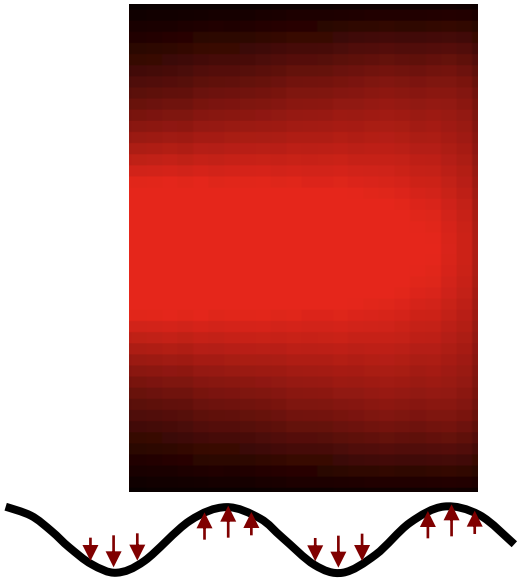
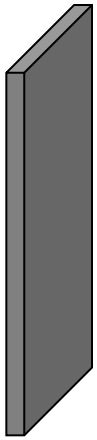
Probability and randomness

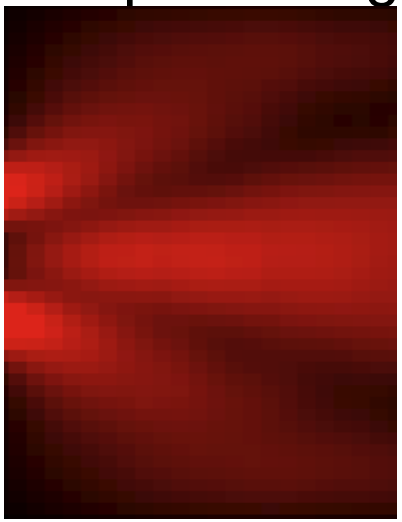
Photon is 3-D spread out little chunk of EM wave.

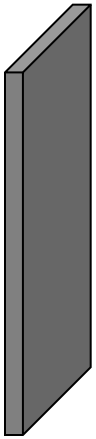




Gazillions of electrons in metal:
Which one will be kicked out?

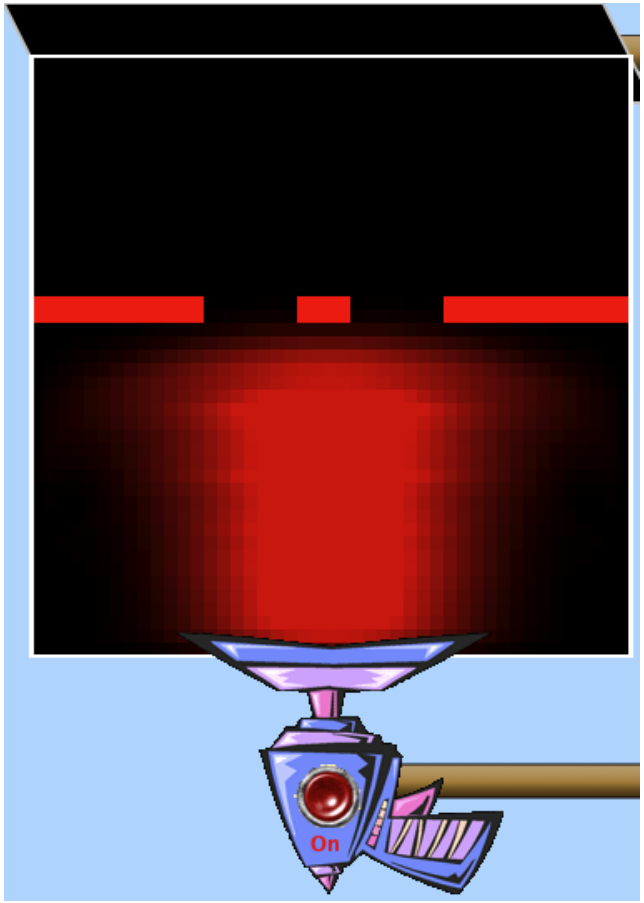
What if shape of single photon wave looked like this?



