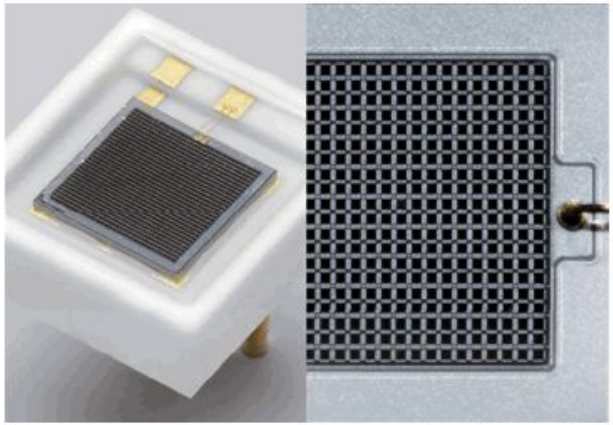
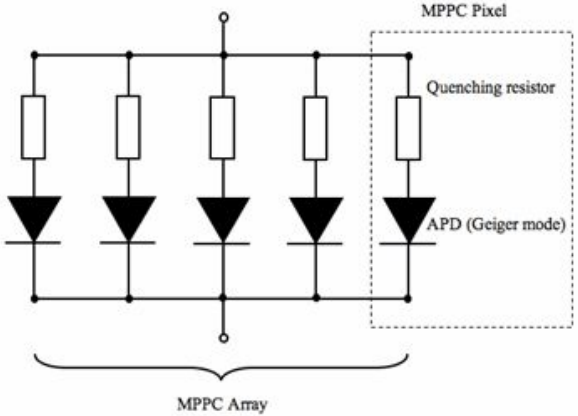
WL Summer Symposium Presentation

Darya Dayanim

Silicon Photomultipliers (SiPMs)

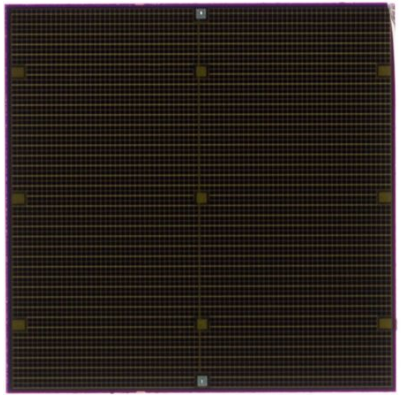


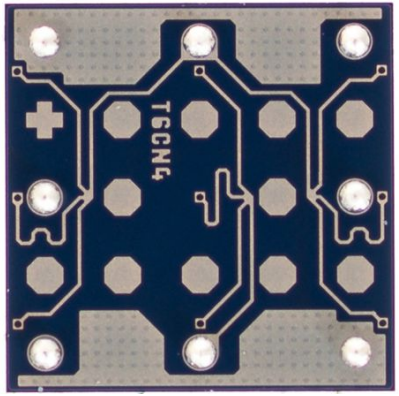
From Hamamatsu



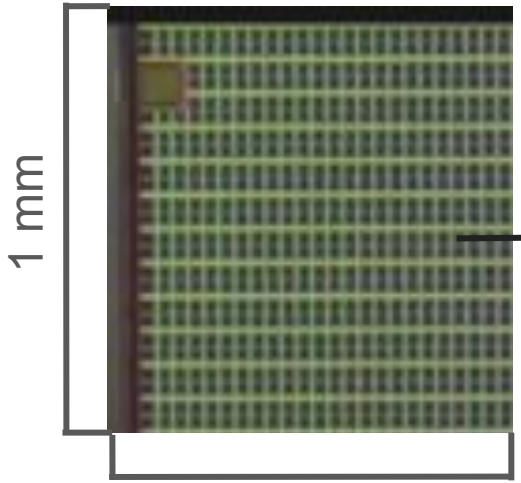
- Increased usage in physics experiments
- Pixels and their reset times

