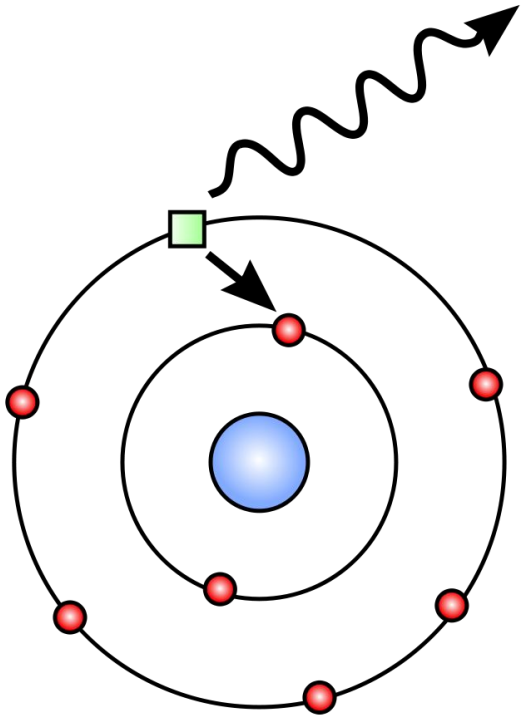
Down-Conversion and Photon Counting

Tristan Perry & Jaden Miller

Potential Application

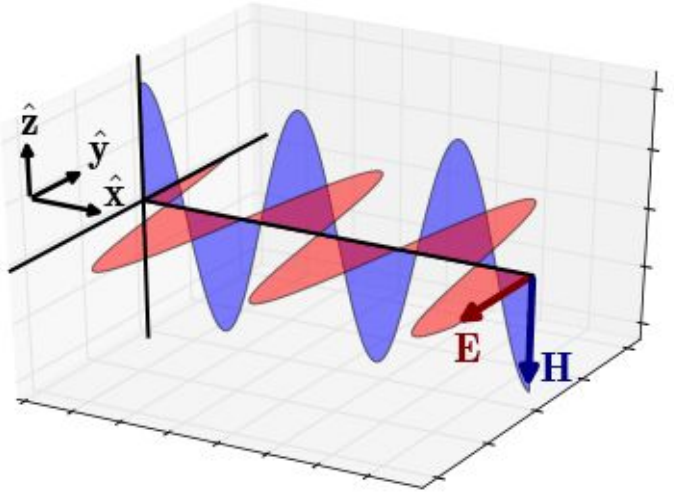
- Optimizing Photon counts
  - Speed of light through some medium
  - Laser testing
  - Detection of downconversion
- Testing downconversion
  - Entanglement experiments
  - Probability testing of photon location



Photon Energy – EWT (energywavetheory.com)

Electromagnetism and the Photon

- Light as a wave and a particle
- Classical Period
  - Newton’s “corpuscles”
  - Thomas Young’s Double Slit
  - Malus’s Law
  - Maxwell
- Modern Period
  - Planck's Quantum Energy & Frequency, **E = hf**
  - Einstein’s Photoelectric theory
  - 2022 Nobel Prize



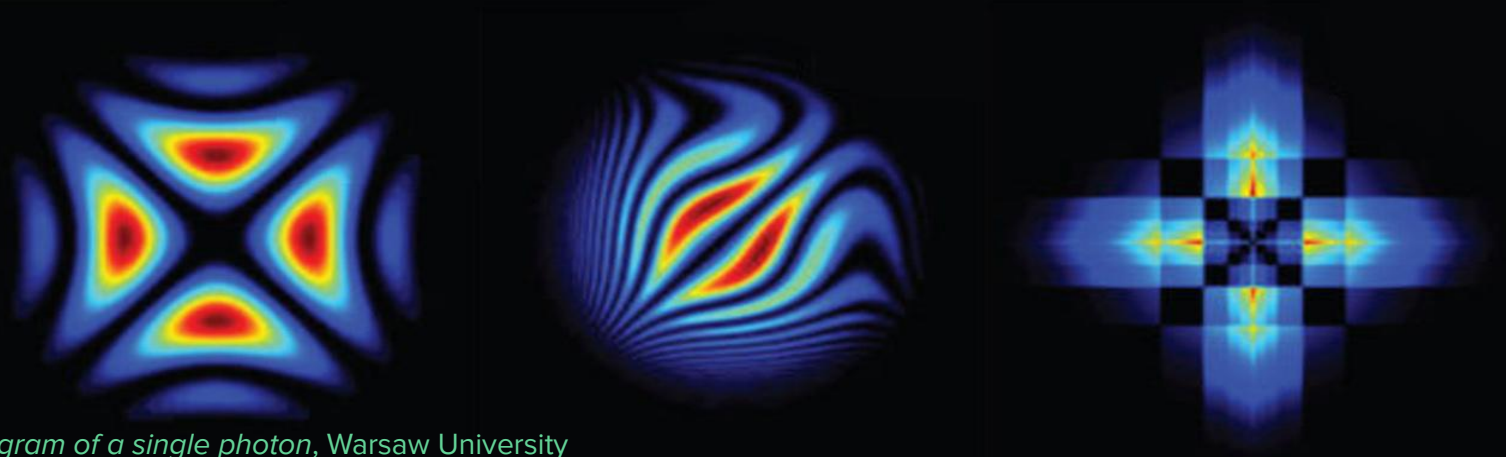
EM wave propagation:

