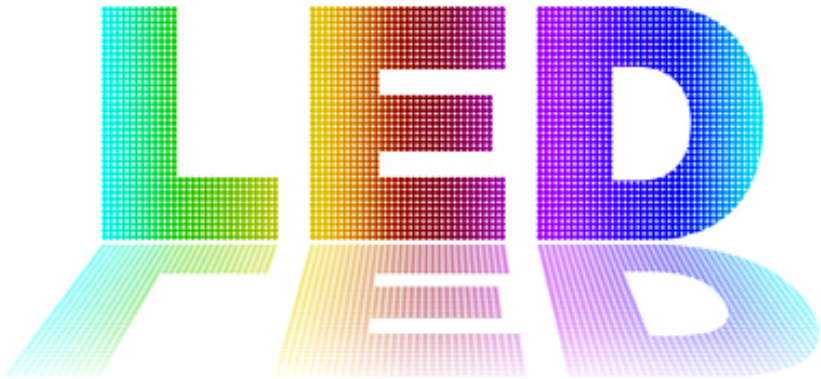
Single photon detection with an actively quenched light emitting diode



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Blake Burger, Edward Miller, Joseph Zolnowski

Penn State Hazleton
October 4, 2014

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Introduction

Can LEDs detect single photons?

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Yes — but can they do it well?

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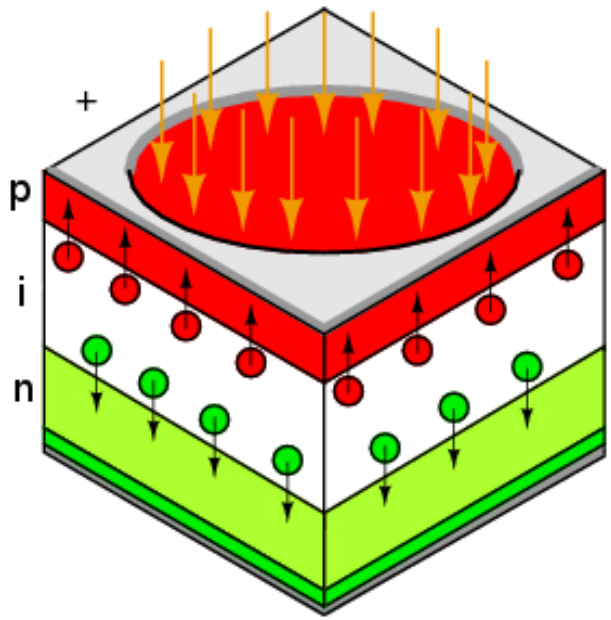
- Why use LEDs?
- Passive Quenching
- Active Quenching
- Temperature

Why use LEDs?

The avalanche photodiode is the standard for single photon detection.



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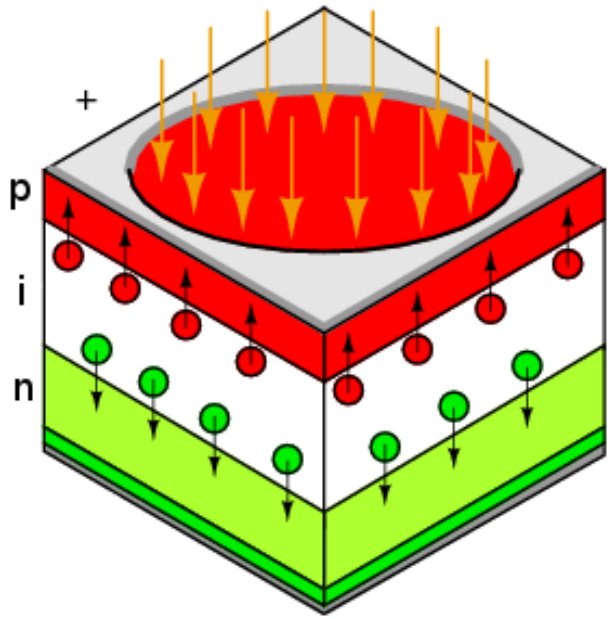
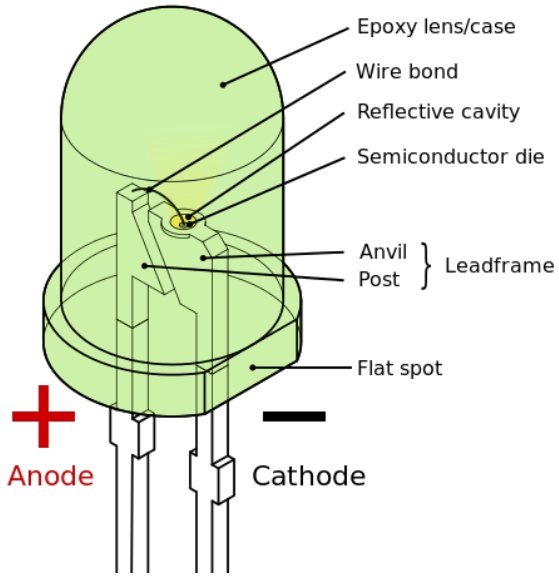