Motivation: Saturation models only exist for short and uniform light pulses…

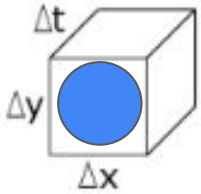


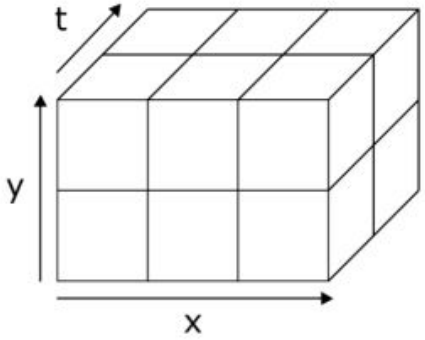


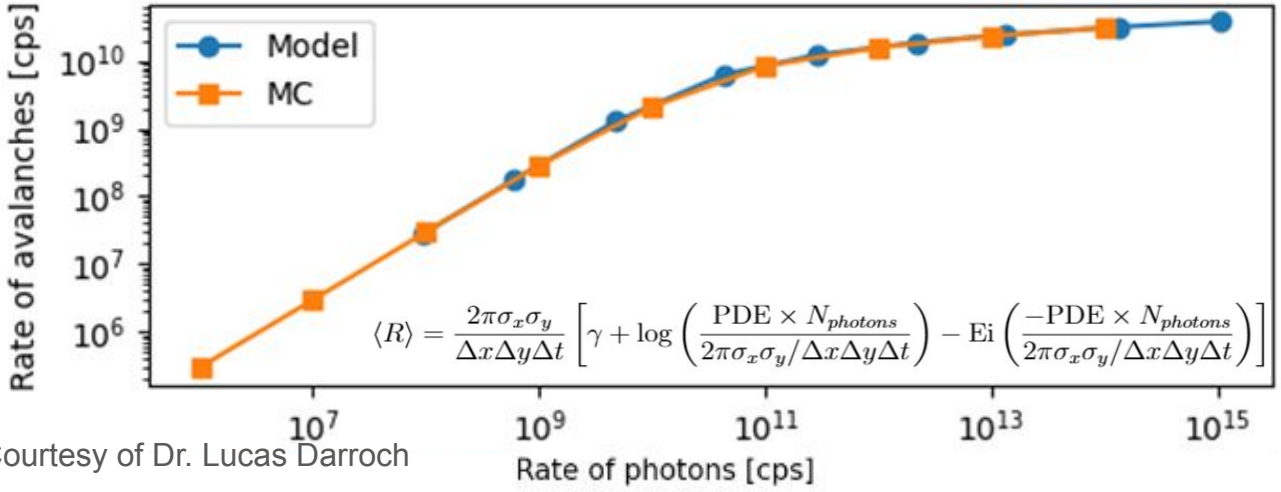
From Onsemi



Model



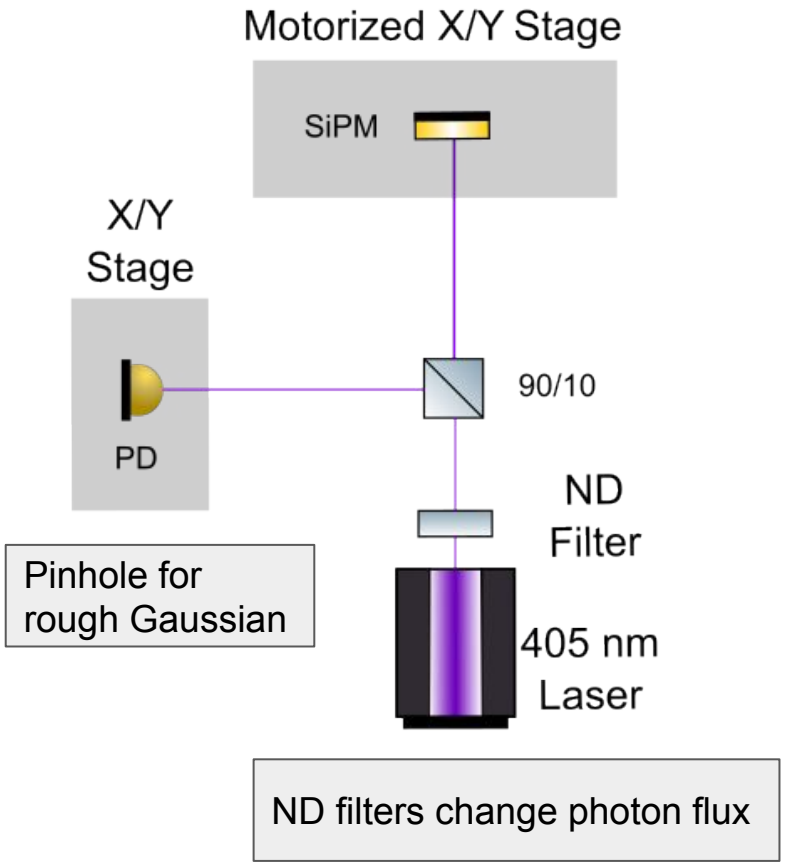


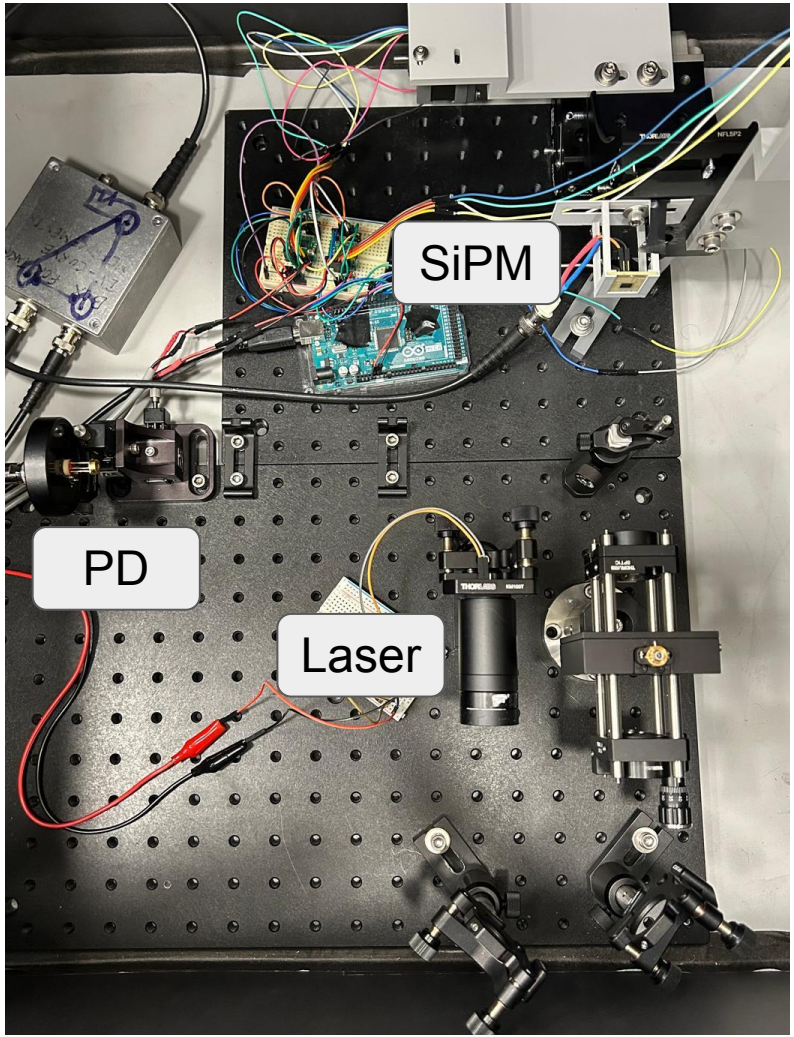


Courtesy of Dr. Lucas Darroch

- Characterize the non-linear response of SiPMs to non-uniform light
- Analytic equation for Gaussian profile
- Varying flux of photons
- Simulation shows it should work

