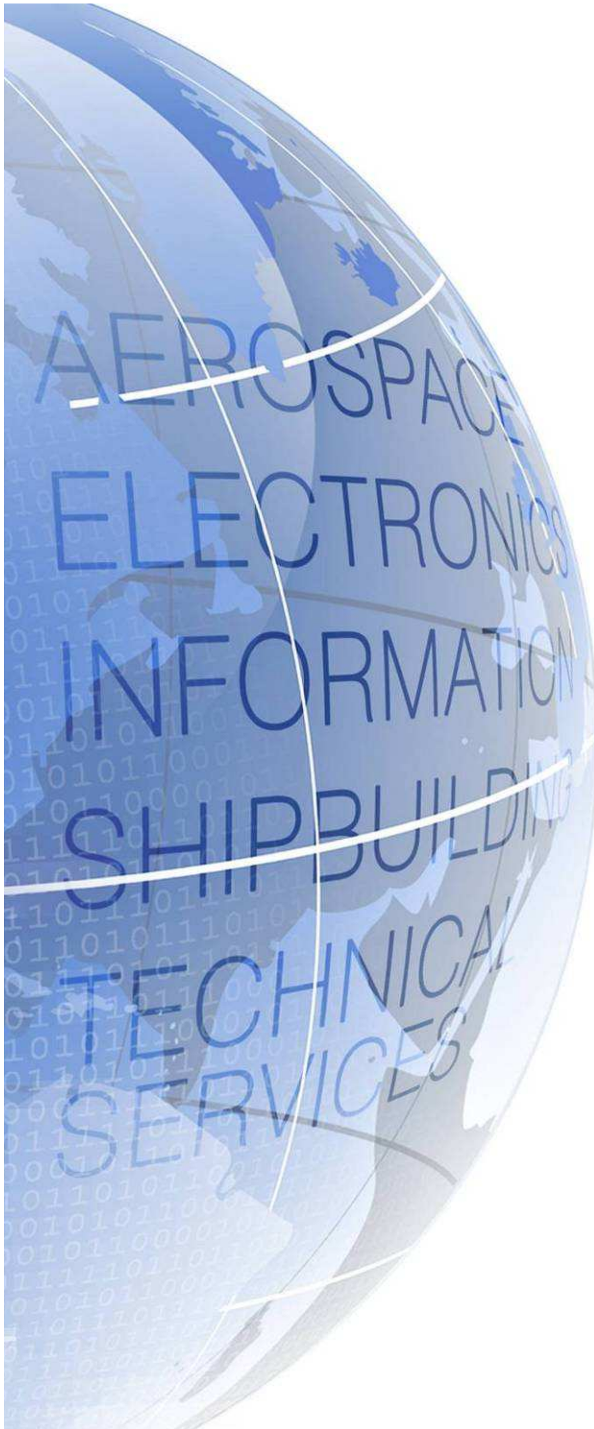

NORTHROP GRUMMAN

Requirements and Candidates for Ladar Single-Photon Detector Arrays

KISS Workshop
Single-Photon Counting Detectors
January 25-29, 2010

William Cottingame, PhD

Placeholder

Charts temporarily withheld pending authorization for public release

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NORTHROP GRUMMAN

MBE Based HgCdTe APDs and 3D LADAR Sensors

The 2009 U.S. Workshop on the Physics and Chemistry of II-VI Materials, October 6-8, 2009, Chicago, Illinois, USA

Dr. Michael D. Jack
Raytheon Vision Systems
805-562-2395

Excerpts 1-26-10

The following charts were provided by Raytheon Vision Systems and are cleared for public release by Raytheon and their sponsors

