Single Photon Experiments

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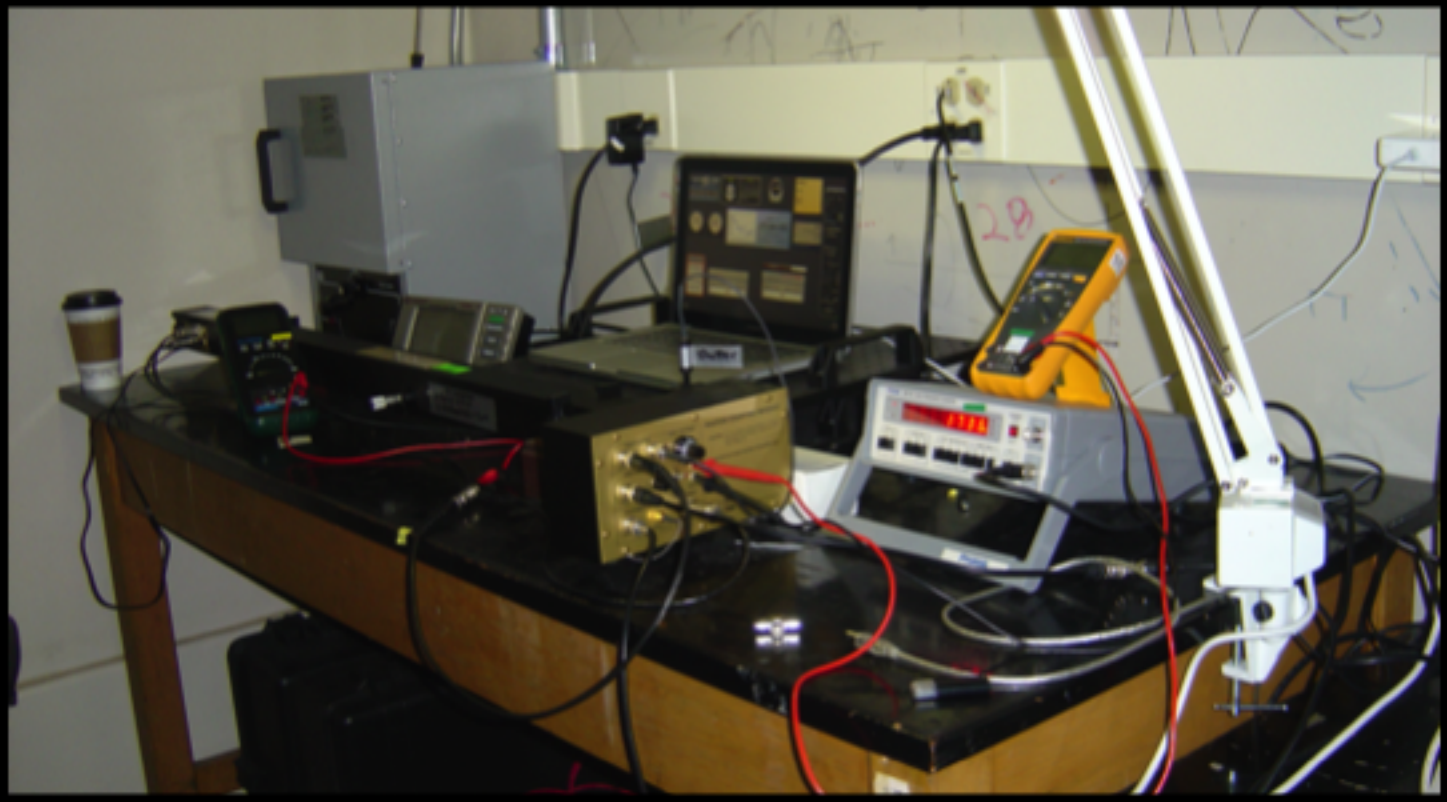
What is a single photon?

- Single photon is most fundamental “particle” of light
- A Single photon interferes with itsself

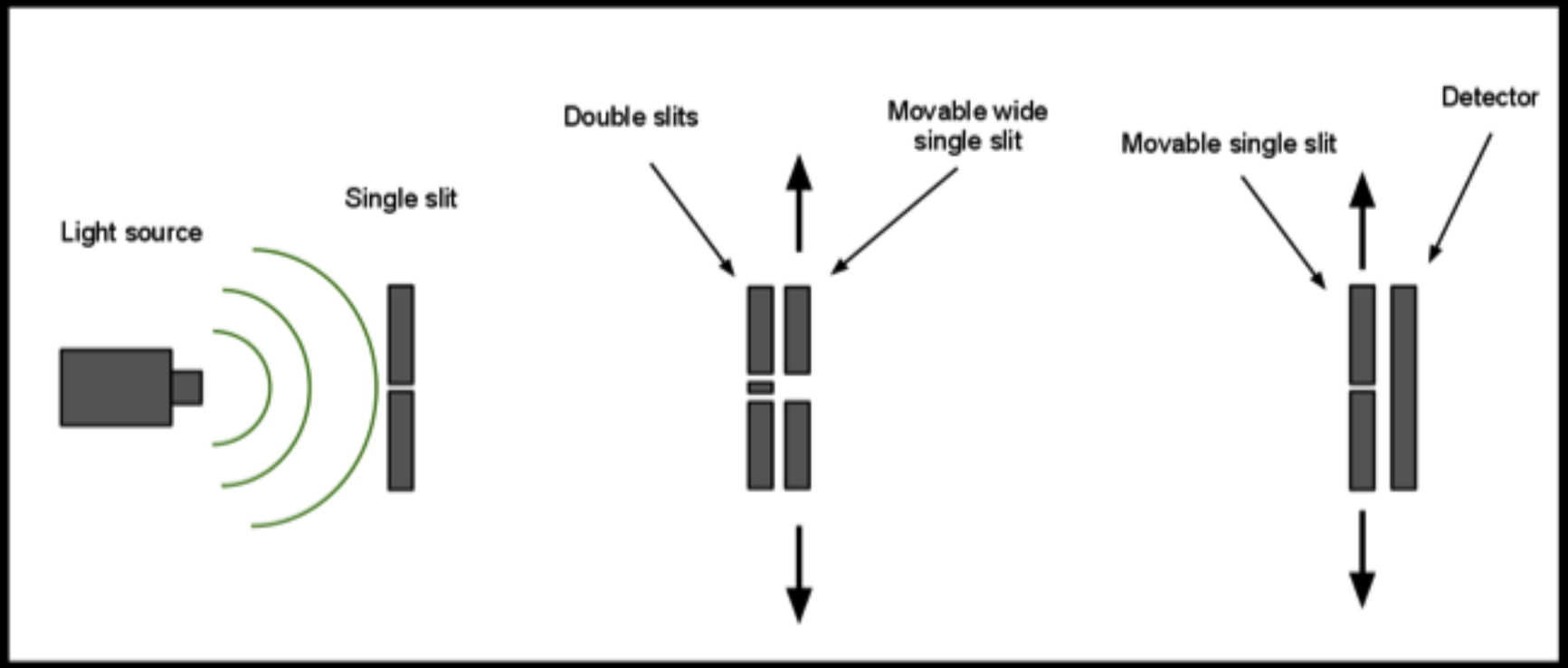
Why Single Photons are important

- Single photon detection is one of fundamental technology of the quantum computing
- Single photon detection is also fundamental of quantum encryption
- Containing paradox of the quantum mechanics

