Learning to Teach Quantum Information Using the Visual Quantum Mechanics Project

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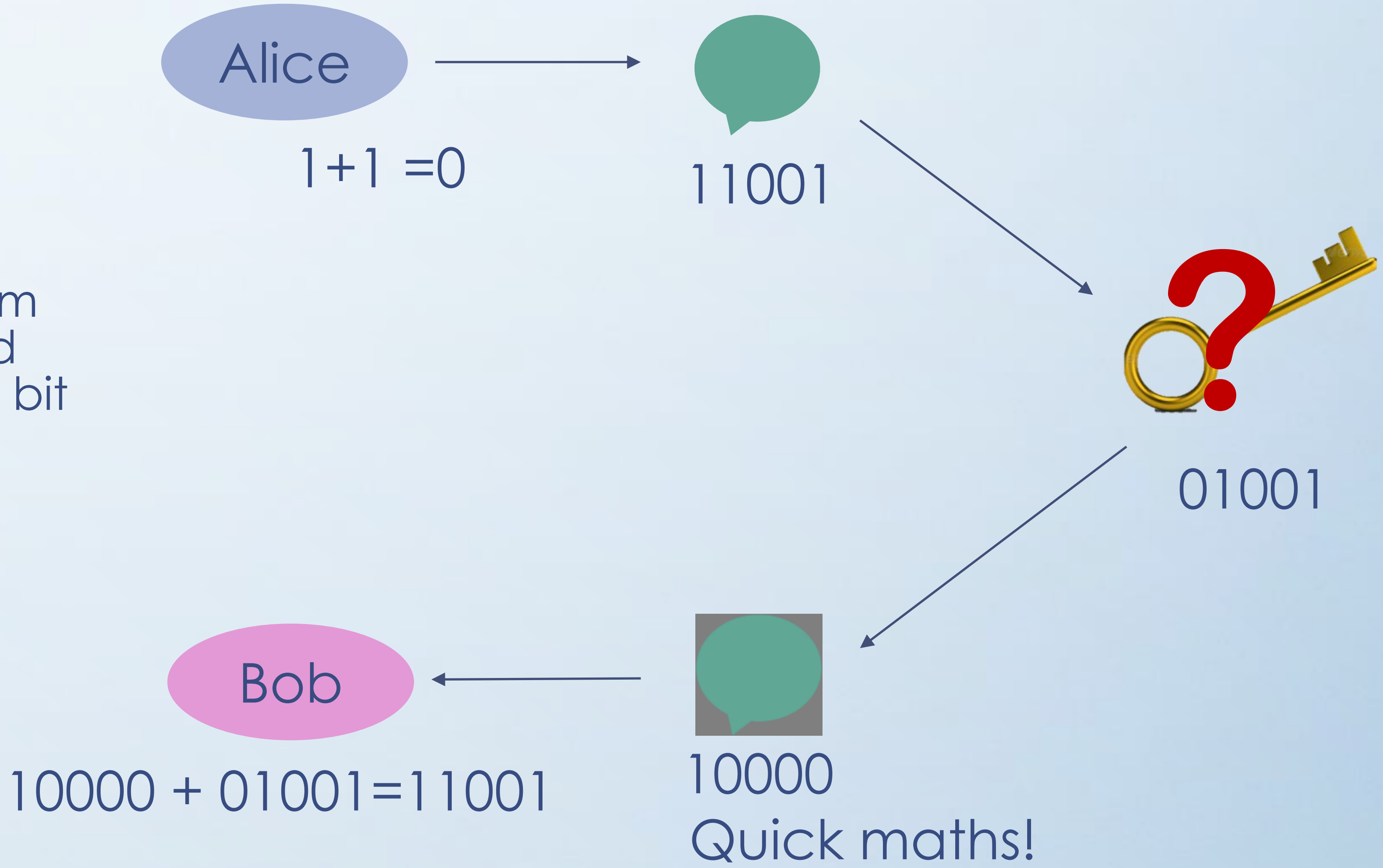
Cryptography

