SiPM characterisation - Notes on "Theory" + Experimental procedure

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10 SiPMs to characterize: Hamamatsu S13370-6050CN (2021-12-23)

(if time allows characterize PMT too? - need to figure out 3D printed "mounting" though...)

Questions and answers:

- Calibrate SiPM: Gain and IV curves to be found and photon count (Elena)
  - maybe I can also add efficiency of detector, more detail to SPE response, plot comparing the different SiPMs, behavior over time... (see lamp paper for some more ideas lol)

- Eventually SiPM characterization will be used to calibrate the dark room / lab lamp source to be used on the ase detector we are actually going "doing research" on.

- Calibration of SiPM done in visible wavelength not Ar 128nm wavelength but it should be fine?? - as long as HV is adjusted accordingly and gain characterized

→ What is gain has non linearities - HV vs. pulse heights is non linear?

→ Is the idea that the same trend (gradient) should follow 128nm scintillation as visible light characterization?

(David's work showed this wasn't true for single SPE at low gains (low HV) though but does that only apply to NaI PMTs)

- Emission energy vs. wavelength ← somewhere my understanding is wrong?

→ I think the difference here is that this isn't spectroscopy! We don't care about the actual energy of the scintillation light (in general it's just SPEs anyway), all we care about is recording that "some pulse" was detected at all or not?

- There might be a premade script to run the data analysis readout but maybe it's not exactly what I need or it's not that efficient so maybe I'll have to make my own. → Make sure the script is general so I can run it for all SiPMs!!

- Each SiPM datataking should take ~1 day of data collection?

Apparently 1st one might take ~1 week as I figure out mounting them, noise issues, readout issues, etc... After that it should just be repetition!

→ Noise issues might be fixed by grounding problems, gl with that lol

→ Do we have poisson noise on waveform and gaussian noise for counts vs. amplitude plot or something else...?

- Either way use 240 notes for efficient work

(isn't energy + λ the same thing here: $E = hc/\lambda$ for emission of γ)

(Remember our source is a ~405 nm laser - visible light not deep VUV)

→ What graphs / plots to produce eventually:

Always average waveforms, we will never use one distinct one really! (~200)

- Gain characterisation: voltage vs. amplitude (avg. for 1 HV / E-field)
- Dark count: Run without "turning on" SiPM / source
- Ghosting effects: Take "idle" runs from time to time to see what outputs we get.

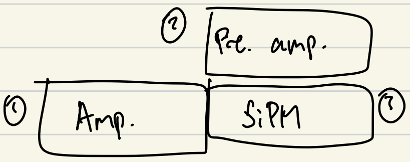
  Maybe let the setup "run empty" for a while before actually recording data - might remove most of the traps (exponential)
- Attenuated plots ?? - Counts vs. Amplitude of waveform (peak amp.?)
- Characterise SPE counts vs. Amplitude - and then efficiency also (with PMT of a known efficiency).
- If field is varied, plot avg. amplitude vs. time over all waveforms in one plot ignoring the huge bill
- Plot amplitude vs. field to then "avalanche gain occurs"
- Somehow generate I.V. curves which idk what that's about? How ???
- Find and characterise breakdown voltage?
- What λ of light is the VUV source? This is why it needs to be dark but we don't need vacuum?

– Breakdown voltage: lower limit for applied bias voltage.

- But ideal min is often higher - min needed for stable operation is point at which dark currents don't "flatten" IV curve!

- Password : solar (lower case)

- Power supply :



1 & 2 : power on/off
& turn on/off when needed

3 : ~60V ? - depends on when mine breakdown.

- 4th channel open on board. Only 1 channel possible on amplifier at a time

- Trigger on LED & amplifier output into digitizer

- Amplifier set to max gain right now?

- Questions : · How does continuous data aquisition work on software
  - How do you actually get a signal ?
  - Describe the waveform shape to me I don't really get it
  - How does one characterise gain exactly - why does it need to run for soo long, is the signal output very weak?
  - How to run the C++ file on the linux machine and export to USB?
  - Can I be in here alone taking data?
  - Apart from gain, what other bits from my lab are useful
  - We avg. all multiple waveforms while keeping energy constant?
  - Notes from Camp paper to analyze waveform - eg. Trapezoid filter?
  - Do I have to account for dark count correlation effects ?

- Using C++ file converter : in Documents ⇒ data-to-root/dat-to-root wave0.dat

→ Output will be a wave0.dat.root file ??? Why .dat.root !?

Compiler has already compiled the program so I just need to execute the programme

- Trying to operate SiPM at 57V since Hamamatsu datasheet says breakdown voltage is 53 ± 5V and ideal operating voltage is 57V.

→ Atm changing (up or down) does nothing, I can only see noise...
(variation of ~20 in adc counts top to bottom)

Characterizing gain

- Need a curve of voltage against gain where gain is measured by pulse height?
- Methodology: · Voltage values from 50V to 60V in 1V increments

  · Take data for ~5 min per voltage value

(all the data for one run will be averaged after bkg subtraction
→ recall stuff in 240 about dimensionality reduction maybe?)

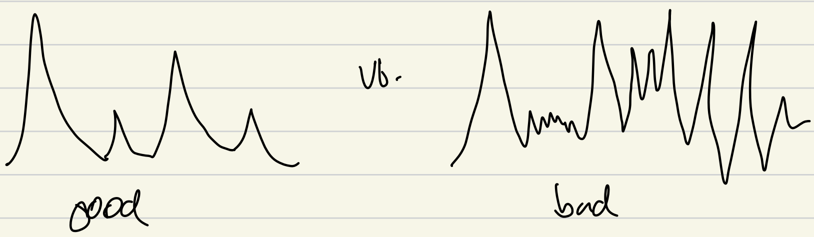
  · Between runs let the system cool off a little while SiPM is both powered and depowered

- Maybe I have the wrong idea - is it more like at a specific voltage for each saved waveform the height in ADC will be roughly in integers so you get:

For example if we have 1000 waveforms, find all the peaks and plot a histogram of them and fit that histogram to gaussians!