- More than $100, made to order
- A *p*-*i*-*n* junction (reduces capacitance to ≈1 pF)
- High breakdown voltage (150 -1000 V)

Why use LEDs?

Light emitting diodes are cheap and easy to work with.



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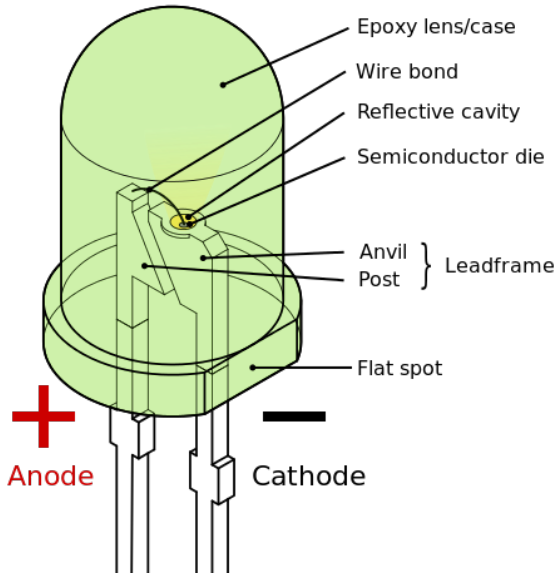
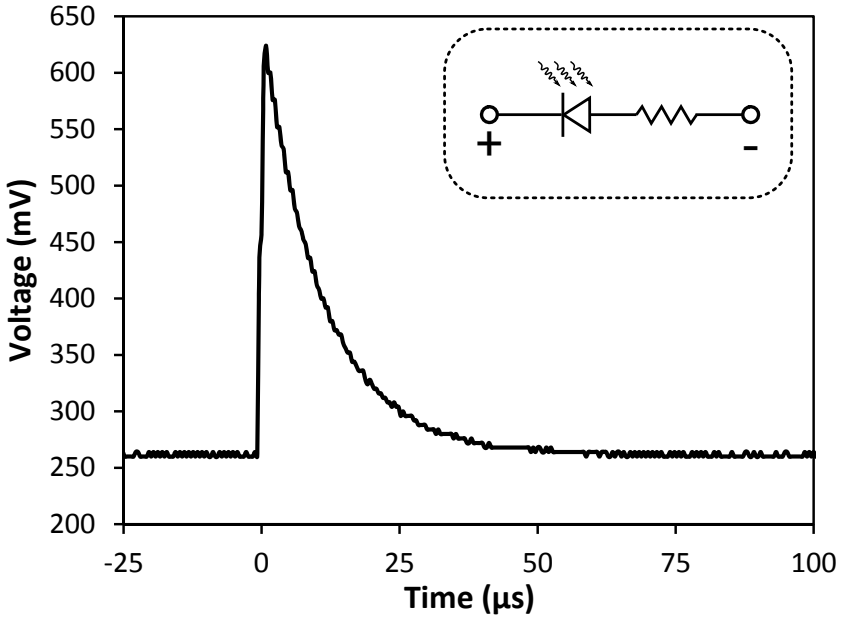


- $0.35
- A *p*-*n* junction (high capacitance of $\approx$ 150 pF)
- *Low breakdown voltage ($\approx$ 20 V)

Passive Quenching

In reverse bias, the LED avalanches just like an APD.



