COLLEGE PLANNING

Corona del Mar
High School

Introduction to Quantum

with hands-on polarization and Qiskit (Python) labs

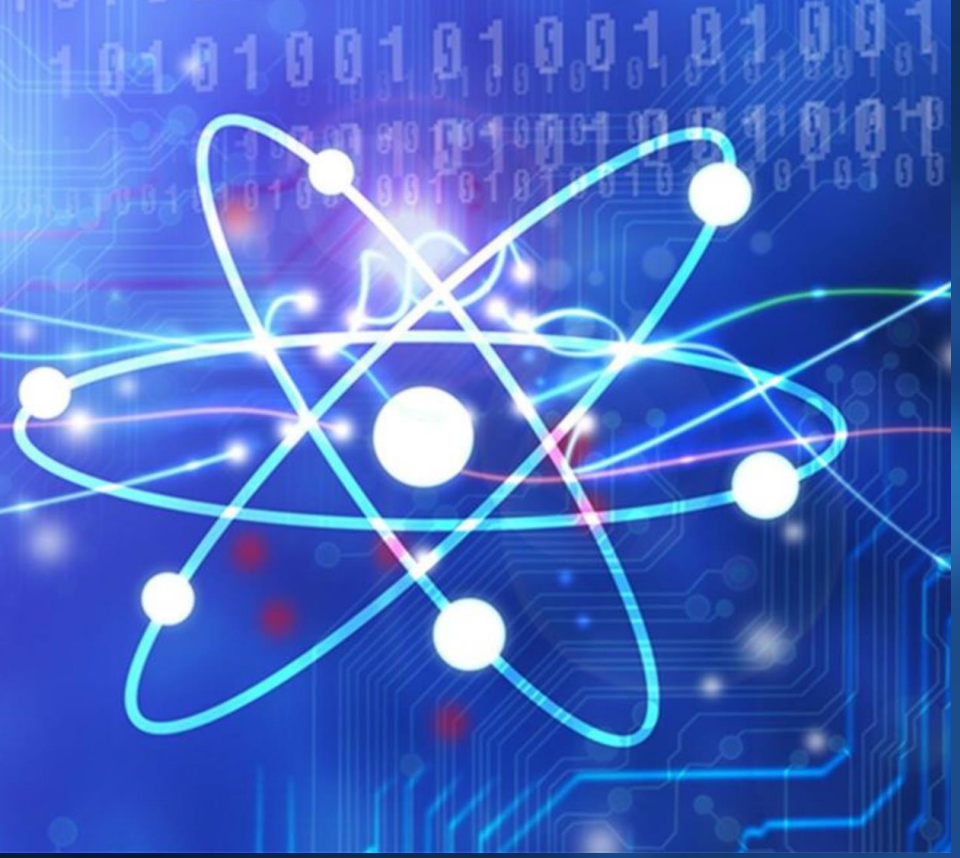
Today's Agenda:

1. What is Quantum & Why should you care?
2. Light is an Electromagnetic Wave
3. Measurements using polarization
4. What is Qiskit? (IBM's Open-Source Quantum Computing Platform)
5. Qiskit programming examples (using Python)
6. Summary – What is this really all about ?? Would you like to learn more ??

Donn Silberman

Mentor

The Optics Institute
Of Southern California



What is Quantum

& why should you care?

Things at the Atomic Scale are very different than at the human scale.

- The Quantum World underlies our modern civilization.
- And Quantum is about take humanity to the next level.
- **You can help make it happen.**

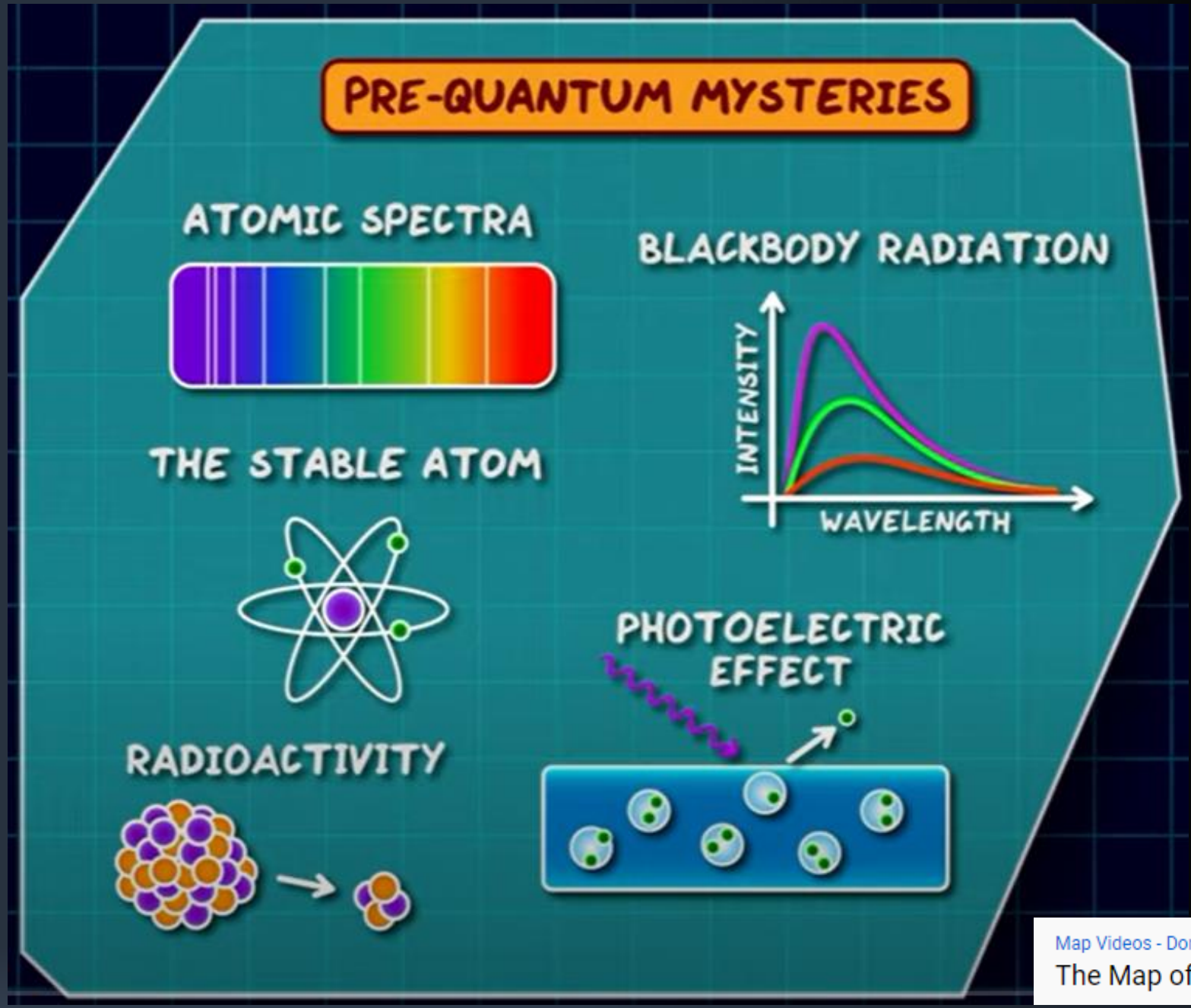
Article Landing Page | opticsage (donn601.wixsite.com)

This web page has the article below and links to all the references.

Quantum Theory with Computer & Cyber Security Applications

Donn M. Silberman, Fellow of the OSSC & SPIE

Here are the first two paragraphs of the article. Click on the link below to download the full article.

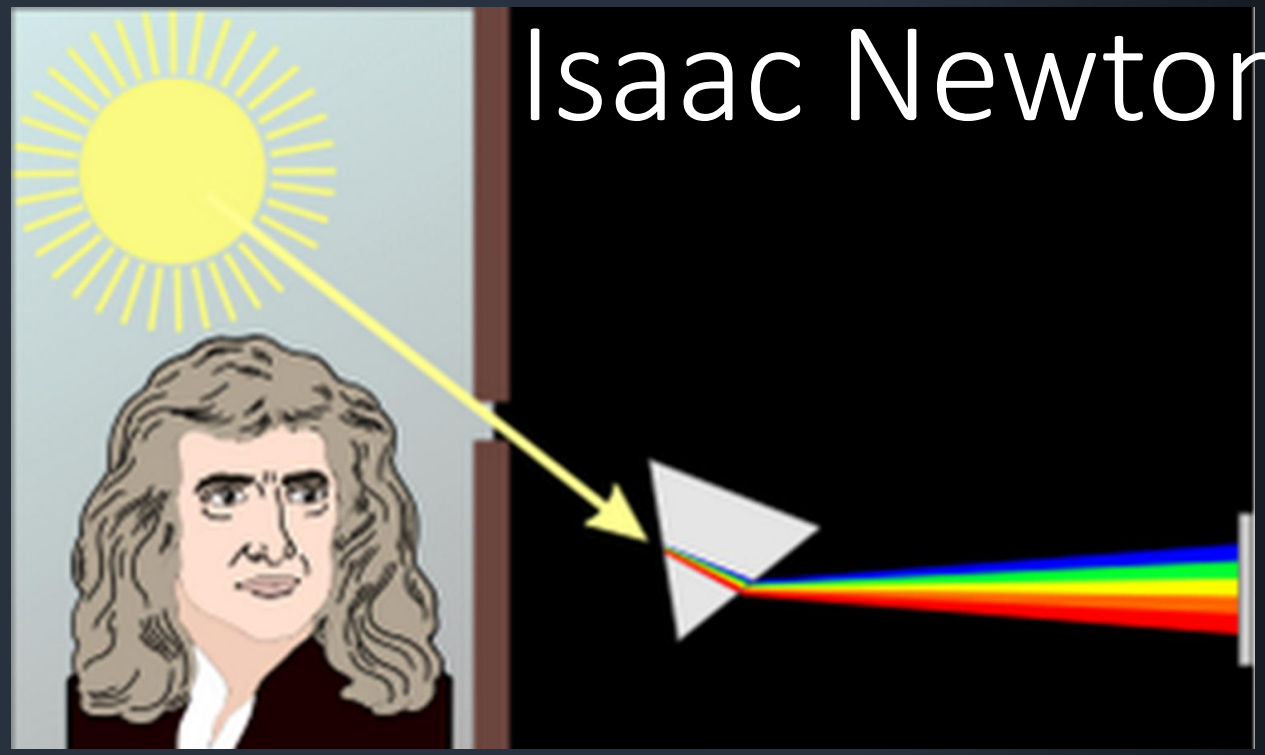


We can discuss these another time. These topics relate to the fundamental Properties of Quantum Theory.

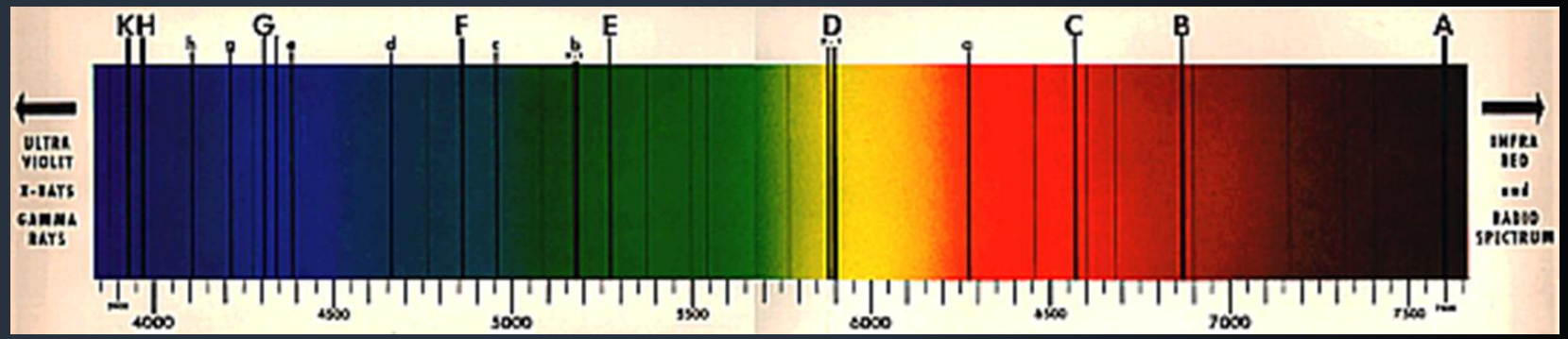
Today we will skip these and get to the heart of Quantum Computing And telecommunications.