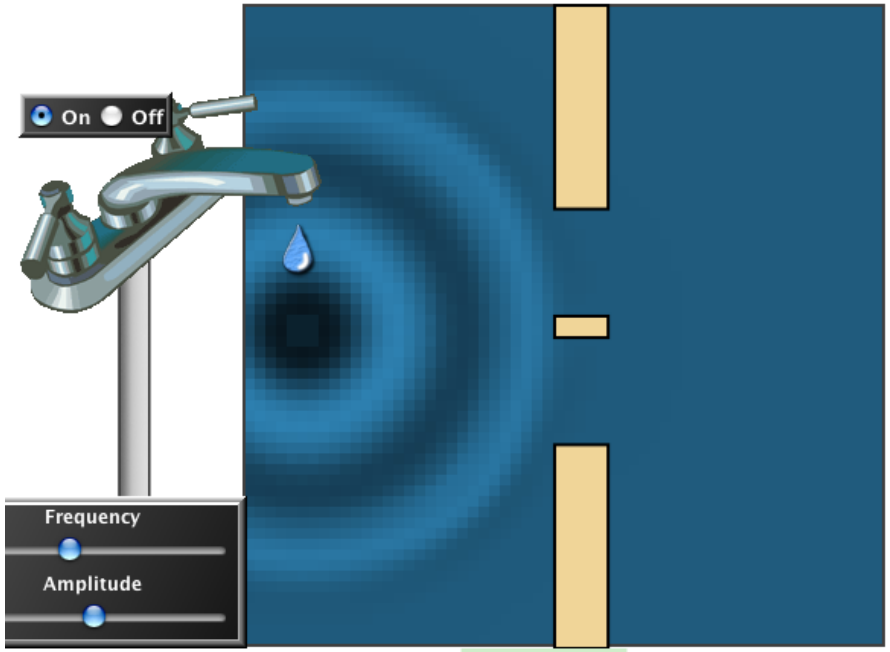


Gazillion electrons
Which one will be kicked out?

How can light behave like a wave (interference etc), but be made up of particles (photons) that seem to hit at random places?



2 slit interference with laser



2 slit interference with wave simulation

http://phet.colorado.edu/new/simulations/sims.php?sim=Quantum_Wave_Interference

http://phet.colorado.edu/new/simulations/sims.php?sim=Wave_Interference

How can light behave like a wave (interference etc), but be made up of particles (photons) that seem to hit at random places?

2 slit interference with laser

2 slit interference with wave simulation

Which is *best* answer, and *why*? (will randomly ask for reasons)

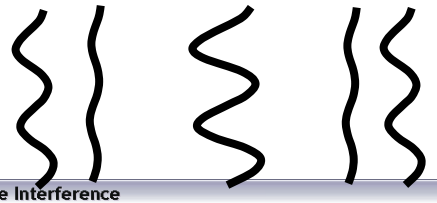
If I shoot a photon through the two slits to hit the screen, it…

a. cannot hit in the middle, because block is in the way.
b. is completely random where it can hit. Has equal chance of hitting anywhere on the screen.
c. must hit at the maximum of the interference pattern
d. has some chance of being anywhere, but on average better chance at being where interference pattern in brightest.
e. will hit anywhere it has a straight shot through either slit

