MIT Lincoln Laboratory has developed focal plane array detectors based on single-photon-sensitive Geiger-mode avalanche photodiodes (GmAPDs) and custom digital readout integrated circuits (ROICs) [1]. Geiger-mode avalanche photodiode focal plane arrays (FPAs) are ideally suited to direct-detect laser radar (ladar) applications because the GmAPD’s impulse response matches that of a pulsed laser. For detection of continuous wave signals, such as those associated with optical communications or coherent ladar, the APDs and readout integrated circuits must be tailored to the application as described below.

For the Geiger-mode APDs, the operating point needs to be tailored to minimize the effect of afterpulsing. Afterpulsing occurs due to charge carriers trapped in the semiconductor after an avalanche breakdown event. Reducing the charge flow during the avalanche is the most promising technique for minimizing afterpulsing. This effect can be studied by characterizing existing discrete GmAPDs, when operated in a regime with large charge flow, and then modelling the effects of hybridization stray capacitance on the current. Performance of next-generation FPAs that further limit avalanche charge flow can also be predicted.

Most imagers operate in a framed mode in which all of the pixels in the camera integrate the optical signal and then readout synchronously with each other. For low-frame-rate applications, such as direct-detect ladar, this synchronous operation is well matched to pulsed laser illumination sources with repetition rates of ~1-10 kHz. The readout time of 20+ μs is more than enough hold off time to reduce the afterpulsing of the GmAPDs to negligible levels. This synchronous style of readout, however, is poorly suited to detecting continuous-wave signals such as those received by optical communication systems or coherent ladar systems. MIT Lincoln Laboratory has developed a 32-by-32 pixel infrared GmAPD-based detector (Async R6) [2] with a custom CMOS ROIC for use with continuous-wave signals such as those mentioned above. In this detector, each GmAPD operates asynchronously from the others preventing blocking loss caused by GmAPD insensitivity during readout. Each pixel can detect a photon, initiate a hold-off time to reduce afterpulsing and readout its photon arrival data while not impacting neighbouring pixels.

![Block diagram of photon-counting coherent ladar test setup](image)

**Fig. 1:** Block diagram of photon-counting coherent ladar test setup

Proof-of-concept optical communication and coherent ladar experiments have demonstrated the utility of single-photon-sensitive GmAPDs in system applications that require continuous-wave input signals. An example experimental setup is illustrated schematically in Figure 1 and data from the system will be presented.

By using focal plane arrays coupled with asynchronous readout integrated circuits, GmAPD-based FPA detectors can be used for single-photon-sensitive detection of continuous-wave signals without the system and performance limitations of either framed operation or short-gate operation [3].

References


*This work was sponsored by the Assistant Secretary of Defense (ASD) for Research and Engineering (R&E) under Air Force Contract No. FA8721-05-C-0002. Opinions, interpretations, conclusions and recommendations are those of the author and are not necessarily endorsed by the United States Government.*