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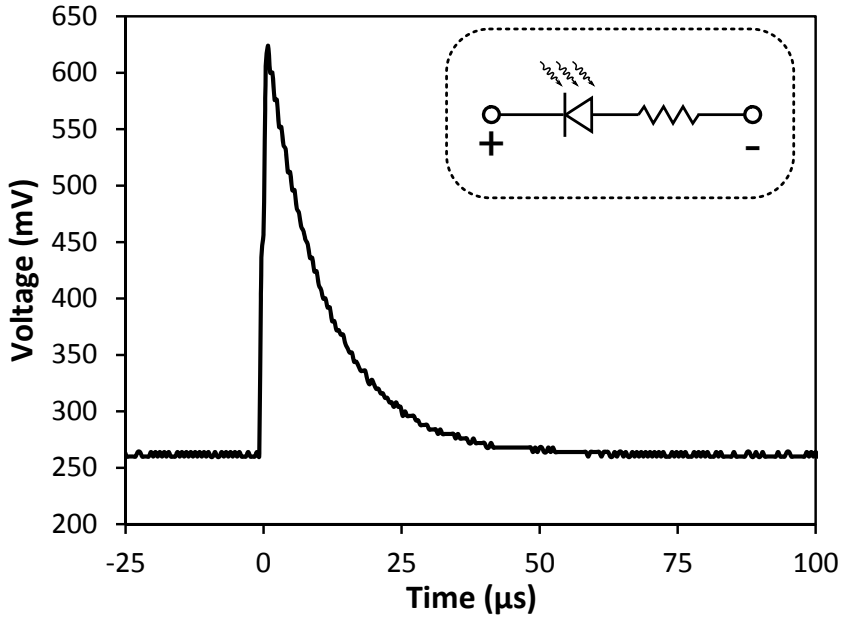
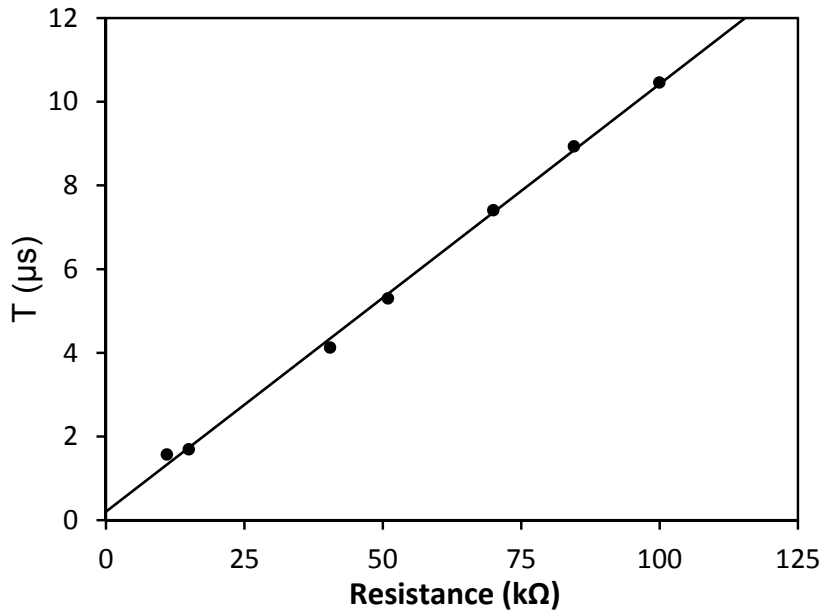


- The spike in current drops the bias voltage
- Output is passed to a comparator and then counted
- The $1/e$ decay time here is 11 μs

Passive Quenching

Lowering the series resistance reduces the reset time.



