

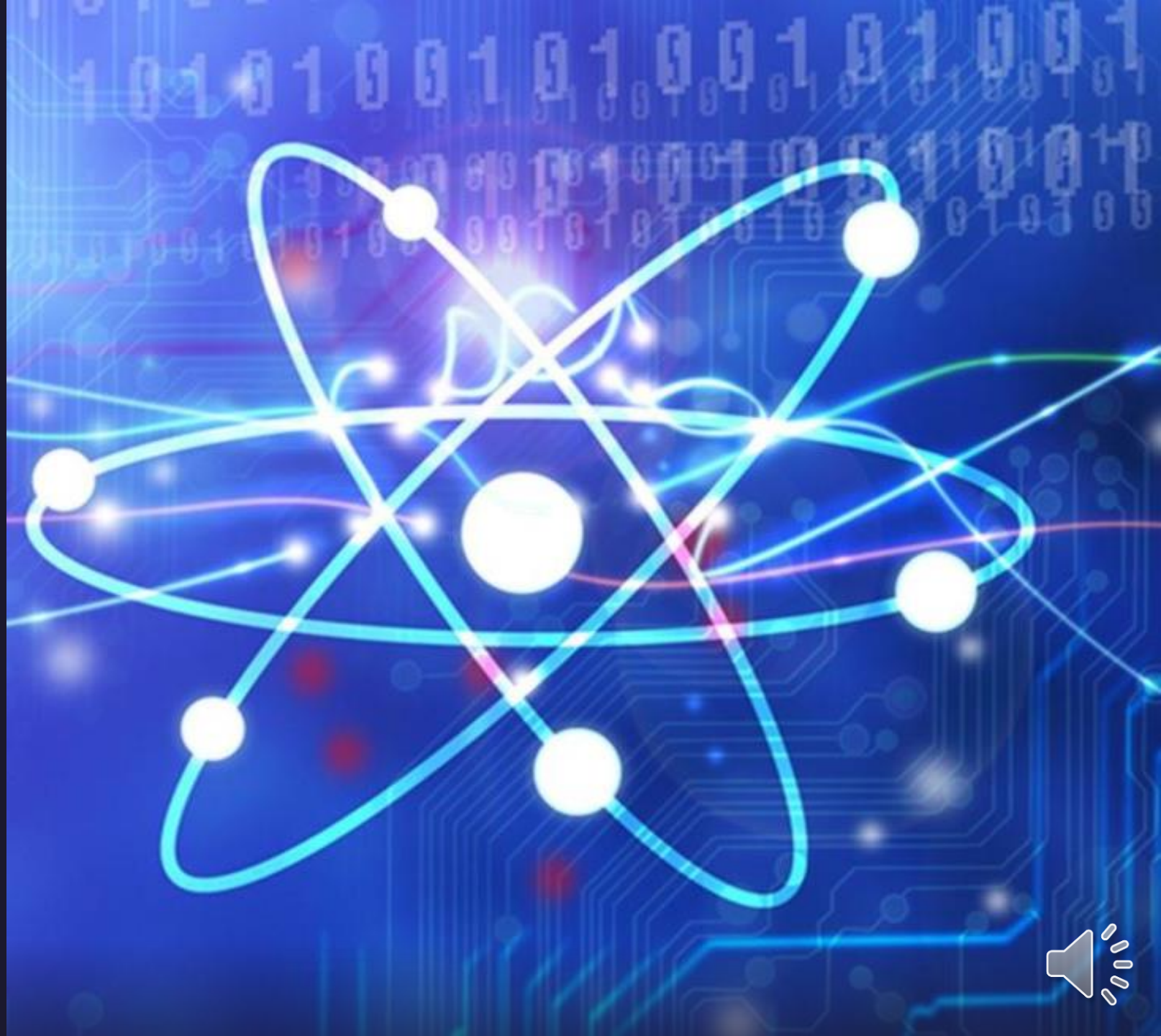
# Quantum for High School & College Students

Education & Career Pathways

Things at the Atomic Scale

**Donn Silberman**

- Optics Institute of Southern California
- <http://oisc.net>



# Introduction

Who am I?

And Why am I here talking to you?

- QuantumOpticsAge –
- <https://donn601.wixsite.com/opticsage>

Welcome to EdQuantum Project

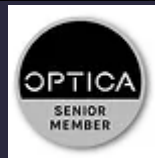
HYBRID CURRICULUM IN ADVANCED OPTICS, SPECTROSCOPY, AND QUANTUM TECHNOLOGIES FOR TECHNICIANS



THE UNIVERSITY OF ARIZONA



Pasadena City College



Society of Physics Students



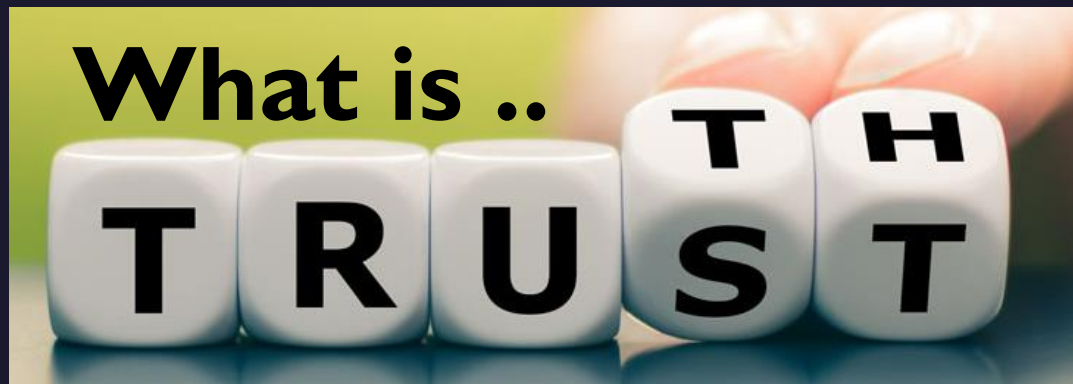
eLas Americas

OptoBotics<sup>sm</sup>  
Robots need eyes too





# Critical Thinking



# Mentors



**Frank Memmer**  
High School  
Astronomy Teacher



**Ke Chiang Hsieh**  
College Physics Professors



**William Bickel**

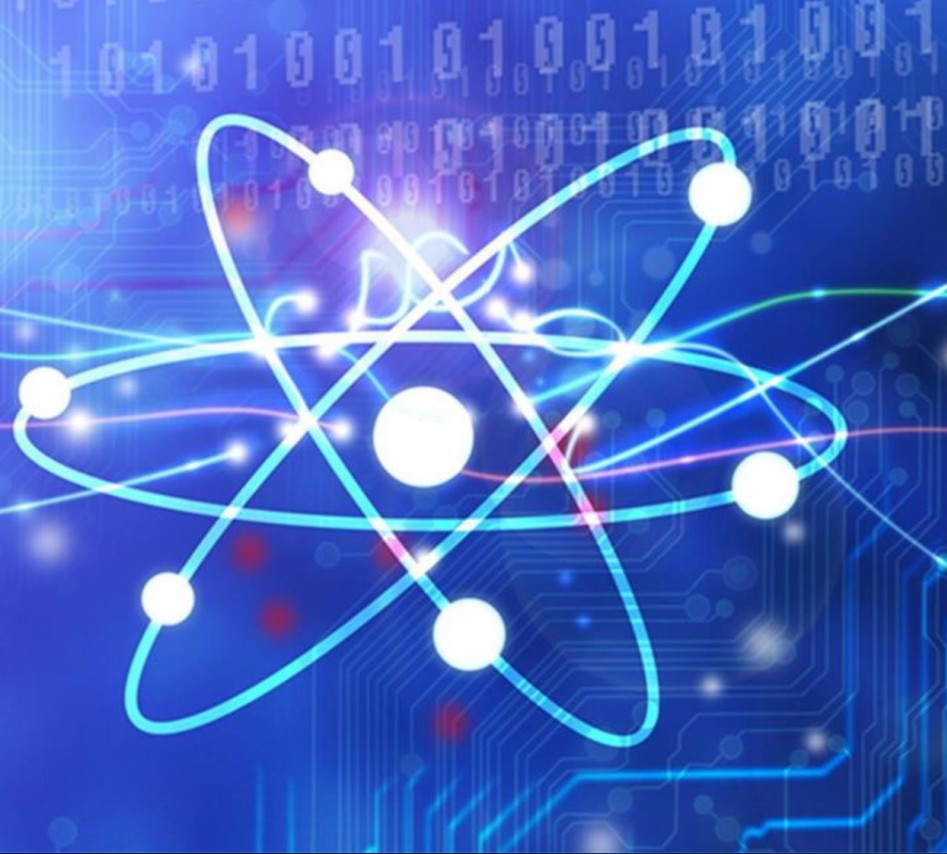


**Steve Jacobs**  
Univ. of Rochester  
Optics Suitcase  
Light Outreach

# Agenda

1. **What is Quantum & why should you care?**
2. **Quantum Computers & Cybersecurity** (Kahoot #1)
3. **Many More Quantum Applications**
4. **Pathways for High School & College Students**
5. **On-line and In-Person Resources** (Kahoot #2)
6. **Questions & Answers**





# 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.**

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.](#)



