Silicon PhotoMultiplier

Krishan Gopal (IISER Tirupati)
Tribeni Mishra (NISER Bhubneshwar)
Jyoti Babbar (Panjab University, Chd)

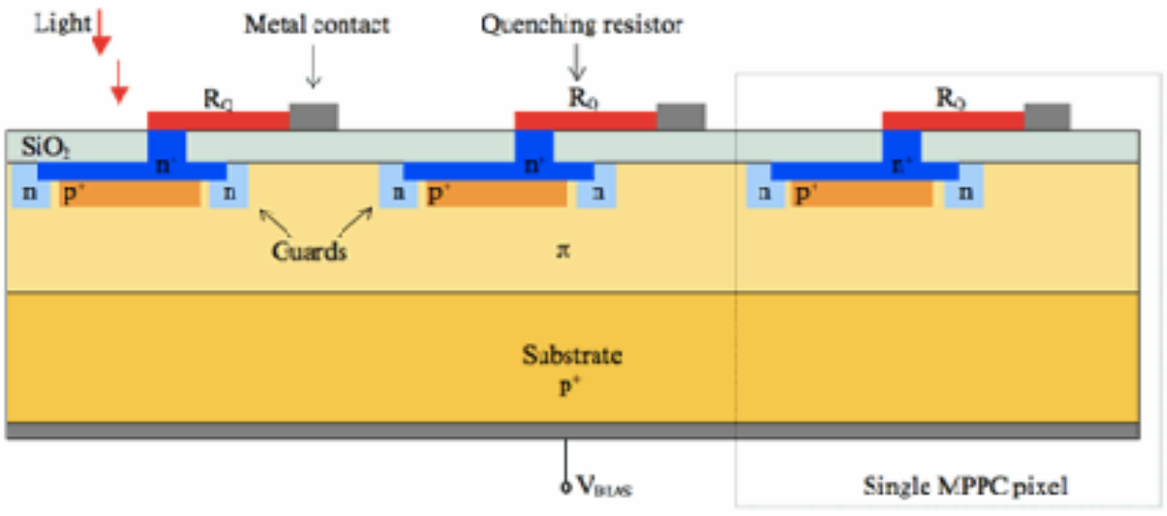
SERB SCHOOL
Tata Institute of Fundamental Research
Mumbai

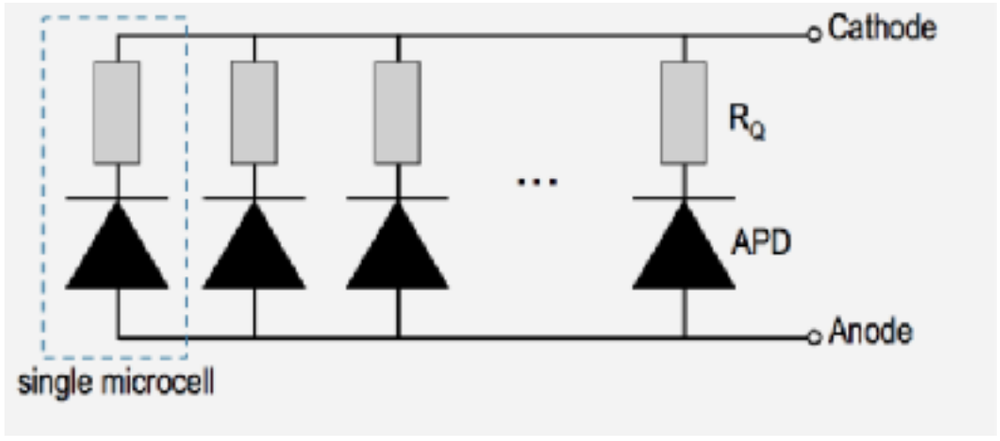
Outline

- What is SiPM?
- Operation of SiPM
- Advantages
- Possible Uncertainties
- Experiment Results

What is SiPM

- Pixelated device where each pixel, or a microcell, is a series combination of an avalanche photodiode (GAPD) and a quenching resistor (R_Q).
- Made by doping Silicon wafers to create a pn-junction type of diode
- All of the microcells are connected in parallel.
- Size : 2*2 mm^2, each pixel of size 50*50 um^2, around 1600 pixels
- Detects the photon when biased above the breakdown voltage (Vbias > Vbr).





