RMD Semiconductor Activities: CMOS APDs, GPDs, SSPMs, APDs, and PSAPDs Detectors and Their Applications

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Abstract

Semiconductor detectors, such as avalanche photodiodes (APDs) and Geiger photodiodes (GPDs), provide internal gain and good low-light level sensitivity. The use of GPD pixel arrays as solid-state photomultiplier (SSPM) devices (Buzhan *et al.*) yields devices whose performance approaches that of traditional photomultiplier tubes as low-light level detectors. In this work, we describe our CMOS APD, GPD and SSPM detectors, and our large area silicon APD detectors.

CMOS provides a convenient environment for integrating pre-amplification with APD pixels whose internal gain, in proportional mode, reduces the relative contribution of readout noise. We present the characterization of CMOS APD pixels with respect to quantum efficiency, and gain, excess noise. When operated above the breakdown voltage in Geiger mode, the APD pixel, referred to as a Geiger photodiode (GPD) pixel, counts individual photon events. We describe the detection efficiency of CMOS GPD pixels, re-examine performance trade-offs encountered when selecting a passive quenching resistor, and characterize the after pulsing in terms of excess noise. An array of GPD pixels connected to a common output terminal composes a solid-state photomultiplier, which provides a gamma-ray spectrum when coupled to a scintillation material, where the number of GPD pixels triggered by the scintillation light is proportional to the energy of gamma ray. In this work, we characterize the effects of the DE, dark count rate, and excess noise on the spectroscopic performance of the SSPM. We summarize applications of SSPM detectors to dosimetry, and PET.

Large-area silicon-based APDs, APD arrays and position sensitive APDS (PSAPDs) are excellent large area, proportional detectors. RMD fabricates, using a planar process, deep diffused silicon APDs and PSAPDs that can be used for direct interaction or scintillation based spectroscopic and imaging applications. We have developed high gain (~1000), high quantum efficiency (25 – 85% in the 120 to 900 nm region) at unity gain, relatively low noise, and magnetically insensitive APDs up to 45 cm^2 in area and PSAPDs up to 65 x 65 mm^2 in area. These detectors have begun to be implemented in a variety of applications such as positron emission tomography (PET) for medical imaging, high-energy physics experiments using liquid xenon (LXe), and homeland security for nuclear contraband detection.