Map Videos - Domain of Science
The Map of Quantum Physics

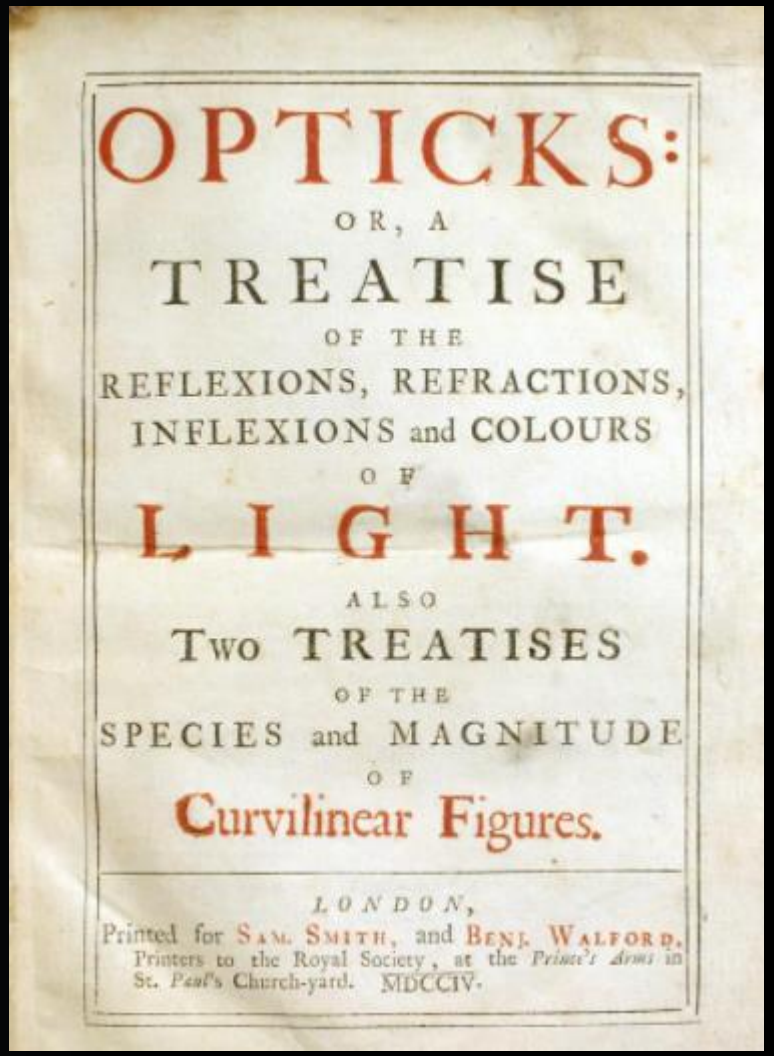
Isaac Newton & the Prism



The Solar Spectrum with Fraunhofer Lines



Discrete spectral lines correspond to the energy levels of various atoms that are burning in the Sun.



OPTICKS:
OR, A
TREATISE
OF THE
REFLEXIONS, REFRACTIONS,
INFLEXIONS and COLOURS
OF
LIGHT.
ALSO
Two TREATISES
OF THE
SPECIES and MAGNITUDE
OF
Curvilinear Figures.

LONDON,
Printed for SAM. SMITH, and BENJ. WALFORD,
Printers to the Royal Society, at the *Prince's Arms* in
St. *Paul's* Church-yard. MDCCIV.

The first, 1704, edition of *Opticks: or, a treatise of the reflexions, refractions, inflexions and colours of light.*

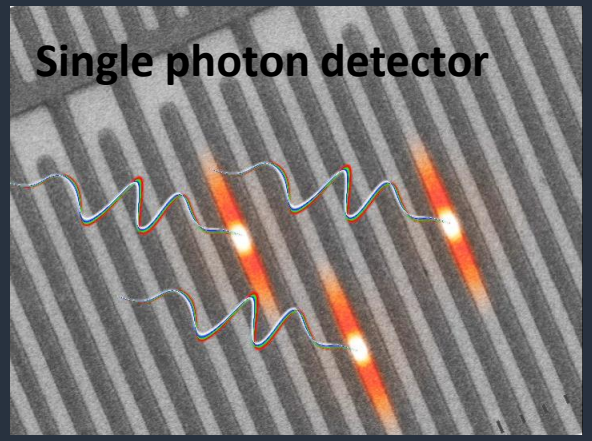
 From Wikipedia: QUANTUM

In physics, a quantum is the minimum amount of any physical entity involved in an interaction. The fundamental notion that a physical property can be "quantized" is referred to as "the hypothesis of quantization".

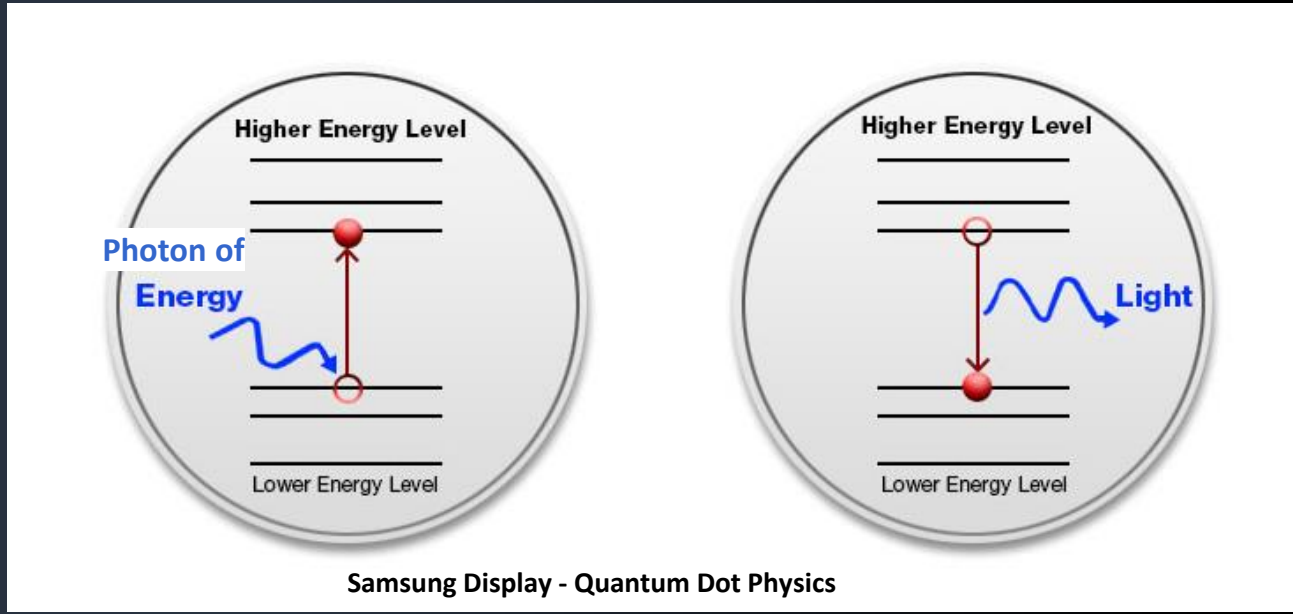
*[1] This means that the magnitude of the physical property can take on only **discrete values** consisting of integer multiples of one quantum.*

Can't have 1 ½ photons
Or ¾ of an electron

Graphic representation of an **electron (red O)** moving from one energy level to another, emitting or absorbing a **photon (Energy)** of light.

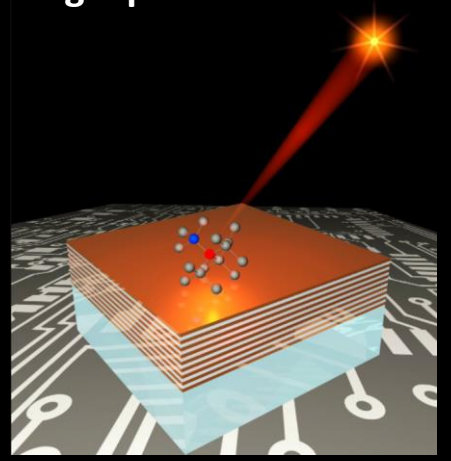


1-singlephoton.jpg (716×536) (b-cdn.net))



Samsung Display - Quantum Dot Physics

Single photon emitter



singlephoton.jpg (1000×1413) (b-cdn.net)

$$E = h\nu$$

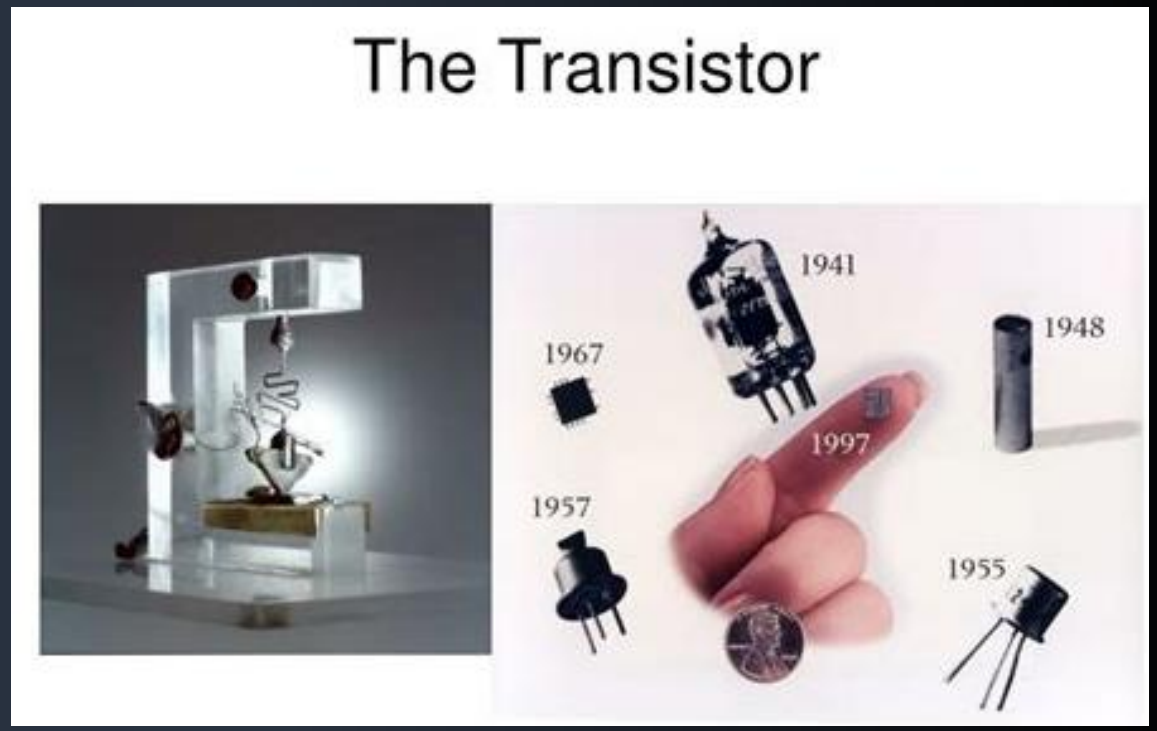
frequency of radiation, sometimes written as f giving expression E = hf.

Quantum energy of a photon.

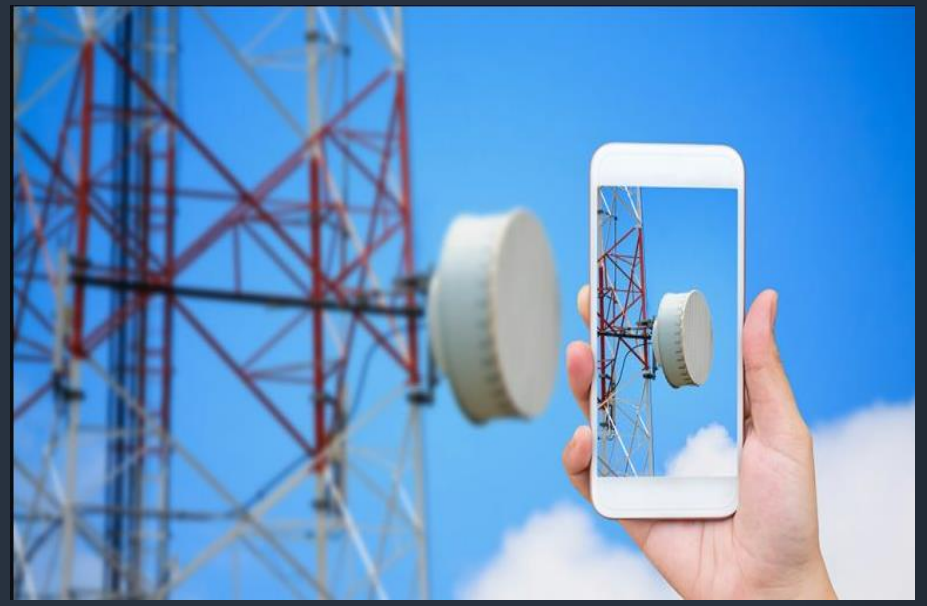
h = Planck's constant = 6.626×10^{-34} Joule·sec = 4.136×10^{-15} eV· s

$$E=mc^2$$

History of the transistor – Wikipedia "After WWII, Shockley decided to attempt the building of a triode-like semiconductor device. He secured funding and lab space, and went to work on the problem with Bardeen and Brattain. John Bardeen eventually developed a new branch of quantum mechanics known as surface physics to account for the "odd" behavior they saw, and Bardeen and Walter Brattain eventually succeeded in building a working device."