High Performance HgCdTe APDs Provide High Gain with No Excess Noise

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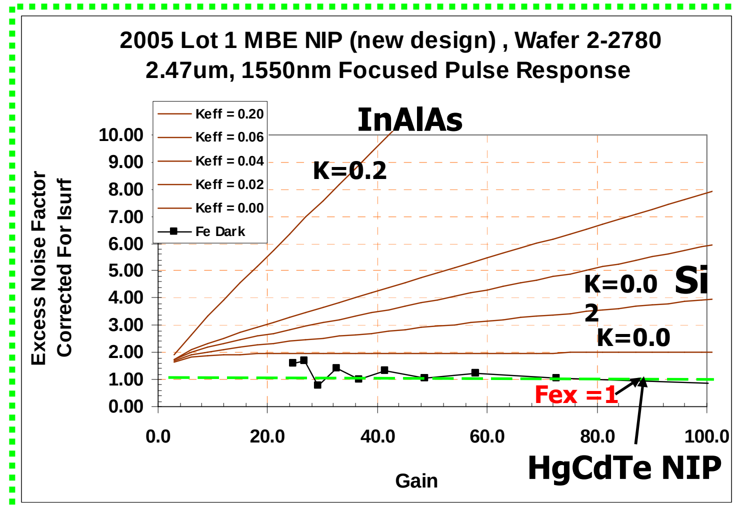
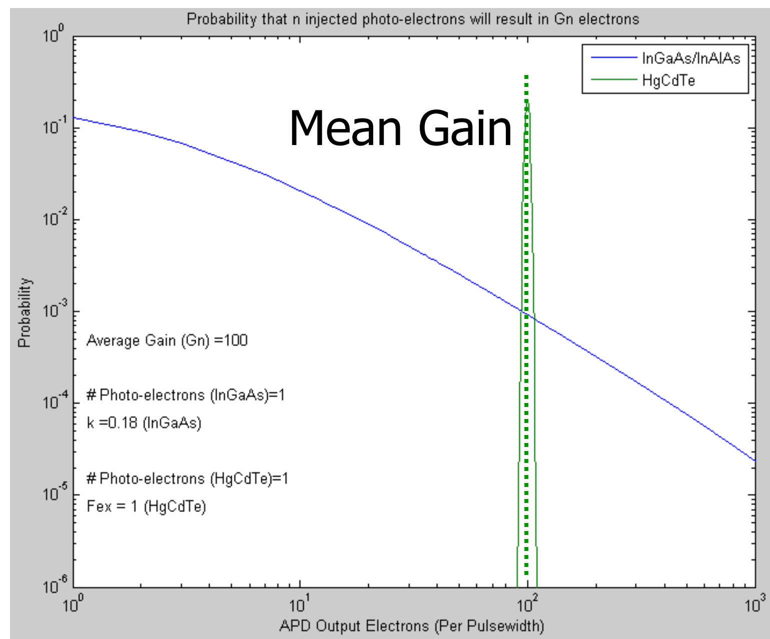
- Most APDs obey the Macintyre excess noise equation

$$F_e = k_{eff} M_e + (2 - 1/M_e)(1 - k_{eff})$$

- HgCdTe electron injection show gain and excess noise properties indicative of single ionization carrier gain
  - **Excess Noise is ~1 (Ideal Amplifier)**
- Significance: electron event to even gain probability is higher
  - Achieves a higher probability of detection

