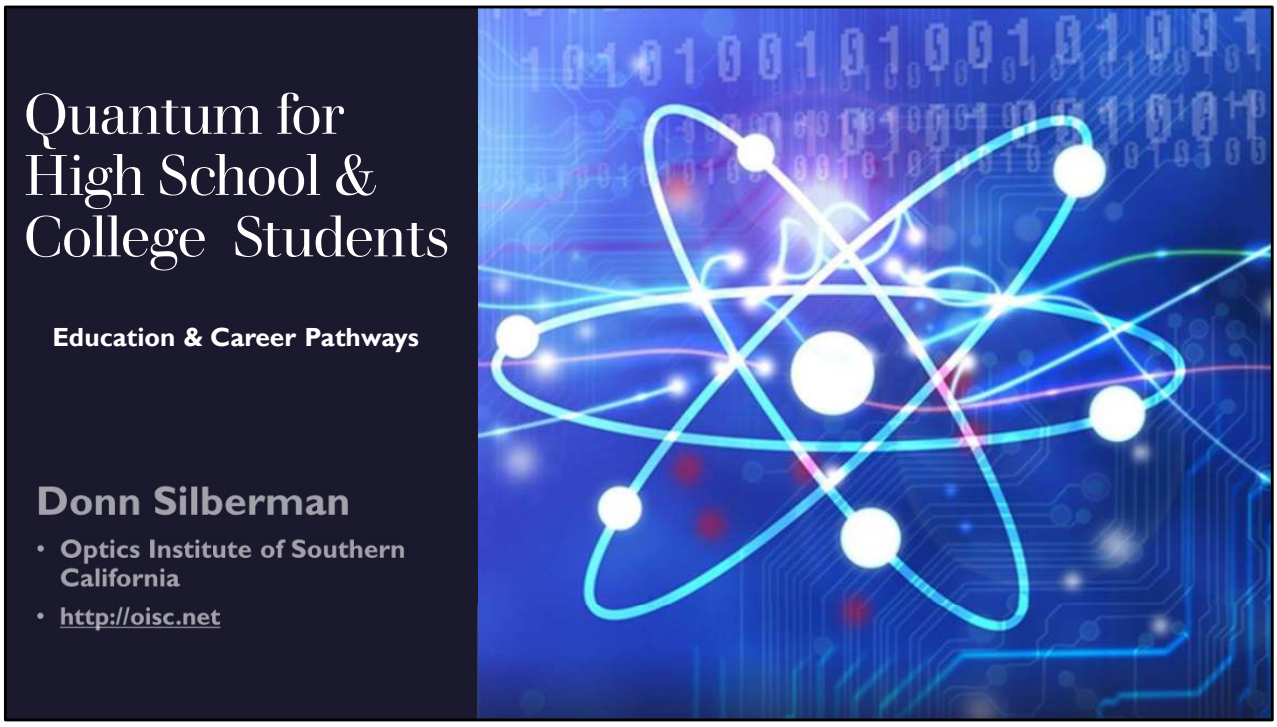


Hello welcome to quantum for high school & college students; education and career pathways.

My name is Donn Silberman and I'm the founder of the optics institute of Southern California .

Before we get started, I want you to know that all the slides and information in this presentation are available on my website with many links to follow deeper into the topics that I will be presenting.

So; while you can take notes, you can also just focus on the flow of the presentation.

The live version of this presentation may differ because questions may be taken and answered in real time; so, some of the details in the scripted notes may be skipped stay within the allotted time.

So, who am I and why am I here talking to you ? Well as I mentioned my name is Donn Silberman and I'm the founder of the Optics institute of Southern California; you can see the logo right under my photograph in this slide.
I also maintain an educational website about Experiencing Life in the Quantum OpticsAge.
I am going to tell you a brief history of my educational career because many years ago, I was your age!!

I was fortunate to go to a high school that taught astronomy and then I went to the University of Arizona to study astronomy, physics, engineering and optics.

I've placed the logos of these entities including the one of the honors college, which I was nominated to join by one of my professors, not because I had a very high-grade point average, but because I was very enthusiastic about physics. He also asked me to teach freshman physics laboratory classes when I was a junior and senior in college. And I had a job as a student assistant in the College of Optical Sciences. I volunteered to be the president of the college chapter of the Society of Physics Students. This allowed me to set up meetings and presentations that I was interested in and even tours of various scientific and technological facilities around the university .

SPS was invited by Optical Society of America (now Optica) to host a presentation at their annual meeting in Tucson in 1982 and I invited my former professor, who was then the acting director of the very first multiple mirror telescope project. I still have a key fob from the very memorable event.

After graduating I became a counselor for the Society of physics students and then a member of the optical Society of America and eventually SPIE & OSSC ; and there are long stories associated with each of these organizations including doing education outreach and teaching laser technology to community colleges and optical engineering at UC Irvine and most recently the EdQuantum project .

Before we get into quantum for students, I want to show you this slide and asked if anyone will volunteer to tell me what they see?

It's a curious engraving from the Middle Ages of a man seeking to understand the workings of the universe beyond the stars, and we are still doing that today.

To understand a little about education and career opportunities in the quantum world, I want to guide you in the fine art of critical thinking. I have these questions I like to ask starting with "what is light?" It seems familiar enough, but when we think critically about light, it's a bit elusive; we'll get into that later in this presentation.

The question, "what is money?" has more to do with career than with science; but again, to think critically about money will be very important in your life.

When we talk about "Trust" & "Truth", all I can say is that each person gets to decide who they trust and what they believe to be true. Quantum Mechanics has some very unusual experimental and theoretical 'truths' that I will introduce in this presentation.

This presentation will not have much to do with money, truth, trust or even love. It's just that words are a bit like light, in that they are not so easy to grasp when you really think critically about them.

Mentors

Frank Memmer

Ke Chiang Hsieh

William Bickel

Bob Fisher

Al Hatheway

Brian Lula

Jim Trolinger

Steve Jacobs
Univ. of Rochester
Optics Suitcase

My wife, Mom & Dad

When we talk about love, I like to point to my mentors starting with Frank Memmer, he was my high school astronomy teacher and professors Hsieh & Bickel who were my physics advisors in college. Steve Jacobs was the creator of the Optics Suitcase, which I learned from, modified and used to do Optics Educational Outreach for many years. Now I am using some Quantum Optics concepts that grew from the Optics Suitcase.

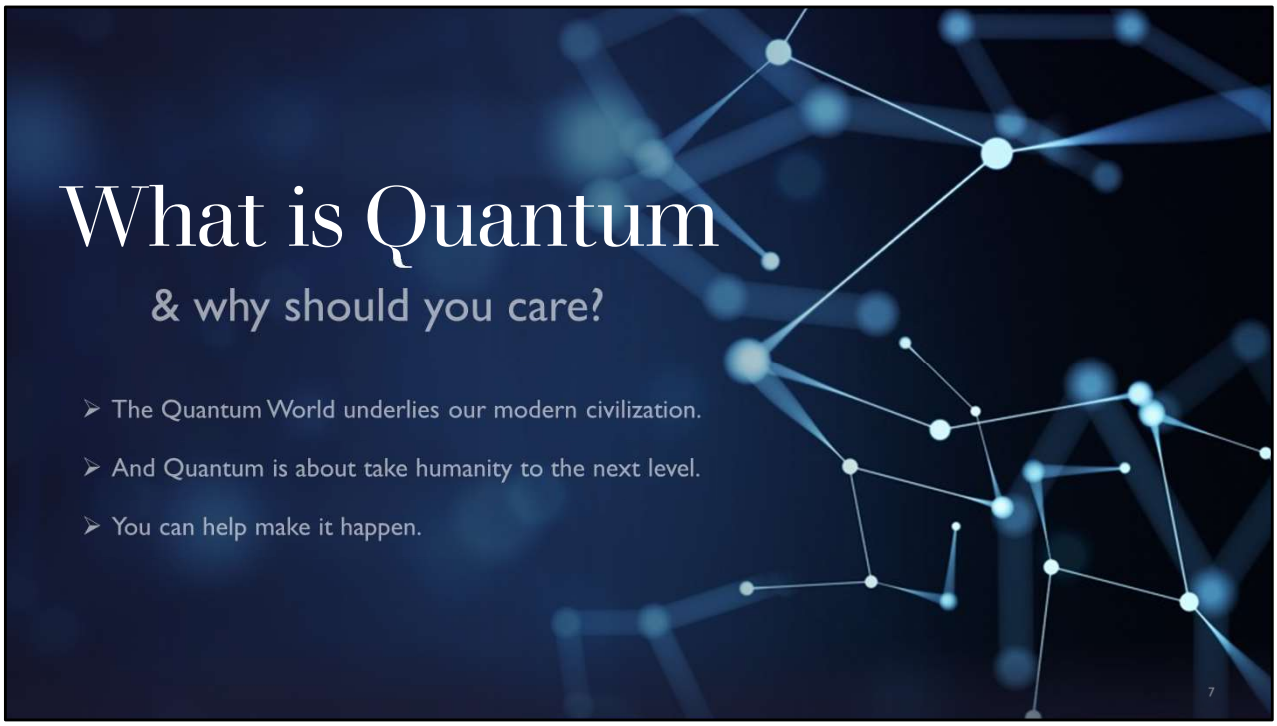
These mentors and the others pictured here help me along my career path and showed me kind affection that helped me through many years of life .

And then of course there is the love I have for my wife and my parents.

So the main idea of this slide is to encourage you to find your mentors in life including those of your family friends and people who will help guide you in your career .

The main topics of this presentation are divided into 6 sections starting with what is quantum and why should you care. Followed by quantum computers and cyber security, which are two main topics that are front and center in the world around us.

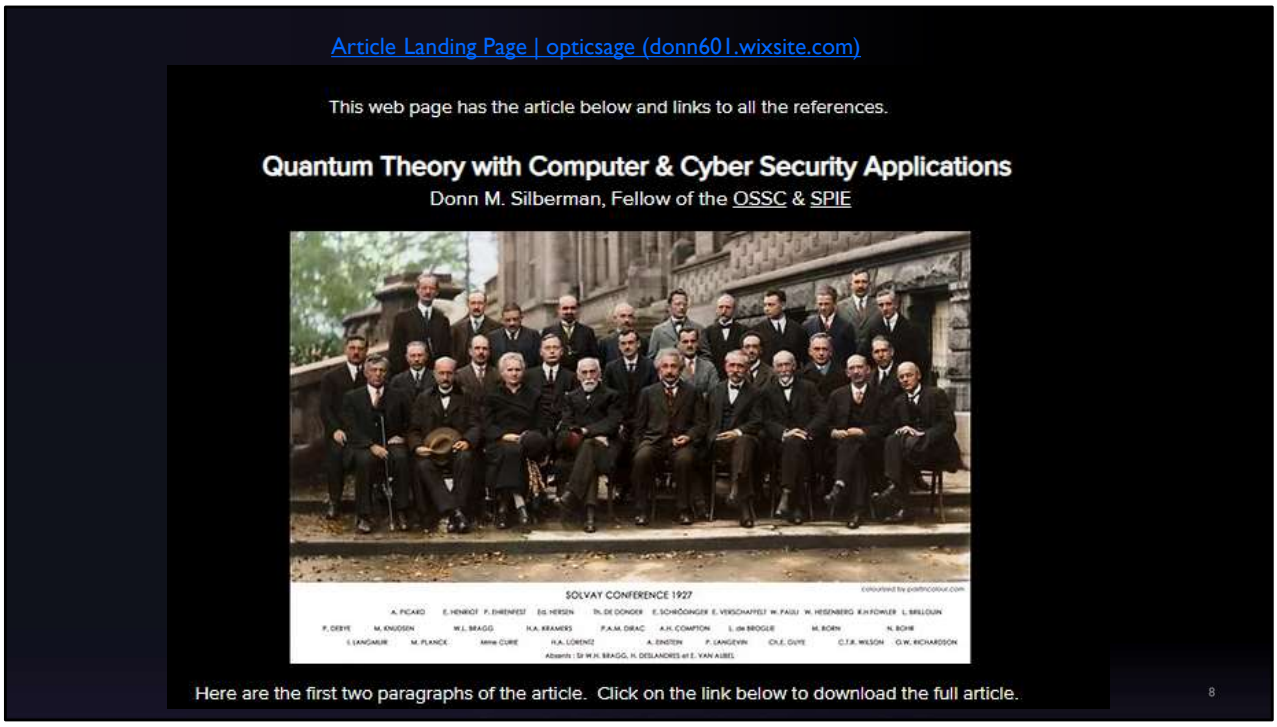
There are many more quantum applications that people are studying and working in right now. And there are pathways for students that I'll show you towards the end of this presentation. We have some online and in person resources to provide and then I can answer any questions you might have at the end.



So what is quantum and why should you care ?

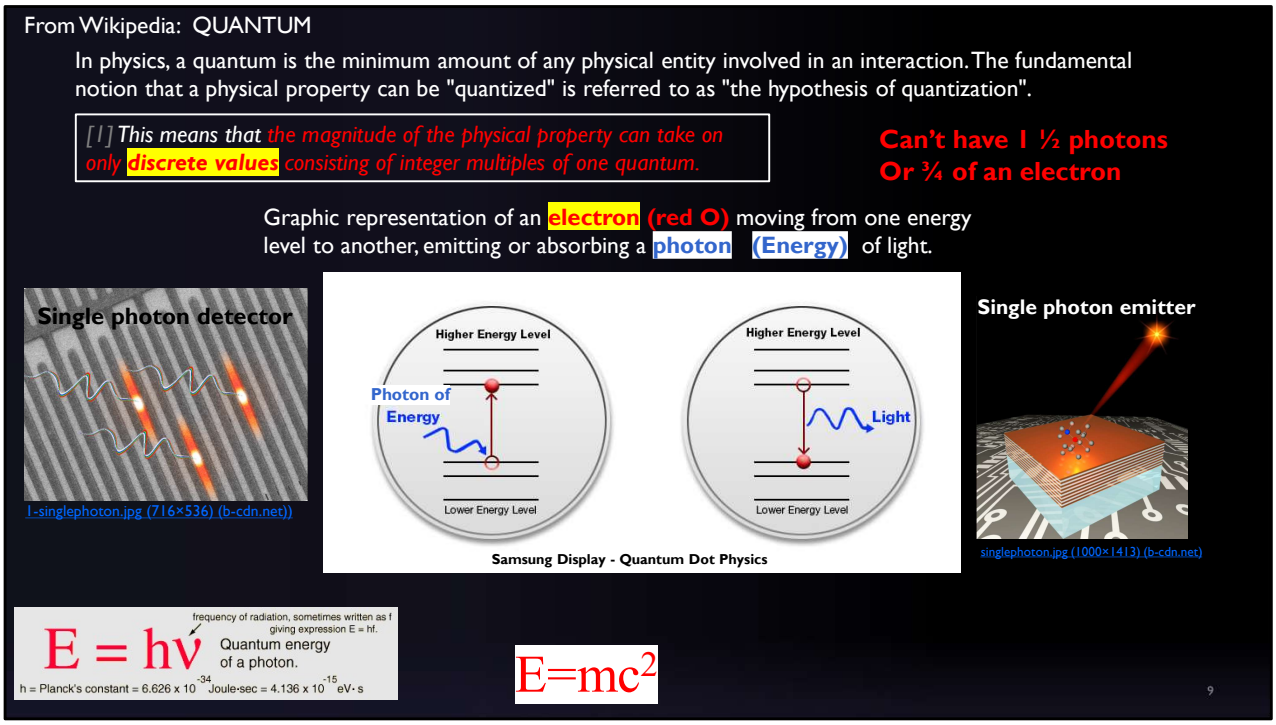
In this presentation, I will show you that:

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



Recently I wrote a short article for a technical business group I belong to titled quantum theory with computer and cyber security applications . and it starts with this photograph and the following text .

"The transition from classical to modern physics (including quantum) has dramatically changed our civilization. The people in the above photo ushered in this change beginning over 100 years ago and the effects are still making exponential change with current and future applications including quantum computing, encryption, sensing, materials development, logistics, communications and much more."



From Wikipedia we can learn that a quantum is the minimum amount of any physical entity involved in an interaction.

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

2. So for example, a photon of energy is a single quantum of light. You cannot have 1½ photons or ¾ of an electron or a fraction of any other quantum entity.