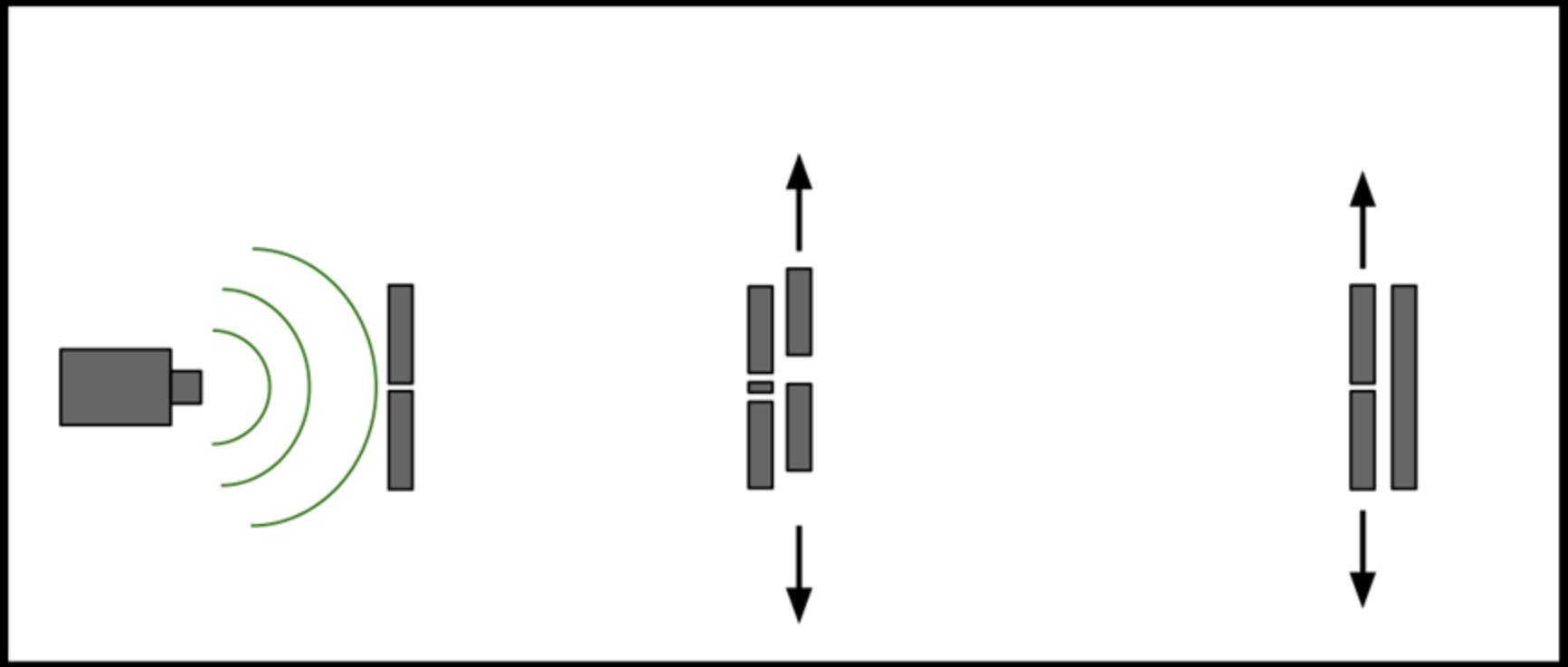
Experiment 1:
Double Slit Interference with Single Photon



Setup


Light source
Single slit
Double slits
Movable wide single slit
Movable single slit
Detector

Setup



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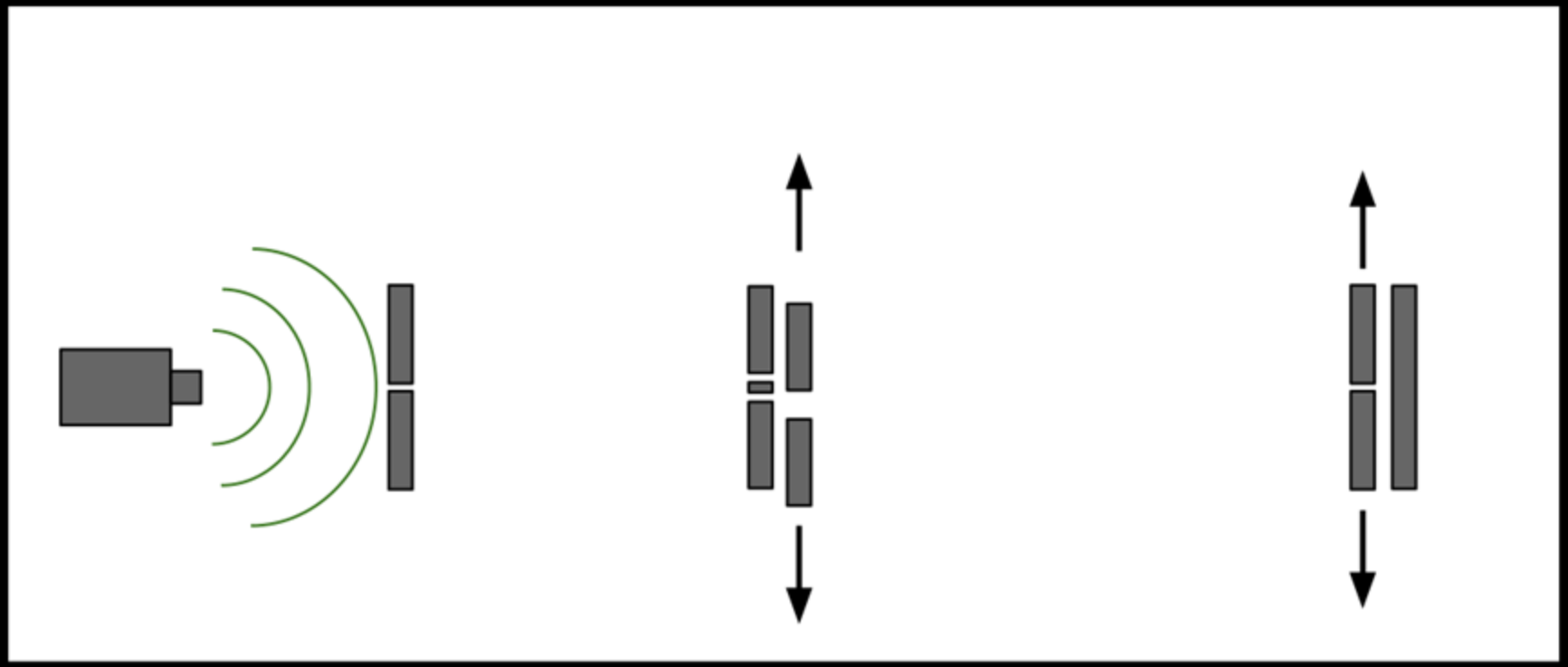

