LED-based Detector Calibration Studies for the SuperCDMS SNOLAB Experiment

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Abstract

SuperCDMS at SNOLAB is a direct search experiment for dark matter, targeting dark matter particles with low mass (≤10 GeV/c²). In order to achieve the projected sensitivity, a lower background, in addition to lower threshold energy, are a necessity. In the past, detector calibration was performed using radioactive sources. Currently, we are exploring the possibility of using LED-based calibration methods. Here we will introduce measurements using LEDs of various wavelengths operated at cryogenic temperatures to study the detector stability. Moreover, we will report the progress made using this new method for detector calibration.

Motivation

The Super Cryogenic Dark Matter Search (SuperCDMS) uses cryogenic Ge and Si detectors operated at a few 10s of mK to search for dark matter. The new generation of SuperCDMS at SNOLAB [1] pushes towards very low energy thresholds where calibration with external radioactive sources is difficult. We investigate new calibration methods covering the eV energy range, utilizing LEDs operated in the cryogenic environment.

Signal Amplification - NTL

$$E_p = E_r\left(1 + \frac{eV_b}{\varepsilon}\right)$$ ← Total phonon energy as a function of bias voltage

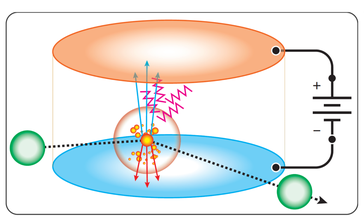


Figure 1: Primary recoil phonons (due to initial particle interaction) and emitted Luke phonons (due to the accelerated charges) are measured in SuperCDMS detectors [2].

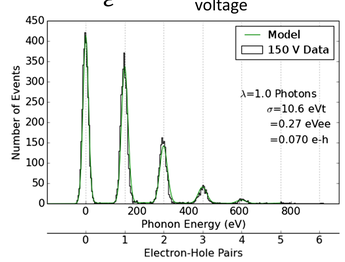


Figure 2: A spectrum for High Voltage detector operated at 150 V and achieving single $e-h$ pair sensitivity [3].

IR-LED Experimental Setup

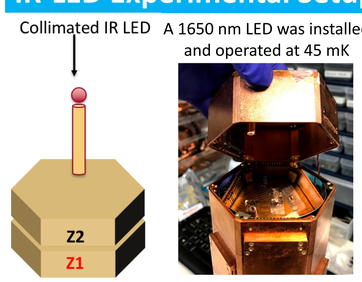


Figure 3: *Left:* A sketch for the setup which includes two iZIP detectors and one IR LED. *Right:* Actual setup showing the top surface of the iZIP detector.

IR – NTL Amplification

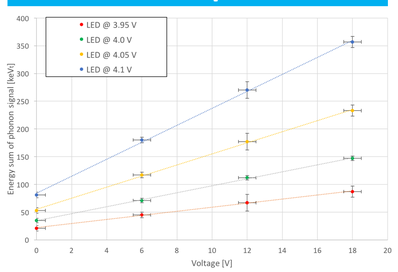
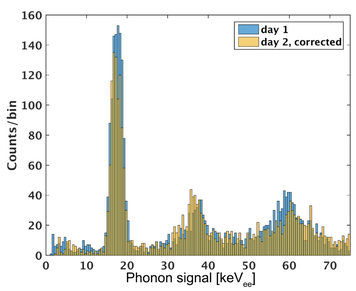


Figure 4: Total energy of phonon signal measured at different detector bias voltages. Which confirms that what we measure is photon interactions in the crystal, rather than warming from the current.

IR – Signal Stability

Figure 5: Two data sets were taken at two different days showing the the stability in LED signal. The measurement on day 2 corrected due to detector's instability.



e-Gun: Conceptual Design

The aim of this design is to develop a low-intensity electron gun as a tunable calibration source in the sub-keV energy range, down to a few eV.

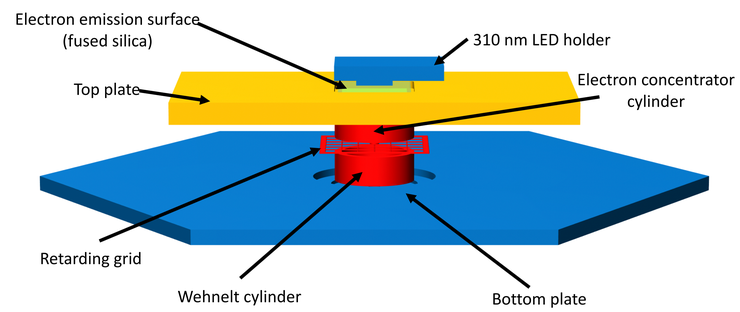


Figure 6: A schematic for the different parts of the e-gun. Colors in this drawing shows parts with identical potential.

