

Why Learn About Quantum Computing?

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MIT Quantum Computing (QC) Course

- “The quantum computing revolution is upon us!”
 - “Quantum computers offer the possibility of technology **exponentially** more powerful than current technology, and they stand to **change** companies, entire industries, and the world by solving problems that seem **impossible** today.”
 - “By 2023, about 20% of organizations will be **budgeting** for quantum computing **projects**. They will face a **shortage** of quantum computing experts.”
- “The time to learn about quantum computing is now.”

Thank You!

Questions?

Just joking!!

Let's make a QUANTUM LEAP
to watch two video snippets...
(Nova's video 38:00-40:30, 44:30-46:15)

Other Academia on QC

- Stanford Univ., USA:
 - “Quantum computing is an **emerging** computational paradigm with **vast potential**.”
- Waterloo Univ., Canada (Institute of Quantum Computing).
 - “Quantum computing is essentially **harnessing** and exploiting the **amazing laws** of quantum mechanics to **process information**.”

More From Academia on QC

- Oxford Univ., UK:
 - “QC has the potential to **transform** areas of our lives such as healthcare, finance, and security --- and Oxford is **pioneering** theory, technology and responsible innovation to ensure that QC power will bring **benefits** for all of society.”
- Cambridge Univ., UK:
 - “Quantum physics allows fundamentally **new modes** of information processing, which have required the existing **theories** of computation, information and cryptography to be **superseded** by their quantum generalizations.”

Even More From Academia on Quantum Science and Technology

- International Max-Planck Research School - Quantum Science & Technology (IMPRS - QST), Germany:
 - “Quantum science and technology is a vibrant and **multidisciplinary** field of research at the interface of physics, mathematics, computer science and material science. With over **twenty** experimental and theoretical research groups, Munich is one of the leading research centres in this field.”
 - Collaboration with **Harvard University** (US).
- Paris Centre for Quantum Computing (PCQC), France:
 - “Quantum information processing has the potential to revolutionize the future of information technologies. The **interdisciplinary** character of this research area necessitates the **simultaneous advancement** of research on the theoretical and practical aspects of the field.”

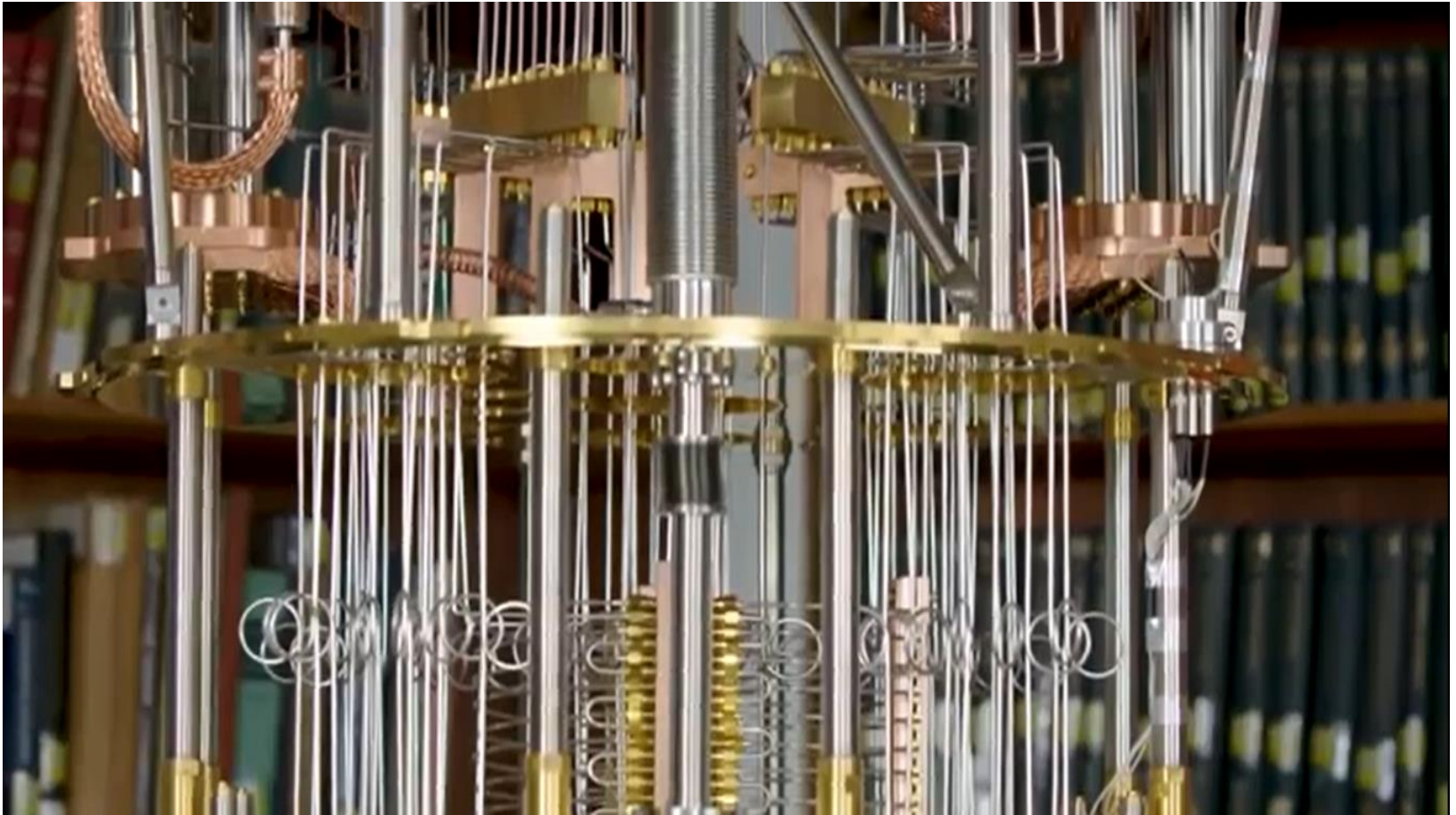
Even More From Academia on Quantum Science and Technology