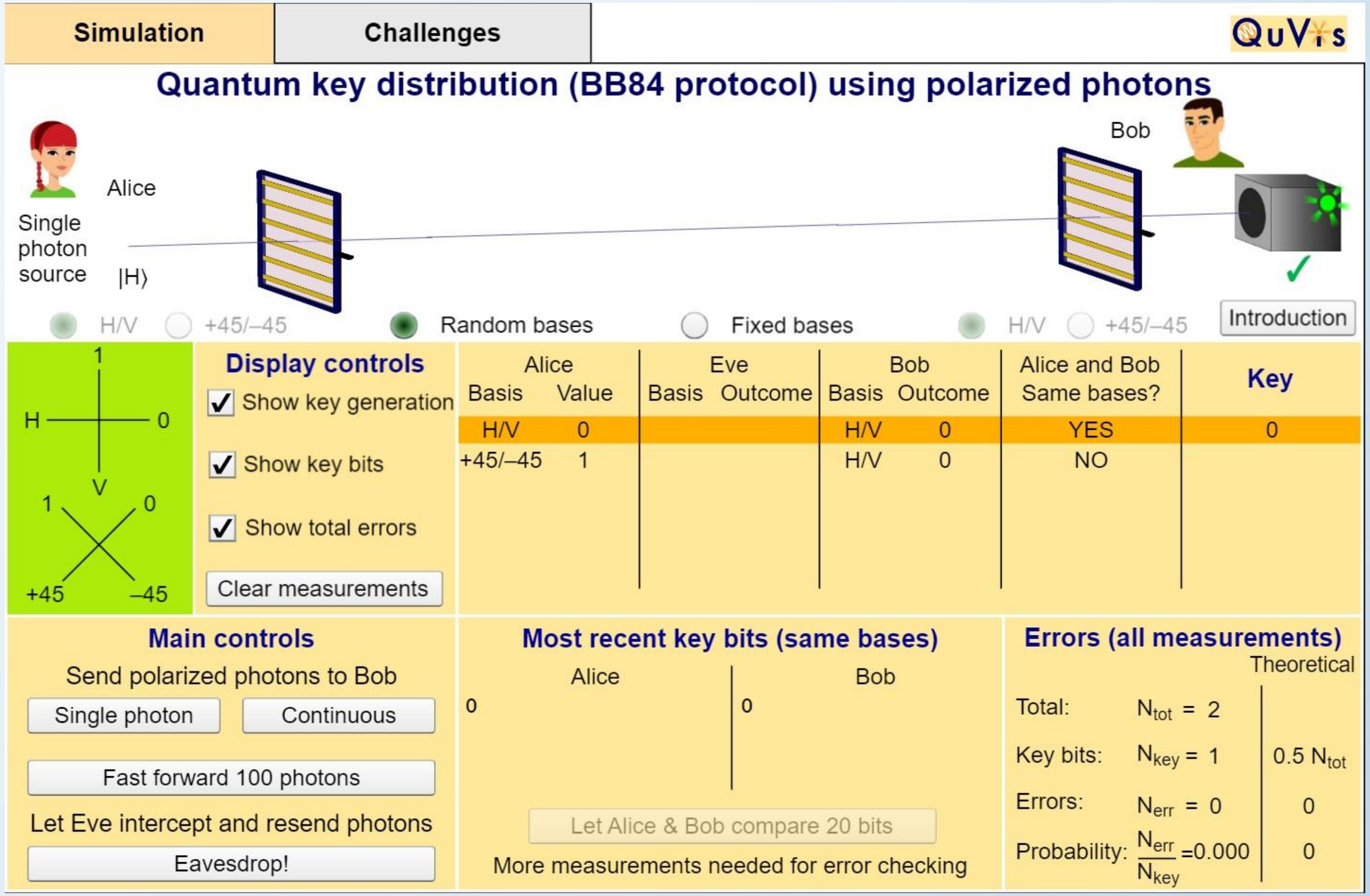
How does it work?