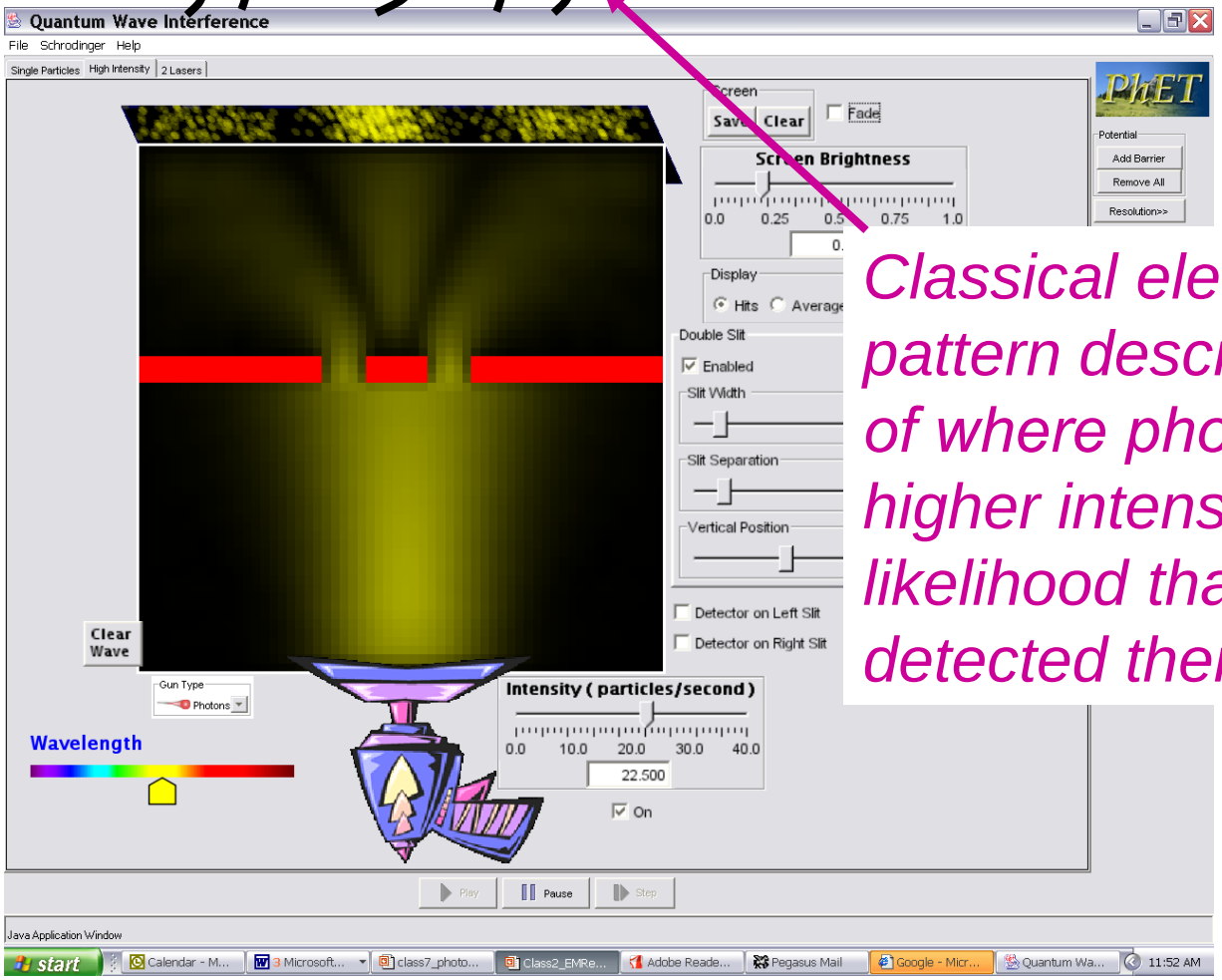
Probability of photon hitting given by where field is biggest

(electric field strength)^2~Intensity &

gives probability of where photon will be!



standard electric field representation of light field

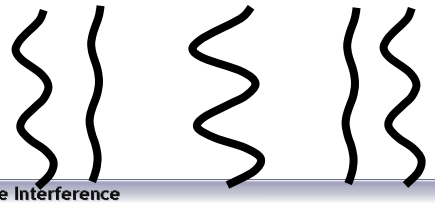


Classical electric field wave pattern describes probability of where photons will be… higher intensity, higher likelihood that photon will be detected there.