# PRE-QUANTUM MYSTERIES

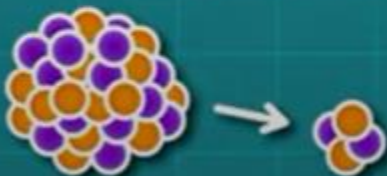
## ATOMIC SPECTRA



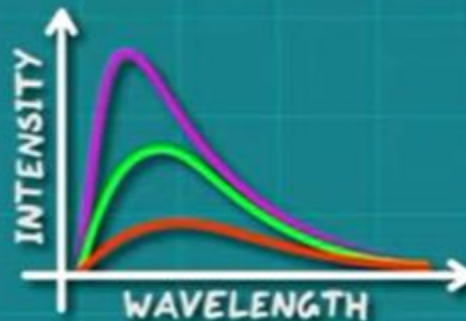
## THE STABLE ATOM



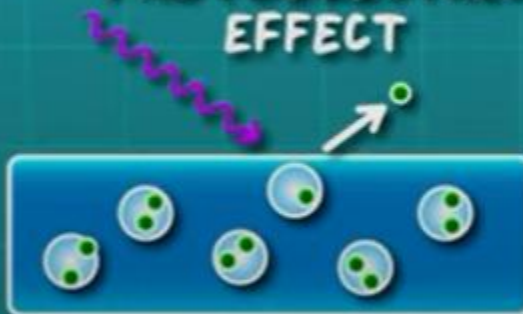
## RADIOACTIVITY



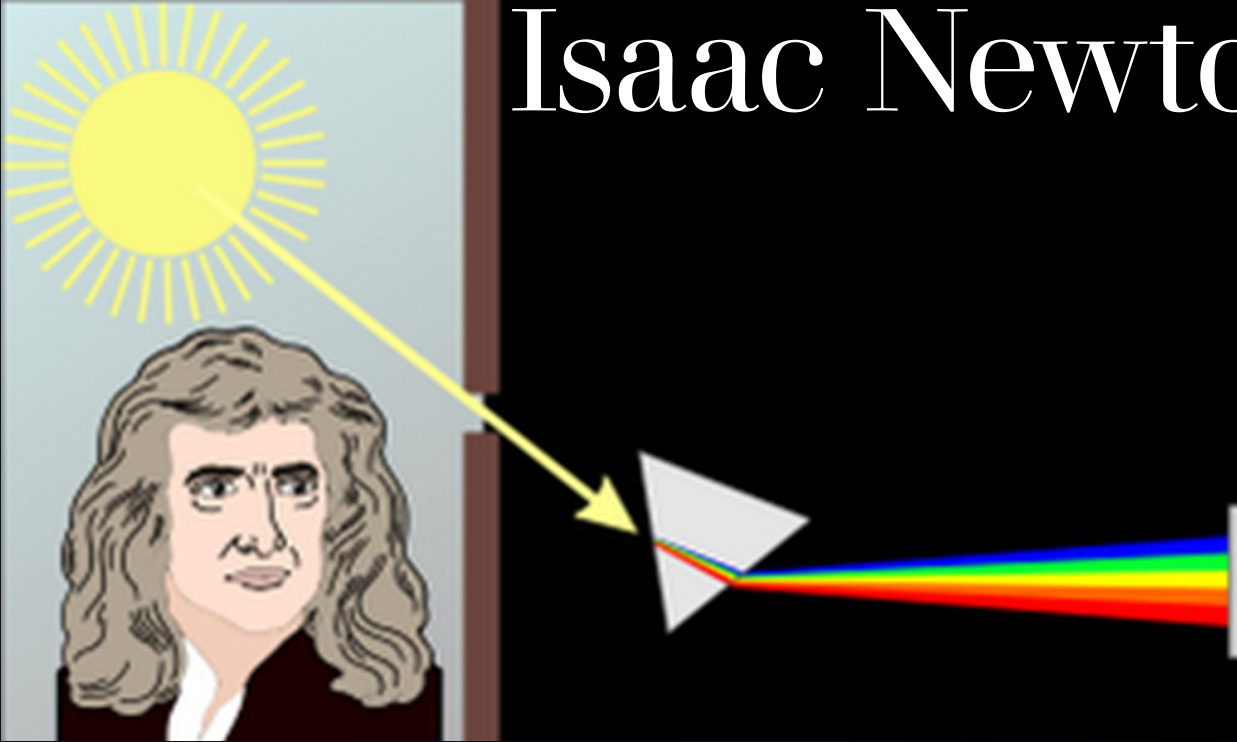
## BLACKBODY RADIATION



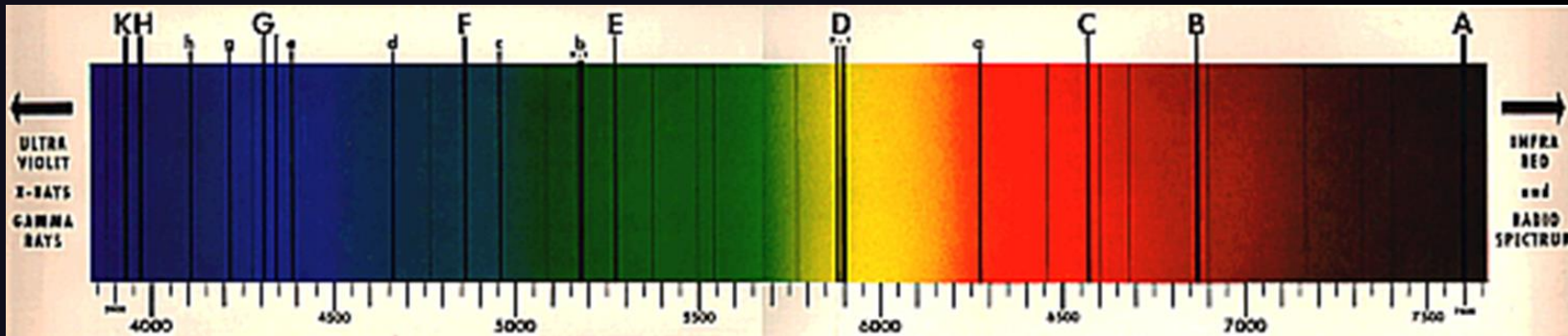
## PHOTOELECTRIC EFFECT



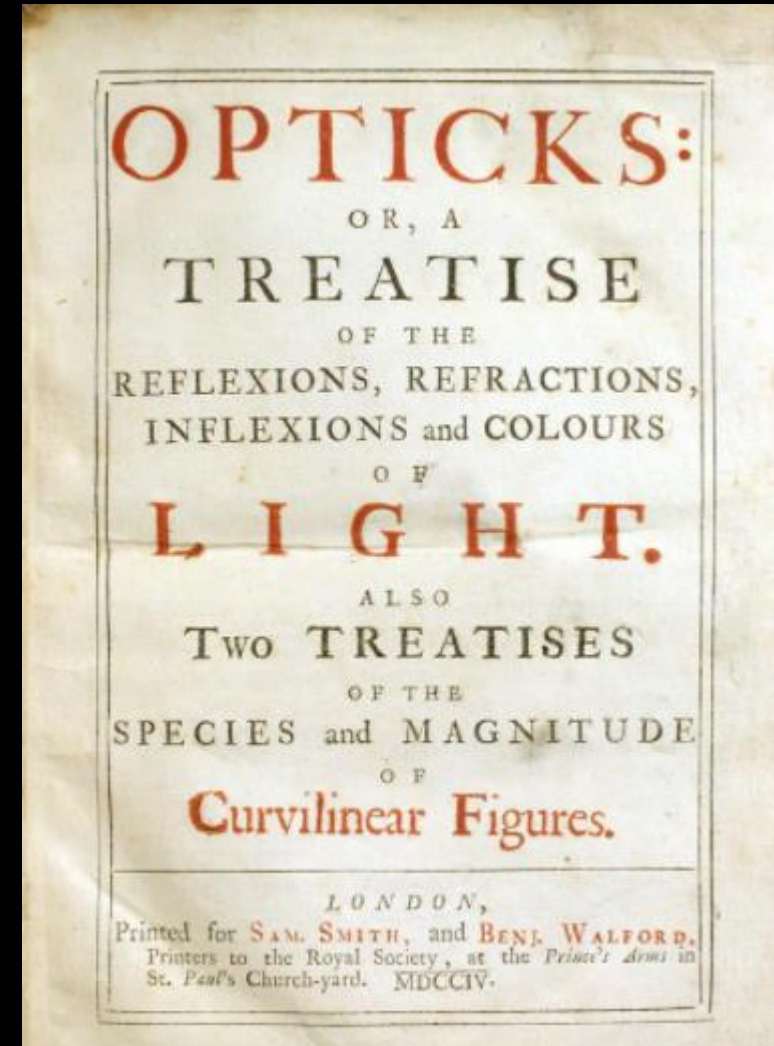
# Isaac Newton & the Prism



## The Solar Spectrum with Fraunhofer Lines



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



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

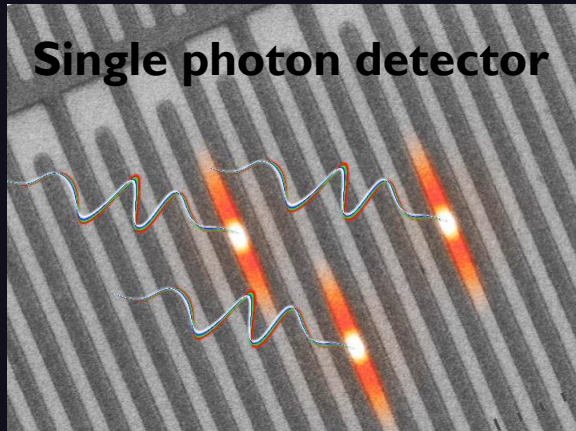
# From Wikipedia: QUANTUM

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".

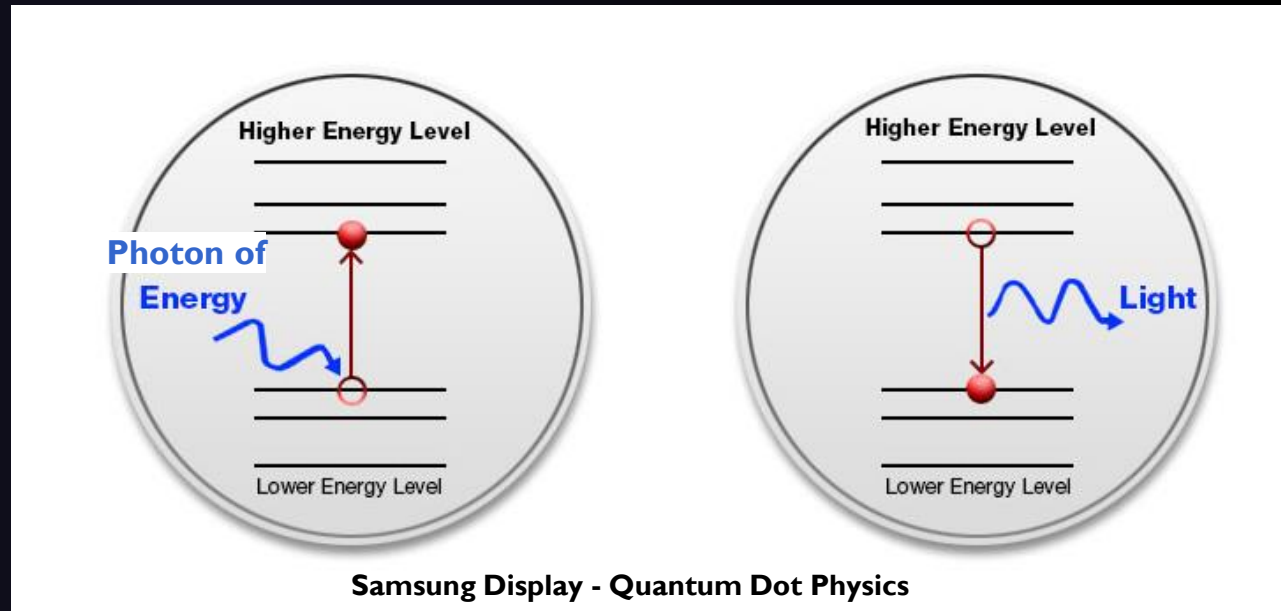
[1] This means that the magnitude of the physical property can take on only **discrete values** consisting of integer multiples of one quantum.