- Sender (Alice)
- Receiver (Bob)
- Secret Key – random sequence of 0s and 1s, where each is a bit
- Bitwise addition
- Ciphertext



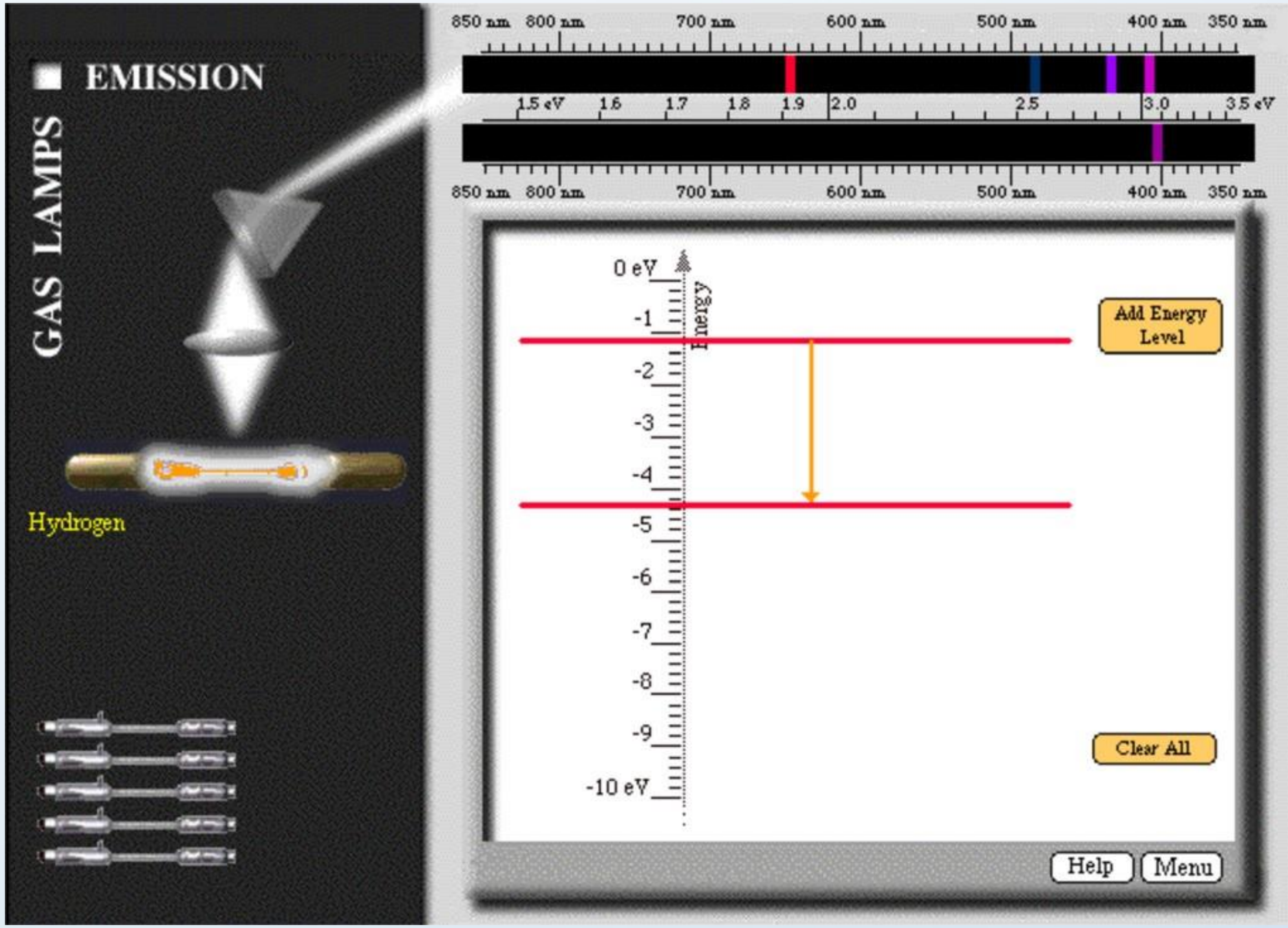
Learning about the key generating using simulation