HgCdTe has a significant performance advantage over competing materials





2nd Gen MBE Engineered APDs Have Enabled Ultrahigh Performance at 300K

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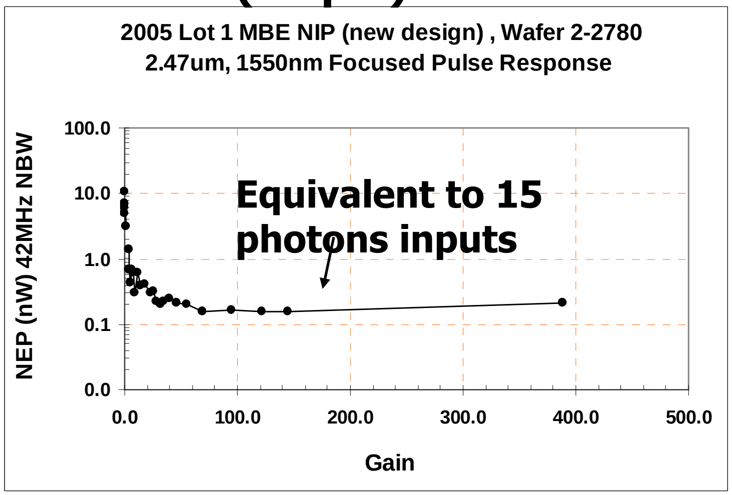
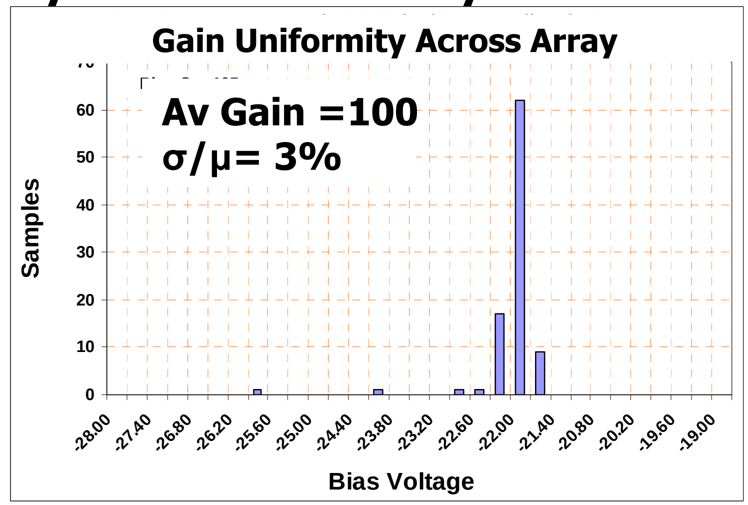
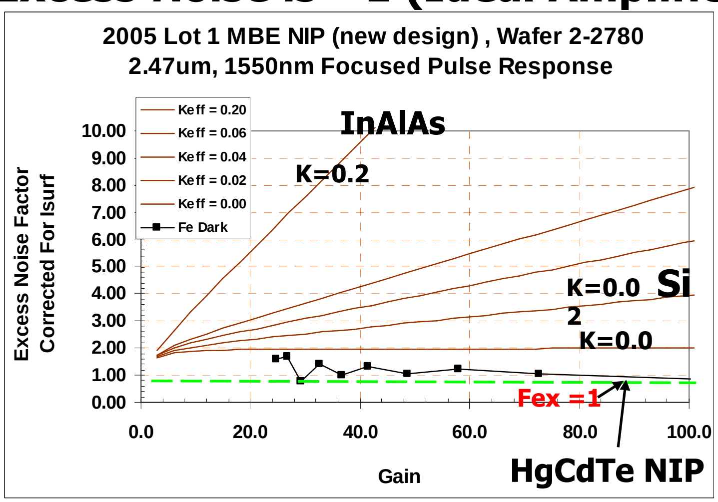
NEP is 0.15nW (15 ph.) to Gain of >300!!!



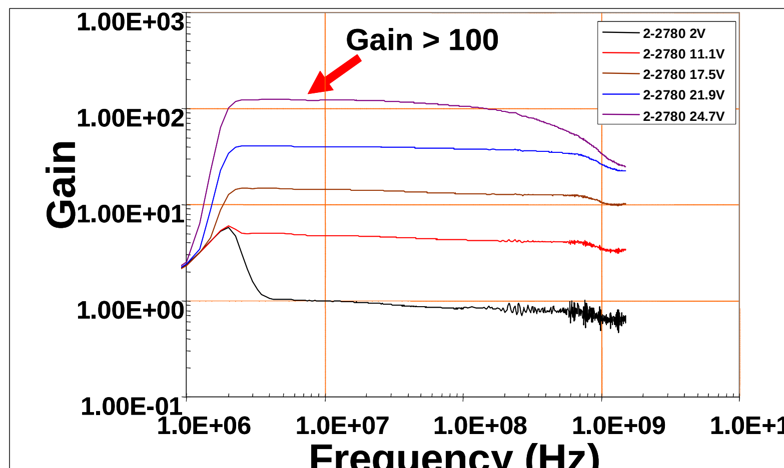
Only 3% Nonuniformity at Gain =100



Excess Noise is ~1 (Ideal Amplifier)