**Can't have 1 1/2 photons  
Or 3/4 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.

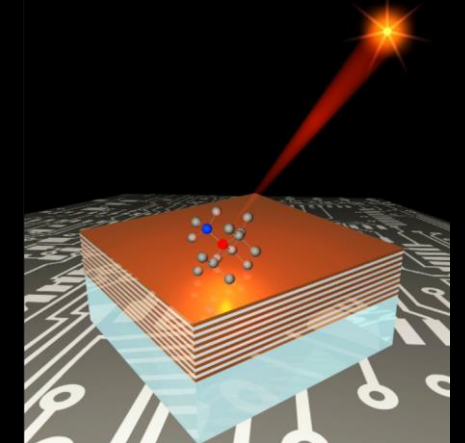


l-singlephoton.jpg (716x536) (b-cdn.net)



Samsung Display - Quantum Dot Physics

Single photon emitter



singlephoton.jpg (1000x1413) (b-cdn.net)

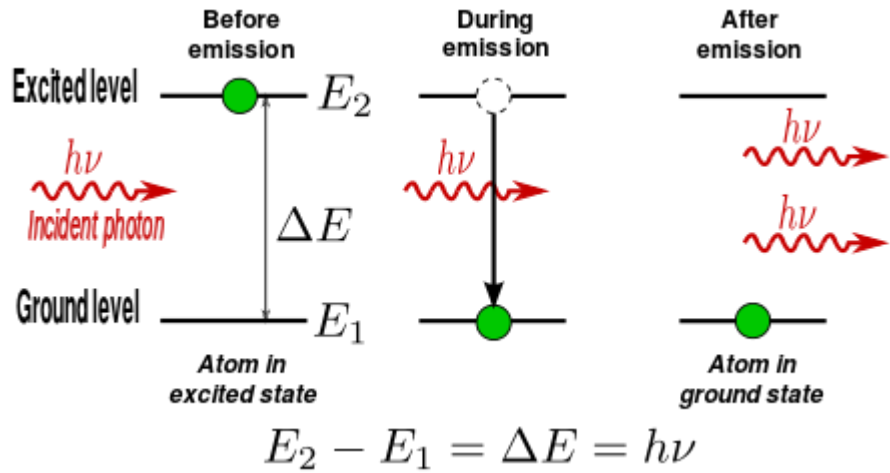
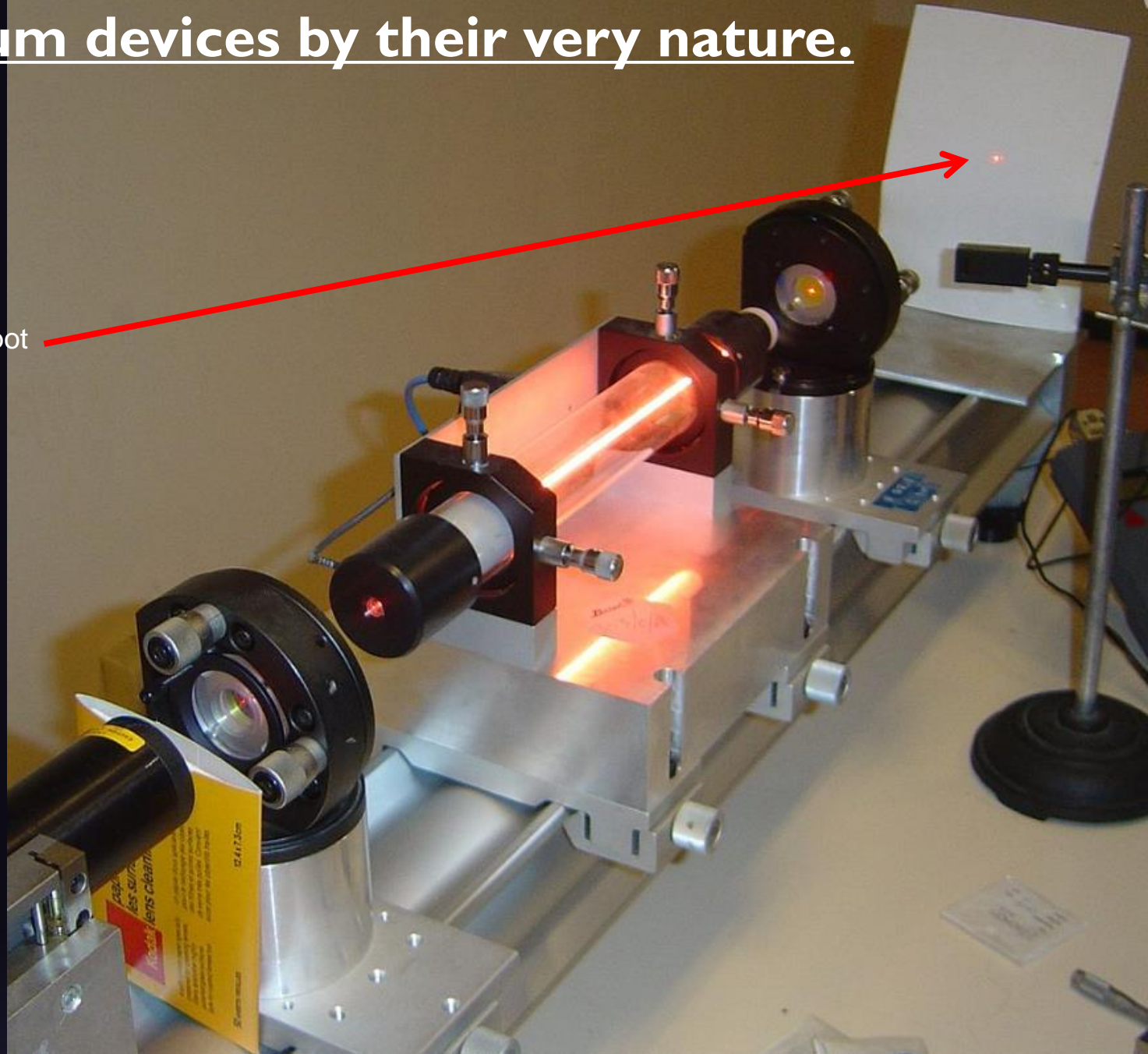
$$E = h\nu$$

frequency of radiation, sometimes written as  $f$  giving expression  $E = hf$ .  
Quantum energy of a photon.  
 $h = \text{Planck's constant} = 6.626 \times 10^{-34} \text{ Joule}\cdot\text{sec} = 4.136 \times 10^{-15} \text{ eV}\cdot\text{s}$

$$E=mc^2$$

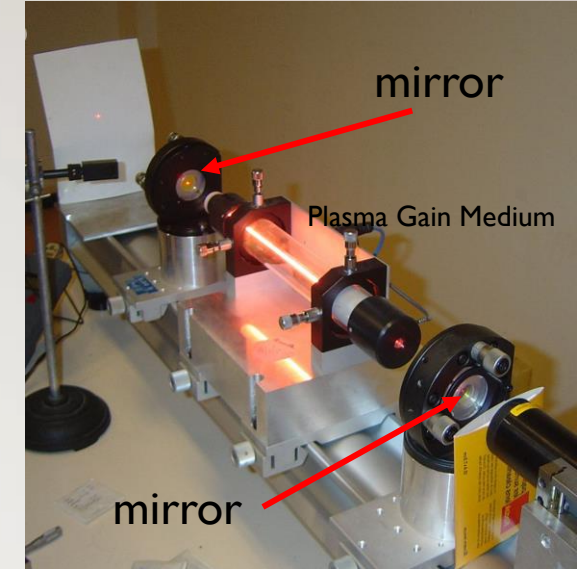
# Lasers are intrinsically quantum devices by their very nature.

A helium–neon laser demonstration. The glow running through the center of the tube is an electric discharge. This glowing plasma is the gain medium for the laser. The laser produces a tiny, intense spot on the screen to the right. The center of the spot appears white because the image is overexposed there.



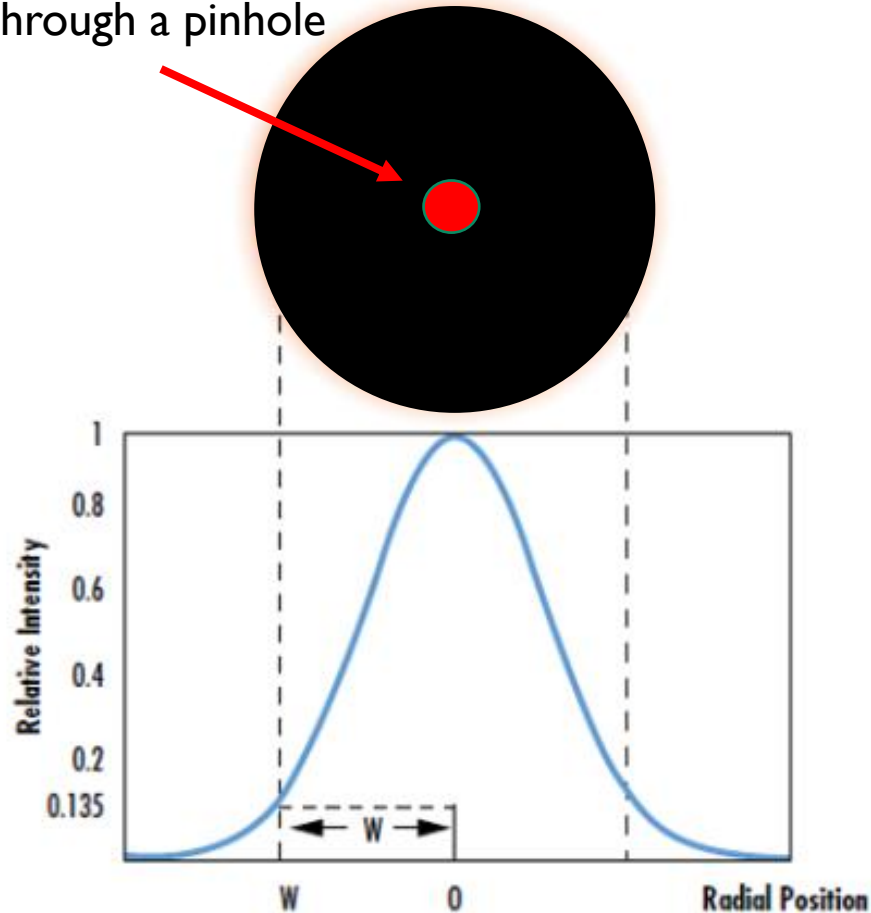
## THE LASER

All the animations and explanations on  
[www.toutestquantique.fr](http://www.toutestquantique.fr)

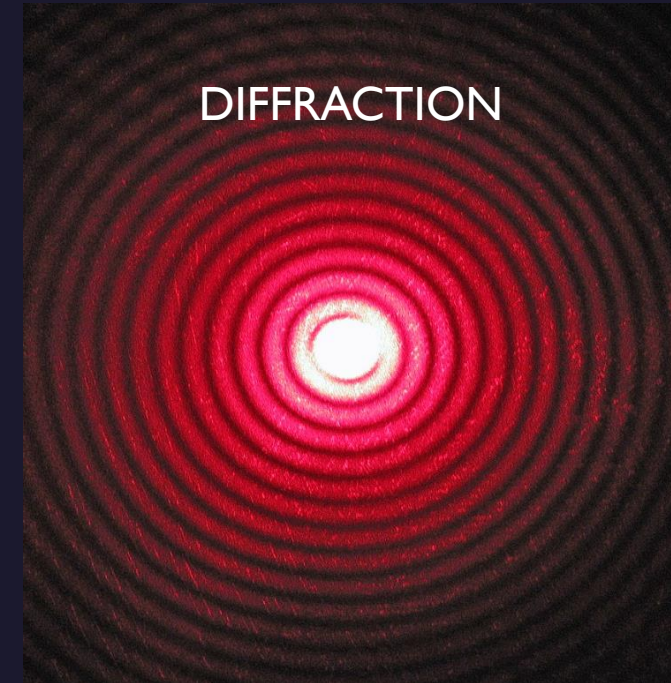


# Laser Light Distribution Patterns

Through a pinhole

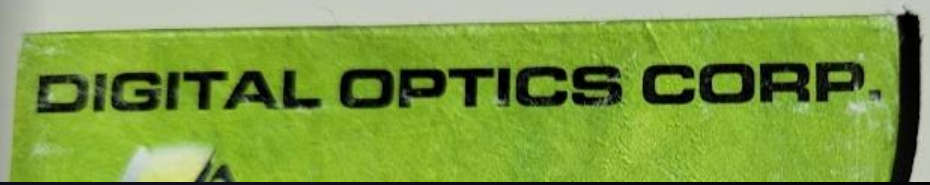


*Figure 1: The waist of a Gaussian beam is defined as the location where the irradiance is  $1/e^2$  (13.5%) of its maximum value*