- $\mathbf{E} = \mathbf{E}_o e^{i(\omega t - k \cdot r)}$
- $\mathbf{H} = \mathbf{H}_o e^{i(\omega t - k \cdot r)}$

https://em.geosci.xyz/content/maxwell1_fundamentals/harmonic_planewaves_homogeneous/impedancephase.html

Photons as a Quantum Particle

- *A hands-on introduction to single photons and quantum mechanics for undergraduates*, Dickinson College PA
  - Brett J. Pearson and David P. Jackson

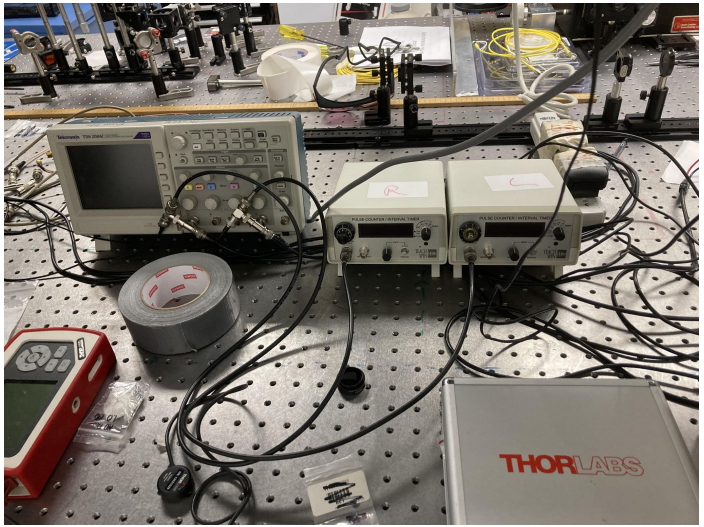


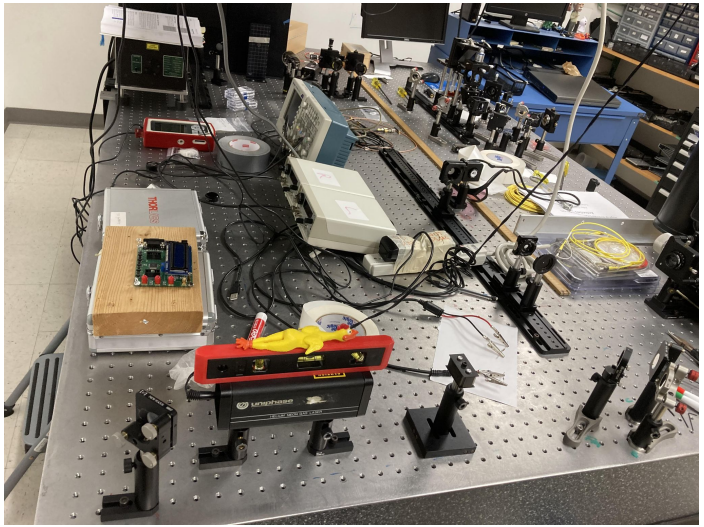
- *Hologram of a single photon*, Warsaw University
  - Radosław Chrapkiewicz, Michał Jachura, Konrad Banaszek & Wojciech Wasilewski

[1509.02890] Hologram of a Single Photon (arxiv.org)

