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(G*) Characterization of Laser-Driven Photon Emission in Silicon Photomultipliers at TRIUMF

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Silicon photomultipliers (SiPMs) are emerging as the technology of choice for single photon detection in large-area experiments used in rare-event physics searches. The SiPM consists of a 2-dimensional array of tightly-packed single photon avalanche diodes (SPADs) with quenching resistor, biased above breakdown. Upon absorption of an incident photon, this generates a self-sustaining charge avalanche.

A regrettable consequence of the avalanche process is the production of secondary, or cross-talk photons. These can travel to neighbouring SPADs, where they can induce delayed or direct cross-talk avalanches, or exit the SiPM completely. In large-area experiments, cross-talk photons leaving the SiPM can trigger other SiPMs in their vicinity, contributing to detector background. While these effects can be partially addressed through isolation structures in SiPMs separating the SPADs (trenches), this does not eliminate the emission of secondary photons. As a consequence, it is vital to study this phenomenon as it has a systematic effect on detector performance.

The SiPM MIcroscope for Excitation Luminescence Characterization (MIEL) was developed at TRIUMF to study the emission of cross-talk photons. This is an inverted microscope system used to observe SiPMs at a sub-SPAD level, permitting the capture of emission microscopy images (EMMIs), and spectroscopic characterization of light emitted as a result of secondary photon production. A previous study at TRIUMF has presented results for photon emission from avalanche pulses in dark conditions.

Thanks to a recent cryogenic upgrade to the MIEL setup, dark noise can be reduced, permitting operation at lower overvoltages and operation of SiPMs at temperatures similar to the cryogenic conditions of a liquid xenon detector, such as the nEXO experiment, searching for neutrinoless double-beta decay. We can study secondary light production from avalanches stimulated by laser pulses centred on a SPAD, building on the previous work on avalanches in dark conditions. We will present results from this laser-stimulated emission, with SiPM EMMIs showing a geographical distribution of emitted light, alongside emission spectra near breakdown, and photon yield per avalanche for two photosensor candidates for nEXO.

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