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processing, which have required the existing **theories** of computation, information and cryptography to be **superseded** by their quantum generalizations."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-Plank 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

- Asia:
  - China: Tsinghua Univ. (Center for Quantum Information).
  - Japan: Yamamoto report (2019).
  - Singapore: Centre for Quantum Technologies.

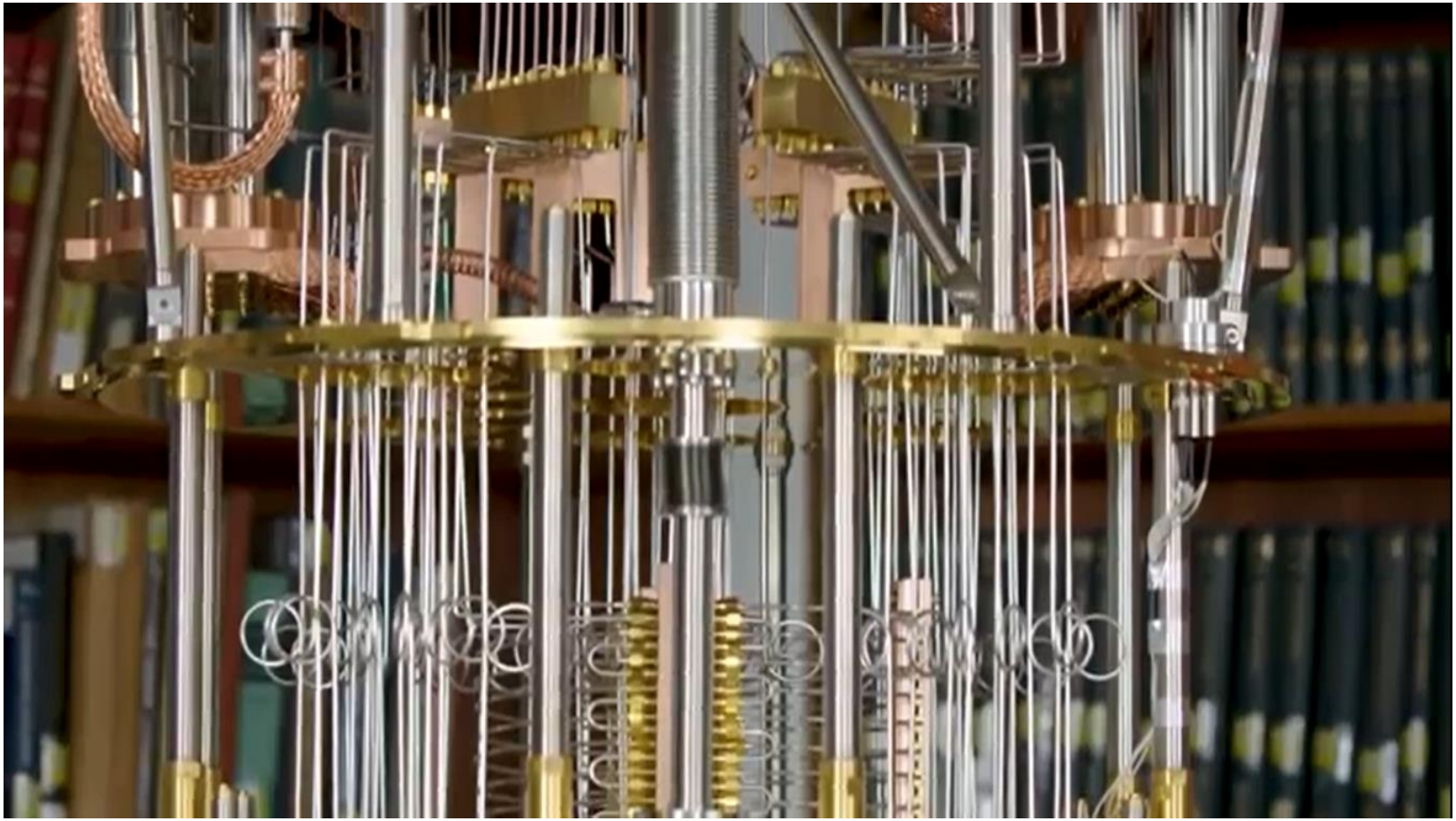
- Egypt:
  - Math & CS Dept., Fac. of Science, Alex. Univ.: AlexQCG.
  - E-JUST (Q Physics, Q Information and Q Communication).
  - Zewail City.
  - CSE Dept., Fac. of Engineering, Alex. Univ.:
    - First engineering (CS-oriented) graduate course (Fall 2019).
  - QC Training: **Where are online and offline courses?**

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??!**

QC Training Starting Point:
Online Summer Course Announcement

Quantum Computing:
An Application-Oriented Approach

Innovative Approach.
Intuitive. Hands-on. Visual. Basic Math. Little Physics.
Part I: Basics. Part II: Apps.

