

# Quantum Education & Outreach

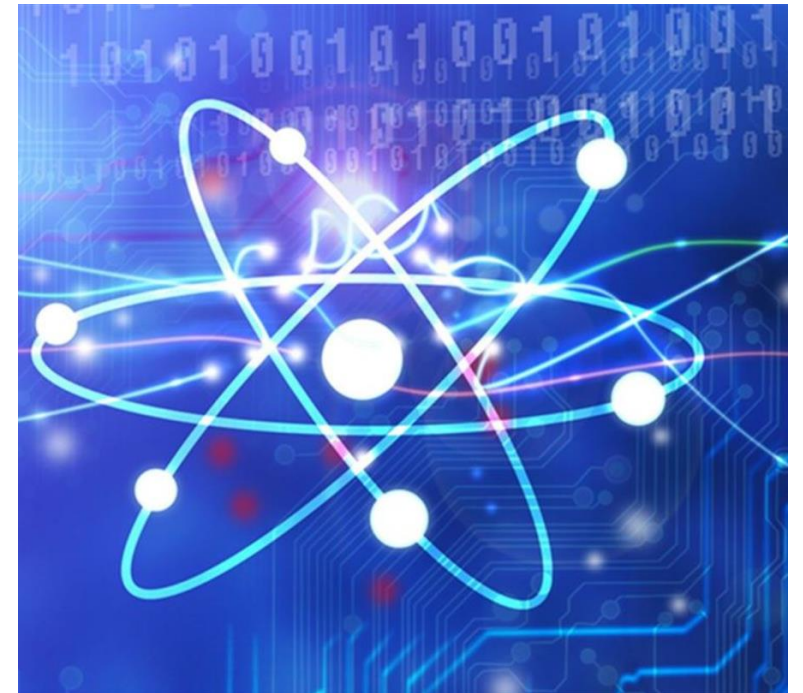
## Education & Career Pathways

**Donn M. Silberman**

OSSC Fellow & Past President  
OSSC Outreach Chair 2022-2023

Optics Institute of Southern California, Founding Director  
<http://oisc.net>

Wed. Nov. 16, 2022



A Special Thanks to  
Mark Bandhauer  
and the OSSC for my  
1<sup>st</sup> presentation



**OPTICAL SOCIETY  
OF SOUTHERN CALIFORNIA**

**MEETING  
NOTICE**

**IOLAB Plant Tour / Lecture  
by Donn M. Silberman  
Wednesday, March 3, 1993 at 6:30 p.m.**



**SPEAKER:** Donn M. Silberman, received his B.S. in Engineering Physics (with honors in Physics) from the University of Arizona in 1983. During his school years at the U of A, he worked at the Optical Sciences Center, taught undergraduate physics labs, and was president of the local Society of Physics Students chapter. His senior honors project, "Optical Levitation", was published in the Journal of Undergraduate Research in Physics. He then worked at Melles Griot Laser Products Division developing the green and infrared HeNe lasers. In 1984 he began working at Spectron Development Laboratories researching particle sizing and laser velocimetry. This work led to a position at American Hospital Supply Corp. (Baxter) where he investigated in-vivo Doppler laser velocimetry and other fiber optic biomedical sensors. Currently, he is a Sr. R&D (Optical) Engineer and Optics Group Leader at IOLAB Corp., a Johnson & Johnson Company, where he leads the companies multifocal intraocular lens (IOL) projects. He has given presentations at SPIE and OSA conferences on Image Quality Evaluation of Multifocal Intraocular Lenses, and hold two patents on novel multifocal IOL designs.

**SUBJECT:** IOLAB, a Johnson & Johnson Company is committed to the continuous improvement of vision care and the surgical treatment of cataracts. IOLAB Corp. has taken a leadership role in developing multifocal IOLs for pseudophakic patients. These lenses have the ability to correct for both near and distance vision after cataract extraction. This represents a significant improvement over monofocal IOLs that require the patients to wear eye glasses most of the time. A presentation on this technology will follow an introductory video on cataracts, eye surgery, and IOL manufacturing technologies. A tour of the IOLAB manufacturing facility will complete the evenings proceedings. Spouses and guests with an interest in eye care and vision are encouraged to attend.

**BUSINESS:** A new job listing service has been made available for Corporate Members who have positions available. Please call Tolle Desis at JPL at (818) 354-9517 to list your openings. Job openings will be announced at the following meeting.

**PLACE:** IOLAB Corp., 500 IOLAB Drive, Claremont, CA (Map on back)

**TIME:** Wednesday, March 3, 1993. Dinner, cafeteria style (full meal) served at 6:30 p.m. The speaker will follow at approximately 7:30 p.m. Tour from about 8:15 - 9:00 p.m. No cameras or recording equipment allowed.

**RSVP:** Call Sharon or Gale at ORA, (818) 795-9101. **Please call in reservations (with all names) for tour (even if not eating dinner) by Friday, March 3.** As always, guests and spouses are most welcome. Dinner is \$15.00. For meeting or membership information, please call the OSSC hotline at (909) 399-1799 x6300 (Do not use # key).

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Pasadena, CA 91108  
(818) 795-9101

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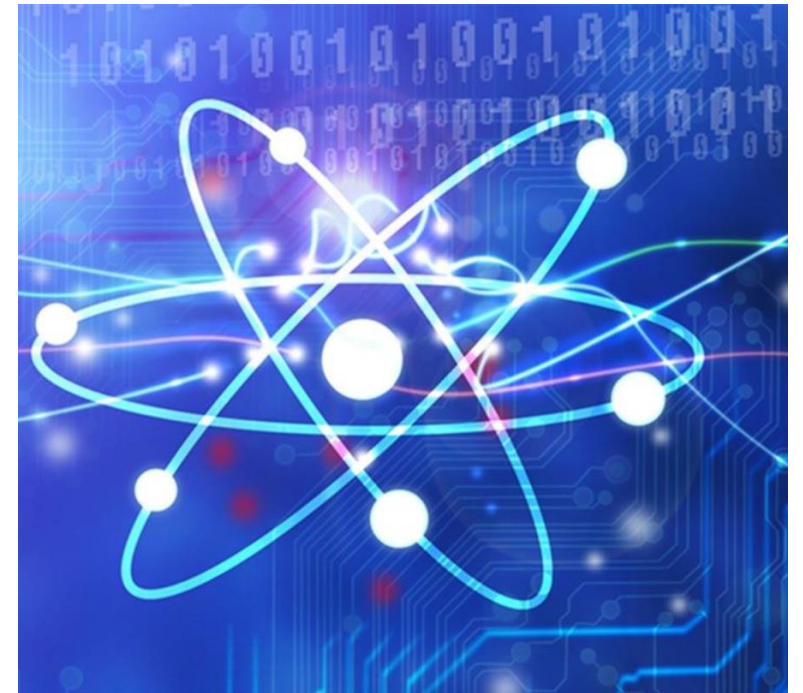
Neil Johnson  
  
Fellowship/Membership  
Scholarship Chair  
David Kramer

**Counselors**

Susan Haffensperger  
Don Wolpert  
Mark Bandhauer

# Today's Topics

1. Getting Oriented with Quantum Education
2. Motivation for the process described
3. Creating the “Quantum Pipeline” – Paths Forward
4. The Samueli Academy’s “Schrodinger’s Club”
5. Quantum Cryptography – Univ. of Waterloo
6. Hands-on Lab for Students
  - a) Polarization
  - b) Atomic Spectroscopy & Laser Diffraction Lab
  - c) Qubit x Qubit – with IBM’s Qiskit
7. Summary with Q&A





1290 1310 1330 1350 1370 1390 1410 1430 1450 1470 1490 1510 1530 1550 1570 1590 1610

1290

1390

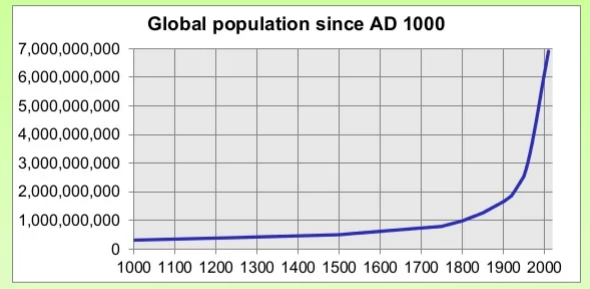
1490  Sailing ship

1590

EARTH ORBIT IN MAN MADE ENVIRONMENT CONTROL:  
PRODUCT OF SUCCESSFUL APPLICATION OF HIGH  
PERFORMANCE PER UNIT OF INVESTED RESOURCES

PROFILE OF THE INDUSTRIAL REVOLUTION  
AS EXPOSED BY THE CHRONOLOGICAL RATE  
OF ACQUISITION OF THE BASIC INVENTORY OF  
COSMIC ABSOLUTES—THE 92 ELEMENTS

Dimensions of Growth: Population



World Population:  
from 1 billion in 1800 to 7 billion in 2012

Leonardo De Vinci  
Columbus  
Copernicus

Galileo

Newton

Watt  
Washington

Avogadro  
Lincoln

9 ELEMENTS WERE ACQUIRED BY CRYSTALLIZATION FROM THE HISTORIC RECORDS OF THE EVENTS, PROBABLY IN 4000 MILENIUM AGO

CARBON	*6	C
LEAD	*82	Pb
TIN	*50	Sn
MERCURY	*80	Hg
SILVER	*47	Ag
COPPER	*29	Cu
SULPHUR	*16	S
GOLD	*79	Au
IRON	*26	Fe

1670 1690 1710 1730 1750 1770 1790 1810 1830 1850 1870 1890 1910 1930 1950 1970 1990 2010 A.D.

1890  Steamship

Airplane Rocket

1990

Steel  
Dynamo  
Automobile  
Flight  
Electronics  
Talky

Boyle

Newton

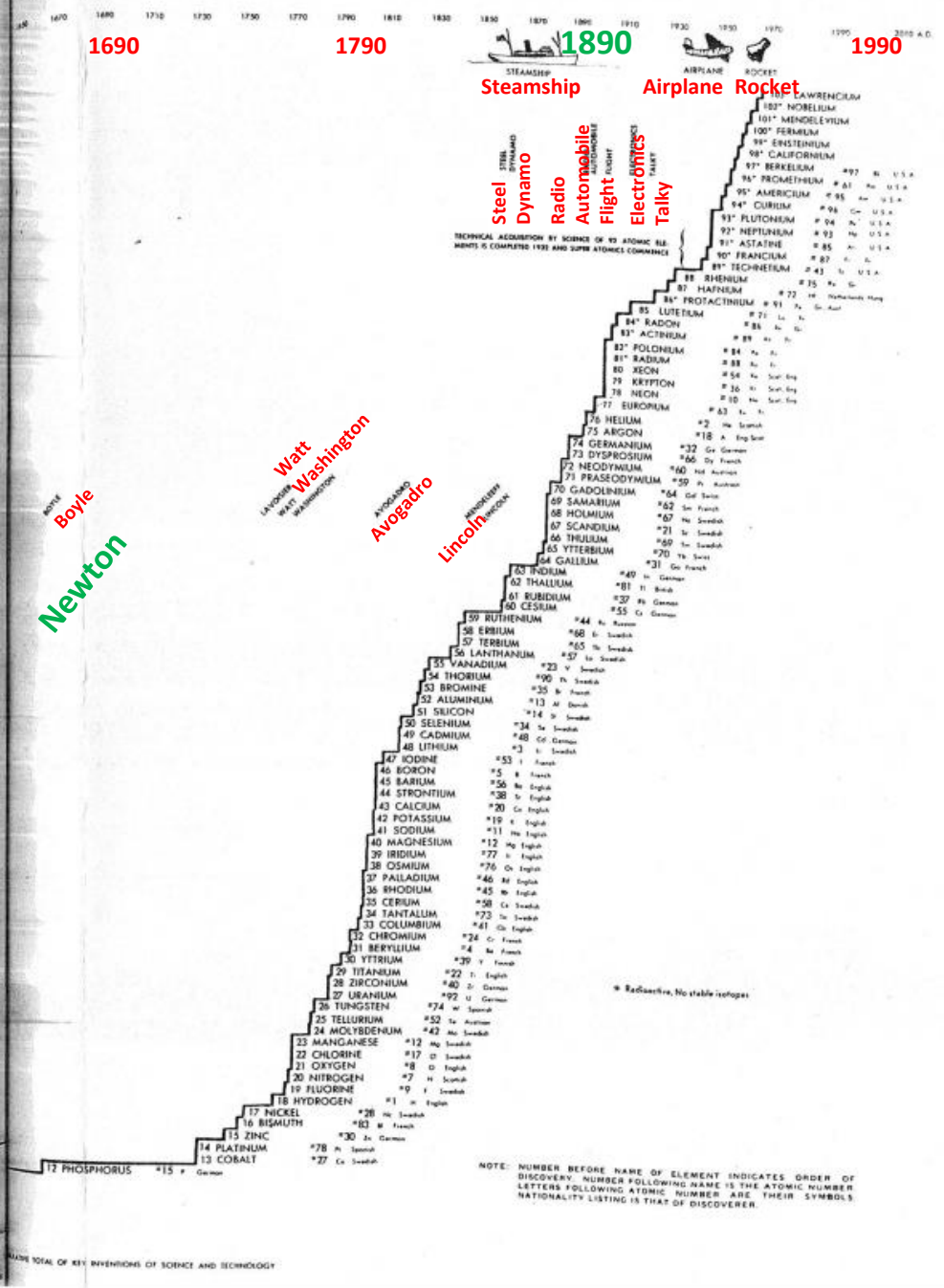
Watt  
Washington

Avogadro  
Lincoln

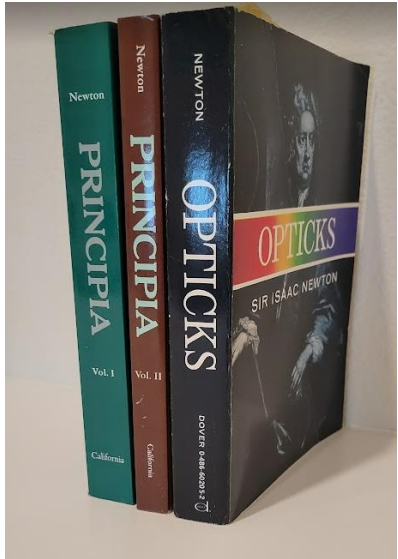
Who learns science and why?