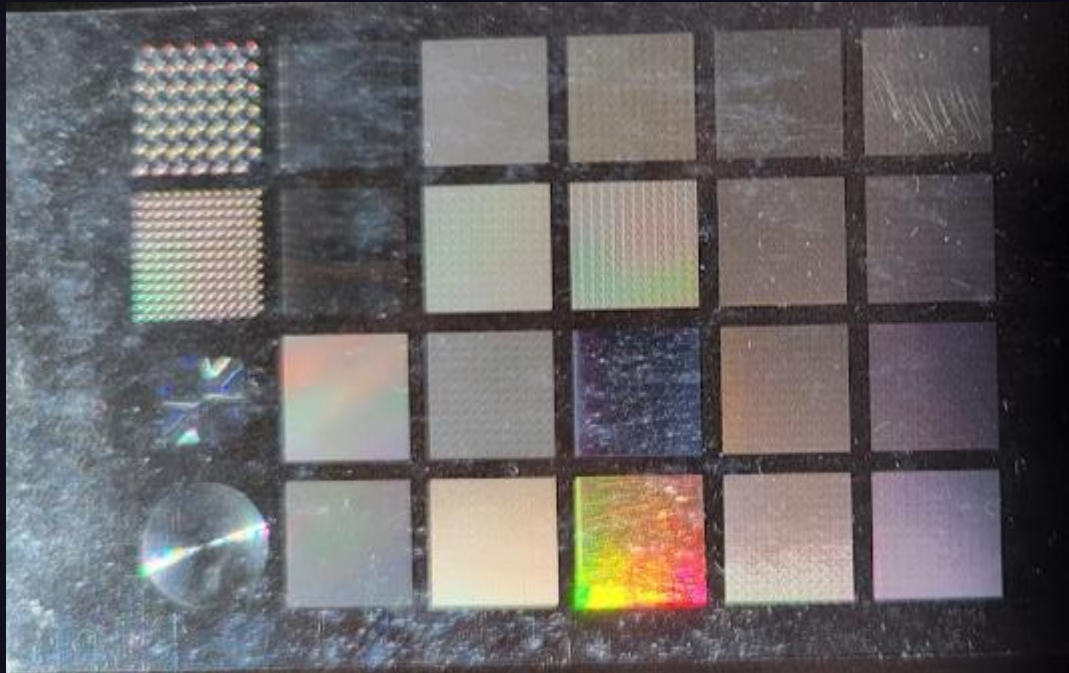


A diffraction pattern of a red laser beam projected onto a plate after passing through a small circular aperture in another plate

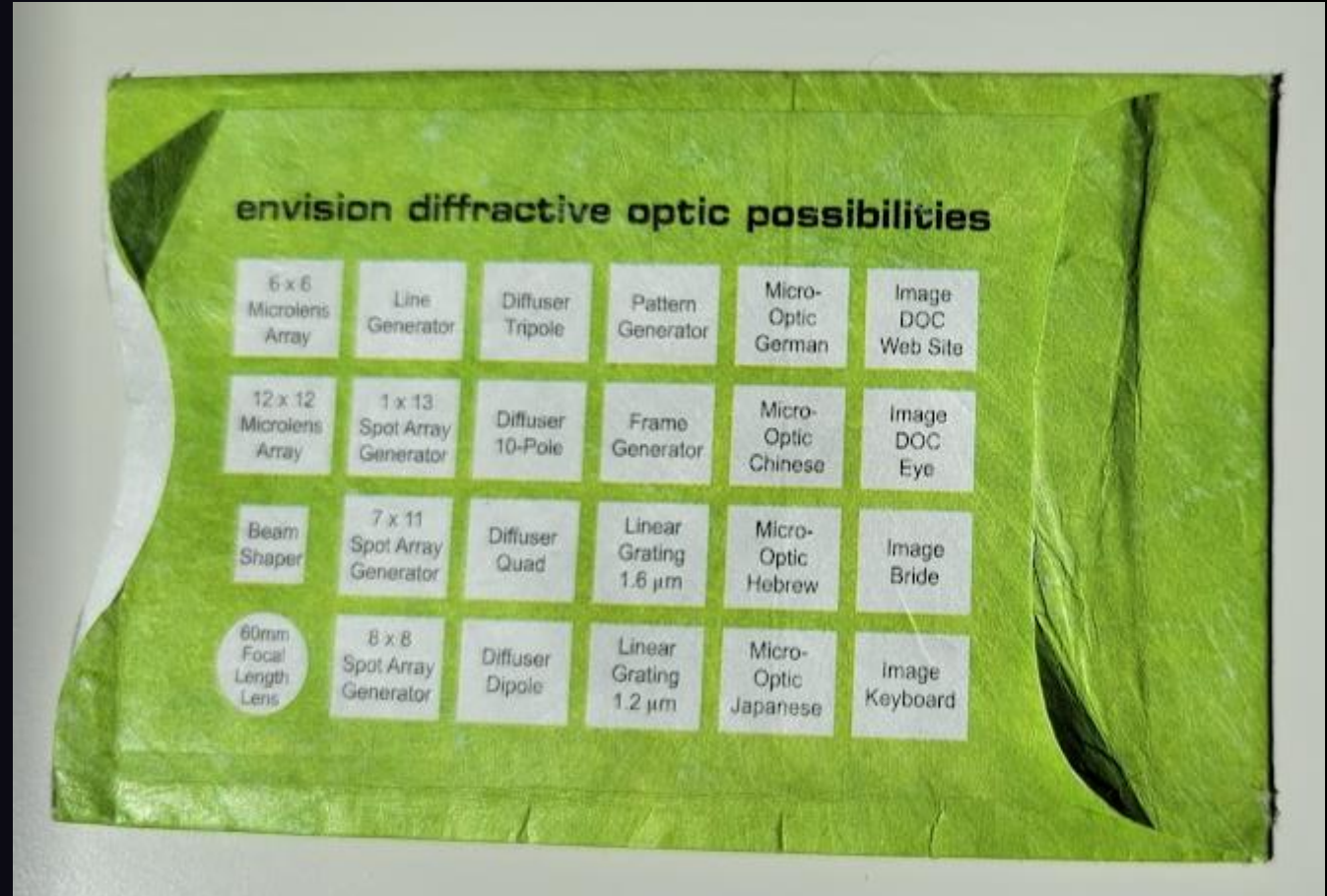
[Laser Interference - Diffraction - Wikipedia](#)



# Computer Generated Diffractive Optical Elements



Not available anymore.





A 5.6 mm 'closed can' commercial laser diode, such as those used in a laser pointer.



Do the live demonstration here or.....  
See video of using the part – [click here.](#)



[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.”

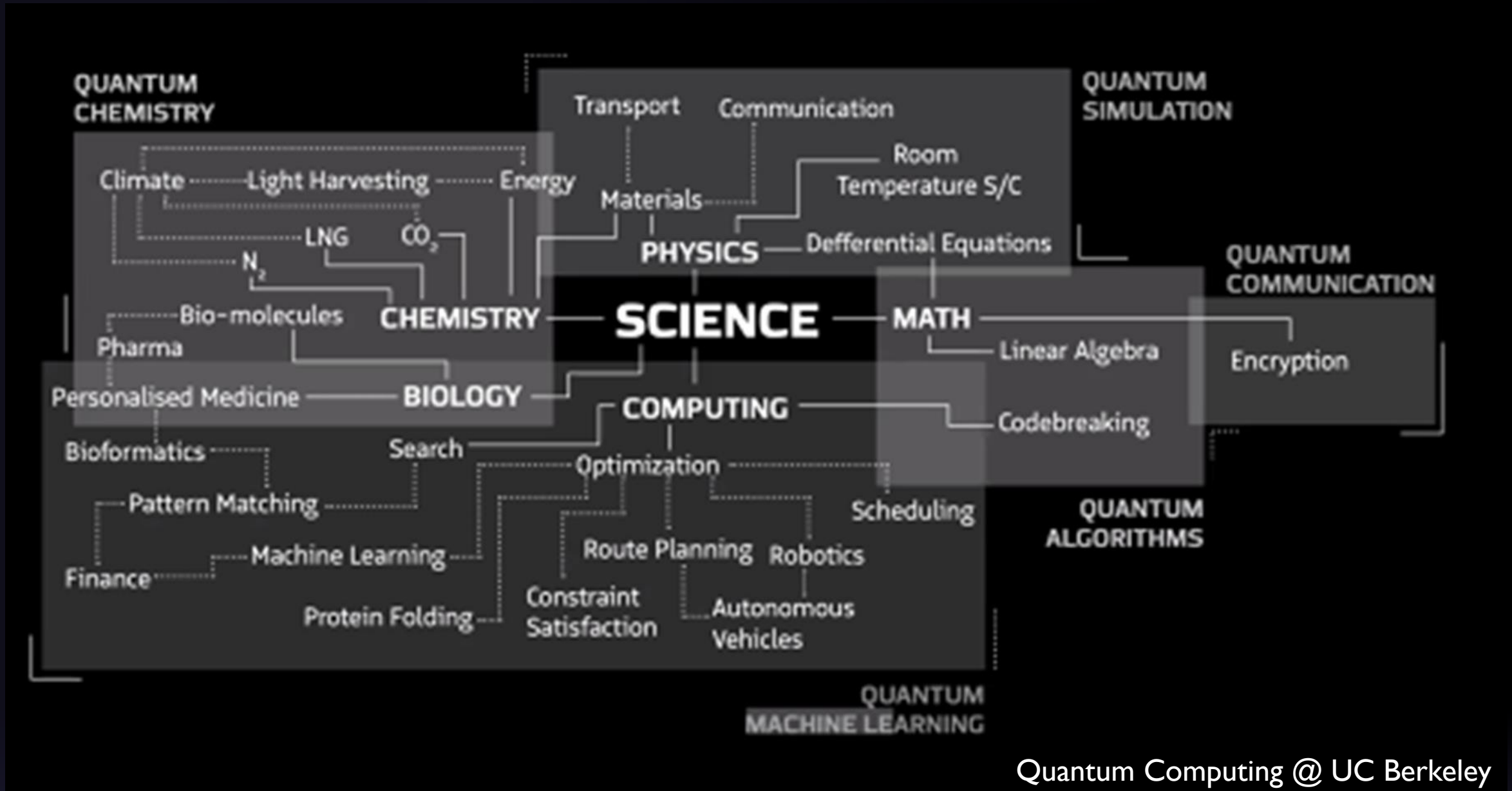


## The Transistor



# Why should you care??

Education and career opportunities.





