6	0.5 ms	None (ALPD-capable)	0.4 km2	4,444

CQD enables lower cost, wider FOV, and/or more pixels on target