Phys 100 2024

Lecture 34

Weds: Read 12.2 - 12.3

Fri: HW 5pm

Photon model of light

When very low intensity light is incident of arrangements of barriers and slits the usual interference pattern does not appear directly. Rather, we observe a succession of dots, seemingly arriving at random locations

DEMO: PhET Quantum Wave Interference.

Tab: Single Particles

Settings: Slit width 25%
Slit sep 25%
Vertical 50%

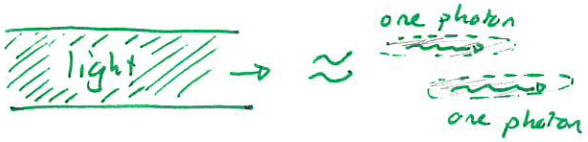
Fade: Off

Auto-Repeat: On.

The wave model of light does not predict this. An alternative model, the photon model does

Basic model

light consists of a stream of individual photons



Fundamental properties of photons

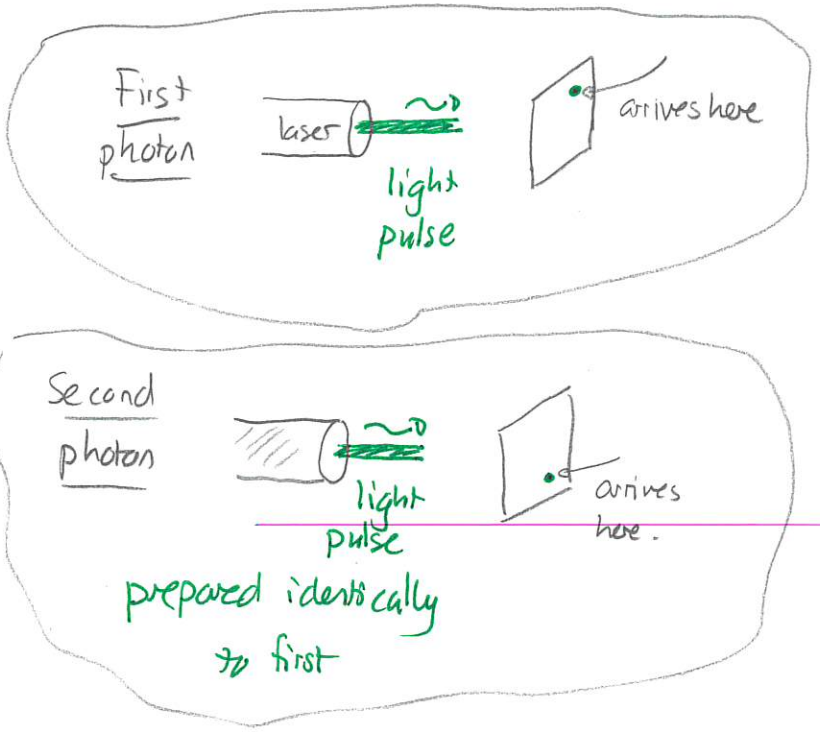
1) a single photon cannot be split into two or more photons
2) a single photon will only be detected at one (detector) location
3) in a vacuum photons propagate at the speed of light

The animation and experimental results suggest that there is an inherent randomness to the location where photons will arrive.

Quiz 1 70%

The physics that describes this states that:

> It is impossible to predict the exact arrival location of any particular photon regardless of how precisely the light pulse or signal is prepared.



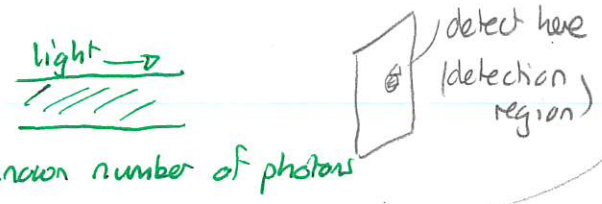
The randomness is inherent to the type of system and cannot be eliminated.

The physical theory that describes this, quantum theory, predicts:

how likely it will be that any photon will arrive at various locations

We can roughly quantify "likely" in terms of probability.

Send a large number (known) of photons toward a screen detector



The probability with which a photon arrives at the detection region = fraction of total number of photons that arrive at region