Counting “Single” Down-converted Photons

Objective: Optimizing the count of single photons





Theory: Detecting Down-converted Photons

$E = hf = hc/\lambda$

$E_1 = E/2 = hf/2 = hc/2\lambda$

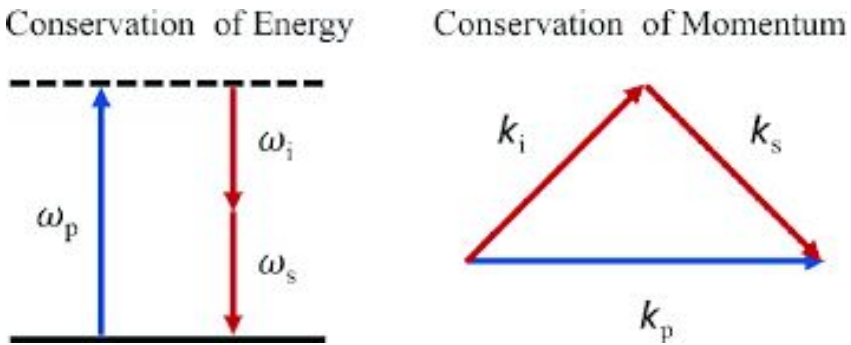
$E_2 = E/2 = hf/2 = hc/2\lambda$

Desired **λ** to be detected is twice that of the StellarPro:

$\lambda_{SP} = (514.5 +/- 1\%)nm$

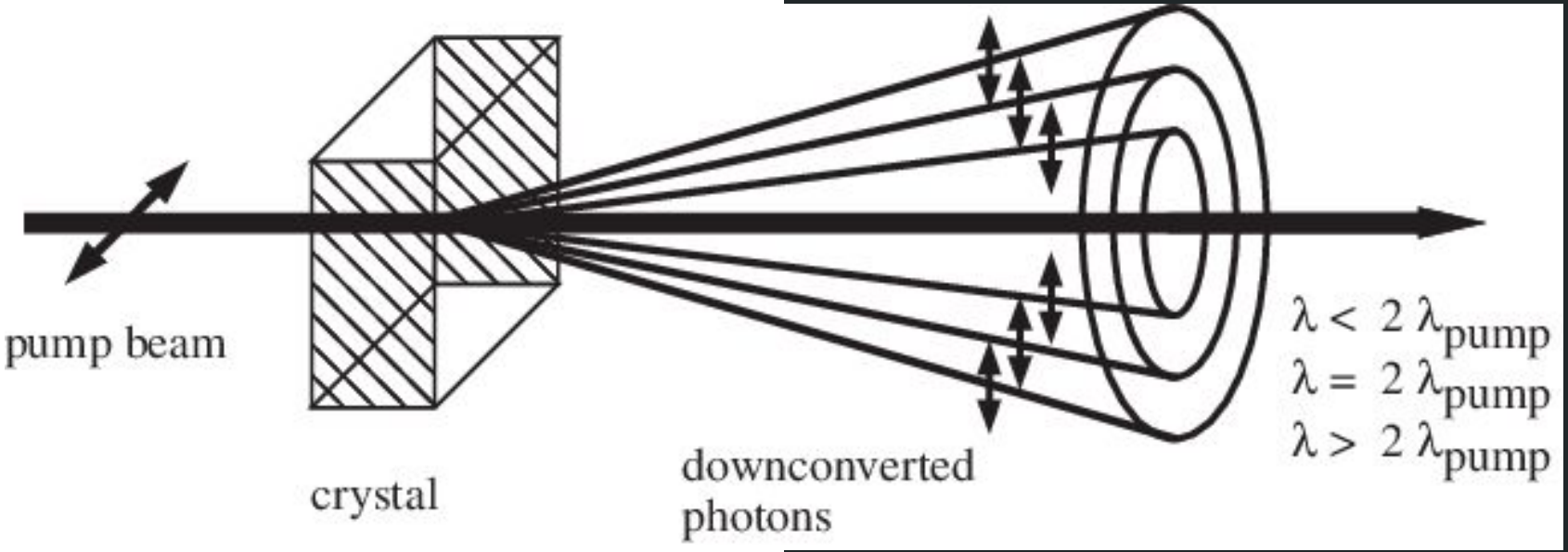
Stellar-Pro ML-150.pdf (modu-laser.com)