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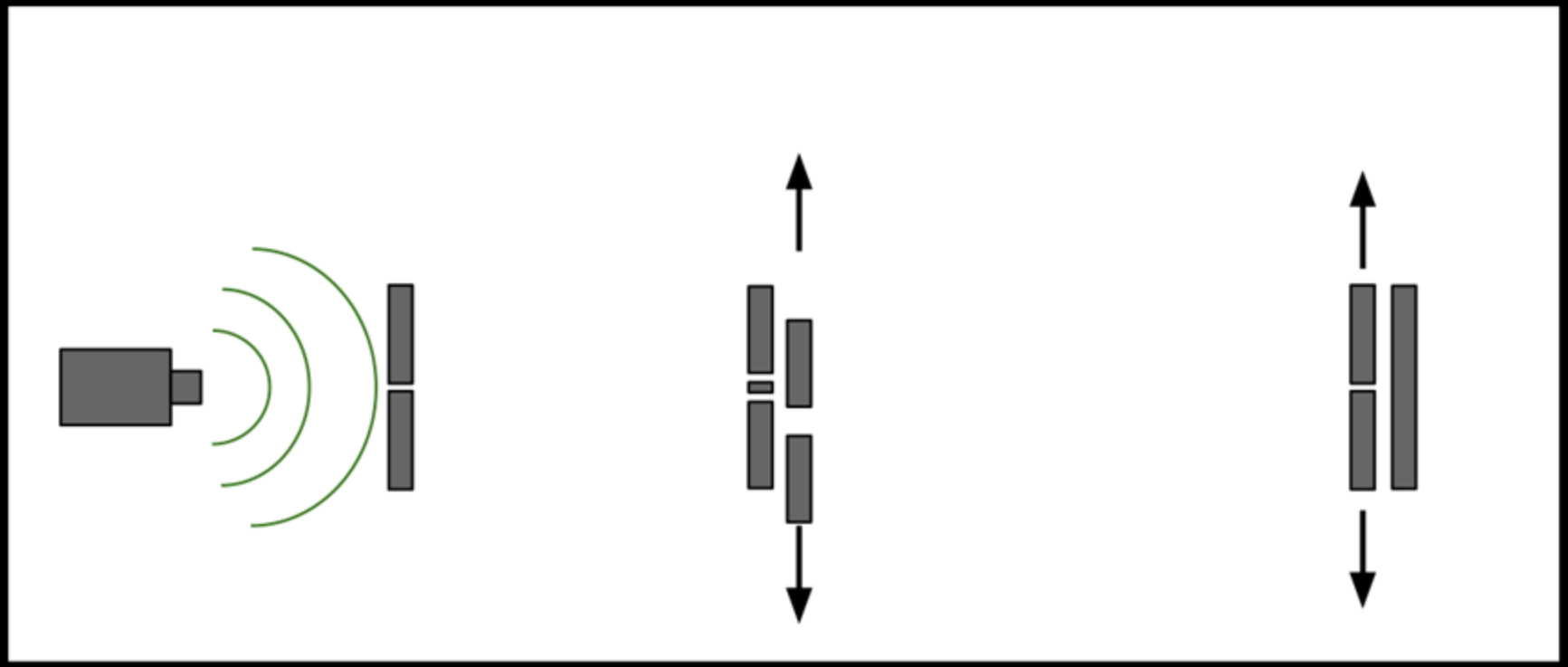


Single Photon Interference

- Each photon has energy of

$$E=h\cdot\nu,$$

- Power of light can be described by

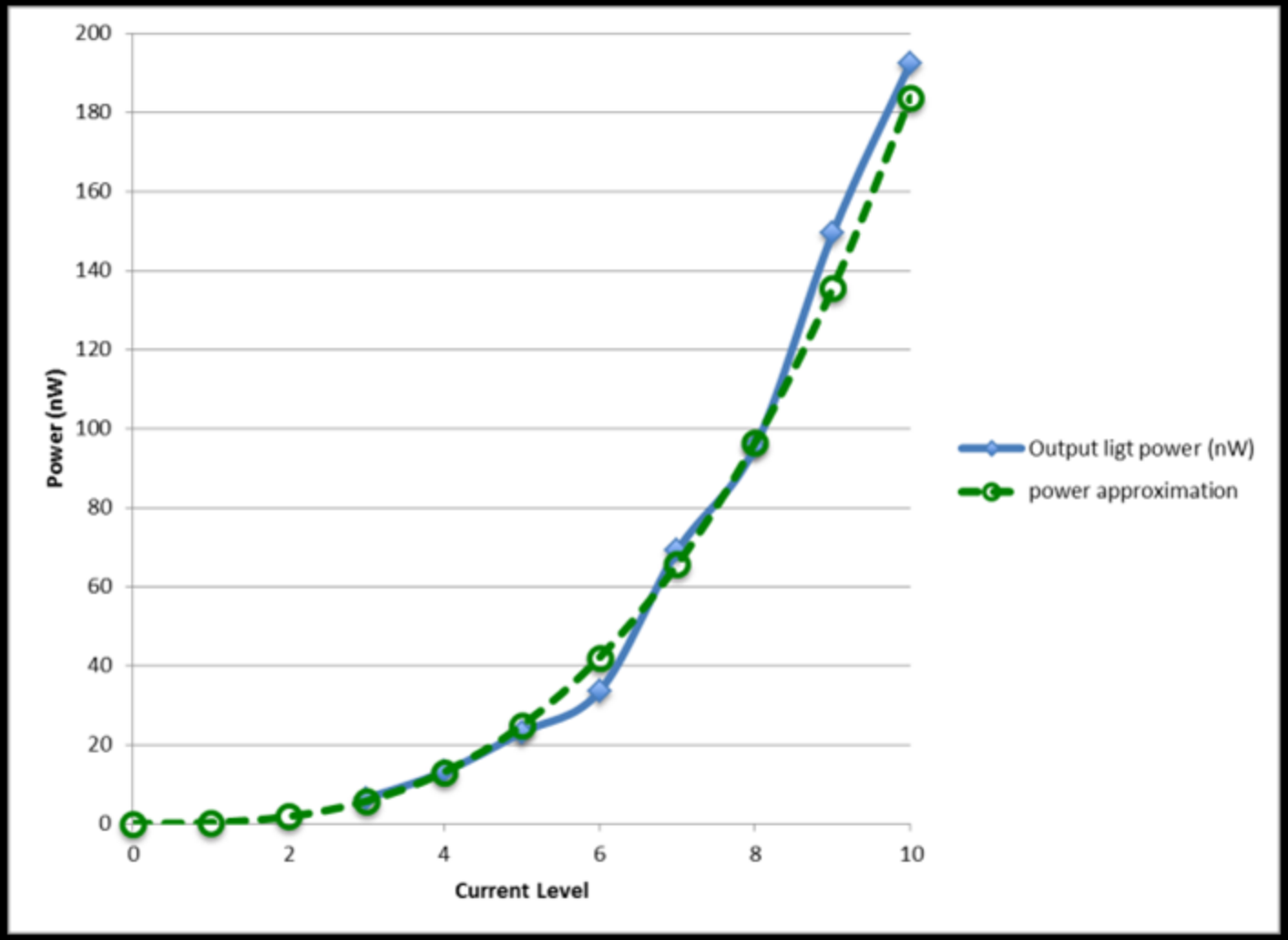
$$P = \frac{N_p \cdot h \cdot \nu}{t},$$

Where N_p is number of photon, h is plank constant, v is frequency and t is unit time