How does your cell phone information get from your phone to another person's phone??



https://www.uyt.co/wp-content/uploads/2019/03/Fiber-Internet-770x430.jpg

https://www.worldwidetopic.com/wp-content/uploads/2019/11/Fiber-Optics-Design.jpg

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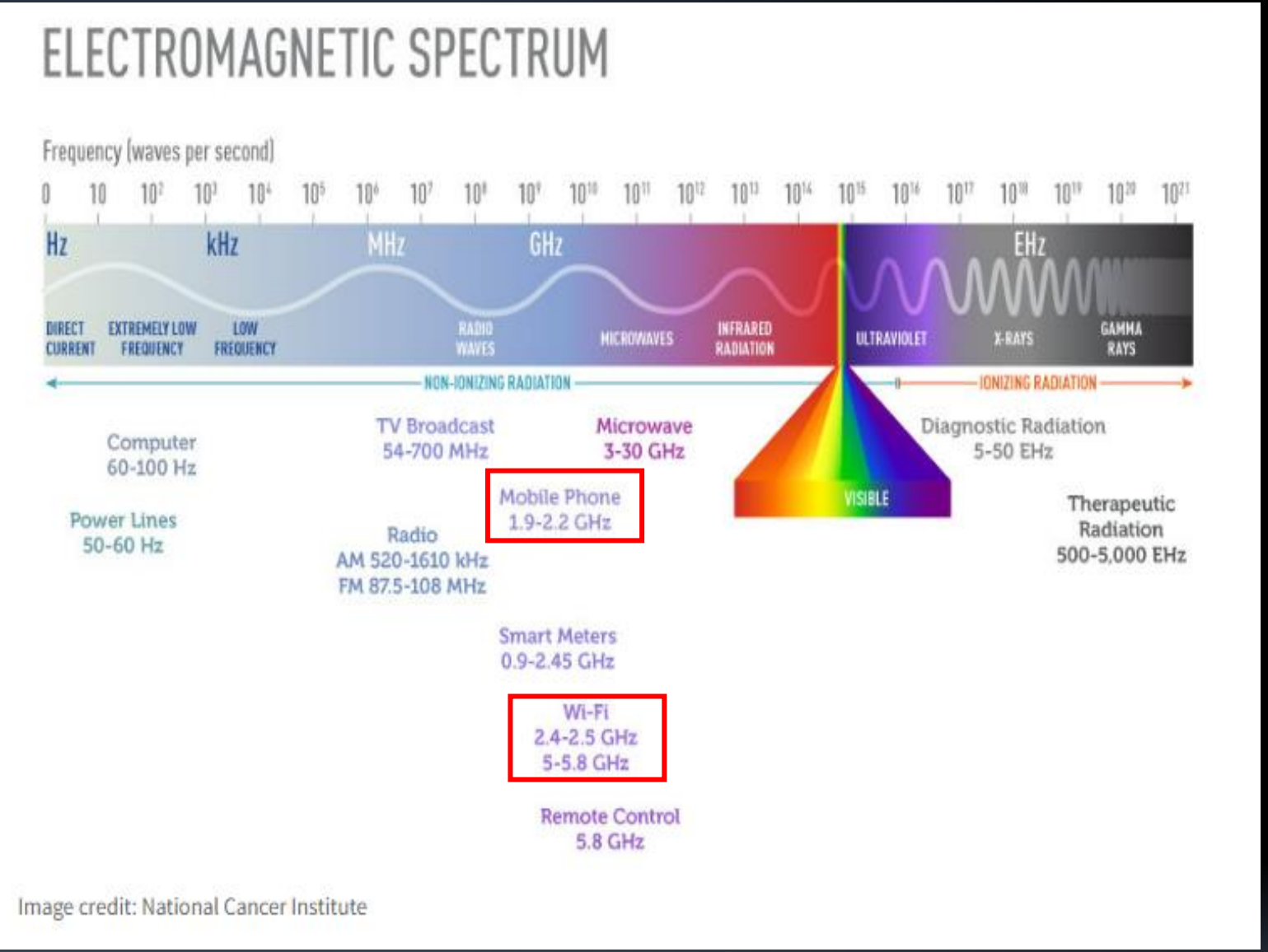
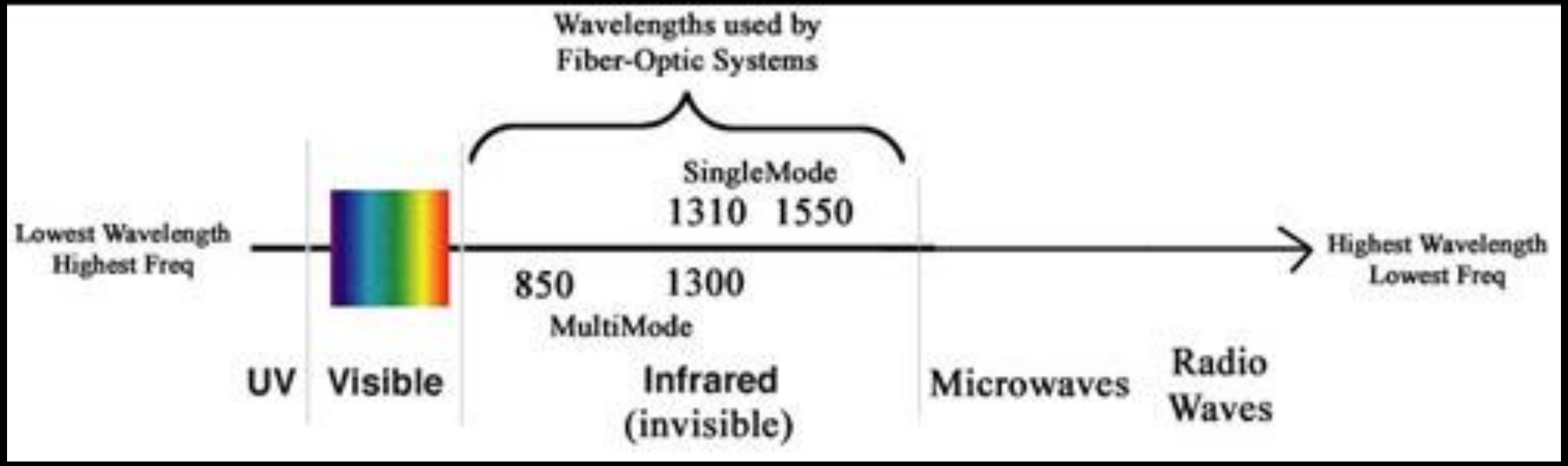


Fiber Optics use infrared laser light pulses to transmit information worldwide.



wavelength.jpg (500×148) (chinacablesbuy.com)

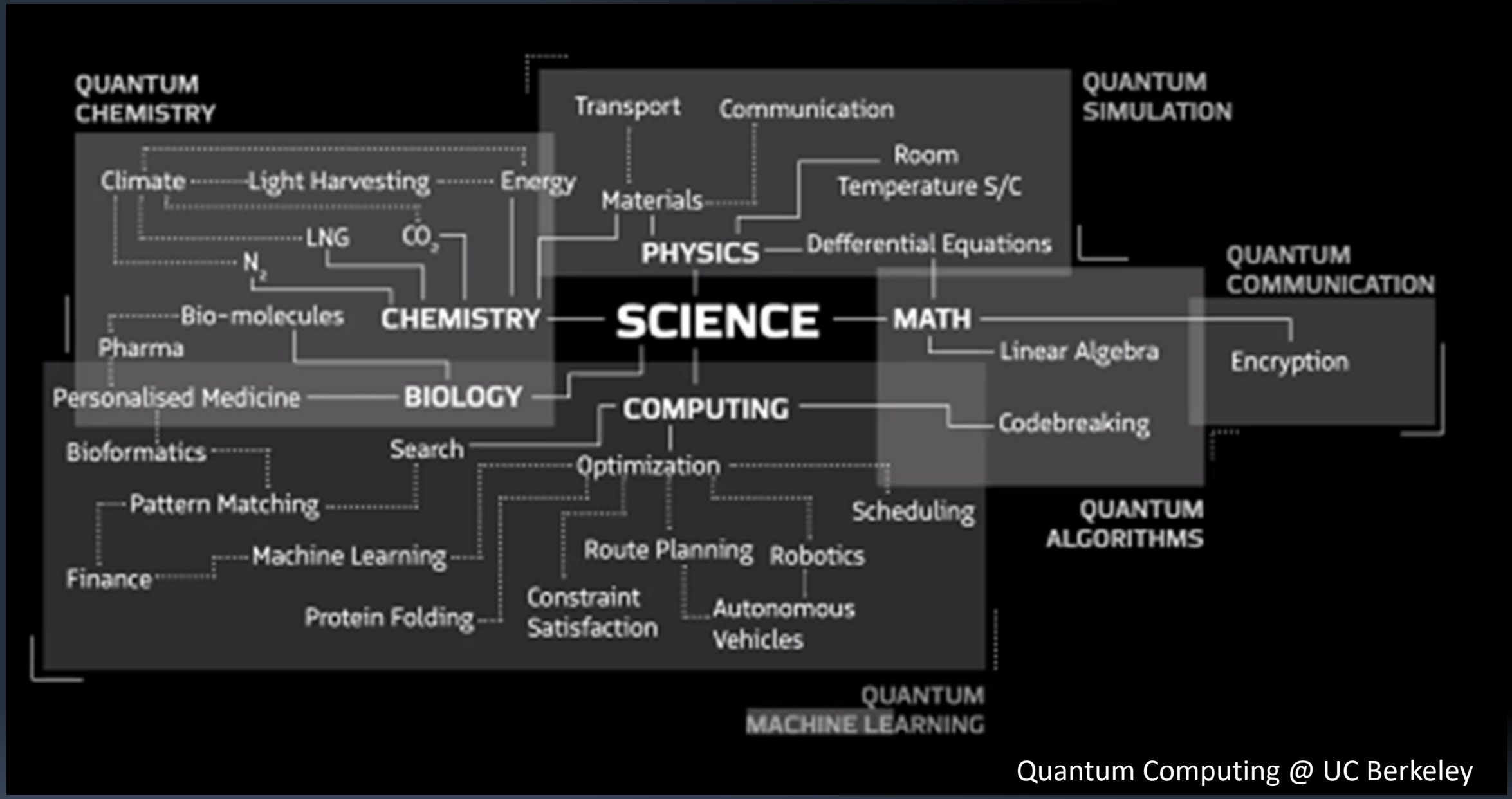
And also, all the information that is on the internet…… how does that get around the world??

https://thediplom

fiber-optic-cable-meh-this-ship-can-lay-diameter-steel-pipe-from-a-reel-in-up-to-m-of-water--10144.jpg (610×459) (photorator.com)

Why should you care??

Education and career opportunities.



PCC LASERTECH

Are you seeking a career with cutting-edge technology that pays well? With the in-demand skills of laser technology, you can work in aerospace, medicine, robotics, manufacturing, entertainment, forensics, or defense!

The Optics and Photonics College Network (OPCN) is Association of Postsecondary Photonics Technician Educators.

LASER-TEC

A National Science Foundation Center

LASER-TEC – Center for Laser & Fiber Optics Education

44

Partner Colleges

Pasadena City College

http://pasadena.edu/academics/degrees-and-certificates/certificates-of-achievement/laser-technology.php

NASA Jet Propulsion Laboratory
California Institute of Technology

Welcome to EdQuantum Project

HYBRID CURRICULUM IN ADVANCED OPTICS, SPECTROSCOPY, AND QUANTUM TECHNOLOGIES FOR TECHNICIANS

Be Laser-Focused

LaserTech is the use of lasers, cameras, lenses, mirrors, sensors, displays, fiber optics, and other technical devices that interact with light.

- ✓Earn skills to be immediately hired as a technician
- ✓Be prepared for success in a university engineering program
- ✓Advance your careeer by mastering more technically demanding skills

naturalsciences@pasadena.edu

Career Assistance
UC Irvine DCE On-Demand
Wm. Bickel - Collected sayings
New HOME Draft

Experience Life in the (cs Age

OpticsAge is a focal point for Donn Silbern ıtures

Weirdness and wonder: Quantum entanglement work ics (spie.org)

Career Assistance

This web page has links to various career assistant and job search websites for the physics, optics, photonics and quantum fields.