$\lambda_{DC} = 2(514.5 +/- 1\%)nm = (1029 +/- 2\%)nm$



Phase matching conditions arising from energy and momentum conservation... | Download Scientific Diagram (researchgate.net)

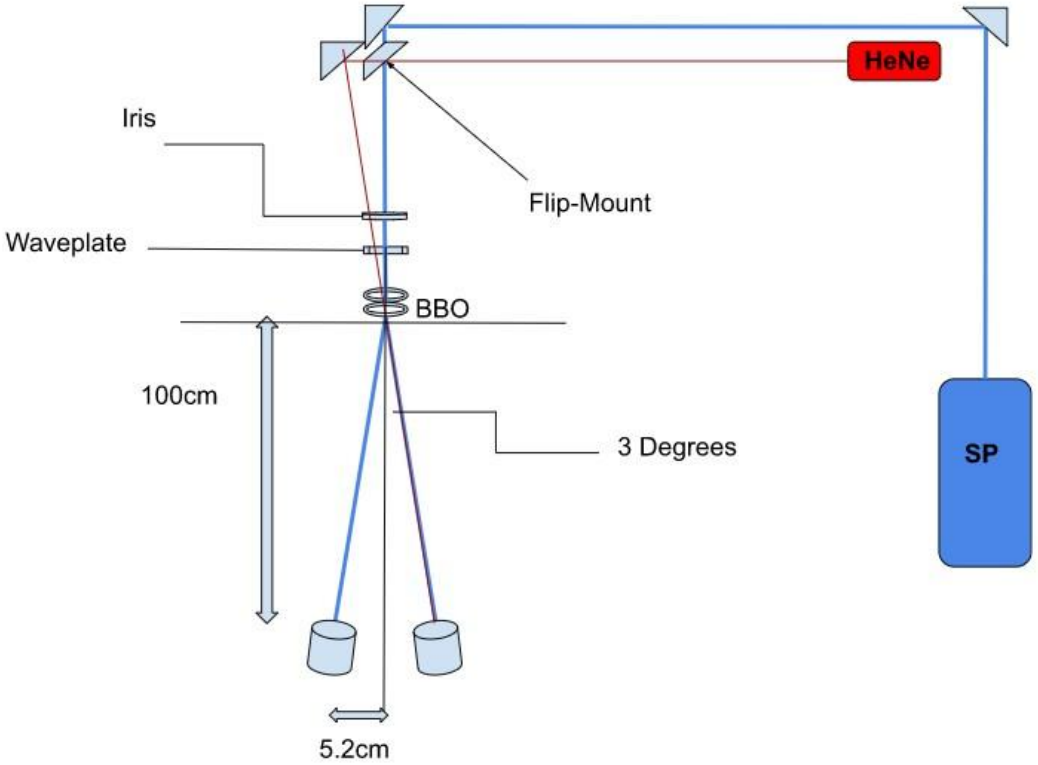
Theory: BBO Downconversion



Type I spontaneous parametric downconversion. Photons from a pump beam... | Download Scientific Diagram (researchgate.net)

Setup & Alignment

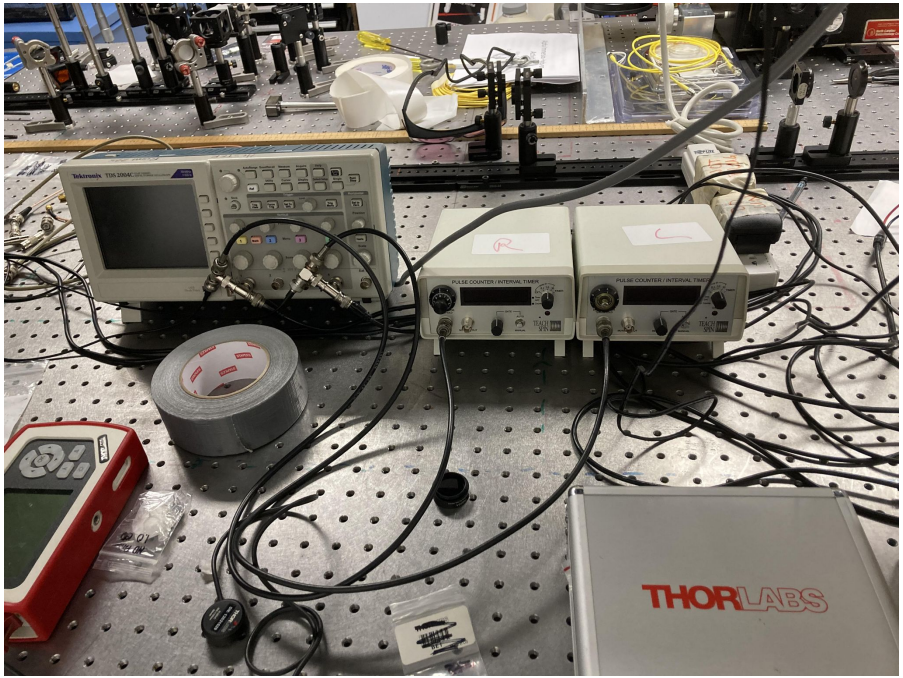
- ModuLaser StellarPro ML/150 Ar laser (λ=514.5nm)
- UniPhase Helium Neon Gas Laser 1508P-0
- EKSMA Optics BBO 6x6x1 th29.2 ph0 (Beta Barium Borate)
- Photon Detectors (IDQ-id100)