11 ANTIMONY \*51 Sn German

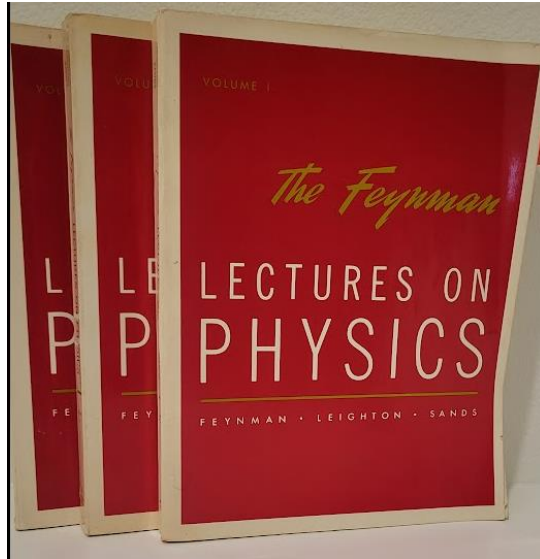
Buckminster Fuller, Synergetics, 1975



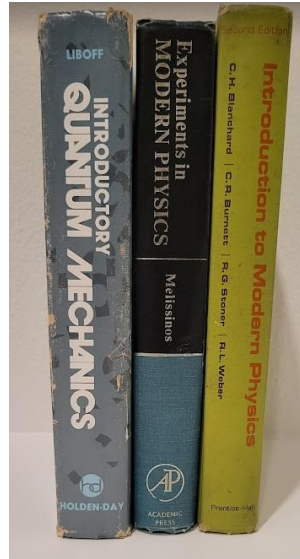
# How do we teach physics and to whom?



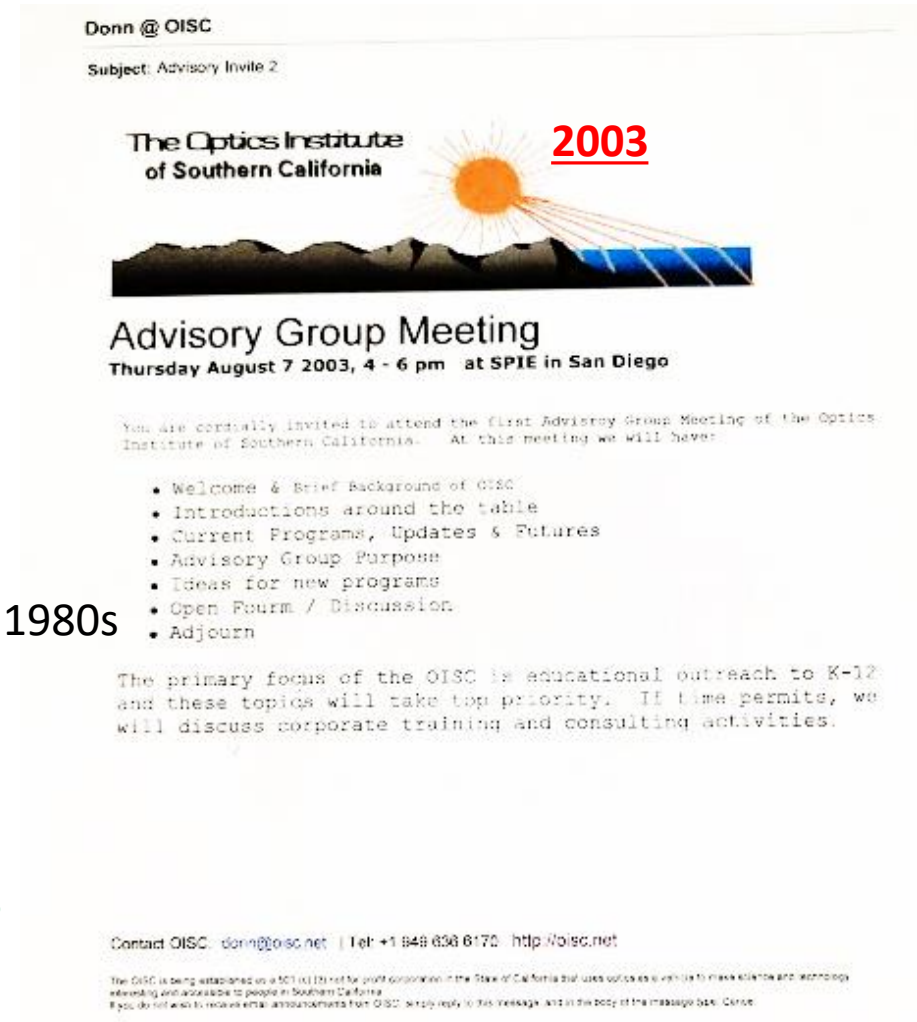
Newtonian Physics



Feynman Lectures Series



Donn's Quantum Books – 1980s



Seems like students 'self-select' themselves to learn science & technology.

Throughout recorded history, only people with 'time and ability' could learn.

Now many more people have both 'time and ability' to learn science.

But how do we get the message to young people that science is fun and interesting??



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# Experience Life in the QuantumOptics Age

OpticsAge is a focal point for Donn Silberman's Optics Education Adventures

[Weirdness and wonder: Quantum entanglement work wins 2022 Nobel Prize for Physics \(spie.org\)](#)



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[Quantum for Volunteers](#)

[Quantum Edu & Work](#)

[Quantum Cybersecurity](#)

[Donn's Quantum Explorations](#)

[EdQuantum - Industry Survey](#)



FELLOW

[Donn's OSSC Bio](#)

[OSSC Annual Report 2017-2018](#)

## Welcome to EdQuantum Project

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



High School Students program starts soon.

Quantum  
WORLD CONGRESS

Nov. 29 - Dec. 1, Washington, D.C.

THE UNIVERSITY OF ARIZONA



[JWST at the UA](#)



[Optics Outreach Materials donated from the OISC](#)



[UCI Optical Engineering 10 yrs - Photonics Spectra from Sept 2019 Photonics Spectra Magazine Information Session - August 2019 - YouTube](#)



This website is now for archival purposes only to be an educational resource.

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

This website is now for archival purposes only to be an educational resource.

**eLas Americas**

This website is now for archival purposes only to be an educational resource. eLas Americas is closed for business. Thank you for your past support.



**Career Assistance Here**



**OPTICS & PHOTONICS GLOBAL SALARY REPORT 2022**

[New Career Assistance page](#)



# Experience Life in the Optics Age

OpticsAge is a focal point for Donn Silbermintz, Wm. Bickel - Collected sayings and photos

[Weirdness and wonder: Quantum entanglement work](#)

[Career Assistance](#)

[UC Irvine DCE On-Demand](#)

[New HOME Draft](#)

[Careers \(spie.org\)](#)



## 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](#).

[Careers | Optica](#)

[Optics and Photonics Jobs](#)

[SPIE Career Development | Membership \(spie.org\)](#)

[Education & Careers - IEEE Photonics Society](#)

[Physics Today Jobs](#)

[Quantum Computing Jobs \(quantumcomputingreport.com\)](#)

[Homepage - Quantum Jobs.net](#)

[QED-C | Quantum Jobs | QED-C \(quantumconsortium.org\)](#)



## Hands-On Optics Making an Impact with Light



An educational collaboration  
of SPIE, OSA, NOAO



# A little History 2005

This unique informal science program, funded by the National Science Foundation, pairs optics professionals with science teachers to introduce underserved middle school students to the exciting world of optics. Optics is all about what light is made of and how it behaves. Optics can be found in many everyday situations, from eyeglasses to CD's to hospitals to outer space.

The hands-on, high-interest, standards-connected activities and materials developed by "Hands-On Optics" (HOO) provide six fun and engaging optics activity modules. Educators, parents, science center staff and optics professionals work with HOO activities via informal education programs that range from Saturday morning programs to after-school activities and science center events. HOO serves a dual role: it introduces teachers and students to basic optics concepts. While introducing them to professionals who make a living through optics.

Visit the "Hands-On Optics" Web site: <http://www.hands-on-optics.org/>



Dr. Murty - The Wizard of Light has been an inspiration for many volunteer optics educators and outreach associates.

© 2005 OSA/FIO 2005

FThD2

### Optricks Day, Optricks Demos, Optricks Suitcases, Optricks Theme Packets; What are all these Optricks Anyway?

Donn M. Silberman, Optics Institute of Southern California

#### Abstract

"Optricks" seems to have been coined back in the 1970s by Dr. Murty Mantravadi in Science Today's Series for Young Readers. Recently, it has been applied to outreach tools and activities in his honor.



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ABET

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## Hands-On Optics | Practical Optics & Photonics Education Tools

### Making an Impact with Light

Hands-On Optics (HOO) was a four-year informal science education program funded by a \$1.7 million grant from the National Science Foundation (NSF). The project was collaboration between SPIE, the Optical Society of America (OSA) and the National Optical Astronomy Observatory (NOAO).

The program brought science education enrichment to thousands of underrepresented middle school students in more than ten states, including female and minority students, who typically have not been the beneficiaries of science and engineering resources and investments. HOO provided more than 100 teachers with up to six activity modules, each containing enough materials for up to 30 students to participate in 6-8 hours of hands-on optics-related activities. Sample activities, developed by education specialists at NOAO, include building kaleidoscopes and telescopes, communicating with a beam of light, and a hit-the-target laser beam challenge.

Through these activities, students gain experience and understanding of optics principles, as well as learning the basics of inquiry, critical thinking, and problem solving skills involving optics, and how optics interfaces with other disciplines. While the modules were designed for use in informal after-school or weekend sessions, the number of venues has expanded to large and small science centers, Boys and Girls Clubs, Girl Scouts, summer camps, family workshops, and use in the classroom.

### Hands-On Activities

#### [I'm Under a Lot of Stress Here!](#)

Structural engineers and other scientists are always trying to find ways to make structures lighter and stronger.

#### [Fun With the Sun](#)

The Sun gives off a great deal of energy in the ultraviolet (UV) range of the EM spectrum.

#### [Hit the Target](#)

This is the culminating activity, requiring students to use all the practiced skills from the previous activities.

#### [Three Lasers Converging at a Focal Point: A Demonstration](#)

In this activity, students will see how we can use the property of refraction to focus parallel rays of light.

#### [Laser Light: An Activity](#)

This simple activity will help students visualize the difference between laser light and normal light.

#### [Multiple Reflections](#)

We know that when light reflects off a plane mirror, the image appears left/right reversed.