- From these, $\frac{N_p}{t}$ (number of photon per unit time) is simply,

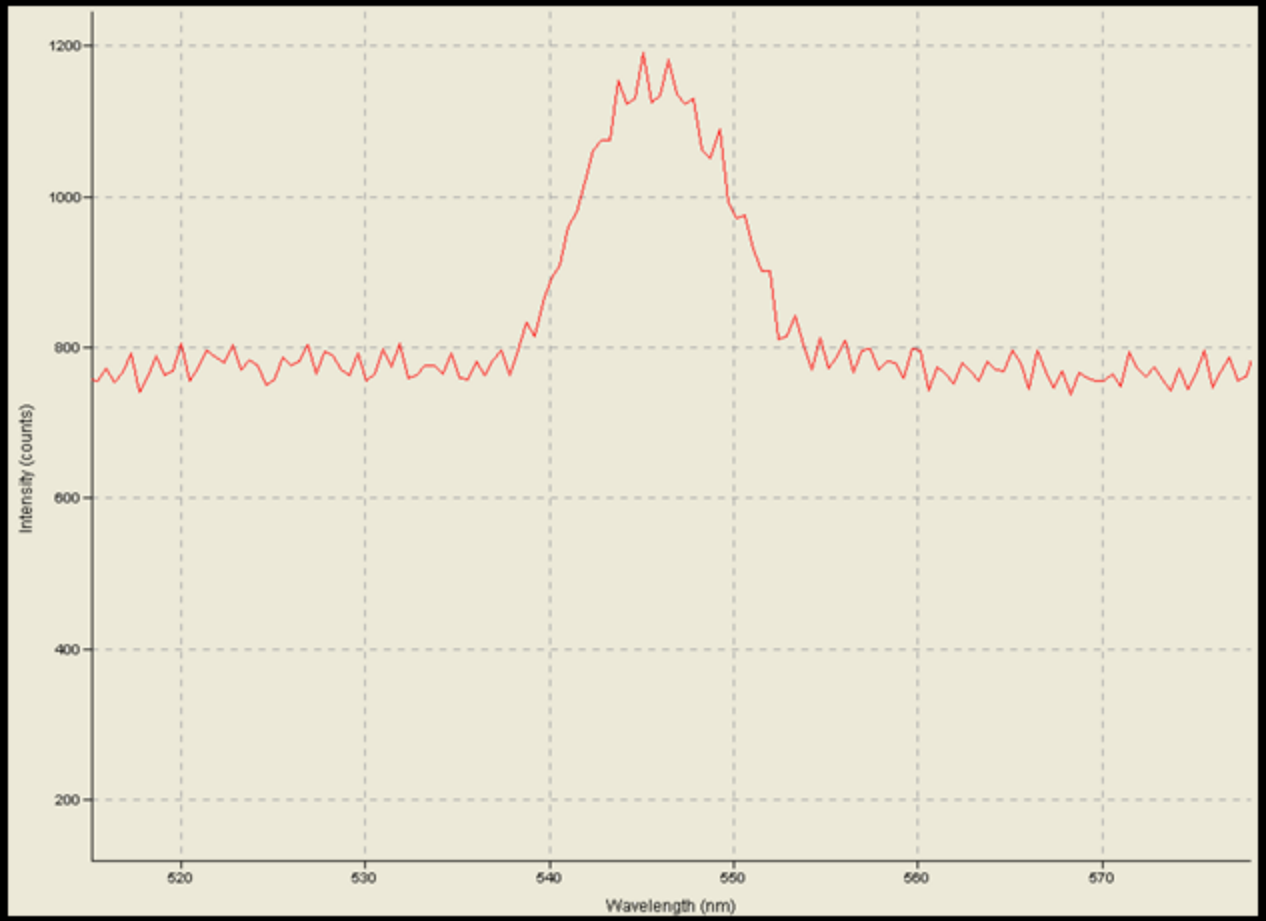
$$\frac{N_p}{t} = \frac{P}{h \cdot \nu}$$

- P was estimated by following graph



Power at operation current : 0.23nW

- ν was measured by spectrometer

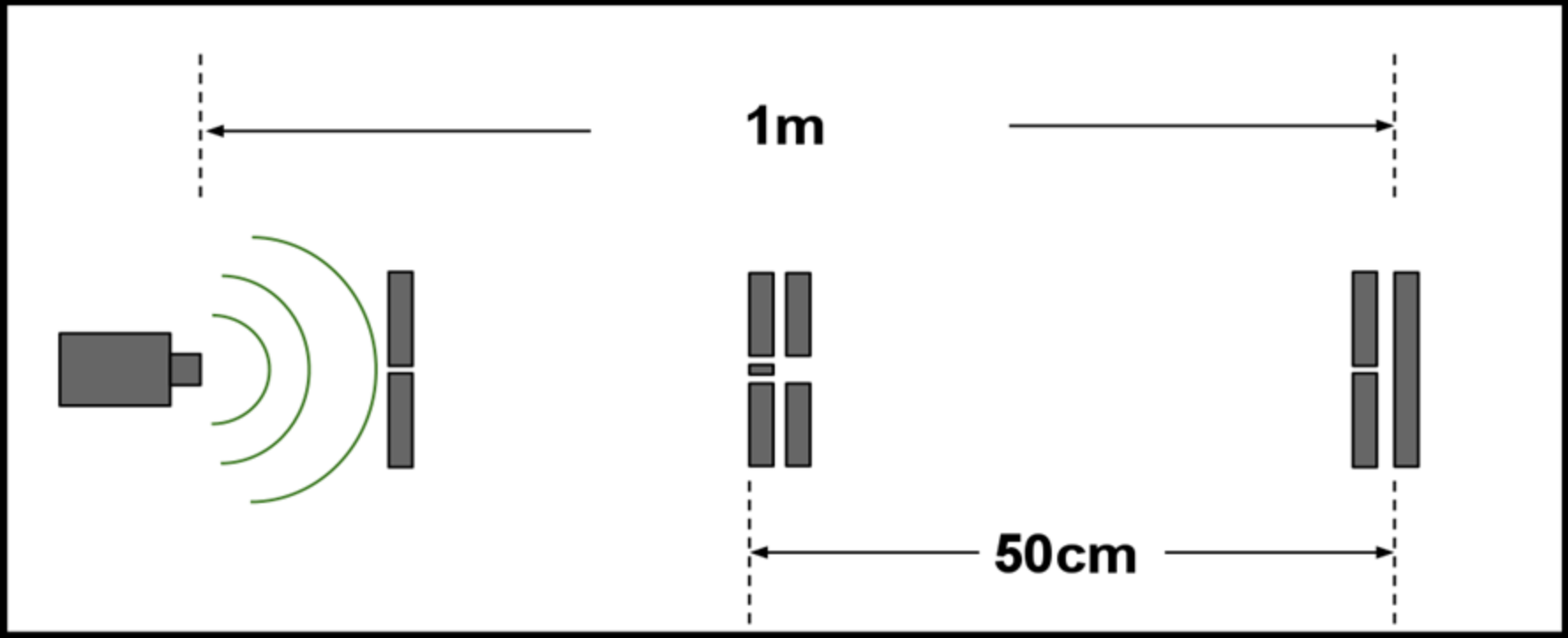


Frequency of light source: 5.5×10^{14} Hz

$$\Rightarrow \frac{N_p}{t} = \frac{0.23nW}{h \cdot 5.5 \times 10^{14} Hz} = 6.31 \times 10^8 \; photons/s$$

- A lot of photons, but this is number of photons per 1 second

- Let's consider how long does it takes photon to travel through one end to other end



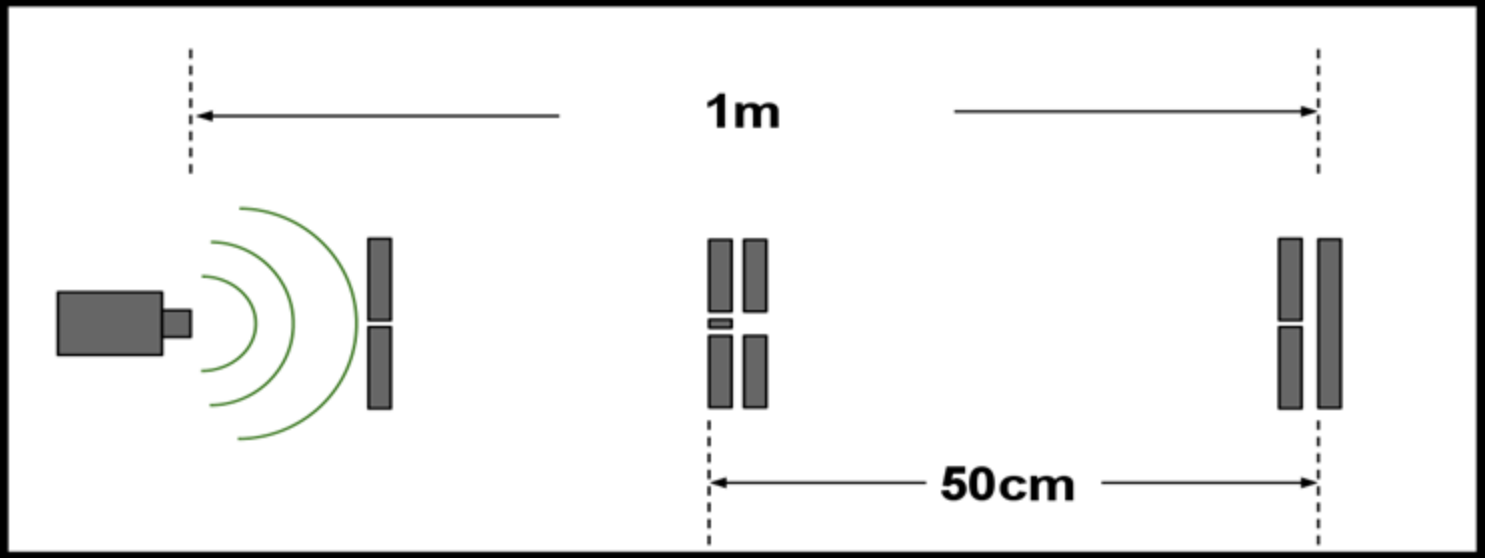
- $t_p = \frac{L}{C} = \frac{1m}{2.998 \times 10^8 m/s} = 3.34 \times 10^{-9} s$

