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## PROJECT PURPOSE:

Our sponsor GeneWEAVE, a Division of Roche Molecular Systems, utilizes a photomultiplier tube (PMT) to detect bioluminescent bacteria in a test tube for medical diagnostics. PMTs are expensive and bulky, so our job was to procure and analyze an inexpensive, compact, ultra-low light detection device that could be used to replace the PMT used in GeneWEAVE's VivoDX system. The bioluminescent bacteria emits blue light (490 nm wavelength) with a photon count rate as low as 200 photons per second. The detector device we chose was a SensL C-Series 1mm<sup>2</sup> silicon photomultiplier. To implement this device, we designed a customized signal processing circuit, detector housing, and cooling system.

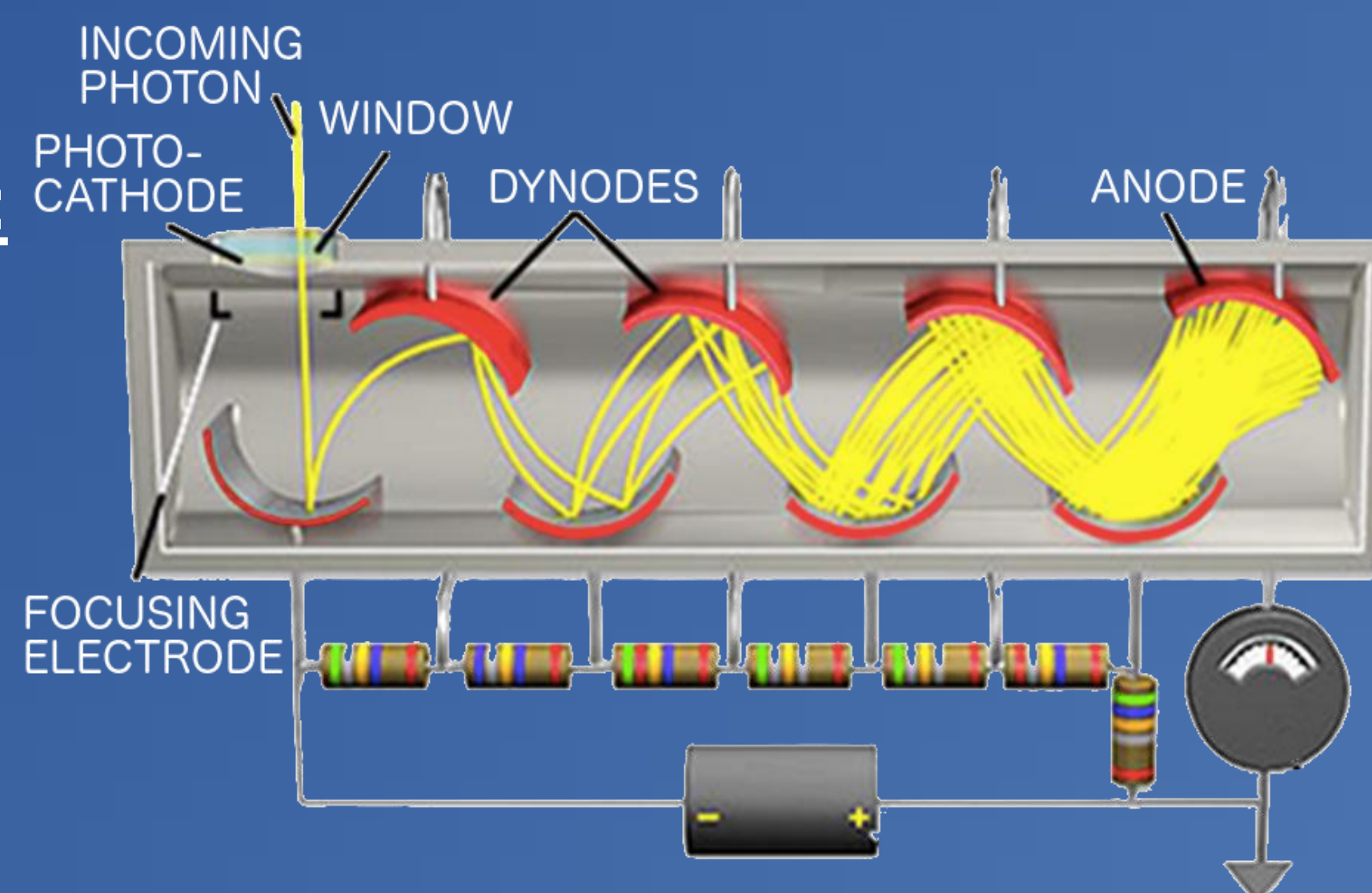
## PHOTOMULTIPLIER TUBES:

### ADVANTAGES:

- Ultra Low Dark Count: 20Hz
- High Photon Detection Efficiency (~25%)
- High Gain

### DISADVANTAGES:

- Bulky
- Damaged By Ambient Light
- Expensive



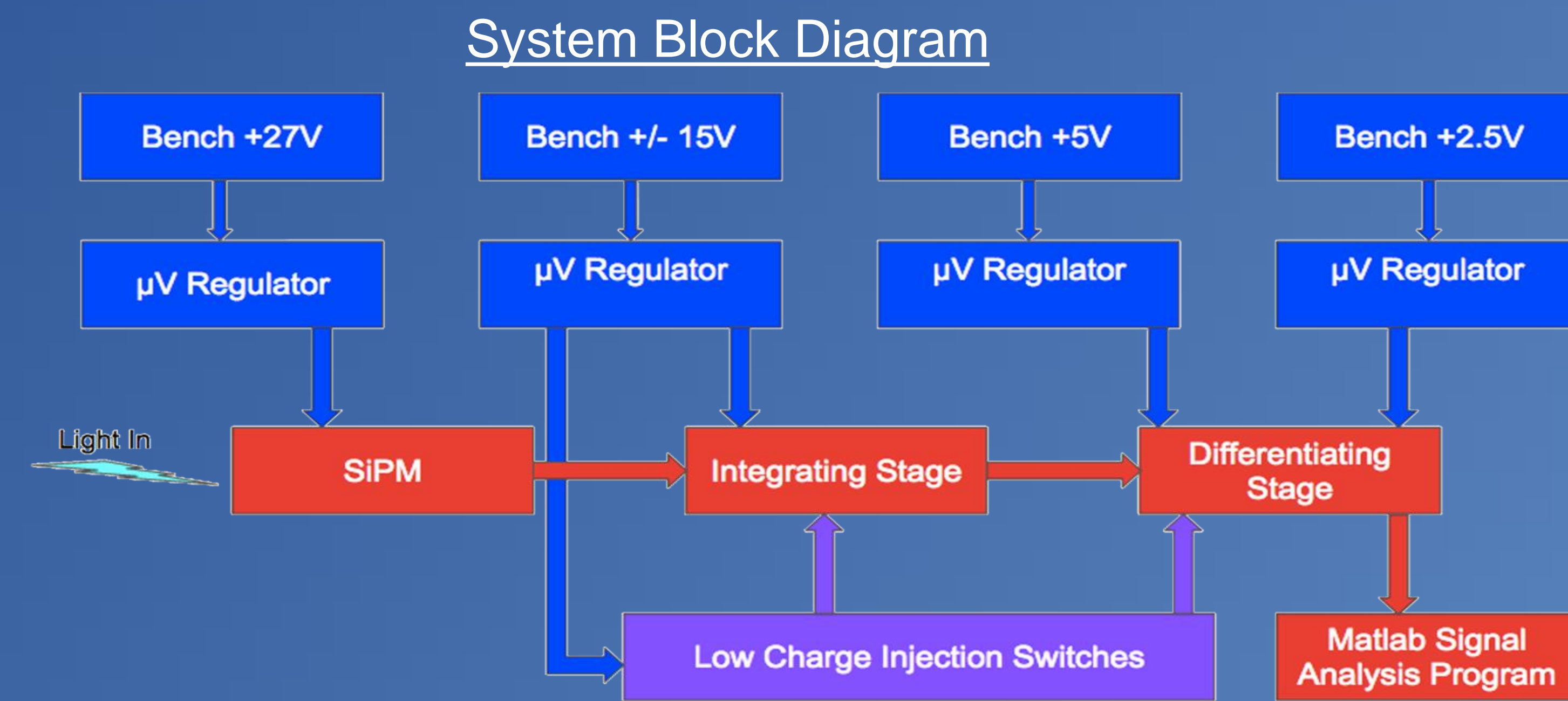
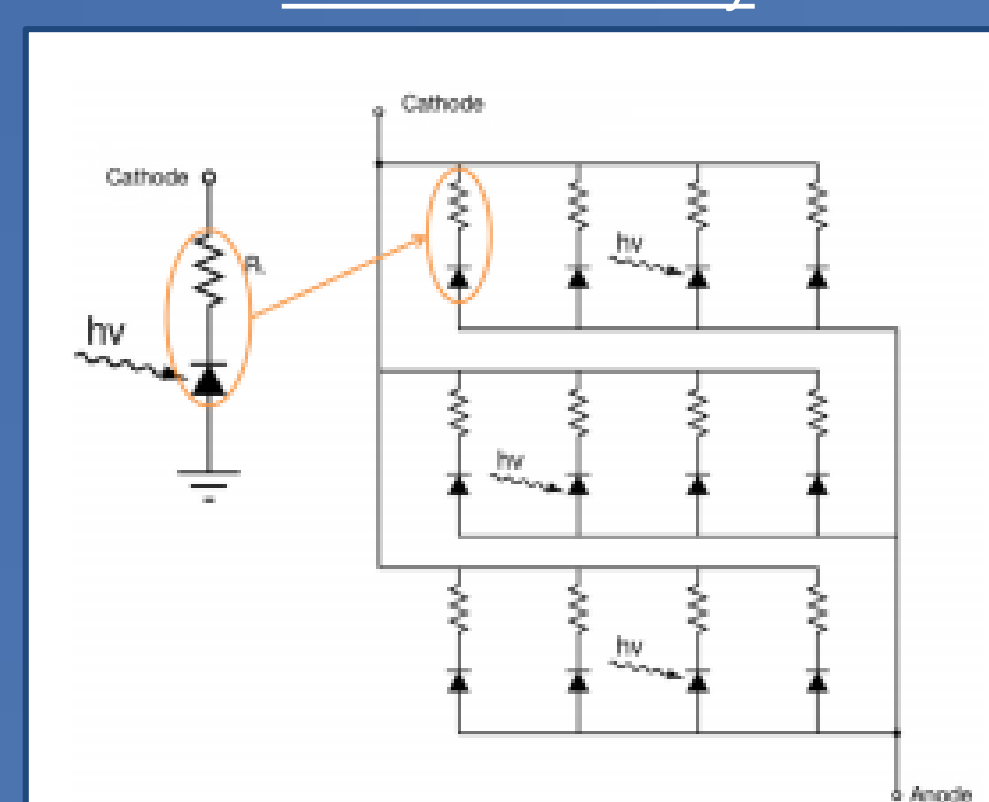
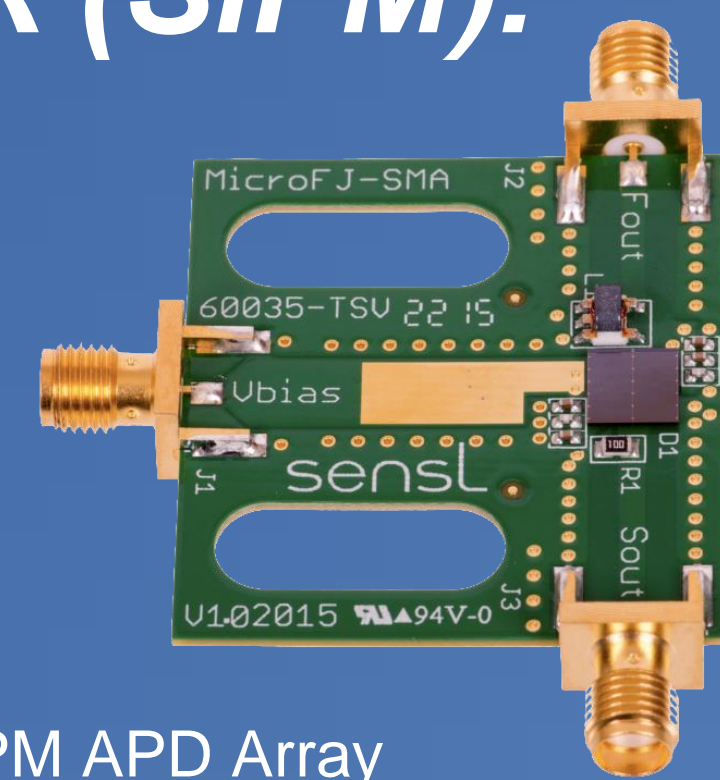
## SILICON PHOTOMULTIPLIER (SiPM):