**Polarization**

**Lasers & Lenses**

**Currently available !!**

***Polarization and Lasers can help educate students about Quantum.***





### UPCOMING EVENTS

No Upcoming Events

### PARTNERS



## What Is The NPI?

In 1998, the National Research Council released a report, "Harnessing Light: Optical Science and Engineering for the 21st Century," that presented a comprehensive view of the potential impact of **optics and photonics** on important industries. In response, several economies – including Germany, China, and the European Union – advanced their already strong optics and photonics sectors. The United States, however, did not develop a cohesive strategy, leaving us at risk of falling sharply behind.

In 2012, the National Research Council released a follow-up report to Harnessing Light - titled "Optics and Photonics: Essential Technologies for our Nation" - that called for an umbrella organization to identify and advance areas of photonics critical to maintaining competitiveness and national security. Heeding the call five organizations – **The Optical Society (OSA)**; **SPIE, the international society for optics and photonics**; the **IEEE Photonics Society (IPS)**; the **Laser Institute of America (LIA)**; and the **American Physical Society (APS) Division of Laser Science** – worked together to form a National Photonics Initiative (NPI).





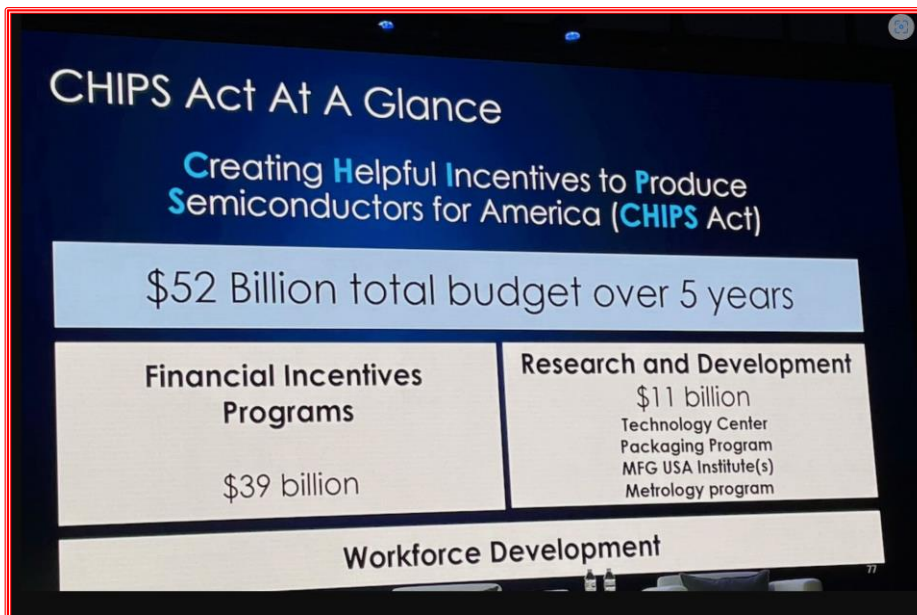
## Formation

In 2014, the United States Office of the Secretary of Defense identified interest in developing a Manufacturing Innovation Institute in the field of integrated photonic circuits. This resulted in the Air Force Research Laboratory publishing a funding opportunity announcement (FOA-RQKM-2015-0009) which ultimately lead to the award of the Integrated Photonics Institute for Manufacturing Innovation operating under the name of the “American Institute for Manufacturing Integrated Photonics.” The Research Foundation for The State University of New York and The United States of America USAF/AFMC entered into Cooperative Agreement Number FA8650-15-2-5220, dated July 9, 2015 for Phase I of AIM Photonics. On September 29, 2021, a new cooperative agreement was signed and extends federal funding for the institute for another seven years.

The Research Foundation for The State University of New York, acting on behalf of SUNY Polytechnic, serves as the administrator of AIM Photonics. AIM Photonics is an unincorporated research and development center. AIM Photonics operates as a program of SUNY Poly, with the Foundation and SUNY Poly providing administrative support to AIM Photonics, and jointly participating in AIM Photonics as an AIM Photonics member.



And recently we have the new CHIPS Act







PROTOTYPING SERVICES

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SUMMER ACADEMY

PHOTONICS BOOT CAMPS

VIRTUAL LAB SIMULATION LIBRARY

DEGREE AND CERTIFICATION PROGRAMS

TEACHING RESOURCES

PHOTONICS WORKFORCE ROADMAP

**We provide end-to-end silicon photonic manufacturing that supports both current and future technologies**

We offer start-ups, designers and developers, and academic researchers access to a supporting infrastructure of services across the entire silicon photonics development cycle: design, simulation, fabrication, packaging, validation, and a path to volume manufacturing.



# Motivatio

An official website of the



<quantum|g

# NATION

THE FEDERAL SOUR

# W

elcome to *quan*  
Quantum Initiative and ong  
Quantum Information Scier  
Act was signed into law on



## Meeting Announcement

June 12, 2019  
Annual Business Meeting

### Quantum Computing & The National Quantum Initiative

Dr. Sandy Irani, UC Irvine & Dr. Jonathan Habib, USC

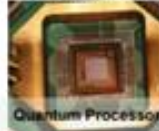


Quantum computing is the use of quantum-mechanical phenomena such as superposition and entanglement to perform computation. A quantum computer is used to perform such computation, which can be implemented theoretically or physically.

The National Quantum Initiative (NQI) Act is an Act of Congress passed on December 13, 2018 and signed into law on December 21, 2018. The law gives the United States a plan for advancing quantum technology, particularly quantum computing. OSSC Fellow Donn Silberman will briefly review the NQI and introduce our speakers.

Visit <https://www.opticsage.com/donn-s-quantum-explorations> to explore these topics prior to the meeting.

**About our speakers:** **Dr. Sandy Irani** received her PhD from UC Berkeley in 1991 after which she was a University of California President's Postdoctoral Fellow at UCSD. She joined the faculty of UC Irvine in 1992 where she is currently a full professor. Much of her research has focused on algorithm design and analysis with an emphasis on applications to computing systems. In the last few years she has been working in Quantum Computation and Quantum Information Science.



**Dr. Jonathan L. Habib** is an experimental physicist and research lead at the University of Southern California information Sciences Institute (ISI). His research has focused on photon-starved, classical communication and imaging, quantum-secured optical communications in free-space and fiber, and integrated nano-photonics for both classical and non-classical applications. Prior to joining ISI, Dr. Habib was with BBN technologies where he served as principal investigator for a number of DARPA-sponsored research programs, partnering with university collaborators to demonstrate revolutionary optical technologies impacting traditional communications, sensing and computation systems.



Reception: 6:00; Dinner starts @ 6:30  
OSSC Business: 7:00; Presentations: 8:00  
Dinner – Cost: \$35  
\$40 after June 7<sup>th</sup>  
OSSC Student Members: \$10,  
\$20 after June 7<sup>th</sup>

**Brea Civic & Cultural Center**  
1 Civic Center Circle  
Brea, CA 92821  
(714) 990-7600

On-line Registration: [www.osscc.org](http://www.osscc.org) or  
Contact: Alex Small, OSSC Arrangements Chair,  
arsmall@cpp.edu  
(909) 869-5202

REPORTS NEWS NQCO

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[agic Plan, February 1, 2022](#)

December 6, 2021

[nformation Science, October 5, 2021](#)

**SPIE. OPTICS+PHOTONICS**  
Conference 12213  
**Optics Education and Outreach VII**  
22 August 2022 | Conv. Ctr. Room 17B



IBM Sponsored High School program

**UCI** Division of Continuing Education  
Optical Engineering & Optical Instrument Design



**Quantum** WORLD CONGRESS  
Nov. 29 - Dec. 1, Washington, D.C.

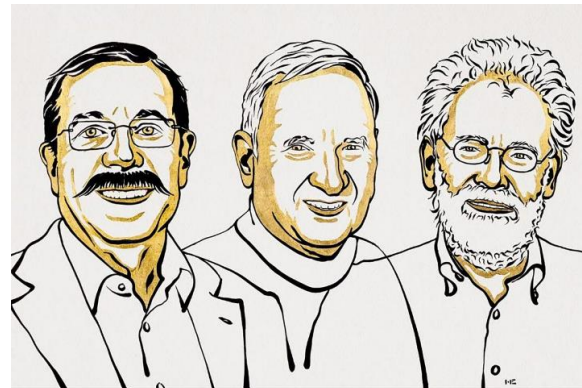
**PASADENA CITY COLLEGE**  
Laser Technology Program

**SCHRODINGER'S CLUB**  
AT SAMUELI ACADEMY

Brown Bag Educational Lunch Series  
Introducing optics to undergraduate ECE students and photonics outreach projects



**vital link**



Weirdness and wonder: Quantum entanglement work wins 2022 Nobel Prize for Physics  
Alain Aspect, John Clauser, and Anton

October 5<sup>th</sup>, 2022  
12 – 1 PM

Speaker:  
**UCSD SPIE Student Chapter**

**DRS DAYLIGHT SOLUTIONS**

**Corona Del Mar High School  
Python Programming Class  
Tues. Nov. 22 – Intro to Quantum Computing**

**High School Quantum Workshop  
Friday Nov. 18th**



**SPIE.** DIGITAL LIBRARY

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4 Presentation + Paper

Select Language

Translator Disclaimer

3 October 2022

### Quantum education and pathways: an open-source modifiable presentation to high school and college students

*Donn M. Silberman*

Author Affiliations +

Proceedings Volume 12213, Optics Education and Outreach VII; 1221308 (2022)

<https://doi.org/10.1117/12.2641537>

Event: SPIE Optical Engineering + Applications, 2022, San Diego, California, United States

ARTICLE CITED BY

#### Abstract

This paper describes and provides examples of a presentation, 'Quantum for High School and College Students' created to give to high school and college students to encourage them to consider using quantum science and technologies in their studies and careers. Some thoughts on critical thinking about abstract subjects and mentoring capture the attention of the student audience, which is followed by the main topics. The presentation includes an introduction to quantum science (including a laser diffraction demonstration), quantum computers and cybersecurity, many more quantum science and technology applications, education and career pathways that use quantum science and on-line resources. There is a very brief history of

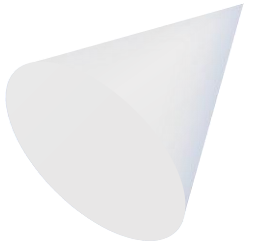
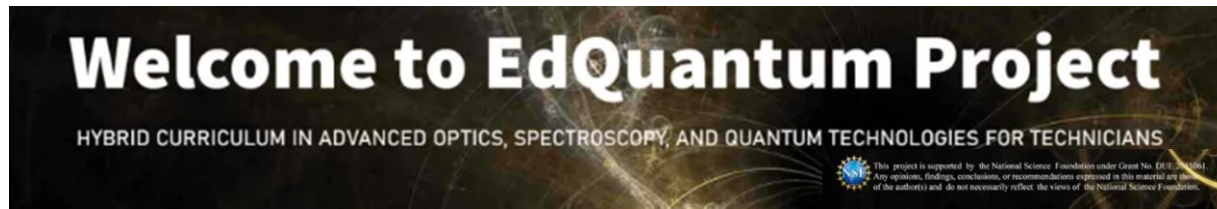
Quantum education and pathways: an open-source modifiable presentation to high school and college students

# Topics for today

1. Motivation for creating an open-source modifiable presentation to High School & College Students
2. The modifiable content
3. Laser Diffraction Demonstration (a Quantum Device)
4. Using 'Kahoot! For Schools' - Realtime quizzes
5. Additional resources for presenters, teachers and students
6. Logistics (how to get the modifiable presentation)
7. Results so far (this is good !!) >>> Future Work
8. Questions & Answers



# Motivation:



12213-19



## Upskilling photonics technicians to meet challenges of quantum 2.0 revolution

Author(s): Moamer Hasanovic, Indian River State College (United States); Chrysanthos Panayiotou, LASER-TEC, National Ctr. for Laser-Photonics and Fiber Optics Education (United States); Donn Silberman, Optics Institute of Southern California (United States)

Hide Abstract -

**A presentation was given in afternoon during the August SPIE Conference..**

Recent advances in quantum research have created a significant mismatch between quantum science and the emerging quantum industry, as there is no sizable trained workforce to support product commercialization. Part of this new workforce will be developed through upskilling of incumbent photonics technicians whose current qualifications present a solid foundation for the new quantum-related competencies. To provide the greatest access to these new skills, the curriculum requirements need to be delivered via flexible distance-learning platforms. In this paper, we describe our efforts to produce an open-access educational curriculum to introduce new quantum-related competencies to an incumbent workforce. A detailed list of the competencies sought by the quantum industry is given followed by the results of a survey through which the proposed competencies were assessed. This project pioneers the introduction of the complex subject of quantum science to advanced technological education. The proposed curriculum is expected to help the US maintain the world lead in quantum technologies. This project is funded by the NSF Advanced Technological Education grant that focuses on the education of technicians for advanced technologies that drive the nation's economy.