Simulation by Antje Kohnle and Aluna Rizzoli 2017



https://www.st-andrews.ac.uk/physics/quvis/simulations_html5/sims/BB84_photons/BB84_photons.html

Visual Quantum Mechanics (VQM)



The Emission module in the *Spectroscopy Lab Suite*. Students drag the light source on the right to the power supply. Then they build an energy level model of the atom to match the observed spectrum. [2]

Instructional materials intended to help understand quantum conceptually for students with minimal physics and math background

Example of A Module

Light, Photons, Electrons, and Waves

Goal

We will look at a property of light and learn how scientists conclude that light behaves as a wave.

Objectives

By the end of this module, you should be able to:

- predict that interference pattern is a unique property of all kinds of waves.
- explore that electrons passing though slits shows interference pattern.
- discover that double slit experiment is an evidence for wave behavior.
- explain why photoelectric effect is an evidence for light behaving as particles.
- deduce that light exhibit particle properties as well as wave properties.
- deduce that electrons exhibit wave properties as well as particle properties.
- detect that interference pattern changes with changing energy, slit spacing and distance to screen.

Prerequisites

- Conservation of energy.
- Electrons in atoms can emit and absorb energy (in the form of heat or light).
- Light spectrum can determine the type of element that is emitting the light.

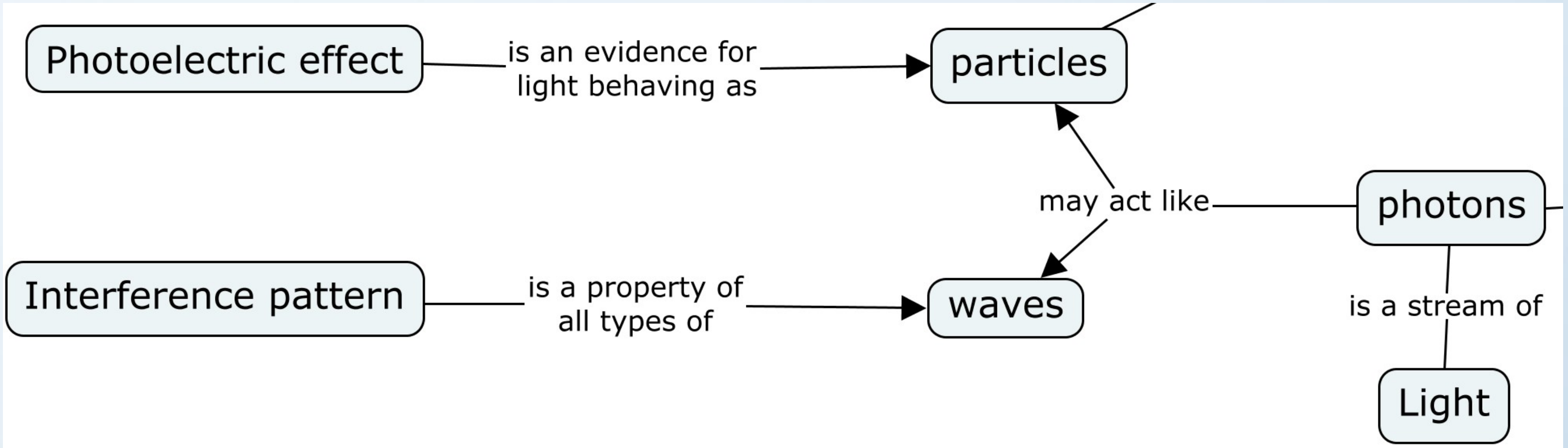
Introduction

The light from atoms indicates that only certain energy transitions occur in each atom. We were able to explain these results using energy diagrams. However, we have not yet explained why only certain energies occur in each atom or why these energies are different for different elements. Getting to the reasons will take us a little time. We begin with a short diversion about the nature of light.