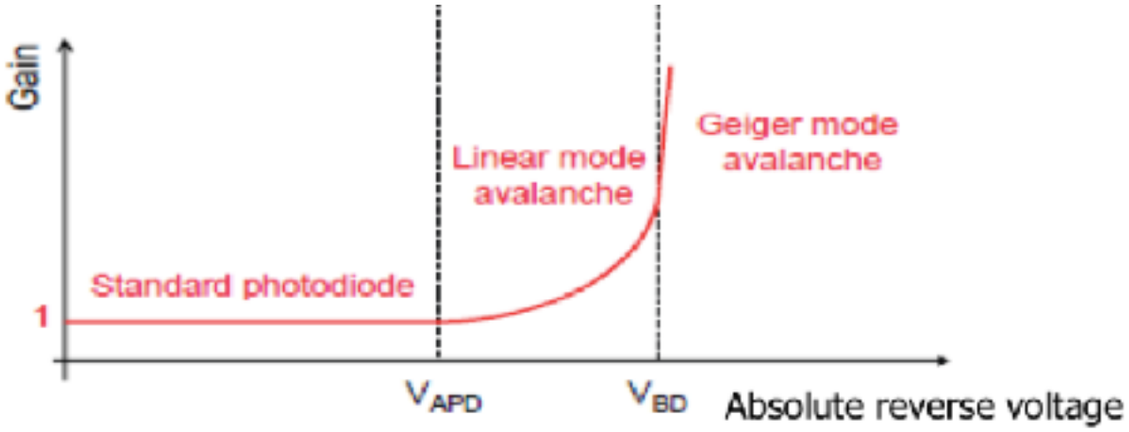
Operation

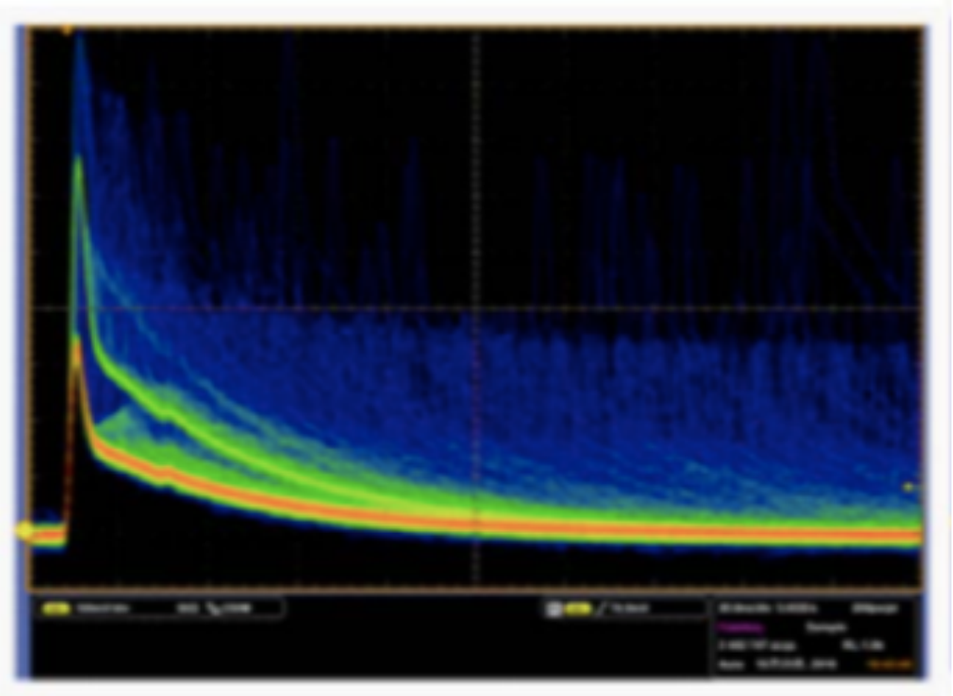
- Operate in reverse biased and conducts in Geiger mode .

- In GAPDs , Avalanches created by holes are used to amplify the input signal. Therefore a high ohmic resistor (quenching resistor) is necessary to discharge the photodiode and stop the avalanche.

- If a charge carrier triggers a discharge in a microcell, the consequence is a current pulse with the total amount of charge Q flowing through the terminals of the SiPM

- The signals from all the micro-cells are summed to give a signal proportional to the number of cells triggered .