**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**

# Motivation:

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

### 6 Alignment with the NSB Vision 2030 Roadmap

The EdQuantum project will specifically develop STEM talent for America by researching any ongoing quantum educational efforts at a middle and high school level using the support structure and network of our partners such as LASER-TEC. To develop a smart workforce, the EdQuantum will integrate into the curriculum higher-level skills such as critical thinking, problem-solving, creativity, and digital literacy as well as the STEM pedagogy and practices for diversity and inclusion. To help fill the quantum education pipeline for future years, the EdQuantum project will use educational tools and recruiting networks for K-12 so EdQuantum students, teachers, and professional industry volunteers can work with K-12 educators in their local regions to prepare K-12 students for college and university programs that include quantum technologies. To expand our outreach across the country, the EdQuantum team will leverage the assets of the Optics and Photonics College Network (OPCN)—currently consisting of 44 college programs in 29 states (see Fig. 4)—to promote the quantum educational content.

# Optics & Photonics Education Pipeline, now will include Quantum

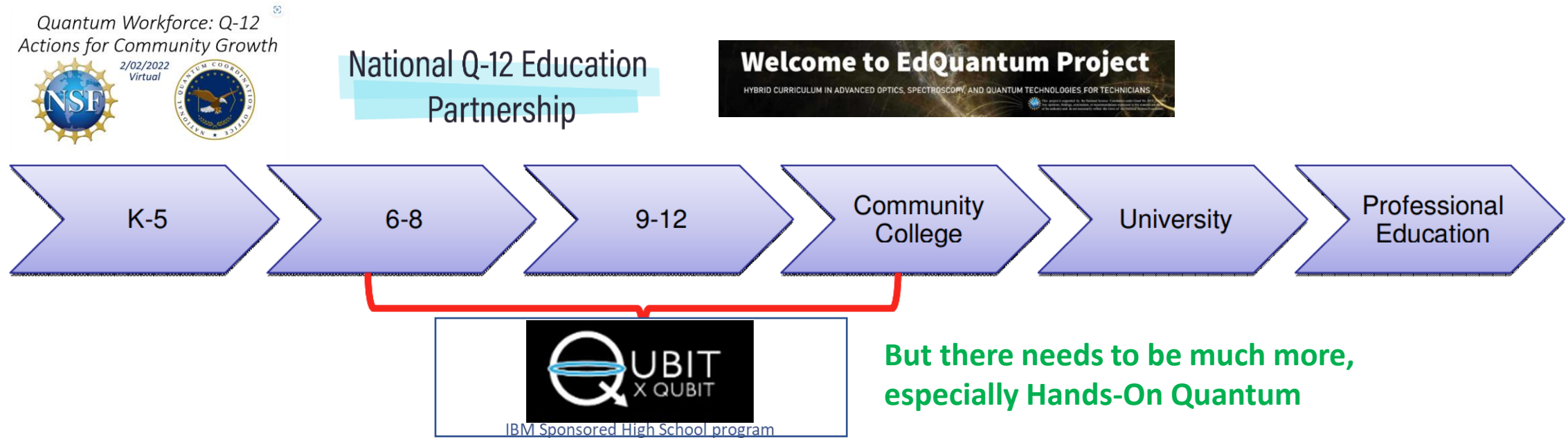


FIG. 1. This Optics education pipeline shows where OptoBotics fits into the progression of optic education outreach.

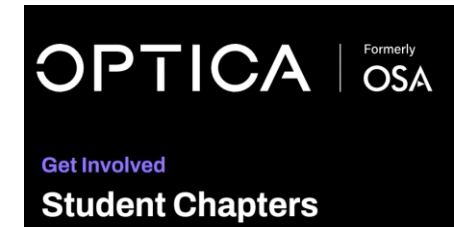
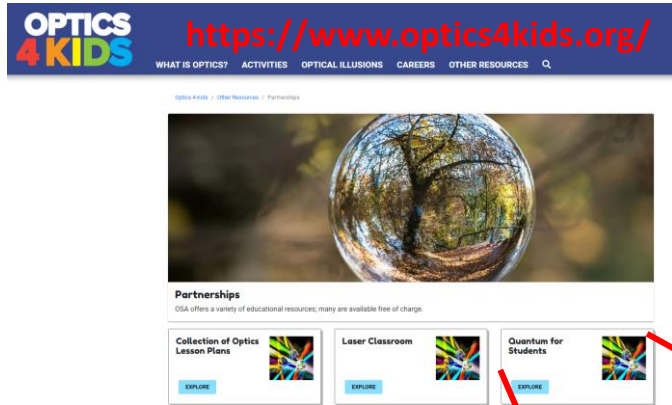
**The Quantum Industry is built on top of the optics, lasers, photonics, semiconductor & general physics fundamentals.**

Optics Education and Outreach III, edited by G. Groot Gregory, Proc. of SPIE Vol. 9188, 91880E © 2014 SPIE · CCC code: 0277-786X/14/\$18 · doi: 10.1117/12.2061268

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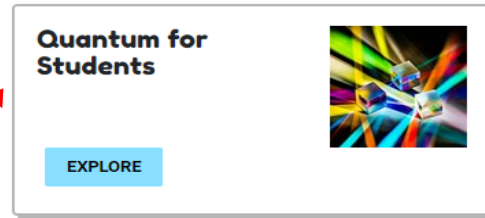
# The Quantum Education & Outreach – Paths Forward



Working with local SPIE, Optica, IEEE Photonics and other College Student Clubs to reach out to local high schools

Working with local Non-profits  
Linking K-12 school districts to industry  
And local colleges and universities

**Brown Bag Educational Lunch Series**  
Introducing optics to undergraduate ECE students and photonics outreach projects



[Quantum for Students | opticsage](https://www.opticsage.com)  
([donn601.wixsite.com](https://donn601.wixsite.com))



Corona Del Mar High School  
Python Programming Class  
Tues. Nov. 22 – Intro to Quantum Computing



October 5<sup>th</sup>, 2022  
12 – 1 PM

Speaker:  
**UCSD SPIE Student Chapter**



**High School Quantum Workshop**  
Friday Nov. 18th



# SAMUELI ACADEMY

## SCHRÖDINGER'S CLUB AT SAMUELI ACADEMY

Hands-On Laser Diffraction, Polarization & Spectroscopy



SCHRÖDINGER'S CLUB

AT SAMUELI ACADEMY

# Introduction to Quantum Cryptography

with a hands-on polarization laser lab

## Today's Agenda:

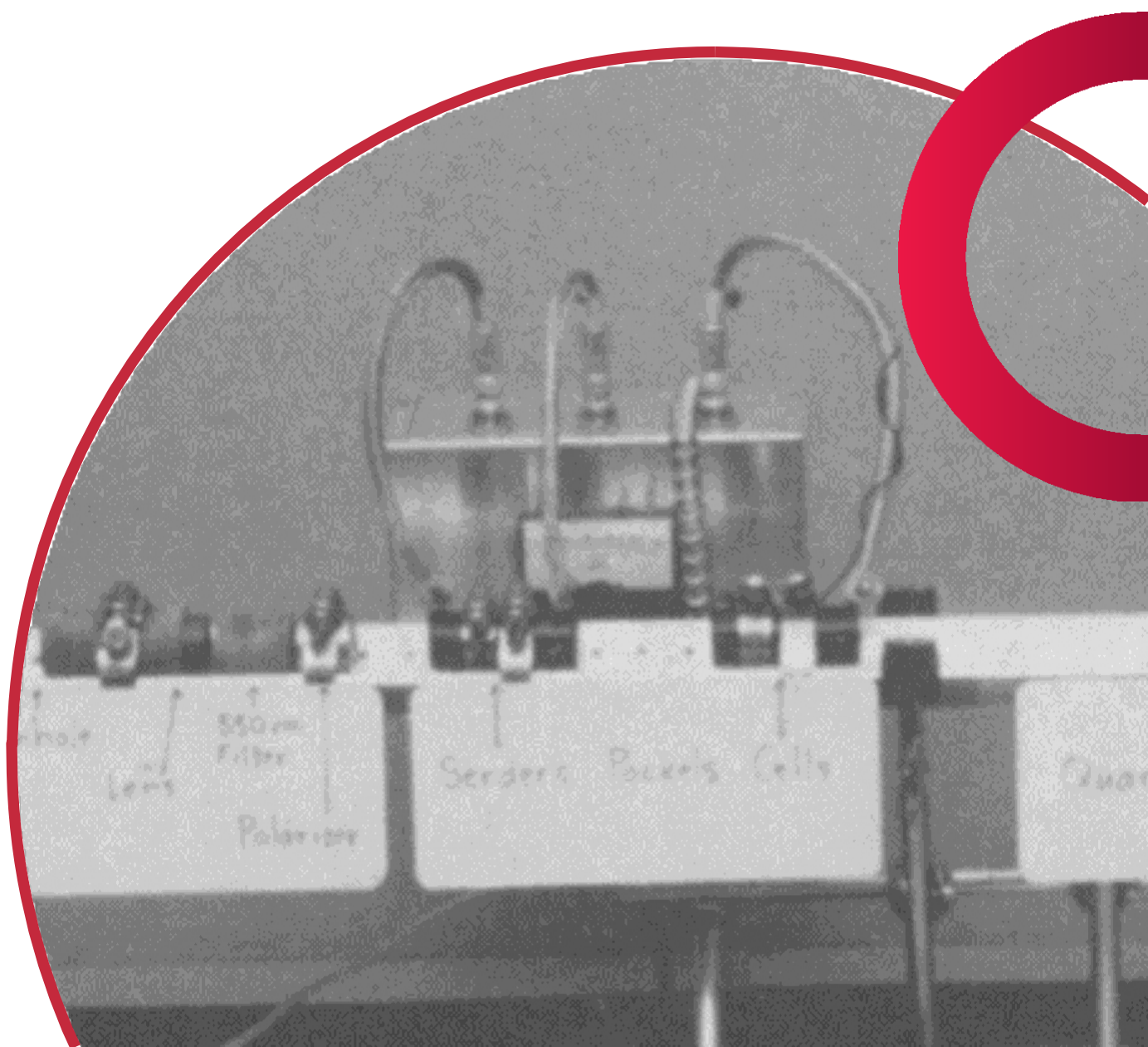
1. Introduction to light as an electromagnetic wave & polarization
2. Introductory polarization lab
3. Quantum Measurements using polarization
4. Introduction to Quantum Cryptography
5. Quantum Cryptography lab with polarization filters and lasers

**Donn Silberman**  
Mentor





# QUANTUM CRYPTOGRAPHY for High School Students



# Learning Objectives

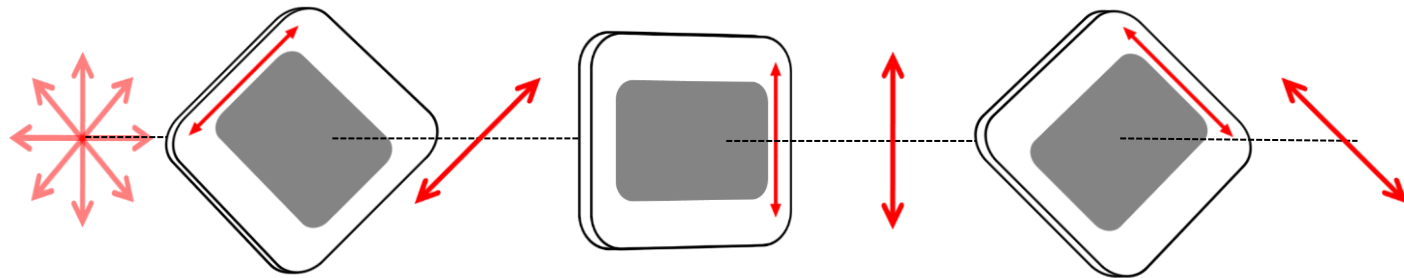
- The role of probabilities in quantum mechanics
  - Outcomes are not *necessarily* definite
- The nature of quantum superposition
  - Superposition as a *relative* concept
- Measurement disturbance
  - We can't make two *incompatible* measurements at once
- We can apply these ideas to build technologies
  - Quantum cryptography is based on quantum measurement