Interference of Light: Young's Experiment

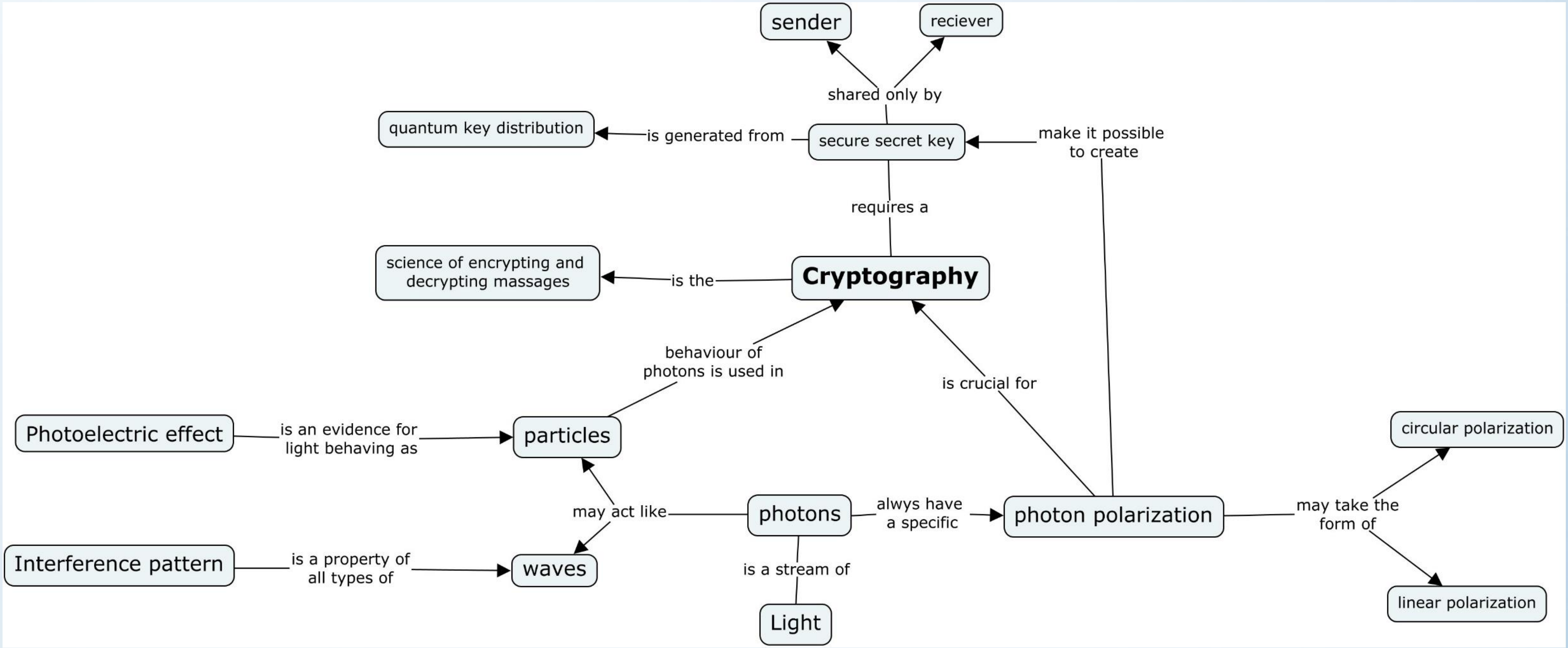
Approximately 200 years ago, scientists (then called "natural philosophers") argued about the fundamental nature of light. In his book *Optiks*, (Wikipedia entry ; full book) Isaac Newton assumed that light consisted of a collection of minute particles. With this model, he explained most of the known optical experiments. Others thought that light must take the form of a wave. In 1801, Thomas Young (Wikipedia) completed an experiment that seemed to end this controversy. However, it was over 50 years before almost all scientists were willing to agree that Young was correct and Newton was wrong.