- Since

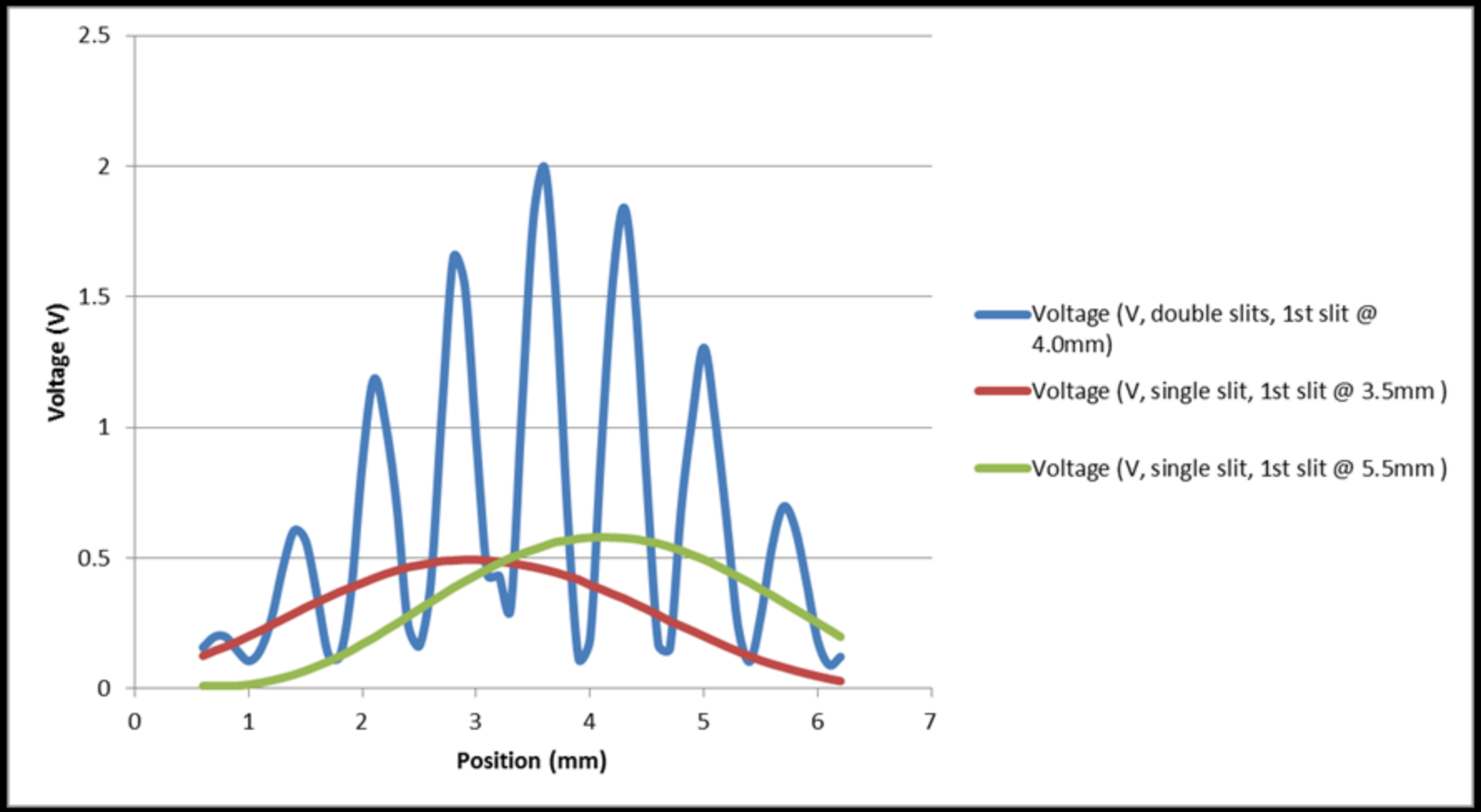
$$\frac{N_p}{t} = 6.31 \times 10^8 \, photons/s,$$

Period of the emitting single photon is

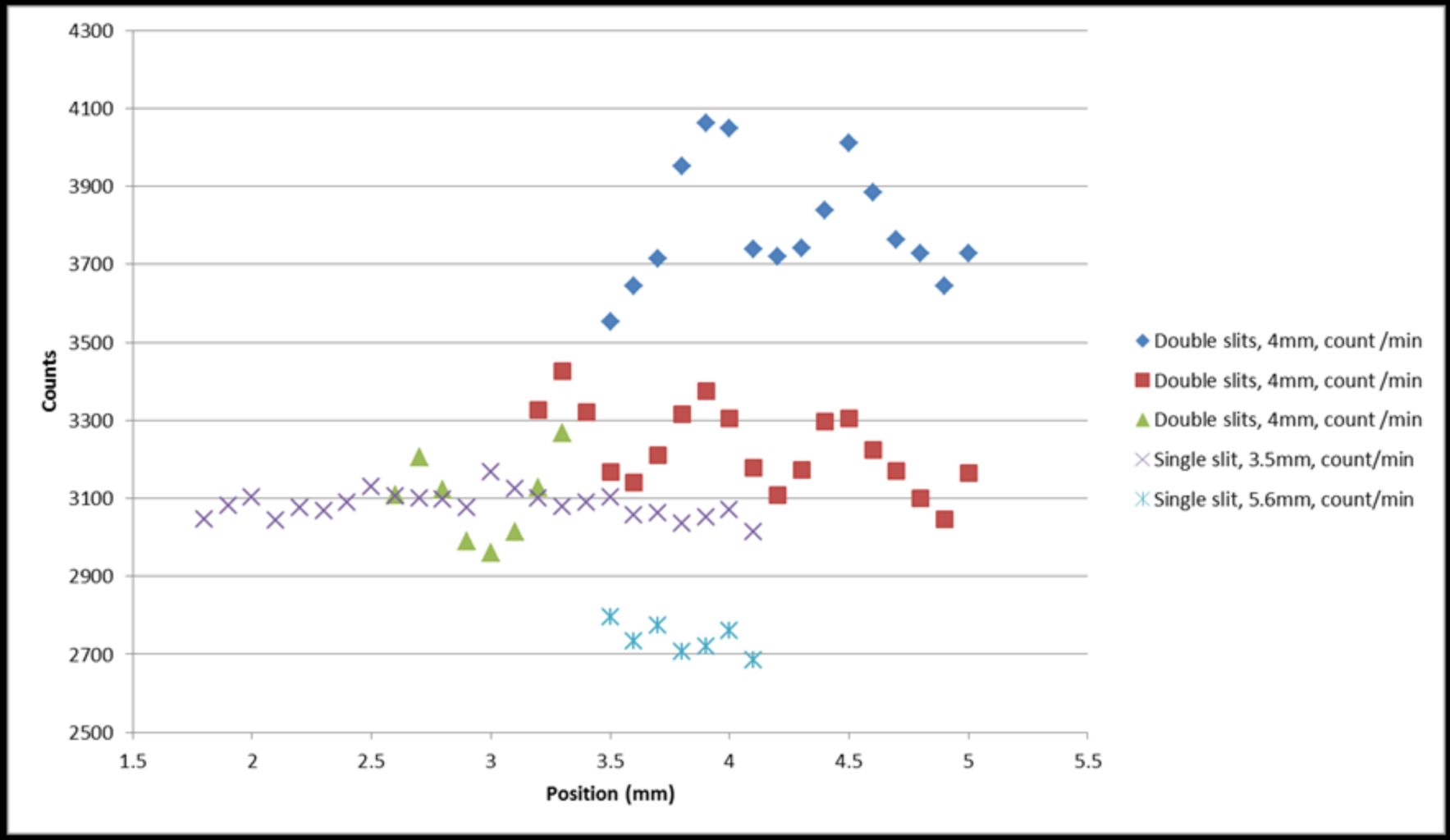
$$\frac{1}{6.31 \times 10^8 \, photons/s} = 1.58 \times 10^{-9} s$$



