A Novel Readout System for Free-Running Negative Feedback Avalanche Diodes to Significantly Suppress Afterpulsing Effect

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In recent years, free-running single-photon detectors (SPDs) at telecom wavelength has attracted vast research interest for its numerous applications including long distance quantum key distribution (QKD) [1]. At this wavelength, InGaAs/InP based detectors are the most practical solution for single photon detection because of their compact size, no requirement for cryogenic temperature, robust operation and low cost. Recently, a new free-running InGaAs/InP detector with a monolithically integrated thin film resistor, known as negative feedback avalanche diode (NFAD)[2], has been developed to quench avalanches quickly. Though, high afterpulsing effect limits NFADs use in high frequency applications.

We developed a unique readout system for processing of signals from an NFAD. The major features of our readout are: i) It includes an active hold-off circuitry to provide an additional dead time across NFAD to suppress the afterpulsing effect and to lower the dark count rate (DCR), ii) The electronics circuit is designed using simple TTL and high speed ECL devices for amplification and processing of photon signals, iii) The detected signal is inductively coupled with the RF amplifier that allows only the transfer of variation in avalanche current with improved sensitivity, and iv) The NFAD operates in a free-running mode.

The NFAD studied to investigate our readout system is from Princeton Lightwave [3], and has $1.1\text{M}\Omega$ thin film resistor integrated with the anode of the NFAD. The diode is cooled to $191K$ temperature for useful operation. The DCR is measured to be $\approx 137,000$ count per second (cps) at 72.5 V bias voltage for no hold-off time. When a hold-off time is applied the DCR drops remarkably, at 5 μs hold-off DCR is measured to be ≈ 260 cps and drop to <100 cps at $20\mu s$ hold-off at optimized operating condition. Figure 1 shows the trend of DCR change with the variation of bias voltage for different hold-off time. Yet, the real challenge to work with NFADs is to reduce their afterpulsing effect. Our photon-counting method is able to significantly suppress the afterpulsing probability (P_{AP}). The P_{AP} is calculated to be 128% at 5 μs hold-off time and drop to 9% at 20 μs hold-off time. Figure 2 depicts the accumulation of counts distribution for afterpulsing measurement at 20 μs hold-off. In the figure, the baseline counts are due to intrinsic dark counts of the histogram.

Our simple circuit that is able to suppress afterpulsing opens up new opportunities to use NFADs in long distance quantum optics applications which requires low noise photon counting.

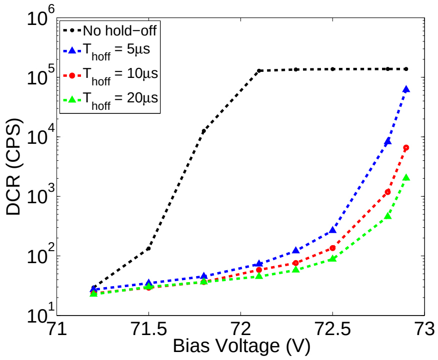

FIG. 1. The measured dark count rate at various bias voltage for different hold-off time. At 72.5 V bias voltage the diode has the maximum efficiency of 3%.

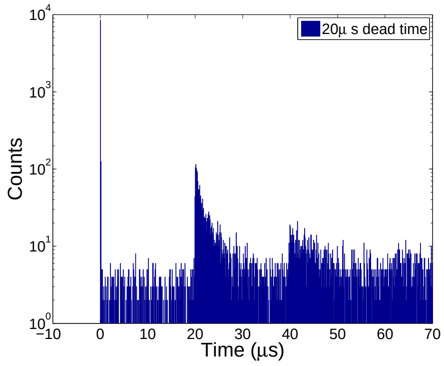

FIG. 2. Measured distribution of photon detections at hold-off time of 20 μs. The detection counts due to laser pulses ($f_t = 1kHz$) occur at $0\mu s$, and the rest are afterpulsing.

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