### ADVANTAGES:

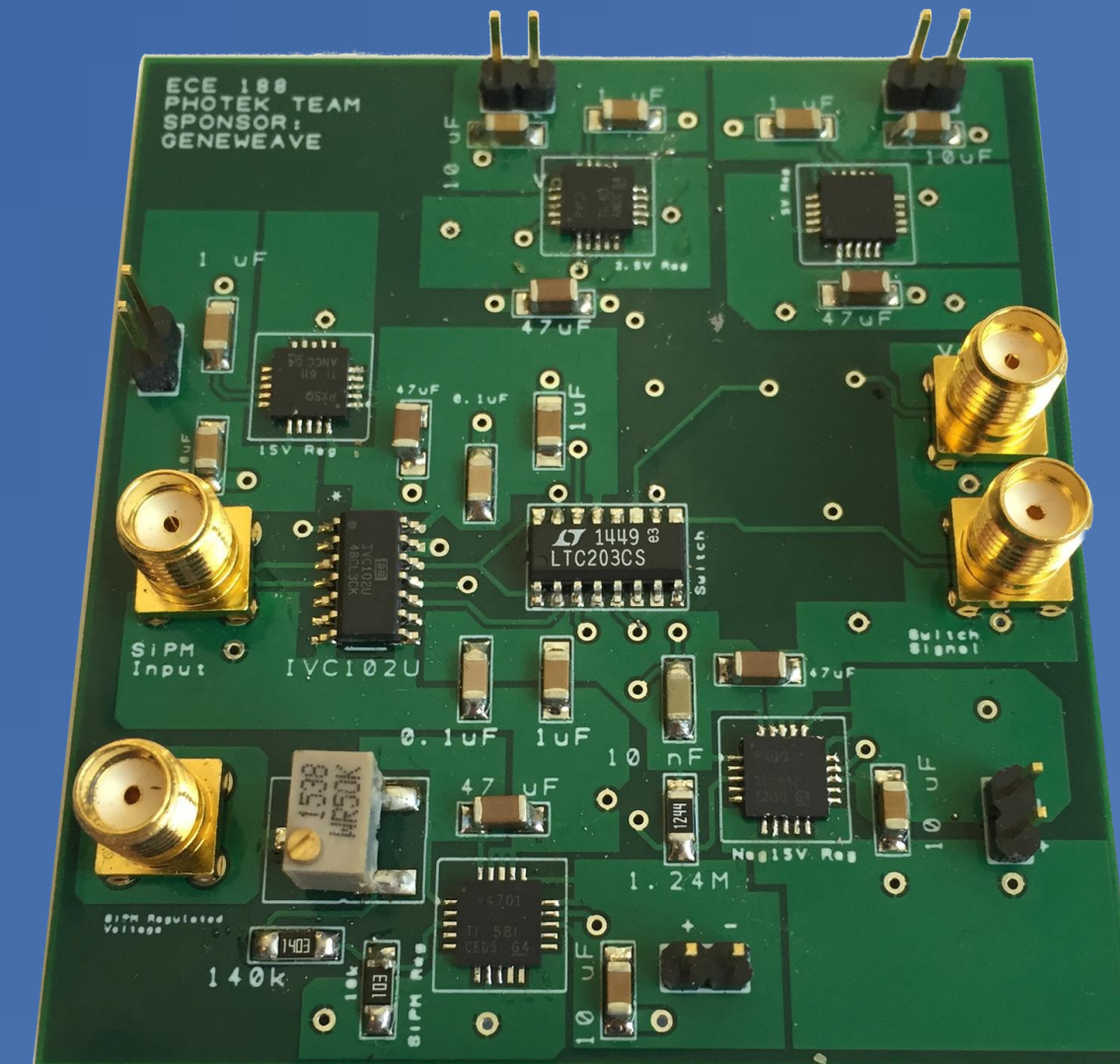
- Array of Avalanche Photodiodes (APDs) in Geiger Mode
- Inexpensive
- High Gain
- Compact (1mm<sup>2</sup>)
- High Photon Detection Efficiency (~29%)