Quiz 2 - 90% - 100%

Quiz 3 - 90% -

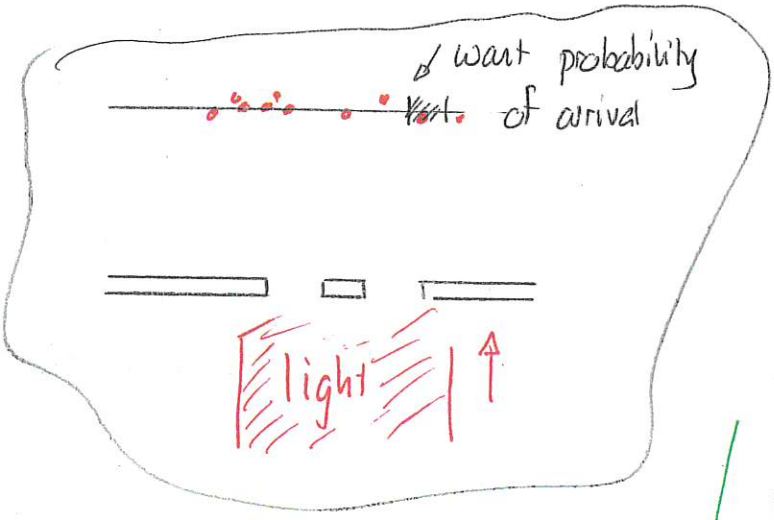
Quantum theory

Classical physics does not address the question of such probabilities.

An alternative theory does:

> Quantum theory ≈ general theory that allows for prediction of probabilities

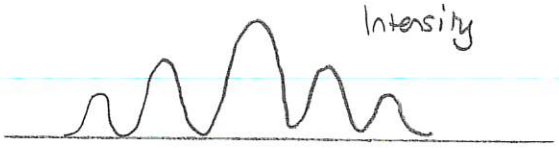
In terms of an interference experiment:



→ Associate a wave with each photon. Describe the wave using known wavelength and frequency of light

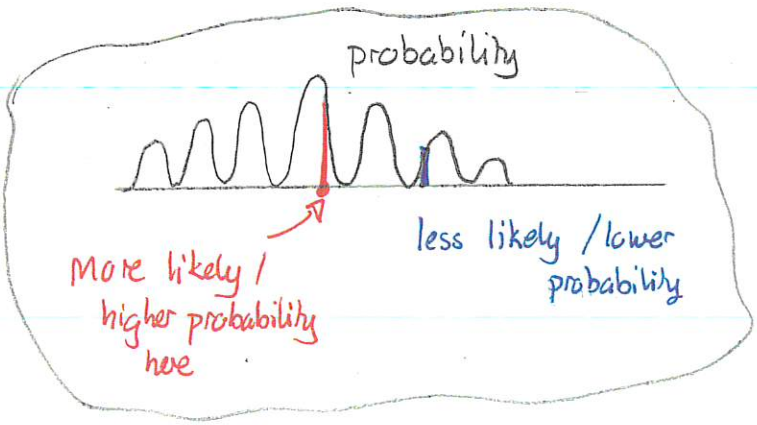
↓ Use physics of waves to predict how wave propagates and interferes

↓ Calculate intensity profile on screen.

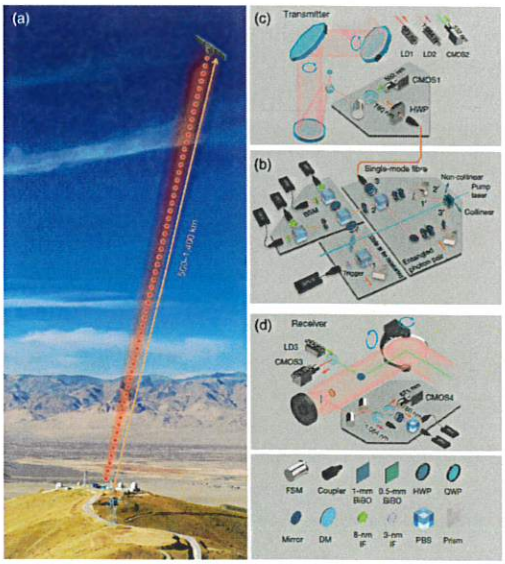


Identical to classical physics

Intensity profile gives relative probabilities for arrival of photon at various locations



1 Light signals from satellites



The Micius satellite, launched by China in 2016, communicates with stations on the ground by transmitting single photons toward a ground station. The purpose of this is to test various protocols for communication using ideas from quantum physics. One example is sharing a secret "key" that can be used to encode messages in a way that is much more secure than is possible with any conventional non-quantum physics method.

a) The satellite orbits at various distances from the ground station. At its closest the satellite is 500 km = 500000 m from the station. Determine the time taken for a single photon to travel from the satellite to the station.

b) The photons used have wavelength 810×10^{-7} m. Determine the frequency of the wave associated with this light.

Answers: a) $\text{speed} = \frac{\text{distance}}{\text{time}}$

$\Rightarrow \text{time} = \frac{\text{distance}}{\text{speed}} = \frac{500000\text{m}}{3.0\times10^{8}\text{m/s}} = 1.7\times10^{-3}\text{s}$

$= 1.7\text{ms}$

b) $\text{speed} = \text{wavelength} \times \text{frequency}$

$\text{frequency} = \frac{\text{speed}}{\text{wavelength}} = \frac{3.0\times10^{8}\text{m/s}}{810\times10^{-7}\text{m}} = 3.7\times10^{12}\text{Hz}$

Slide : Photon Interference Double Slit

Quiz 4

Quiz 5