Advantages

- High Gain (10^5-10^6) with low voltage
- Low power consumption
- Effect of magnetic filed is less
- Compact Size
- High Photon Detection efficiency (PDE)

PDE = N (output pulses)/N (incident photons) = QE * P * G

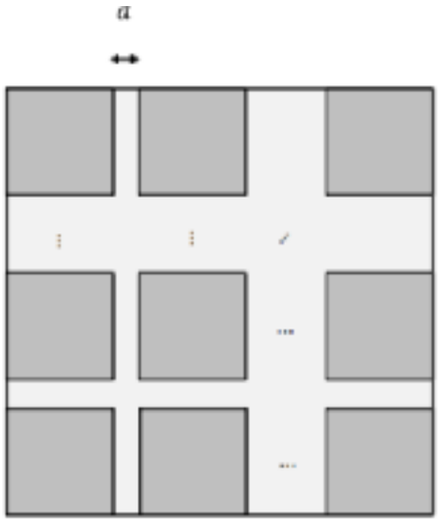
Quantum Efficiency(QE) = probability for a photon to generate a carrier

Triggering probability (P) = probability for a carrier traversing to generate an avalanche

Geometrical fill factor(G) = fraction of dead area due to structures between the pixels

Possible Uncertainties

- Cross Talk :Free carriers may recombine with their counterparts and create photons that can be detected by other cells. An additional photon event is generated. This effect is called optical crosstalk. The spacing a is added to reduce optical crosstalk and to host the quenching resistors. The total area of the SiPM is not the geometrical area for pixels.
- Afterpulses : During an avalanche process, a small portion of avalanching carriers get trapped in impurity energy levels but are released after short delays upon receiving the required energy to reenter the conduction or valence band. Upon their release, these carriers initiate new avalanche pulses, which appear with delays after the genuine parent pulse and are hence referred to as afterpulses.
- Thermal Noise : Electron-hole-pairs can be randomly created by thermal excitation. This is called dark rate or thermal noise rate. The SiPM mistakes thermal excitation for photons. Evidently, the dark rate has to be measured for different temperatures



