Application Note

AFBR-S4P11P012R

NIR30 SiPM Electro-Optical Performance Parameter Correlation

The Broadcom® AFBR-S4P11P012R is a silicon photomultiplier (SiPM) that is used for ultra-sensitive precision measurements of single photons. This SiPM is based on the NIR30 technology with optimized photon detection efficiency (PDE) in the red and NIR and a high dynamic range using a 12.5 SPAD pitch.

The SiPM performance in application systems depends on the electro-optical performance parameters, such as the photon detection efficiency, noise characteristics (crosstalk, afterpulsing, and dark count rate), and gain. All of these parameters are a function of the applied overvoltage and must be tuned such that the overall performance at the system level is optimized in this multidimensional performance parameter space.

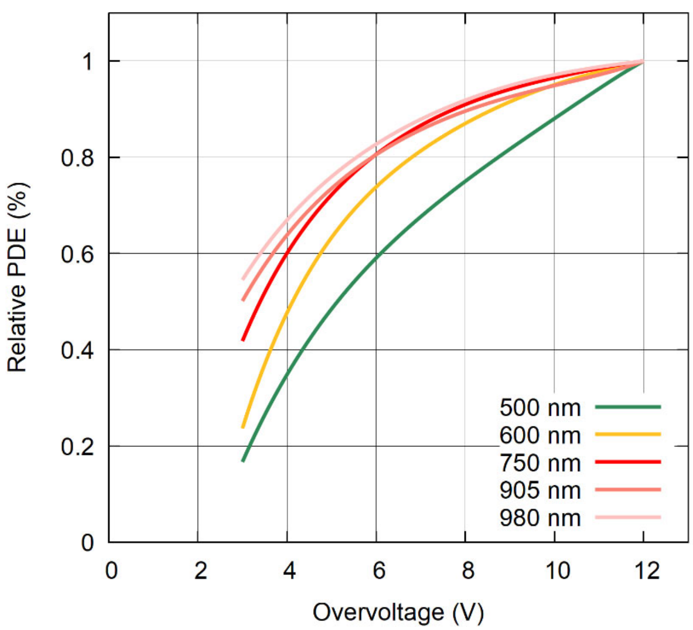
As a guideline, this application note provides correlation plots for different performance parameters.

PDE Saturation Point

The avalanche trigger probability in an SiPM increases with higher overvoltages until a specific maximum (saturation) is reached. From this saturation point on, overvoltage on the PDE no longer increases significantly. The overvoltage at which trigger probability saturation occurs is wavelength dependent and tends to shift toward higher overvoltages for shorter wavelengths in NIR30 SiPMs. The following figure plots the PDE relative to the maximum reachable PDE at the given wavelengths as a function of the overvoltage. The increase of the PDE relative to the maximum is steeper for shorter wavelengths, whereas for longer wavelengths, PDE saturation is already reached for lower overvoltages.

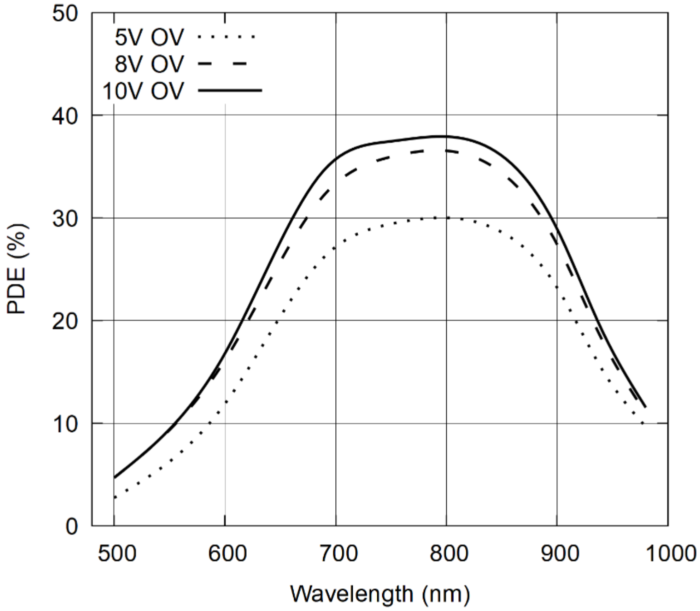
Consequently, for NIR and red light, the overvoltage can be decreased to reduce SiPM noise, such as crosstalk and dark count rate, while still maintaining a high PDE.

Figure 1: Relative PDE vs. Overvoltage



The following figure displays the corresponding PDE spectrum of the NIR30 SiPM series at 5 VOV, 8 VOV, and 10 VOV.

