First-Principle SiPM Characterization to Enable Radiation Detection in Harsh Environments

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INTRODUCTION

- Silicon Photomultipliers (SiPMs) are solid-state photodetectors with high single-photon sensitivity and photon detection efficiency that are coupled to scintillation detectors to detect the light produced upon interaction of the scintillators with ionizing radiation.
- In applications where small form factor and low power requirements are needed, SiPMs are candidates to replace traditional photomultiplier tubes.

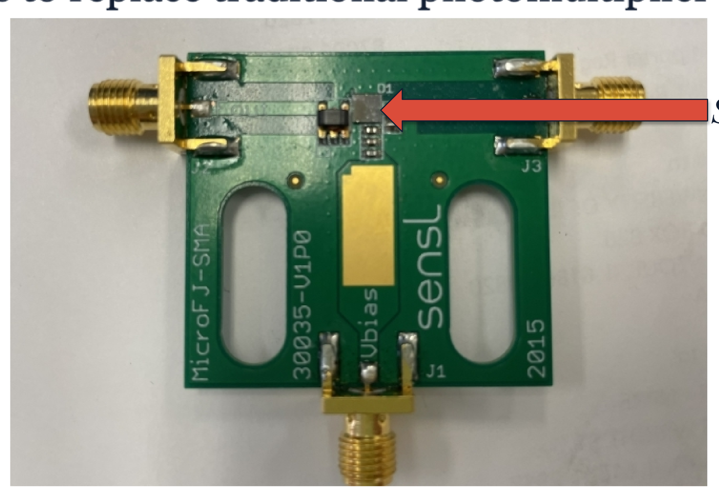

Figure 1: MicroFJ-30035 mounted on a MicroFJ-SMA SiPM evaluation board. 3mm × 3mm active area. 5676 microcells.

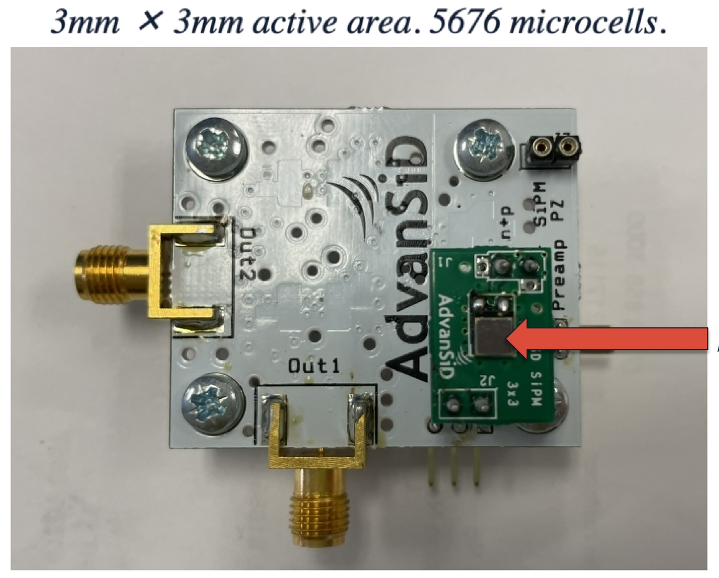

Figure 2: ASD-NUV3S-P SiPM mounted on an ASD-EP-EBPZ evaluation board. 3mm × 3mm active area. 5520 microcells.

- The use of SiPMs in radiation detection would benefit from high fidelity comprehensive models and the characterization of SiPM performance impact on detection properties, such as the energy resolution and pulse shape discrimination.
- The goal of this work is to characterize the SiPM response, the dark count rate (DCR) and the single photoelectron response (SPER) of two commercial SiPMs, MicroFJ-30035 by ONSemi (Figure 1) and ASD-NUV3S-P by AdvanSiD (Figure 2).
- The fluorescence emission spectra of two plastic organic scintillators (EJ-200 and EJ-276) have also been measured and will be included in the SiPM-based detector model. The scintillators are both $3mm \times 3mm \times 6mm$.

AIM

The aim of this work is to characterize the SiPMs and organic scintillators experimentally and use the measured data to develop high-fidelity models of their response under a broad range of operating conditions.