More will be added as time goes on. For high school students in Orange County CA, see Vital Link of Orange County

Finding colleges & universities in the Quantum Optics Age

Optics and Photonics Education Directory | SPIE.org

Education & Careers - IEEE Photonics Society

Looking for Jobs Worldwide

Careers | Optica

Optics and Photonics Jobs

SPIE Career Development | Membership (spie.org)

Physics Today Jobs

Quantum Computing Jobs (quantumcomputingreport.com)

Homepage - Quantum Jobs.net

QED-C | Quantum Jobs | QED-C (quantumconsortium.org)

Quantum Computers & Cybersecurity

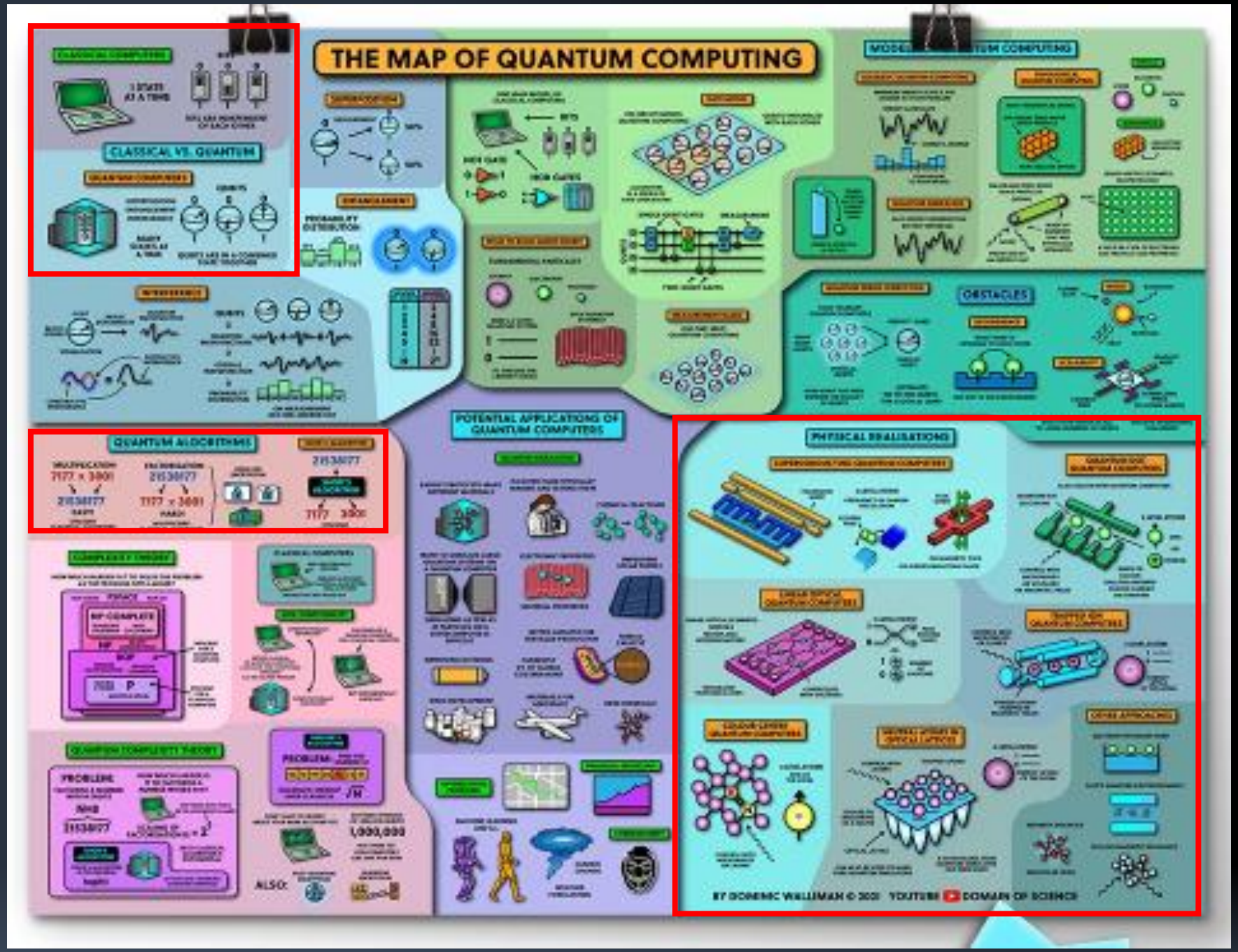
Including cryptocurrencies and blockchain technologies

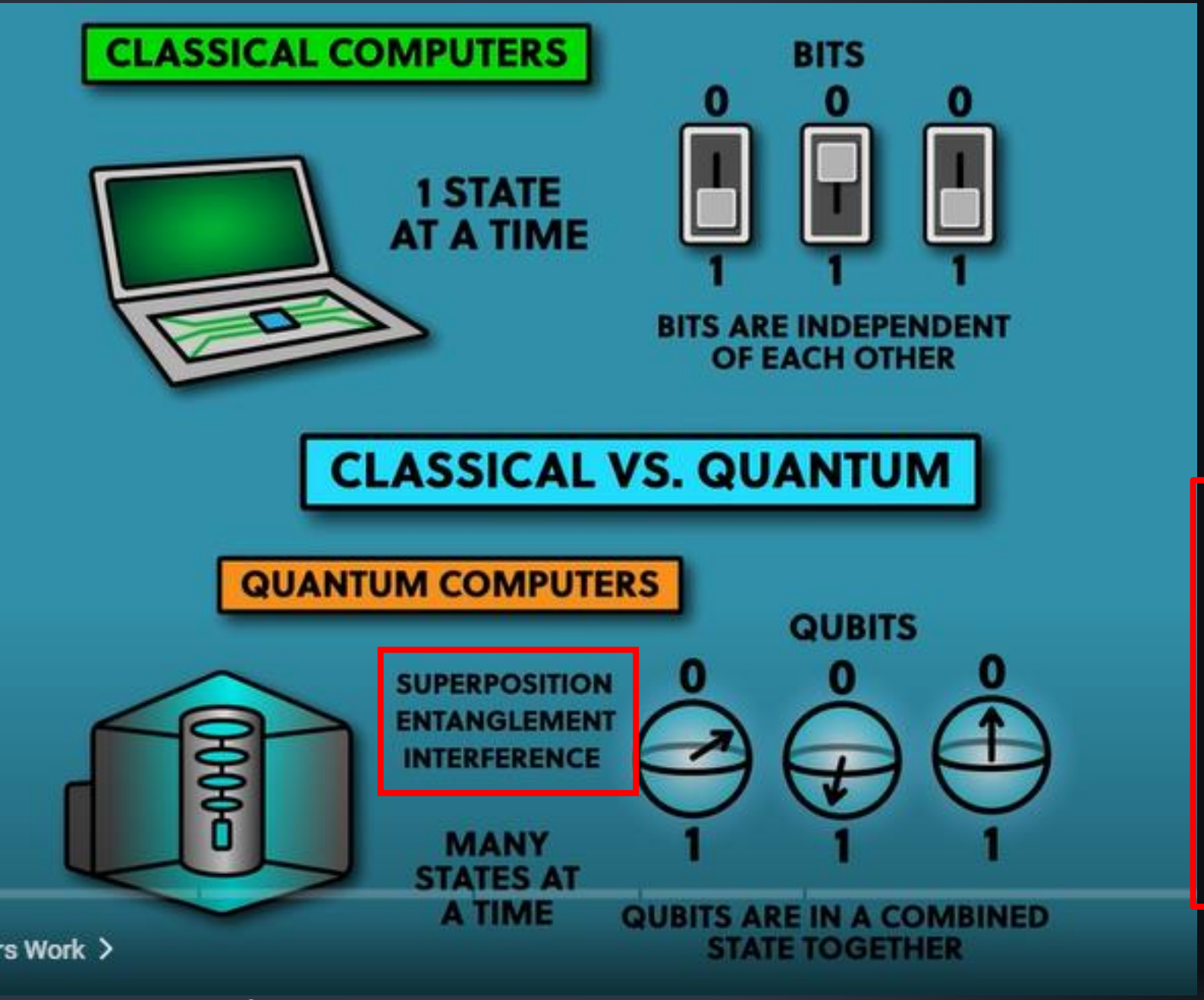
Risks & Opportunities

The global race to develop practical quantum computers that can 'hack' all current encryption technologies
Against the implementation of quantum resistant encryption technologies.

Intellectual property (IP) -

- **in the public domain via patents and published papers**
- **Trade Secrets – held 'close to the vest'**

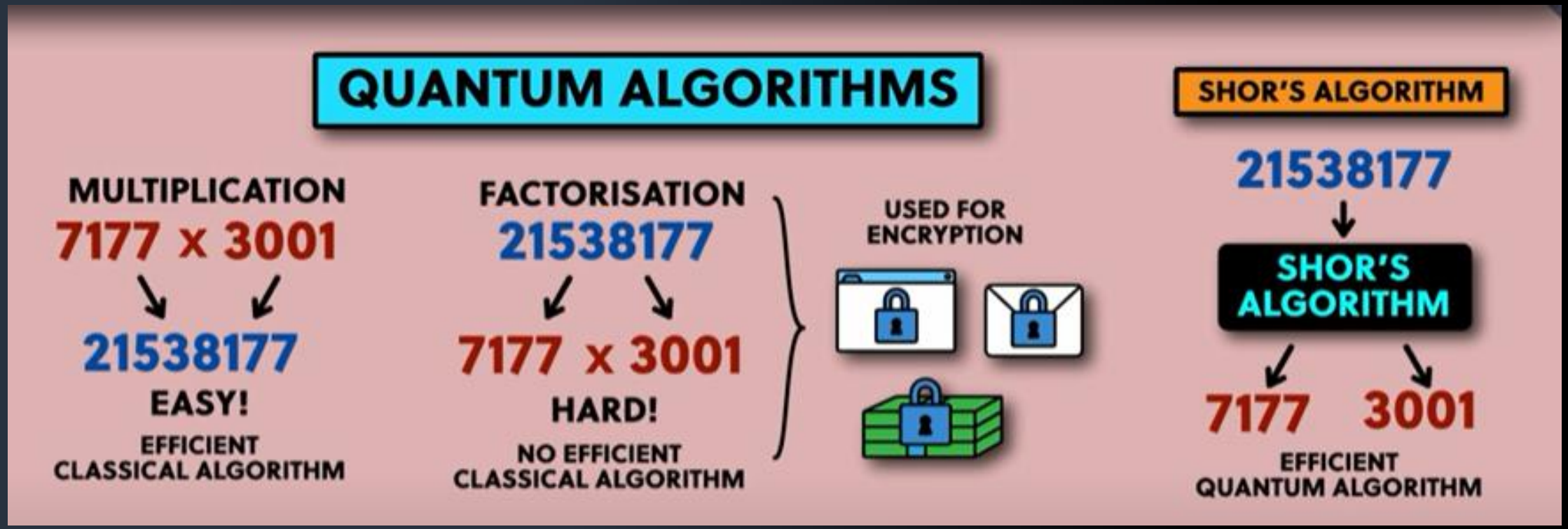

THE MAP OF QUANTUM COMPUTING
CLASSICAL VS. QUANTUM
OBSTACLES
QUANTUM ALGORITHMS
POTENTIAL APPLICATIONS OF QUANTUM COMPUTERS
PHYSICAL REALISATIONS
BY DOMINIC WALLIMAN © 2020 YOUTUBE DOMAIN OF SCIENCE



Superposition
Entanglement
Interference

Einstein's
"Spooky Action at a Distance"

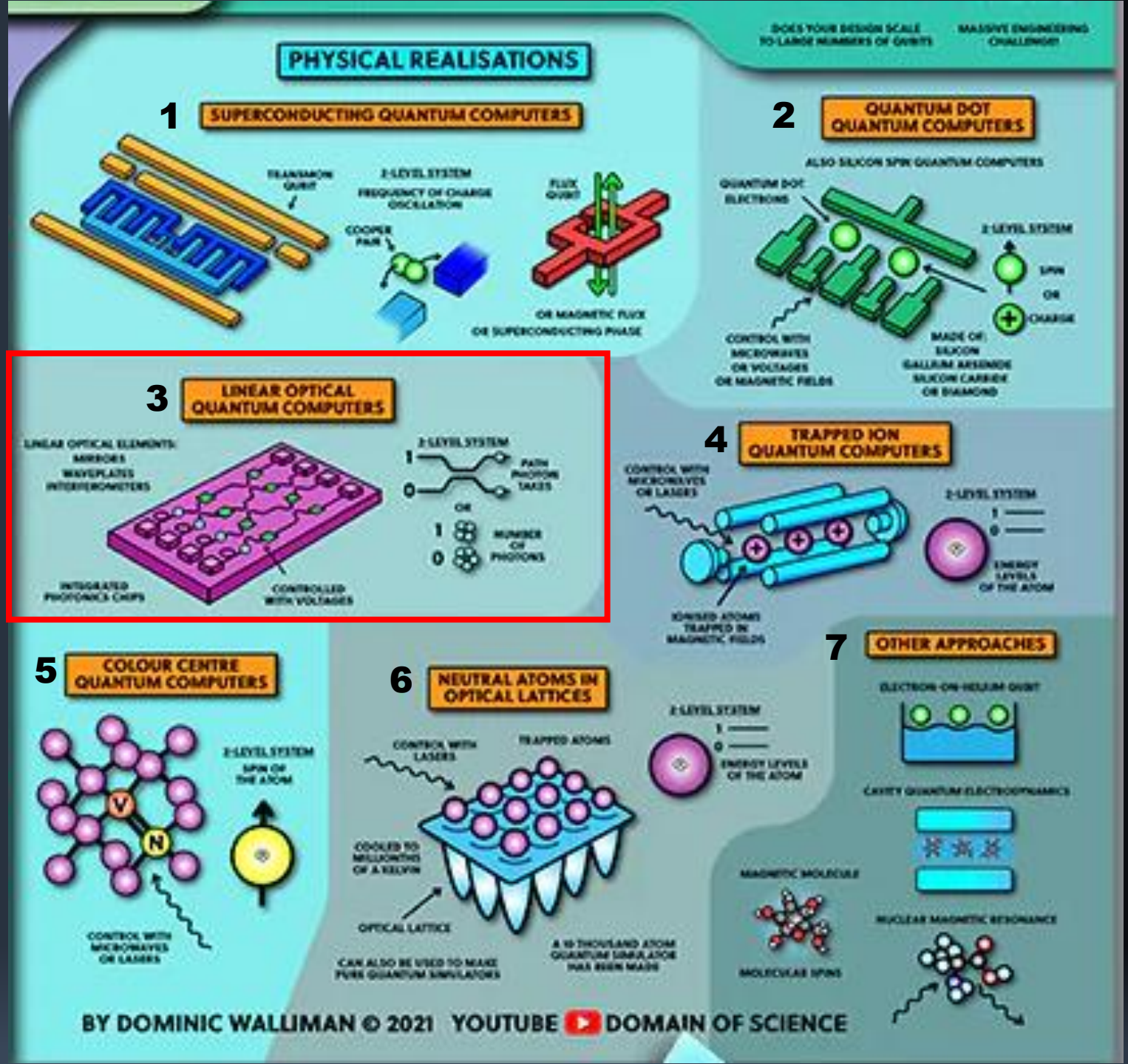
The Map of Quantum Computing | Quantum Computers Explained
DoS - Domain of Science – YouTube



