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Design and characterization of a GAPD pixel detector prototype for future particle trackers

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A monolithical GAPD (Geiger-mode Avalanche PhotoDiode) detector aimed to particle tracking at future linear colliders is being developed. A first prototype of a bidimensional GAPD pixel array has been designed and fabricated with a conventional 0.35 µm HV-CMOS process. The experimental characterization of the device shows that the expected noise counts generated by the sensor can be reduced to ˜10E-7 fake pulses per bunch by time-gating the detector in the nanosecond scale while reducing the working temperature to -20 ºC. The design and complete characterization of the GAPD detector will be presented at the conference.

Summary

Physics aims at the ILC and CLIC projects impose such stringent requirements on detector systems that exceed those met by any previous technology. Amongst other novel detector systems, GAPD (Geiger-mode Avalanche PhotoDiodes) detectors are being developed to track high energy particles at future linear colliders. These sensors offer outstanding qualities, such as an extraordinary high sensitivity, ultra-fast response time and virtually infinite gain, apart from compatibility with standard CMOS technologies. In particular, GAPD detectors enable the direct conversion of a single particle event onto a CMOS digital signal in the sub-nanosecond time scale without the utilization of either preamplifiers or pulse shapers. As a result, GAPDs can be read out after each single bunch crossing. However, the generated signals are due not only to the absorbed radiation, but also to the intrinsic noise phenomena of the sensor which are originated by dark counts, after-pulses and cross-talks. Because the noise signals cannot be distinguished from real particle events and worsen the detector occupancy, solutions to reduce the sensor noise that are compliant with the severe specifications of next generation particle colliders are investigated.

A first prototype of a GAPD detector designed and fabricated as a proof of concept of such devices aimed to future particle trackers is presented in this contribution. The detector consists of a 10 x 43 GAPD pixel array in which the sensors and the readout electronics have been monolithically integrated with a conventional 0.35 µm HV-CMOS process. The pixels are composed of a 20 µm x 100 µm GAPD and a readout circuit that comprises 8 transistors only to achieve a 67% fill-factor, which is of the highest values that can be obtained with conventional 2D technologies. The fill-factor can be further increased to values close to 100% with the utilization of 3D technologies. The array presents an average DCR (Dark Count Rate) of 67 kHz at 1 V of excess bias. The array is operated in a time-gated mode (i.e. periodically activated and deactivated) to reduce the probability to detect the sensor noise down to ˜10E-4 fake counts per bunch with an active period of 4 ns. Nevertheless, these figures can be further improved to ˜10E-7 fake counts per bunch with the reduction of the working temperature to -20 ºC. The array is sequentially read out row by row during the quiet intervals between two consecutive bunch crossings. Measured results demonstrate that the proposed techniques are advantageous in improving the SNR (Signal-to-Noise Ratio), dynamic range and spatial resolution of the detector. The performance of the GAPD detector in beam-tests at CERN-SPS has also been explored. Details about the design and experimental characterization of the GAPD detector will be presented at the conference.

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