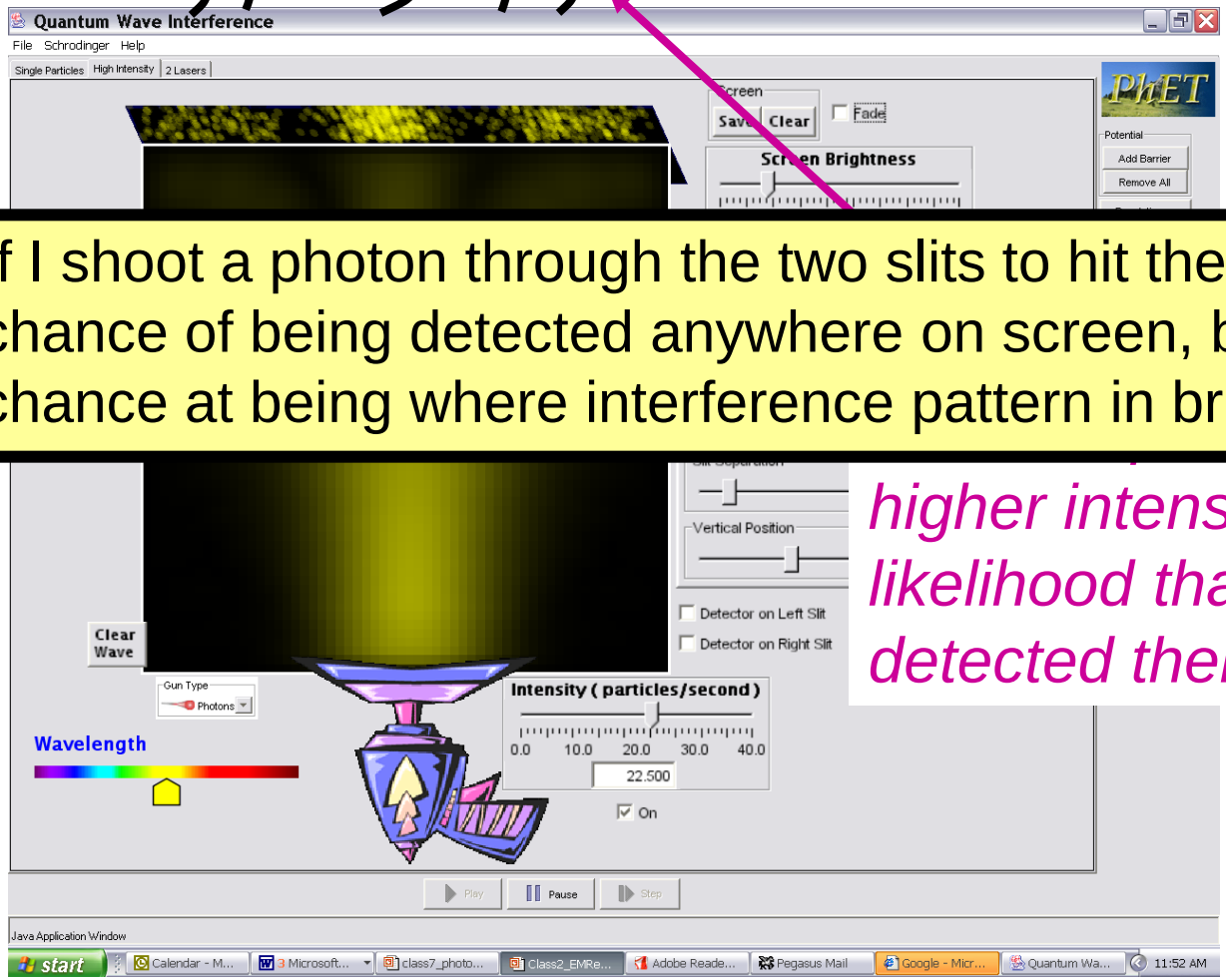
Probability of photon hitting given by where field is biggest

(electric field strength)^2~Intensity &

gives probability of where photon will be!