>1 GHz BW at Gain = 100



MBE HgCdTe APDs Provide M>100, Fex ~1 & GHz BW at 300K

Ultralow Dark Current and Photon Counting for Cryocooled APDs

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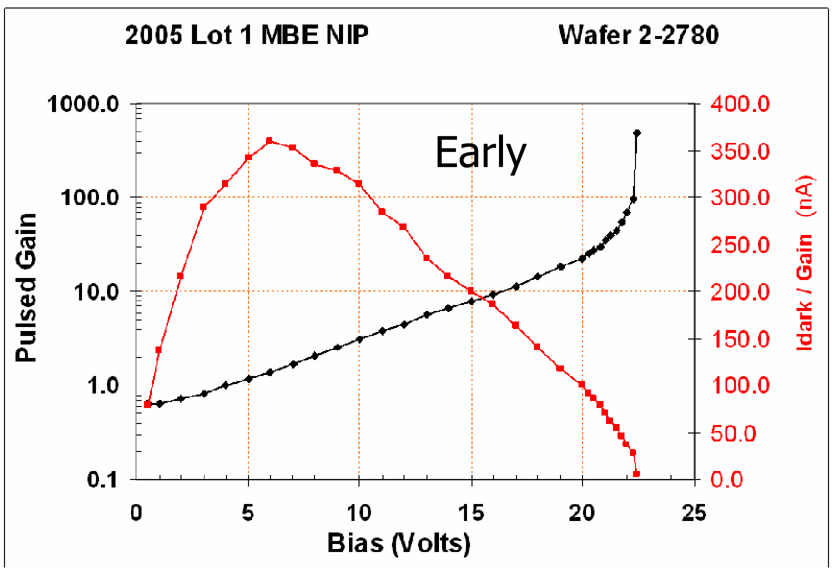
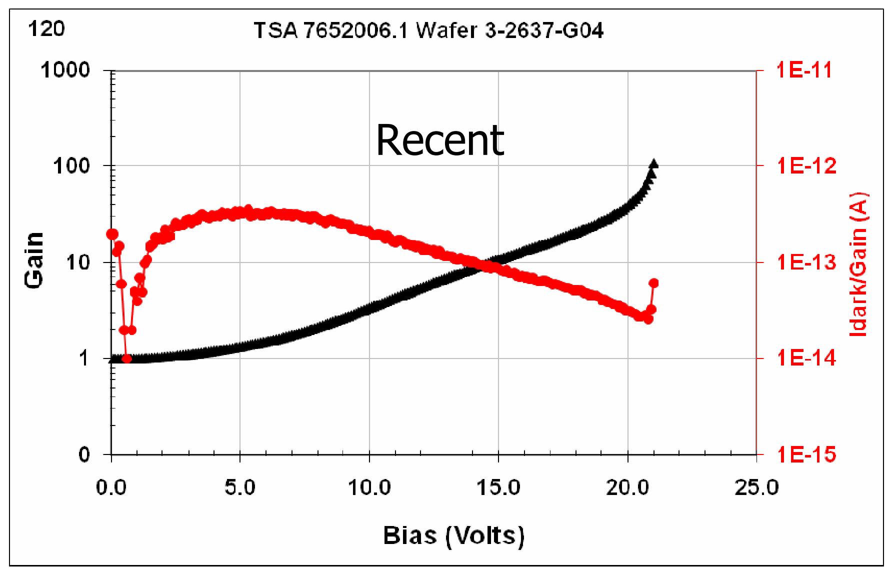
- Demonstrated devices for Photon Counting Application
  - Idark/Gain < 5E-14 A. (bulk dark count lower)
  - Maintain Fex ~1.
  - Cryogenic Operation.
- Surface leakage component greatly decreased in recent devices.





