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Readout Electronics for Low Dark Count Geiger Mode Avalanche Photodiodes Fabricated in Conventional HV-CMOS Technologies for Future Linear Colliders

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The high sensitivity and excellent timing accuracy of Geiger-mode Avalanche PhotoDiodes makes them ideal sensors for particle tracking pixel detectors in high energy physics experiments. However, it is well known that they suffer from dark counts which in practice enlarge the necessary area of the readout electronics. Dark count can be dramatically reduced lowering the bias overvoltage of the diode to a few mV from the ground. Consequently, it is mandatory to replace the conventional front-end electronics by a readout circuit that enables low bias overvoltage operation. In this contribution, different readout topologies for low overvoltage biased GAPDs are presented.

Summary

Particle tracking pixel detectors for high energy physics (HEP) experiments can be performed by means of several sensor devices. Among others, Monolithic Active Pixel Sensors (MAPS), Depleted Field Effect Transistors (DEPFETs) and Charge Coupled Devices (CCDs) are being considered. However, only Geiger-mode Avalanche PhotoDiodes (GAPDs), which were first fabricated in conventional HV-CMOS technologies by [1] in 2003, fit the high sensitivity and timing accuracy requirements for particle counting and timing applications in future linear colliders. GAPDs can fulfill the specifications in a high granularity and low material budget tracker with the advantage of very high speed. As a result, they constitute at present time the most interesting sensor option for particle tracking purposes.

Unfortunately, GAPDs suffer from dark counts, which induce false counts and represent a severe limitation of the performance of the photodiode as well as an increase of the necessary area of the readout electronics to store the false hits. Dark counts depend on the technology, the sensitive area of the detector, the period in which the device is active, the excess bias voltage and the temperature [2]. In this work, the conventional 0.35μm AMS HV-CMOS technology has been chosen for its low level of intrinsic noise. Apart from that, GAPDs with a sensitive area of 20μm x 100μm have been proved to achieve a good fill factor.

Once the technology and the area of the sensor have been fixed, two different strategies can still be explored in order to minimize the dark count rate. First, it is possible to reduce the period in which the device is active, so that the dark count probability is also reduced. Here, a gated acquisition with a on period of 10ns has been set for ILC bunch crossing tests, but it could be further reduced to fit CLIC requirements. On the other hand, the reduction of the reverse bias overvoltage allows a severe reduction of the noise while maintaining the Geiger efficiency.

Although a wide range of readout configurations have been published [3], none of them is concerned about the reduction of the dark count noise of GAPD pixel detectors thanks to low bias overvoltages. In this contribution, we report readout electronic circuitry that replaces the typical simple CMOS inverter and enables low overvoltage GAPDs operation in order to minimize false counts. For this purpose, several readout circuits that provide a fast enough response time for ILC applications have been designed. In addition, since the response time of the GAPD is around 100ps in the worst case, these topologies are also valid for CLIC experiments.

[1] A. Rochas etal., "Single photon detector fabricated in a complementary metal-oxide-semiconductor high-voltage technology", Review of Scientific Instruments, vol. 74, pp. 3263-3270, 2003.

[2] E. Charbon, "Towards large scale CMOS single-photon detector arrays for lab-on-chip applications", Journal of Physics D: Applied Physics, vol. 41, 094010, 9 pp, 2008.

[3] S. Cova etal., "Avalanche photodiodes and quenching circuits for single-photon detection", Applied Optics, vol. 35, no. 12, pp. 1956-1976, 1996.

Primary authors: Dr DIÉGUEZ, Angel (University of Barcelona); Mrs VILELLA, Eva (University of Barcelona)

Co-authors: Mr COMERMA, Albert (University of Barcelona); Mrs ARBAT, Anna (University of Barcelona); Dr VILÀ, Anna (University of Barcelona); Dr GASCON, David (University of Barcelona); Dr GARRIDO, Lluís (University of Barcelona); Mr ALONSO, Oscar (University of Barcelona)

Presenter: Mrs VILELLA, Eva (University of Barcelona)

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