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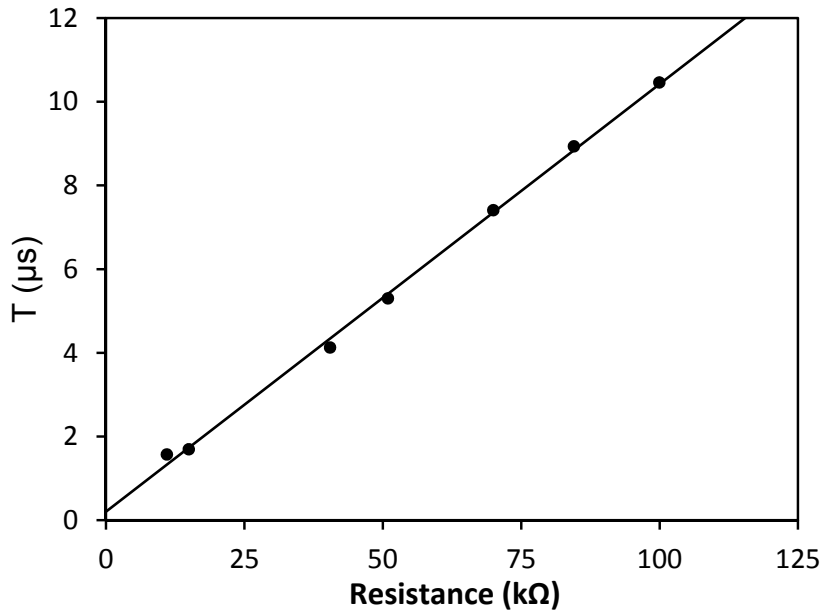
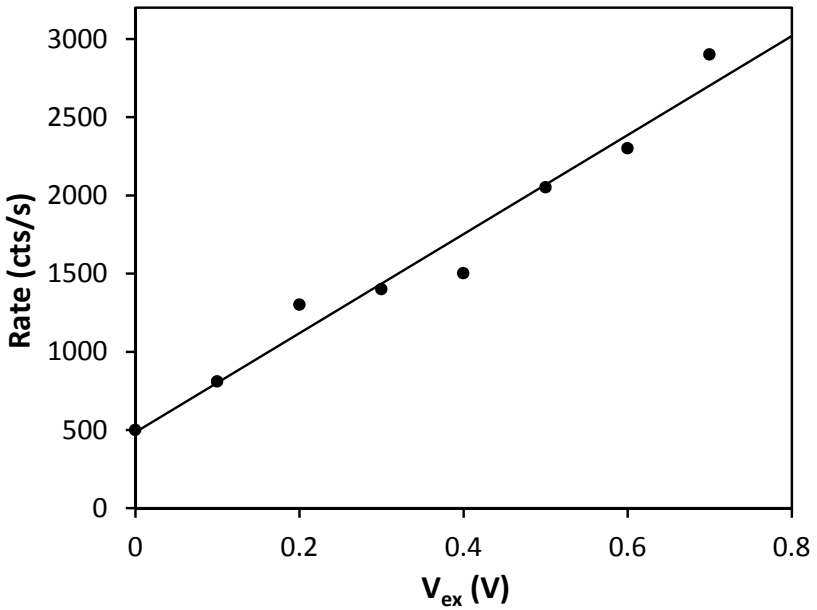


- Quickest reset: 1.56 μs at 11 kΩ
- Increase of 100 ns for every 1 kΩ

Passive Quenching

Excess bias voltage increases the dark counts and efficiency.