Classical Computing

Quantum Computing

The Map of Quantum Computing | Quantum Computers Explained
DoS - Domain of Science – YouTube

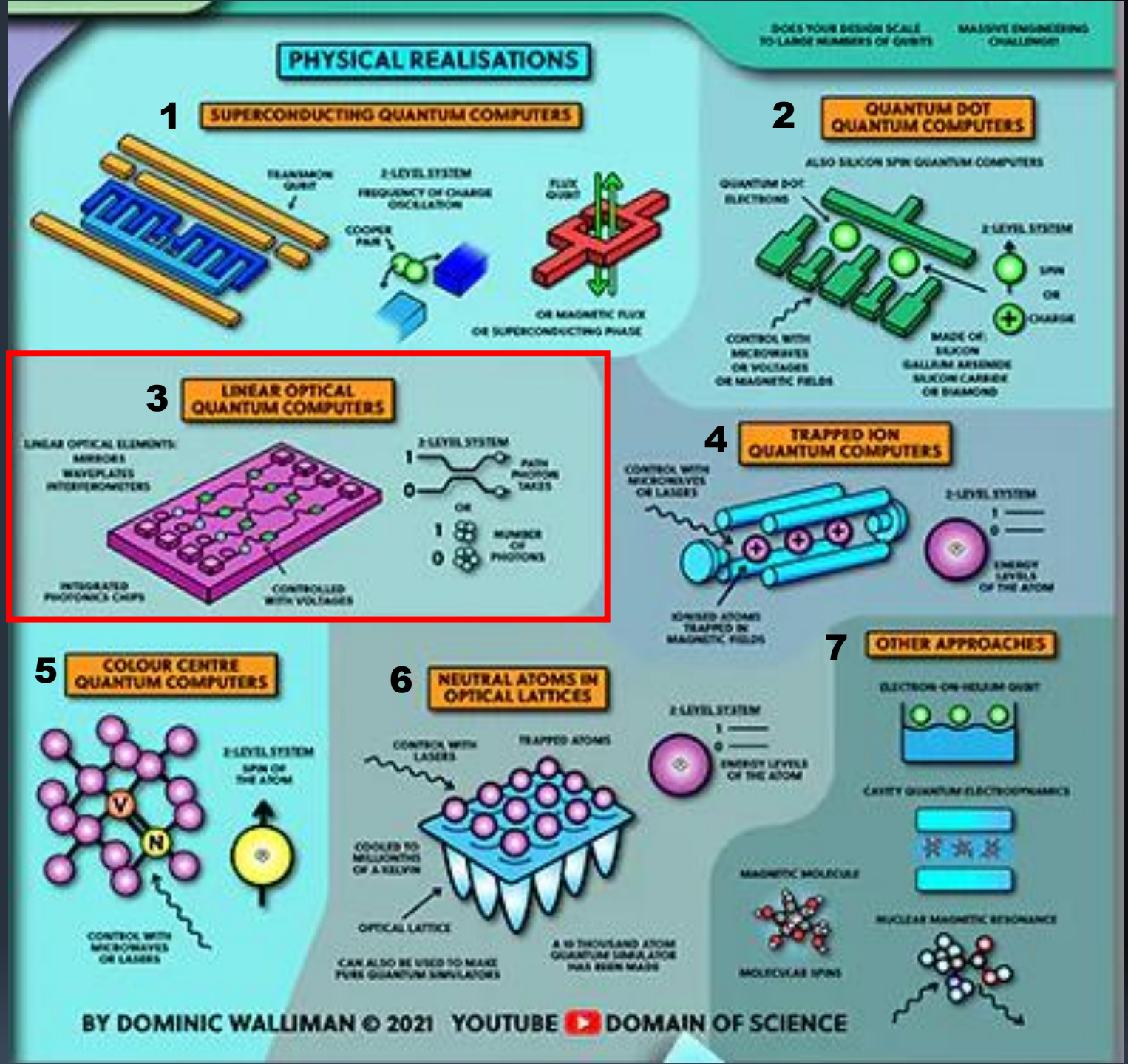


Fundamental Quantum Computer Technologies

1. Super Conducting
2. Quantum Dots
3. Linear Optical (Photonic)
4. Trapped Ions
5. Color Centers
6. Neutral Atoms in Optical Lattices
7. Other Approaches
   - ✓ Electron-on-Helium Qubit
   - ✓ Magnetic Molecule - Spin
   - ✓ Cavity Quantum Electrodynamics
   - ✓ Nuclear Magnetic Resonance

Kahoot #1

CLICK HERE FOR LINK.



Fundamental Quantum Computer Technologies

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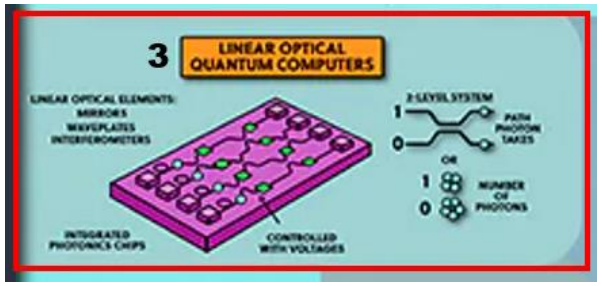
6. Neutral Atoms in Optical Lattices
7. Other Approaches
   - ✓ Electron-on-Helium Qubit
   - ✓ Magnetic Molecule - Spin
   - ✓ Cavity Quantum Electrodynamics
   - ✓ Nuclear Magnetic Resonance

Fiber Optics already in place can be used
To get information in & out of quantum computers

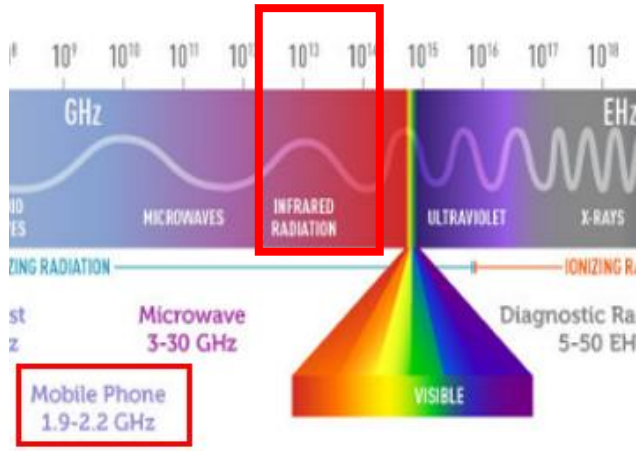
https://www.worldwidetopic.com/wp-content/uploads/2019/11/Fiber-Optics-Design.jpg

3. Linear Optical (Photonic)



Light is an Electromagnetic Wave

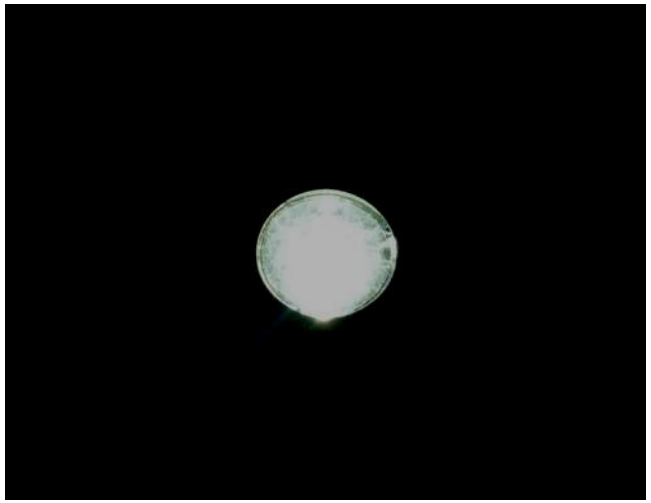
- **Amplitude** → Size of each vibration
- **Direction** → Path of each vibration
- **Length** → Separation between vibrations



Scientists study the properties of things.
Properties of waves include:
Amplitude, Direction, Length

Light is an Electromagnetic Wave

- **Amplitude** → Size of each vibration → ***Power***
- **Direction** → Path of each vibration
- **Length** → Separation between vibrations



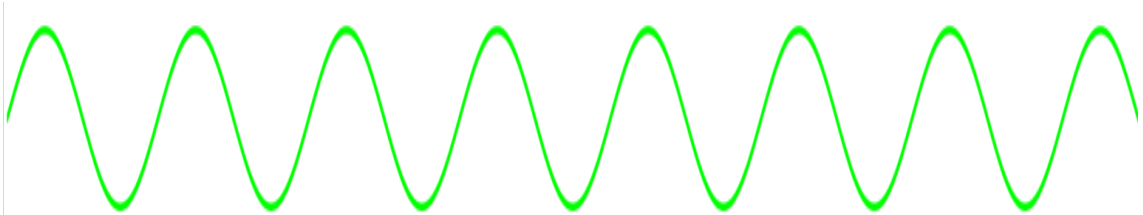
dim light
small vibrations

Bright Light
LARGE VIBRATIONS

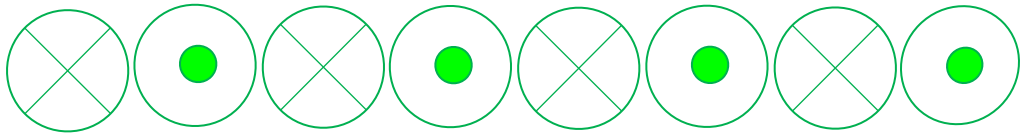
Images courtesy Brian Monacelli

Light is an Electromagnetic Wave

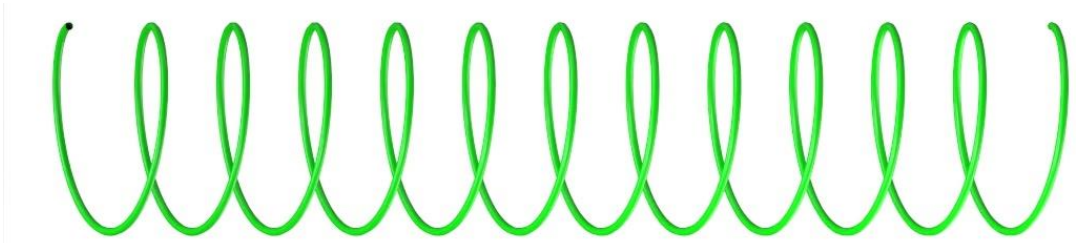
- **Amplitude** → Size of each vibration → ***Power***
- **Direction** → Path of each vibration → ***Polarization***
- **Length** → Separation between vibrations