- China:
 - Tsinghua Univ. (Center for Quantum Information).
- Japan:
 - Yamamoto report (2019).
- Egypt:
 - Math & CS Dept., Fac. of Science, Alex. Univ.: AlexQCG.
 - E-JUST (Q Physics, Q Info., and Q Comm.).
 - Zewail City.
 - CSE Dept., Fac. of Engineering, Alex. Univ.: **Where are we??**

Industry Interest in QC (US)

- IBM: Built real five-qubits quantum computer, 2018.
 - Q Experience, Qiskit, OpenQASM.
 - “Aims to advance **foundational** quantum computing **research** that will make **real-world impact**.”
- Google:
 - Quantum supremacy (2019)?
 - “Aims to build quantum **processors** and develop novel quantum **algorithms** to dramatically **accelerate** computational tasks for **machine learning**.”

IBM's Real 5-Qubit Quantum Computer



Industry Interest in QC (US)

- Microsoft: Q|SI> (Quantum .NET) & Q#.
 - “Prioritizes a **long-term** commercially **viable** quantum solution, [to address **challenges**] such as food scarcity, clean energy, cyber-security, and financial risk modeling.”
- Intel: Intel Labs
 - “Producing quantum **processors**; targets **production-level** quantum computing within **ten** years.”
- D-Wave (Canada) & Rigetti:
 - Non-universal quantum computers (e.g., with superposition, but not entanglement).

Industry Interest in QC (Worldwide)

- China.
 - Alibaba (largest Chinese tech. and e-commerce company).
- EU and UK ().
- Japan and Australia.
- Billions, and billions of \$\$\$, €€, £££, ¥¥¥, ... spent on quantum computing research & development (QC R&D).
- **Egypt: Where are we??**

QC Apps: Gov. and Industry Interest

- Security, Intelligence, and Research Support Agencies.
 - Shor's quantum factoring algorithm, and quantum cryptography (QKD) (see 'Schrödinger's Killer App').
 - US (DARPA, NSA, NIST, NSF, ...), China, UK, Russia,
- Oil & Gas Industry.
 - Grover's quantum search algorithm.
 - Large amounts of time-sensitive data (big data), and a 'non-convex optimization' problem.