Concept Map



Photoelectric effect
is an evidence for
light behaving as
particles
may act like
photons
Interference pattern
is a property of
all types of
waves
is a stream of
Light

Concept Map



sender
reciever
shared only by
quantum key distribution
is generated from
secure secret key
make it possible
to create
requires a
science of encrypting and
decrypting massages
is the
Cryptography
behaviour of
photons is used in
is crucial for
Photoelectric effect
is an evidence for
light behaving as
particles
circular polarization
may act like
photons
alwys have
a specific
photon polarization
may take the
form of
Interference pattern
is a property of
all types of
waves
is a stream of
Light
linear polarization

Process

Light, Photons, Electrons, and Waves

Goal

We will look at a property of light and learn how scientists conclude that light behaves as a wave.

Objectives

By the end of this module, you should be able to:

- predict that interference pattern is a unique property of all kinds of waves.
- explore that electrons passing though slits shows interference pattern.
- discover that double slit experiment is an evidence for wave behavior.
- explain why photoelectric effect is an evidence for light behaving as particles.
- deduce that light exhibit particle properties as well as wave properties.
- deduce that electrons exhibit wave properties as well as particle properties.
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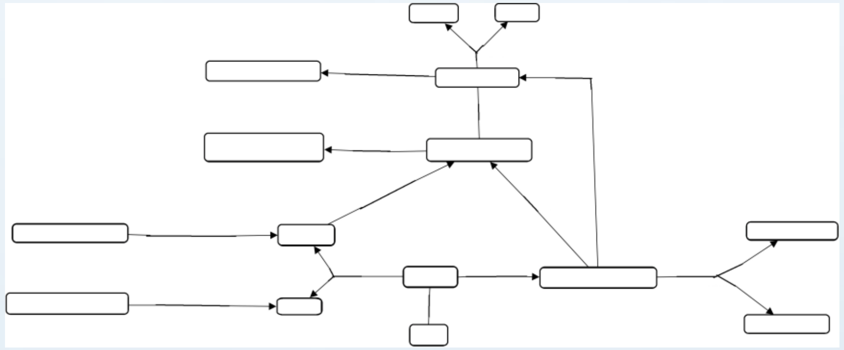
Current Objectives

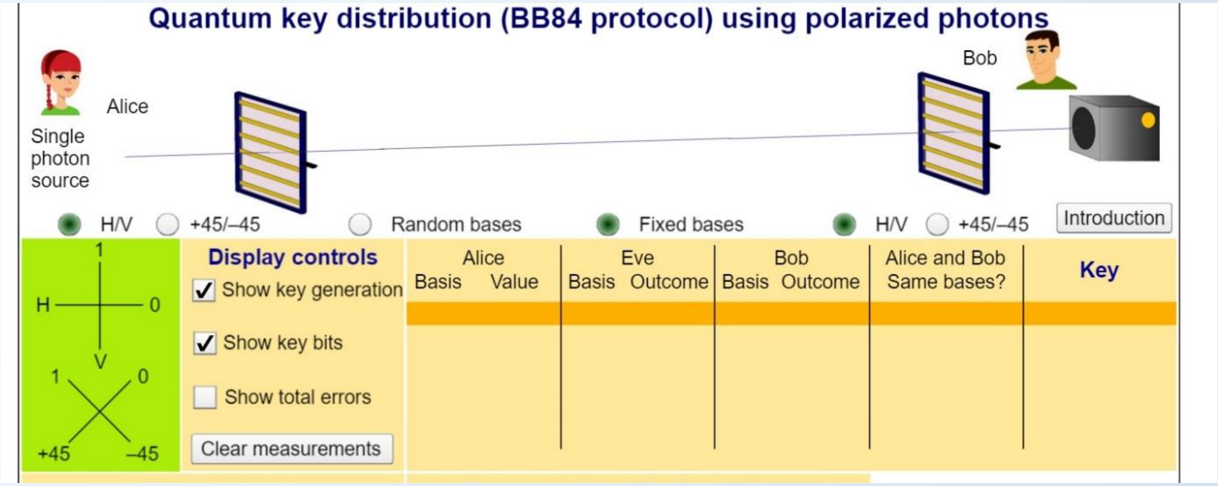
Concept Map



Objectives	
	Importance of securing messages
	Understand how to create a key
	Need Same basis
	The need for random distribution