### DISADVANTAGE:

- Moderate Noise: 30 kHz



## SIGNAL PROCESSING CIRCUIT:

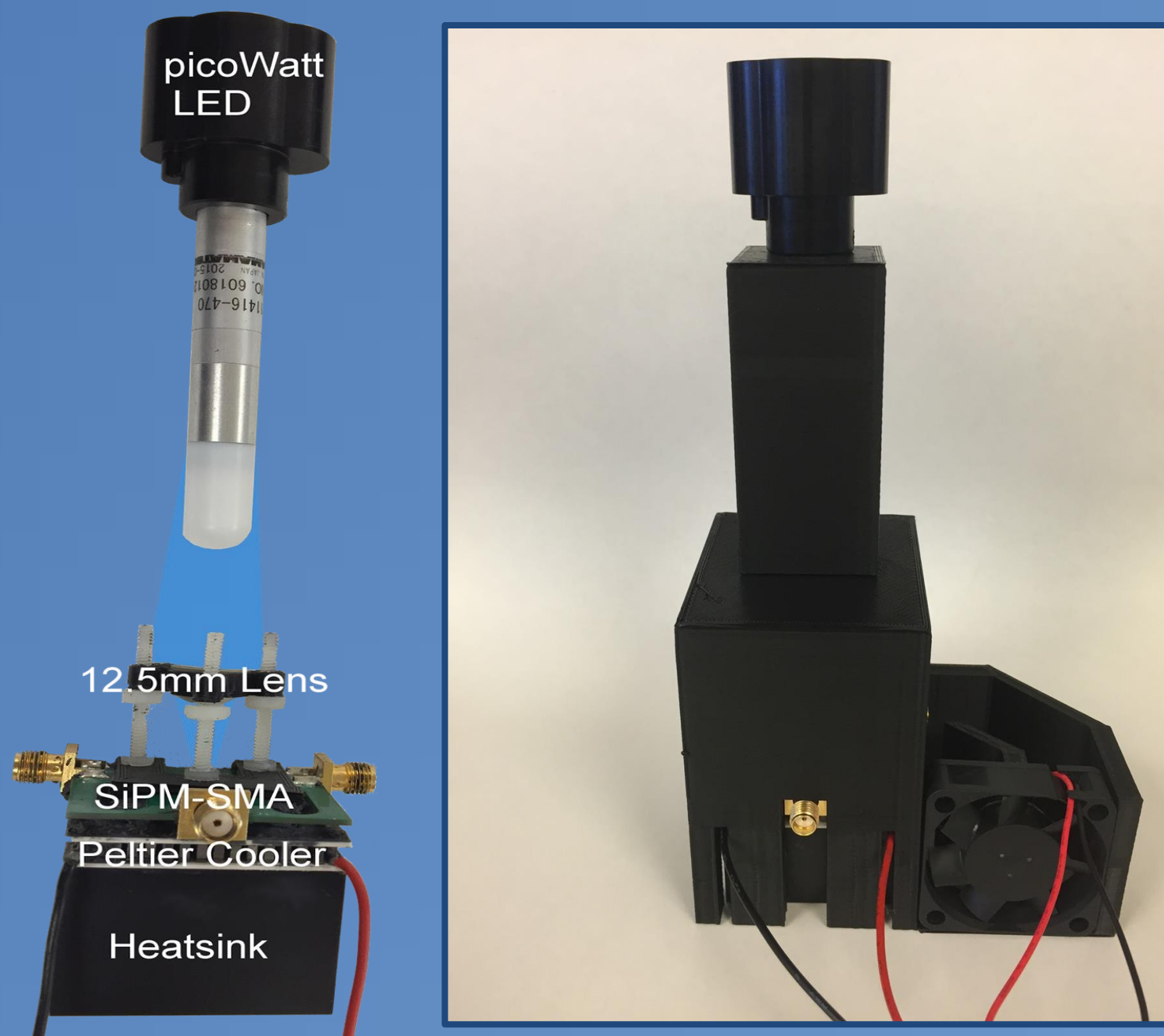


- Integrating Transimpedance Amplifier Followed by Differentiating Amplifier
- Output Voltage Proportional to Input Current
- High Gain with Low Added Noise
- Low Charge Injection Switches Reset Integrator

## DETECTOR SYSTEM:

### LIGHT ISOLATION HOUSING:

- Blocks Ambient Light
- Houses Test Tube and SiPM Detector
- Contains a 40x40mm<sup>2</sup> Cooling Fan
- Reflective Tape Inside