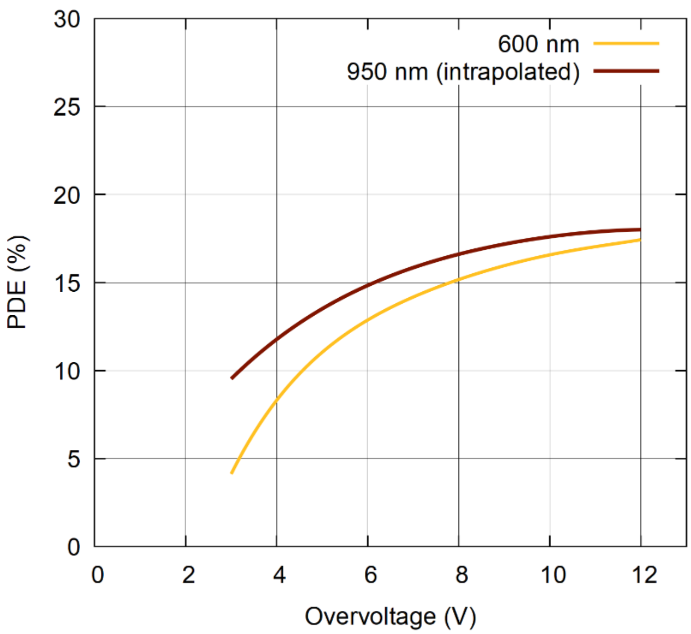
Figure 2: PDE Spectrum



One implication of the wavelength dependency of the PDE saturation is that for two wavelength values with similar maximum absolute PDE but at different sides of the peak PDE, the overvoltage setting required to obtain the best signal-to-noise ratio might be different.

The following figure compares the absolute PDE at 600 nm and 950 nm as function of the applied overvoltage. Although at both wavelengths, the maximum PDE is about 17%, at 3 VOV and a wavelength of 950 nm, the PDE is about twice the value at 600 nm.

Figure 3: PDE vs. Overvoltage at 600 nm and 950 nm



Electro-Optical Parameter Correlation

The measurement results of dim light signals often depend on the achievable signal-to-noise ratio (SNR). To increase the SNR, the signal can be increased or the noise can be reduced. Although the PDE, and hence the signal at a given light intensity, can be increased by increasing the SiPM's overvoltage, the noise also increases at higher overvoltages. Reducing the noise by decreasing the applied overvoltage results in decreasing the PDE.

Therefore, an overvoltage scan is often required to find the ideal operation point of an SiPM in a specific application. This operation voltage point depends not only on the SiPM and its electro-optical parameters but also on the following:

- The light signal (for example, the wavelengths, pulse width, and intensity)
- The readout electronics
- The mode of measurement (for example, amplitude measurements and charge integrations)
- The measurement environment (for example, the temperature and ambient light)

In addition to the wavelength dependency of the PDE and its increase with overvoltage, the overvoltage dependency might be nonlinear, which might complicate finding the ideal operation point without an overvoltage scan.

The following graphs provide the correlation between the key electro-optical parameters of the Broadcom NIR30 SiPM series.

The following figure displays the PDE of the Broadcom NIR30 NIR SiPM series versus the dark count rate (DCR), the afterpulsing probability, the crosstalk probability, and the gain. The correlation between these parameters is shown for 600 nm, 750 nm, 905 nm, and 980 nm.

Figure 4: PDE as a Function of the Dark Count Rate, Afterpulsing Probability, Crosstalk Probability, and Gain (Part 1)