- Measure the DCR and SPER of the SiPM to determine performance parameters
- Measure the fluorescence emission spectra of plastic organic scintillators.
- Couple the scintillators with the SiPMs and characterize their performance in different environments.
- Using the measured characteristics of the scintillators and SiPMs, create a model of the scintillators' response (GEANT4) and the SiPM response (GosSiP simulation package).

EXPERIMENTAL METHODS

Single Photoelectron Response and Dark Count Rate

- Measuring the DCR and SPER provides important characteristics about the SiPM performance, such as its gain and photon detection efficiency.

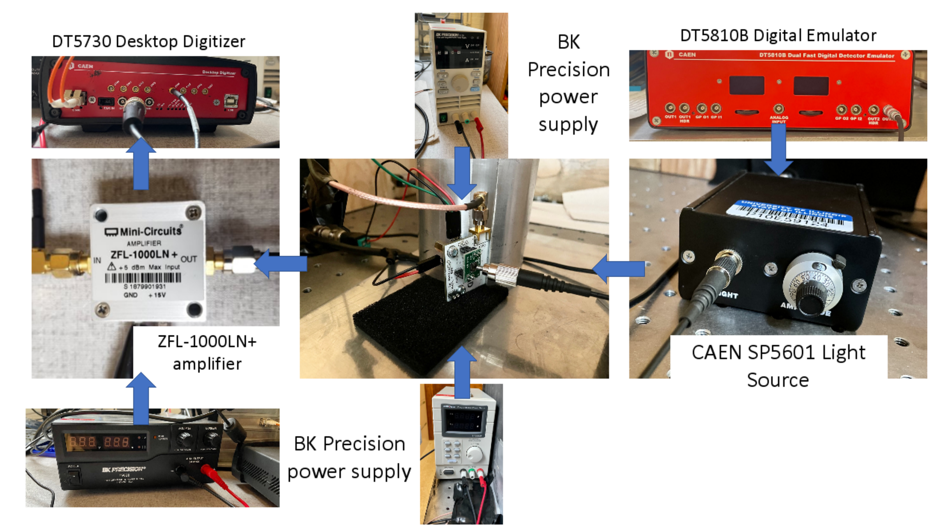

Figure 3: SPER and DCR measurement setup

- The SPER and DCR (without the light source) were studied using the setup in Figure 3.
- The light source projected a low intensity beam at the SiPM through an optical fiber link. For measuring DCR, the light source was not used.
- The pulse emulator triggered the light source with a 10 kHz TTL pulse.
- The SiPM was powered with a 5V (MicroFJ) or 4.9V (ASD) overvoltage.
- The output signal was amplified using a low-noise amplifier and digitized by a desktop digitizer (14 bits, 500 MSPs).
- A leading-edge triggering strategy was used.

Photoluminescence Response of Plastic Scintillators

- A SLM/ISS fluorometer was used to determine the photoluminescent response of the organic scintillators.
- The scintillators were placed in a cuvette and irradiated by a beam of light produced by a Xenon lamp with 200 nm wavelength.
- The incoming light produced a fluorescent response in the scintillators. A photo-multiplier tube then measured the light emitted by the scintillators in the 300 nm-550 nm range.