3. Here, a photon of energy is graphically interacting with an atom, so that an electron's energy is raised by a discrete amount. On the left is a graphically enhanced photo showing a single photon detector. The reverse can happen as shown on the right with a graphic showing a single photon being emitted from the surface atom of a material.

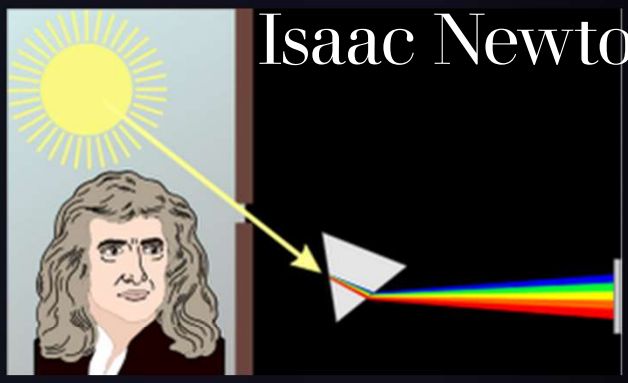
4. Quantum mechanics does not tell us why this is the case but the theory including the energy of a photon E= Plank's constant h times the frequency (or color) of the light photon.) matches the experimental evidence to such a high degree, that our entire modern civilization is based on QM and QM has been proven to be true using modern scientific methods .

5. This includes Einstein's famous energy equation E=mc^2, where m is the mass of any object and c is the speed of light.

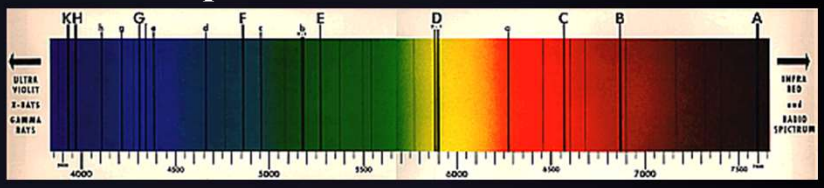
(Atoms and matter in general are stable because electrons can exist only at discrete energy levels within an atom.) Quantization is one of the foundations of the much broader physics of quantum mechanics. Quantization of energy and its influence on how energy and matter interact (quantum electrodynamics) is part of the fundamental framework for understanding and describing nature.

Wiener, N. (1966). Differential Space, Quantum Systems, and Prediction. Cambridge: The Massachusetts Institute of Technology Press

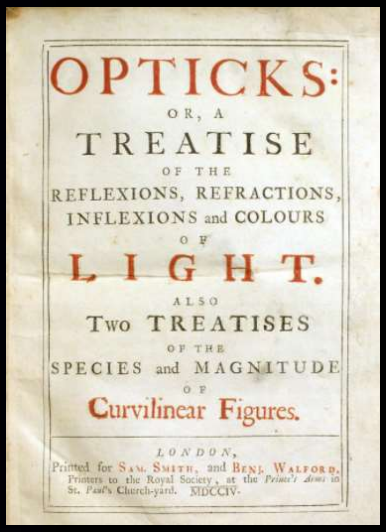
Isaac Newton & the Prism



The Solar Spectrum with Fraunhofer Lines



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



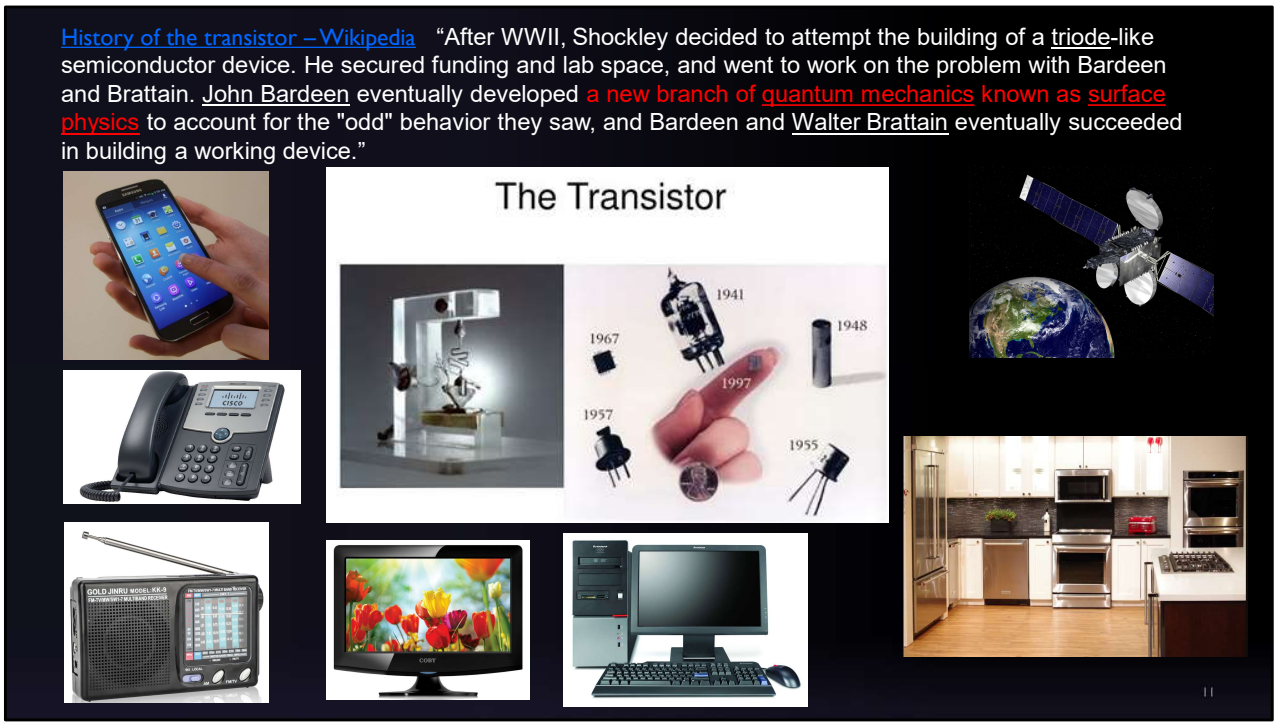
OPTICKS:
OR, A
TREATISE
OF THE
REFLEXIONS, REFRACTIONS,
INFLEXIONS and COLOURS
OF
LIGHT.
ALSO
Two TREATISES
OF THE
SPECIES and MAGNITUDE
OF
Curvilinear Figures.
LONDON,
Printed for SAM. SMITH, and BENJ. WALFORD,
Printers to the Royal Society, at the Prince's Arms in
St. Paul's Church-yard. MDCCIV.

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

10

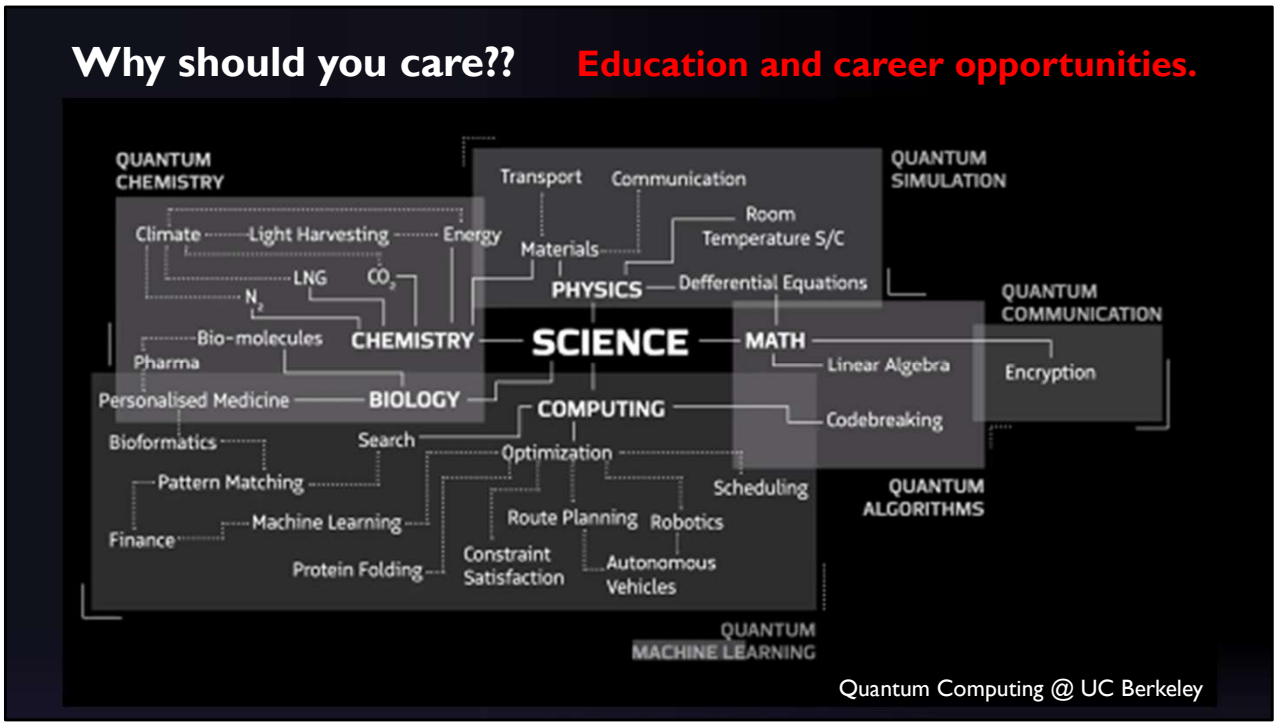
Isaac Newton first published his book on optics in 1704 and included information on reflection, refractions, inflextions, colors, prisms, and spectroscopy.

The discrete Fraunhofer lines shown in this typical solar spectrum are a direct experimental result of the quantum nature of light and the frequencies shown on the x-axis related directly to frequency in Plank's energy equation in the last slide.



From Wikipedia "The History of the transistor," we learn that it was not until *"After WWII, when William Shockley decided to attempt to build 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."*

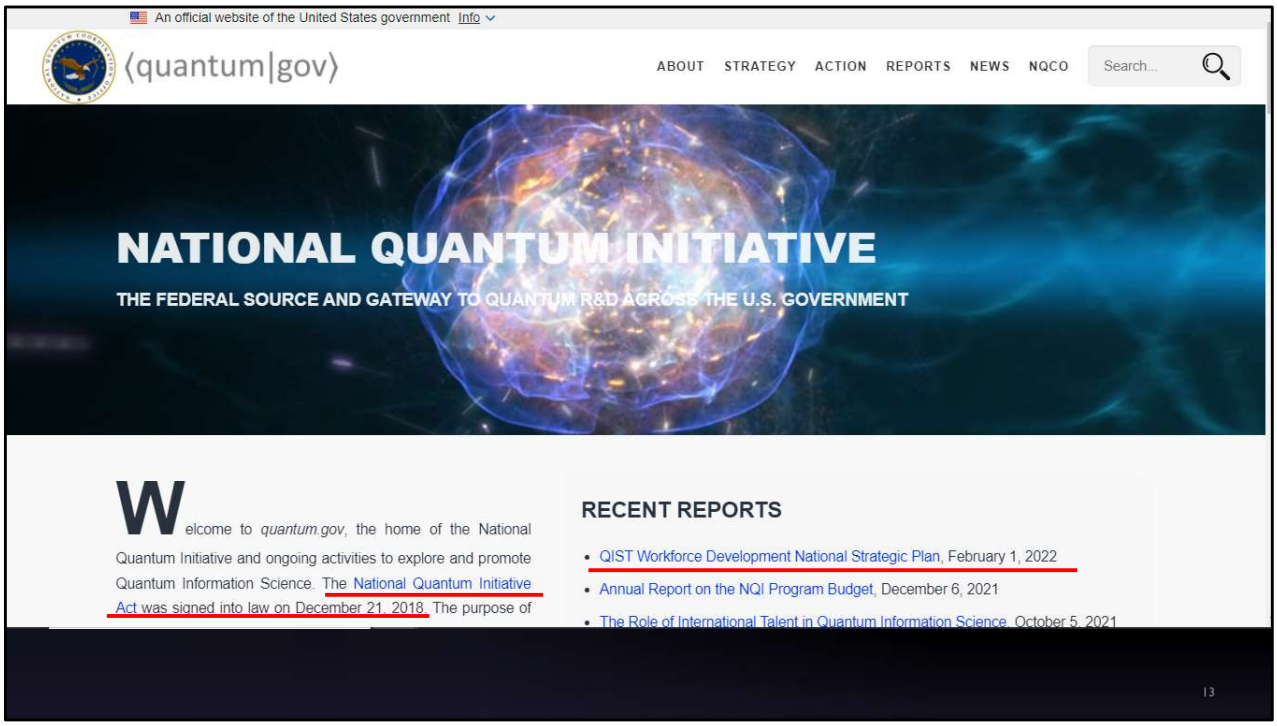
This is the foundation of modern electronics and computers which our entire modern civilization has been built. Every cell phone, telephone, radio, television, computer, satellite, and all the other modern electronic conveniences have their bases in the simple transistor which is a quantum mechanical device .



So why should you care ? Because there are education and career opportunities throughout the sciences that can now use fundamental quantum mechanical principles and devices to help create the next generation of our modern civilization.

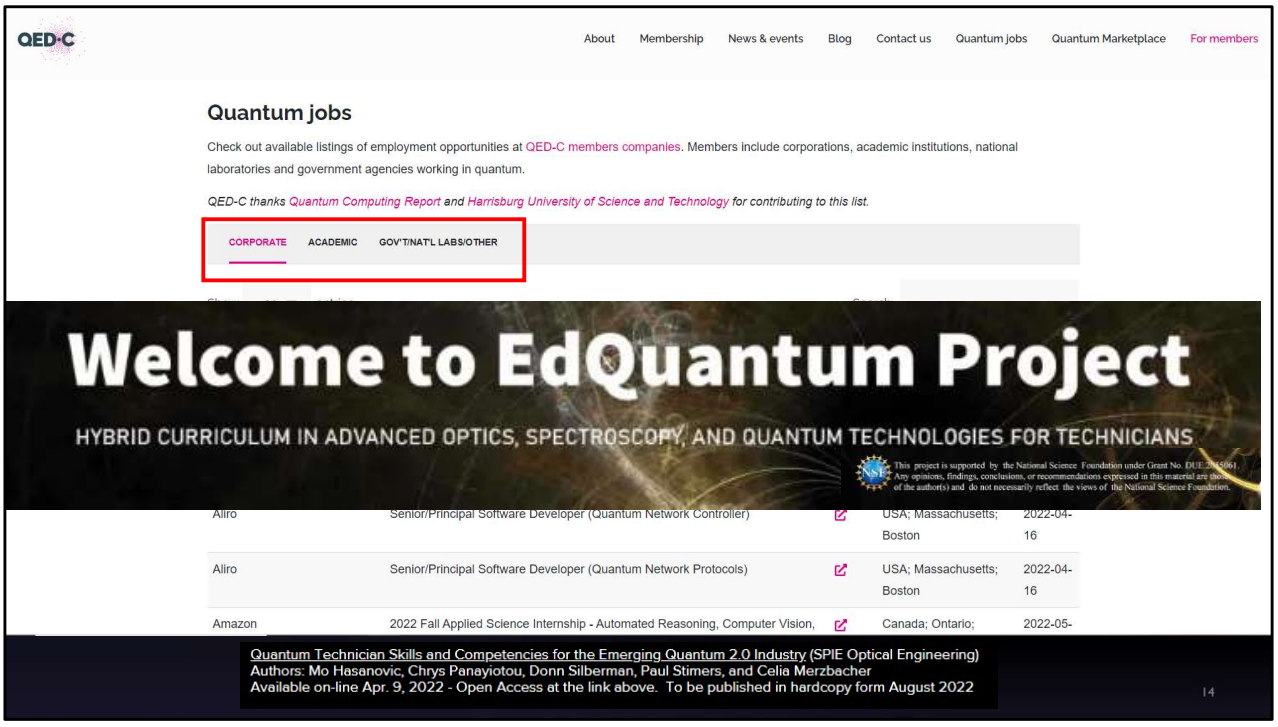
And for each one of you to become knowledgeable and valuable to prospective educators and employers, learning about quantum science and technologies at this phase of your educational career will further set you apart from other students vying for those same educational and career opportunities .

