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Reducing pixel-to-pixel disparities in Geiger mode avalanche photodiodes by using gated operation

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The gated operation is proposed as an effective method to reduce and uniformize noise figures in particle tracking pixel detectors based on Geiger mode avalanche photodiodes for future linear colliders. A protoype based on a 3x3 array with the sensor and the front-end electronics monolithically integrated has been fabricated with the conventional HV-AMS 0.35µm technology. Experimental results demonstrate the reduction of pixel-to-pixel variations by applying this technique.

Summary 500 words

The near-infinite internal gain and accurate time response of Geiger mode avalanche photodiodes (GAPDs) make these sensors attractive candidates for ILC or CLIC forward tracker detectors. However, the high intrinsic gain of the sensor also induces false counts that cannot be distinguished from real events. The false counts generate a high level of intrinsic noise, which represents a reduction of the performance of the detector as well as an increase of the necessary memory to store the total counts. Moreover, due to variations in the cleanness of the fabrication process, defective pixels with intrinsic noise well above the acceptable value may appear at any position of the detector. These pixels contribute to large dark count pixel-to-pixel variations. Since the arrival time of impinging particles is a known parameter in most high energy physics experiments performed in accelerators, it is possible to operate the detector in a synchronized fashion with the beam by using the gated acquisition, which can reduce and uniformize noise variations.

In contrast with the free-running regime, in the gated acquisition the detector operates under the control of a gate command. This gate command switches the sensor from gated 'on'to gated 'off'by swinging its bias from a slightly larger to a slightly lower voltage than the breakdown voltage of the sensor. During the gated 'on' interval or period of observation (tobs) the sensor is enabled for detection. Otherwise, during the gated 'off' interval the sensor is inhibited, which is effective in reducing the number of false hits due to the dark count. Furthermore, if the photodiode has been gated 'off'for a sufficiently long period (longer than the lifetime of charge carriers) before bringing it to operation, the afterpulsing probability is eliminated.

In order to validate the proposed idea, a 3x3 GAPD array operated in the gated acquisition has been fabricated with the standard HV-AMS 0.35µm technology. Each pixel is comprised of a monolithically integrated 20µmx100µm GAPD as well as quenching and front-end electronics. The readout electronics also include a level shifter to allow low reverse bias overvoltage, which is also advantageous in reducing noise hits. Typically, the gated operation is implemented by means of a rectangular bias voltage pulse, but in the 3x3 GAPD array case it is performed by inhibiting the sensor with the integrated front-end electronics being controlled through external signals. Moreover, tobs can be easily synchronized with the bunch crossing.

We have proved that noise figures can be sharply reduced by decreasing tobs to short intervals of 10ns. The GAPD array is free of afterpulses, the dark count rate is reduced and the performance of the detector is highly improved. Undesired situations, like the blindness of the detector because of the noise, are avoided. Furthermore, pixel-to-pixel disparities are drastically reduced, relaxing the necessary utilization of cooling systems in other steps. In this contribution, we will present the results of our experiments to show the potential of the proposed technique.

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