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Dark Count rate measurement in Geiger mode and simulation of a photodiode array, with CMOS 0.35 technology and transistor quenching.

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Abstract

Some decades ago single photon detection used to be the terrain of photomultiplier tube (PMT), thanks to its characteristics of sensitivity and speed. However, PMT has several disadvantages such as low quantum efficiency, overall dimensions, and cost, making them unsuitable for compact design of integrated systems. So, the past decade has seen a dramatic increase in interest in new integrated single-photon detectors called Single-Photon Avalanche Diodes (SPAD) or Geiger-mode APD. SPAD detectors fabricated in a standard CMOS technology feature both single-photon sensitivity, and excellent timing resolution, while guarantying a high integration. SPAD are working in avalanche mode above the breakdown level. When an incident photon is captured, a very fast avalanche is triggered, generating an easily detectable current pulse. In this work, we investigate the design of SPAD detectors using the Austriamicrosystems 0.35 µm CMOS Opto technology. A series of different SPADs has been fabricated and benchmarked in order to evaluate a future integration into a SPAD-based image sensor. The main characteristics of each SPAD operating in Geiger-mode are reported: current voltage, breakdown voltage as a function of temperature. From this first set of results, a detailed study of the Dark Count Rate (DCR) has been conducted. Our results show a dark count rate increase with the size of the photodiodes and the temperature (at T=22.5°C, the DCR of a 10µm-photodiode is 2020 count.s-1 while it is 270 count.s-1 at T=-40°C for a overvoltage of 800mV). We found that the adjustment of overvoltage is very sensitive and depends on the temperature. The temperature will be adjusted for the subsequent experiments. A mathematical model is presented for reproduce the DCR of a single photodiode. We simulated the noise (DCR) of array of 32x32 photo-detectors. Our results show, of course an increase of DCR of 1024, but especially, the probability of having two pulses simultaneously is 0 (without light). By studying these probabilities of occurrence of the pulses, we think we can reduce the DCR of 50% with a statistical method and reduce the crosstalk of 90%. This study is realized in order to prepare the first digital matrices sensor in Geiger mode.