**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.



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>



**Jet Propulsion Laboratory**  
California Institute of Technology

## Be Laser-Focused

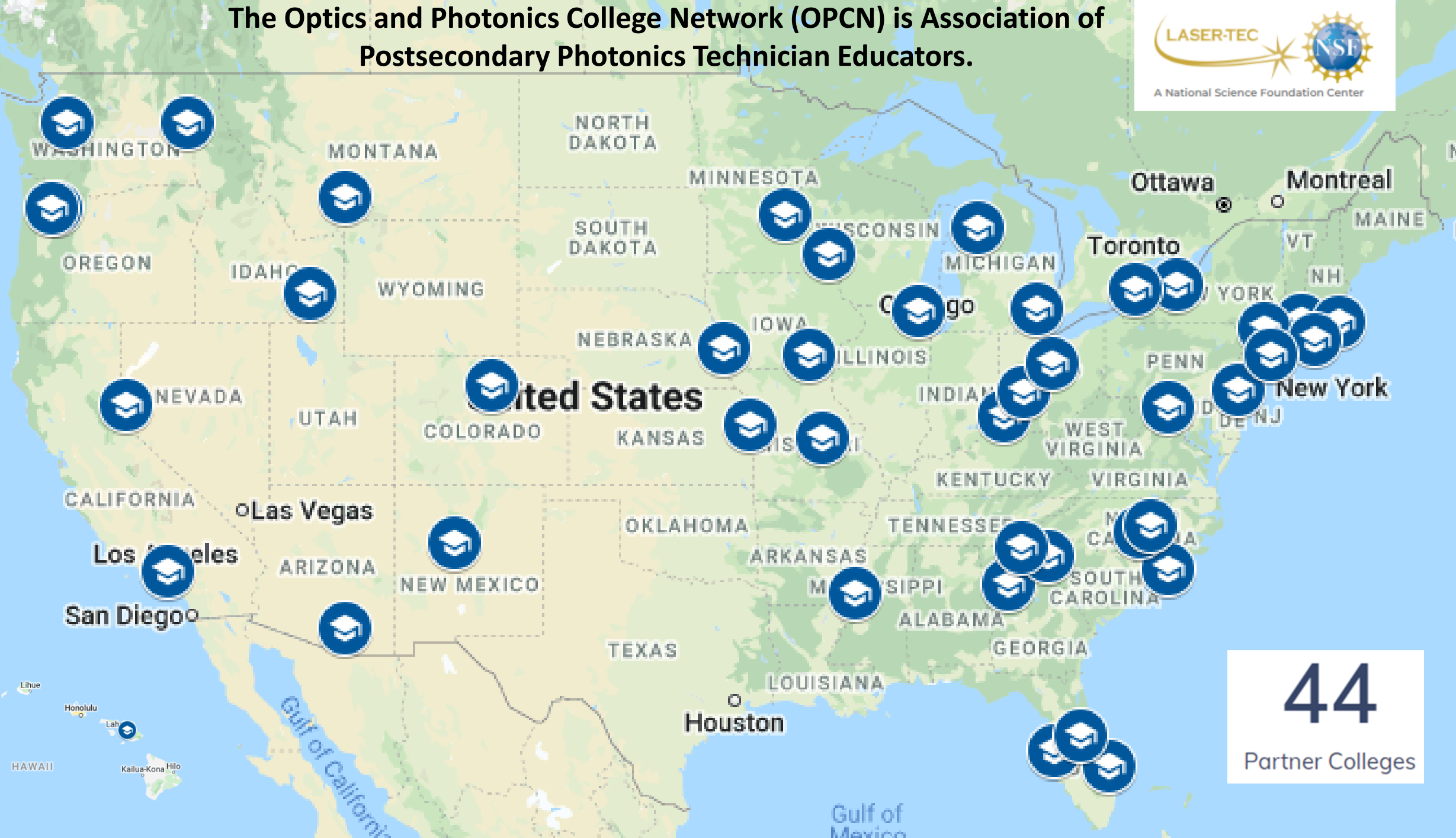
LaserTech is the use of lasers, cameras, lenses, mirrors, sensors, displays, fiber optics, and other technical devices that interact with light.



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

[naturalsciences@pasadena.edu](mailto:naturalsciences@pasadena.edu)

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



**44**  
Partner Colleges

# 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.

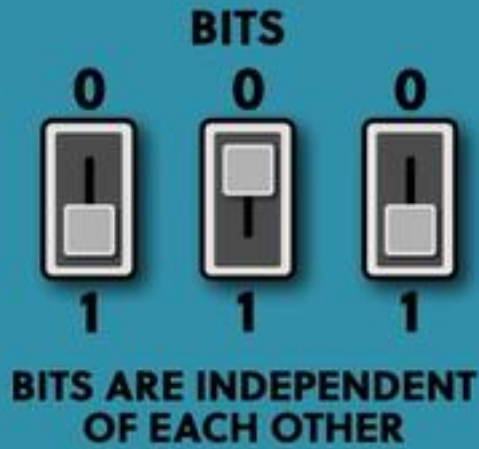
### **Intellectual property (IP) -**

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

# CLASSICAL COMPUTERS

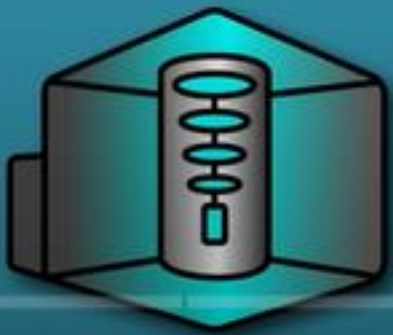


1 STATE AT A TIME



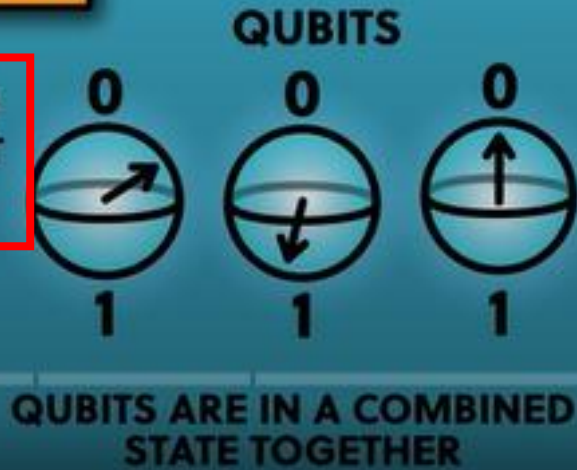
## CLASSICAL VS. QUANTUM

# QUANTUM COMPUTERS



SUPERPOSITION  
ENTANGLEMENT  
INTERFERENCE

MANY STATES AT A TIME



Superposition  
Entanglement  
Interference

Einstein's  
“Spooky Action at a Distance”

ers Work >

# QUANTUM ALGORITHMS

**MULTIPLICATION**  
**7177 x 3001**  
↓ ↓  
**21538177**  
**EASY!**  
EFFICIENT  
CLASSICAL ALGORITHM

**FACTORISATION**  
**21538177**  
↓ ↓  
**7177 x 3001**  
**HARD!**  
NO EFFICIENT  
CLASSICAL ALGORITHM

USED FOR  
ENCRYPTION



## SHOR'S ALGORITHM

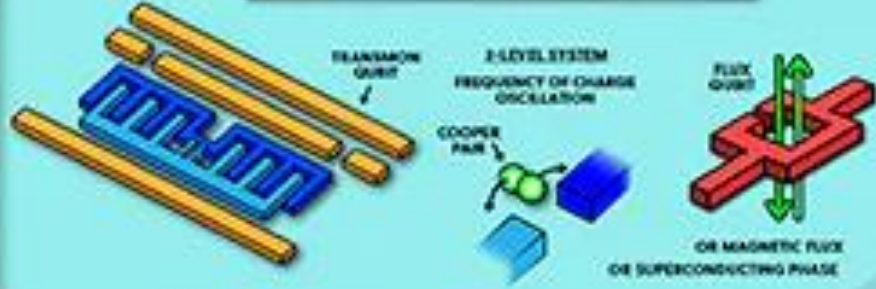
**21538177**  
↓  
**SHOR'S ALGORITHM**  
↓ ↓  
**7177 3001**  
EFFICIENT  
QUANTUM ALGORITHM