QC Apps: Gov. and Industry Interest

- Drug Industry and Healthcare.
 - Quantum simulation (on QCs) of quantum chemical reactions and quantum physical phenomena.
 - New materials, new medicines, protein modeling & analysis,
- Tech. Industry.
 - Quantum PCA, Quantum SVM,
 - Quantum Machine Learning (QML).
- And more... .
- **Egypt: Again, where are we??!**

(We are here! Our QC Starting Point) Course Announcement

Quantum Computing: An Application-Oriented Approach

Thanks to course textbook, a novel approach to QC pedagogy ... unprecedented nationally and worldwide.
Intuitive hands-on visual approach. Basic math, little to no physics.

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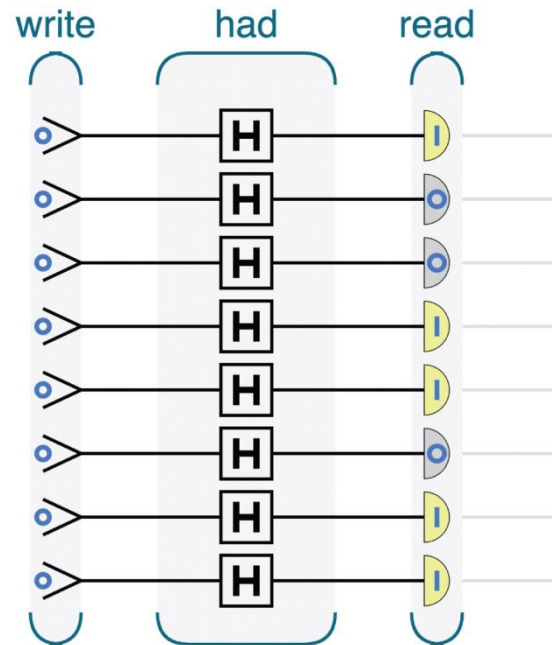
Quantum Computing: An App-Oriented Approach

(Outline: Intro)

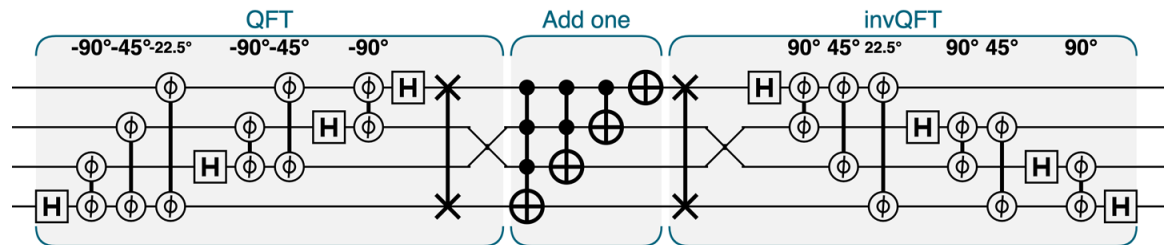
- Introduction to Quantum Computers.
 - Basics of Quantum Physics, QC Hardware.
 - Superposition, Entanglement, Measurement, Decoherence, and Teleportation.
 - Quantum Information and Qubits.
- Quantum Programming: Primitive Operations.
 - Read (measurement), write, and no-op.
 - Superposition (or H, or Had) gate, NOT (or X) gate, Phase (ϕ) gate, CNOT (or CX) gate, CCNOT (or Toffoli) gate,
 - To build quantum programs, prim-ops and modules are put together
 - like pieces of Lego — on a musical score-like form!

Quantum Computing: An App-Oriented Approach (Sample Quantum Programs)

```
qc.reset(8)
qc.write(0)
qc.had()
var result = qc.read()
```



```
var s = qint.new(4, 's')
s.QFT()
s.add(1)
s.invQFT()
```



Quantum Computing: An App-Oriented Approach

(Outline: Apps)

- Quantum Programming: Modules and Libraries.
 - Quantum integer addition and subtraction.
 - Amplitude amplification.
 - QFT (Quantum Fourier transform), phase estimation,
- Quantum Search.
 - Grover's search algorithm.
 - Interesting to: Many, e.g., Google and the oil & gas industry.