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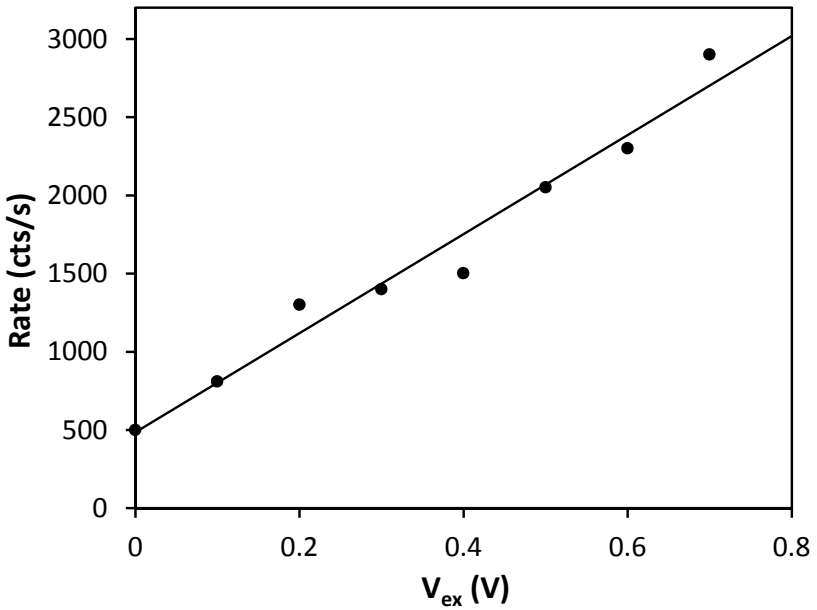
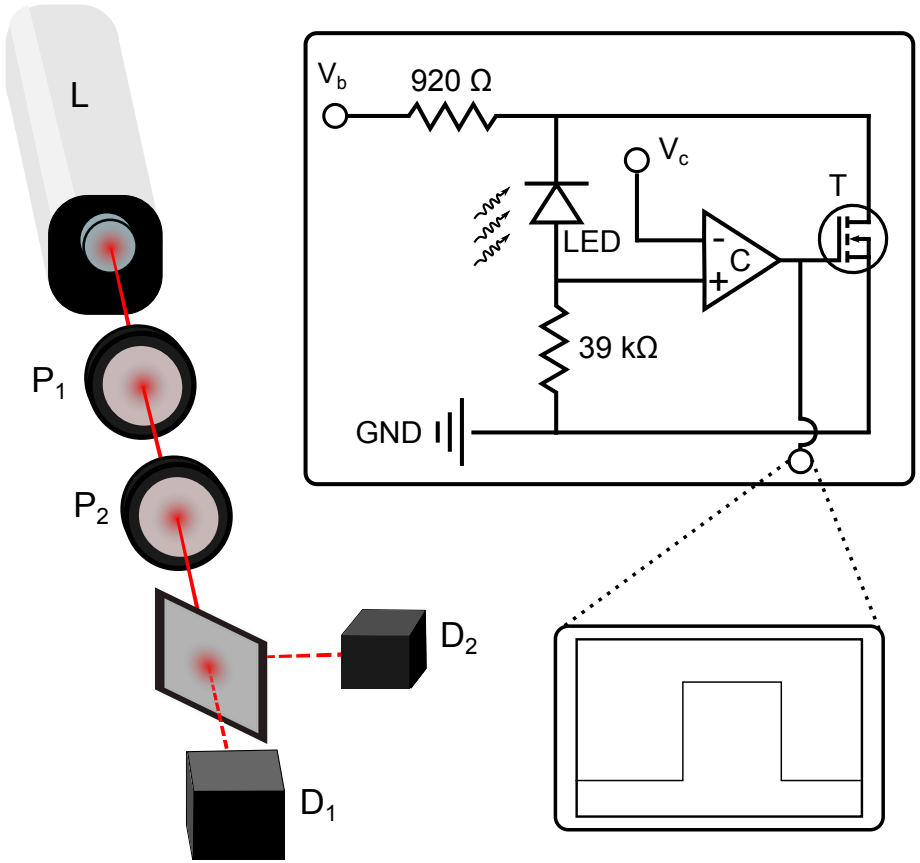


- Series resistance: 81 kΩ
- Bias voltage: 22.2 V

Active Quenching

Dropping the bias voltage once a photon is detected reduces the reset time.