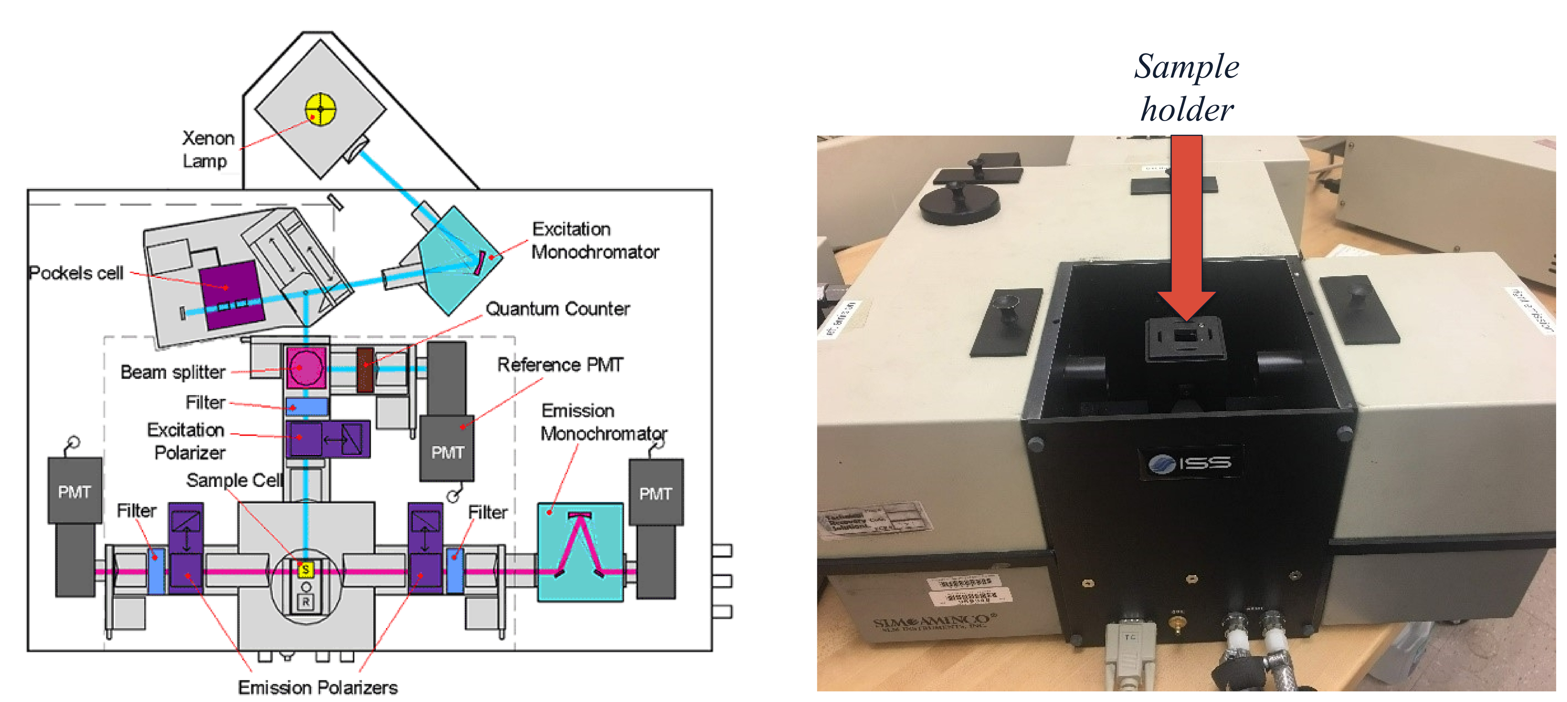

Figure 4: SLM/ISS fluorometer schematic (l), SLM/ISS fluorometer instrument (r)

RESULTS

Dark Count Rate Spectrum

- The DCR spectrum for the MicroFJ and ASD SiPMs are plotted in Figure 5 and 6 with a curve fit that calculates the dark count rate, among other SiPM response parameters.
- The DCR is defined as the number of events counted above the noise pedestal.

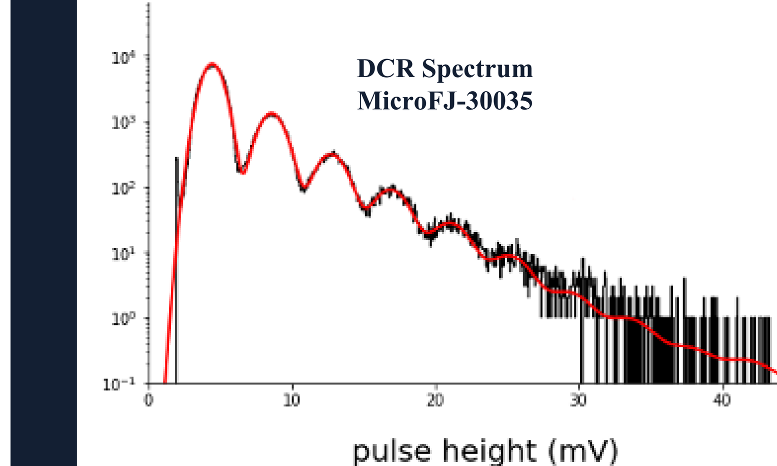

Figure 5: DCR spectrum for the MircoFJ SiPM.

