Technology Offer

Modular Scalable Low-Light Sensor Array

Ref.-No.: 0206-5874-BC

Abstract

This technology introduces a modular and scalable architecture for **large-area** low light level detection systems based on silicon photomultipliers (SiPMs). By integrating these with multi-tier read-out electronics into compact “base cells”, a **seamless** assembly of detector surfaces extending **up to square meters** while preserving fast read-out performance can be formed. The vertically stacked design of a base cell combines sensing and signal processing layers, allowing independent optimization and easy replacement of components. Transversal interconnection of base cells supports both planar and curved configurations, significantly enhancing design flexibility. Furthermore, adaptive read-out electronics enable dynamic adjustment of spatial resolution and temporal sampling. This innovation addresses scalability and integration challenges in current detector technologies, making it highly suitable for applications requiring high sensitivity, large detection areas, and flexible system configurations.

Background

Silicon photomultipliers (SiPMs) have become essential for detecting low-intensity optical signals across scientific, medical, and industrial domains. Their high sensitivity and fast response make them suitable for applications such as tomography, particle detection, and life sciences. However, current SiPM technologies face limitations in scalability and system integration. Detector sizes are typically restricted to dimensions below approximately 10 mm, requiring complex and non-standardized interconnection strategies to achieve larger detection areas. Additionally, read-out electronics often lack uniformity and scalability, complicating system design and increasing development effort. These challenges hinder the deployment of large-area detectors with consistent performance. Therefore, a need exists for a standardized, modular approach that enables scalable detector architectures while maintaining high temporal resolution and efficient signal processing capabilities.

Technology

The invention relates to a modular detector architecture based on hybrid “base cells”, each integrating multiple vertically stacked functional layers. The uppermost layer consists of a low light level detector array, such as silicon photomultipliers (SiPMs), responsible for photon detection. Beneath this, a first-level read-out layer - typically implemented in CMOS technology - performs immediate signal amplification and preprocessing. A second-level read-out layer provides backend functionalities, including data aggregation,

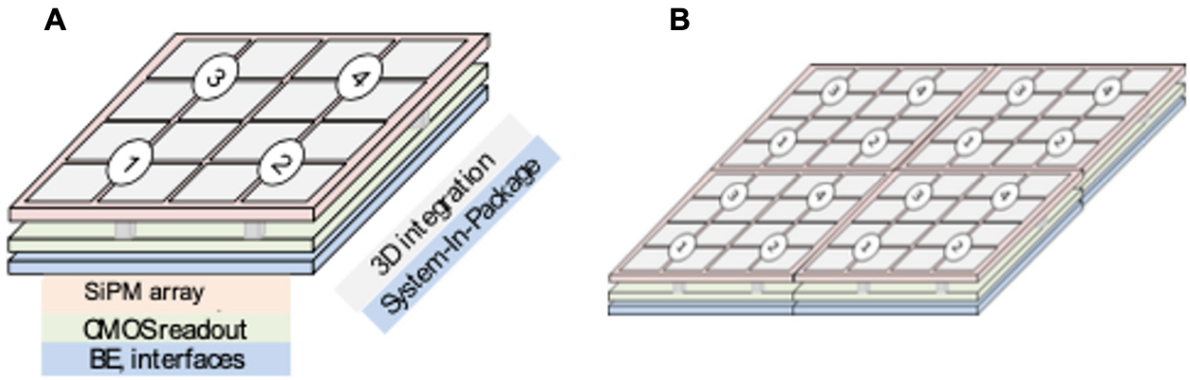

Figure 1: (A) A base cell made up of three tiers: (i) a low light level detector, here a silicon photomultiplier (SiPM), (ii) a first level electronic read-out, here a complementary metal-oxide-semiconductor (CMOS), and (iii) a second level read-out: back end (BE), interfaces. **(B)** seamless assembly built of four base cells.

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synchronization, and external interfacing. All layers are electrically interconnected through vertical junctions, enabling compact integration and efficient signal transfer.

A central feature of the technology is the transversal interconnection of these base cells. This approach enables the creation of virtually seamless detector surfaces that can be configured in planar or curved geometries. The second-level electronics support scalable communication architectures, including optical or Ethernet-based interfaces, ensuring efficient data handling across extensive arrays. Furthermore, configurable read-out circuits allow dynamic adjustment of effective pixel size and temporal resolution. This enables flexible operation modes, such as combining multiple pixels to increase sensitivity or adapting timing from nanosecond-scale acquisition to slower sampling regimes, depending on specific application requirements.

Advantages

- **Scalable detector surface**: Enables seamless expansion from small modules to square-meter arrays.
- **Flexible geometry**: Supports both flat and curved surfaces to fit diverse system architectures.
- **Modular design**: Easy replacement or upgrade of detector or electronic layers without system overhaul.
- **Adaptive resolution**: Virtual pixel grouping allows tuning between higher sensitivity and finer spatial detail.
- **Efficient performance**: Low power consumption (<100 mW/cm²) with fast, nanosecond-level read-out.

Potential applications

- Medical imaging systems, including PET and CT, requiring high-sensitivity large-area photon detection.
- High-energy physics and astrophysics experiments detecting low-intensity or rare particle interactions.
- Industrial non-destructive testing and tomography using low light signal acquisition.
- Life science instrumentation for fluorescence detection and bioimaging applications.
- Security and environmental monitoring systems relying on precise low light sensing technologies.

Patent Information

Patent active in US (US12295180 B2) and patent application pending in EP (EP 4094291 A1)

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