**Classical Computing**

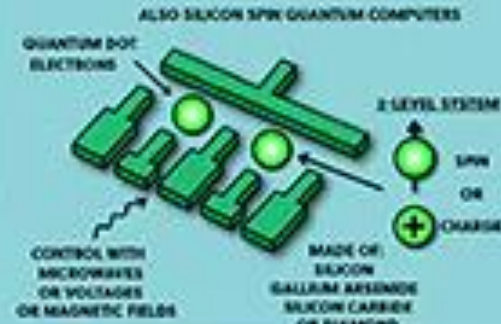
**Quantum Computing**

## PHYSICAL REALISATIONS

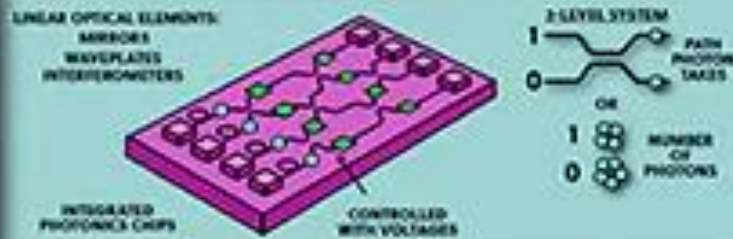
### 1 SUPERCONDUCTING QUANTUM COMPUTERS



### 2 QUANTUM DOT QUANTUM COMPUTERS



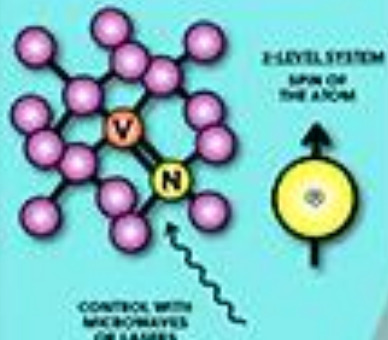
### 3 LINEAR OPTICAL QUANTUM COMPUTERS



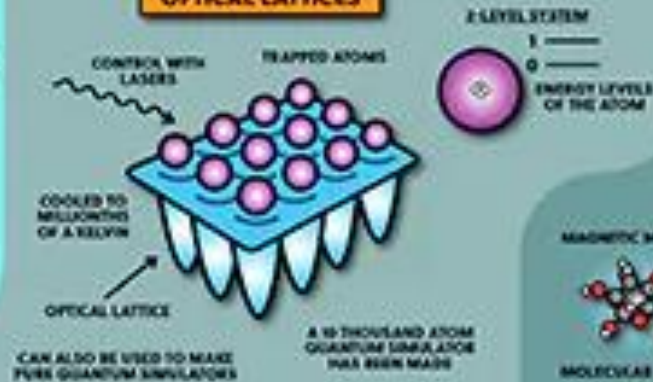
### 4 TRAPPED ION QUANTUM COMPUTERS



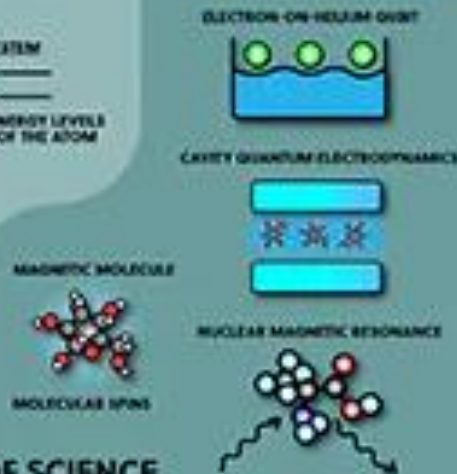
### 5 COLOUR CENTRE QUANTUM COMPUTERS



### 6 NEUTRAL ATOMS IN OPTICAL LATTICES



### 7 OTHER APPROACHES



## Fundamental Quantum Computer Technologies

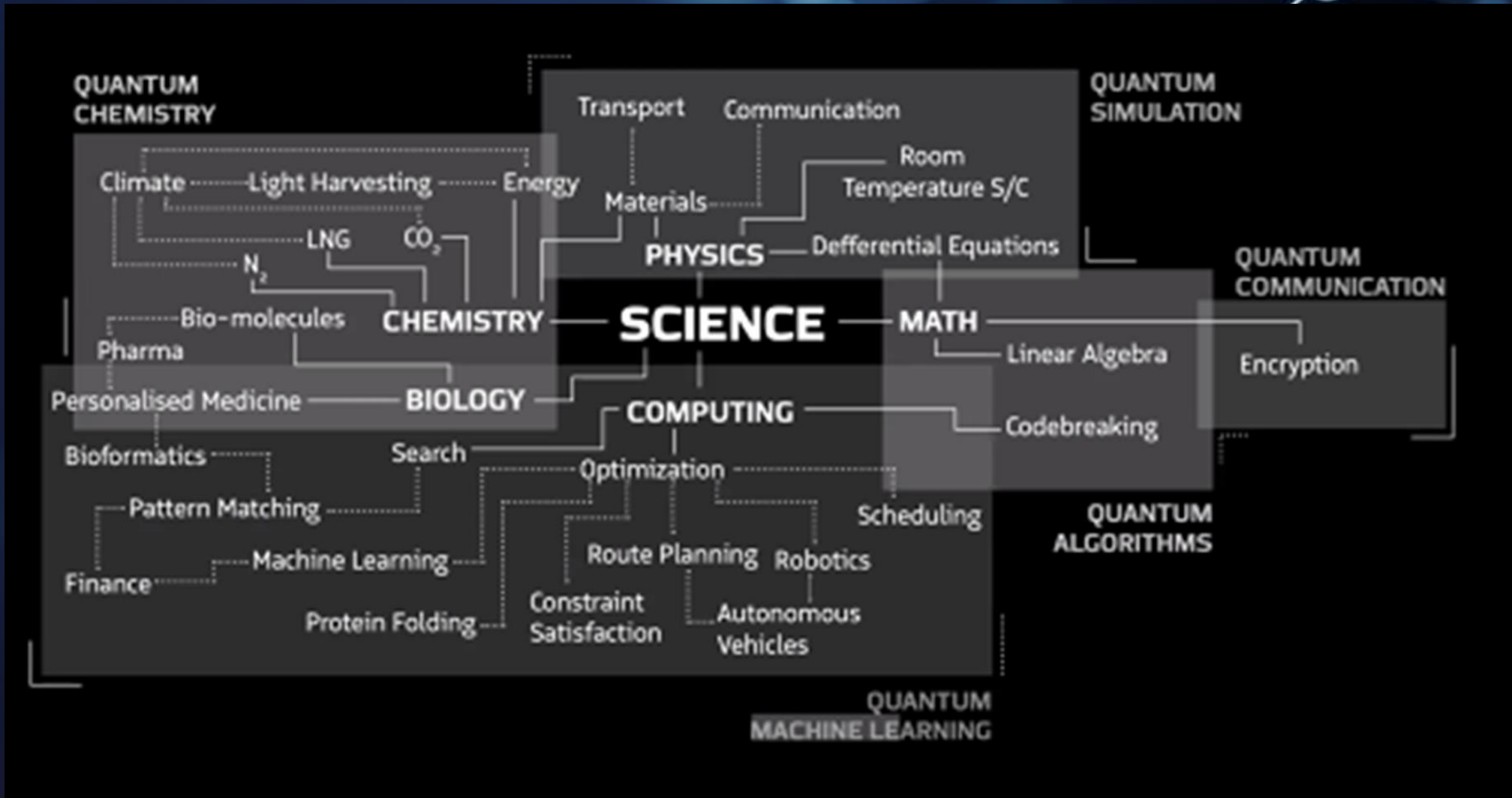
1. Super Conducting
2. Quantum Dots
3. Linear Optical (Photonic)
4. Trapped Ions
5. Color Centers
6. Neutral Atoms in Optical Lattices
7. Other Approaches
  - ✓ Electron-on-Helium Qubit
  - ✓ Magnetic Molecule - Spin
  - ✓ Cavity Quantum Electrodynamics
  - ✓ Nuclear Magnetic Resonance



# Kahoot #1

[CLICK HERE FOR LINK.](#)

# Many More Quantum Applications



## Quantum Computing Applications

1. [The Future of Quantum Drug \(medicine\) Discovery - Cambridge Quantum](#)
2. [Quantum computer models a chemical reaction \(scitation.org\)](#)
3. [Quantum Computing: Accelerating the Digitization of Chemistry • EFMaterials Blog](#)
4. [Inside Google's Quantum Computing Data Center](#)
5. [Quantum ML - Quantum: Machine Learning & Analytics](#)
6. [Exploring quantum computing use cases for manufacturing | IBM](#)
7. [University of Arizona Awarded \\$26M to Architect the Quantum Internet](#)

[\\*High School Quantum | opticsage \(donn601.wixsite.com\)\\*](#)

1. Financial Services – Investing, transacting
2. Oil & Gas Exploration and distribution
3. Better Batteries
4. Cleaner Fertilization
5. Traffic Optimization
6. Weather Forecasting and Climate Change
7. Improving Solar Panels
8. Quantum Systems Simulations
9. Quantum Sensors

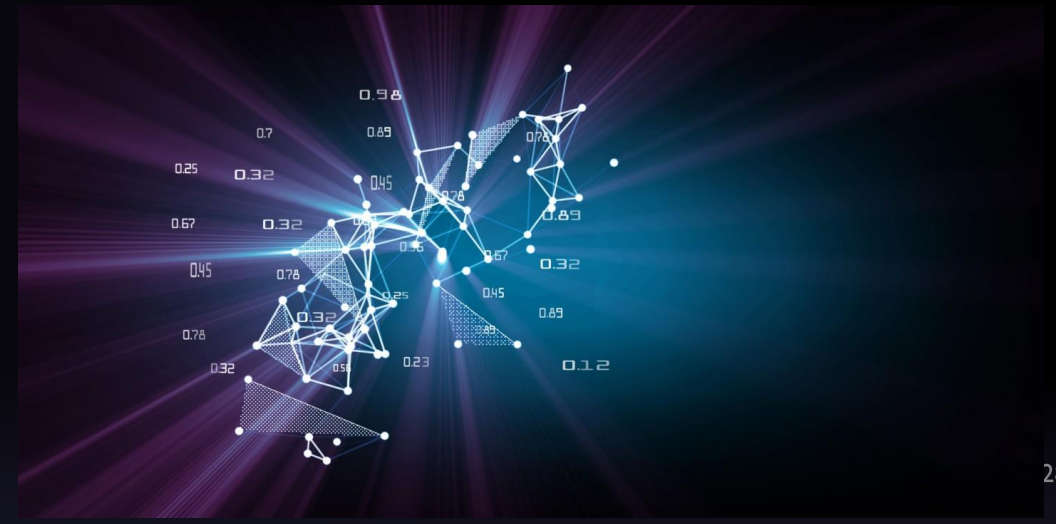
# Quantum Computing: Accelerating the Digitization of Chemistry

August 25, 2020 | In Solution | By Ryan Esner

- Companies creating semiconductors, magnets, and superconductors will now be able to more precisely predict and optimize the structure of their solid-state materials.
- Tech companies creating OLED displays will now move away from endless trial-and-error methods to achieve desired brightness and hue of colors: thanks to simulation techniques, materials are simulated accurately before the first stage of production even begins.
- Catalyst design will be made more accurate, reducing research costs and, more importantly, making catalyzed processes less energy intensive. In other words, catalysis will advance exponentially.
- Drug discovery depends heavily on biochemical interactions; by optimizing the simulation process of pharmaceuticals and helping labs accelerate the research process, better drugs will be synthesized in less time.
- The in-depth study of molecular structure allowed by quantum computers will enable researchers to take the investigation of proteins and biomaterials to the next level and will allow for the creation of next-generation optical materials.

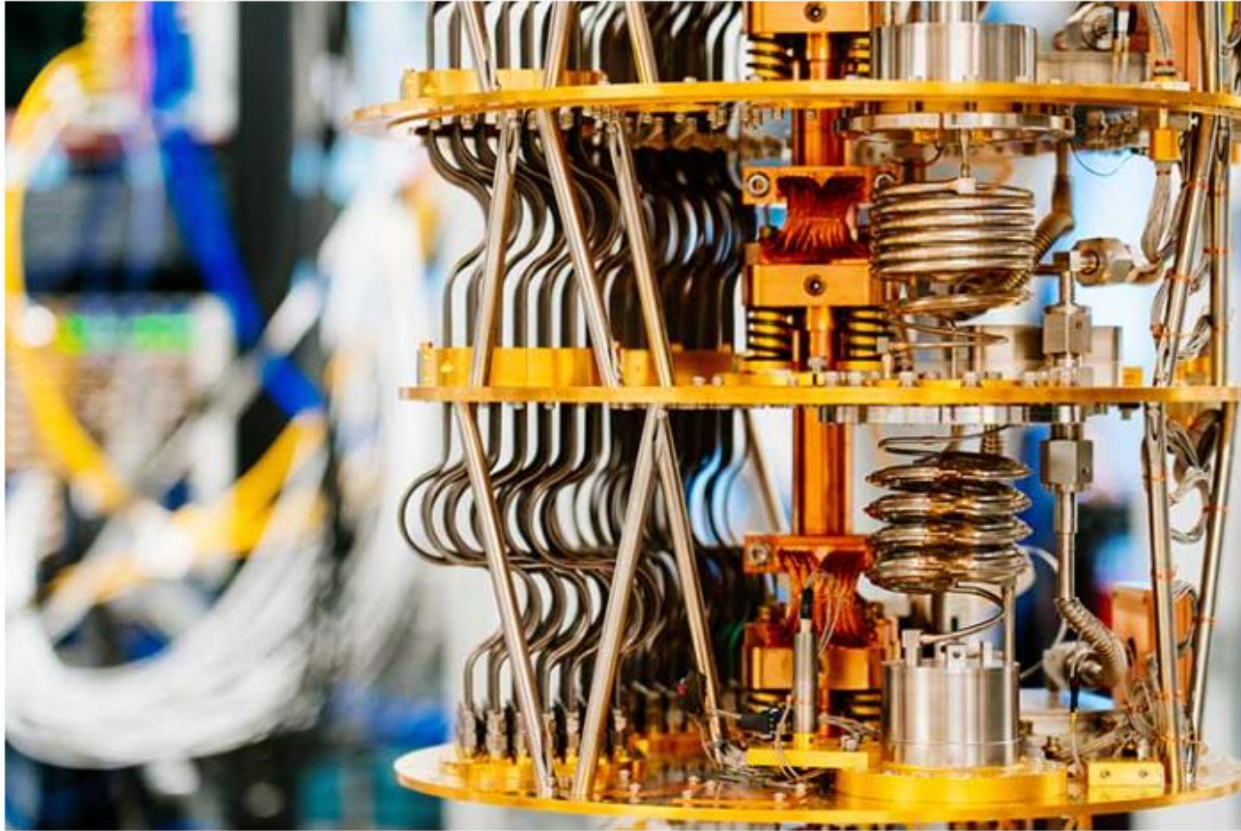
## Quantum chemistry – the last frontier of materials science

[Quantum Computing: Accelerating the Digitization of Chemistry • EFMaterials Blog](#)



# Inside Google's Quantum Computing Data Center

BY RICH MILLER - NOVEMBER 22, 2021 — LEAVE A COMMENT



One of the cryostats at the Google Quantum AI Lab in Santa Barbara, Calif. (Image: Google)



Source: Interior of one of Google's Data Center, [www.google.com/about/datacenters/](http://www.google.com/about/datacenters/)