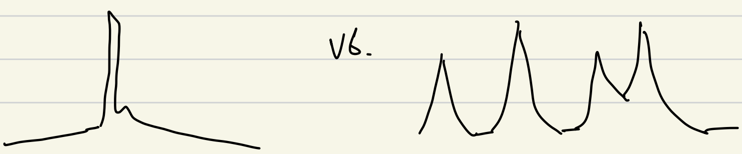
- A lot of what I was thinking was wrong lmao.
- First had to make sure the container the SiPMs were in was actually dark and use black tape instead of foil! Also added black covers!

  · On the oscilloscope it was obvious a lot of ambient light and noise was entering the system which is not good - always check by turning the light on/off and with smartphone flashlight around the chamber

  · 

Latter has too much noise with too many photons entering the system!

- Next had to fix saturation problem - the signals from LED were completely saturating the SiPM making it impossible to acquire single SPE data!

  · 

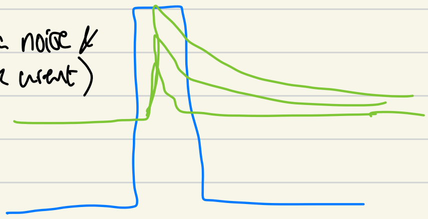
Former has just LED pulse washing out all SPE stuff so you cannot see them on that scale

(Want voltage and LED intensity as high as possible to see the most signals but not high enough to saturate the whole setup!)

- Dark current peaks are actually single SPE peaks, it's what we want – it's not background! The reason we have the LED is cause sure at room temp. there's a lot of photons hitting the SiPM and producing a signal, in cryogenic temperatures the dark current rate goes from ~ MHz to $\alpha 10^{-?}$ Hz and not useable, I am still using an LED cause it's standard practice!

(See this by turning SiPM voltage!)

- General idea is to turn LED off and see if you can see unsaturated dark currents hitting the SiPM and then slowly turn the LED up and up to see how the waveform changes and keep turning it up until those new peaks are just not saturated so that you can get the best results!



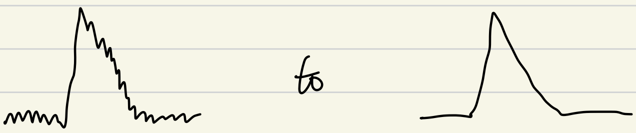
The blue is the LED trigger so the green ones are the photoelectron peaks directly from the LED (time delay due to software delay between trigger and sending out a pulse)

Saturation would have the signal be capped out at the top!

Here after capping out there is a massive "undershoot" as the huge currents in the SiPM overwhelms everything!

The system then slowly "recovers" only for the process to repeat again on the next trigger....

- There's also "wiggles" on each waveform that is the actual noise here that would be needed to smooth out via either pre analysis or post analysis



makes the integration analysis much easier to do!

Ideas: ☹ Reduce acquisition rate in oscilloscope so it doesn't register these high freq. noise. So far couldn't find the setting on the scope - see data manual maybe?

↳ Tried averaging but that only worked in continuous mode and each saved waveform would still be noisy.

☹ Maybe a setting in ADC waveform analysis to smooth out these curves? Will be using that to collect data anyway so worth investigating!

☹ Post saving can some sort of "smoothing script" to remove wiggles

☺ Fit the waveform to a function or sum of functions to smooth stuff out.

☺ Do nothing! When integrating use a trigger system similar to David's!

To reduce "wiggles", have to ground the SiPM better!

[I wanted clear single SPE pulses but I was getting noisy & extremely saturated pulses that weren't SPE.]

- For actual analysis in producing the "finger plot", we will use pulse area (not pulse height) to characterise the gain!

  - Actually similar to David's script to use pulse area/height and convert that into a histogram of ADC vs. count. Essentially the same thing lol.

    ↳ He used sourced runs while we are looking at single SPE behaviour - something he also did that one time at the start!

For actual integrating, suggestions are listed above or I could try to repurpose either David's or Daniel's script and see if they work!

  - Careful with multiple overlapping pulses which will come out as ~Js of SPEs which has the effect of reducing the resolution of the finger plot

    ↳ Soln, can ignore waveforms not well defined for example.

- Potential future steps: ~10k waveforms in histogram

  - Go to him after I get the finger histogram plot for help with fitting

  - Could vary voltage to see gain variation with voltage

  - IV curves (currently SiPM run in reverse bias?) - helps find breakdown V.

  - Do I only count pulses that are directly from the LED or can I count dark current pulses as well.

- The whole using dark current instead of LED is also viable here cause of the timescale, the pulses are coming in on the ns. scale (~100 ns) which is a lot of data!

  - This is why on the ADC which is configured on the microsecond scale it all looks a bit squished!

This fast timescale also allows us the option written above of removing overlapping waveforms in our analysis since we will/should still have enough in theory!

  - if rate was too slow, waiting for ~10k non-overlapping pulses may have taken too long

- I have a good signal to noise ratio so this analysis works without needing bkg subtraction or something like that!

  - this is also something that I can study later if time permits

- Generally paper on SiPMs have: IV characterisation, breakdown voltage, gain characterisation (→ gives directly →) at 3 different voltages? Anything else?

→ Run 1 : 57 V , ~ 3.3 2ED strength (? units)

see jupiter notebook
for more!