Photon Counting devices Demonstrated

HgCdTe Single-Photon Detection Output Examples
Statistics Match Closely to Poisson Statistics

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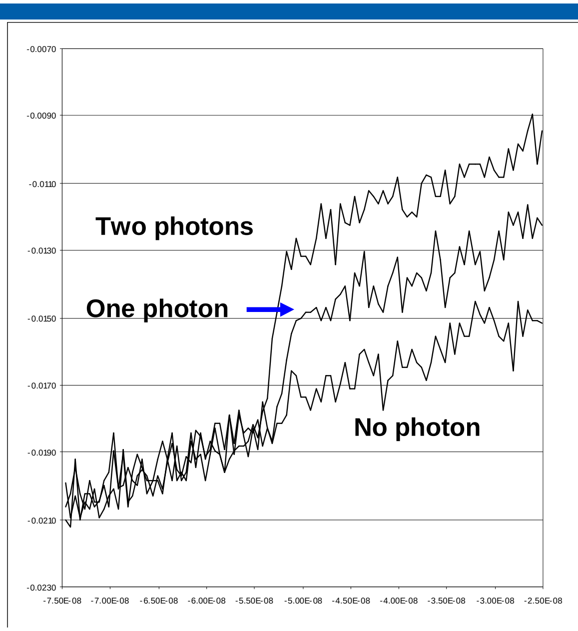
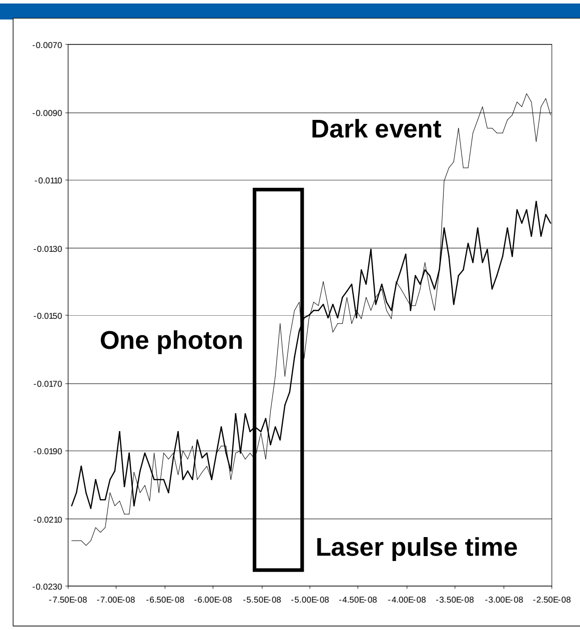
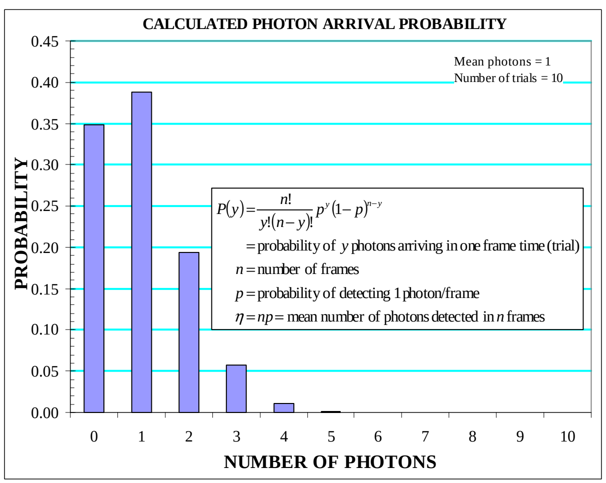
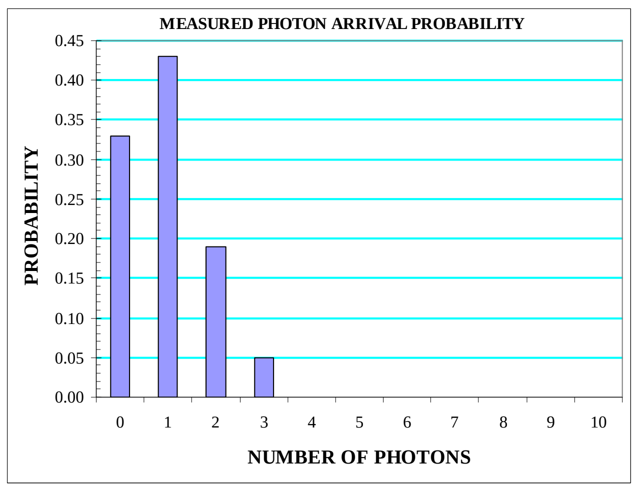