Regular Double Slits Interference

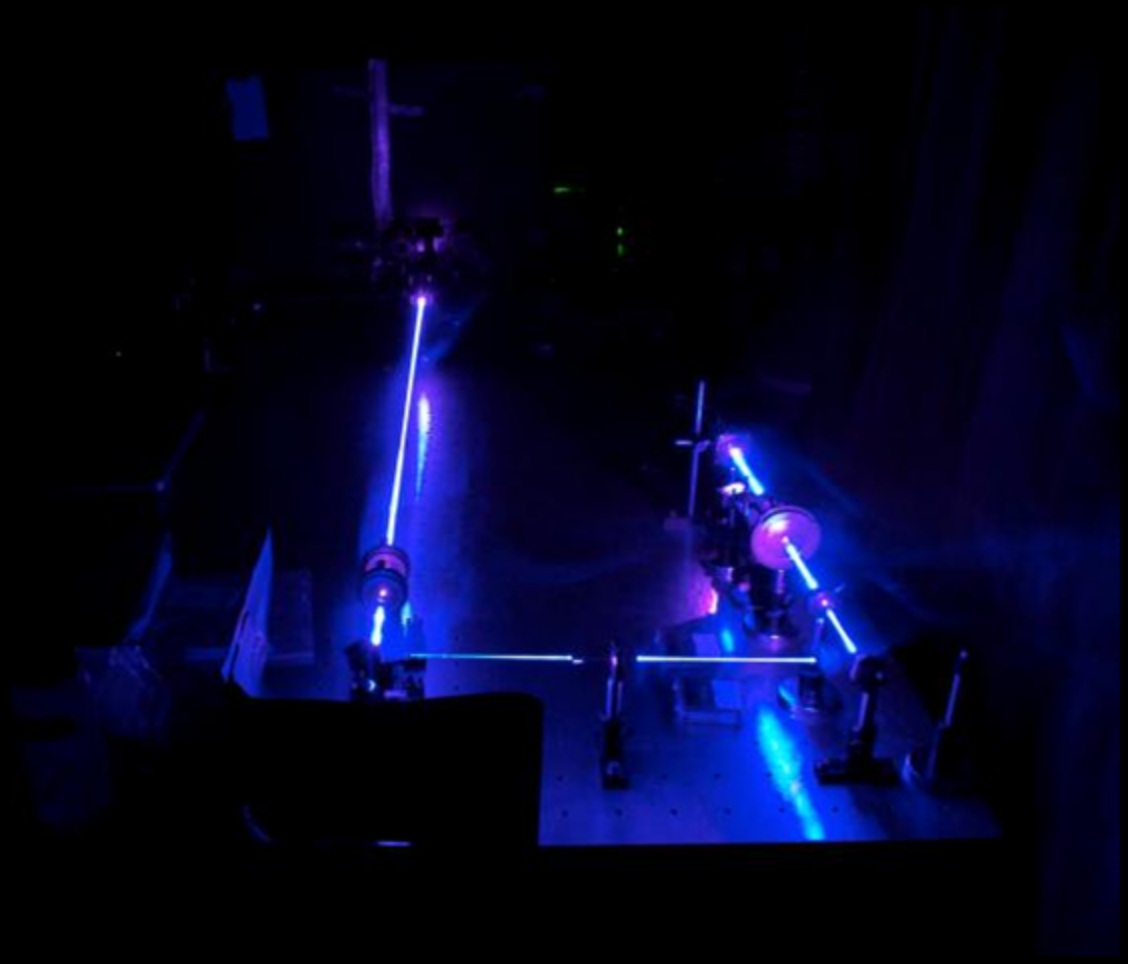


Single Photon Double Slits Interference

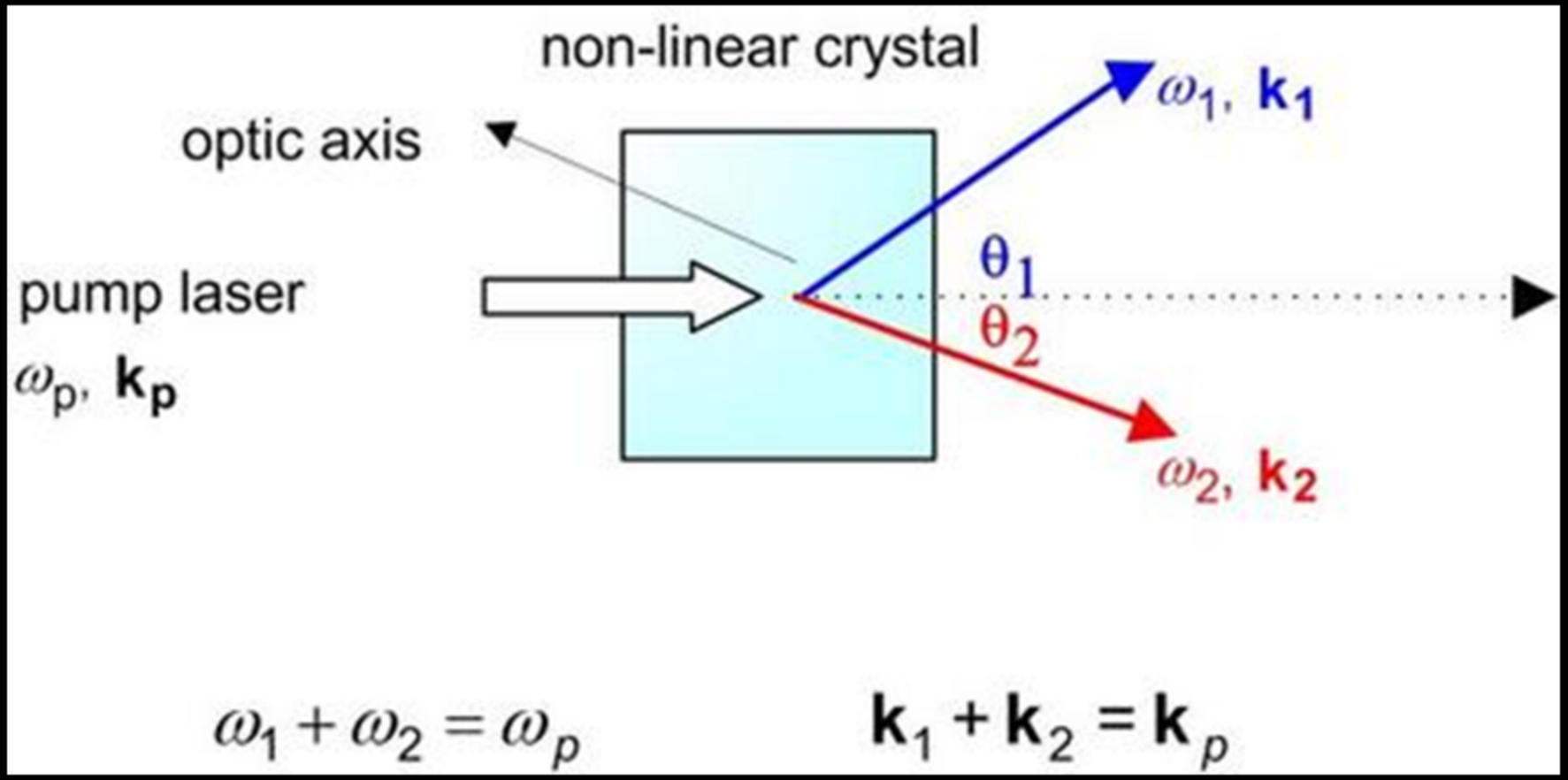


Experiment 2:

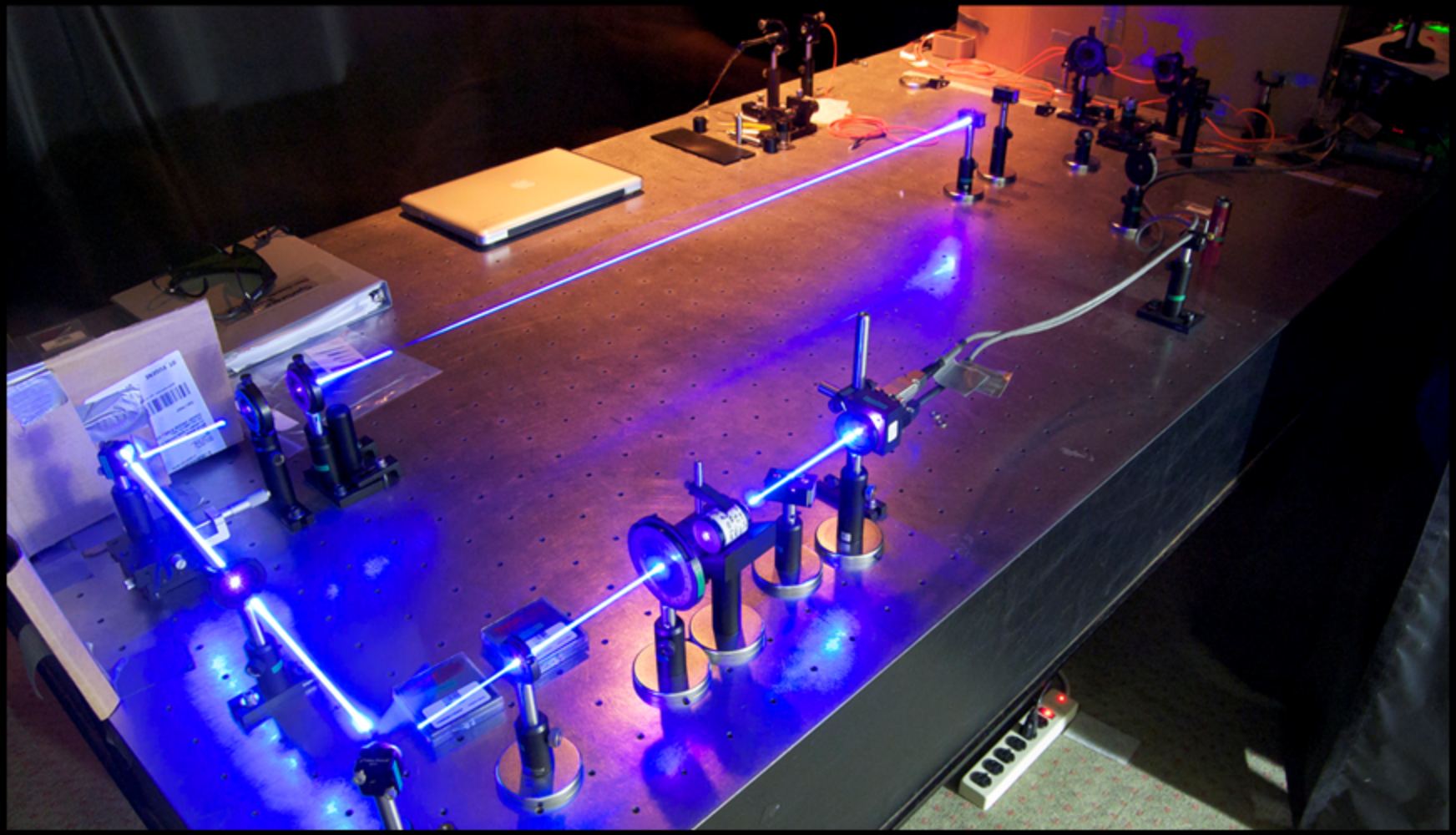
Parametric Down-conversion



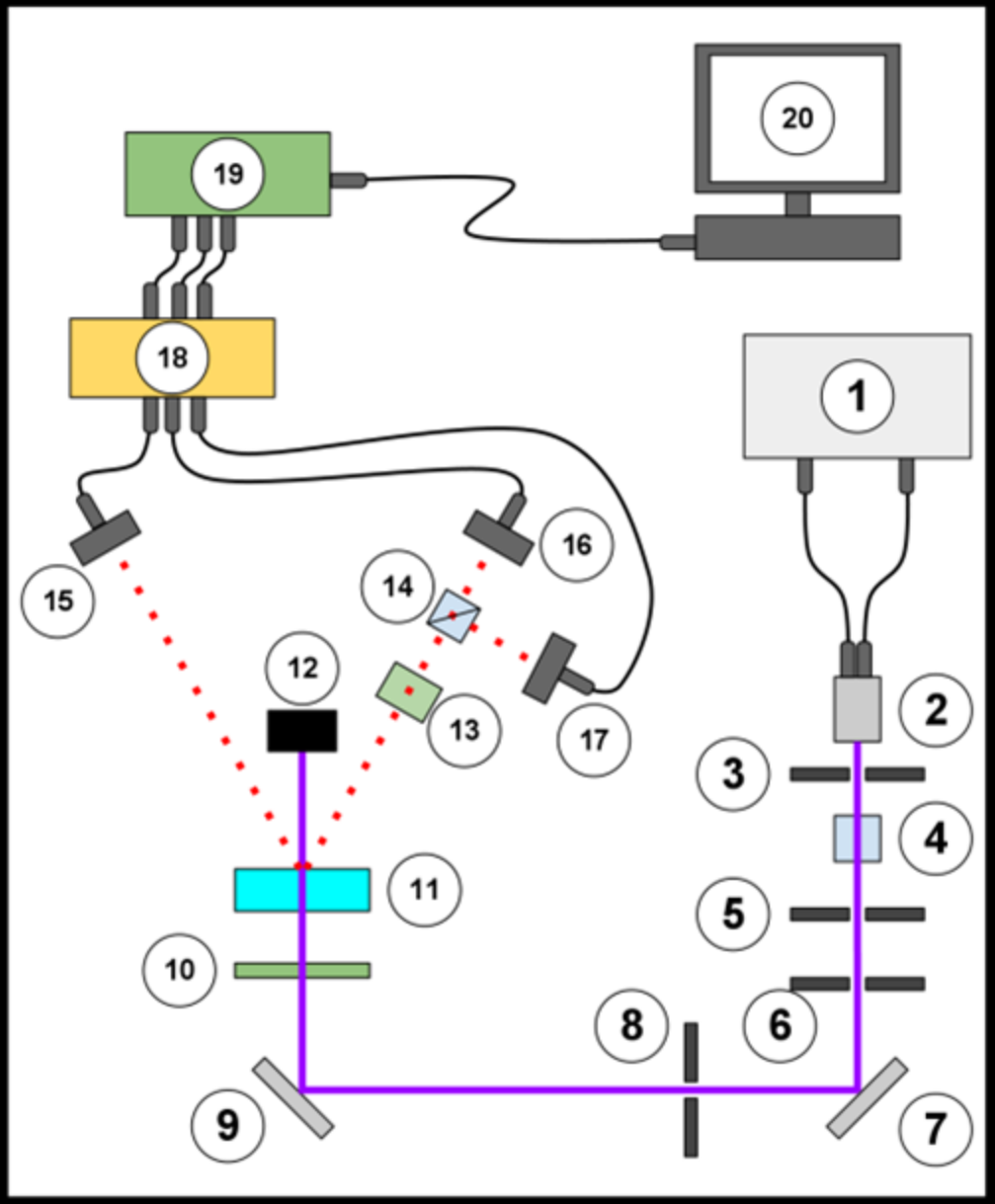
What is parametric down-conversion?