Setup & Procedure

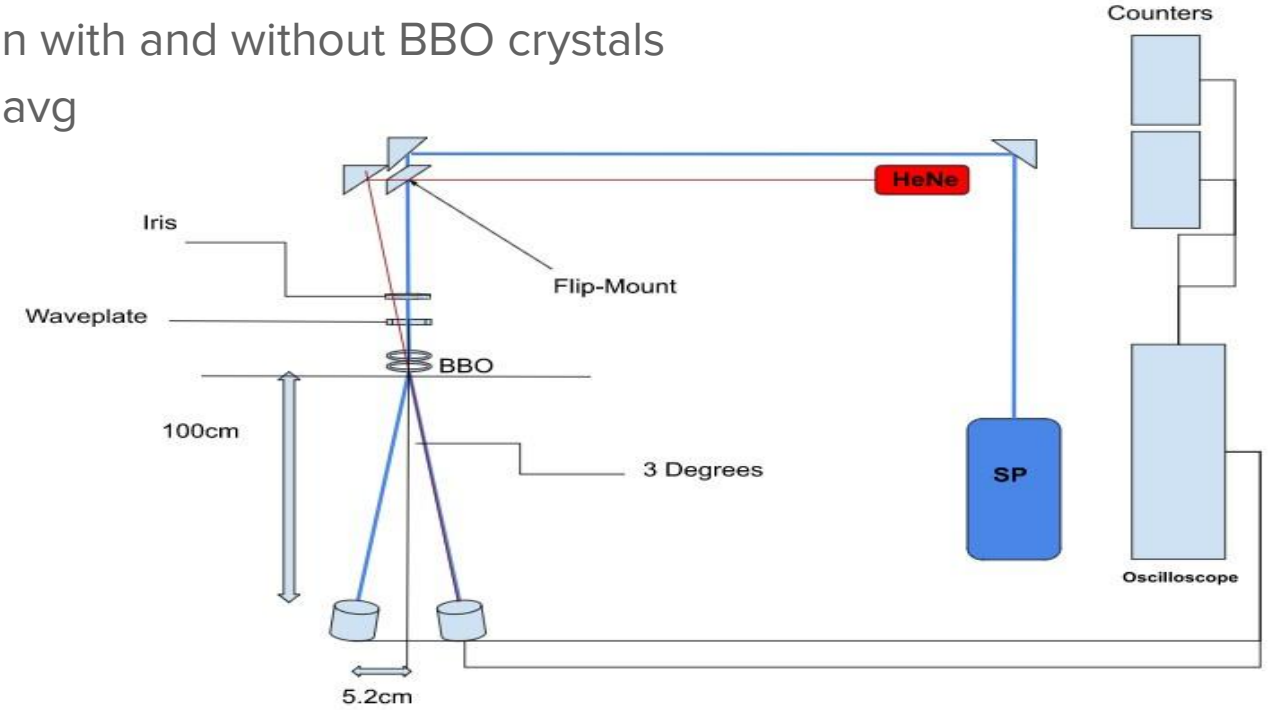
- Oscilloscope (Tektronix TDS 2024C)
- TeachSpin Pulse Counters/Interval Timers
- ThorLabs waveplate and iris
- IDQ-id100/150 UN single Photon detectors

