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Laser-driven secondary photon emission of SiPMs

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The recent R&D for underground low-energy particle physics experiments involve SiPMs extensively as the prime photo-detectors due to their ability to enhance the sensitivity of rare particle events. Along with their advantages of having low operating voltages, high PDE, and excellent single-photon resolution, they cause secondary photon emissions which are responsible for at least three processes: (i) internal cross-talk (ii) external cross-talk and (iii) optically-induced afterpulsing. While the internal crosstalk and afterpulsing involves photon transport within the SiPM, the external cross-talk photons escape from the surface of one SPAD and potentially: (i) reflect back into the SiPM at the surface coating interface and trigger avalanches in neighbouring SPADs, (ii) transmit through the SiPM surface coating. External crosstalk can be a significant background in future multi-ton detectors such as DarkSide-20k and nEXO that will cover large surface areas with SiPMs which can trigger each other in the vicinity. This may reduce the accuracy of photo-electron resolution for high photo-electron events, leading to a degradation in the position and energy reconstruction. To quantify the systematic effects which deteriorate the overall performance of such detectors, a study on SiPM secondary photon emission was conducted. It determined the absolute secondary photon yield equal to the number of photons emitted per charge carrier (γ/e^-) using a spectroscopy setup at TRIUMF, Canada. The setup comprises an Olympus IX83 microscope with light filters and a Princeton Instruments spectrometer. The SiPM is triggered by 405 nm laser that stimulates the emission of secondary photons from the SiPM. These photons pass through the long pass filter of the microscope to finally be detected by the spectrometer. We have characterised FBK VUV-HD3, HPK-VUV4, and the FBK NUV-HD Cryo SiPMs at 163 K and 87 K (for FBK NUV-HD Cryo) to mimic the SiPM performance at liquid Xenon and liquid Argon temperatures. In this talk, I will summarise the data analysis used to quantify the secondary photon yield at these temperatures. I will also present a model of the SPADs which allows us to estimate the photon yield for an impact on the sensitivity of large-area detectors.

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