Measurements
at 280°K





Probability	Calc	2V Pulse
0 photons	0.35	.33
1 photon	0.39	.43
2 photons	0.19	.19
3 photons	0.06	.05

Waveform Shows Two Single Photon Pulses Spaced at 6 ns

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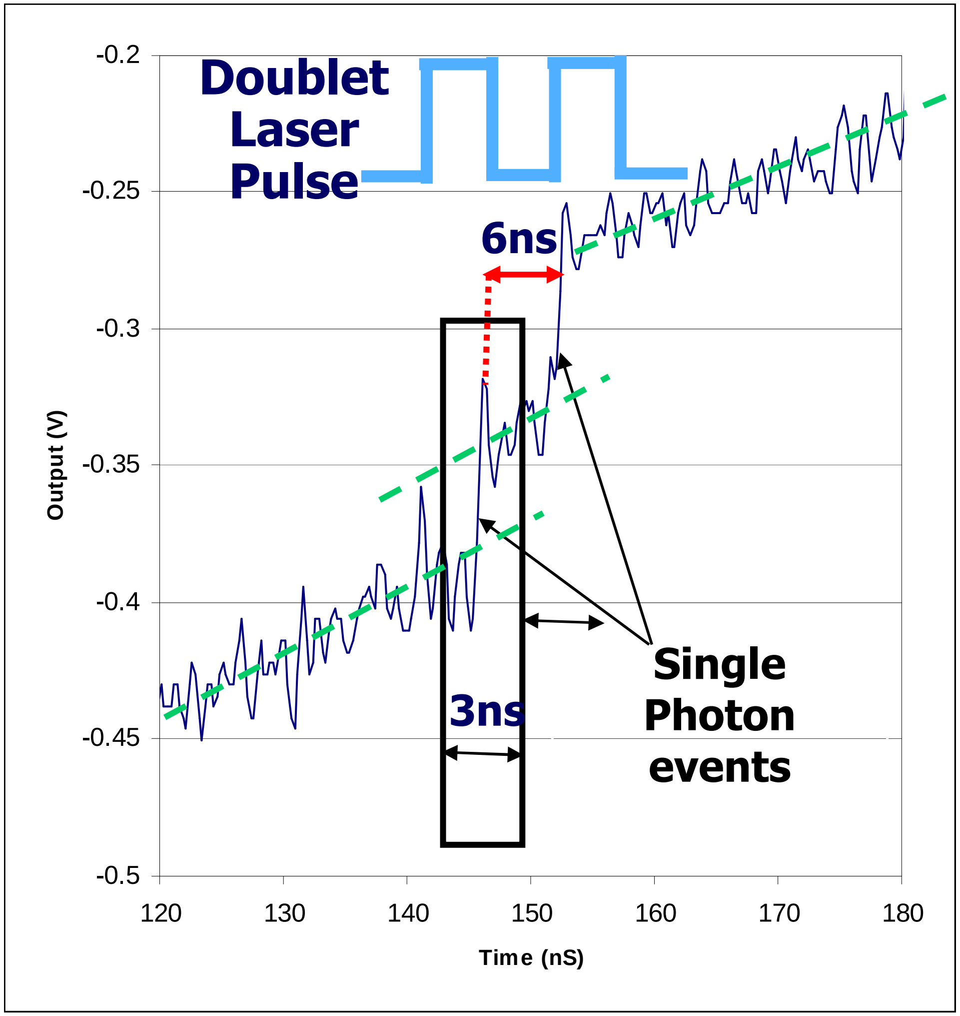

One Single frame acquisitions on one pixel from a 4 x 4 array

Doublet Laser Pulse with 6ns spacing <u>limited</u> by minimum setting of pulse generator

4x4 assembly 7617614

HgCdTe Detector 2-2780-J22

Bias -18.1V at 180K

100nS integration time

<u>Two 3nS laser pulses</u>

<u>< 1> photon/pulse</u>

Linear mode detection makes it possible to detect closely spaced targets