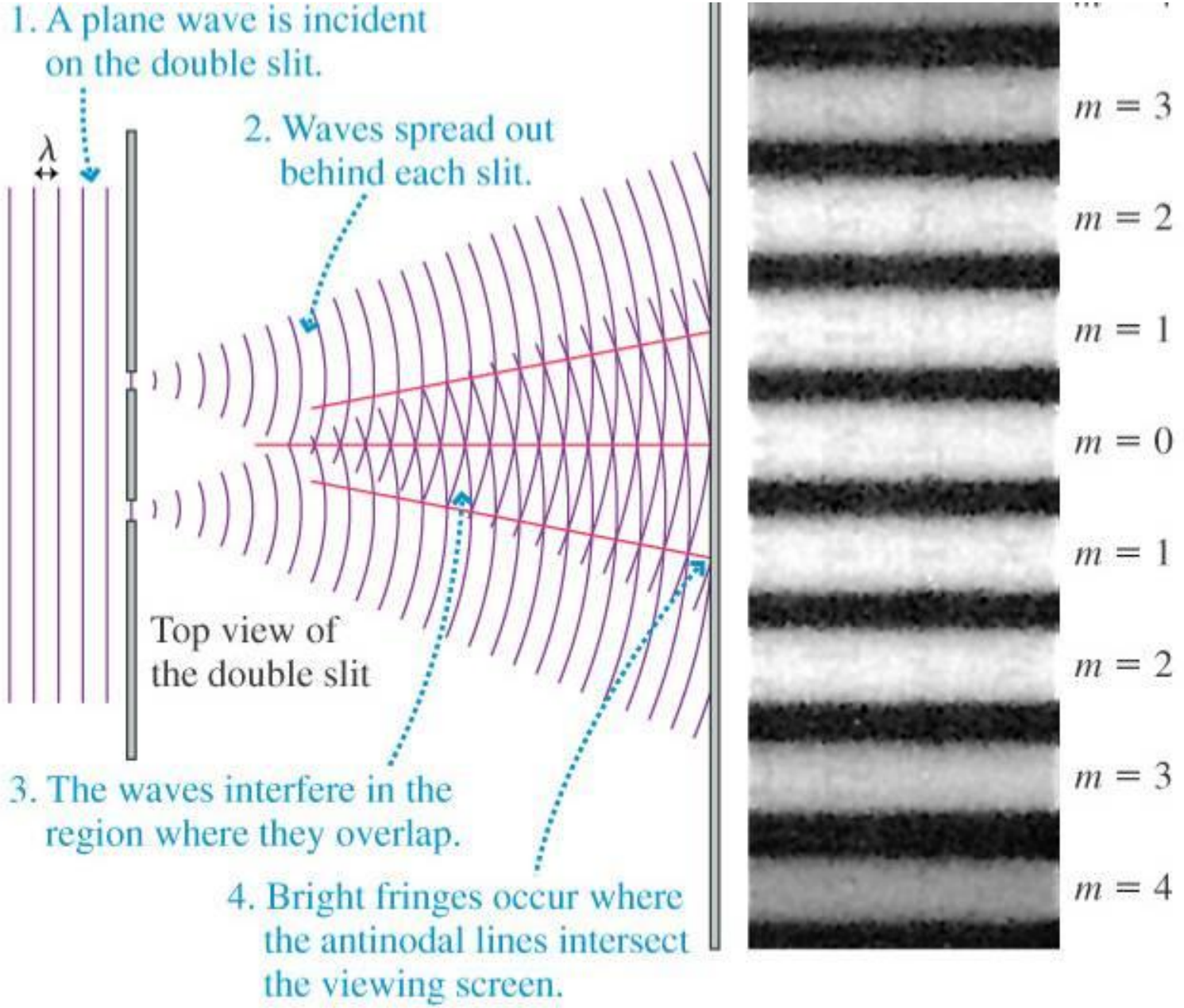
standard electric field representation of light field



If I shoot a photon through the two slits to hit the screen, it has some chance of being detected anywhere on screen, but on average better chance at being where interference pattern in brightest.

higher intensity, higher likelihood that photon will be detected there.

Two slit interference



To all those students feeling confused and asking questions:
You are listening carefully and thinking about the material!!

Should be bothered and asking these kinds of questions.

Fundamental change in way to think about physics.

Before (pre 1900, Physics I and II) -- everything could be known exactly, if measured and calculated carefully enough.

Now-- physics behavior is fundamentally inexact.
Contains randomness, can only predict and measure probabilities for what happens, not exact behavior!

(Amount of randomness very small on human size scale, big on electron and atom scale.)

Which slit did this photon go through?