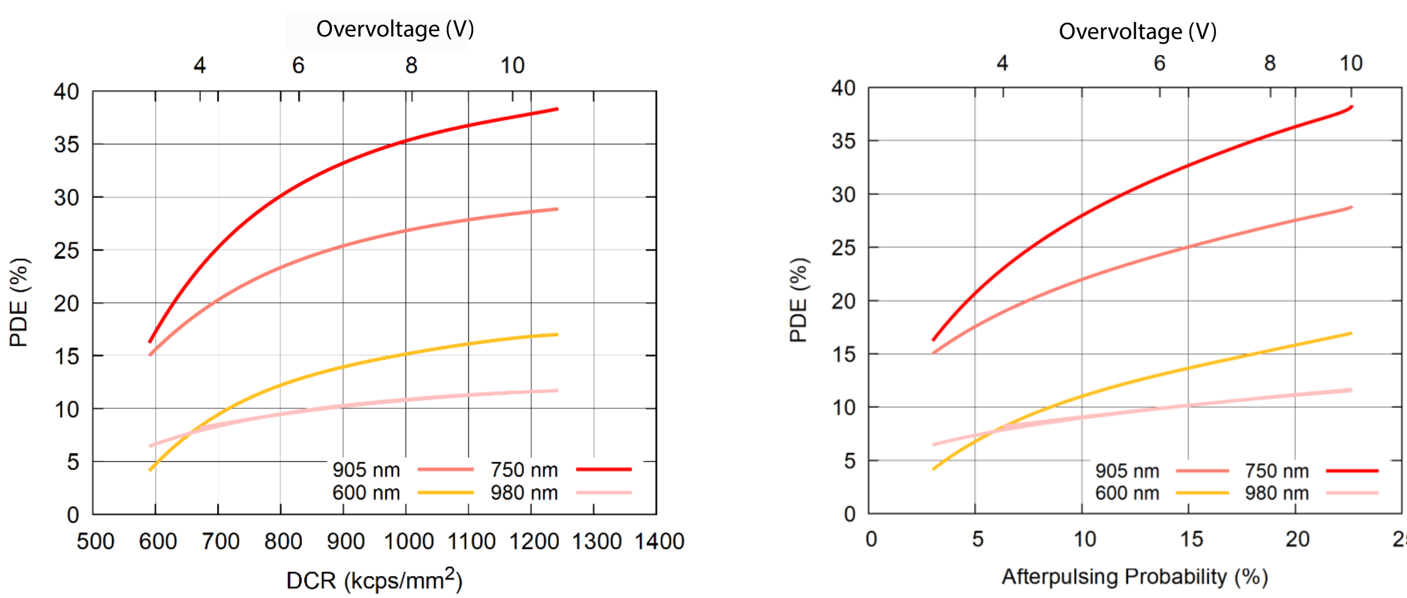
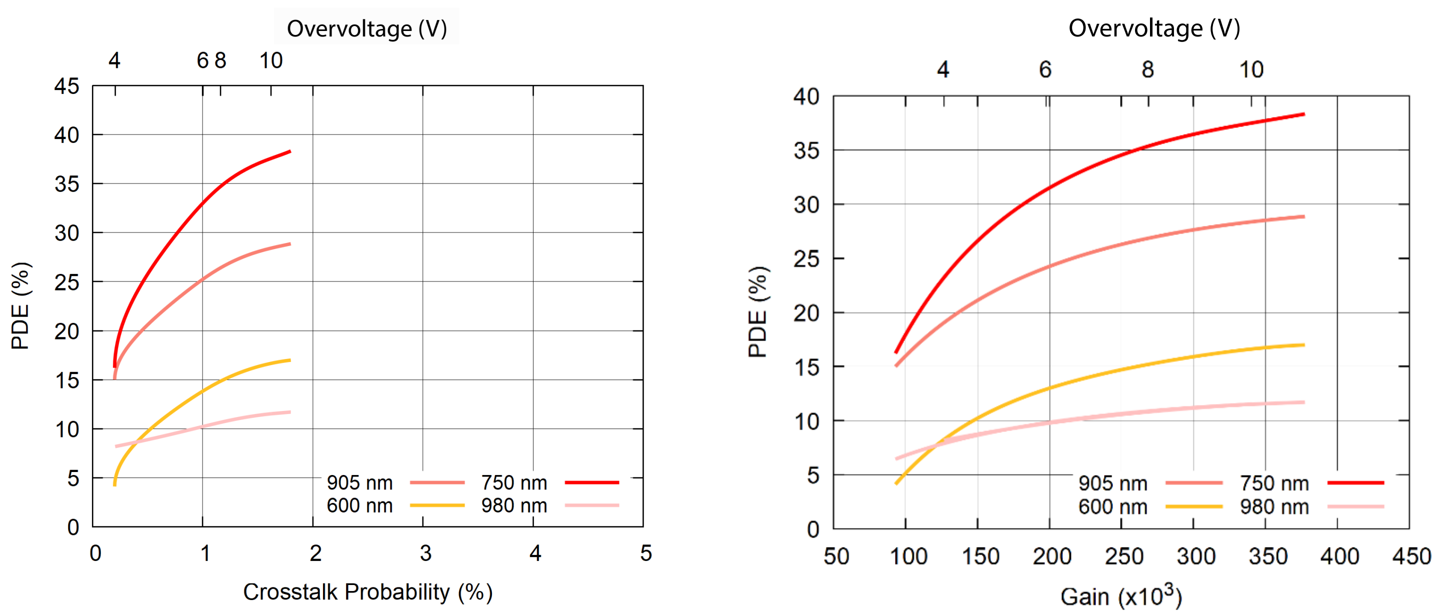


Figure 4: PDE as a Function of the Dark Count Rate, Afterpulsing Probability, Crosstalk Probability, and Gain (Part 2)



The AFBR-S4P11P012R combines high detection efficiency in the red and near infrared with very low crosstalk (<2%) and high dynamic range. This unique combination of electro-optical parameters makes this SiPM series an excellent device to boost system performance in a variety of applications, such as the following:

- 3D ranging (LiDAR)
- Direct time of flight (dTOF)
- Biophotonics and life sciences

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