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Performance Characteristics of Gieger Photodiodes for the Next Generation of CMOS Solid-State Photomultipliers

Due to high magnetic fields and high radiation fields, many high-energy physics experiments replace photomultiplier tubes with solid-state photomultipliers (SSPM) coupled to scintillation detectors. Existing SSPMs use a large feature size CMOS process to maximum the silicon die area for the lowest-cost solution. The structures available in a specific commercial CMOS process defines, and may limit, the optimum performance characteristics of SSPM devices fabricated with the process. As new goals for future high-energy physics experiments, such as those at the Large Hadron Collider (LHC), require improved nuclear detection capabilities, a high-performance SSPM detector technology with improved optical and noise characteristics, timing, dynamic range, and radiation hardness will be developed.

As the SSPM is fabricated from an array of Geiger photodiodes (GPD), the initial design of a next generation of SSPMs consists of improving the GPD element. We have designed, fabricated and evaluated a number of prototype Geiger photodiodes in a small feature size CMOS technology. Some of these devices show a significant improvement in detection efficiency and dark current when compared to existing technology. We see overall improvement in quantum efficiency and enhancement in light detection below 400 nm. The diodes also show an improvement in the dark count rate with values measured on the order of Hz for a 30 μm × 30 μm device, when compared to kHz for previous devices of similar sizes. The signal-to-noise ratio has improved by at least a factor of ten in comparison to the previous Geiger photodiodes. These results will be presented along with measurements and a model that quantifies the expected device performance for a potential SSPM, which will include estimates of after pulsing, cross talk, dark count rate, and detection efficiency.

Author: Dr JOHNSON, Erik B (Radiation Monitoring Devices)

Co-authors: Dr WHITNEY, Chad (Radiation Monitoring Devices); Dr STAPELS, Christopher (Radiation Monitoring Devices); Dr CHRISTIAN, James (Radiation Monitoring Devices); Mr RINES, Rich (Radiation Monitoring Devices); Dr CHEN, Xiao Jie (Radiation Monitoring Devices)

Presenter: Dr JOHNSON, Erik B (Radiation Monitoring Devices)

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