And you still get to choose from many different fields of study in careers that are shown diagrammatically on this chart from our friends at the UC Berkeley quantum computing club . I'll talk more about some of these in a few minutes but just to list a few of the broad categories they include quantum chemistry, physics, biology, math, quantum algorithms, quantum simulations, quantum computing, and quantum communications .



In December 2018, the US Federal Government passed the National Quantum Initiative that recognized and funded some of the current efforts in developing the quantum industry in the United States. Other countries have done this both before and after the US, making this a global race to capitalize on the significant progress that has been made in past decades.

On their website ‘ quantum.gov’ they have links to the original act and recent reports. I’ll talk about the QIST Workforce Development National Strategic Plan is just a few minutes.

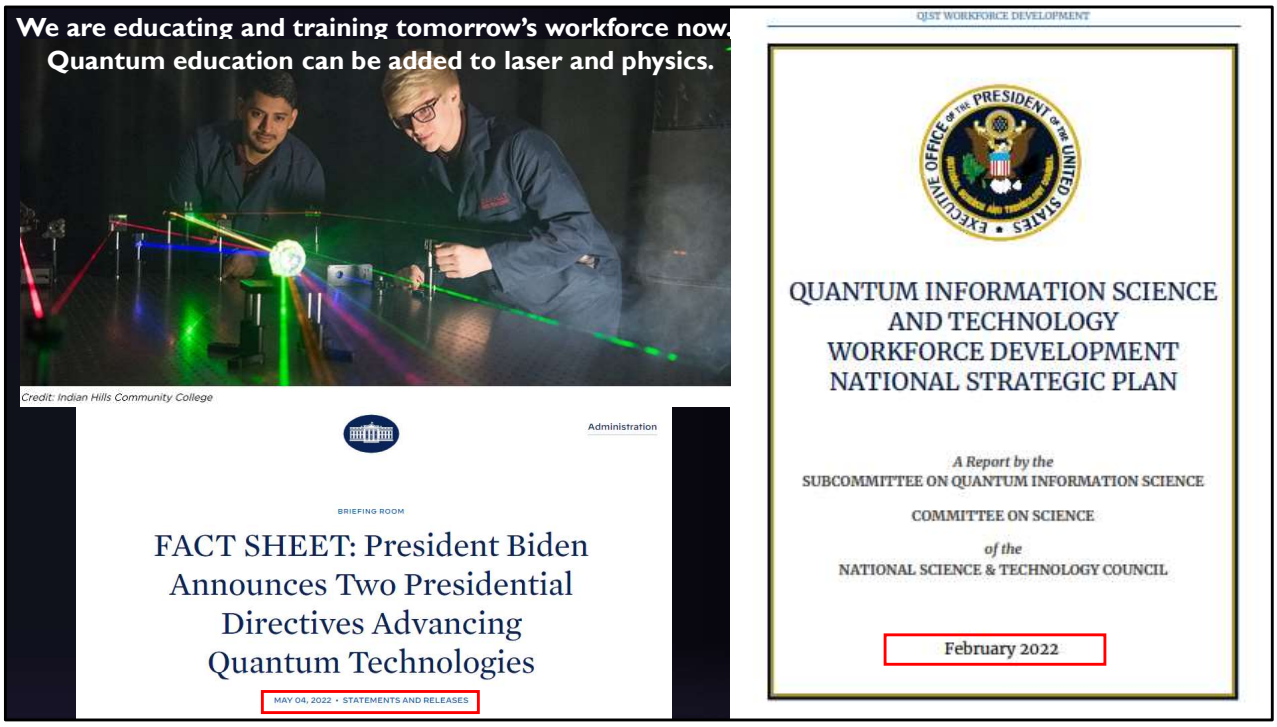


The Quantum Economic Development Consortium (QED-E) has been established to to enable and grow a robust commercial quantum-based industry and associated supply chain in the United States.

1. In the past few years, the amount of attention that has been focused on many advances has left companies, national laboratories, colleges, and universities with many open positions for people skilled with knowledge and experience in quantum technologies. Some very excellent work has been done assessing the needs of the quantum industry. Most of this work has been for people with undergraduate and graduate degrees in physics, chemistry, math, engineering, computer science, material science and related technologies.

2. In line with some of my past educational endeavors, I have been consulting with EdQuantum to develop a hybrid curriculum in advanced optics, spectroscopy, and quantum technologies for technicians to fill the workforce gap between those with undergraduate and high school degrees.

3. My colleagues and I at Ed quantum recently published a paper through SPIE regarding the EdQuantum program. This paper is available free of charge from my website .



In February of this year the executive office of the president of the United states subcommittee on quantum information science published the quantum information science and technology workforce development national strategic plan which includes the national Q through 12 education partnership . This strategic plan is also available to download from my website.

Here it says we are educating and training tomorrow's workforce now.
That means you !!

And on May 4th, the White House announced that the president signed two new directives advancing quantum technologies.

The national Q through 12 education partnership has a dedicated website at q12education.org and has many corporate and institutional sponsors.

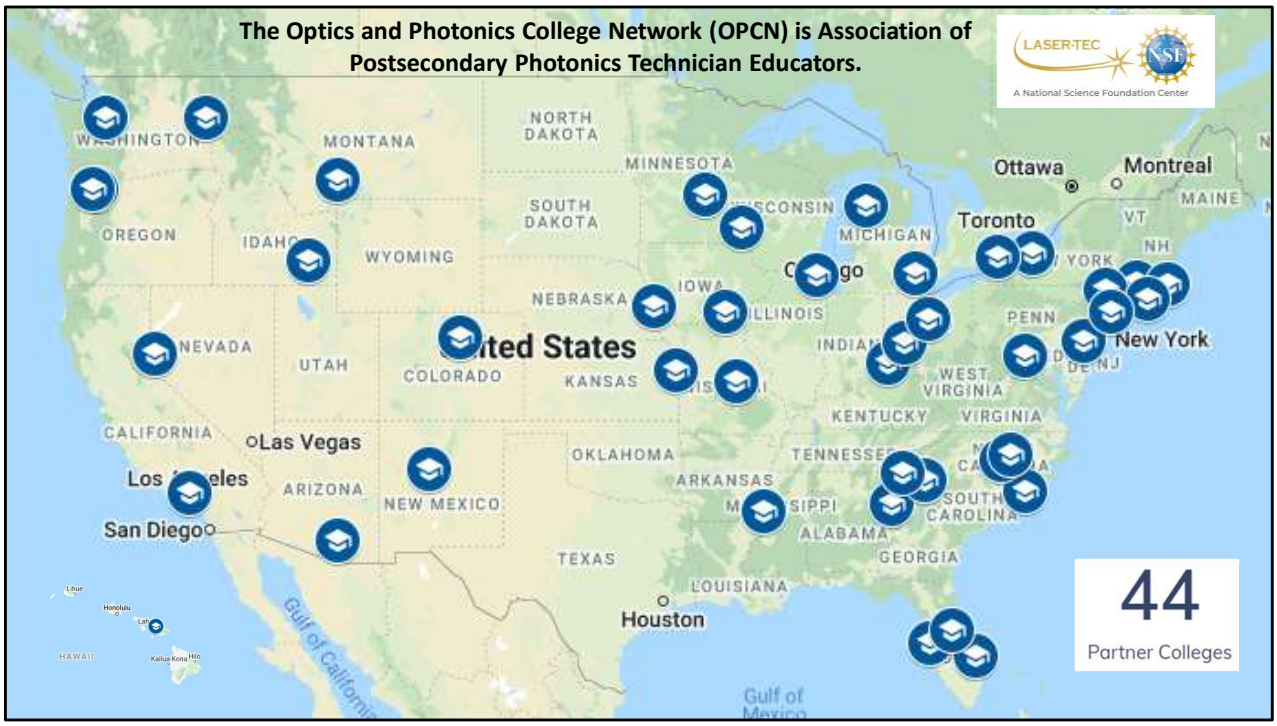
Their aim is to support and grow a quantum workforce that is diverse and equitable, invent new technologies and drive societal change and to increase opportunities for students from all backgrounds.

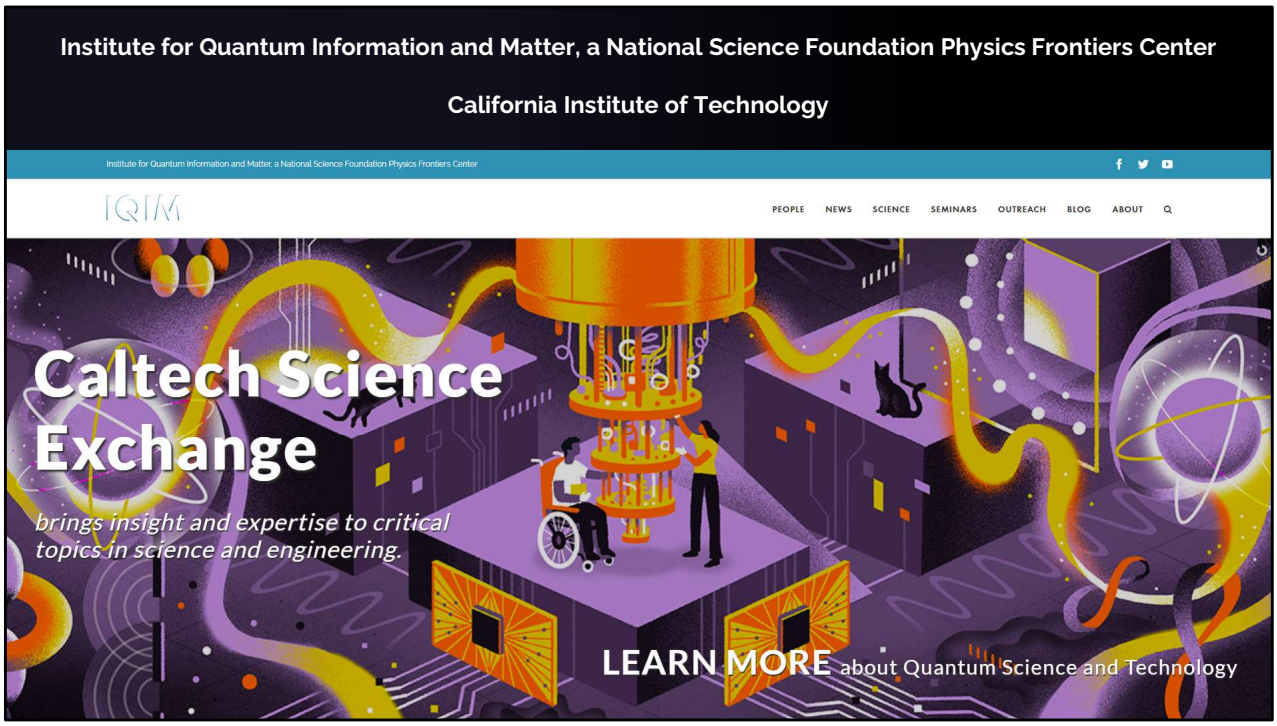
My good friend Dr. Brian Monicelli wanted me to share this with you now in case you might like to take a course in this program beginning in the fall.

I was involved with a program like this at Irvine Valley College for about 25 years and in 2008 Dr. Monicelli took over the program and two years ago we moved it to Pasadena City College where it's close to the Jet Propulsion Laboratories where he works and California Institute of Technology which has many great science and technology programs including some in quantum mechanics. They also have a joint quantum program with Amazon Web Services.

The quantum science and technology curriculum will be added to programs like this one as soon as we are done developing the course content and hands-on experiments.

The EdQuantum program is adding quantum education to the Laser-Tec programs that have established at 44 colleges across the country including Pasadena City College .


The Optics and Photonics College Network (OPCN) is Association of Postsecondary Photonics Technician Educators.
LASER-TEC
NSF
A National Science Foundation Center
WASHINGTON
MONTANA
NORTH DAKOTA
MINNESOTA
OREGON
IDAHO
WYOMING
SOUTH DAKOTA
MICHIGAN
Ottawa
Montreal
Toronto
MAINE
VT
NH
NEBRASKA
IOWA
ILLINOIS
NEVADA
UTAH
COLORADO
KANSAS
INDIANA
PENN
New York
WEST VIRGINIA
KENTUCKY
VIRGINIA
CALIFORNIA
Las Vegas
OKLAHOMA
TENNESSEE
ARKANSAS
ARIZONA
NEW MEXICO
San Diego
SOUTH CAROLINA
ALABAMA
GEORGIA
TEXAS
LOUISIANA
Houston
HAWAII
Gulf of Mexico
44
Partner Colleges

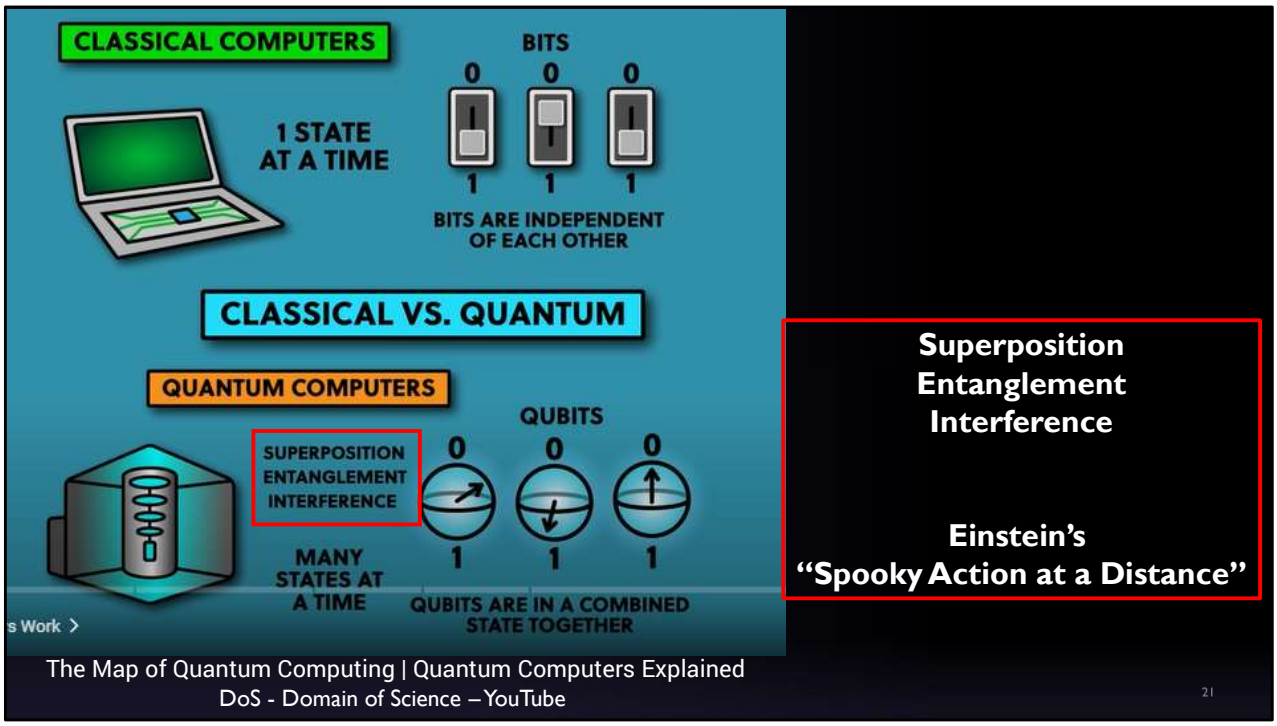


Many colleges and universities have dedicated institutes for quantum science and technologies. This example from Cal Tech has a nice graphic. You can find one near your home so you can get involved locally.

While there will be many aspects of modern life that will continue to be affected by the push to integrate quantum technologies into many products and services, I will now focus on quantum computing, encryption, and the internet, as they pose the greatest risks and opportunities to people's everyday economic life.

Cryptocurrencies have been developed on Blockchain technologies and is a fast-growing sector of the modern financial landscape. Blockchain technologies are also being applied to many other industrial sectors; but quantum computer technologies poise a threat to all these currently secure applications. Quantum computers also may be used to hack all other encryption technologies currently in use.