V_{out} = (3.3 +/- 1%)V per pulse



Procedure

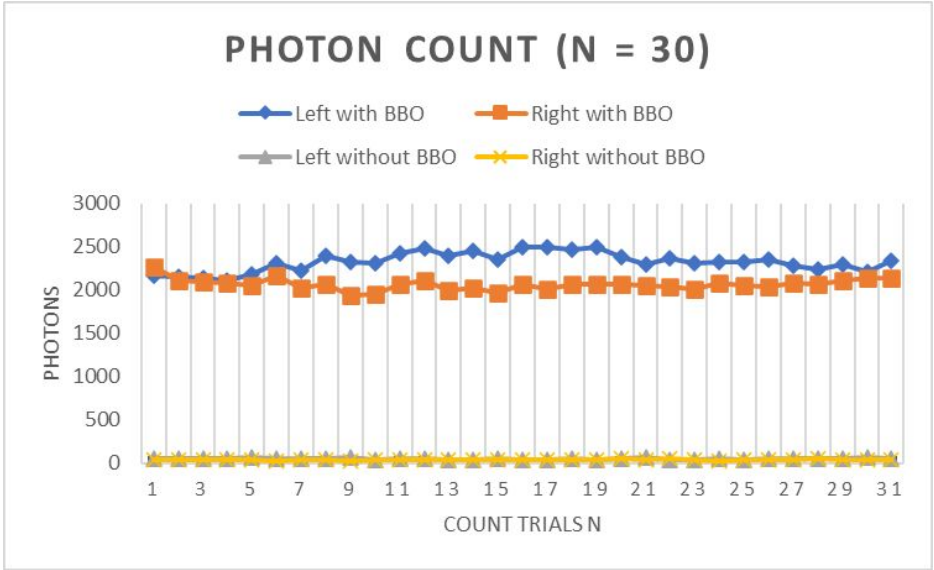
1. Filters to prevent overload
2. Count data taken with and without BBO crystals
3. 30 trials to give avg



Data & Results

- For N = 30

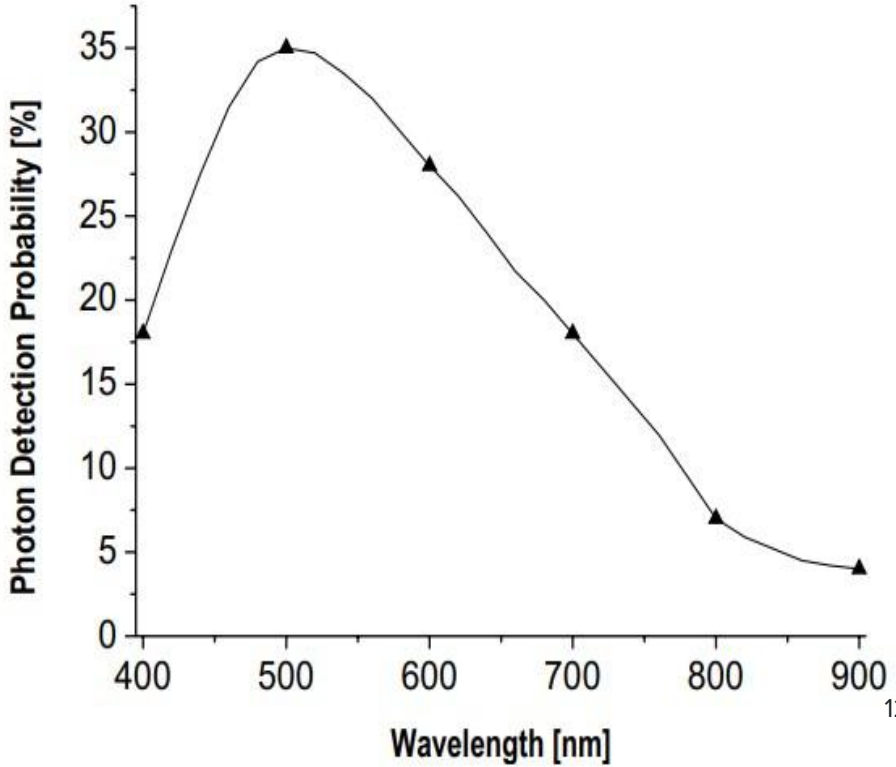
Detector	W_{AVG} Photon count with BBO	δW_{AVG}
Left	2318.7	8.7
Right	2059.3	8.2
Both	2138.3	6.0
	W_{AVG} Photon count No BBO	
Left	48.7	1.3
Right	37.7	1.1