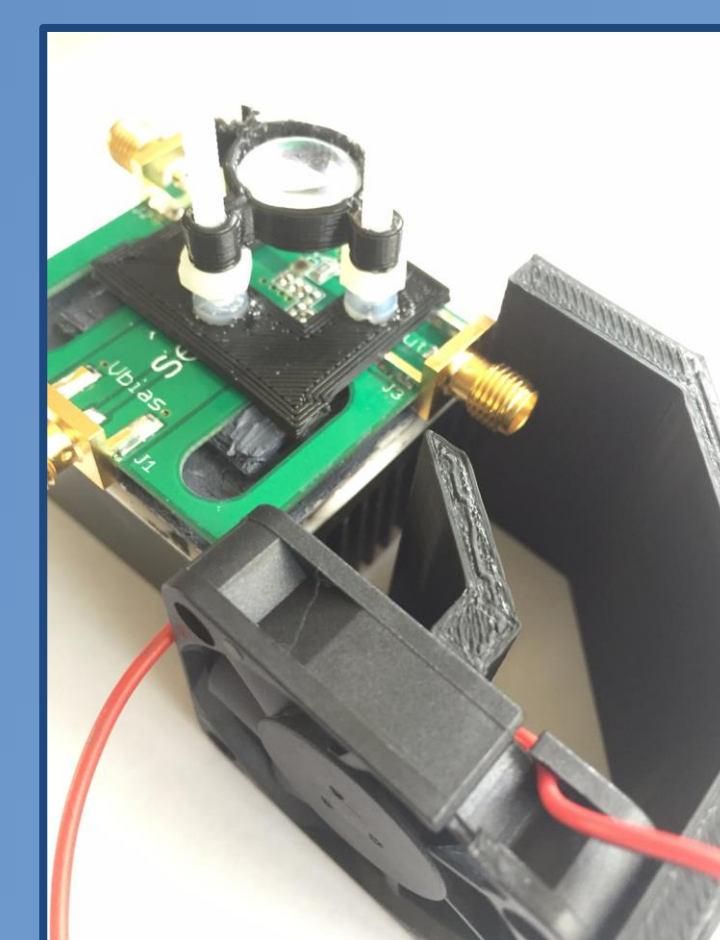


### LOW AREA HIGH SENSITIVITY DETECTOR:

- SensL SiPM 1mm<sup>2</sup> Detector Area
- Detector Attached to a Peltier Cooler to Reduce Dark Count