Optical Path





Block Diagram of Commissioned Setup

- Automated data acquisition
- Stage moving properly

Power Supply

Laser Diode PL201

X-stepper motor

X-micrometer stage

PC

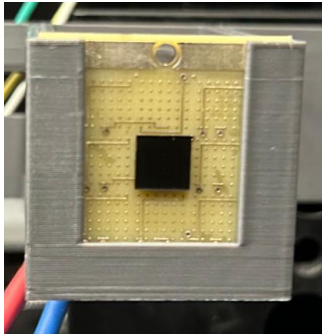
Arduino

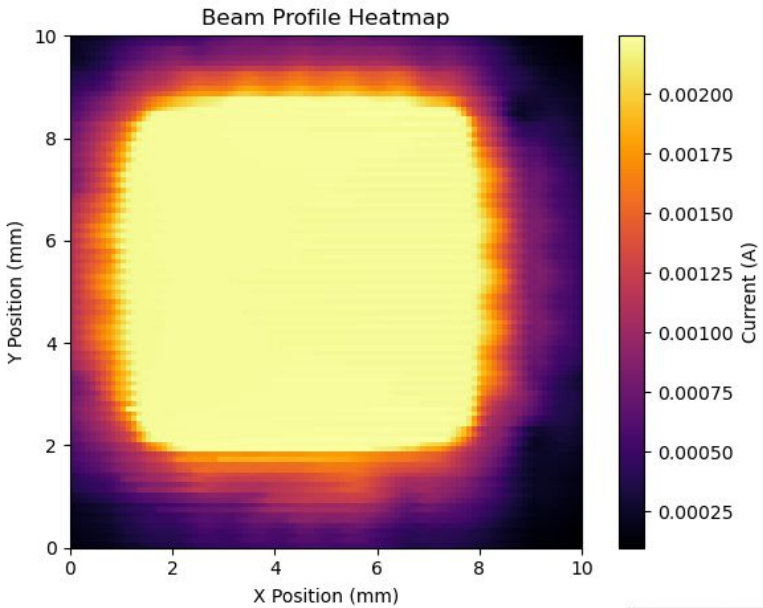
SiPM ONSEMI 60035

Y-stepper motor

Y-micrometer stage

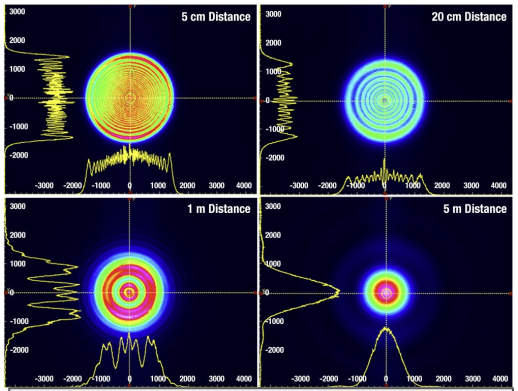
Picoammeter



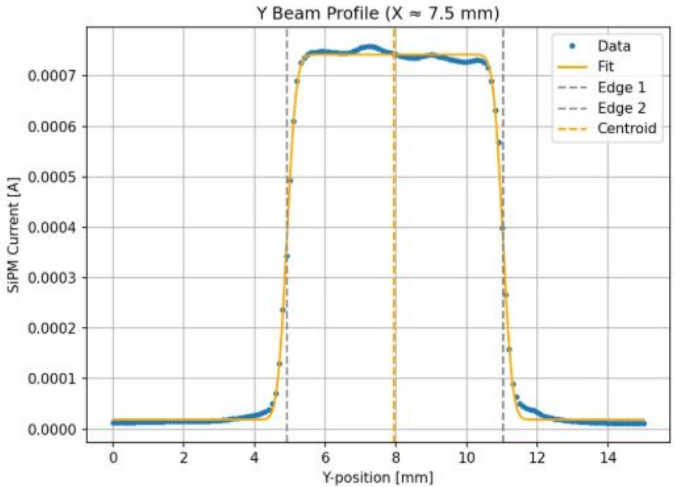


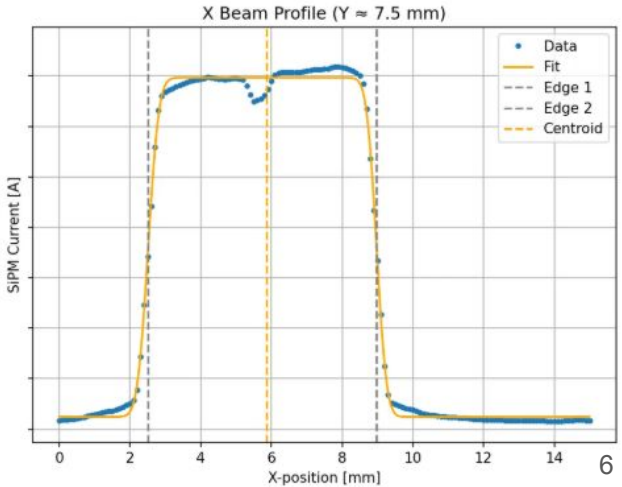
Data for Commissioned Setup

- 2D raster scan of device
- Measurement devices and stage work properly
- 1D line scans used to profile beam
- Integrating top hat beam