Errors, Improvements

1. Laser Variance
2. False Counts from Signal Noise - 20 photons background S:N
   a. Equipment & Environment
3. Visual Setup Alignment / Detector Alignment / Realignment
4. Detector limitations

3 Photon Detection Probability versus λ

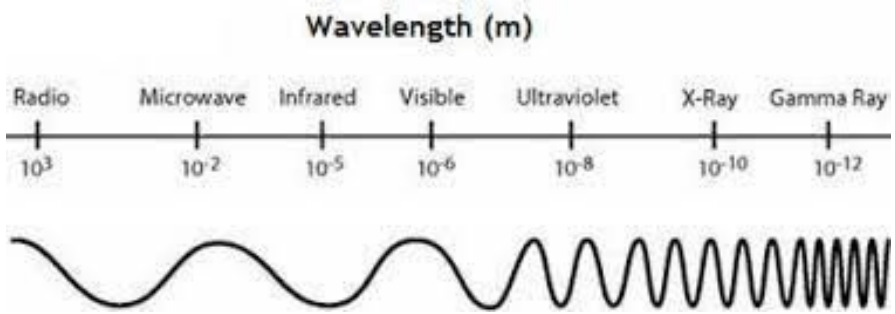


3 ID100 visible photon counting module from ID Quantique

Improvements

Future experiments include:

1. IDQ IQ230 IR detector (900-1700nm)
2. Potential entanglement pair detection



http://labman.phys.utk.edu/phys222core/modules/m6/The%20EM%20spectrum.html

ID230 NIR photon detector from ID Quantique

References

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Questions

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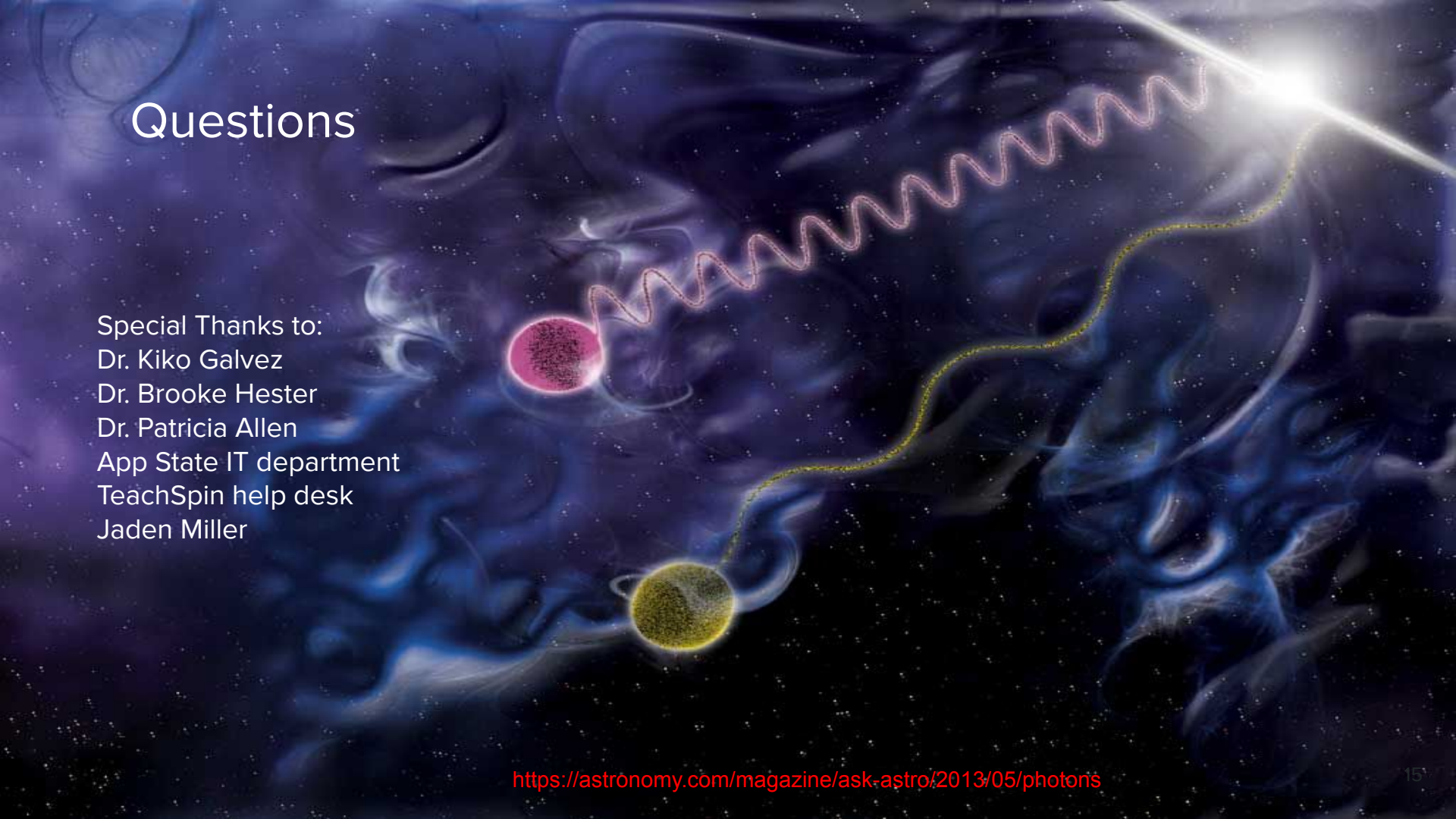
Jaden Miller