Experiment Results

I-V Characterstic

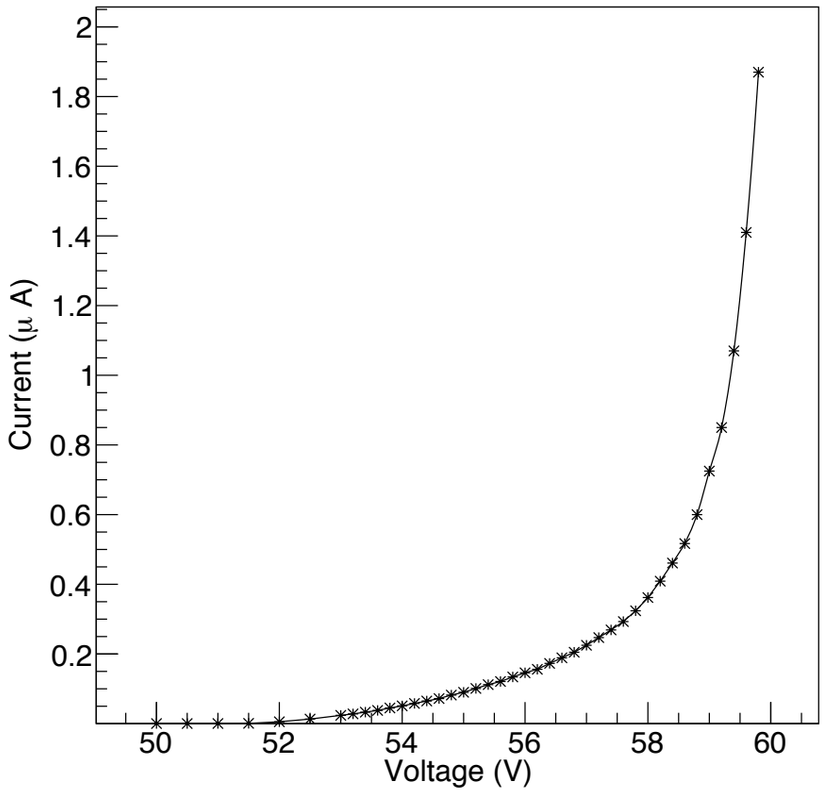
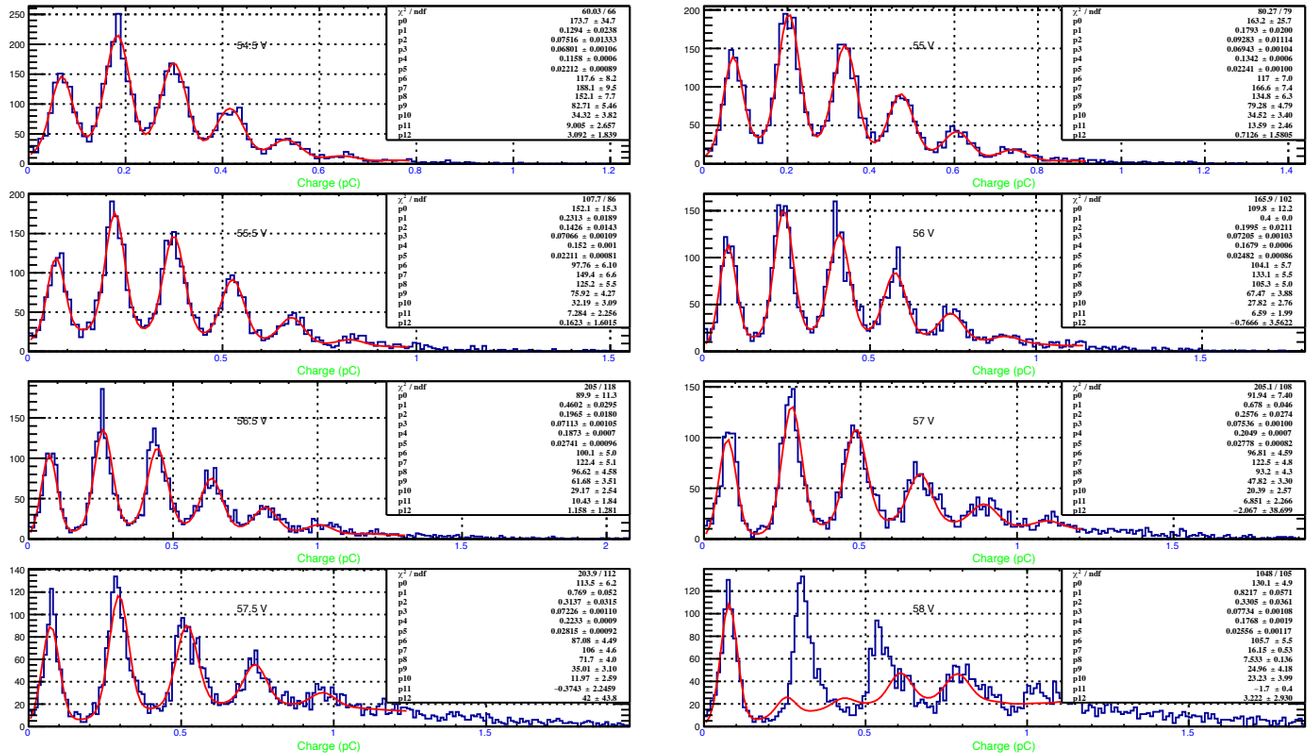
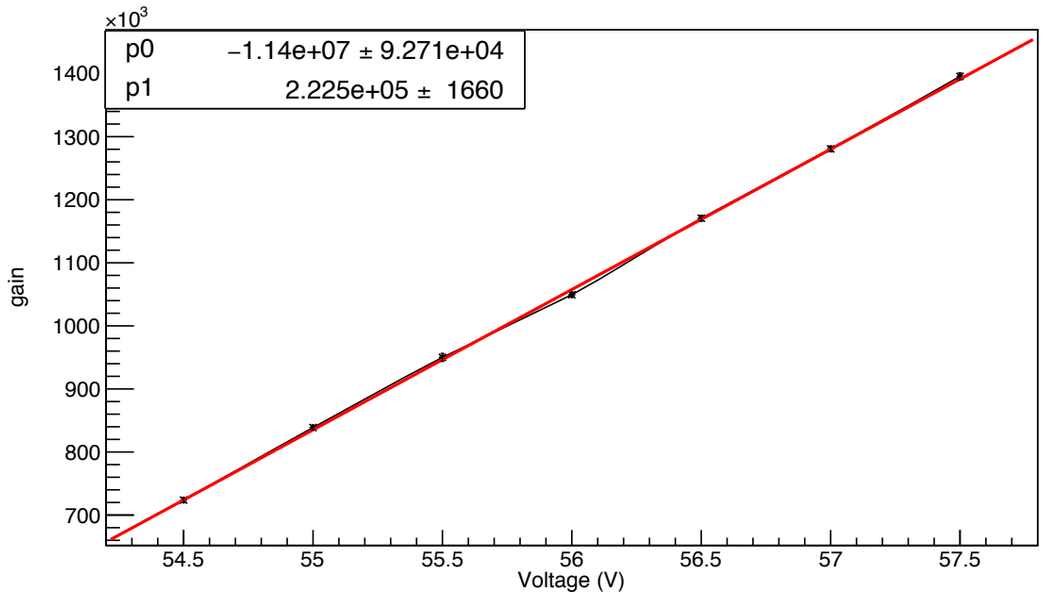


Photo-Electron spectrum at different High voltage



Operating Voltage = 51.26 Volts

Gain plot



Thanks to all the instructors for answering our silly questions , specially Bharat Singh , PethuRaj and Pathaleswar