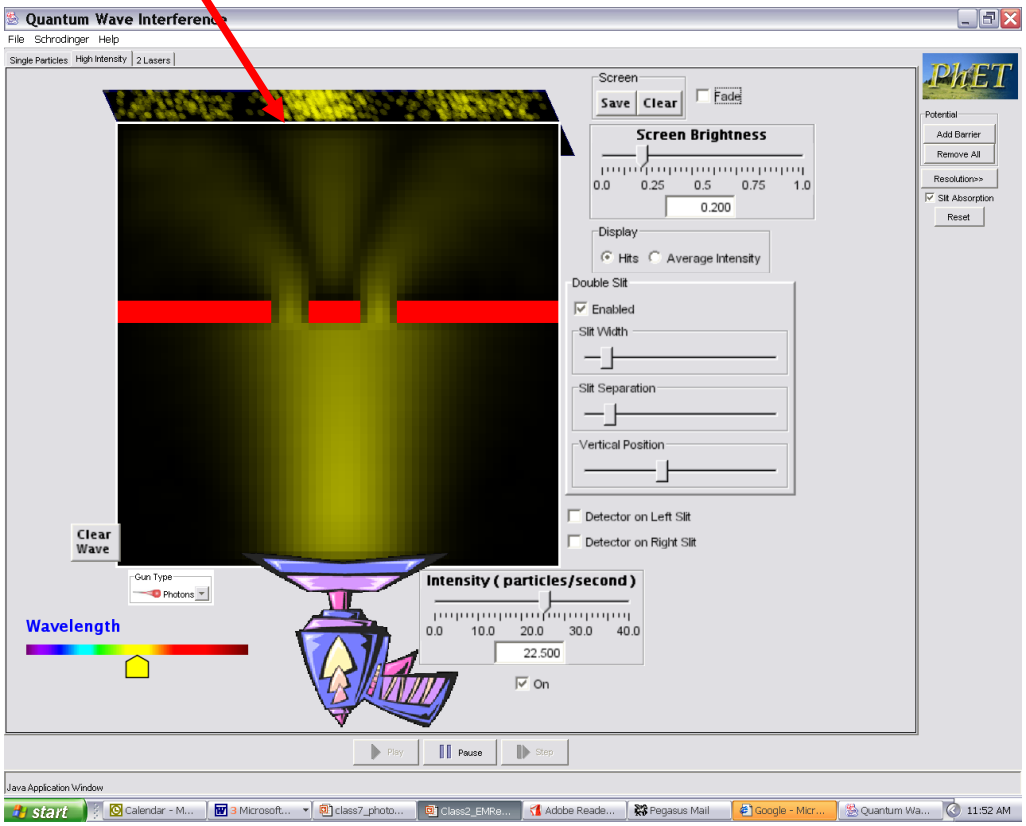
a. left

b. right

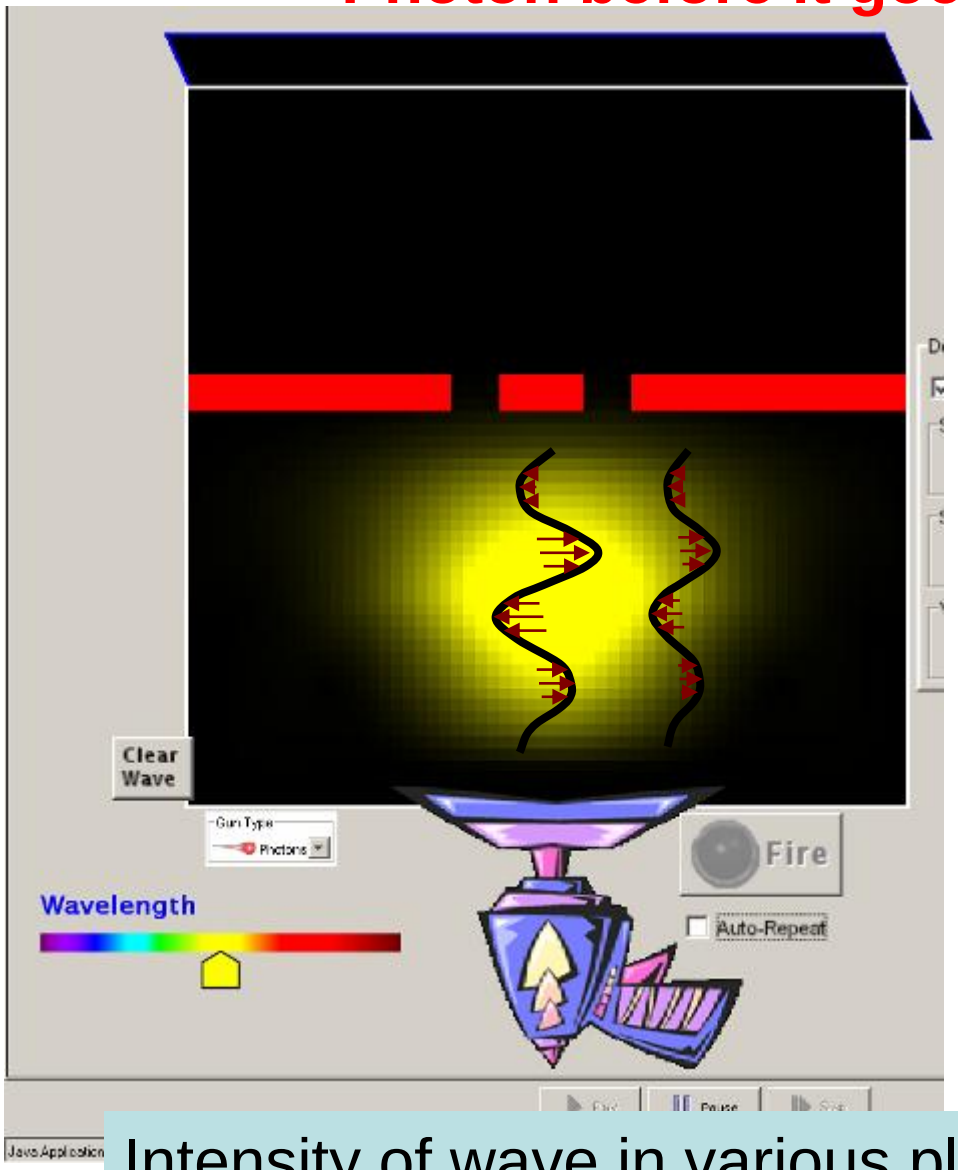
c. both

