Requirements and Candidates for Ladar Single-Photon Detector Arrays

KISS Workshop
Single-Photon Counting Detectors
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Placeholder

Charts temporarily withheld pending authorization for public release
MBE Based HgCdTe APDs and 3D LADAR Sensors

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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

- Most APDs obey the Macintyre excess noise equation
  \[ F_e = k_{\text{eff}} M_e + (2 - 1/M_e) (1 - k_{\text{eff}}) \]

- HgCdTe electron injection show gain and excess noise properties indicative of single ionization carrier gain
  - Excess Noise is \( \sim 1 \) (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

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

- Demonstrated devices for Photon Counting Application
  - $I_{\text{dark}}/\text{Gain} < 5\times 10^{-14}$ A. (bulk dark count lower)
  - Maintain Fex $\sim 1$.
  - Cryogenic Operation.

- Surface leakage component greatly decreased in recent devices.
HgCdTe Single-Photon Detection Output Examples
Statistics Match Closely to Poisson Statistics

Measurements at 280°K

<table>
<thead>
<tr>
<th>Probability</th>
<th>Calc</th>
<th>2V Pulse</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 photons</td>
<td>0.35</td>
<td>.33</td>
</tr>
<tr>
<td>1 photon</td>
<td>0.39</td>
<td>.43</td>
</tr>
<tr>
<td>2 photons</td>
<td>0.19</td>
<td>.19</td>
</tr>
<tr>
<td>3 photons</td>
<td>0.06</td>
<td>.05</td>
</tr>
</tbody>
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\[
\text{Probability of } y \text{ photons arriving in one frame (trial):}
\]
\[
P(y) = \frac{\eta^n}{y! \eta^y} e^{-\eta} \quad \eta = \text{mean number of photons detected in } n \text{ frames}
\]
Waveform Shows Two Single Photon Pulses Spaced at 6 ns

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

Doublet Laser Pulse with 6ns spacing **limited** by minimum setting of pulse generator

4x4 assembly 7617614  
HgCdTe Detector 2-2780-J22  
Bias -18.1V at 180K  
100nS integration time  
Two 3nS laser pulses  
< 1 > photon/pulse

Linear mode detection makes it possible to detect closely spaced targets