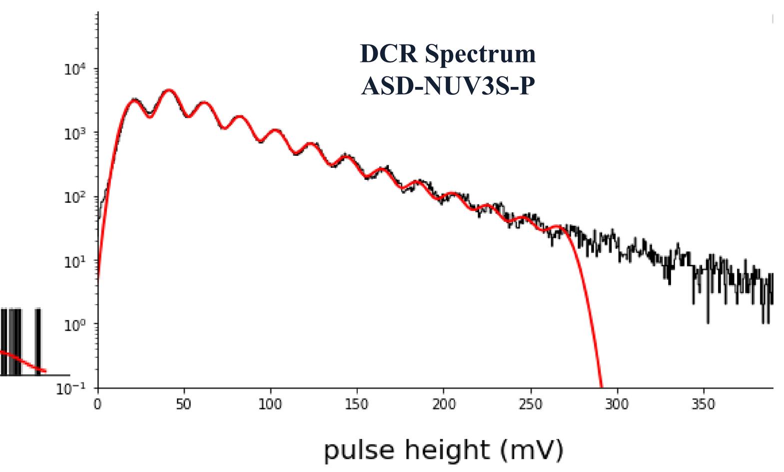

Figure 6: DCR spectrum for the ASD SiPM.

Table 1: DCR values compared with expected DCR values.

	MicroFJ DCR	AdvanSiD DCR
Measured	413 kHz/mm^2	556 kHz/mm^2
Data sheet value	125 kHz/mm^2	~100 kHz/mm^2

Photoluminescence Spectrum of EJ-200 and EJ-276 Scintillators

- Figure 7 shows the photoluminescence emission spectra of the EJ-200 and EJ-276 scintillators.

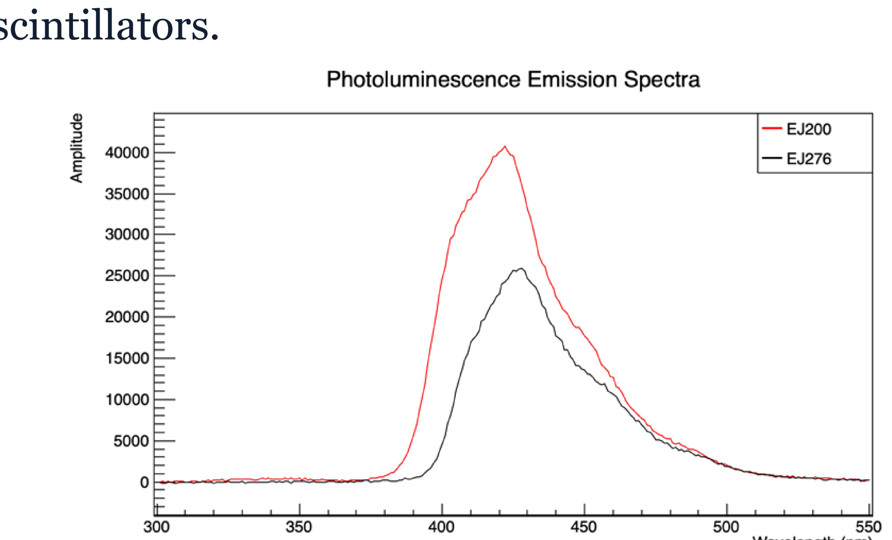

Figure 7: Photoluminescence Emission Spectra for the EJ-200 and EJ-276

CONCLUSIONS AND FUTURE WORK

- The DCR of the ASD was measured to be 35% higher than the MicroFJ.
- The photoluminescence emission response of the EJ-200 is 60% higher than the EJ-276 at their emission peak at 425nm.
- According to the SiPMs' data sheets, the ASD was expected to have a lower DCR. Additionally, the ASD has a guard ring that is supposed to lower noise.
- The higher DCR could be caused by the active evaluation board being used for the ASD compared to the passive board for the MicroFJ. This will be investigated by designing and testing the ASD with a passive board like that of the MicroFJ.

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