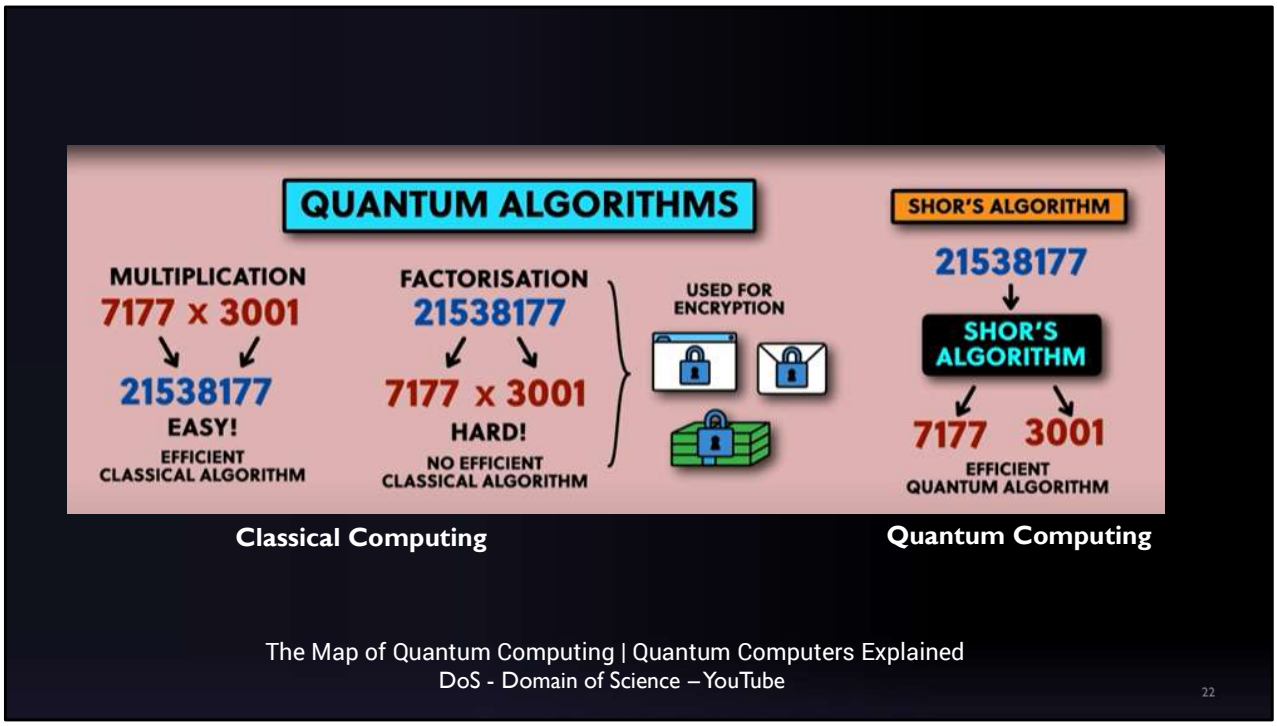
A global race is currently being run by private and public entities, some individually and some in consortium to develop both practical quantum computers and quantum resistant technologies. Much of the work is being published in the public domain that can be tracked; and some must be held 'close to the vest' and their progress is unknown to the public. Herein lies the greatest risk, if an unknown entity develops a quantum computer with the capability to hack current encryption technology and does it without anyone knowing; losses could be substantial.



So what is the difference between a classical computer like we have on our desktops today and a quantum computer that may exist in the labs at a university or modern corporate entity ? Fundamentally you might know better classical computer has bits that are independent of each other and can only be in one state at a time either zero or one.

In a quantum computer, as we can learn from our friends at the domain of science , a qubit (or quantum bit) can be at many states at the same time and that is the confusing part of quantum mechanics that we need to begin educating many people on how this works.

The most important concepts in quantum mechanics that relate to these states our superposition, entanglement, and interference . Quantum entanglement is what Albert Einstein described as "spooky action at a distance " and we can discuss that a little bit later in this presentation.



A clear example of the differences between a classical computer and a quantum computer is the process of factorization . in a classical computer we can see that multiplication is easy and quick 7177 * 3001 equals 21,538,177.

But to factor 21 million 538,177 into 7177 * 3001 is very hard and not efficient in a classical computer, it takes a very long time.

However, using the famous Shor's algorithm and a quantum computer the same factorization problem can be accomplished very quickly. And factorizations is used in standard encryption technology all across the Internet all over the globe.

So, a practical quantum computer with sufficient qubits and error correction can be used to break current encryption technologies using Shor's algorithms and other mathematical constructions .

There is also the concept that encrypted information could be collected secretly, from the current internet and stored until the quantum computer is available to crack the code and read the information later.

There are two paths that need to be tracked;

1. the development of quantum computers and their ability to hack secure encrypted information and

2. the development of quantum resistant encryption.

One parallel technology being developed is quantum secure communications over the internet.

Millions and even billions of dollars are being spent on quantum technologies globally and China is clearly the leader in dollars spent.

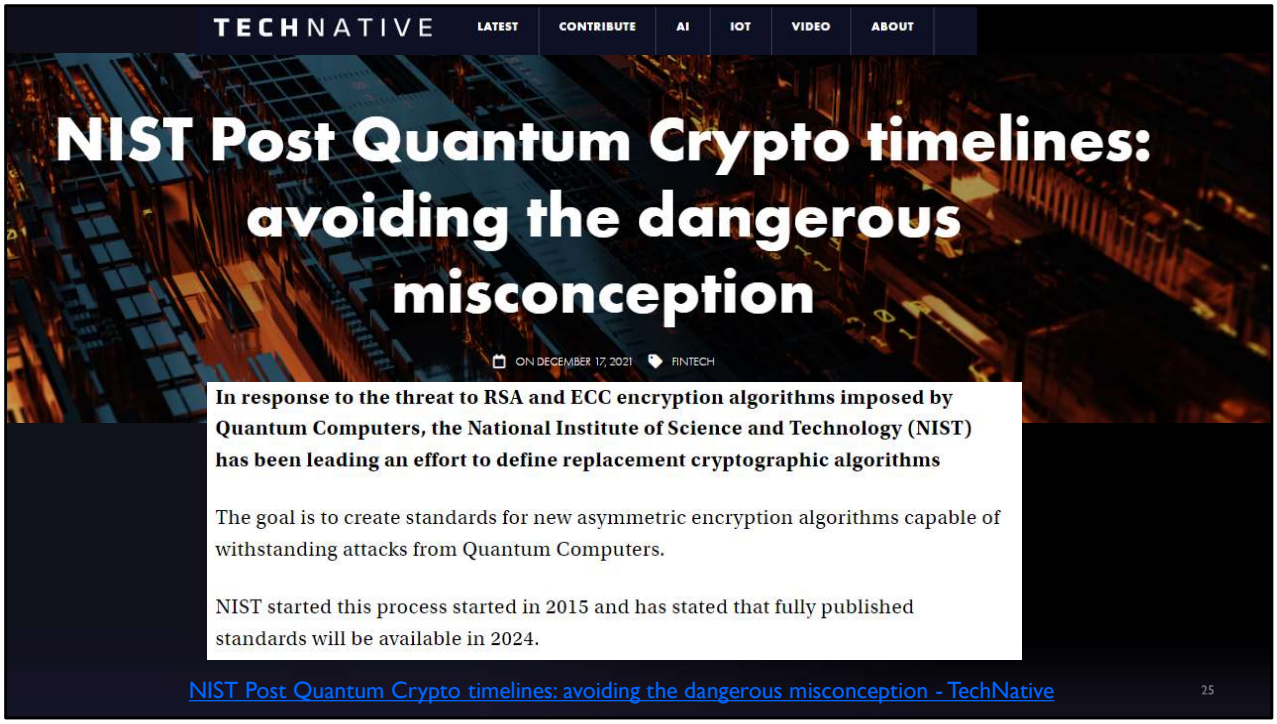
It is possible that they are also acquiring intellectual property in this domain faster than all other countries combined.

So, the actual ability to successfully implement effective quantum technologies through trade secrets will likely be the deciding factor winning this global race.

The federal government wants to help.
In December 2021, the US Department of Homeland Security published an article titled, "DHS wants state and local governments to start planning for quantum computing; releases road maps and resources to help."

This short article describes this situation and mentions that the **National Institute of Science and Technology (**NIST) has been working on new quantum-resistant encryption algorithms to provide guidance to US based entities and will be narrowing down the final entries and releasing the results this year.

This article mentions that the DHS believes quantum computers may be attacking public and private information by 2030; my belief is that it will come much sooner.



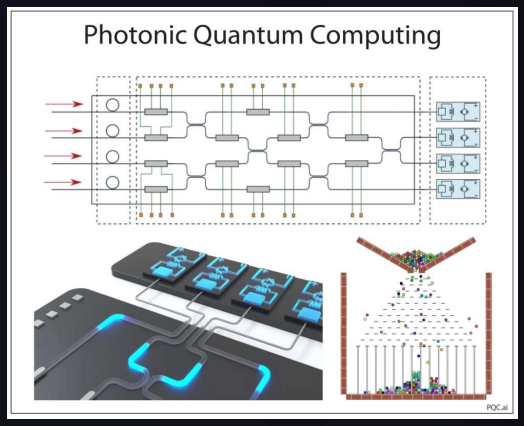
In an article on TechNative in December 2021, Alan Grau, the Vice President of Business Development for PQShield, a post quantum crypto solutions company with both hardware and software implementations. He writes about the threat encryption algorithms will face by Quantum Computers.

NIST and partners have been working to define quantum resistant cryptographic algorithms with a goal to have them fully published standards will be available in 2024.

But companies are already implementing the Post Quantum Crypto solutions based on standardized algorithms. Implementations of these algorithms are available, so companies don't have to wait until 2024 to begin migration from classical crypto solutions to the new Post Quantum Crypto (PQC) algorithms.

Twenty Years at Light Speed: The Future of Photonic Quantum Computing

DECEMBER 20, 2021 *BY* DAVID D. NOLTE



Twenty Years at Light Speed:The Future of Photonic Quantum Computing | Galileo Unbound (galileo-unbound.blog)

The Quantum Era Emerges - How PI Fast Automated Alignment Enables Practical Manufacturing

PI (Physik Instrumente) L.P.

Silicon photonics wafer testers require much higher precision and alignment algorithm complexity compared to classical semiconductor wafer probers. The image shows PI's double sided alignment system for fast NxM alignment of SiP devices Cascade Microtech's CM300xi photonics-enabled wafer probe station. (Image: Cascade Microtech, a FormFactor company)

Quantum Technology, Alignment & Nanopositioning | PI (pi-usa.us)

26

My belief that the 2030 DHS time prediction is too long, is based on my years of industry and academic experience with physics, optics, lasers, fiber optics, and Silicon (Photonic) Integrated Circuits (SICs). Part of that work experience was with PI (Physik Instrumente) where I helped with applications of Fast automated alignment systems for test and measurement of advanced silicon photonic integrated circuits.

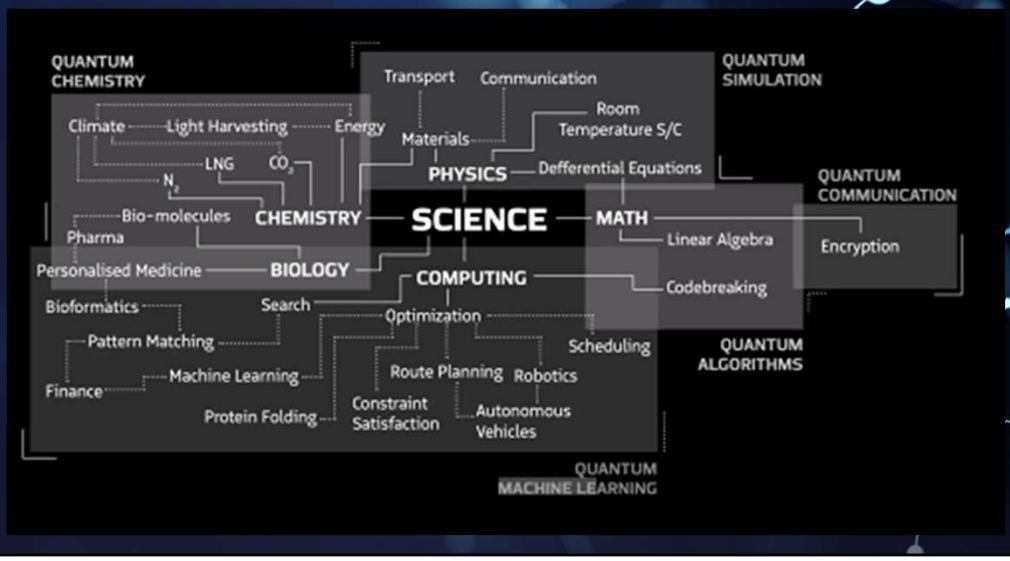
These are one type of hands-on instruments technicians need to get experience with to help companies bring the next generation quantum computers to the marketplace.

In one of the articles in my references, the authors review over a dozen different quantum computing hardware technologies and companies that are all in this race to build and implement a practical quantum computer.

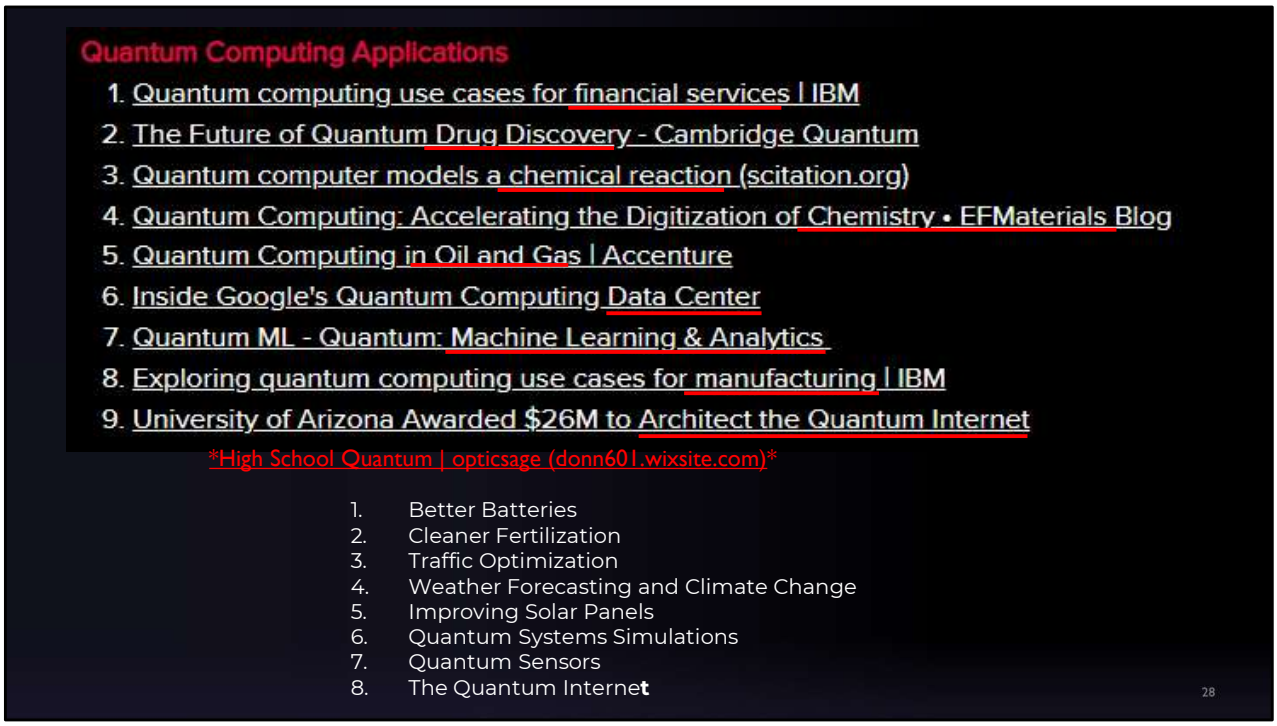
The details and technical references are all provided for readers interested in exploring them further.

My perspective is that Quantum Photonic Integrated Circuits (QPICs) will be the winning technology for multiple reasons that are reviewed in a recent blog article that reviews 20 years at light speed – the future of photonic quantum computing.