From Thorlabs





Updated Block Diagram

Photodiode FDS-100 CAL

Picoammeter

Power Supply

Laser Diode DL5146

PC

Arduino

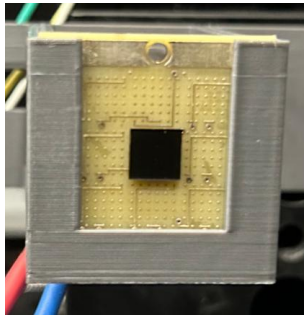
X-stepper motor

X-micrometer stage

Y-stepper motor

Y-micrometer stage

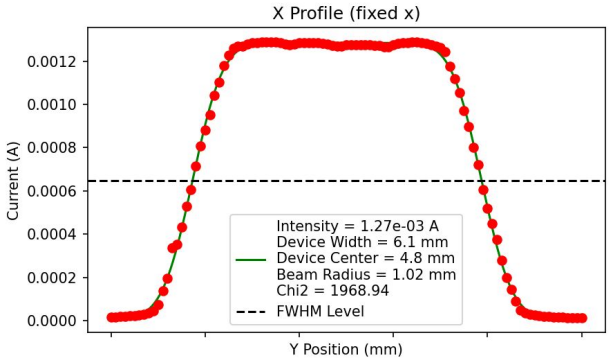
SiPM ONSEMI 60035

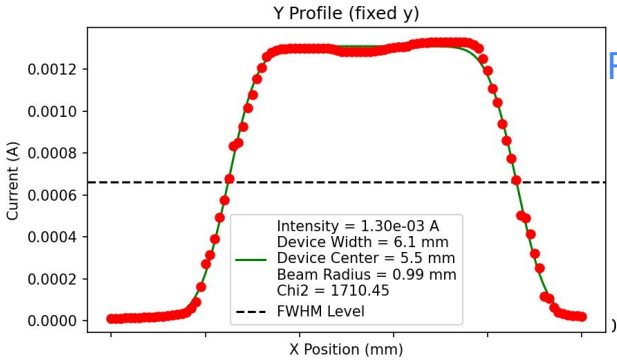


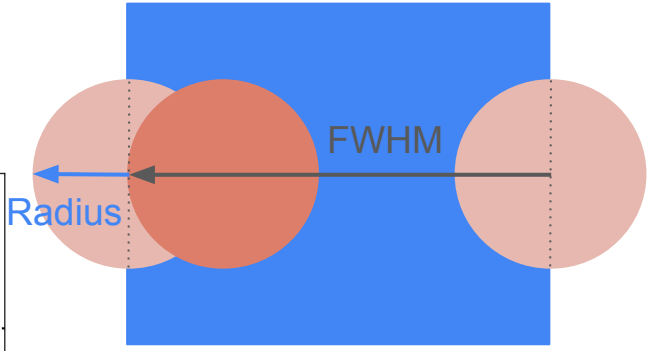
Digital multimeter

Changes are bolded

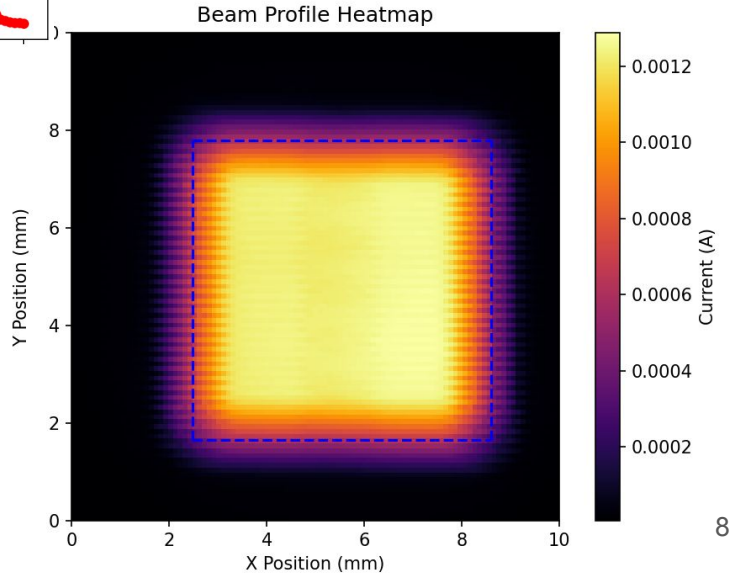
Final Data







- Profile of beam show a roughly Gaussian beam with ~1mm radius
- Better raster scan with dimension of SiPM outlined in blue: 6.1x6.1mm
  - FWHM helps to find center

