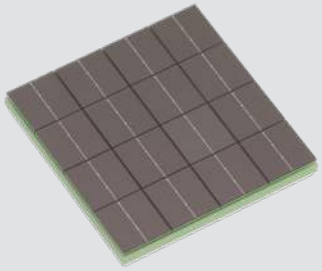
BROADCOM®

Product Brief

AFBR-S4N44P163

4×4-Pixel NUV Silicon Photomultiplier in High-Density Technology



Key Features

- High photo-detection efficiency (PDE) of up to 55% at 420 nm
- High fill factors (pixel and tile)
- Excellent single-photon timing resolution (SPTR) and coincidence timing resolution (CTR)
- Uniformity of breakdown voltage (Δ <300 mV across tile)
- With TSV technology, arrays are four-side tileable
- Cell pitch: 30 × 30 µm², pixel pitch: 4 × 4 mm²
- Tile size: 15.9 × 15.9 mm²
- Array thickness of only 1.28 mm
- Highly transparent glass protection layer
- Sixteen backside contacts, reflow solderable
- Operating temperature range: –20°C to +50°C
- REACH compliant

Applications

- Positron emission tomography (PET)
- Gamma-ray and X-ray detection
- High-energy physics detectors
- Analytical instrumentation
- Safety and security

Overview

The AFBR-S4N44P163 is a 4×4-pixel NUV (near ultraviolet) silicon photomultiplier (SiPM) array developed in high-density technology[1] for the ultra-sensitive precision measurement of single photons.

The device makes efficient use of surface area by using through-silicon via (TSV) technology allowing for a high packing density without wires. Larger detector areas can be covered by tiling multiple arrays almost without edge losses.

The detector has a broad response in the visible light spectrum with particular optimization towards blue and NUV light. A thin glass layer that is highly transparent down to UV wavelengths protects the array, making it well suited for the detection of scintillation or Cherenkov light from the most common scintillators such as LSO, LYSO, GSO, BGO, NaI, CsI, BaF, and LaBr.

Highlights

- High photo-detection efficiency (PDE): Depending on operating parameters, the PDE exceeds 55% at 420 nm with a cell pitch of only 30 µm.
- Excellent timing resolution: A single-photon timing resolution (SPTR) of 50 ps[2] (measured on a SPAD level of comparable dimension) provides the basis for excellent coincidence timing resolutions (CTRs) with scintillators for time-of-flight (TOF) positron emission tomography (PET) applications. Values between 75 ps and 120 ps FWHM have been reported[3]. Note that the final Broadcom product will use the identical silicon layer structure, but with a modified lateral design. Timing measurements with the Broadcom product are ongoing and may deviate from the above values.
- Large dynamic range: High-density technology provides large dynamic range, thus significantly reducing saturation effects.
- High tile fill factor (TFF): The TSV-based design enables a TFF of 95% with minimal gaps.

Figure 1: Array Dimensions

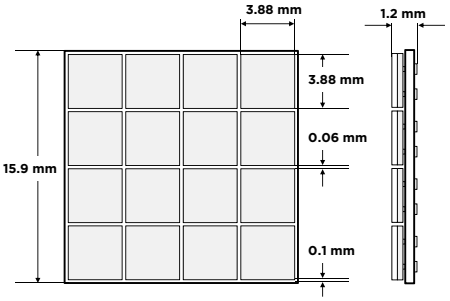
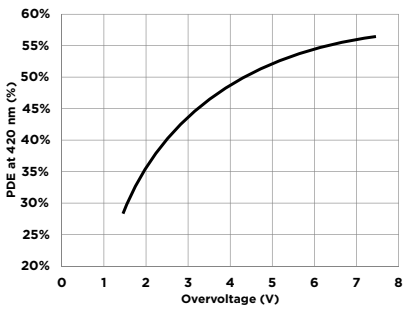


Figure 2: PDE vs. Overvoltage (Typical)



The SiPM Principle

SiPMs are arrays of single-photon avalanche diodes (SPADs) operated in Geiger mode, enabling the detection of single photons. Their dimensions typically range from 10 to 100 μm^2. Depending on the light source and application, several hundred to thousands of SPADs are connected in parallel into pixels.