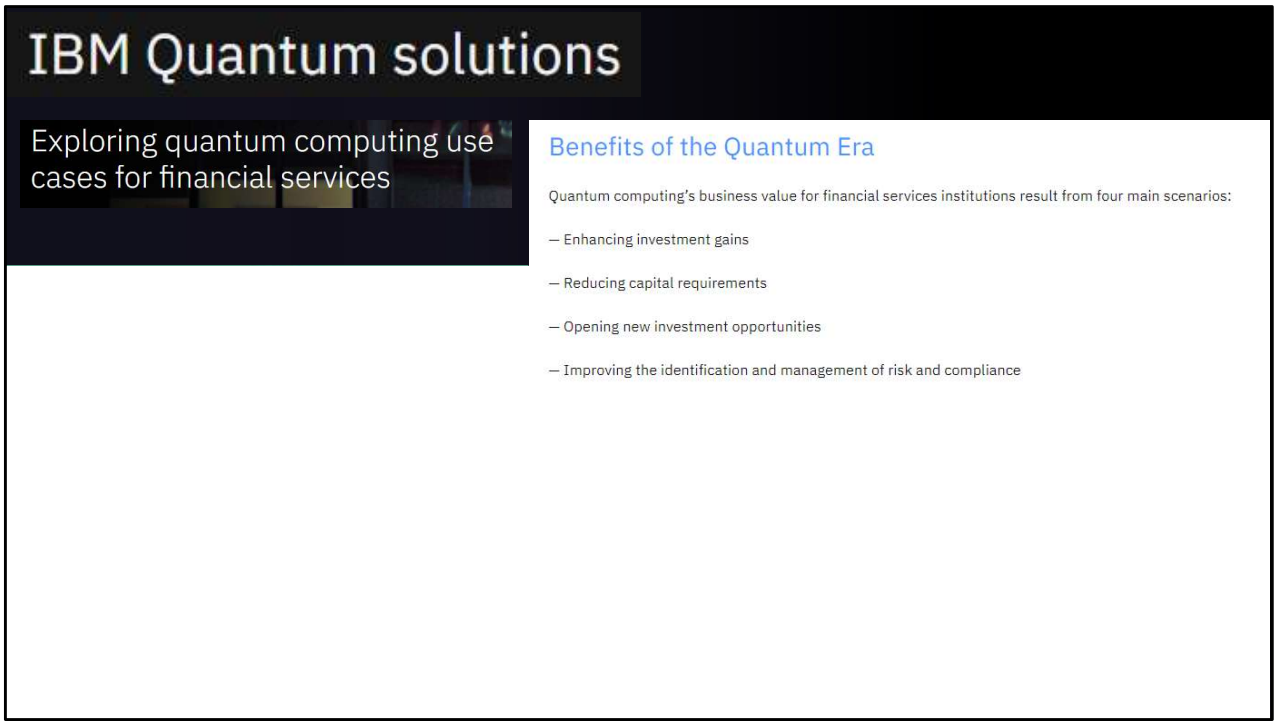
Many More Quantum Applications



OK that was an introduction to quantum computing and quantum encryption technologies. So, we'll leave that behind for the rest of this presentation and talk about many other quantum computing applications in some of the fields and industries seen on this chart from earlier in this presentation.



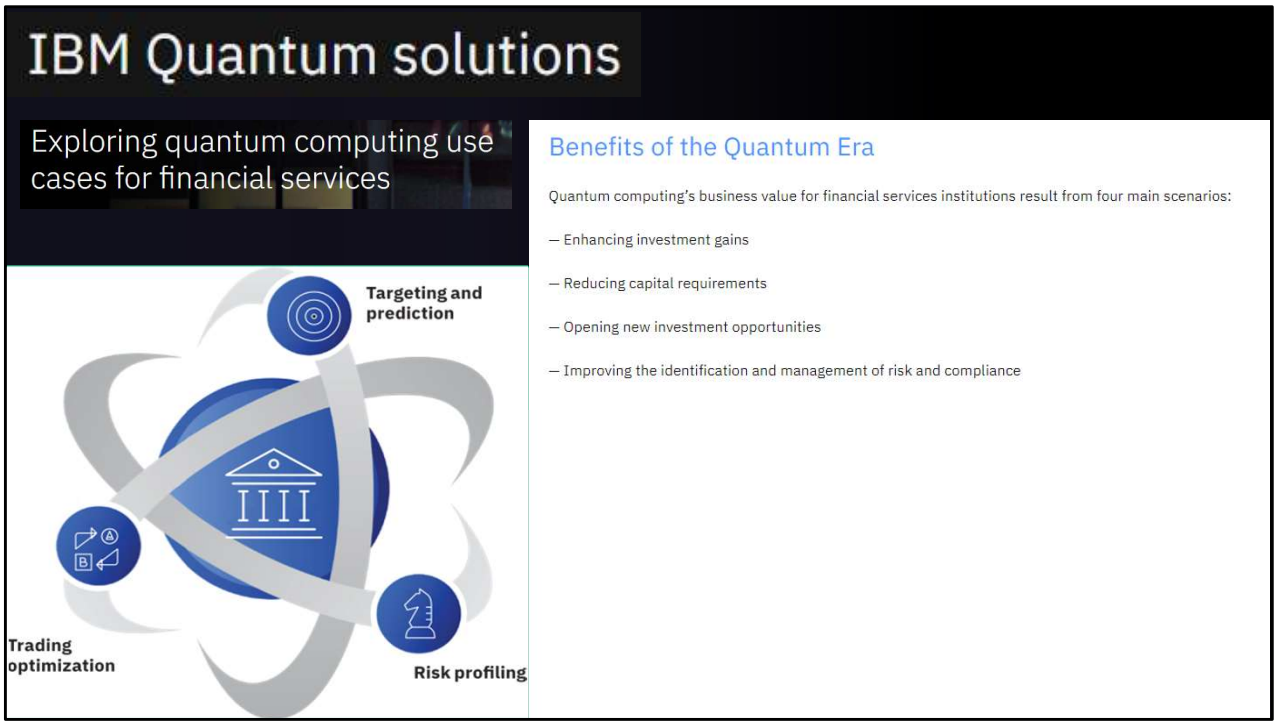
In the next set of slides I'll review these nine quantum computing applications in a little more detail so you can see some companies that are already working in areas very important to modern civilization . These include financial services, drug discovery, chemical reaction modeling, the oil and gas industry, data center management, machine learning and analytics, general manufacturing, and telecommunication infrastructure. In addition, you can find more information to each of these case studies in direct links to company websites on my webpage 'High School Quantum' and you can search for more links to information on the industries and fields listed below .



IBM is one of the oldest and biggest computer companies in the world and of course they are at the forefront of quantum computing and applications. One of the most important quantum computing applications is actually in the finance industry. In this composite chart we can see that IBM has highlighted four benefits of using quantum computing:

1. enhancing investment gains,
2. reducing capital requirements,
3. opening new investment opportunities, and
4. improving the identification and management of risk and compliance .

Now one might ask how does quantum computing benefit these four areas of the financial services industry?

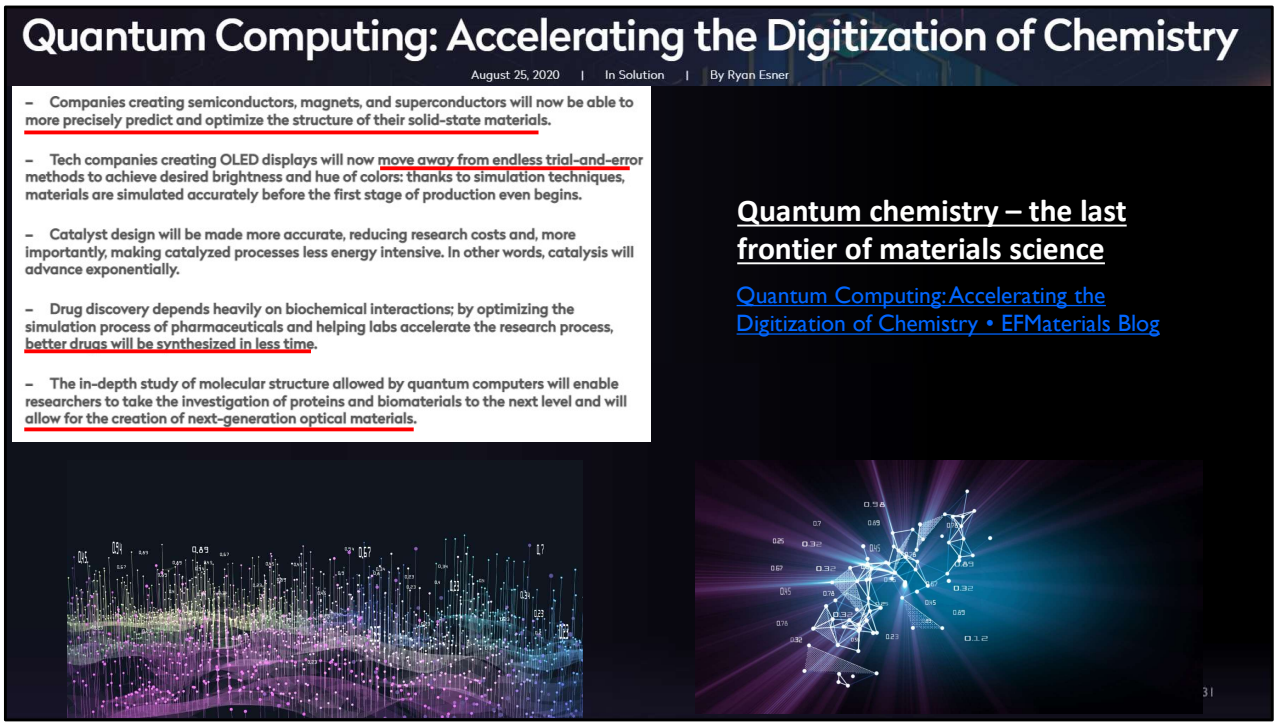


Using the speed and parallel type processing power of quantum computing on financial problems—particularly those dealing with

- ✓ trading optimization,
- ✓ targeting and predicting financial movements and
- ✓ profiling many different risks

should prove hugely advantageous for those companies that adopt using quantum computers first.

Beyond that, greater compliance, employing behavioral data to enhance customer engagement, and faster reaction to market volatility are some of the specific benefits people expect quantum computing to deliver.

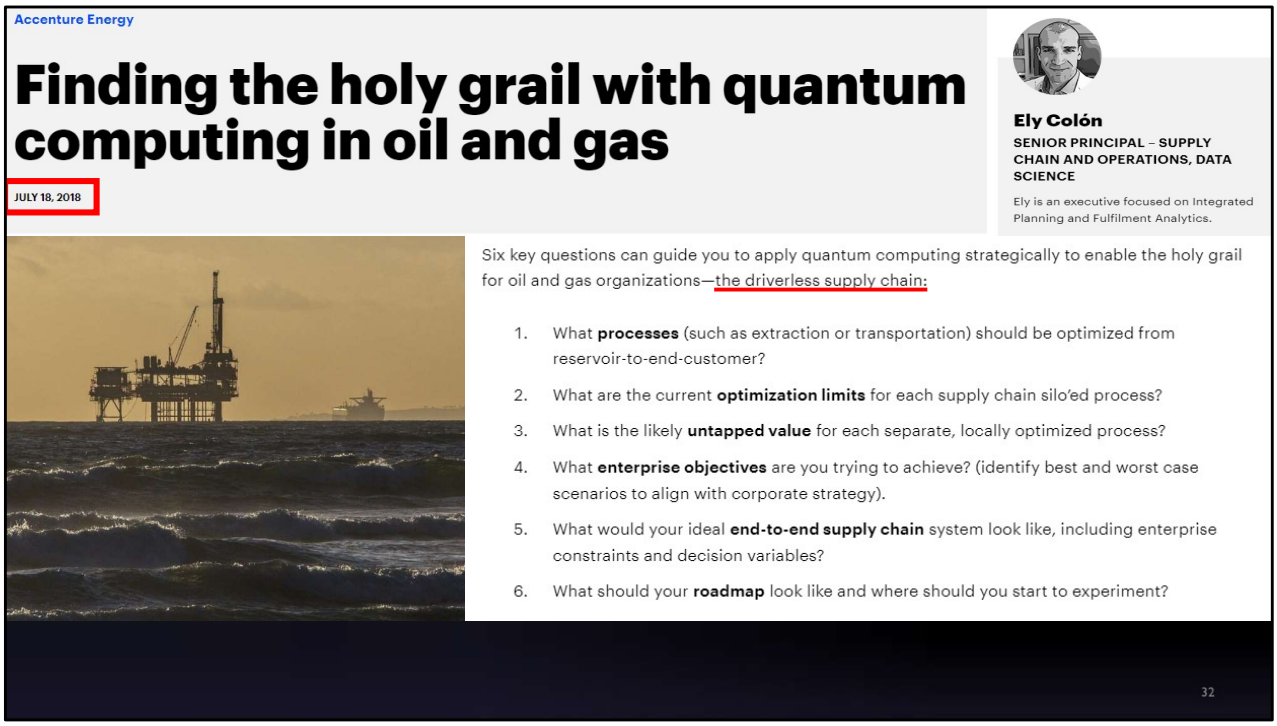


Because chemistry is quantum mechanical at its very nature there are many applications where using a quantum computer will help the process of discovering and engineering new materials in many fields. The ability to more precisely predict and optimize the structure of solid state materials in semiconductors, magnets, and superconductors will help companies bring advanced new products to markets where their customers will be able to implement them in many different end user products .

High tech companies making specialty display monitors based on quantum dot and organic LED technologies will move away from the endless trial and error methods to achieve desired brightness and colors by using quantum computer simulation.

Pharmaceutical companies using current advanced computing systems to optimize drug discovery will be able to synthesize better drugs faster with quantum computers.

And the next generation of optical materials using the molecular structure of proteins and other biomaterials will be enhanced by the use of quantum computers .

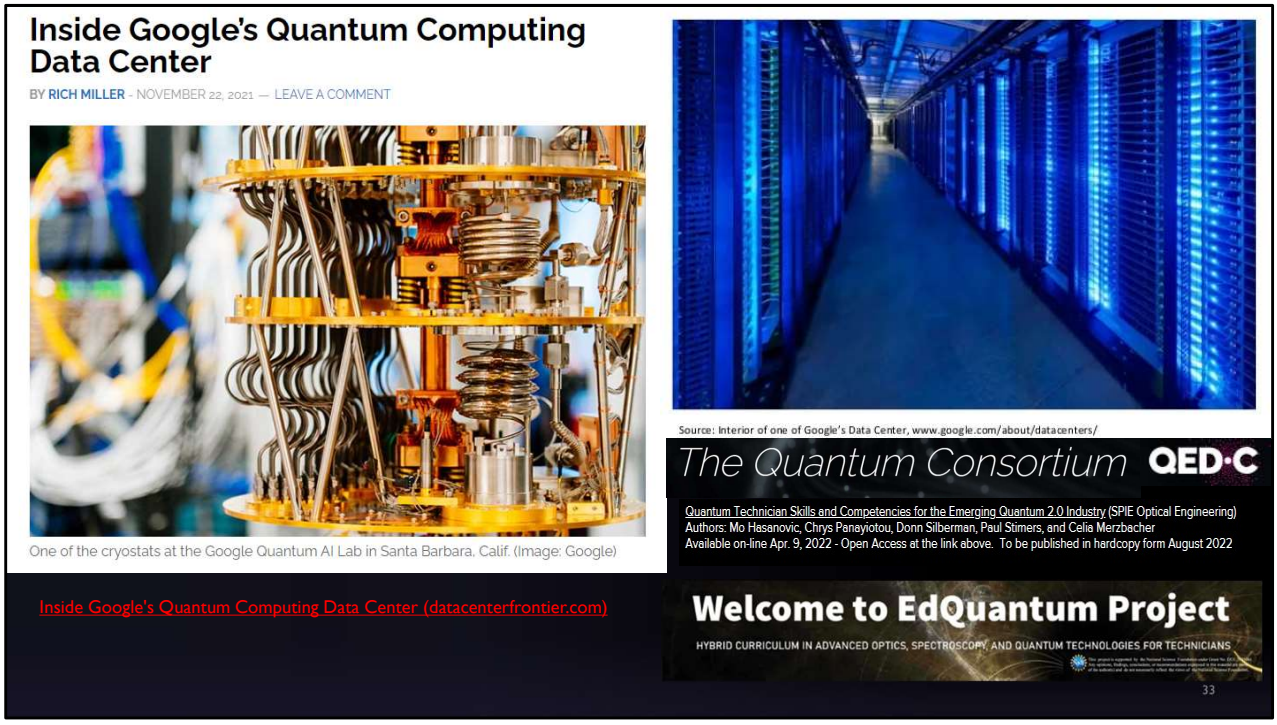


As you can see by this slide from 4 years ago, the author wrote about using quantum computers in the oil and gas industry . he posed six key questions to guide users in the oil and gas organizations toward their 'holy grail – the driverless supply chain' or how to get the oil & gas to the customers without tanker trucks.