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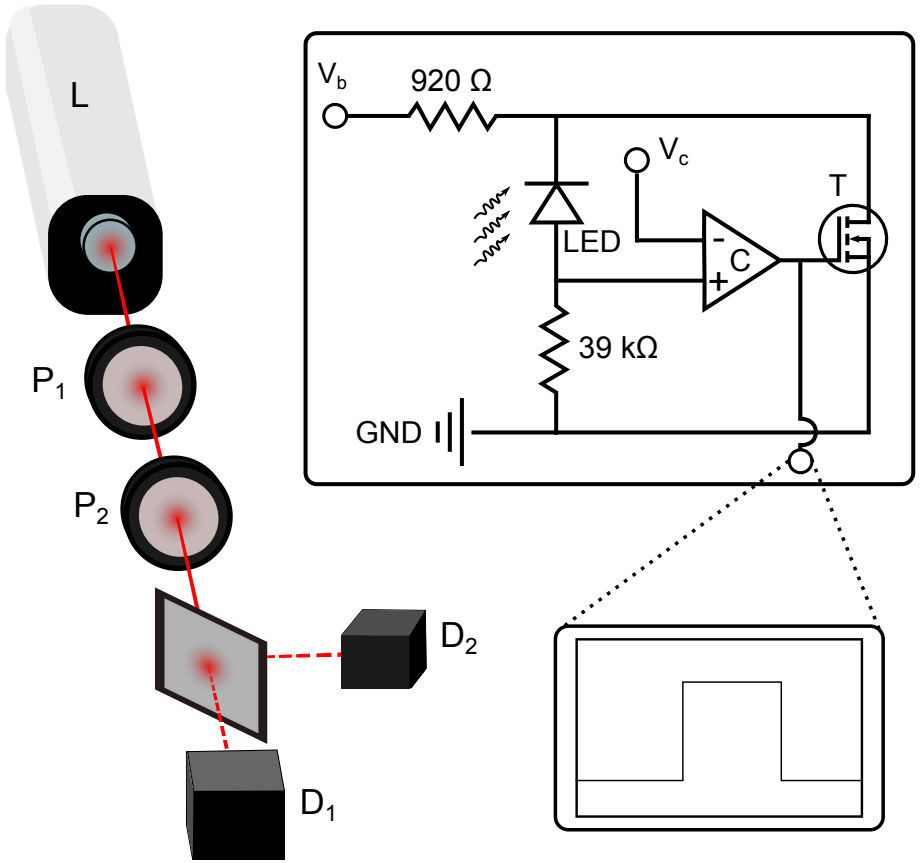
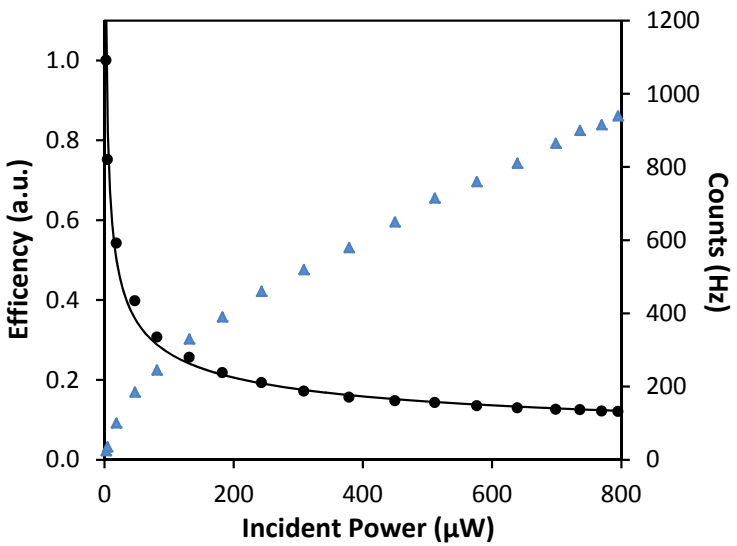


Improves max counts by a factor of 13!

Active Quenching

The detector is not linear over all incident powers.