Using concept map to highlight the main points in the objectives

Module Attempt: the challenging part



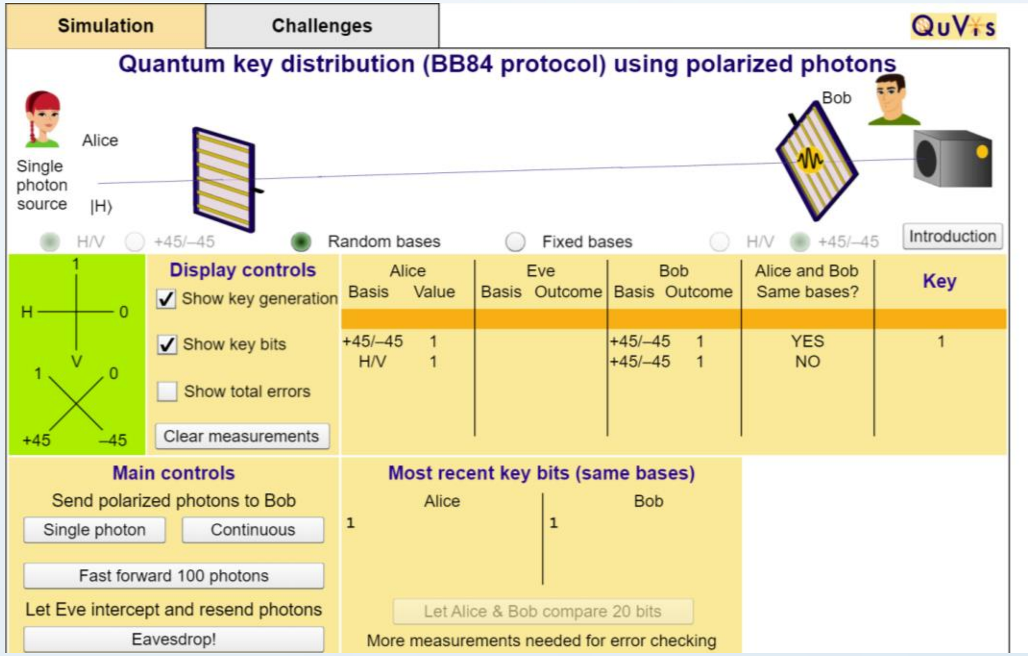
- Short introduction about cryptography historically, making the reference of the German Enigma
- Reminders of photon polarization and bases
- A general layout of the simulation
- Focus on how a key is made using Fixed Bases
    - the use of questions
    - an attempted review

Research Questions

- <u>Can we actually teach quantum information in an introductory level?</u>

- How can we incorporate previous lessons into this new module?
  - How do we word the lesson with language accessible to the students?
  - What questions can we generate?
- What other resources can we add in this module?
  - What videos and simulations are helpful to enhance student understanding?

Next Steps



Short term

- Rework and Revise current work
- Considering adding another module on random bases
- Adding “pre” modules such as photon polarization

Long term

- Testing the module on students

Acknowledgements

- Special thanks to:
  - Dr. Dean Zollman
  - Raiya Ebini
  - KSU PER
  - Kansas State Physics REU program
  - Physics group

Supported by the US National Science Foundation

References

[1] D. Zollman, (AAPT, 2016).

[2] D. A. Zollman, N. S. Rebello and K. Hogg, American Journal of Physics **70** (3), 252-259 (2002).

[3] A. Kohnle and A. Rizzoli, European Journal of Physics **38** (3), 035403 (2017).