AFBR-S4NxxPyy4M

SiPM Characteristics for PMT Users

The Broadcom® AFBR-S4NxxPyy4M is a silicon photomultiplier (SiPM) series that is used for ultra-sensitive precision measurements of single photons. This SiPM is based on the NUV-MT technology with a SPAD pitch of 40 µm. The encapsulation for good mechanical stability and robustness is realized by a clear mold epoxy compound, which is highly transparent down to UV wavelengths, resulting in a broad response in the visible light spectrum with high sensitivity toward the blue and near-UV region of the light spectrum.

SiPMs are suitable for many applications for which photomultiplier tubes (PMTs) are used. One basic property of both detector types is their sensitivity to UV and VIS light. The sensitivity is typically expressed in terms of *radiant sensitivity* or *quantum efficiency (QE)* for PMTs, whereas for SiPMs, *photo detection efficiency (PDE)* is the term commonly used. This application note provides an overview of these parameters and is meant to facilitate the comparison between the two different types of photodetectors in terms of their sensitivity.

Photo Detection Efficiency

Photo detection efficiency (PDE) is the commonly used term to describe the sensitivity of SiPMs. The PDE is the probability that a photon impinging onto a SiPM is detected or in other words—for many impinging photons—the ratio of detected photons and impinging photons. “Detected photons” in this context are photons that trigger an avalanche breakdown in one of the SiPM SPADs and therefore contribute to the electrical output signal.

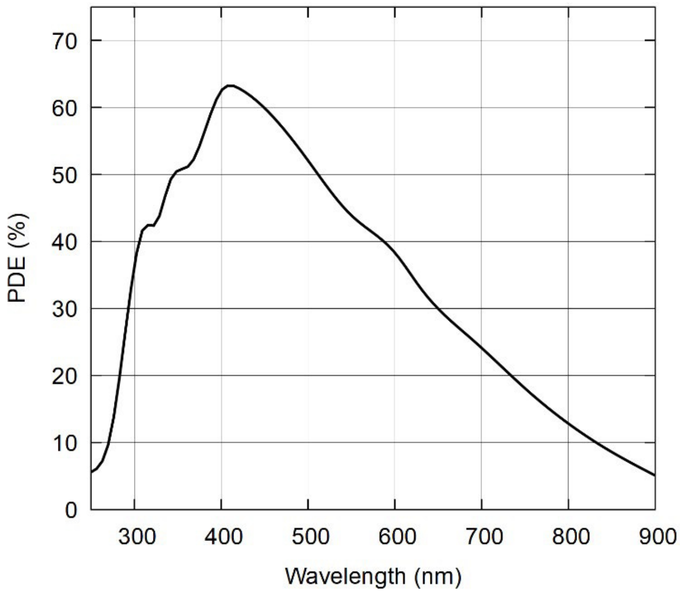
The PDE can be expressed as the product of the quantum efficiency (QE), the probability for a generated electron-hole pair to trigger an avalanche ($P_{Trigger}$), and a geometrical factor ε.

$$PDE = QE \times P_{Trigger} \times \epsilon$$

- *Quantum efficiency* describes the efficiency of the conversion process of a photon into an electron-hole pair in the SPAD.
- $P_{Trigger}$ provides the probability that the electron-hole pair causes a Geiger breakdown in the SPAD.
- ε is a factor that accounts for the geometrical efficiency, that is the ratio between the active parts of the SPAD and the overall SPAD size.

Figure 1 displays the PDE of Broadcom's NUV-MT technology in the NUV and visible region of the electro-magnetic spectrum.

Figure 1: PDE vs. Wavelength



NOTE:

- To compare the efficiency of PMTs with that of SiPMs, one typically compares a PMT's quantum efficiency with the PDE of the SiPM. For today's PMTs, the QE at peak sensitivity reaches up to approximately 40%, but can also be well below that value for certain types of PMT. The Broadcom's NUV-MT SIPM reaches a peak PDE of 63% at 420 nm and also surpasses the QE of many NUV PMTs with over a 30% PDE at 300 nm.
- For more details on the PDE of Broadcom's NUV-MT SiPMs, contact sipm@broadcom.com.