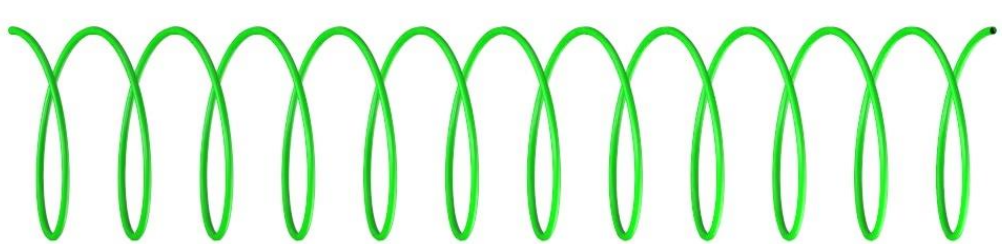
Vertical Linear Polarization



Horizontal Linear Polarization



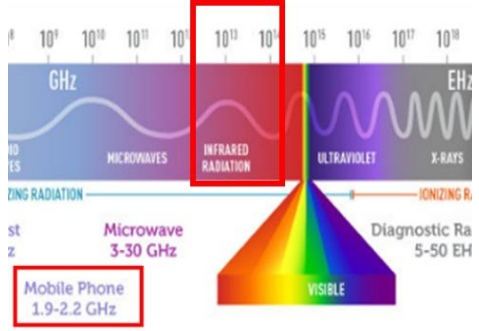
Left Circular Polarization



Right Circular Polarization

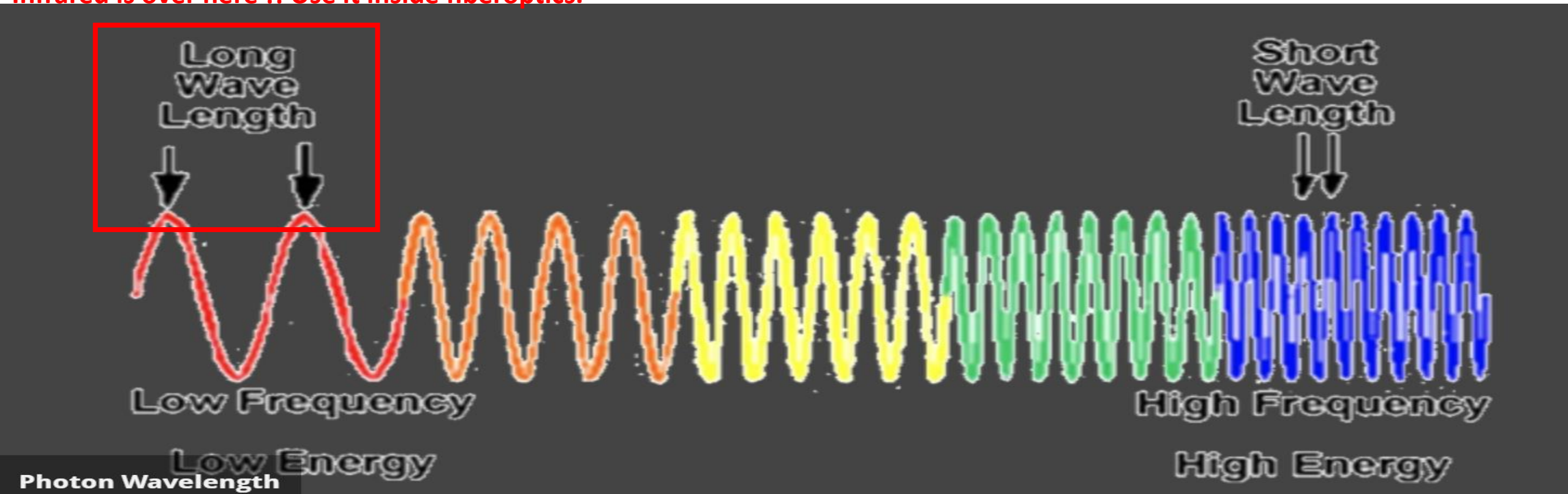
Figure courtesy Brian Monacelli

Light is an Electromagnetic Wave



- Amplitude → Size of each vibration → *Power*
- Direction → Path of each vibration → *Polarization*
- **Length** → Separation between vibrations → *Color*

Infrared is over here !! Use it inside fiberoptics.



Linear Polarizers

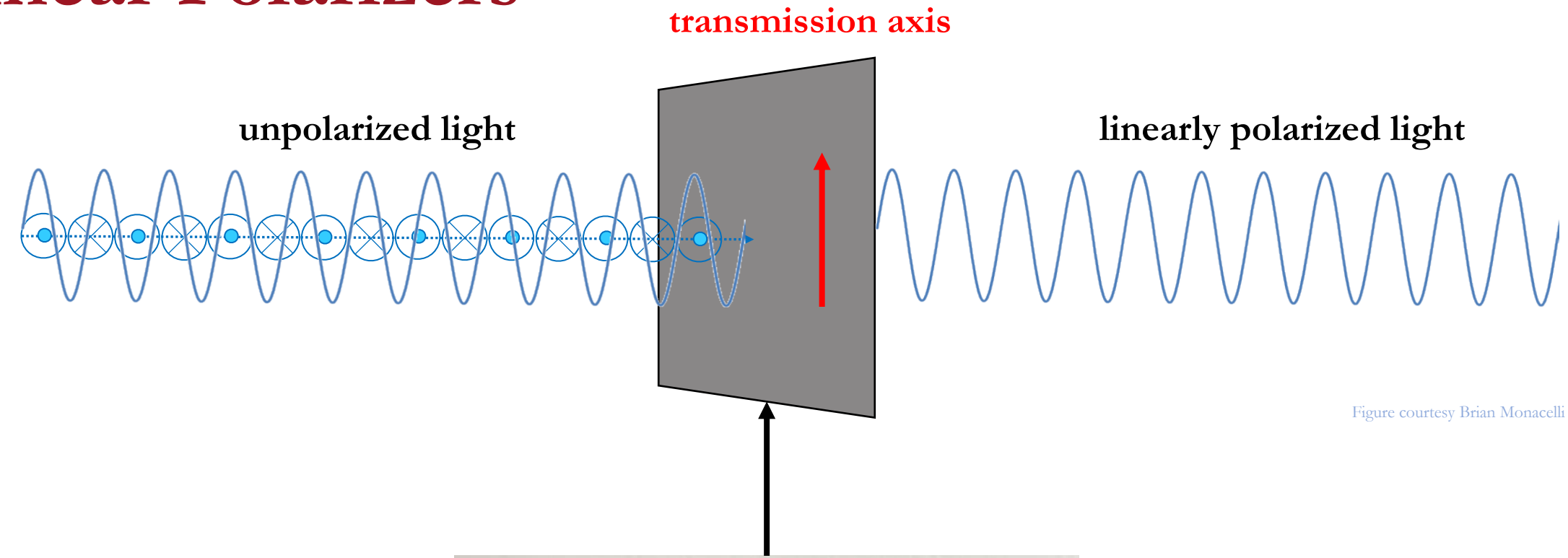
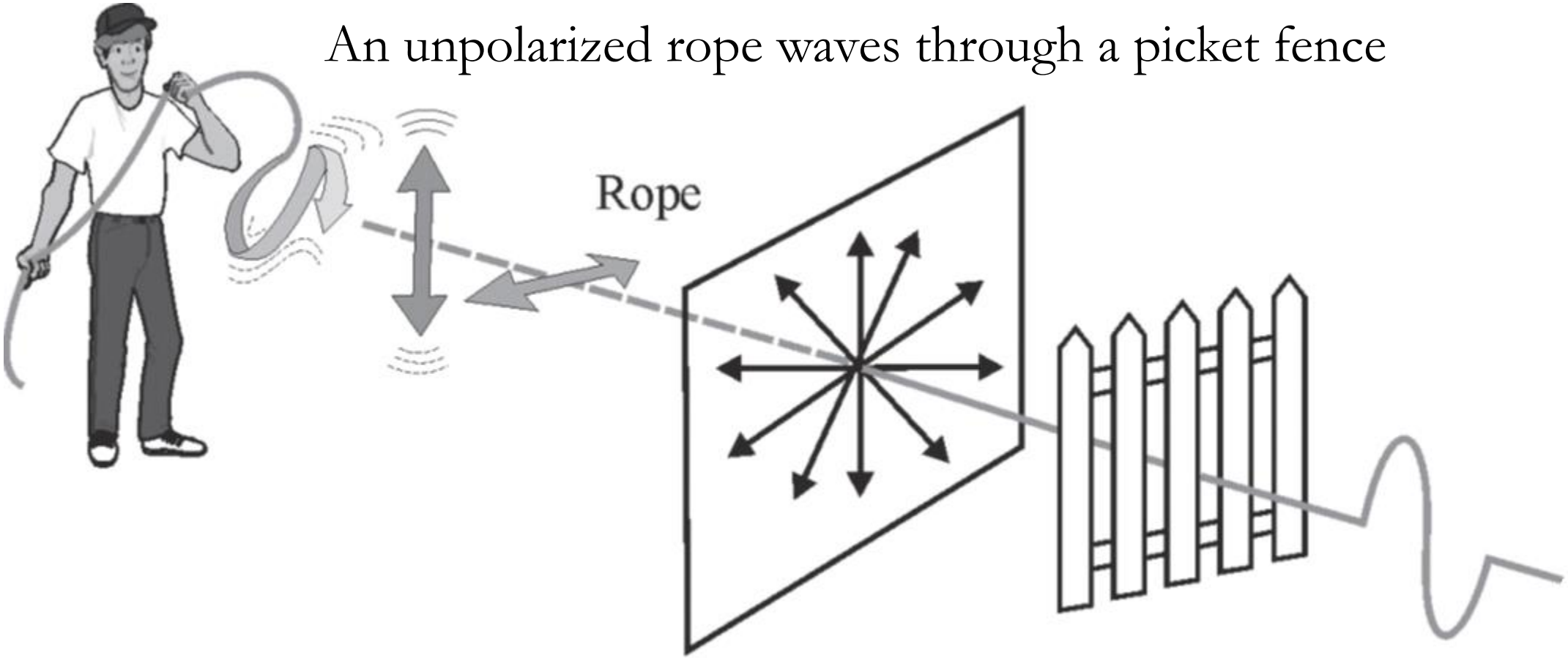


Figure courtesy Brian Monacelli

Image courtesy Erin Monacelli

Polarization Analogy

An unpolarized rope waves through a picket fence

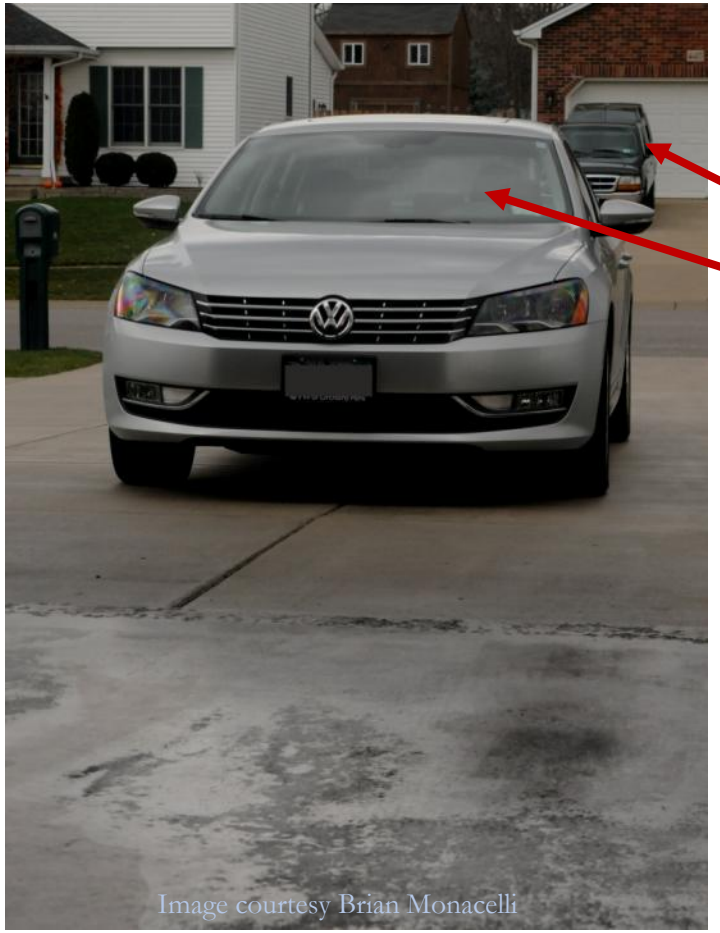


On the other side of the picket fence, the rope's motion is polarized along the slats

This figure by LASER-TEC is licensed CC BY-NC-SA.

Polarized Sunglasses Block Glare

without polarized sunglasses

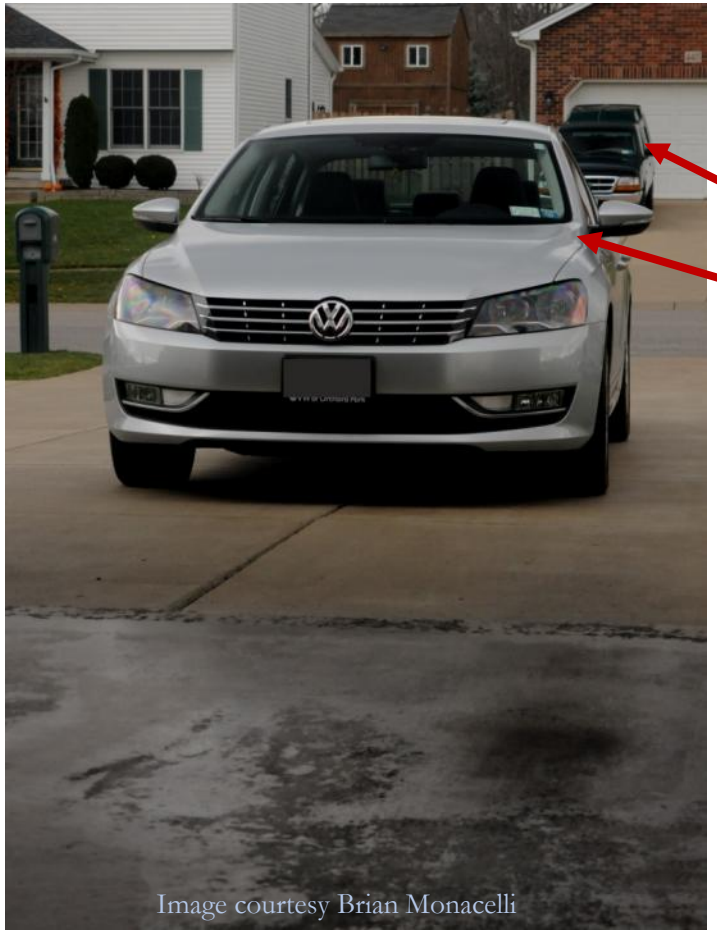


Watch the car windshields and hood

Polarizers block horizontally s-polarized light, and transmit vertically p-polarized light