d. neither

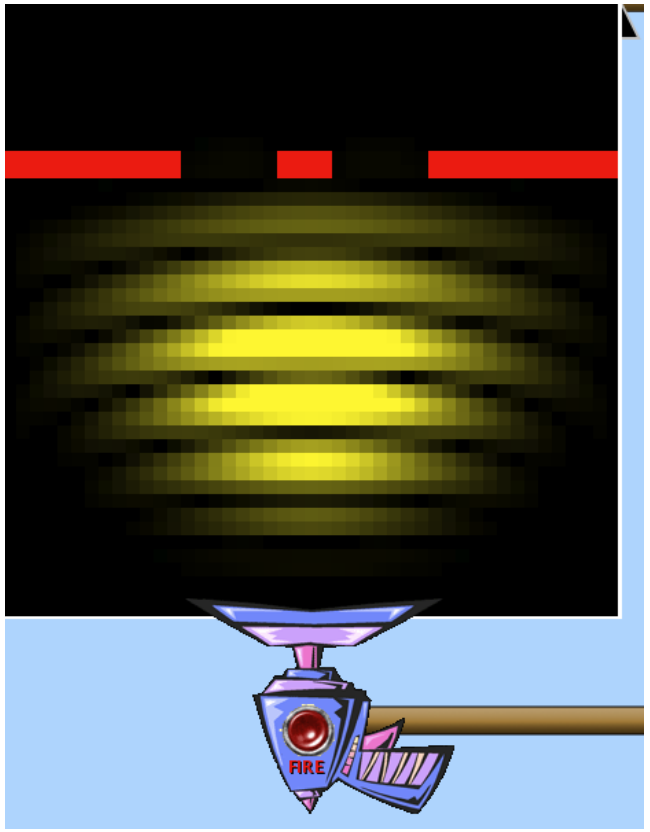
e. either left or right we just cannot know which one