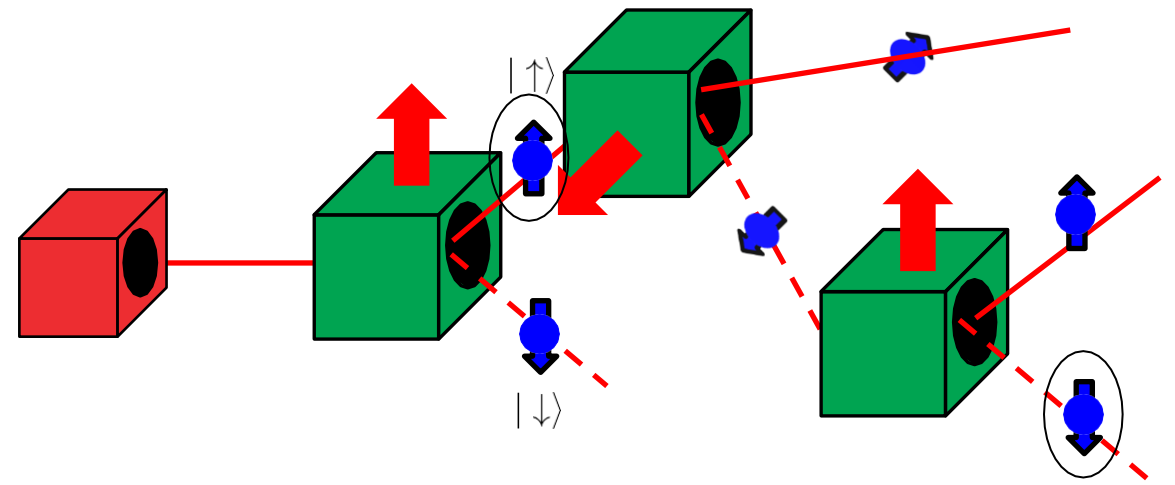
# Polarization and Spin

The three-polarizer experiment is mathematically equivalent to the Stern-Gerlach experiment



Polarized Photons

Spin-Polarized Electrons

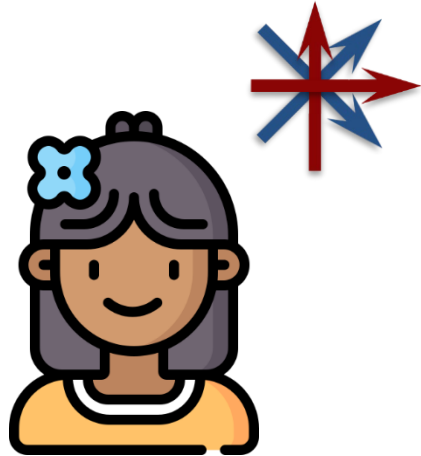
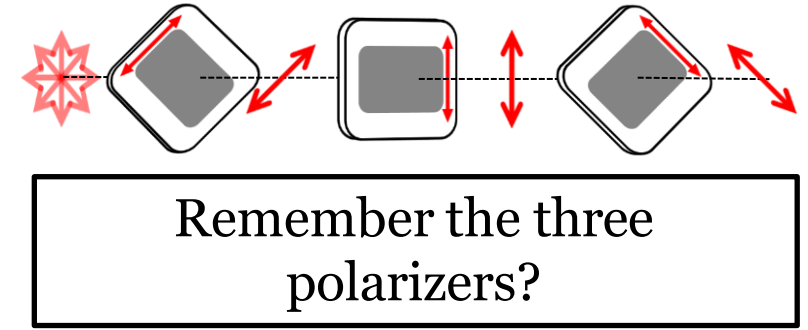


Check out the simulation on QuVis!  
[www.st-andrews.ac.uk/physics/quvis/](http://www.st-andrews.ac.uk/physics/quvis/)  
“Measurement Uncertainty” Demo

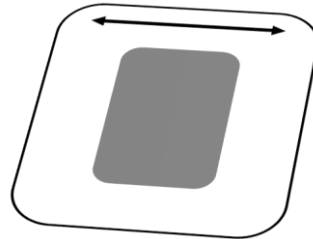




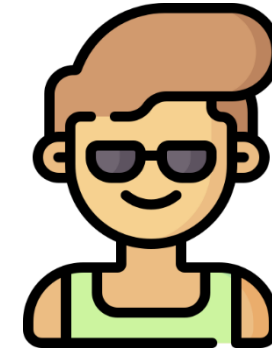
# Quantum Key Distribution



Alice



EVE



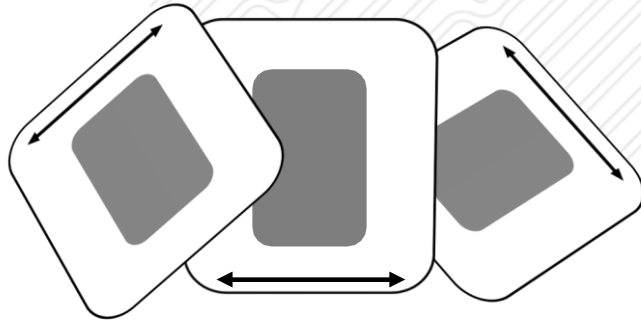
Bob

If the eavesdropper intercepts,  
they'll disturb the polarization state



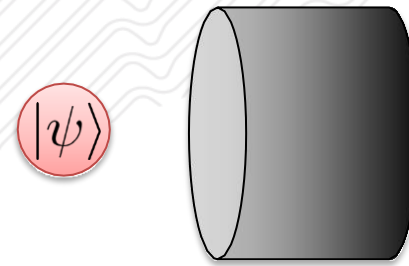
# The Heart of Quantum Key Distribution

## Measurement Disturbance



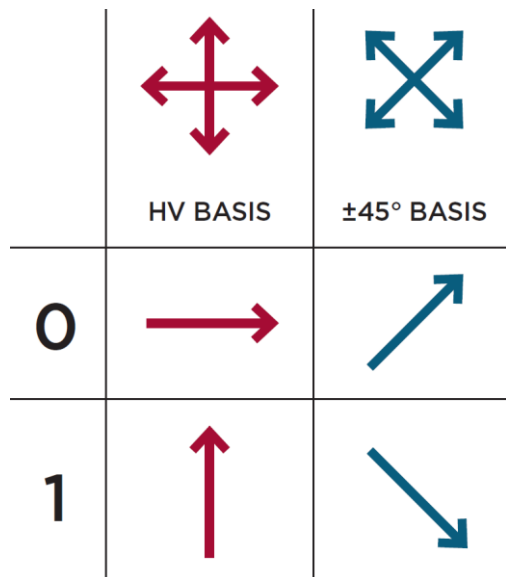
When we measure a quantum state,  
we disturb it

## The No-Cloning Theorem






**FORBIDDEN**

# Polarization Qubits

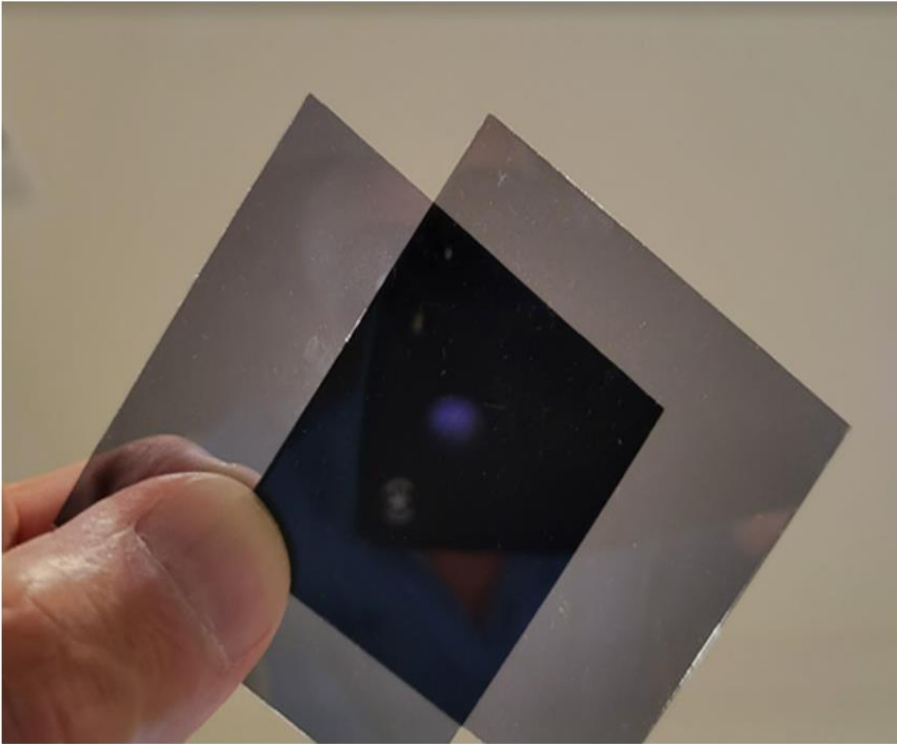


Encode binary “0” or “1” as a polarization state, with two possible bases

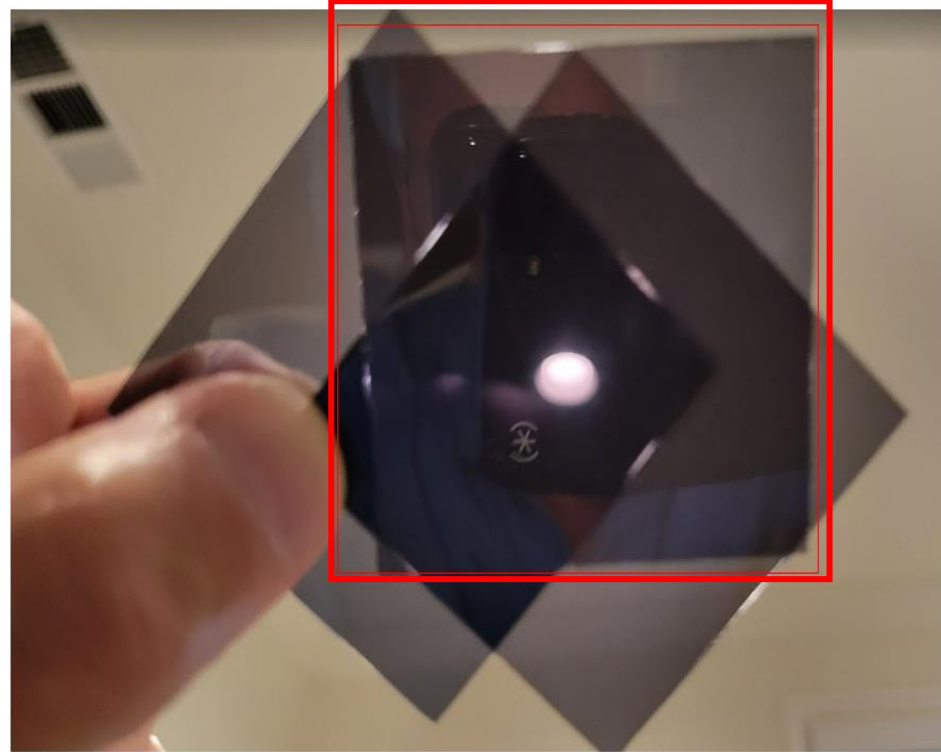
	 H/V measurement	 A/D measurement
	H for sure	random ?
	? V for sure	random
	random ?	D for sure ?
	random	A for sure