These questions ask about:

1. Optimizing the process from the reservoir to the end user
2. Optimization limits of silo'ed supply chain processes
3. Finding the untapped value for separate locally optimized processes
4. Achieving global enterprise objectives aligned with corporate strategies.
5. Identifying ideal end-to-end supply chain systems.
6. Creating a roadmap for using quantum computers and figuring out where to start.

While this author has written about using quantum computers in the oil and gas industries, these key topics could also be applied to other industries.

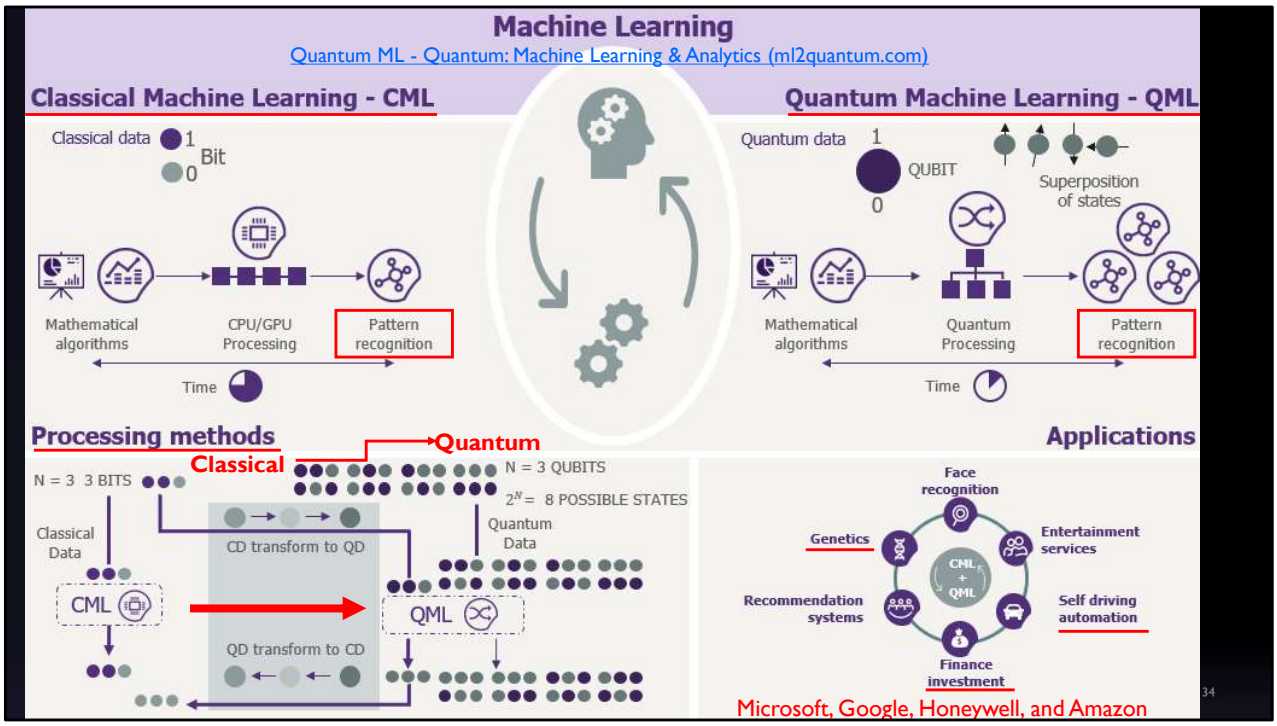


In November 2021 Rich Miller wrote an article for Data Center Frontier discussing Google's artificial intelligence lab efforts on creating a quantum computing data center. In the article Rich discusses the differences between classical and quantum computing and the challenges and pathways to create a quantum computer and then scale that up to a quantum data center. These are envisioned to be very different than today's generation of cloud and high-performance data centers due to the significant differences between classical and quantum computing.

One main difference pictured here is the cryostat needed for some implementations of a quantum computer. In the article, there is a 3-minute video tour of the Google AI labs where Erik Lucero, a Google Research Scientist, walks the viewer through their facility and talks through their vision of the future Google AI Quantum Computing Data Center.

Rich ends his article by noting that other key players in the quantum computing race are using different technical approaches to build quantum computers and these may have dramatic effects on the facilities required to make their versions of quantum data centers; especially if the quantum computers can operate at room temperature, as Celia Merzbacher, Director of the Quantum Economic Development Consortium (QED-C) described in her keynote talk at Data Center World in the summer of 2021.

This year I had the honor of co-authoring a journal paper with Celia and others associated with the EdQuantum project titled "Quantum Technician Skills and Competencies for the Emerging Quantum 2.0 industry in SPIE's Optical Engineering Journal. This is available to download from my website too.



On the Quantum Machine Learning website, you can learn more about the differences between classical and quantum computers and their respective applications using machine learning and data analytics. The advances in:

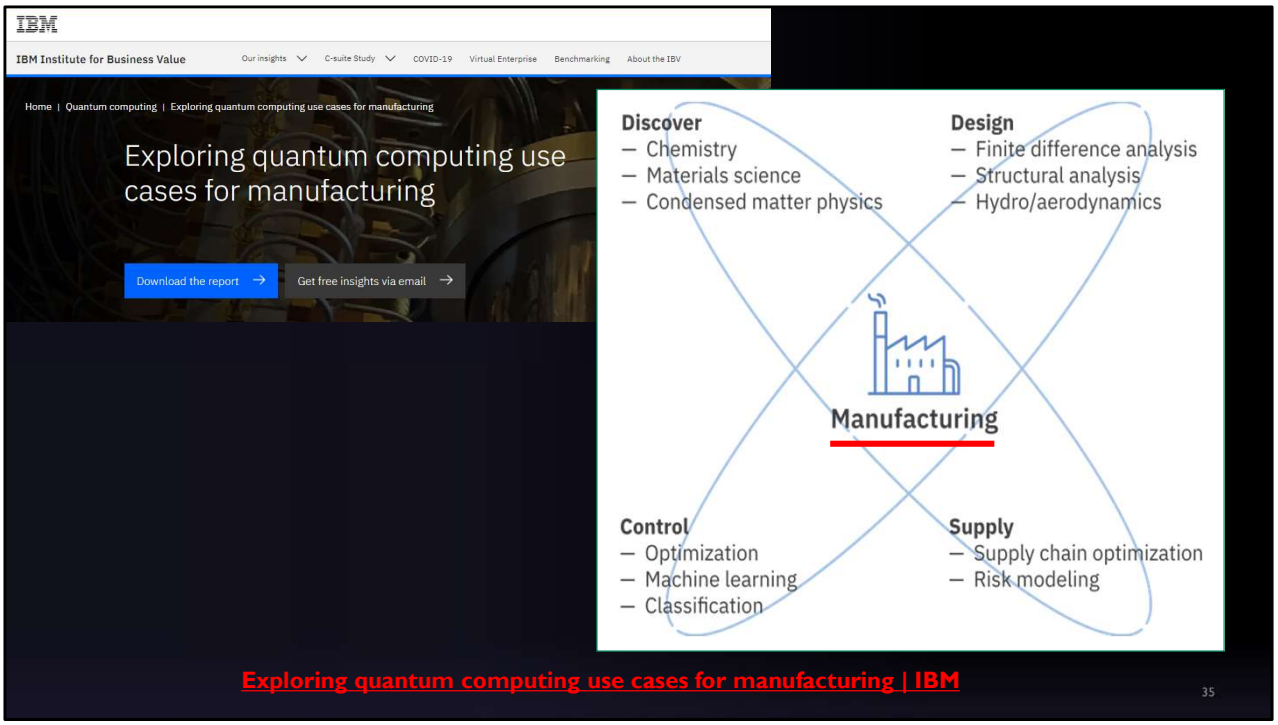
1. fundamental processing methods gained using quantum computing, shown here in this diagram, can lead to extreme advances in

2. pattern recognition which can be applied to end user applications such as

3. genetics, self driving cars, financial investments, logistics and many more, some of which we have already discussed and others that we listed.

This website also has some information about the Machine Learning efforts from larger key companies such as

4. Microsoft, Google, Honeywell, and Amazon.



Once again, we look to IBM to help us understand the business use cases in some manufacturing industries to gain a sense of how and why quantum computing seems like such a worthwhile technology to explore and invest time, money and resources.

There is a complete report you can download from this website that highlight (and I quote) “the enormous potential that quantum computing is expected to help develop breakthrough products and services that will disrupt and redefine manufacturing”

There will be business advantages in these areas shown here on this diagram with substantial opportunities for early adopters to lock in that followers will have a difficult time overcoming.

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

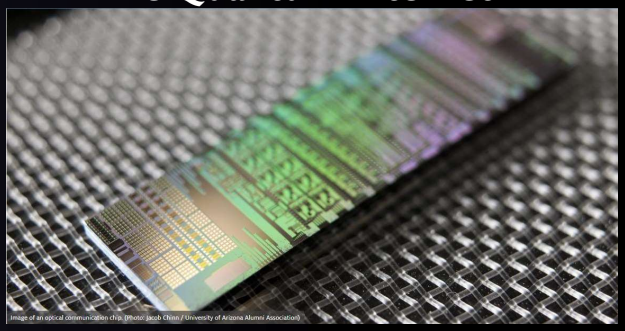


Image of an optical communication chip. (Photo: Jacob Chinn / University of Arizona Alumni Association)

University of Arizona Awarded $26M to Architect the Quantum Internet | News | College of Engineering | The University of Arizona

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The last and possibly most important application of quantum computing is when these are networked together in the world's first quantum internet. The Univ of AZ is leading the National Science Foundation's Center for Quantum Networks, with core partners Harvard, MIT and Yale.

The team at the University of Arizona is led by the James C. Wyant College of Optical Sciences and includes the College of Engineering the James E. Rogers College of Law and the College of Social and Behavioral Sciences. This is due to the significant impact the quantum internet will have on society, workforce development, community outreach and the legal implications of inclusion.

So, if any of this sounds interesting for you, and you want find out how to get involved in the quantum world, I'll give you these three main points:

1 be interested.
2 find a mentor and
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

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

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To find a good mentor, you might start with your physics teacher or whoever brought this presentation to your school or group.

Then, “take action”, by visiting my website and click on links and read the articles that seem to interest you most. There is far too much information for anyone person to digest and use it all effectively, so you will need to focus on what interests you the most and find your own path.

You can watch YouTube videos, some are good, others – not so much.

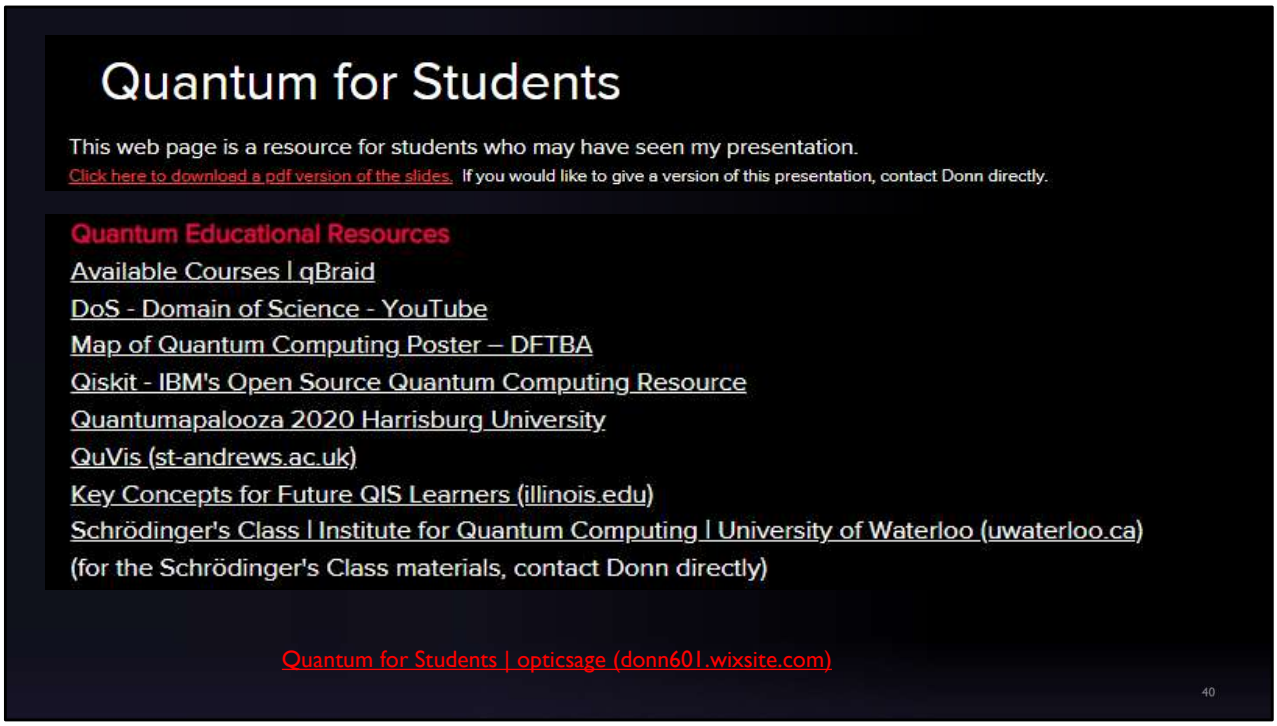
Maybe you can find some hands-on workshops that you can attend in person, or even on-line.

There are colleges and universities that offer courses in quantum sciences; but not too many that have specific applications like those described in the previous slides.

Look for an internship in the field that interests you most.

Join or start a club at your school and engage with like minded fellow students.

To help you with the ‘Take Action’ steps, I have assembled a list of on-line and in-person resources where you can start your journey.



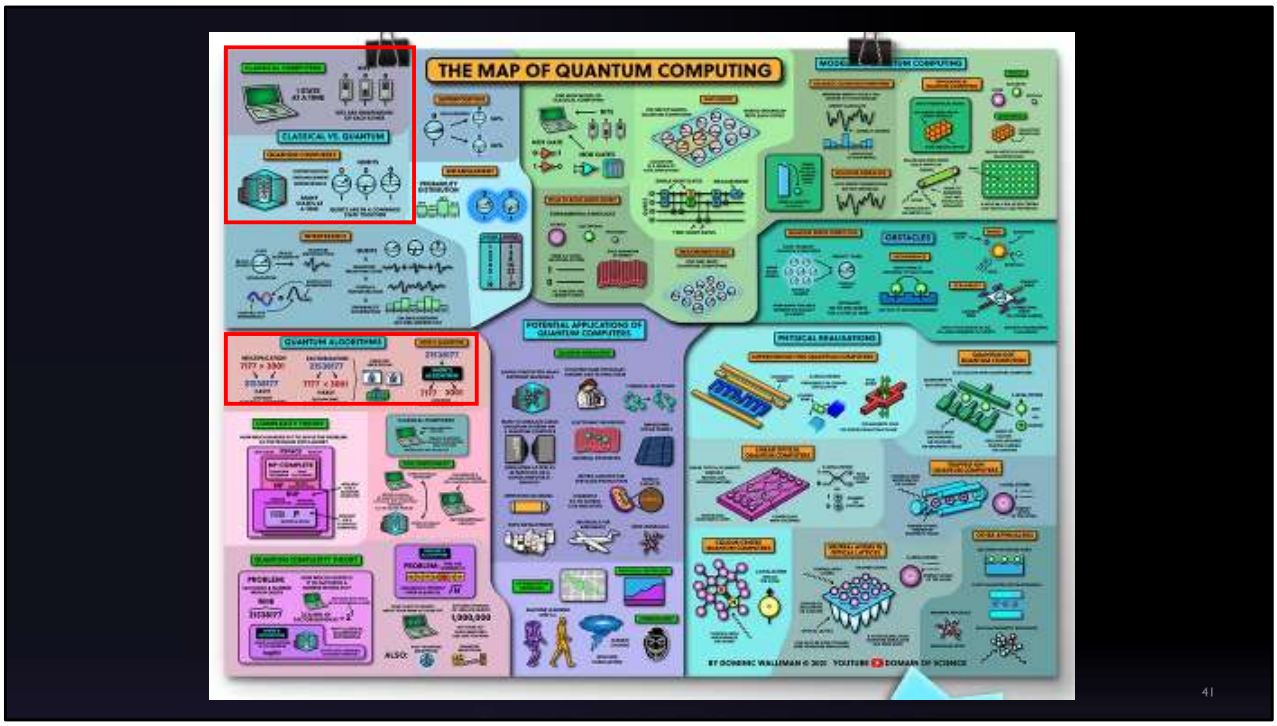
This slide shows a modified screen shot from my webpage Quantum for Students.