The SPAD signals rise very quickly. To rapidly reset the diode for the next incoming photon, integrated resistors are used to quench the avalanche. The summed electrical current output of such a pixel (typically, 1 to 36 mm^2) is proportional to the number of photons hitting its surface. This signal is transferred by TSV to the processing electronics and shapes, amplifies, and digitizes the signals. Time-to-digital converters (TDC) allow the determination of the arrival time of photons.

Based on this technology principle, various SiPM designs are possible and offer a high-technology potential for application-specific adaptations.

SiPM Technology Potential

- Wavelength range: Besides the near-UV optimized silicon structure, a green optimized structure (RGB) using high-density technology has been developed and is available. Typical application areas for RGB include luminescence detection and visible light detection.
- Geometrical properties: Cell size, pixel size, array size, and shape can be adapted to the application requirement.
- Dynamic range: The dynamic range can be adapted to the application by defining the appropriate size and number of SPADs per pixel in the design.
- Packaging and electronics: Broadcom provides SiPM arrays using advanced packaging technology (TSV and WLP). Module functionality can be achieved by the integration of electronic post-processing circuitry.

Figure 3: Schematic of SPADs and SiPM Pixel

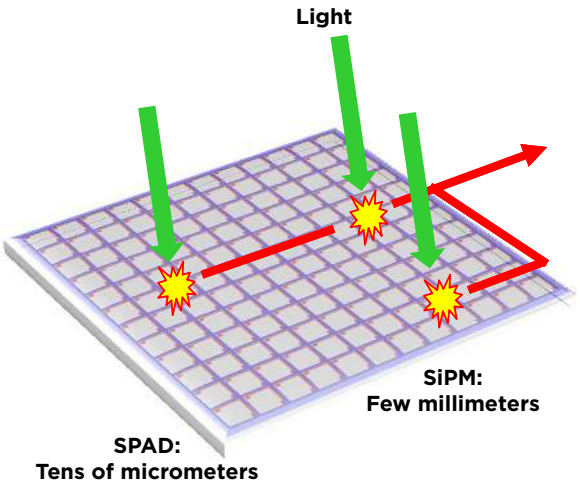
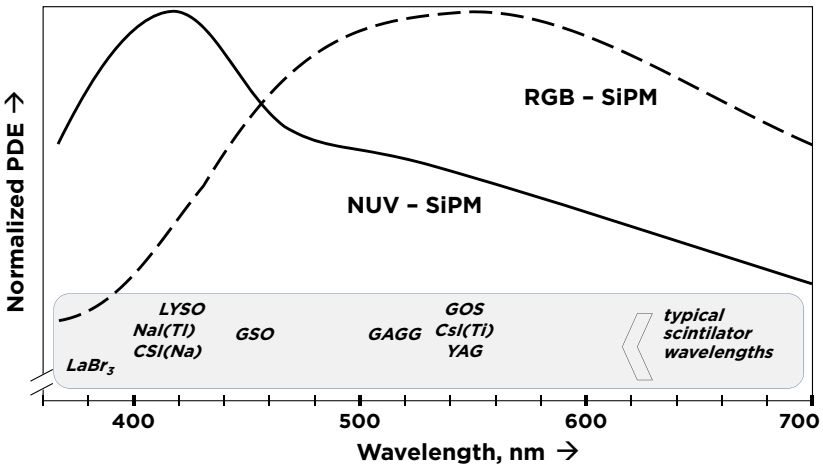


Figure 4: Wavelength Range



References:

[1] Technology for the NUV-HD SiPM licensed from FBK, Trento, Italy

[2] Acerbi and others, IEEE-TNS, Vol. 61, No. 5 (2014)

[3] Gundacker and others, JINST 08 (2016)

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