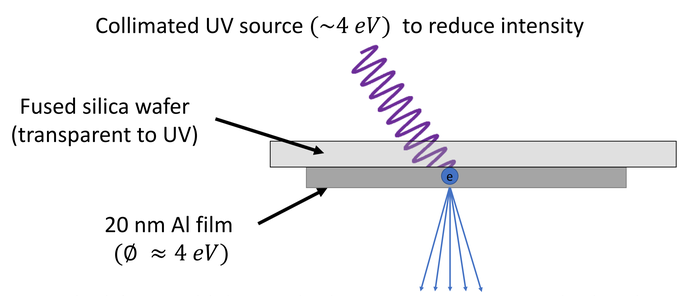


Figure 7: A sketch *(not to scale)*, depicting the electron emission process using the photoelectric effect out of Al film.

Simulated Data

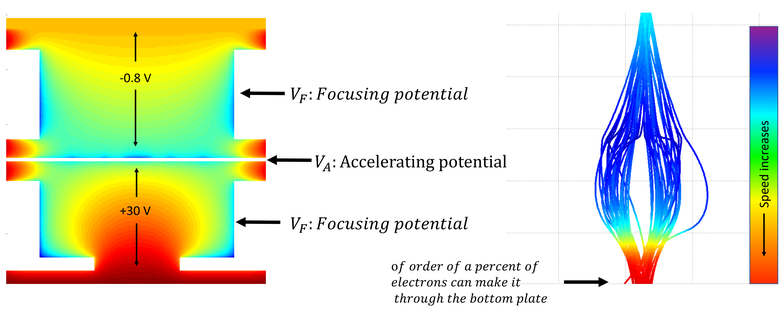
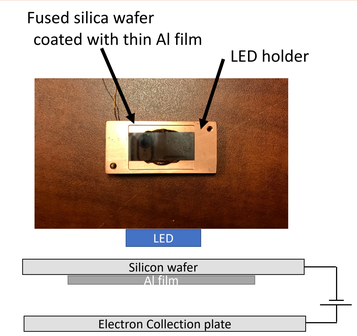
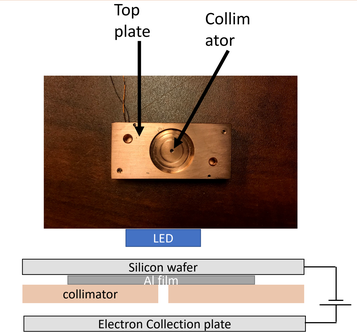


Figure 8: *Left: A simulation for the* E-field mapping. *Right:* A simulation for the electrons' path through the electron concentrator, the retarding grid and the Wehnelt cylinder, color represent electron's increase in electron's speed (blue to red).

Preliminary Tests

Without Collimator	With collimator
	
In here, current was measured using a copper plate in a vacuum chamber and by applying a bias of 12.5 V to the LED holder relative to the copper plate.	In here, current was measured using a copper plate in a vacuum chamber and by applying a bias of 12.5 V to the top plate relative to the copper plate.

Measured current @ 80% of the maximum emission	1.5 pA	Measured current while having the collimator	0.2 pA

Based on the measured current values, we have 13% transmission probability through the collimator, which will be implemented in the future simulations to predict the exact number of transmitted electrons though the bottom plate.

Estimated number of emitted electrons

Based on the simulations, and after attaching the whole setup for the electron gun. If we assume that the maximum number or transmitted photons is about 1%. That should correspond to about 2 fA.

$$\#\ of\ electrons: \frac{2fA}{1.6\times10^{-19}} = 12.5\times10^{3}\ electron/sec$$

If we pulse the LED for about 50 μs , then the expected number of electrons will be:

$$\#\ of\ electrons\ in\ 2\ fA\ \rightarrow \sim 0.6\ electrons$$

Further Tests

In order to test the operation of the e-gun, we need a detector that is sensitive to a single electron-hole pairs. SuperCDMS collaboration have recently developed a High Voltage prototype detector that is sensitive to single electron-hole pairs, HVeV [3] and the plan is to utilize this detector to confirm the emission of electrons through the bottom plate. We would also need to test the detector response at various bias voltages.

References

[1]. *Agnese R et al. Physical Review Letters, 121(5), 2018.*
[2]. *Wei, W.Z., and Mei, D.M. Journal of Instrumentation 12 (2017).*
[3]. *Agnese R et al*. Physical Review D, 95(8), 2017.

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