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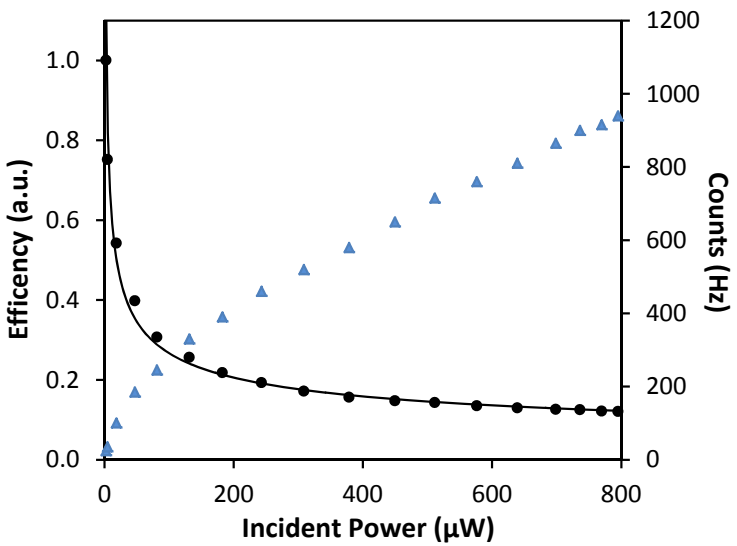
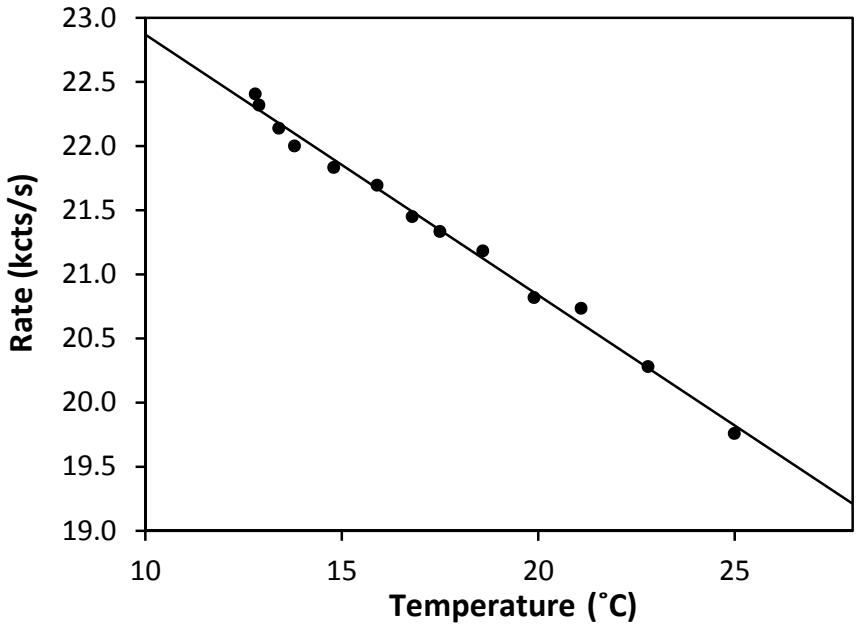


Possible causes for low efficiency:

- Thick *p* region
- Small interaction region
- Low bias voltage (gain)
- Lens transparency at 633 nm

Active Quenching

The dark counts *increase* as the LED is cooled.



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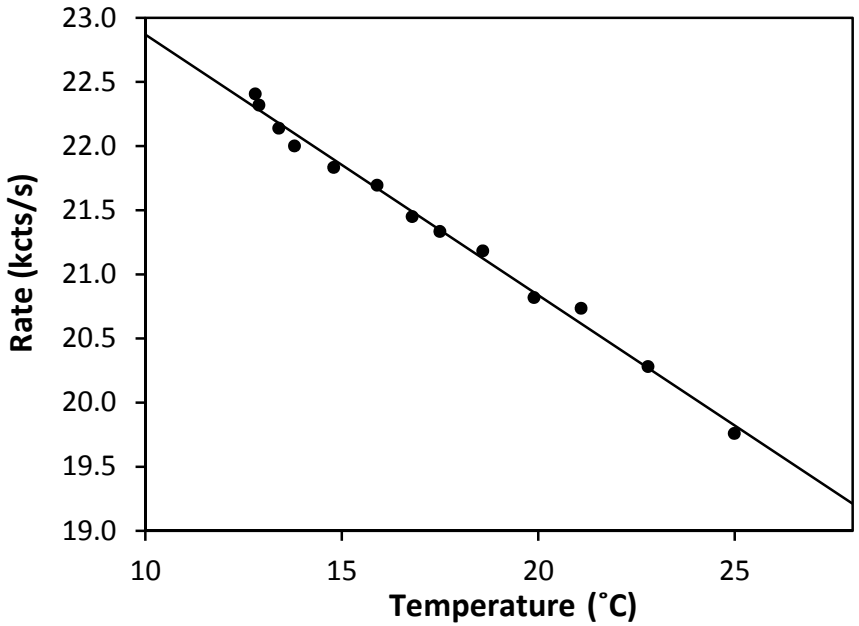

- Active quenching, 24.5 V bias
- Gain 5000 counts per degree Celsius

Results

LEDs can be used to detect single photons:

(a) very low efficiency;

(b) active quenching improves count rates dramatically;

(c) cooling *increases* dark counts;

(d) cheap solution for advanced labs.

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Contact Information:

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- website: www.david-starling.com