# 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)

# Polarization Filters with a Polarized Laser




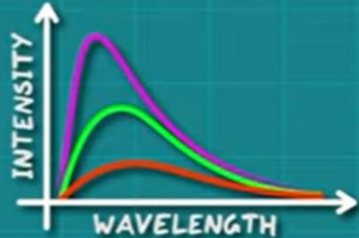
Laser with P(h+v) filters




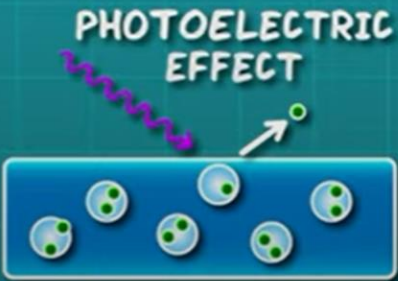
Laser with P(h+ v + 45) filters

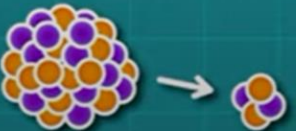
### PRE-QUANTUM MYSTERIES

**ATOMIC SPECTRA**  


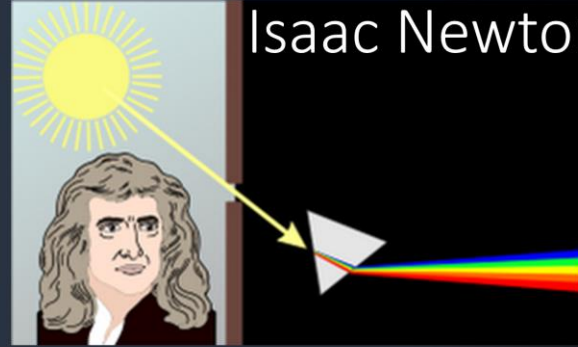
**BLACKBODY RADIATION**  


**THE STABLE ATOM**  


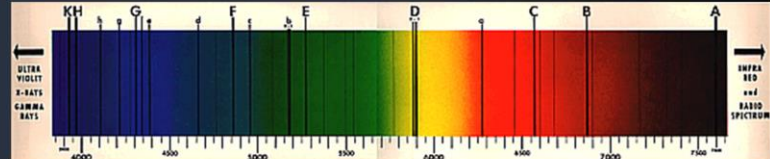
**PHOTOELECTRIC EFFECT**  


**RADIOACTIVITY**  


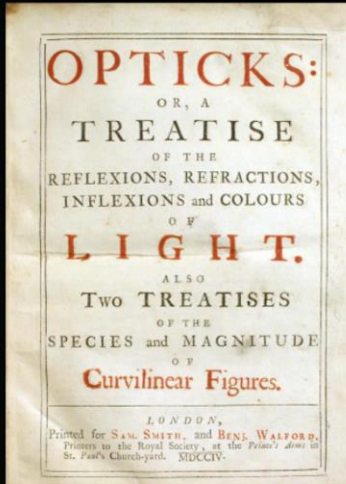
### Isaac Newton & the Prism



**The Solar Spectrum with Fraunhofer Lines**



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

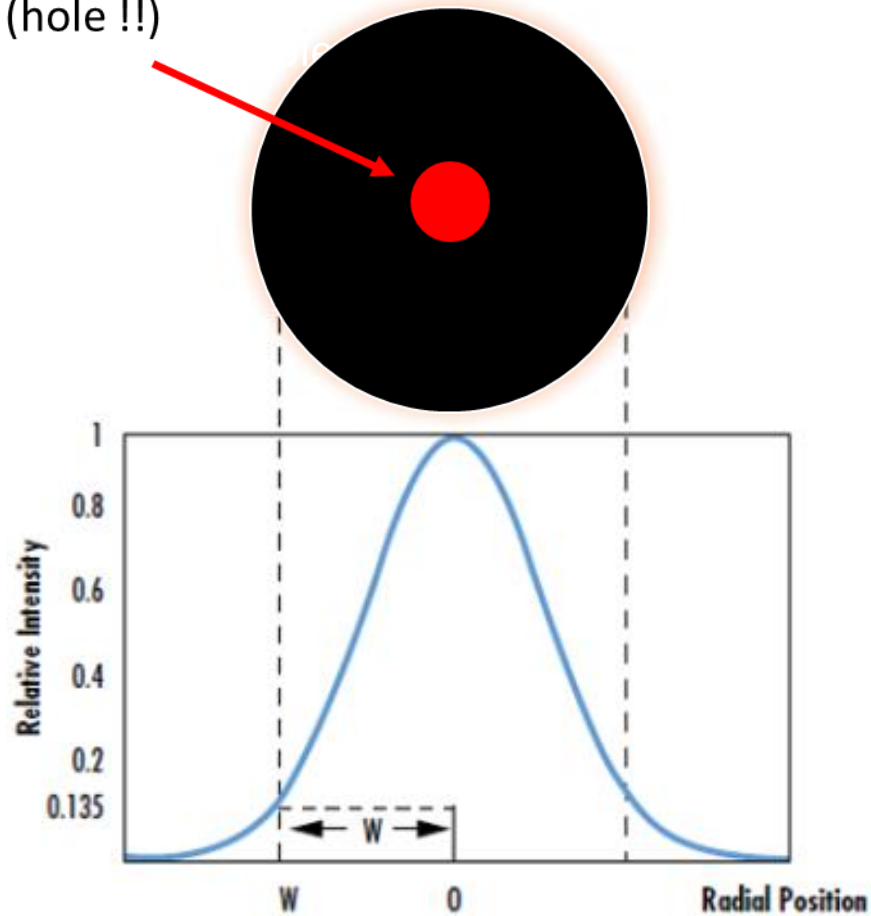


The first, 1704, edition of *Opticks: or, a treatise of the reflexions, refractions, inflexions and colours of light.*

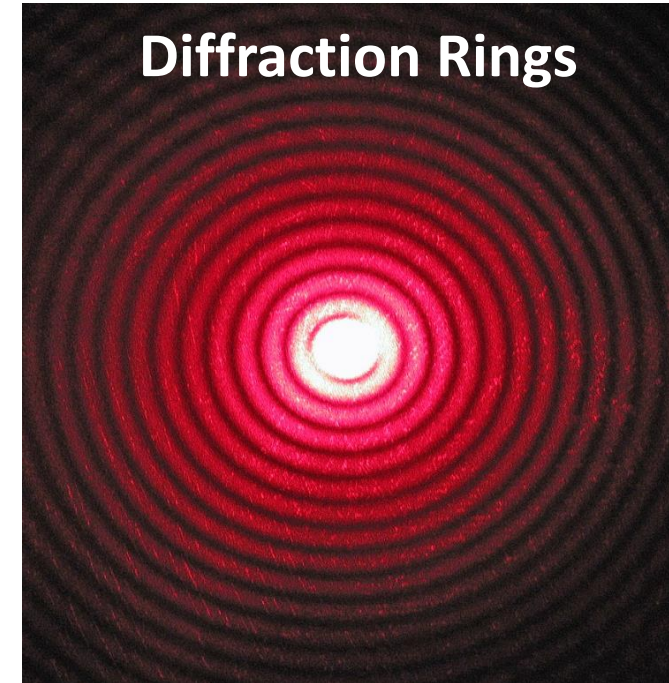


# Laser Light Distribution Patterns

Small Aperture  
(hole !!)



*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

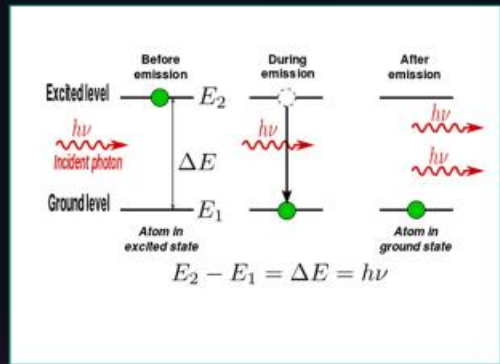
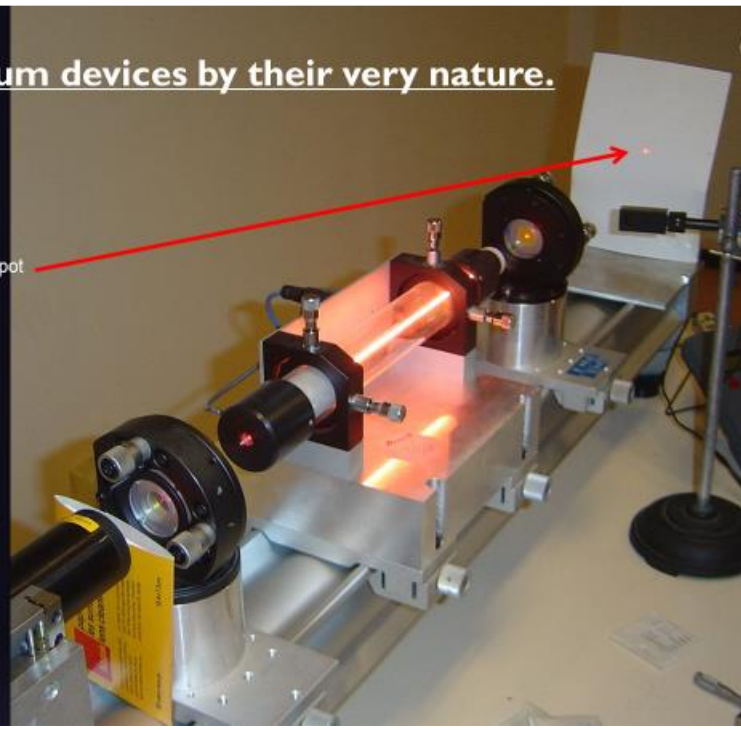
[Laser Interference - Diffraction - Wikipedia](#)

# A brief introduction to lasers as quantum devices and A nice diffractive optics demonstration to keep their attention.

There is a video of the demonstration if presenters do not have a nice diffractive demo slide.)

## 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.



1000 lines/mm  
linear diffraction grating

300 400 450 500 550 600 650 700  
Wavelength,  $\lambda$  (in nanometers)

No longer

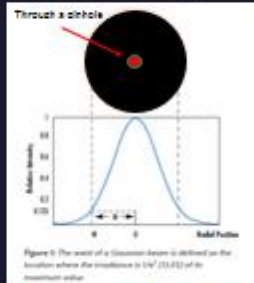
### THE LASER

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



Also included is a short video on laser basics.

## Laser Light Distribution Patterns



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

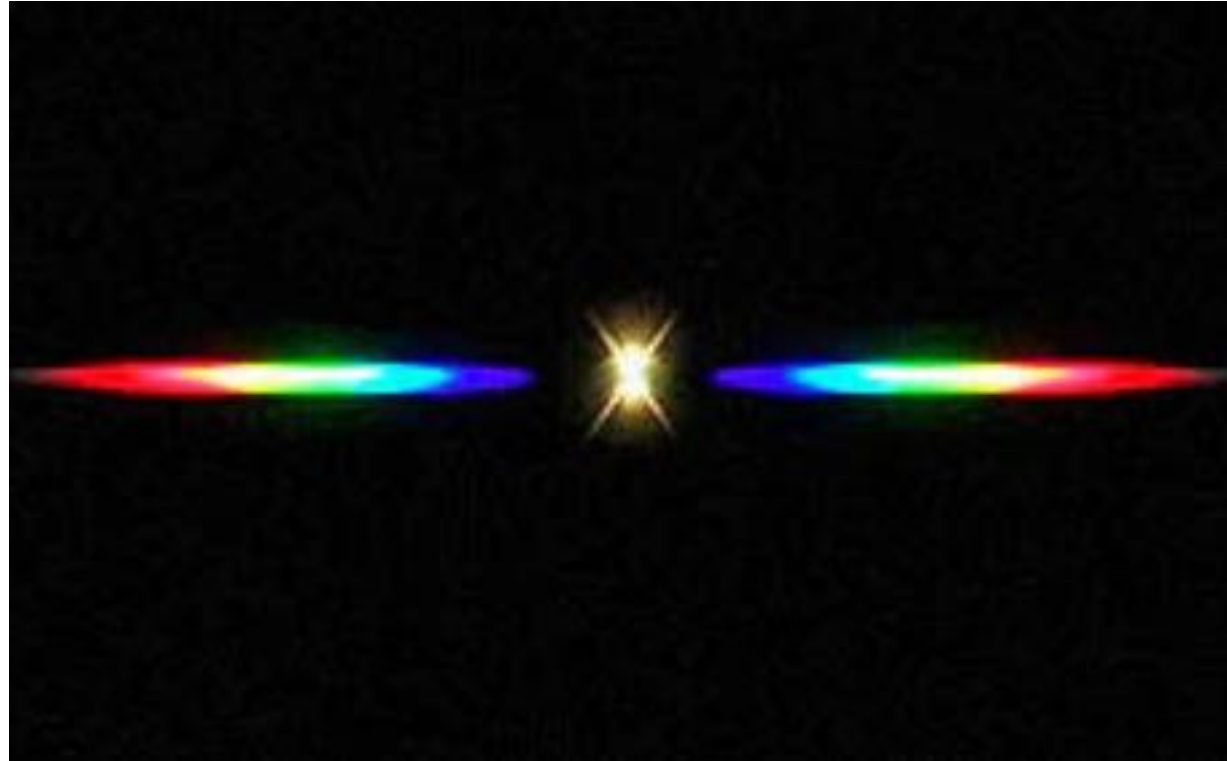
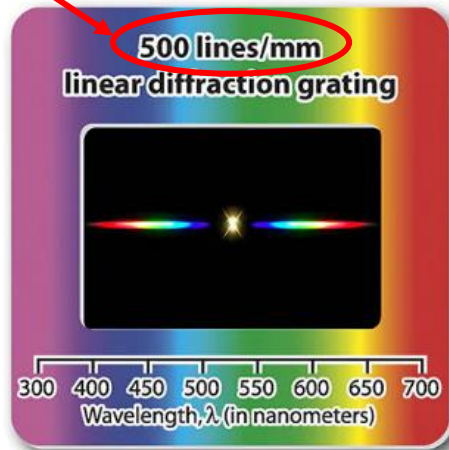
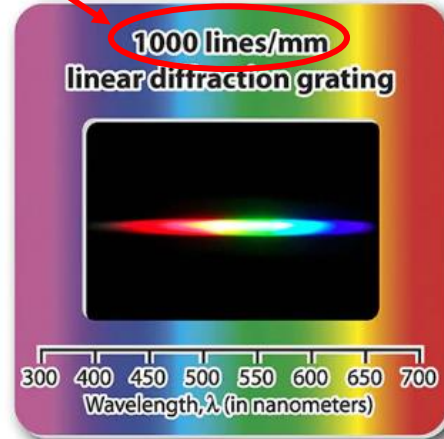
[www.tourinquantique.fr](http://www.tourinquantique.fr)

Copyright: Aram Prokhorov, I. Edward Chabay

3.38 mm diameter circular laser diode, multi-line, fiber-coupled laser pointer.