Setup



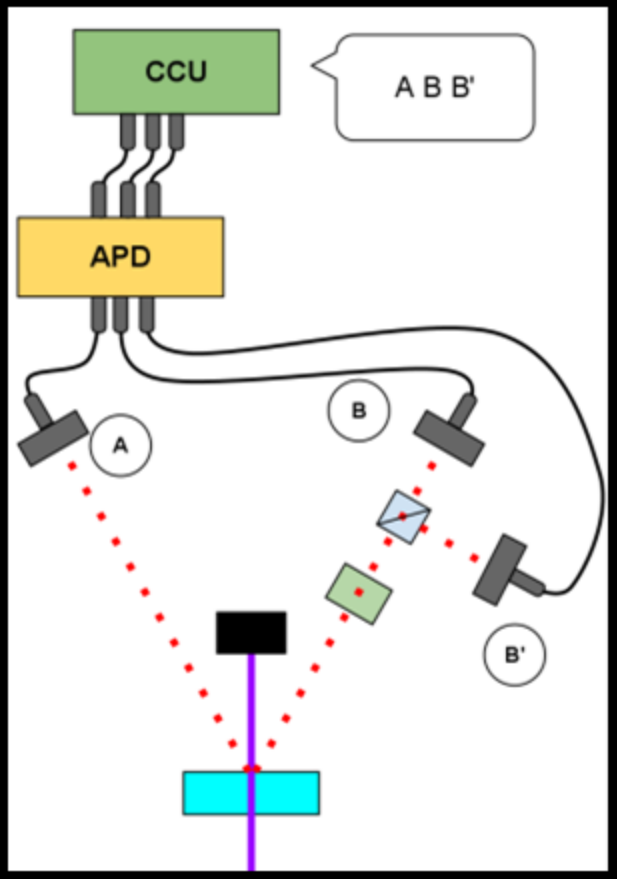
Block Diagram



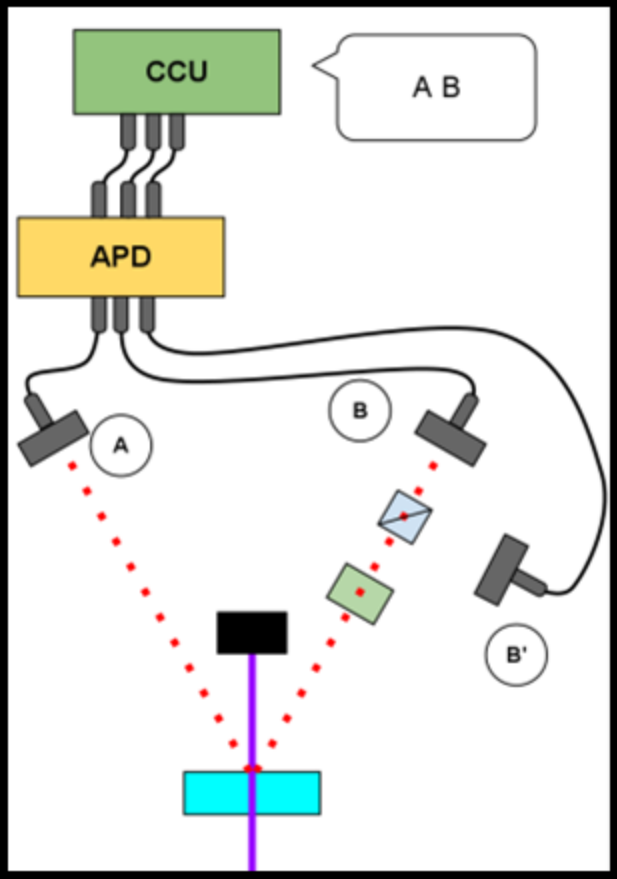
①:Laser Diode Controller
②:Laser Diode (406nm)
③、⑤、⑥、⑧:Aperture
④:Anamorphic prism pair
⑦、⑨:Mirror
⑩:Polarizer
⑪:Down-conversion crystal
⑫:Beam blocker
⑬:1/2 wave plate
⑭:Beam splitter
⑮、⑯、⑰:Detector
⑱:APD
⑲:Coincidence counter unit
⑳:Computer

Which one is single photon counting?

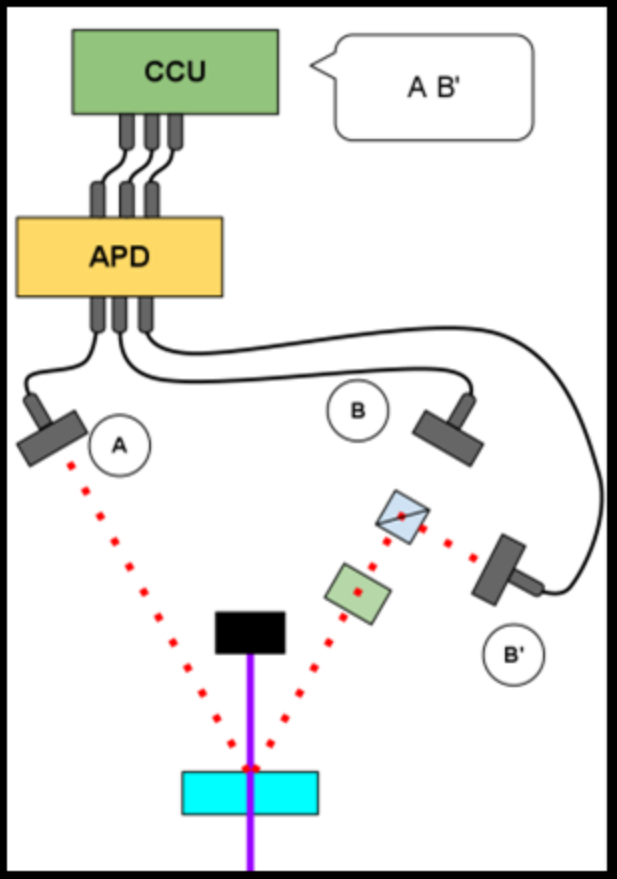
①



②



③



- $g^{(2)}(0) = \frac{N_A \cdot N_{ABB'}}{N_{AB} \cdot N_{AB'}}$

Where N_A is number of count for A detector, N_{AB} is number of coincidence count for A and B detectors, $N_{AB'}$ is number of coincidence count for A and B' detectors, $N_{ABB'}$ is number of coincidence count for A, B, B' detectors

- If $g^{(2)}(0) < 1$, then it is consider as success (can not enplaned by classically)

Data

*number of points 600

*time per step (seconds) 1.000000

*ABB' coincidence window (ns) 8.370000

*average g(2) 0.000236

***standard dev. of g(2) 0.004089**

***expected g(2) 0.195125**

Questions?