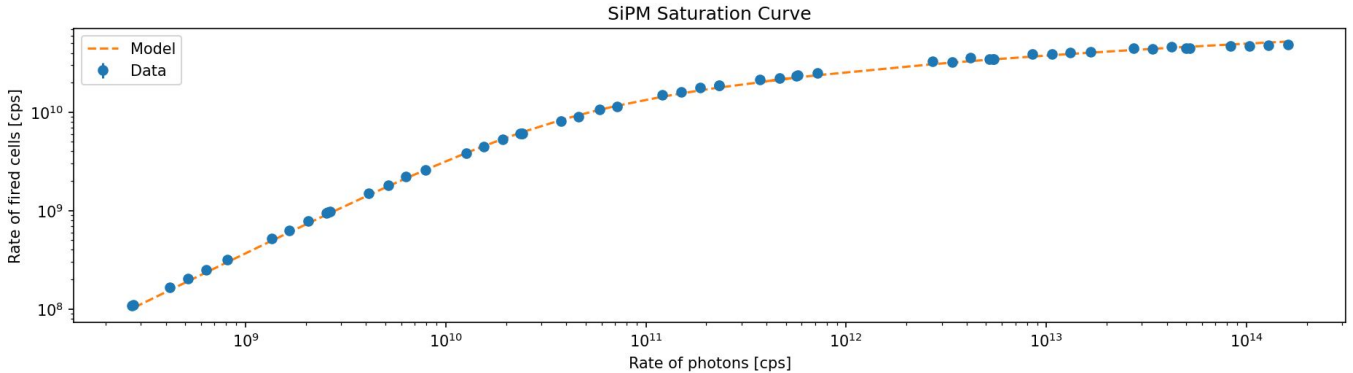


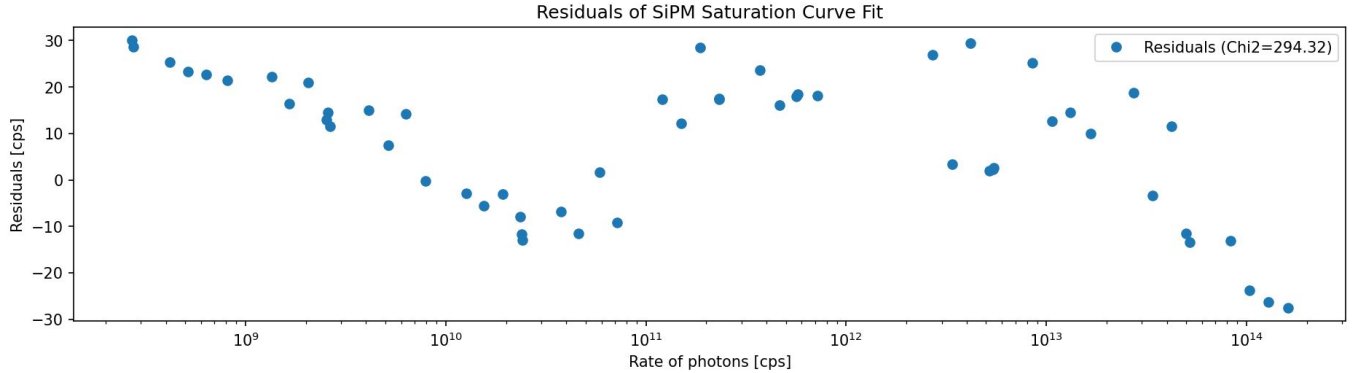
Parameters

Data Sheet: Pixel Size (Δx, Δy), PDE, Gain, ECF

Measured Data: Beam Standard Deviation (σ), $N_{photons}$

Floating: Reset Time (Δt)





$$\langle R \rangle = \frac{2\pi\sigma_x\sigma_y}{\Delta x \Delta y \Delta t}\left[\gamma + \log\left(\frac{\mathrm{PDE} \times N_{photons}}{2\pi\sigma_x\sigma_y/\Delta x\Delta y\Delta t}\right) - \mathrm{Ei}\left(\frac{-\mathrm{PDE} \times N_{photons}}{2\pi\sigma_x\sigma_y/\Delta x\Delta y\Delta t}\right)\right]$$

Summary

I measured the SiPM's saturation response to non-uniform light and it matched the model!

Next Steps

- Spatial filter for cleaner Gaussian
- Test with different voltages
- Write up the findings

From Thorlabs website

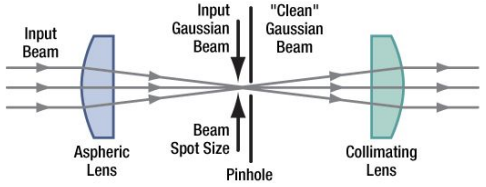


Figure 1.1 Spatial Filter System

tensity "noise". When a beam is focused by an aspheric lens, the input beam is transformed into a central Gaussian s
re 1.2). The radial position of the side fringes is proportional to the spatial frequency of the "noise".

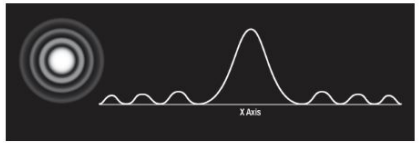


Figure 1.2 Input Gaussian Beam

he "clean" portion of the beam can pass while the "noise" fringes are blocked (see Figure 1.3).

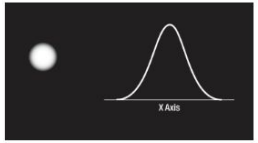
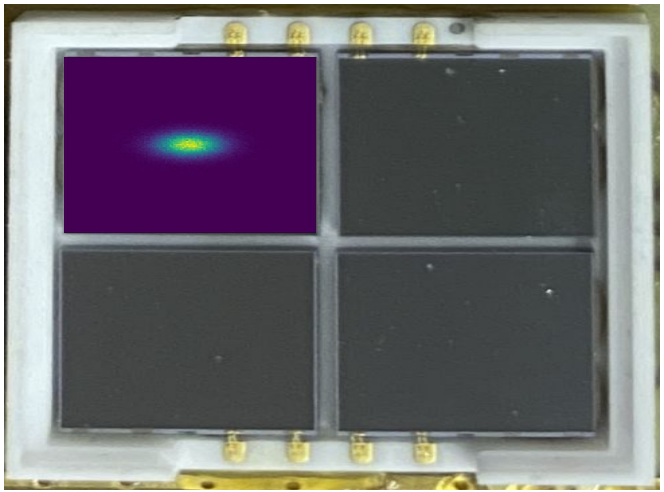
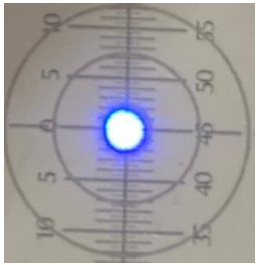


