Near-infrared single-photon-counting detectors for laser instrument applications at NASA Goddard Space Flight Center

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Abstract

We discuss single-photon-counting detectors requirements for NASA remote sensing and communications systems. We present experimental measurements on several different near-infrared single-photon-counting detectors including InGaAs/InP and InGaAs/InAlAs avalanche photodiodes (APD), an InGaAsP photocathode hybrid photomultiplier (PMT) and an InGaAs photomultiplier. We present the experimental performance of prototype instruments for laser ranging, communication, and trace-gas detection that use these detectors.

Single-Photon-Counting Detector Performance

We have conducted preliminary photon counting experiments at low temperatures (160 - 220 K) using a simple passive quenching circuit.

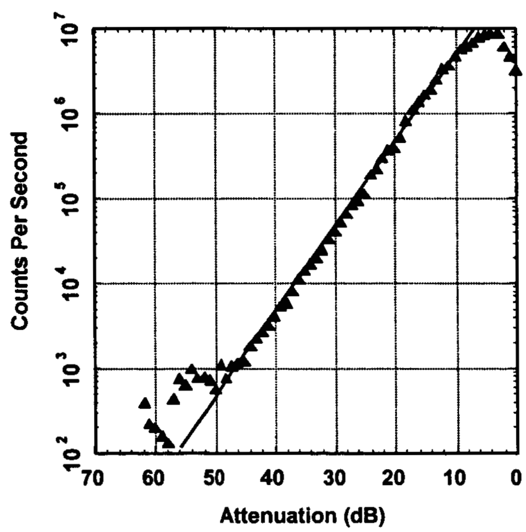

Figure 1. Dynamic Range and linearity of photon counts with 200 μm InGaAs-InAlAs APD.

Both dynamic range and linearity are important for our applications. Fig. 1 shows the photon count rate (1540 nm wavelength light source) as a function of optical attenuation (power) demonstrating good linearity over four orders of magnitude dynamic range. The dark count rate for this measurement was 3.9 kcps and was subtracted off from the illuminated count rate. These data show that the photon count rate scales linearly with attenuation and demonstrates that the APD is operating as a photon counter. For these photon-counting measurements (with a passive quenching circuit and 50 ohm input impedance RF amplifier), the counting efficiency was low (< 0.1%) since the RF amplifier noise was still a dominant factor. We are about to begin measurements with an active quenching circuit that should greatly improve the detection efficiency. We will present additional experimental measurements on several different near-infrared single-photon-counting detectors including InGaAs/InP and InGaAs/InAlAs avalanche photodiodes, an InGaAsP photocathode hybrid photomultiplier and an InGaAs photomultiplier.

Single-Photon-Counting Detector Application Instrument Demonstration

We have performed some initial measurements of a Pseudo-Noise (PN) coded altimetry system[1] operating at 1570 nm with a photon-counting PMT (Hamamatsu Model H9175) detector (1.5 % QE @ 1570 nm). Figure 2 shows, from top to bottom, the reference PN waveform, a detected photon counting histogram accumulated in 1.27 msec integration time. The bottom plot shows the cross correlation, which shows the expected range spike with an offset of about 100 range bins. Only ~1 detected photon per range bin is required to achieve reliable range information.

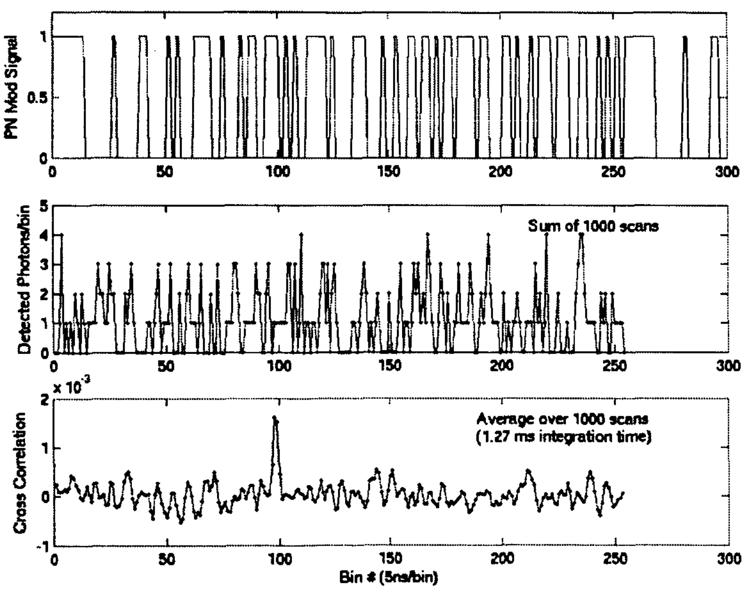

Figure 2. Signals and correlation peak measured at 1.27 msec integration time for PN ranging experiment

We will present additional experimental performance of prototype instruments for laser ranging, communication, and trace-gas detection that use near-infrared single-photon-counting detectors.

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1 . N. Takeuchi, N. Sugimoto, H. Baha, K. Sakurai, "Random Modulation CW Lidar," Applied Optics, 22 (9), 1382-1386 1983.