Moez A. AbdelGawad

Summer 2020

PYRANOVA

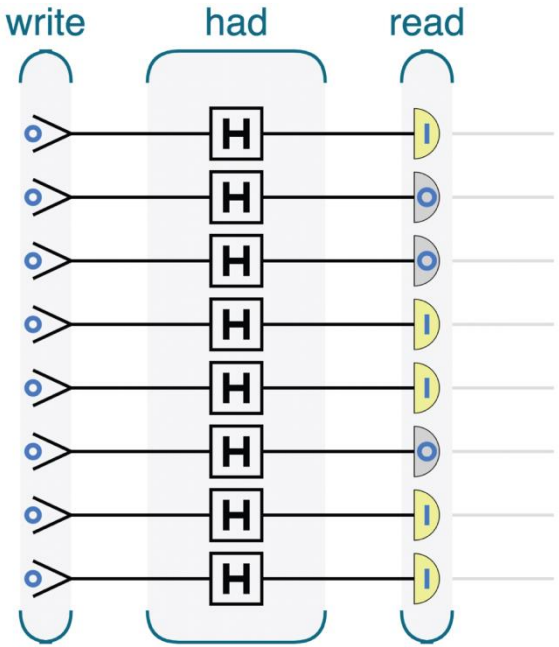
Quantum Computing: An App-Oriented Approach (Outline: Basics)

- Introduction to Quantum Computers.
  - Basics of Quantum Physics, QC Hardware.
    - Superposition, entanglement, measurement, and interference.
    - Photon polarity, electron spin, … etc.
  - Quantum Information and Qubits.

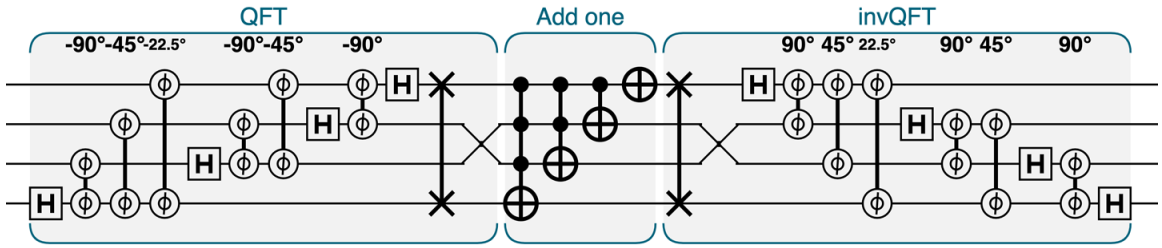
- Quantum Programming: Primitive Operations.
  - Read (measurement), write, and no-op.
  - Superposition (or H, or Had) gate, NOT (or X) gate, Phase (ϕ) gate, CNOT (or CX) gate, CCNOT (or Toffoli) gate, … .
  - To build quantum programs, prim-ops and modules are put together —like pieces of Lego—on a 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: Basics)

- Quantum Programming: Modules and Libraries.
  - Quantum integer addition and subtraction.
  - Amplitude amplification.
  - QFT (Quantum Fourier transform), phase estimation, … .
- Apps (Part I): Quantum Simulation.

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

- Apps (Part II): Quantum Search.
  - Grover's search algorithm.
  - Interesting to: Many, e.g., Google and the oil & gas industry.

- Apps (Part II): 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)

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

- Apps (Part II): 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).
  - Optional:
    - 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 others, produced by MIT, MS and others.

Quantum Computing: An App-Oriented Approach (References)

- Main Reference: **Programming Quantum Computers** (A Hands-on Approach) Eric Johnston, Nic Harrigan, and Mercedes Gimeno-Segovia, O'Reilly, July 2019.

- Suggested Readings:
  - **Quantum Computing for Everyone**, Chris Bernhardt, MIT Press, 2019.
  - **Practical Quantum Computing for Developers** (Python, OpenQASM, Qiskit, and IBM Q Experience), Vladimir Silva, Apress, 2018.
  - **Schrödinger's Killer App** (Cryptography), Jonathan Dowling, CRC Press, 2013.
  - **Quantum Computation and Quantum Information**, Michael Nielsen and Isaac Chuang, Cambridge University Press (CUP), 2010.
  - **Quantum Computing for Computer Scientists**, Yanofsky and Mannucci, CUP, 2008.

- And more… .

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

Summer 2020:

http://eng.staff.alexu.edu.eg/~moez/teaching/pqc-su20

(Fall 2019 Grad Course)

(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).
  - Simulation, and Search.
  - Security, Graphics, and Machine Learning.
- Application-Oriented QC Course.
  - Outline: Basics and Apps.
  - Tools.
  - References.

Why Learn About Quantum Computing?

NOT

Why Learn About Quantum Computing?!!

MIT Quantum Computing Course

- "The quantum computing revolution is upon us!"

- "The time to learn about quantum computing is now."

Thank You!