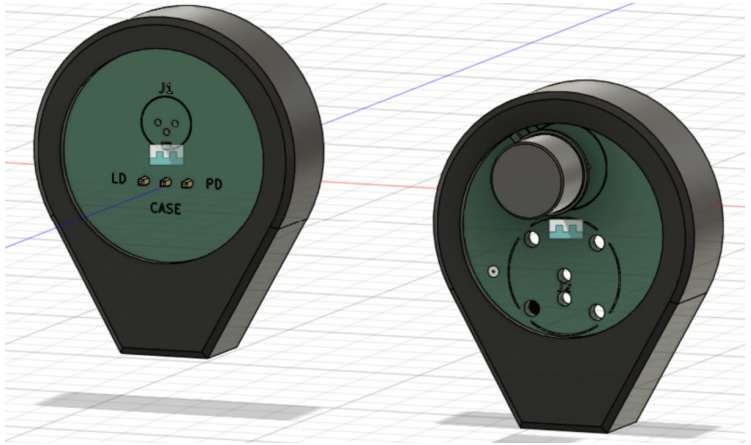
Figure 1.3 Clean Gaussian Beam

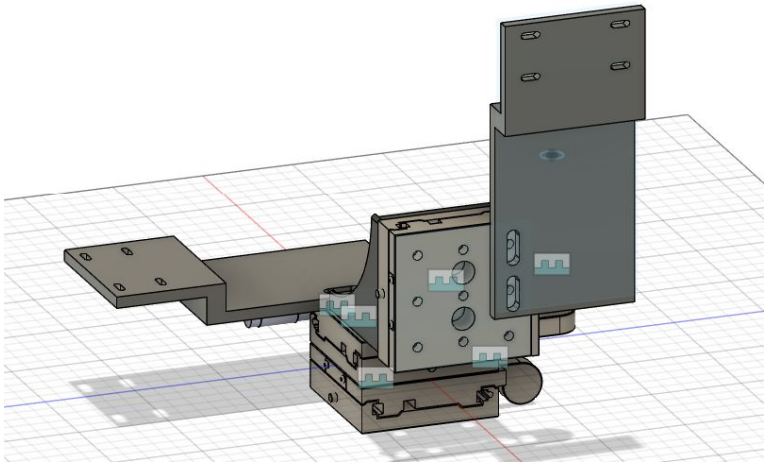
Questions?