Quantum Computing: An App-Oriented Approach

(Outline: Apps)

- Quantum Computer Security.
 - Shor's factoring algorithm: Breaks almost all of internet's secure data!
 - E.g., Online banking, e-commerce, Facebook, email, WhatsApp, Telegram,
 - Quantum Cryptography: Unbreakable, even by quantum computers!
 - Interesting to: Security and intelligence agencies; everyone else for personal privacy.

Quantum Computing: An App-Oriented Approach (Outline: Apps)

- Quantum Computer Graphics.
 - Quantum Super Sampling (QSS) and Quantum Shading.
 - Digital Image Processing (DIP) $\Rightarrow$ Quantum Image Processing (QIP).
 - Interesting to: Computer/video gaming enthusiasts; everyone else (for GUIs).

Quantum Computing: An App-Oriented Approach

(Outline: Apps)

- Quantum Machine Learning (QML).
 - Solving Systems of Linear Equations.
 - Quantum Principal Component Analysis (QPCA).
 - Quantum Support Vector Machines (QSVM).
 - Interesting to: Google (e.g., for ad analytics, ...), Facebook (e.g., tagging), Uber (e.g., self-driving cars), Alibaba,
- And more... .

Quantum Computing: An App-Oriented Approach (Tools)

- Quantum Programming Languages and Quantum Simulators.
 - JavaScript on **QCEngine** (a very simple quantum simulator).
 - Python on IBM's **Qiskit** and OpenQASM on IBM's **Q Experience**.
 - Q# on Microsoft's **Q|SI>**; Python on Google's **Cirq**.
 - Drag-and-drop on **Quirk**.
- Educational Apps, Videos and Websites.
 - Apps: Bloch Sphere Simulator (Windows). Android: IBM's Hello Quantum, dotBloch, Quantum Tic-Tac-Toe,
 - Videos: IBM's Beginner's Guide to QC, Qiskit tutorials; Nova's video Quantum Leap (into Quantum Theory).
 - And many others, produced by MIT, MS and others.

Quantum Computing: An App-Oriented Approach (References)

- **Programming Quantum Computers** (A Hands-On Approach), Eric Johnston, Nic Harrigan, and Mercedes Gimeno-Segovia, O'Reilly, July 2019.
- Suggested Readings:
 - **Practical Quantum Computing for Developers** (Python, OpenQASM, Qiskit, and IBM Q Experience), Vladimir Silva, Apress, 2018.
 - **Quantum Computation and Quantum Information**, Michael Nielsen and Isaac Chuang, Cambridge University Press (CUP), 2010.
 - **Foundations of Quantum Programming**, Mingsheng Ying, Elsevier (MK), 2016.
 - **Quantum Computing for Everyone**, Chris Bernhardt, MIT Press, 2019.
 - **Quantum Computing for Computer Scientists**, Yanofsky and Mannucci, CUP, 2008.
 - **Picturing Quantum Processes** (Category Theory), Coecke and Kissinger, CUP, 2018.
 - **Schrödinger's Killer App** (Cryptography), Jonathan Dowling, CRC Press, 2013.
 - **Visual Group Theory** (Reversible Ops), Nathan Carter, Math. Assoc. of America, 2009.
 - **The Road to Reality** (Laws of The Universe), Roger Penrose, Random House, 2004.
- And more... .

Quantum Computing: An App-Oriented Approach (Course Webpage)

<http://eng.staff.alexu.edu.eg/~moez/teaching/pqc-f19>

Recap

- Academia Interest in QC.
- Industry and Government Interest in QC.
- Quantum Applications (Why everyone is interested in QC).
 - Security, and Search.
 - Simulation, Graphics, and Machine Learning.
- Application-Oriented QC Course.
 - Outline.
 - Tools.
 - References.

Why Learn About Quantum Computing?

NOT
Why ^v Learn About
Quantum Computing?!!

MIT Quantum Computing Course

- “The quantum computing revolution is upon us!”
 - “Quantum computers offer the possibility of solving problems that are intractable for classical computers. They will revolutionize our understanding of the world, from materials science to cryptography, and they will transform the way we do business and the way we live our lives.”
 - “By 2025, about 20% of research and development in quantum computing projects. They will revolutionize our understanding of the world, from materials science to cryptography, and they will transform the way we do business and the way we live our lives.”
- “The time to learn about quantum computing is now.”

Thank You!