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SiPM WORKING PRINCIPLE

Silicon Photomultipliers (SiPMs) are silicon-based solid state low level light sensors. From a technological point of view they are basically an array of silicon avalanche photo diodes (APDs), each operated in Geiger-mode. This results in the SiPM's advantages of high gain, low temperature dependency, easy operation and enhanced next generation sensor performance.

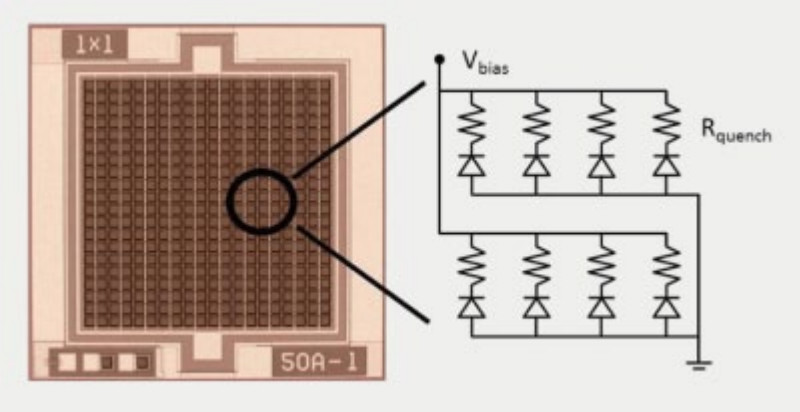

Figure 1: Top view and schematic of a Silicon Photomultiplier. Each photodiode is operated in Geiger-mode and has an individual quenching resistor. Photodiode and quenching resistor together are referred to as microcell. The microcell size equals to the pitch between microcells and is either 15 µm, 25 µm or 50 µm.

The internal structure of a KETEK SiPM is formed by an array of several hundred up to several ten thousand square-shaped micro-APDs, referred to as microcells, with a pitch of 15µm, 25µm or 50µm. The total number of microcells depends on the total active area and the microcell size. Both figures are implied in the first letters of the article number. For example a PM3325-WB comprises a microcell array of 3 x 3 mm² size (active sensor area) with a microcell pitch of 25µm. PM stands for PhotoMultiplier whereas WB indicates the SiPM series.

All microcells are connected in parallel to one common cathode and one common anode output. Therefore the macroscopic KETEK SiPM connection schematic does not differ from any normal APD. The SiPM signal is the superposition of all microcell signals, whereas each microcell delivers the same signal upon breakdown.

The microcells are electrically decoupled from each other by individual quench resistors. Its value is in the range of 200 kΩ to 400 kΩ, depending on the microcell size.

The quench resistor enables a microcell-operation above the breakdown voltage and thus above the proportional region. In Geiger regime the microcell gain is in theory infinite but practically limited by the quenching resistor and the microcell's capacitance.

The Geiger regime operation offers a very high signal-to-noise ratio compared to conventional APDs. Therefore the detection of single photons is possible and KETEK SiPMs can easily count single photons but are also capable of being used in CW mode.

The single photon signal of a microcell, the so called Geiger discharge, is asymmetric with a very fast rise time below 1 ns and a recovery time limited by the quenching resistor and the microcell capacitance to a value down to 13 ns.

The internal timing of a microcell Geiger discharge is very fast (below 100 psec). For its latest SiPM series, KETEK has improved the read out network of the microcell array in order to transmit the different microcell signals with very low time jitter to the SiPM output. Best in-class timing values can be achieved with KETEK SiPMs.

All KETEK SiPM products have highly sensitive microcells. The base for the high sensitivity is formed by a very shallow P-doped silicon entrance-window with an antireflective layer on top as well as a high fill factor of this region within the microcell itself.

In summary KETEK SiPM products are combining the benefits of vacuum PMTs (high photon detection efficiency, gain and signal-to-noise) with the benefits of APDs (robustness, miniaturized design, low operation voltage, cost-effective and magnetic insensitivity) to an outstanding low level light sensor with an exceptional performance at low cost. KETEK’s fabless foundry business is offering cost-effective in-time production with scalability to nearly any imaginable customer demand.