Polarized Sunglasses Block Glare

with polarized sunglasses



Watch the car windshields and hood

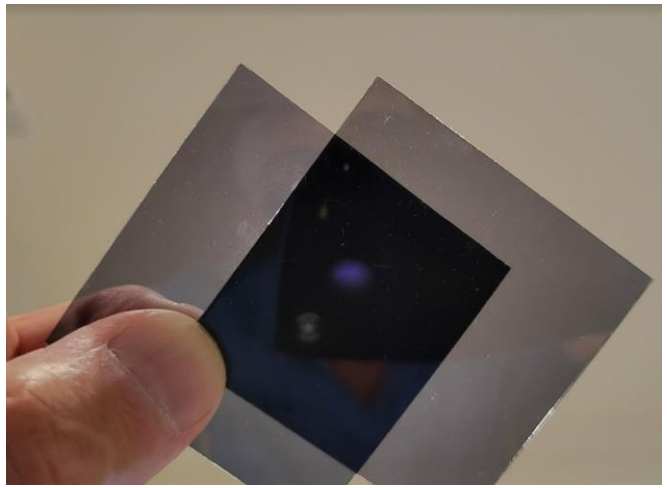
Light reflecting off the ground is horizontally s-polarized

Polarization Filters – Hands-on Experiment

Ceiling light – no **P** filters

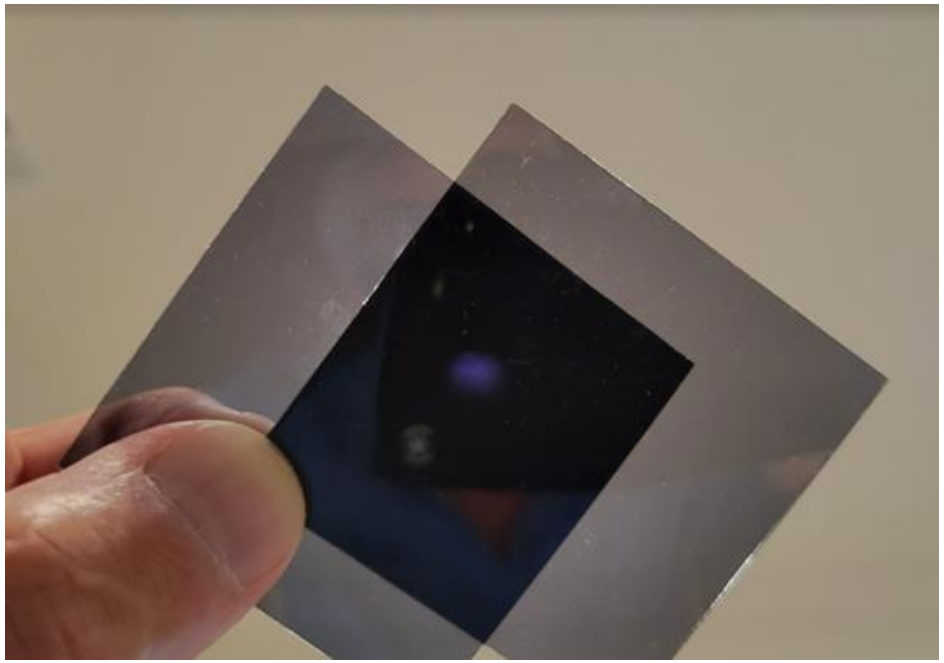
Ceiling light – one **P(h)** filter

Ceiling light – one **P(v)** filter

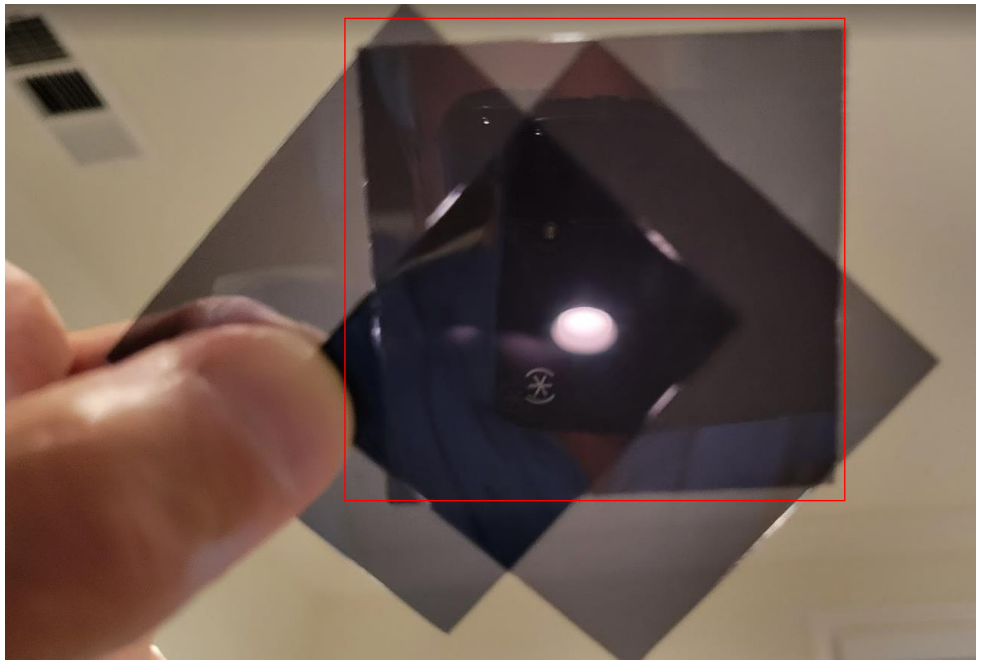


Ceiling light – both **P(h & v)** filters

Polarization Filters



Ceiling light – both **P(h & v)** filters



Ceiling light – both **P(h & v)** filters
Plus a third **P** filter at 45 deg !!!
(sandwiched in-between

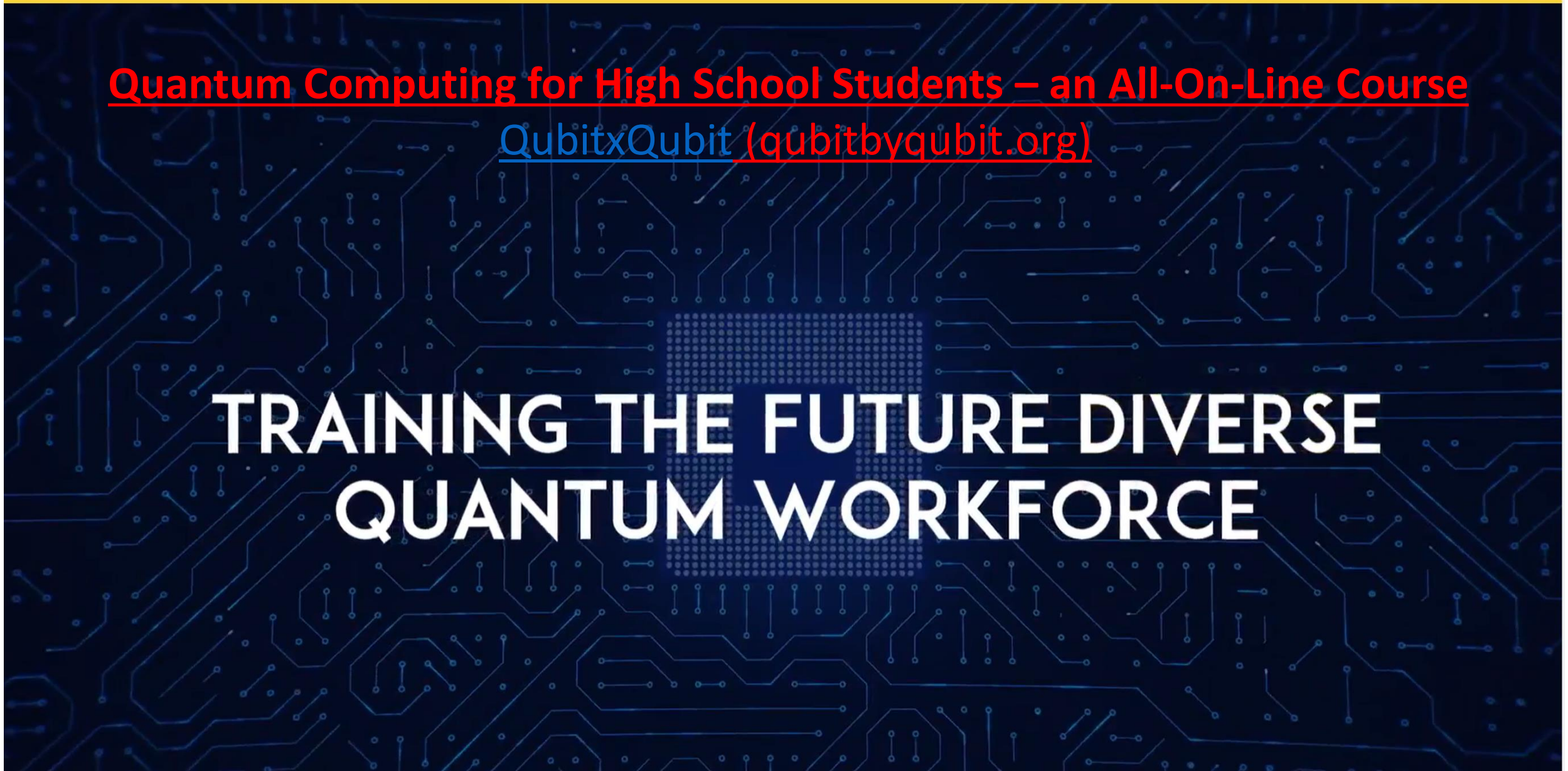
QUBIT X QUBIT

About Us Programs Impact Donate

The 2022-23 course has launched with 3,000+ students! Learn more below.

Quantum Computing for High School Students – an All-On-Line Course

QubitxQubit (qubitbyqubit.org)



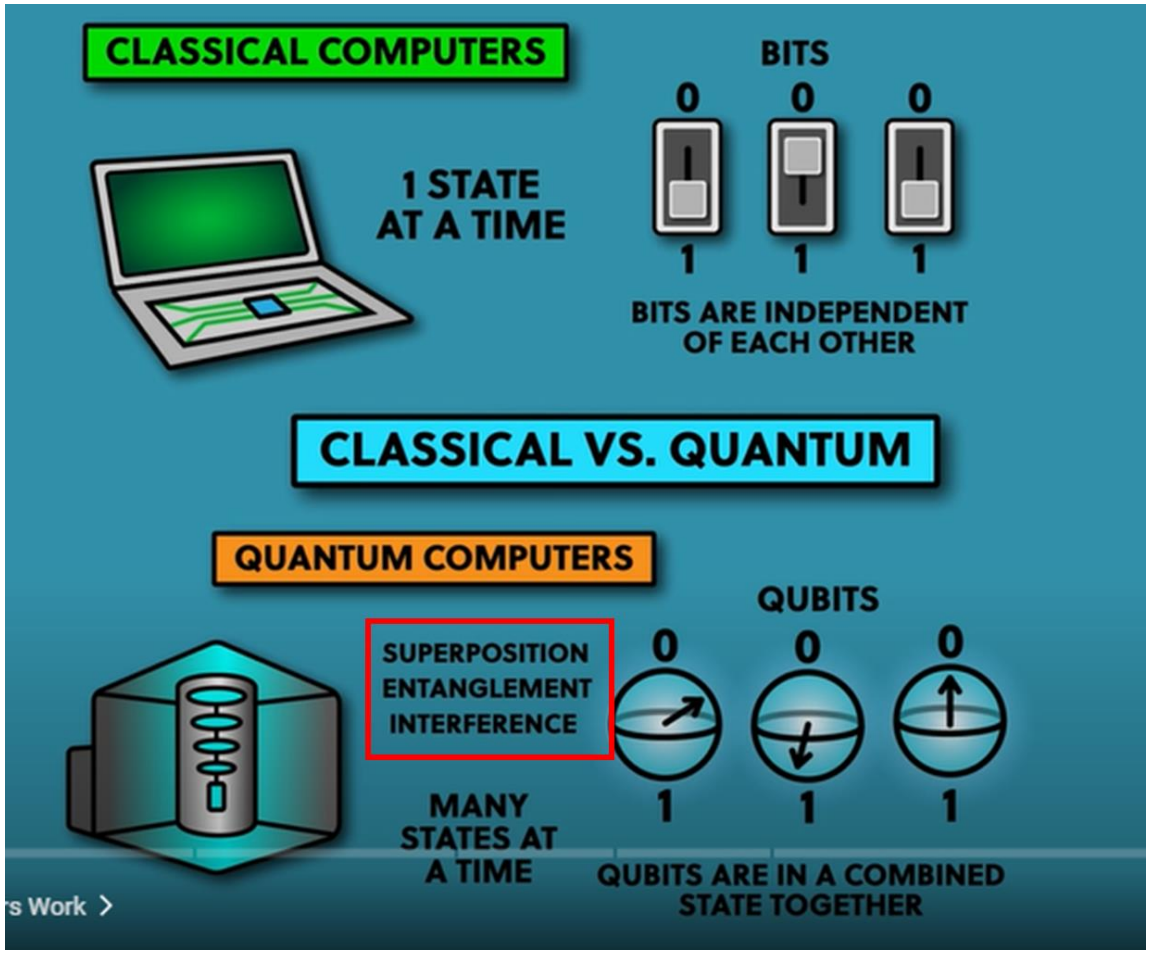
Interested in bringing quantum to your school?