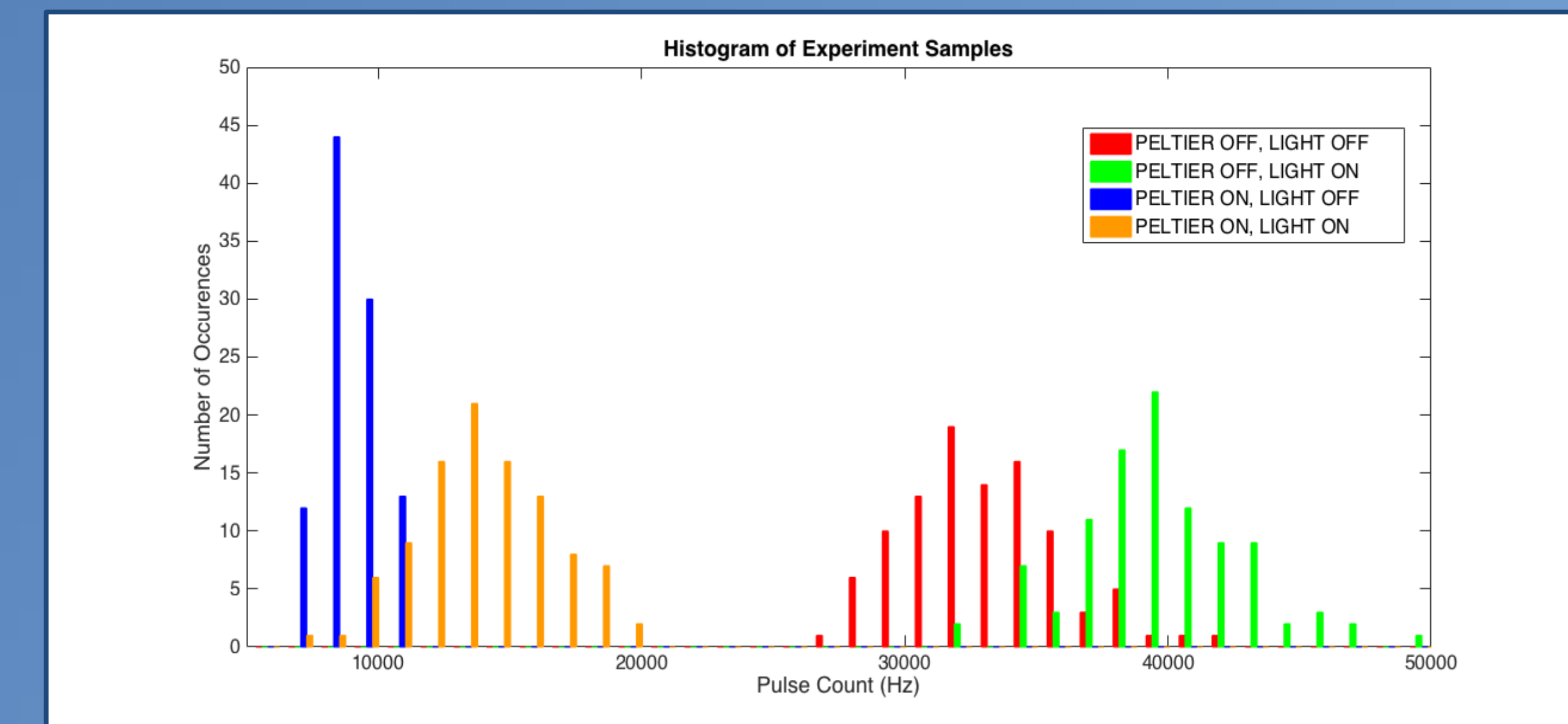
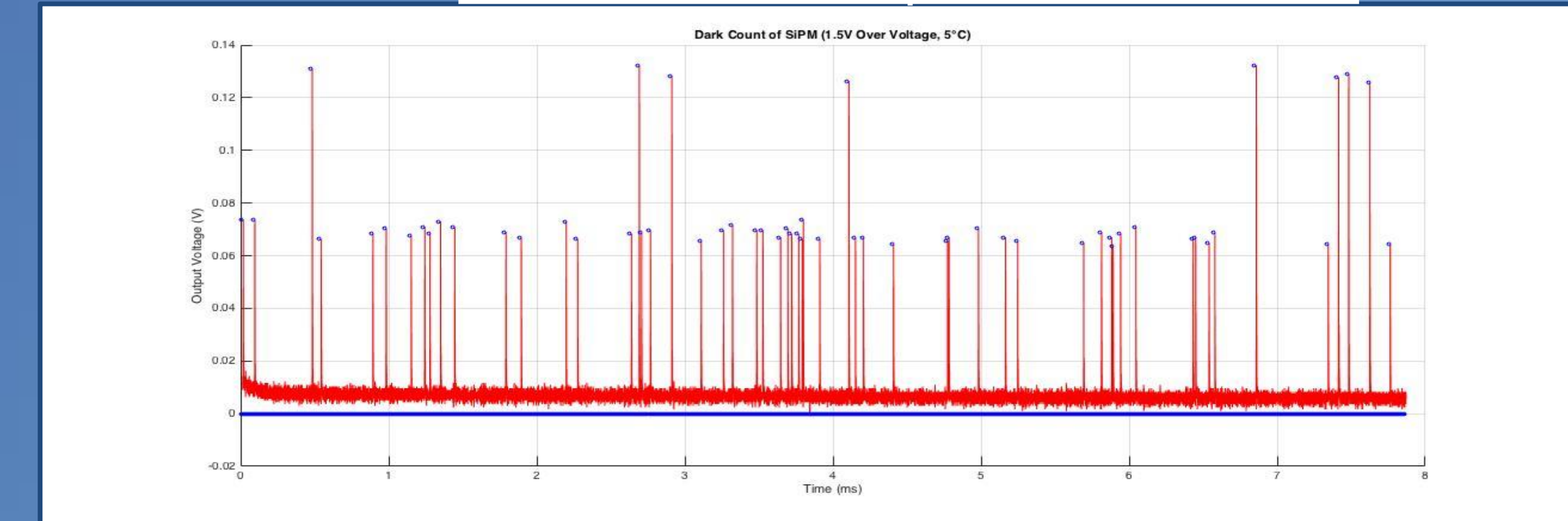
### DARK COUNT REDUCTION COOLER:

- 40x40mm<sup>2</sup> Peltier Cooler
- At 8V Bias, Cools the SiPM to 4°C
- Opposite Side Affixed to a Heatsink
- No Significant Electrical Noise