## *The Quantum Consortium* **QED·C**

[Quantum Technician Skills and Competencies for the Emerging Quantum 2.0 Industry \(SPIE Optical Engineering\)](#)

Authors: Mo Hasanovic, Chrys Panayiotou, Donn Silberman, Paul Stimers, and Celia Merzbacher

Available on-line Apr. 9, 2022 - Open Access at the link above. To be published in hardcopy form August 2022

## **Welcome to EdQuantum Project**

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

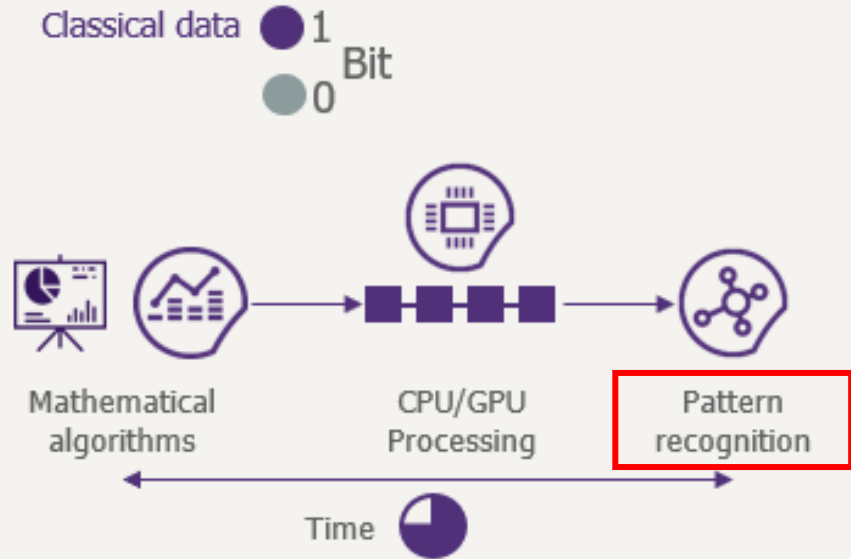
This project is supported by the National Science Foundation under Grant No. DUE-2000601. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

[Inside Google's Quantum Computing Data Center \(datacenterfrontier.com\)](http://datacenterfrontier.com)

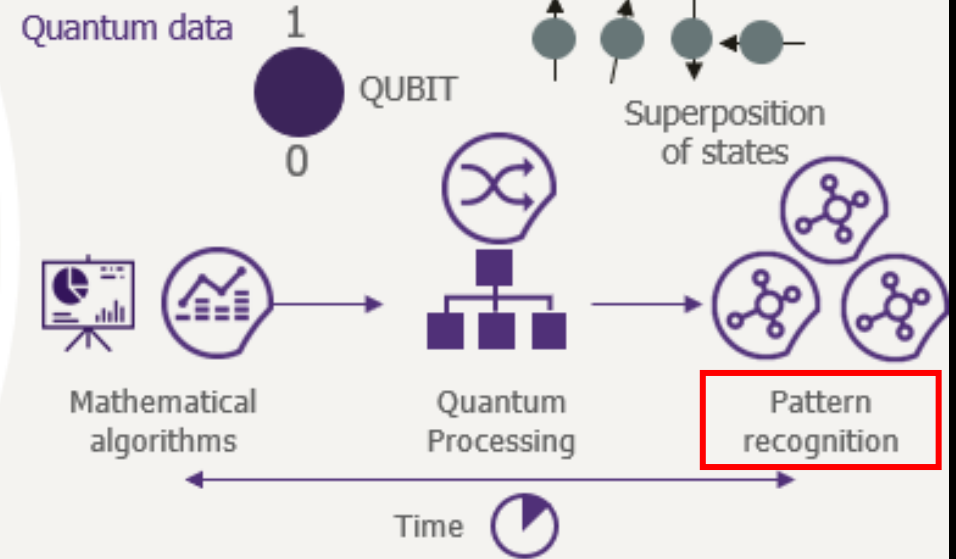
# Machine Learning

Quantum ML - Quantum: Machine Learning & Analytics ([ml2quantum.com](http://ml2quantum.com))

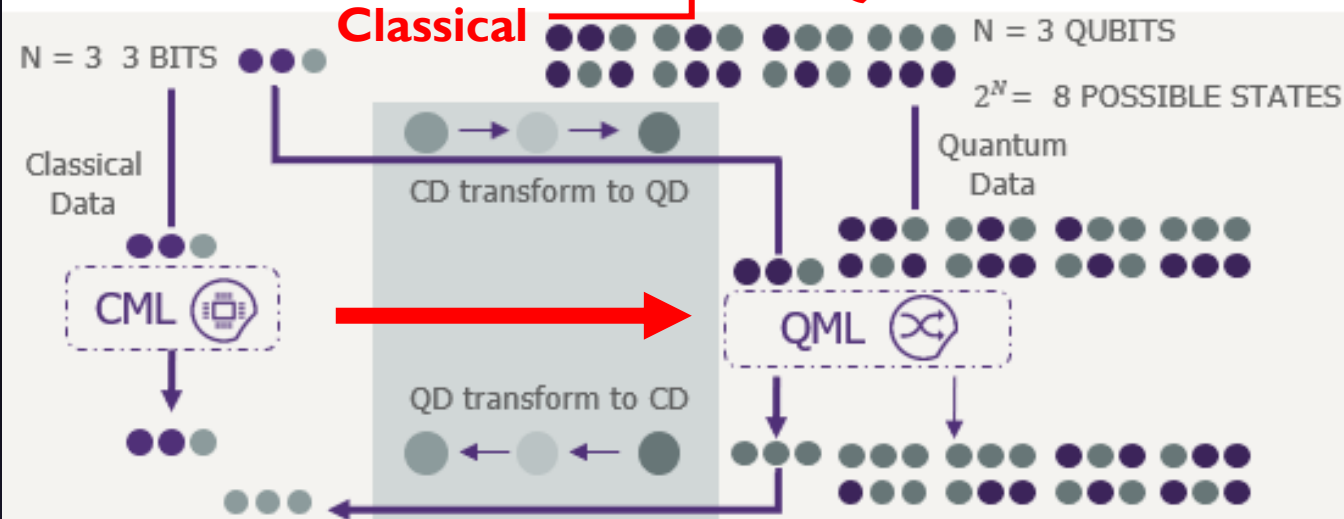
## Classical Machine Learning - CML



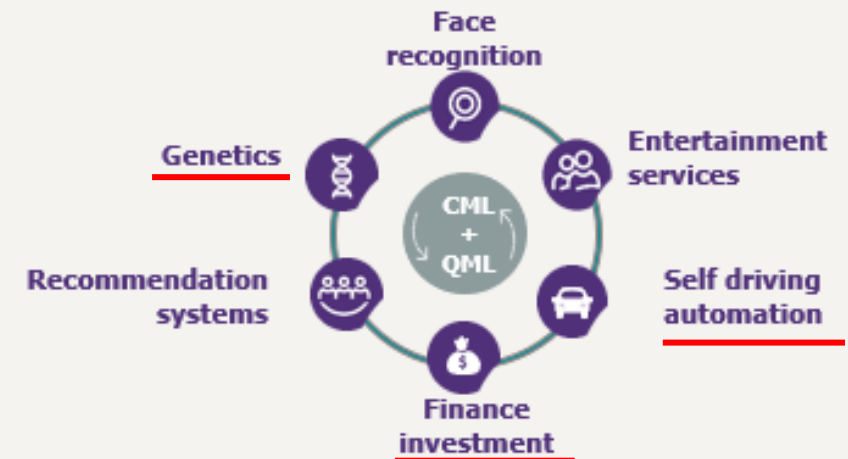
## Quantum Machine Learning - QML



## Processing methods



## Applications



Microsoft, Google, Honeywell, and Amazon

# Exploring quantum computing use cases for manufacturing

[Download the report →](#)[Get free insights via email →](#)

## Discover

- Chemistry
- Materials science
- Condensed matter physics

## Design

- Finite difference analysis
- Structural analysis
- Hydro/aerodynamics



## Manufacturing

## Control

- Optimization
- Machine learning
- Classification

## Supply

- Supply chain optimization
- Risk modeling

# Telecommunications



Quantum computing is just one of the many functions towards the development of a quantum network that will deliver the quantum Internet

# The Quantum Internet

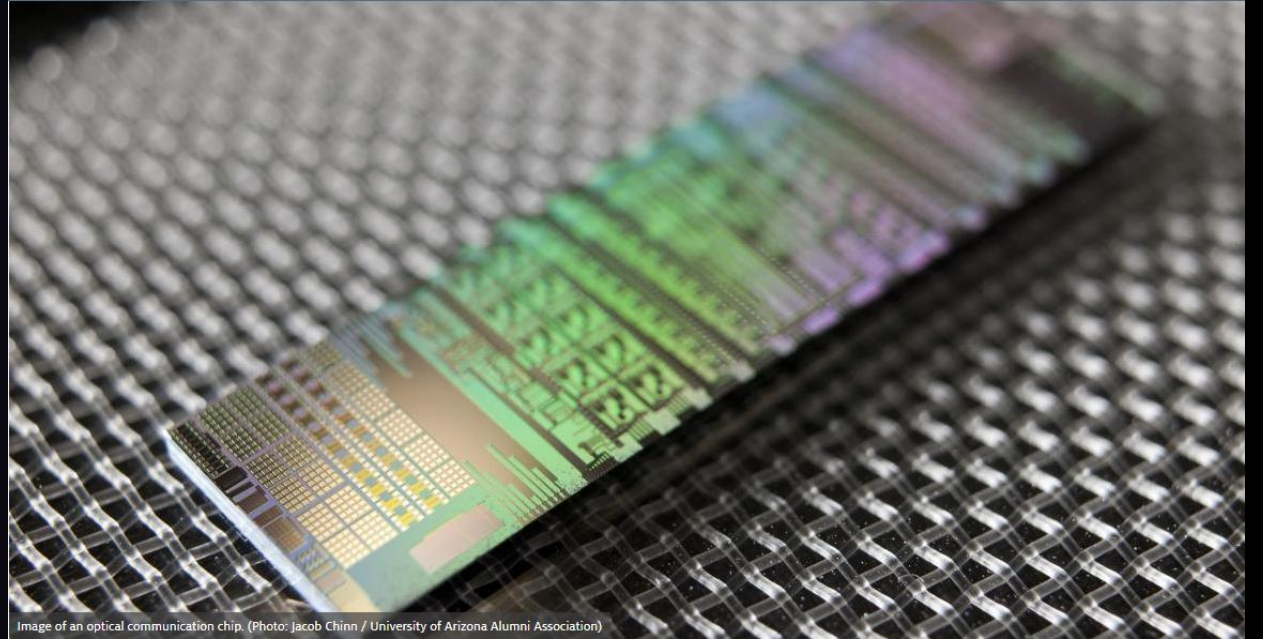


Image of an optical communication chip. (Photo: Jacob Chinn / University of Arizona Alumni Association)

Image of an optical communication chip. (Photo: Jacob Chinn / University of Arizona Alumni Association)

[University of Arizona Awarded \\$26M to Architect the Quantum Internet | News | College of Engineering | The University of Arizona](#)



# Pathways for High School & College Students



What can you do to get involved with the Quantum World?