Do the live demonstration here of.....  
See video of using the part - [Link Here](#)

# Diffraction Gratings



The grid of bumps in the plastic **diffract** the colors of the white light into the **visible spectrum**.



# Diffraction Gratings



Photo by Donn Silberman

## 17. DETERMINING LASER WAVELENGTH USING GRATING

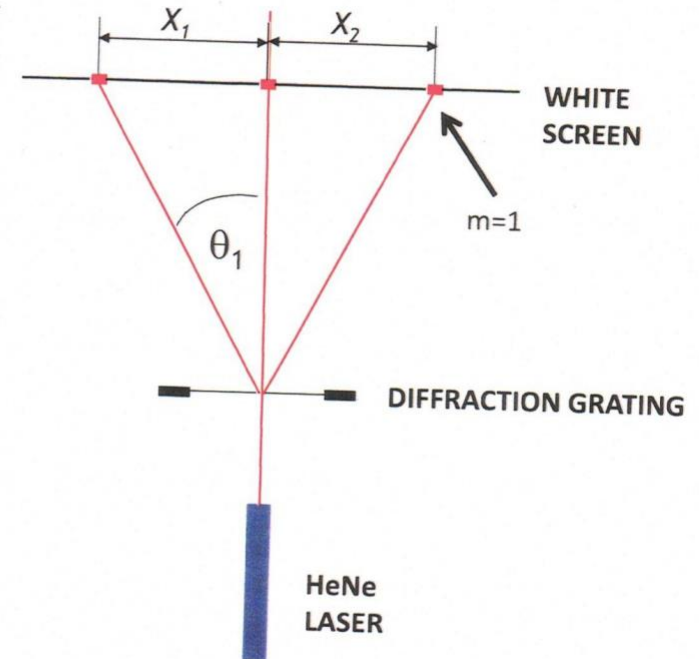
Perform the calculations below (see the figure).

Diffraction equation states the following:

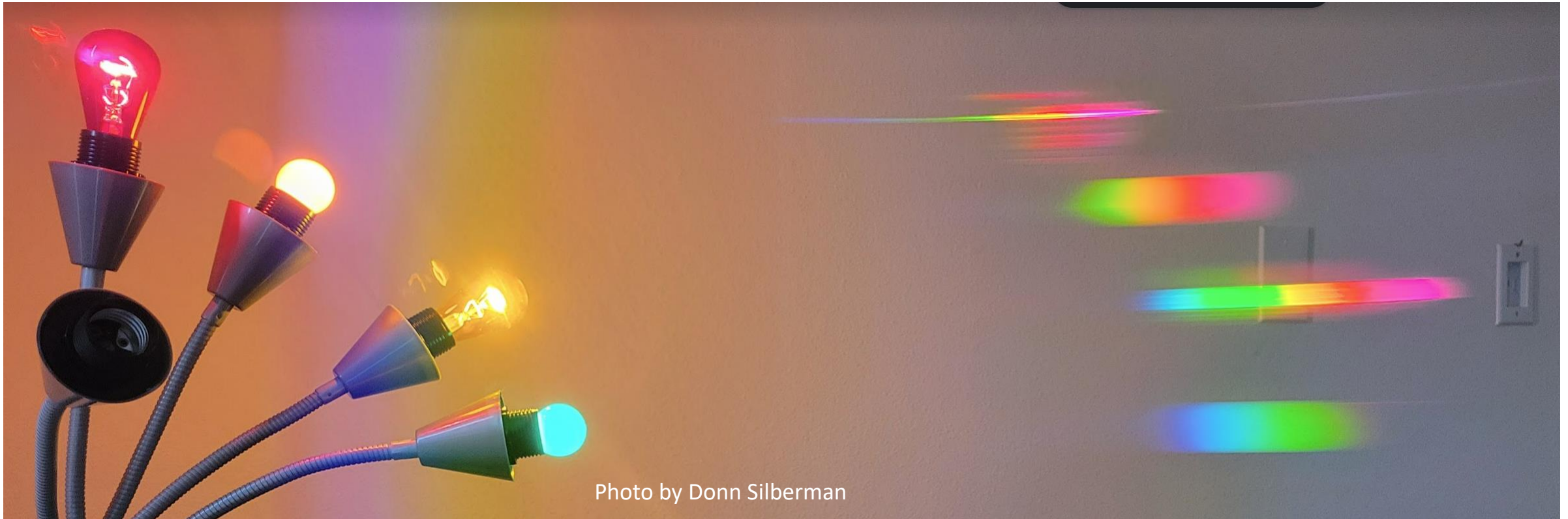
$$m\lambda = d \sin\theta_m$$

where  $m$  is the order of the dot relative to the center,  $\theta_m$  is diffraction angle, and  $\lambda$  is wavelength of the laser beam light. In our case (since we are considering two dots immediately next to the center dot),  $m = 1$ :

$$\lambda = d \sin\theta_1$$



# Spectroscopy & Diffraction Gratings

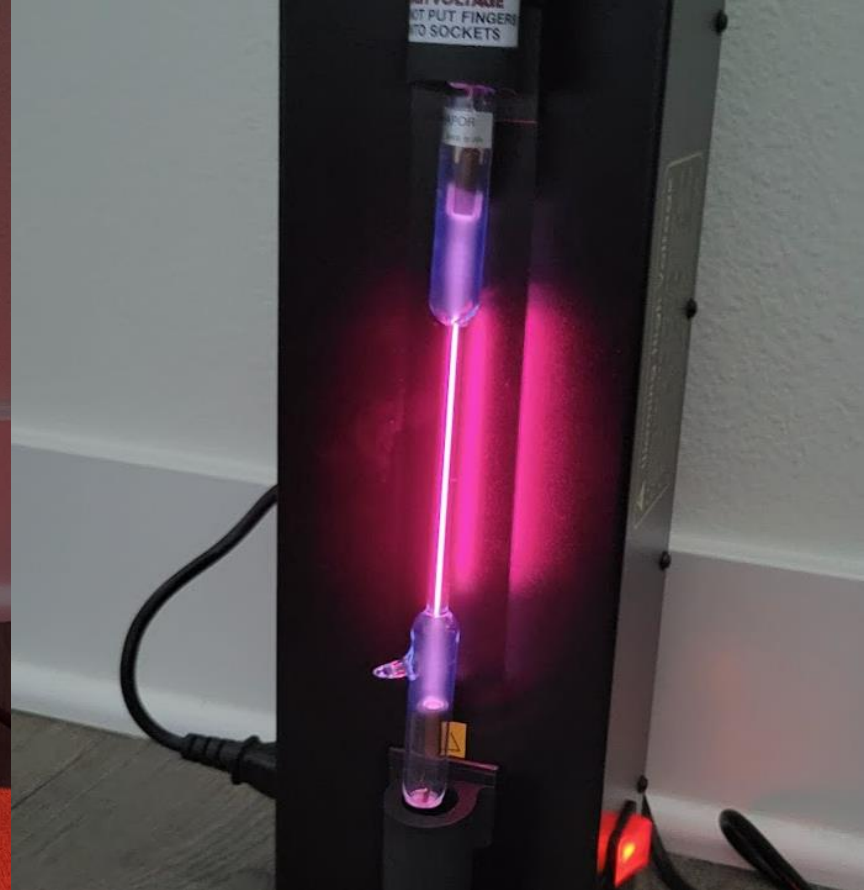


**Specialty Light Bulbs with photo taken through a diffraction grating.**

The images of the spectra are blurry compared to when you look through the grating with your eyes.

Try it on your own and draw what you see on the Spectroscopy worksheet.





# Spectroscopy & Diffraction Gratings

Use the Spectroscopy Worksheets to draw the spectra you see with your eyes when looking through the gratings.

Photos by Donn Silberman





# SPECTRUM ANALYSIS

COSMIC RAYS — GAMMA RAYS — X-RAYS — ULTRA VIOLET

INFRA RED — SHORT WAVE RADIO — LONG WAVE RADIO

## VISIBLE SPECTRUM

3800 TO 7000 ANGSTROM UNITS (A.U.)

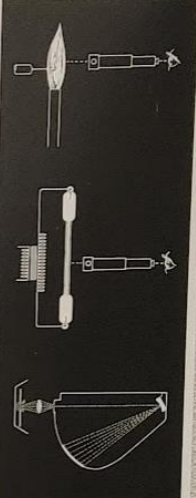
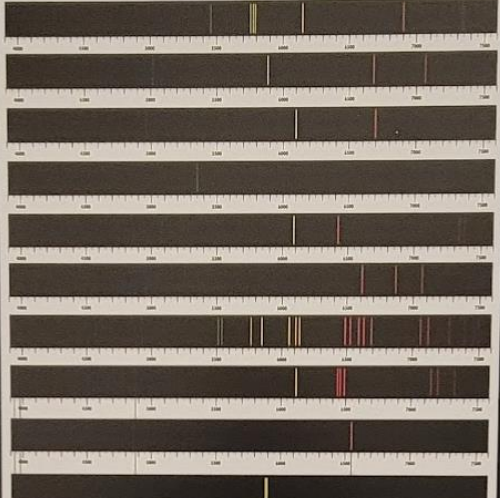
### CONTINUOUS SPECTRUM



Continuous Spectra are produced by incandescent solids, liquids and gases under high pressure.

### EMISSION (BRIGHT LINE) SPECTRA

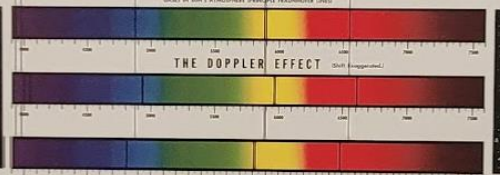
MERCURY  
HELIUM  
LITHIUM  
THALLIUM  
CADMIUM  
STRONTIUM  
BARIUM  
CALCIUM  
HYDROGEN  
SODIUM



NOTE: THE WIDTH OF LINES IN THE EMISSION SPECTRA HAS BEEN ENLARGED IN MANY CASES FOR THE SAKE OF VISIBILITY.

### ABSORPTION SPECTRUM

GASES IN SUN'S ATMOSPHERE PRODUCE FRANKLIN LINES



### THE DOPPLER EFFECT



### SOLAR SPECTRUM

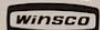
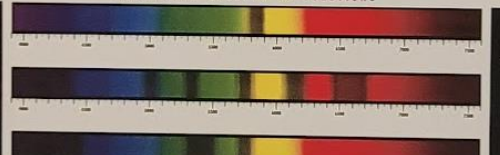
RECEDING  
EDGE OF SUN

APPROACHING  
EDGE OF SUN

THE DOPPLER EFFECT: If the source of light is receding, the wavelength of the light is increased. If the source is approaching, the wavelength is decreased. This is analogous to the change in pitch of a sound as it approaches or recedes. The same principle applies to the absorption lines in the solar spectrum.

### ABSORPTION SPECTRA OF SOLUTIONS

DIDYMIUM GLASS  
CHLOROPHYLL  
OXYHEMOGLOBIN



WABASH INSTRUMENT CORPORATION



Spectroscopy & Diffraction Gratings

Photo by Donn Silberman



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 \(qubitbyqubit.org\)](https://qubitbyqubit.org)

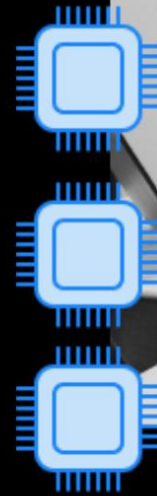


# TRAINING THE FUTURE DIVERSE QUANTUM WORKFORCE

# Interested in bringing quantum to **your school**?

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

[Learn More](#)







# Highlights of the IBM Quantum Summit 2022

IBM Quantum announced leaps forward in quantum computing performance, scale, and adoption. Discover the latest software and hardware breakthroughs that are now putting quantum advantage within reach.