This is where you can download a pdf version of the slides and notes, and an audio / video version of the presentation. There are also URL links to all the websites I have referenced already and more that I will review in the time remaining.

These include:

1. Map of Quantum Computing Poster – DFTBA
2. Qiskit - IBM's Open Source Quantum Computing Resource
3. Quantumapalooza 2020 Harrisburg University
4. QuVis (st-andrews.ac.uk)
5. Schrödinger's Class | Institute for Quantum Computing | University of Waterloo (uwaterloo.ca)

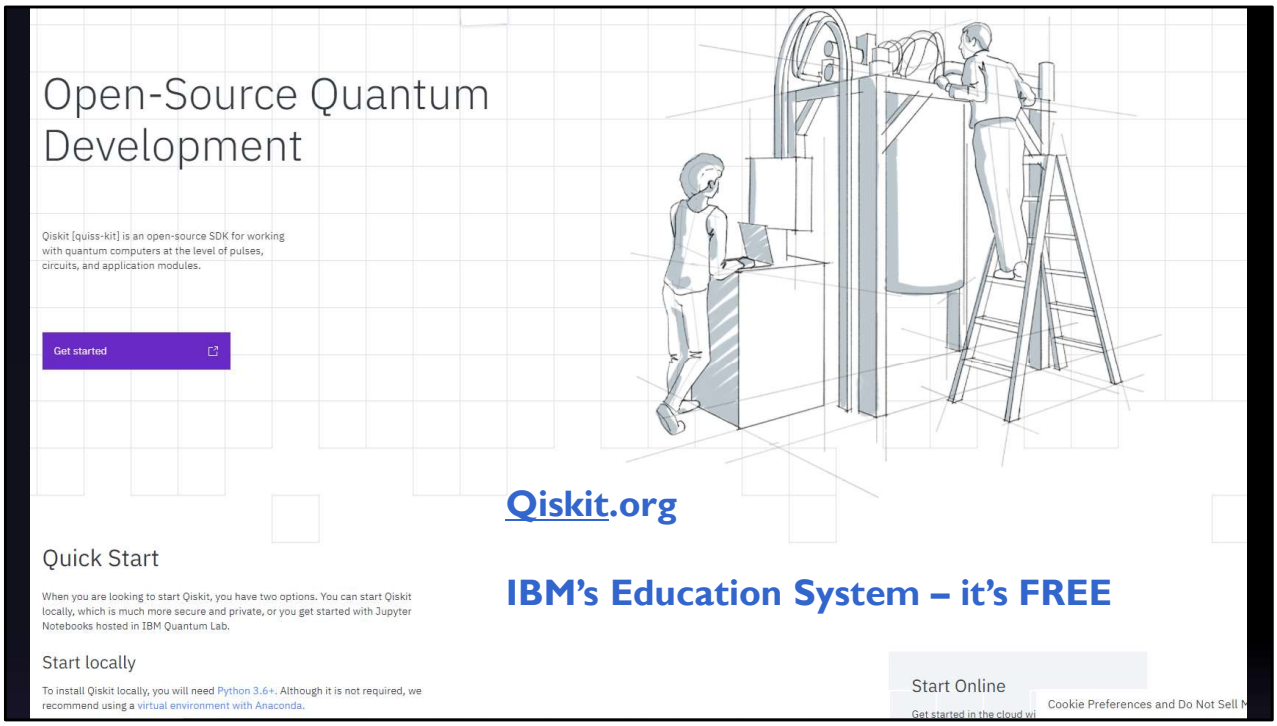
(for the Schrödinger's Class materials, contact Donn directly)



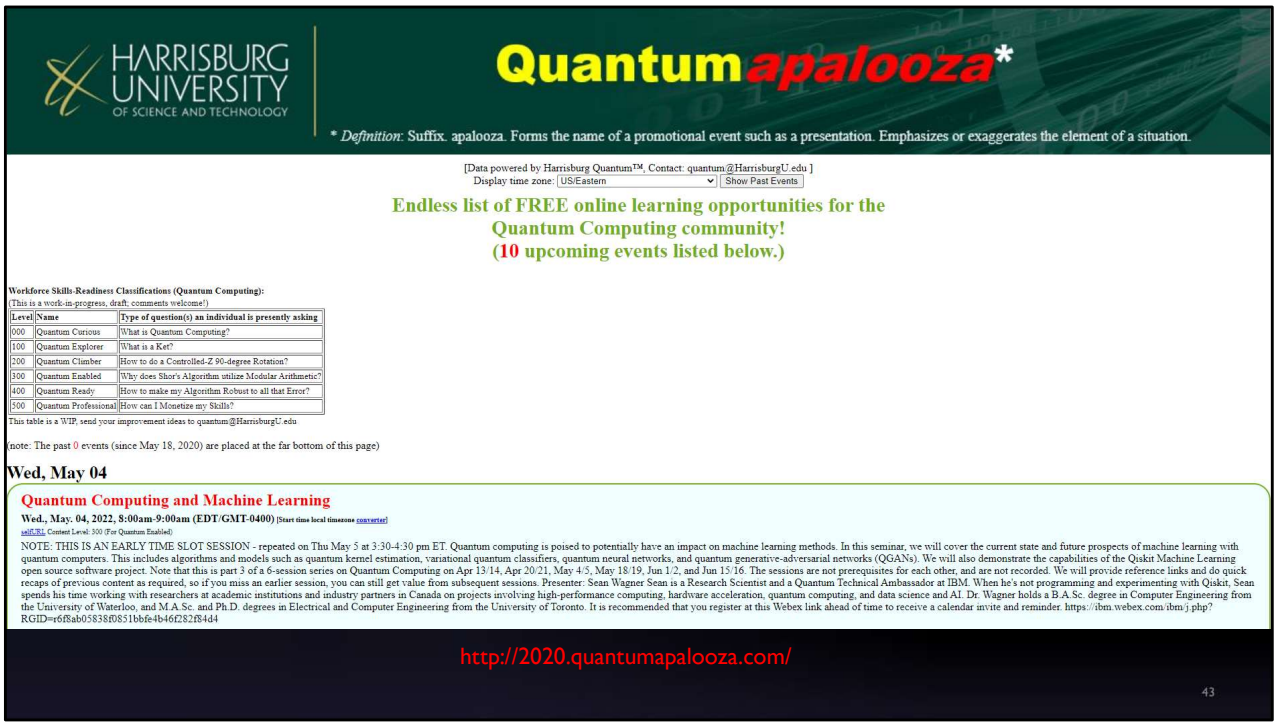
The Domain of Science YouTube channel and associated posters and books has been Made and hosted by Dr. Dominic Walliman, an experimental quantum physicist and author. Out of all the authors and publishers trying to communicate about science topics and particularly quantum science and computing; I have found these to be the most informative, educational and easiest to digest.

A couple of the slides and concepts I have used earlier in this presentation have come directly from this 'Map of Quantum Computing'. You can see the graphics in the two red squares, the first one showing the differences between classical and quantum computing and the second one showing how a quantum computer can factor large numbers much faster than a classical computer.

Clearly, I have only scratched the surface of this map and all the topics on quantum computing. But this map and the associated website and YouTube videos are a great place to start.

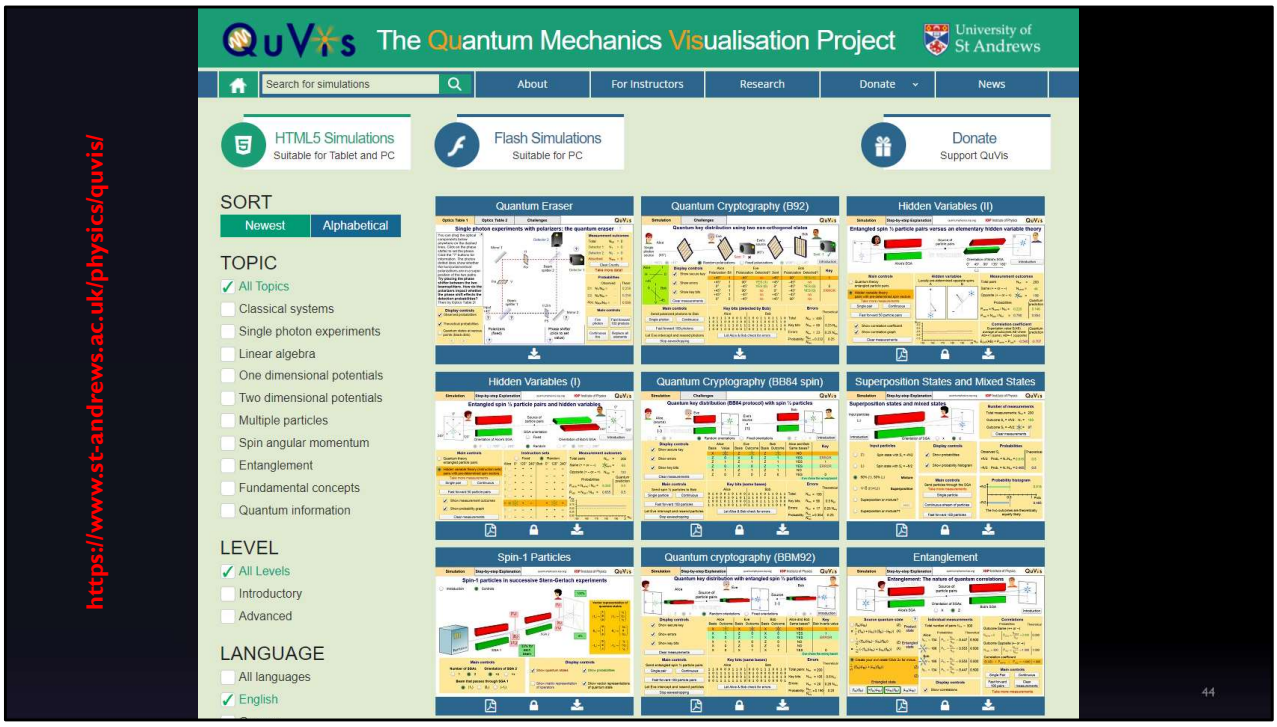


If this has really captured your attention and you want to take the next step to start learning about actually programming on a quantum computer; then IBM has this great open-source education system that is free. They call it Qiskit. I am not going to go into any details about this development tool; but if you are already programming on classical computers, then this could be a great place for you to explore.



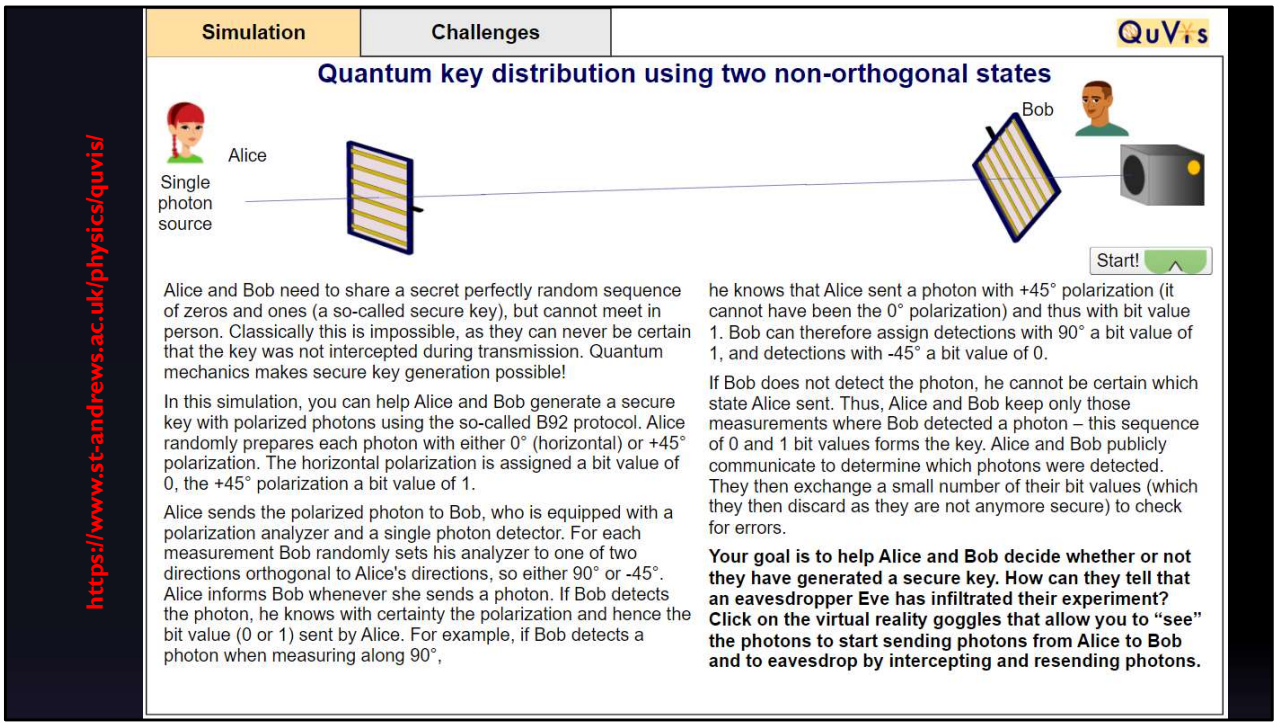
Harrisburg University of Science and Technology, Quantum Computing Academy (QCA) in Harrisburg, Pennsylvania, maintains this quantumapalooza website.

They continuously update this Endless list of FREE online learning opportunities for the Quantum Computing community! They have 10 upcoming events listed on this webpage like the one that just happened on May 4th - Quantum Computing and Machine Learning.



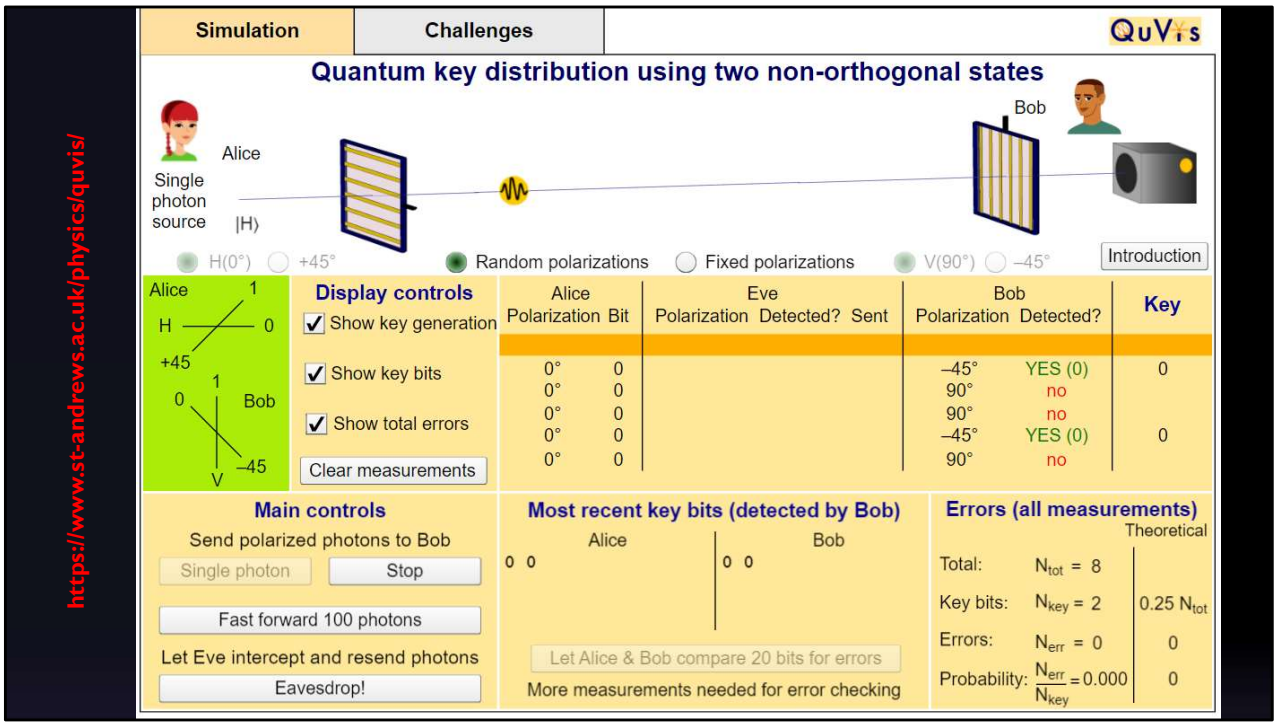
The Quantum Mechanics Visualization Project, developed and maintained by the University of St. Andrews School of Physics & Astronomy in the United Kingdom, offers students the ability to use very good graphical simulations to learn more about the fundamentals of quantum mechanics which can help them understand some of the non-intuitive outcomes of various physical experiments and the mathematics that describe them.