## DATA:

Pulse Count Sample from the SiPM

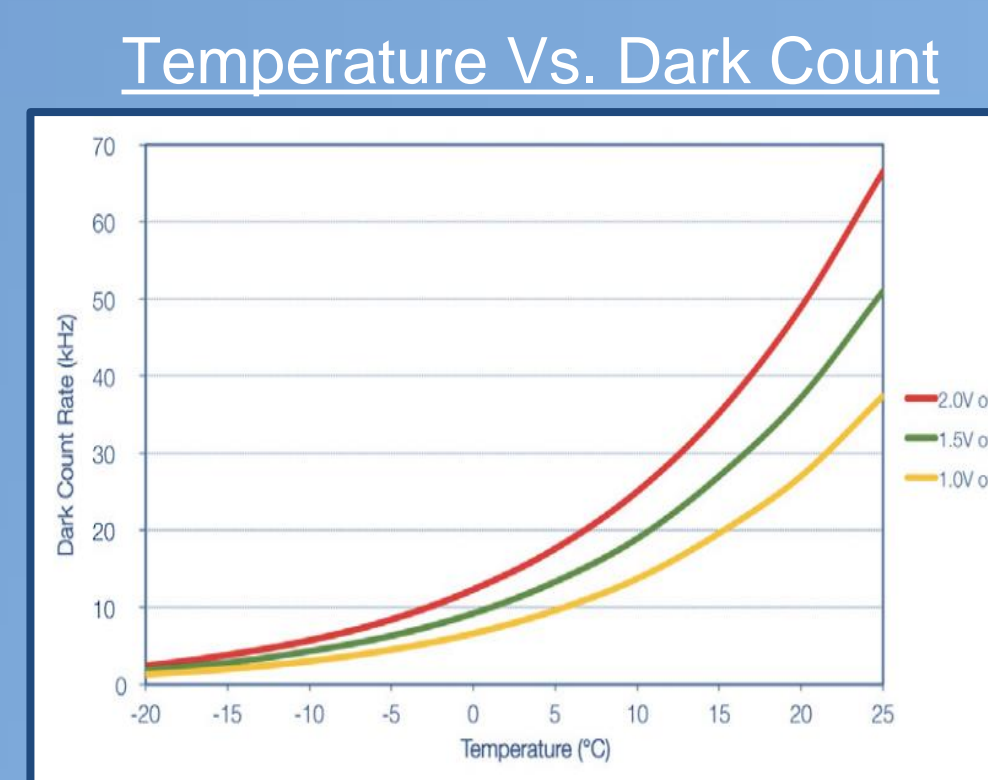


## CHALLENGES & POTENTIAL SOLUTIONS:

Compared to a PMT, our dark count of 6 kHz was low enough to detect light from GeneWEAVE's supplied 1pW stabilized light source but too high to see a minimum count of 200 photons/sec.

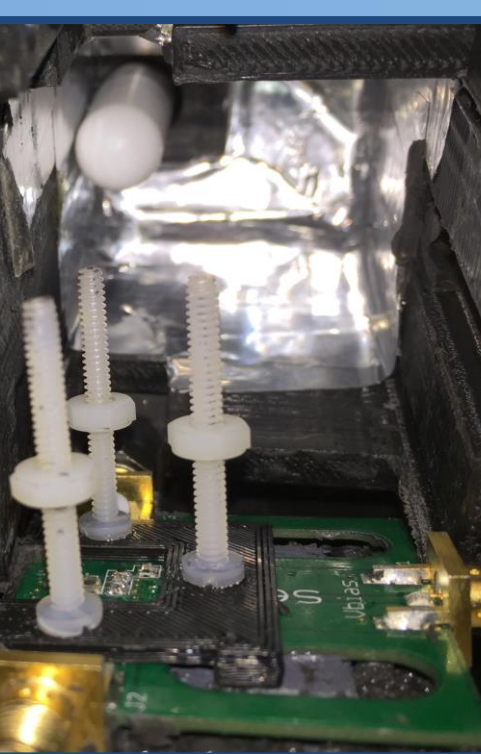
### OVERCOMING HIGH DARK COUNT

- SiPM Cooled to 5°C Reduced Dark Count From 32 kHz to 6 kHz
- More Cooling Would Further Reduce Dark Count



### FOCUSING THE LIGHT SOURCE

- Using Larger SiPM Area Would Allow More Photons to Hit Detector
- Optimize Housing as Light Guide to Increase Photon Flux



### MAINTAINING CONSTANT LOW TEMP OF SiPM

- Water Cooling System to Avoid Localized Heating
- Use Temperature Control Circuit to Stabilize Dark Count