[Explore what's new](#) →

[Read the blog](#) ↗



[Get started with IBM Quantum today](#)

[Launch Qiskit Runtime on IBM Cloud](#) ↗


# IBM Quantum Computing Lab Accessed through the Internet


Browser address bar: <https://quantum-computing.ibm.com>

Navigation tabs: Inbox (17,511) - opt..., Microsoft account |..., wx HOME | opticsage, Finances, Quantum, RMV, Real Estate, Medical, OSSC, Fitness

IBM Quantum logo and navigation icons (Search, Help, Profile)

## Welcome, Donn Silberman


 Graphically build circuits with IBM Quantum Composer



 Develop quantum experiments in IBM Quantum Lab

[Launch Composer](#) [Launch Lab](#)

Jump back in:

- [QXQ\\_YLC\\_Homework\\_6\\_STUD...](#)
- [QXQ\\_YLC\\_Lab\\_6\\_STUDENT.ipyn...](#)
- [QXQ\\_YLC\\_Lab\\_5\\_STUDENT.ipyn...](#)
- [QXQ\\_YLC\\_Homework\\_5\\_STUD...](#)


API token 

\*\*\*\*\*  

[View account details](#)

### Optimize circuit execution with Qiskit Runtime programs

2 Primitive programs    9 Prototype programs



### Recent jobs

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You have no recent jobs.

Create one by running a circuit or notebook on one of your IBM Quantum Systems.

### Run on circuits & programs via IBM Quantum compute resources

[View all](#)

6 Your systems    5 Your simulators    0 Reservable systems

- Service Alert**  
Planned Maintenance October 27th through Nov 7th  
16 days ago
- Quantum News**  
IBM Quantum Challenge Fall 2022 is coming!  
17 days ago | [Learn more](#)
- Service Alert**  
Maintenance event on October 11th and 18th  
about 1 month ago
- Quantum News**  
Interested in helping us build the future of quantum? Take part in the IBM Quantum Feedback Program.  
2 months ago | [Learn more](#)
- Product Update**  
Updates to job executions - optimizing classical computation  
4 months ago
- Service Alert**  
ibmq\_armonk has been retired  
4 months ago

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

IBM Quantum Lab

File Edit View Run Kernel Tabs Settings Help

QXQ\_YLC\_Lab\_6\_STUDEN X

Python 3 (ipykernel)

Lab files /

Name	Last Modified
qiskit-textbook	seconds ago
qiskit-tutorials	seconds ago
Untitled Folder	a year ago
QXQ_YLC_Homework_5_ST...	16 days ago
QXQ_YLC_Homework_6_ST...	2 days ago
QXQ_YLC_HW2_SOLUTIONS...	21 days ago
QXQ_YLC_HW2_STUDENT (...)	a month ago
QXQ_YLC_Lab_4_STUDENT.i...	21 days ago
QXQ_YLC_Lab_5_STUDENT.i...	15 days ago
QXQ_YLC_Lab_6_STUDENT.i...	5 days ago
Untitled.ipynb	a month ago
Week 0 Lab.ipynb	2 months ago

## 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 multi-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!



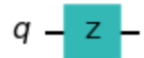
## Part 2: The Z Gate

### 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]:

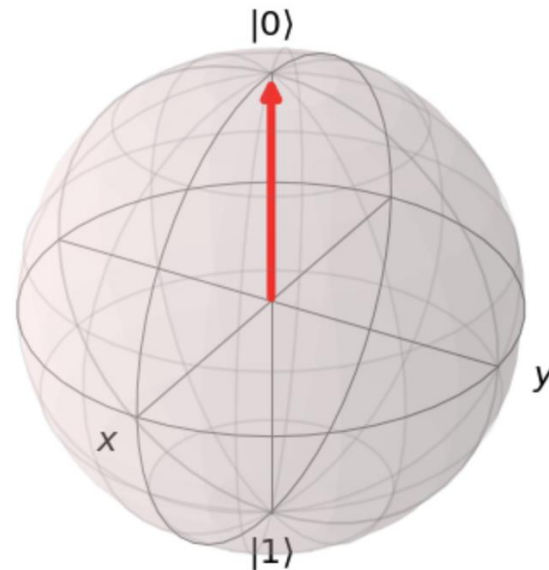


### Exercise #2

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]:



New file +

Filter files by name

Lab files /

Name	Last Modified
qiskit-tutorials	34 minutes ago
Untitled Folder	a year ago
QXQ_YLC_Homework_5_S...	18 days ago
QXQ_YLC_Homework_6_S...	a day ago
QXQ_YLC_HW2_SOLUTIO...	23 days ago
QXQ_YLC_HW2_STUDEN...	a day ago
QXQ_YLC_Lab_4_STUDEN...	23 days ago
QXQ_YLC_Lab_5_STUDEN...	17 days ago
QXQ_YLC_Lab_6_STUDEN...	a day ago
QXQ_YLC-Homework 7 ST...	8 hours ago
QXQ_YLC-Lab 7 STUDENT...	9 hours ago
Untitled.ipynb	a month ago

File Edit View Run Kernel Tabs Settings Help

Console x QXQ\_YLC-Homework 7 ST X QXQ\_YLC-Lab 7 STUDENT.X

No Kernel

### 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

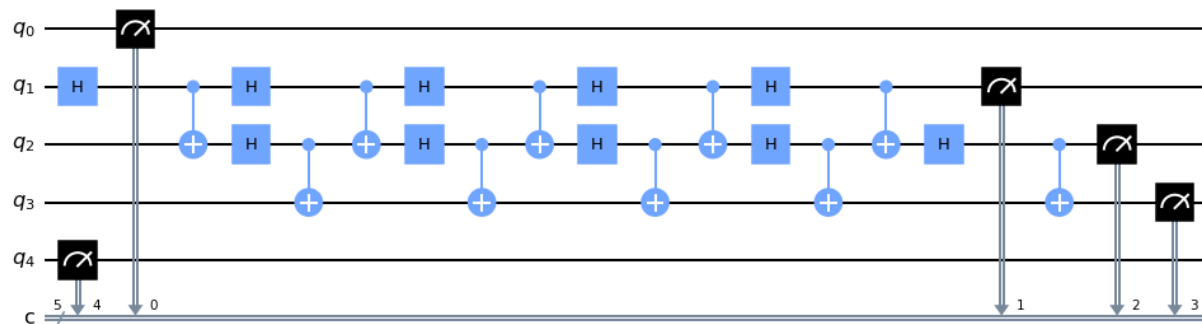
H gate on qubit 2

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.**

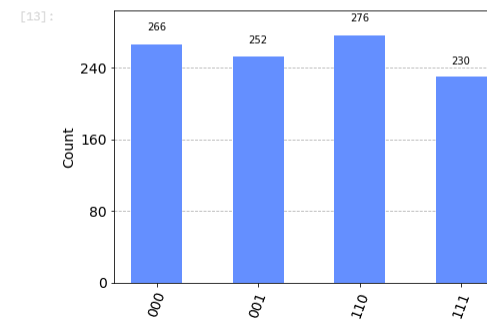
```
[41]: qc = QuantumCircuit(5, 5)
      for qubit in range(5):
          qc.h(qubit)
          qc.cx(qubit, qubit+1)
      qc.measure([0, 1, 2, 3, 4], [0, 1, 2, 3, 4])
      qc.draw()
```

[41]:



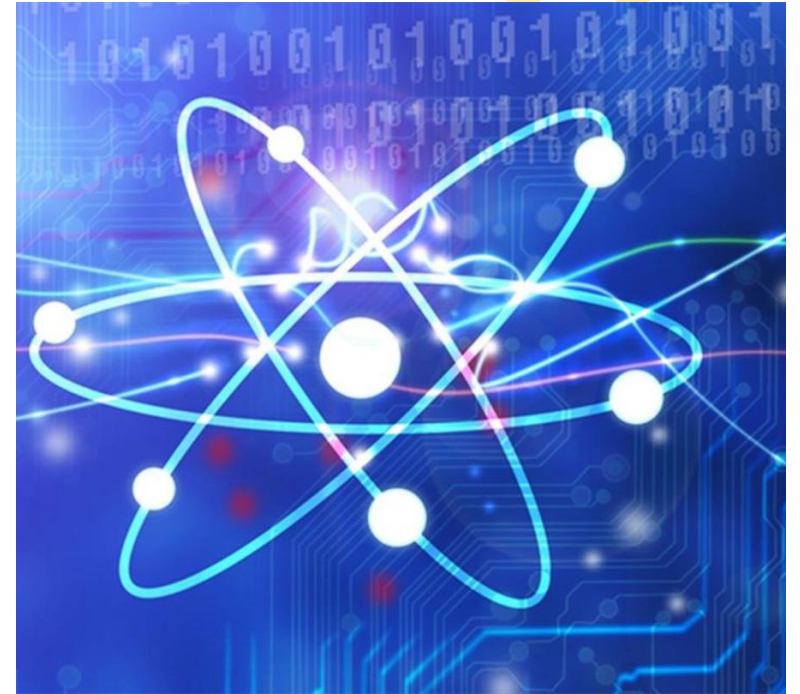
Run the code below to simulate the measurement results using QASM.

```
[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)
```



# Summary

1. Getting Oriented with Quantum Education
2. Motivation for the process described
3. Creating the “Quantum Pipeline” – Paths Forward
4. The Samueli Academy’s “Schrodinger’s Club”
5. Quantum Cryptography – Univ. of Waterloo
6. Hands-on Lab for Students
  - a) Polarization
  - b) Atomic Spectroscopy & Laser Diffraction Lab
  - c) Qubit x Qubit – with IBM’s Qiskit
7. Q&A
8. Thank you for your attention !!



## Would you like to help ??

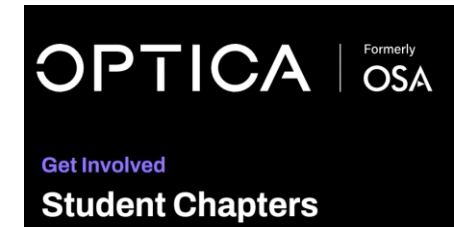
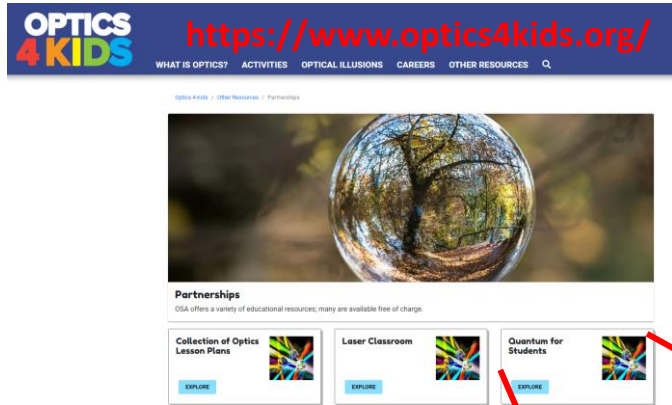
1. SPIE / Optica Student Chapters in your area?
2. Local Non-profits & schools in your area?

Materials & guidance are available now.

[Next Slide](#)



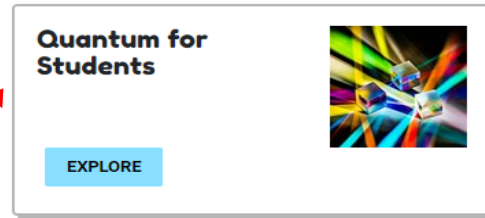
# The Quantum Education & Outreach – Paths Forward



Working with local SPIE, Optica, IEEE Photonics and other College Student Clubs to reach out to local high schools

Working with local Non-profits  
Linking K-12 school districts to industry  
And local colleges and universities

**Brown Bag Educational Lunch Series**  
Introducing optics to undergraduate ECE students and photonics outreach projects



[Quantum for Students | opticsage](https://www.opticsage.com)  
 [\(donn601.wixsite.com\)](https://donn601.wixsite.com)



Speaker:  
**UCSD SPIE Student Chapter**



October 5<sup>th</sup>, 2022  
12 – 1 PM

**High School Quantum Workshop**  
**Friday Nov. 18th**

**vital link**  
Corona Del Mar High School  
Python Programming Class  
Tues. Nov. 22 – Intro to Quantum Computing