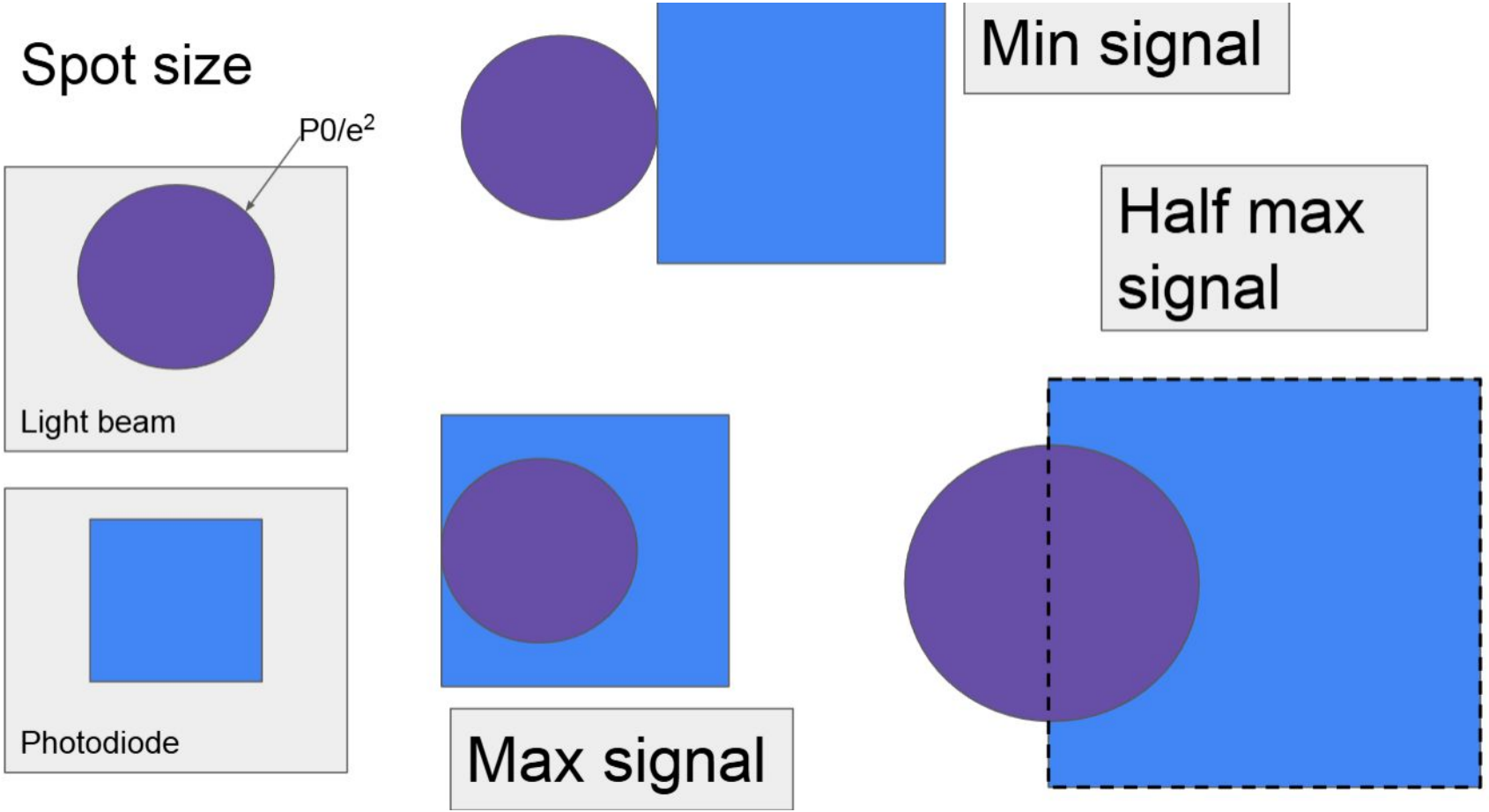
Additional Resources





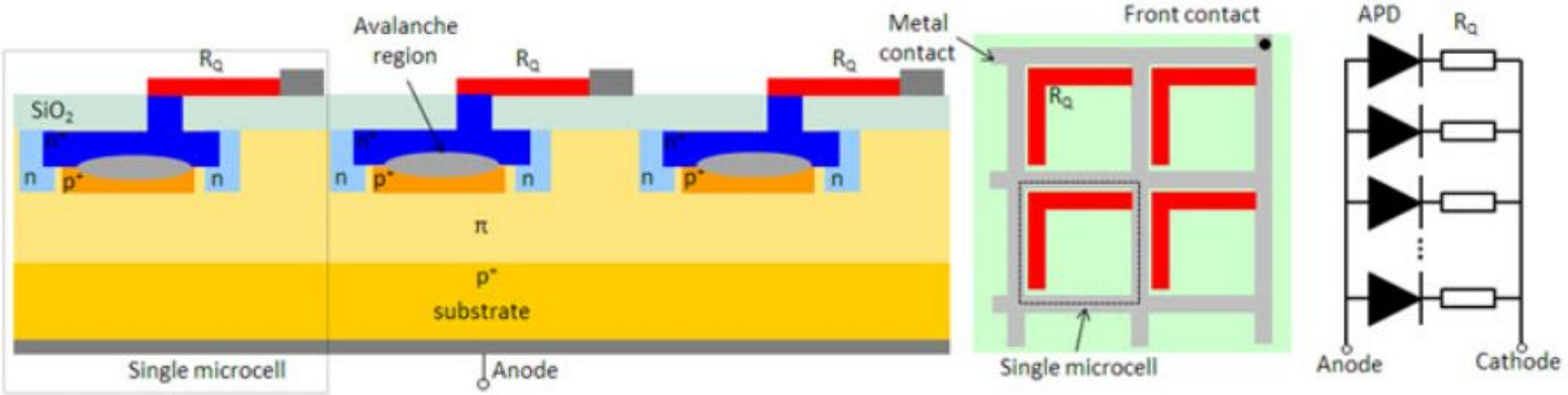


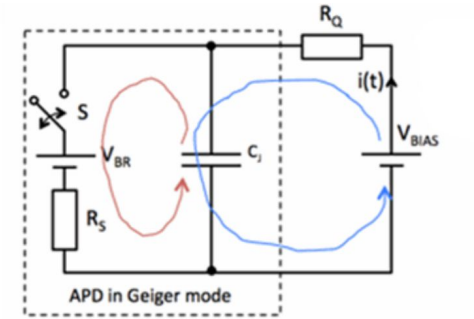




Courtesy of Lucas

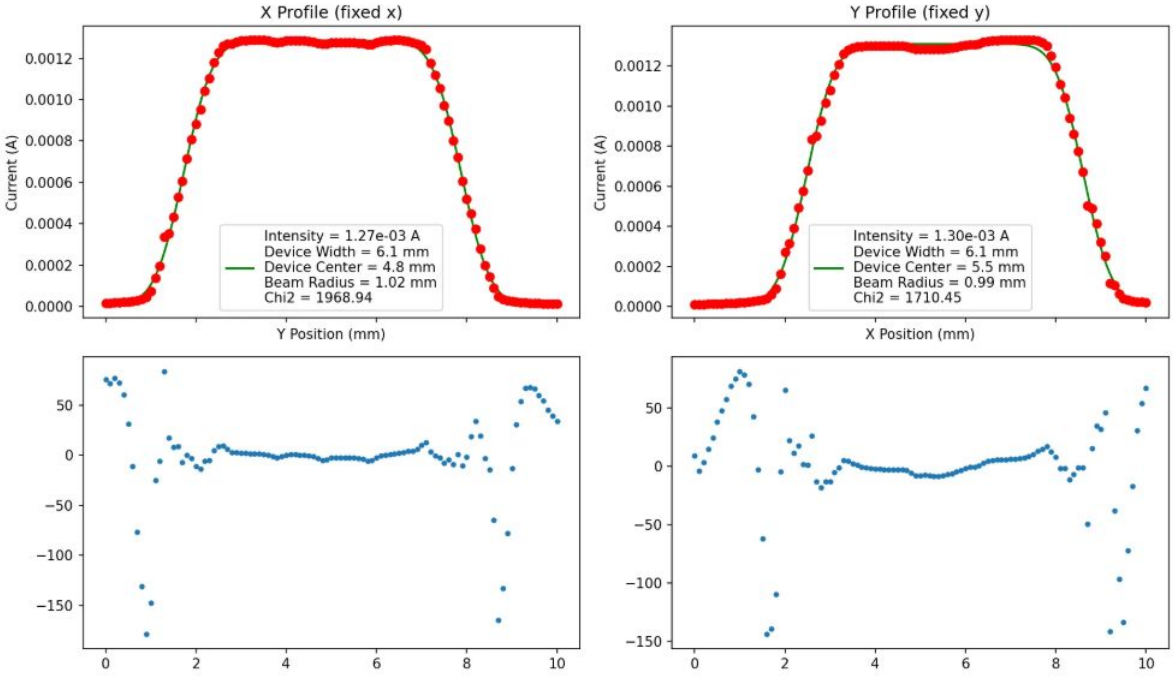
More about SiPMs - All Hamamatsu Images



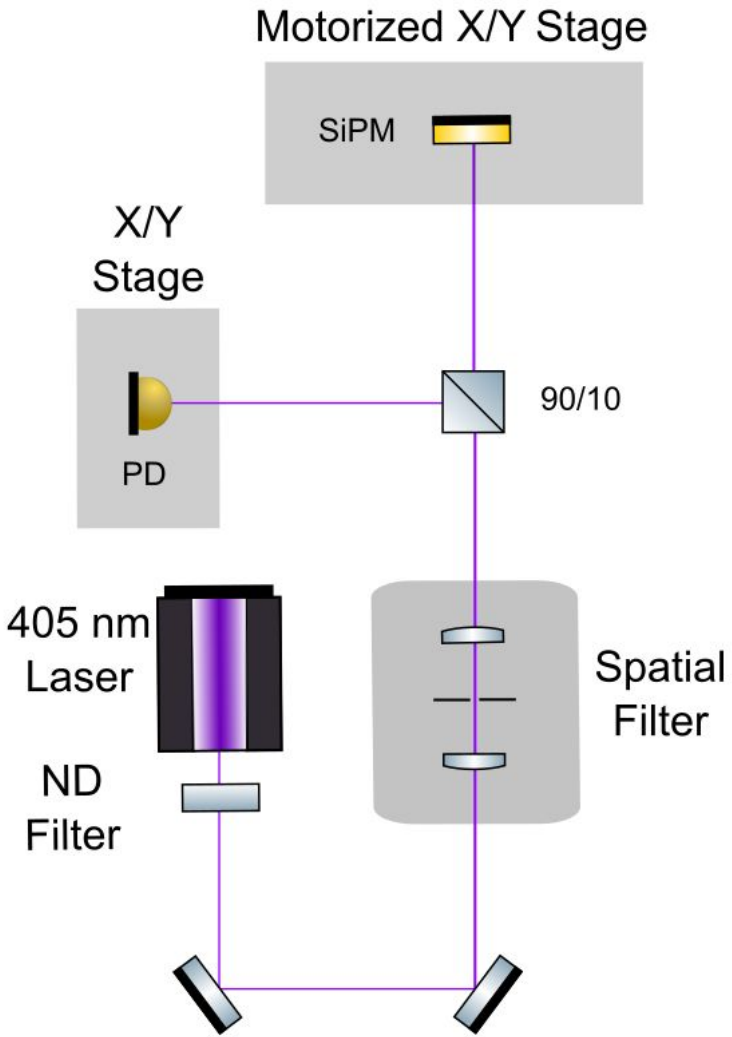


(Recharge) Time Constant = $R_Q C_J$

- Fully recharged after about five time constants


X Profile (fixed x)
Current (A)
Y Position (mm)
Intensity = 1.27e-03 A
Device Width = 6.1 mm
Device Center = 4.8 mm
Beam Radius = 1.02 mm
Chi2 = 1968.94
Y Profile (fixed y)
Current (A)
X Position (mm)
Intensity = 1.30e-03 A
Device Width = 6.1 mm
Device Center = 5.5 mm
Beam Radius = 0.99 mm
Chi2 = 1710.45

I = <R> * gain * ECF



$$\langle N \rangle = \sum_{ijk}^{n_x n_y n_t} \left(1 - \exp\left(-PDE_{ij} \cdot U_{ijk}\right)\right)$$

$$\langle N \rangle = \int \frac{\mathrm{dx\ dy\ dt}}{\Delta x \Delta y \Delta t} \left(1 - \exp\left(-\mathrm{PDE} \cdot \Phi(x, y, t) \Delta x \Delta y \Delta t\right)\right)$$

$$\langle R \rangle = \frac{2\pi\sigma_x\sigma_y}{\Delta x \Delta y}\left[\gamma + \log\left(\frac{\mathrm{PDE} \times N_{photons}}{2\pi\sigma_x\sigma_y/\Delta x \Delta y}\right) - \mathrm{Ei}\left(\frac{-\mathrm{PDE} \times N_{photons}}{2\pi\sigma_x\sigma_y/\Delta x \Delta y}\right)\right]$$

Motivation

- Silicon photomultipliers (SiPMs) are solid state photodetectors widely adopted in particle physics experiment
- Many detectors require large arrays of SiPMs
- High-throughput wafer-level testing typical for SiPM mass production
- High-throughput (IV) testing in tension with precision testing (pulse counting)
- Can we extract the same information from pulse counting measurements using IV?
- **Resolving temporal and spatial saturation is the first step required for IV parameter extraction**

Automation IV Probe Station

FormFactor Inc: SUMMIT200 Probe Station for Automated Wafer Handling - FormFactor