1. Be interested
2. Find a Mentor
3. Take Action

# Get involved with the Quantum World.

## 1. Find good mentors

1. Start with your Physics Teacher

## 2. Take Action:

1. Go to my website, click on links and read articles
2. Watch YouTube videos on Quantum
3. Find hands-on workshops close to home
4. Take on-line courses
5. Got to a college that offers quantum courses
6. Take an internship that works in the field
7. Join a club or start one your self

Hybrid curriculum for upskilling photonics technicians in advanced optics, spectroscopy and quantum research enabled technologies

**Donn Silberman**  
Consultant  
949-636-6170  
donn@oisc.net  
www.edquantum.org



This project is supported by National Science Foundation grant DUE2055061

---



**Donn Silberman**  
donn@oisc.net 949-636-6170

To learn more about Donn's related endeavors scan the QR code.

This is my business card – you can have one - FREE

# On-line and In-Person Resources

A network diagram consisting of numerous white circular nodes connected by thin white lines, set against a dark blue background. The nodes are arranged in a complex, interconnected pattern, resembling a molecular structure or a data network. The lines vary in thickness, with some appearing as simple thin lines and others as thicker, more prominent bands.

# Quantum for Students

This web page is a resource for students who may have seen my presentation.

[Click here to download a pdf version of the slides.](#) If you would like to give a version of this presentation, contact Donn directly.

## Quantum Educational Resources

[Available Courses | qBraid](#)

[DoS - Domain of Science - YouTube](#)

[Map of Quantum Computing Poster – DFTBA](#)

[Qiskit - IBM's Open Source Quantum Computing Resource](#)

[Quantumapalooza 2020 Harrisburg University](#)

[QuVis \(st-andrews.ac.uk\)](#)

[Key Concepts for Future QIS Learners \(illinois.edu\)](#)

[Schrödinger's Class | Institute for Quantum Computing | University of Waterloo \(uwaterloo.ca\)](#)

(for the Schrödinger's Class materials, contact Donn directly)

[Quantum for Students | opticsage \(donn601.wixsite.com\)](#)

# Quantum for Students

## Quantum Educational Resources

[DoS - Domain of Science - YouTube](#)

[Map of Quantum Computing Poster – DFTBA](#)

[Qiskit - IBM's Open Source Quantum Computing Resource](#)

[Schrödinger's Class | Institute for Quantum Computing | University of Waterloo \(uwaterloo.ca\)](#)

[Quantum for Students | opticsage \(donn601.wixsite.com\)](#)

# THE MAP OF QUANTUM COMPUTING

### CLASSICAL VS. QUANTUM

**CLASSICAL COMPUTING**  
1 BITS AT A TIME  
ALL ARE PARTS OF EACH OTHER

**QUANTUM COMPUTING**  
QUBITS  
QUBITS ARE IN A COMBINED STATE TOGETHER

### MODEL QUANTUM COMPUTING

**SUPERCONDUCTING**  
QUANTUM TUNNELING  
QUANTUM COHERENCE

**ION TRAP**  
ION TRAP  
ION TRAP

**PHOTONIC**  
PHOTONIC  
PHOTONIC

### POTENTIAL APPLICATIONS OF QUANTUM COMPUTERS

**CRYPTOGRAPHY**  
CRYPTOGRAPHY  
CRYPTOGRAPHY

**OPTIMIZATION**  
OPTIMIZATION  
OPTIMIZATION

**DRUG DISCOVERY**  
DRUG DISCOVERY  
DRUG DISCOVERY

### PHYSICAL REALISATIONS

**SUPERCONDUCTING QUANTUM COMPUTERS**  
SUPERCONDUCTING QUANTUM COMPUTERS

**ION TRAP QUANTUM COMPUTERS**  
ION TRAP QUANTUM COMPUTERS

**PHOTONIC QUANTUM COMPUTERS**  
PHOTONIC QUANTUM COMPUTERS

### QUANTUM ALGORITHMS

**MULTIPLICATION**  
7177 x 3801  
21538177

**FACTORISATION**  
21538177  
7177 x 3801

**SEARCH**  
7177 3801

### COMPLEXITY THEORY

**NP-COMPLEX**  
NP-COMPLEX

**NP-HARD**  
NP-HARD

**NP-COMPLET**  
NP-COMPLET

### PHYSICAL REALISATIONS

**DIAMOND QUANTUM COMPUTERS**  
DIAMOND QUANTUM COMPUTERS

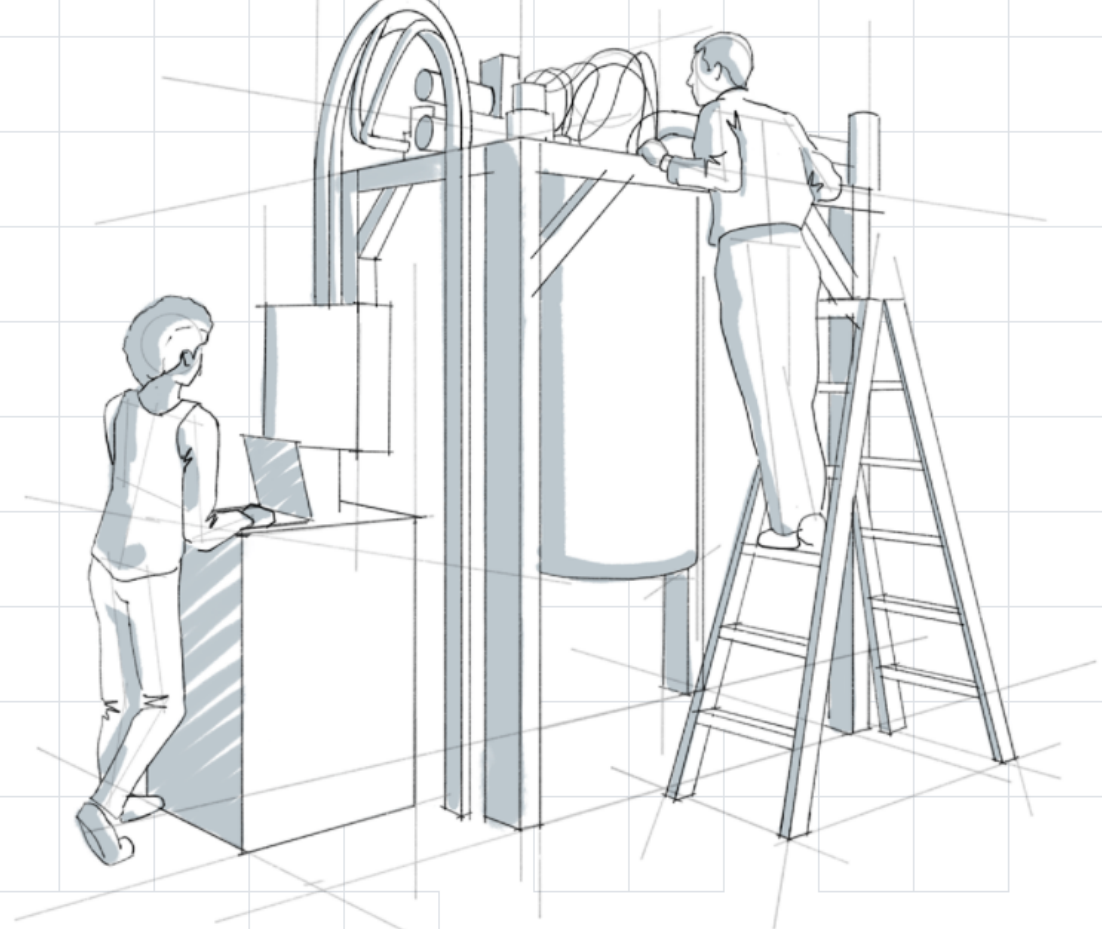
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# Open-Source Quantum Development

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

Get started 



[Qiskit.org](https://qiskit.org)

## Quick Start

When you are looking to start Qiskit, you have two options. You can start Qiskit locally, which is much more secure and private, or you get started with Jupyter Notebooks hosted in IBM Quantum Lab.

### Start locally

To install Qiskit locally, you will need [Python 3.6+](#). Although it is not required, we recommend using a [virtual environment with Anaconda](#).

## IBM's Education System – it's FREE

Start Online

Get started in the cloud with

Cookie Preferences and Do Not Sell My Info

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## Schrödinger's Class

Applications for Schrödinger's Class 2021 are now closed.

### Quantum for high school teachers

Learn how to teach quantum in your high-school class, and gain the tools to do it.

### A free online workshop series for 2021

Schrödinger's Class 2021 will be held as a series of online micro-workshops this fall, geared toward lessons that can be implemented both in-person and virtually.

Registration is free and open to all interested teachers, but space is limited.

### Online workshop schedule 2021

Schrödinger's Class will be offered in two identical sessions. Successful applicants will be asked to sign up for **either** Session 1 (evenings) **or** Session 2 (weekend).

[EXPAND ALL](#)
[COLLAPSE ALL](#)

SESSION 1: TUESDAY, NOVEMBER 30-THURSDAY, DECEMBER 2 ▾

SESSION 2: SATURDAY, DECEMBER 4-SUNDAY, DECEMBER 5 ▾

### What is Schrodinger's Class?

**It is a professional development workshop for secondary school science teachers that takes**

Interested in attending a local  
Quantum Education Workshop ??



# Kahoot #2

[CLICK HERE FOR LINK](#)

# Experience Life in the QuantumOptics Age

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.



## Follow the Digital White Rabbit

To learn more about:



### Contact Us

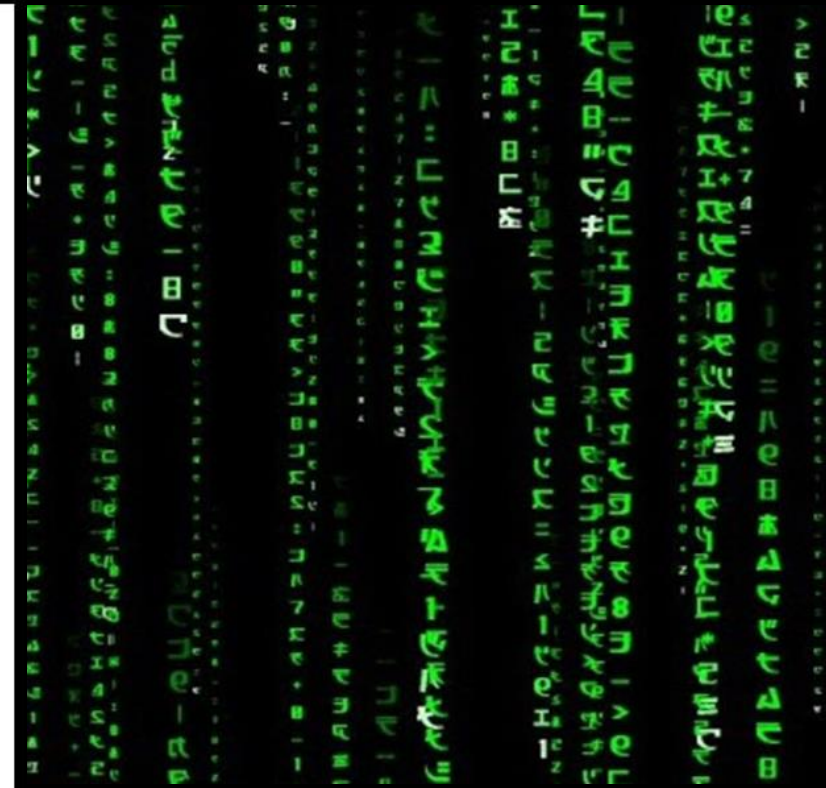
First Name

Last Name

Email \*

Write a message

Submit





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**

Optics Institute of Southern California

<http://oisc.net>