Photon before it goes through the slits

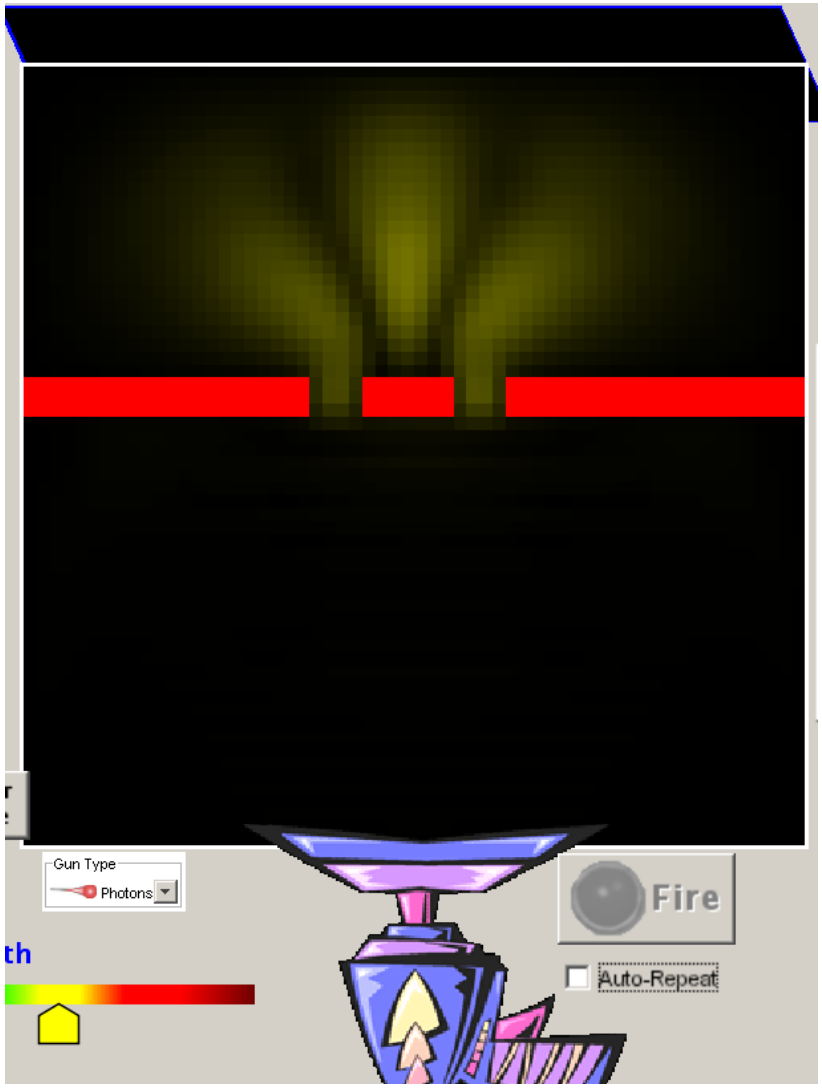


Photon as little segment of wav
moving towards slits



Intensity of wave in various places, indicates probability of finding the photon there if you looked at that moment.

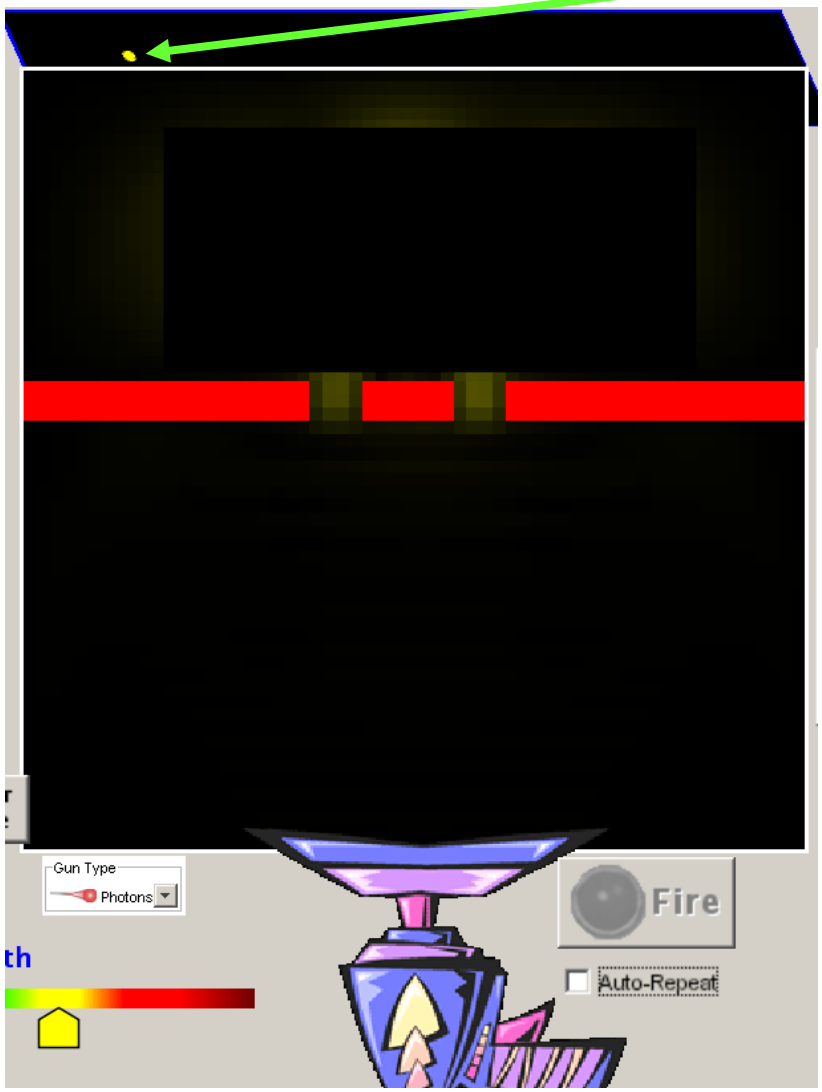
Photon after it goes through the slits



Photon is a wave…
it can interfere with itself.

Intensity of wave in various places still indicates probability of the photon concentrating at that spot if you had detector (e.g. a bunch of atoms or a sheet of metal)

Photon after it goes through the slits



When photon *interacts* with an electron or atom, all energy ends up in one spot… behaves like a particle with energy = hc/λ

Photon is a wave…
it can interfere with itself.

Intensity of wave in various places still indicates probability of the photon concentrating at that spot if you had detector (e.g. a bunch of atoms or a sheet of metal)

Questions?

- What does this imply about the nature light?
- What does this say about the nature of measurement?