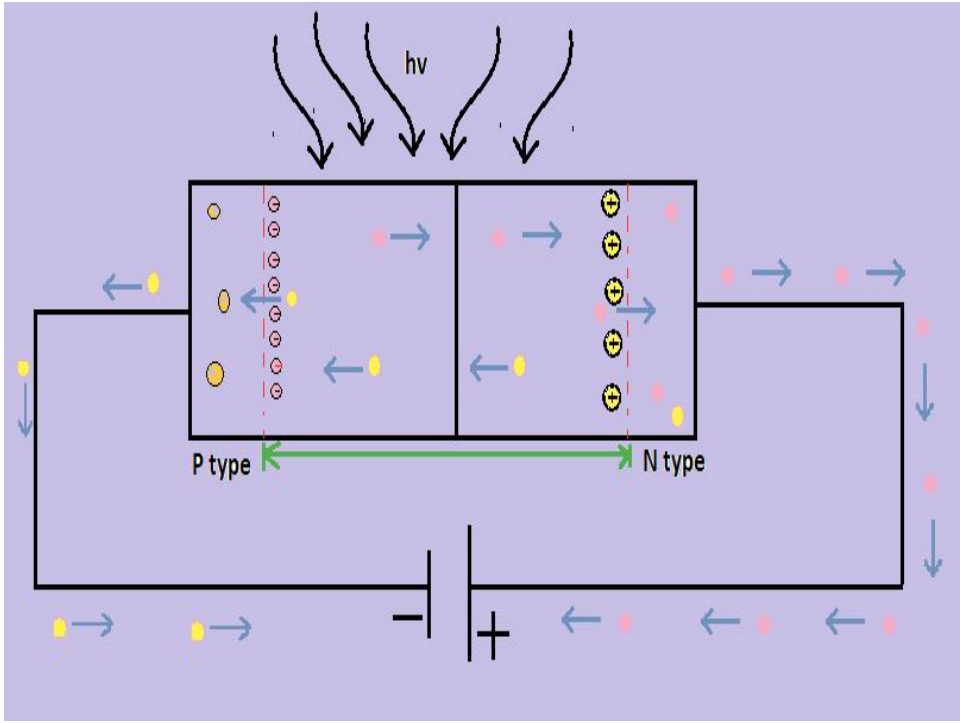


https://astronomy.com/magazine/ask-astro/2013/05/photons

Additional info: Photodiodes

- Photons incident on reverse biased PN junction
- Photons break bonds to create e^- - hole pairs
- $hf > E_{bg}$
- Voltage produced relative to intensity

($h = 6.62607015 \times 10^{-34}\ m^2\ kg\ /\ s$)



Photodiode Basics, Working and Its Applications | EFY (electronicsforu.com)

Additional Info: Video of Photon from MIT

https://www.youtube.com/watch?v=_QAPQO6EL8o