There are many different introductory and advanced topics to choose from including a few applications such as quantum cryptography that I mentioned earlier.

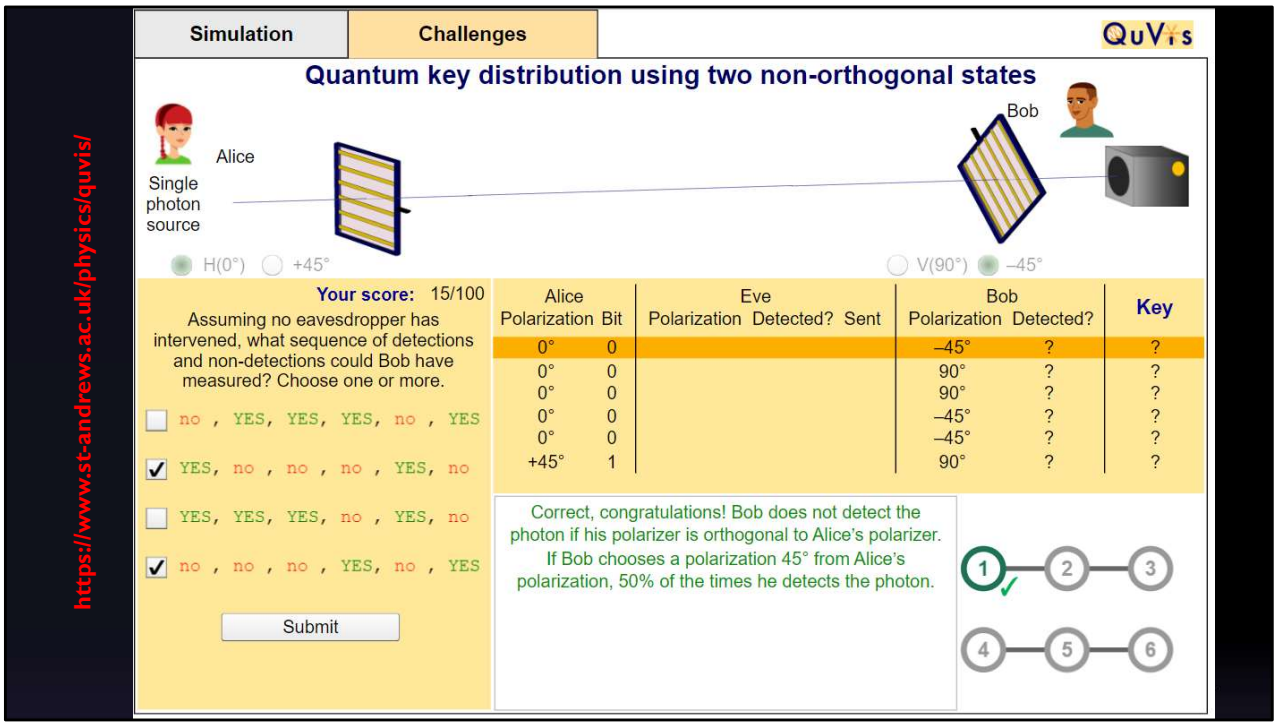


In this Quantum key distribution simulation & challenge, the student is provided a detailed description of the physics experiment, in this case using familiar polarization filters and a single photon source as the quantum object.

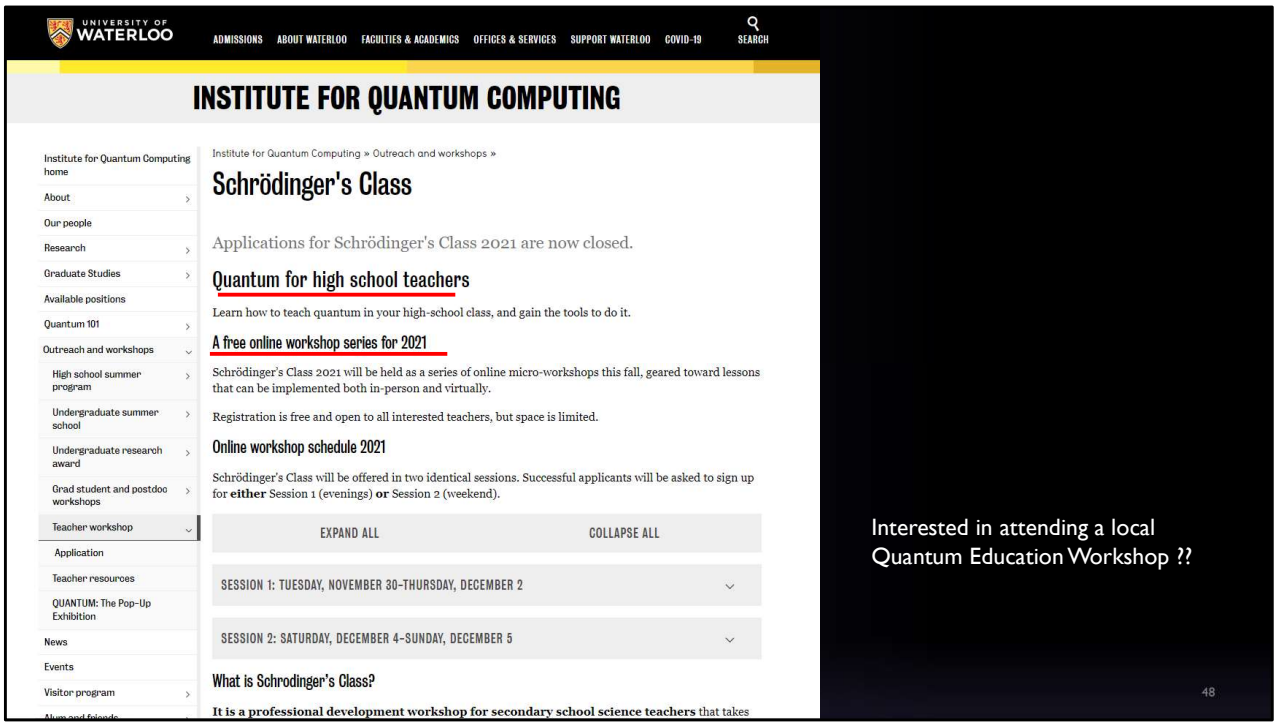
The student's goal is to help Alice and Bob determine if they have a secure quantum key that has been distributed without Eve eavesdropping.



The student can watch a simulation of the experiment using several polarization settings, display and main controls. Here I used the continuous setting with all the display controls shown.



In this slide I show my results of the challenge where I choose the correct sequence of detections assuming there was no eavesdropping. There are many more variations in this simulation and challenge that students can go through to further their understanding of this experiment. This can lead to a deeper understand of quantum science in general and quantum cryptography in particular.

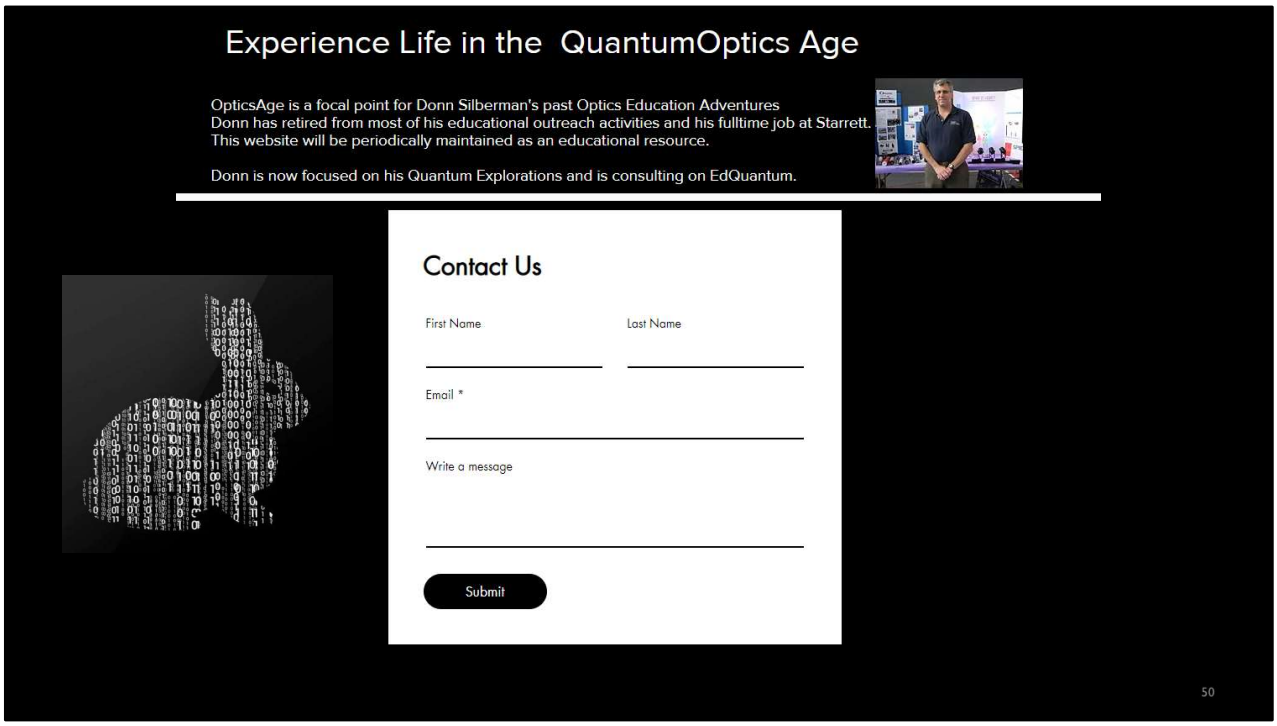


Last summer I attended a two-day on-line workshop where I learned how to provide a short course on quantum science to high school students. This was offered by the University of Waterloo in Canada and was called Schrodinger's Class, after the famous quantum scientist Erwin Schrodinger and his conceptual cat.

I have the complete set of all the course materials (for students and teachers) and can work with your teachers to help bring this unique educational opportunity to your school. Some of the concepts are similar to the simulation and challenge I just described from the Univ. of St. Andrews.

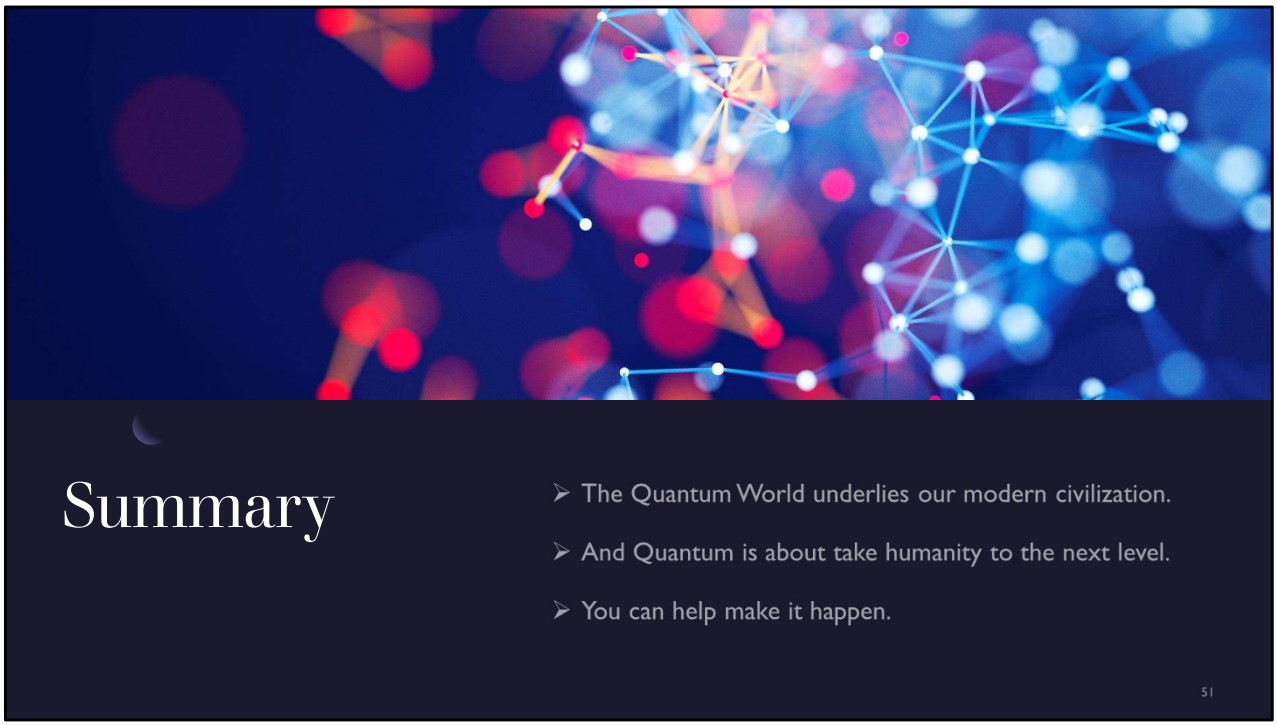
We are now at the end of this presentation. If you think this is something you want to learn more about, then follow the white rabbit into the new quantum world of superposition, entanglement, and interference… or as Albert Einstein named it…."Spooky Action at a Distance"

It has always been a goal of mine to better understand the quantum world and now I have finally jumped down the rabbit hole and am hoping to guide many students.



If you have any questions you would like to ask, you can contact me from my website.

Just follow the Digital White rabbit.



We are living in the Quantum World where the smallest subatomic particles and energy fields make up everything in our Marco world.

These new quantum technologies built on quantum science is taking humanity to the next level of our modern civilization and likely to many worlds beyond.

And you can be a part of making this all happen.

If we have time, there is a 3 minute video we can watch from the Q-12 education website.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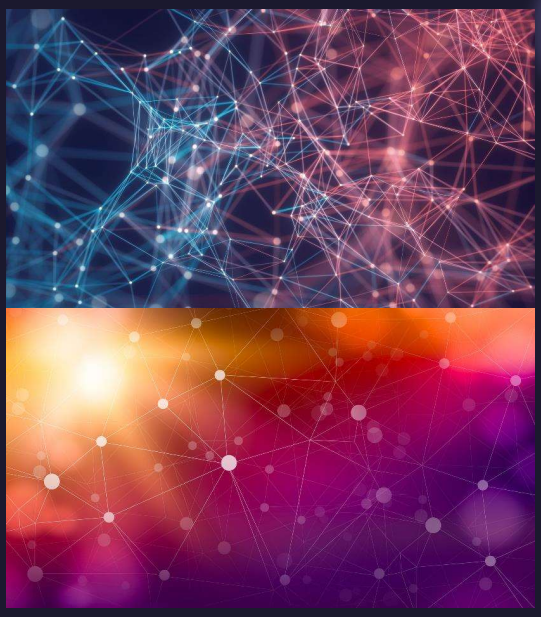
Thank You

Donn Silberman

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




Questions &
Answers
Tuesday, February 2, 20XX
Sample Footer Text
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