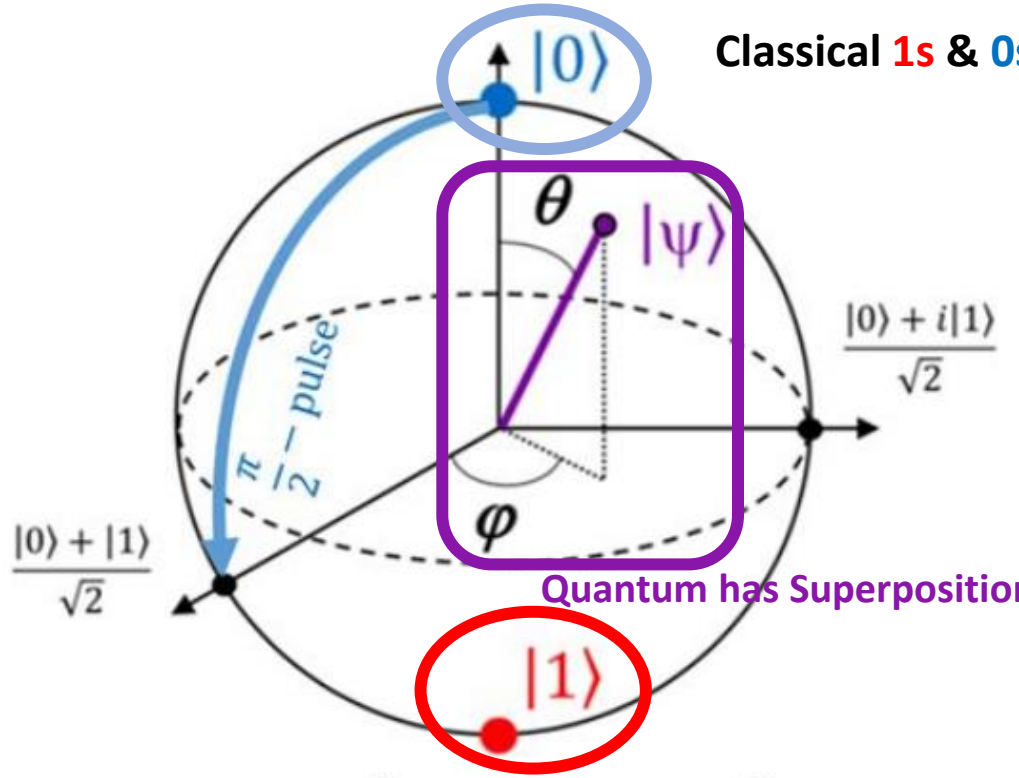
We offer free workshops and courses for K-12 schools and universities.

Learn More

Quantum vs. Classical Computing

Using polarized photons of light as the Qubits





Classical 1s & 0s

Quantum has Superposition States

$$|\psi\rangle = \cos\frac{\theta}{2}|0\rangle + e^{i\varphi}\sin\frac{\theta}{2}|1\rangle$$

The-Bloch-sphere-provides-a-useful-means-of-visualizing-the-state-of-a-single-qubit-and.ppm (850×770) (researchgate.net)

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How to program a Quantum Computer…..

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IBM's https://Qiskit.org

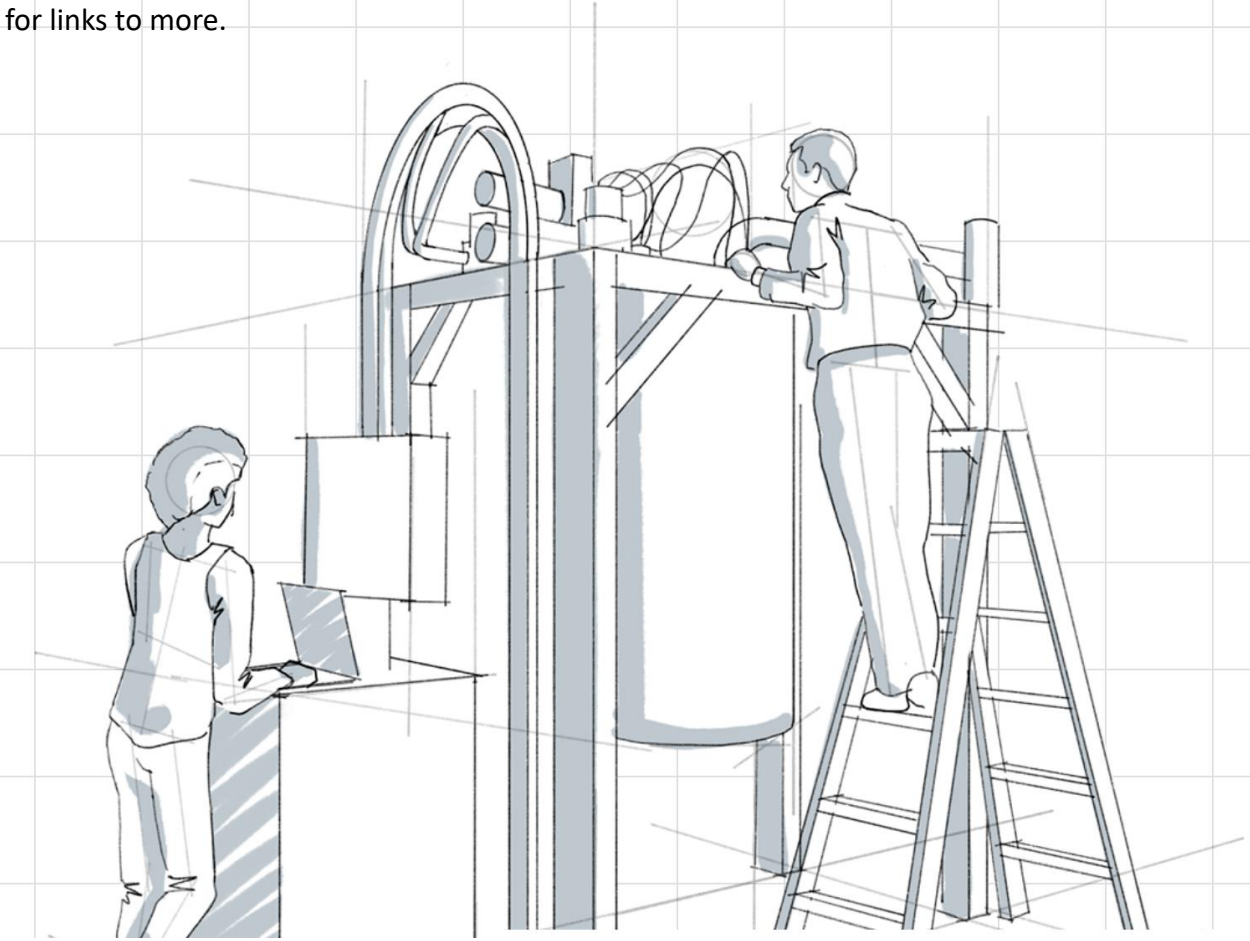
There are other companies that have quantum computer programming platforms,
See my website for links to more.

qiskit 0.39.2
see release notes

Open-Source Quantum Development

Qiskit [kiss-kit] is an open-source SDK for working with quantum computers at the level of pulses, circuits, and application modules.

Get started



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Example from Donn's Qubit x Qubit Week 6 Lab on IBM's Qiskit

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Python 3 (ipykernel)

Lab: Week #6 | The Z Gate and Multi-Qubit Circuits

Description: ¶

In this week's lab, we will create and simulate quantum circuits involving the Z gate, multi-qubit circuits, and mulit-qubit gates.

Cheat Sheet: Qiskit Cheat Sheet

Part 0: Importing from Qiskit

Run the cell directly below before doing anything else. This will import all of the functions that we will use today.

[1]:
```
# Importing standard Qiskit libraries
from qiskit import QuantumCircuit  #Importing the QuantumCircuit function from Qiskit. We will use this to create our quantum circuits!

# We will use these functions to run our circuit and visualize its final state
from qiskit import Aer, execute
from qiskit.visualization import *

import warnings  # We are using this library to suppress some warning messages
warnings.filterwarnings("ignore")

print("Libraries imported successfully!")
```

```
Libraries imported successfully!
```

QXQ_YLC_Lab_6_STUDEN

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Python 3 (ipykernel)

Part 2: The Z Gate

Exercise #1

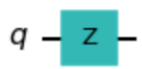
Together, let's create and draw a 1-qubit circuit with 1 Z gate.

[8]:
```
qc = QuantumCircuit(1)

qc.z(0)

qc.draw()
```

[8]:



Exercise #2

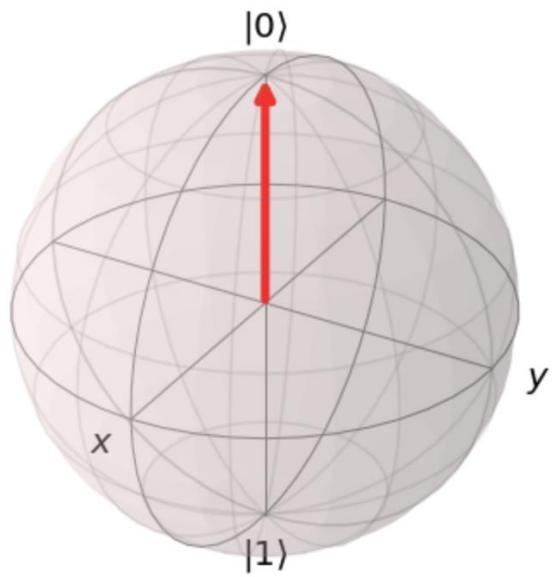
Together, let's create and run a 1-qubit circuit with 1 Z gate using `visualize_transition` with `fpg = 5`.

[9]:
```
qc = QuantumCircuit(1)

qc.z(0)

visualize_transition(qc, trace = True, fpg = 5)
```

[9]:



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Exercise #5

Create and draw a 5-qubit/5-classical bit quantum circuit where you apply the gates listed below using a loop and measure.

H gate on qubit 0

CX with qubit 0 as the control and qubit 1 as the target

H gate on qubit 1

CX with qubit 1 as the control and qubit 2 as the target

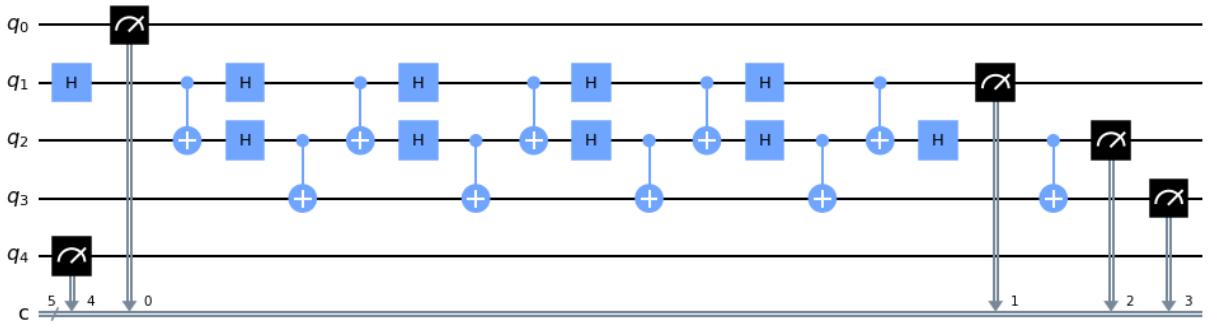
H gate on qubit 2

CX with qubit 2 as the control and qubit 3 as the target

NOTE: Be careful of going over the number of qubits in the loop.

[41]:
```
qc = QuantumCircuit(5, 5)

for qubit in range(5):

    qc.h(1)
    qc.cx(1, 2)
    qc.h(2)
    qc.cx(2, 3)

qc.measure([0, 1, 2, 3, 4], [0, 1, 2, 3, 4])

qc.draw()
```

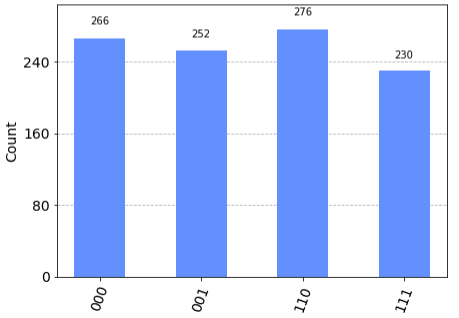
[41]:



Run the code below to simulate the measurement results using QASM.

[13]:
```
# Simulate using QASM
backend = Aer.get_backend('qasm_simulator')
job = execute(qc, backend = backend, shots = 1024)  # Make sure you change "qc" to the name of your quantum circuit in this line!
result = job.result()
counts = result.get_counts()
plot_histogram(counts)
```

[13]:



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Kahoot #2

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OpticsAge is a focal point for Donn Silberman's past Optics Education Adventures
Donn has retired from most of his educational outreach activities and his fulltime job at Starrett.
This website will be periodically maintained as an educational resource.

Donn is now focused on his Quantum Explorations and is consulting on EdQuantum.

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Things at the Atomic Scale are very different than at the human scale.

Summary

- The Quantum World underlies our modern civilization.
- And Quantum is about take humanity to the next level.
- **You can help make it happen.**

Thank You

Donn Silberman

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