Radiant Sensitivity

Radiant sensitivity is more commonly used in the context of PMTs rather than SiPMs and is defined as the output photocurrent over the incoming radiation flux and is provided in A/W:

$$S = \frac{I_{Photo}}{\phi}$$

If the radiant sensitivity of SiPMs must be compared to that of PMTs, the following formula can be used to calculate a SiPM's radiant sensitivity at a given wavelength λ.

$$S[A/W] = \frac{e\lambda}{hc} \cdot PDE(\lambda) \cdot Gain \cdot (1 + P_{CT} + P_{AP})$$

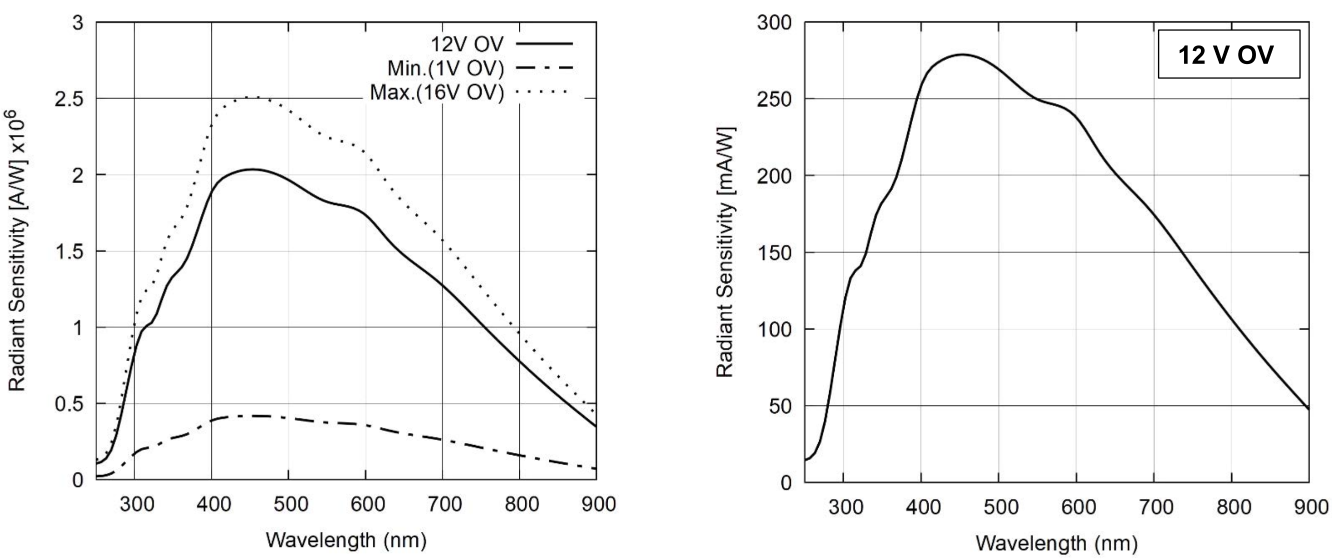
Where:

- *e* is the charge of an electron.
- λ is the wavelength of the incoming photons.
- *h* is the Planck constant.
- *c* is the speed of light.
- *PDE* is the photo detection efficiency at a given wavelength.
- P_{CT} is the crosstalk probability.
- P_{AP} is the afterpulsing probability.

As becomes evident, the radiant sensitivity of a SiPM is mostly an unpractical parameter to use due to its dependency on the gain and the correlated noise (P_{CT} and P_{AP}) and should only be used with care for direct comparisons between SiPMs and PMTs.

Figure 2 (left) shows the radiant sensitivity of Broadcom's NUV-MT SiPM for three different overvoltages and therefore three different values for gain, crosstalk, and afterpulsing. For a better comparison to PMTs, the radiant sensitivity normalized with respect to the gain (Gain = 1) is also shown (Figure 2 right) at 12 V OV.

Figure 2: Radiant Sensitivity vs. Wavelength



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