Open Source Quantum Computing

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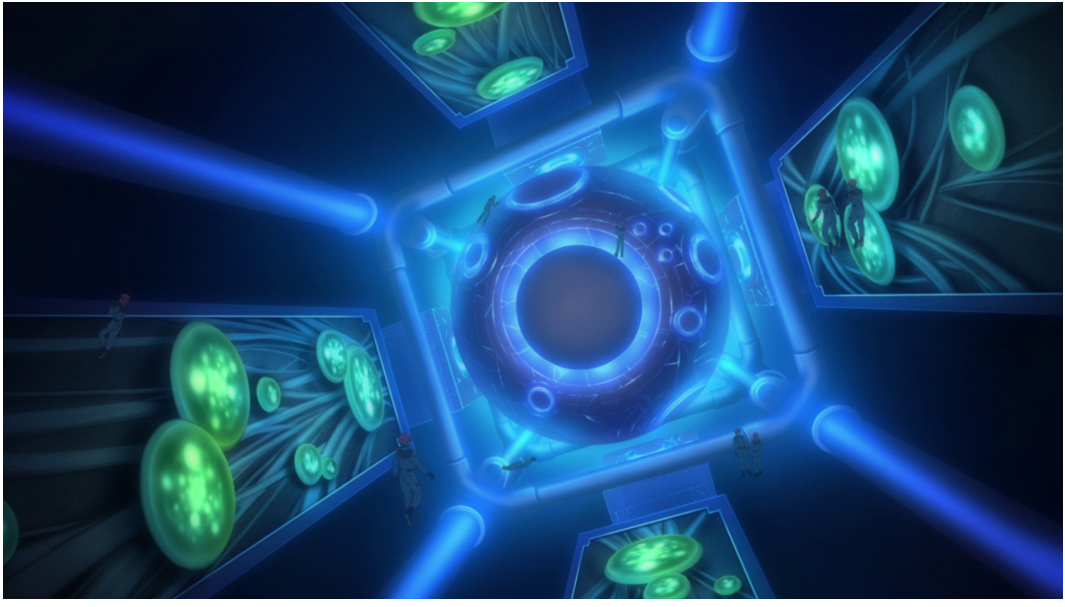
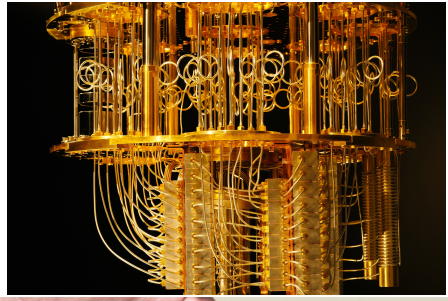
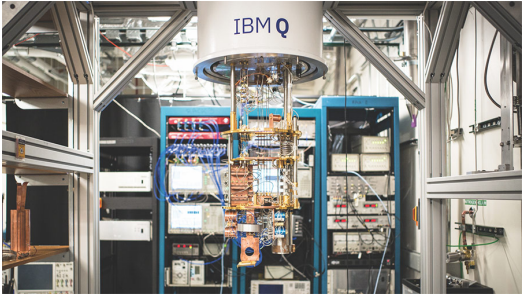
https://github.com/mtreinish/open-source-quantum-computing

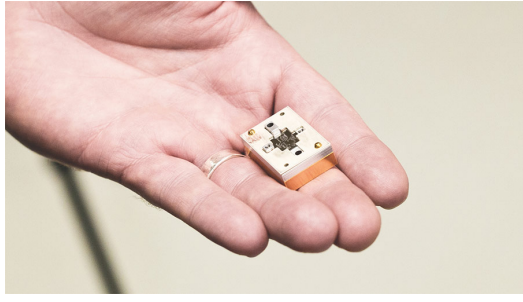
January 25, 2019



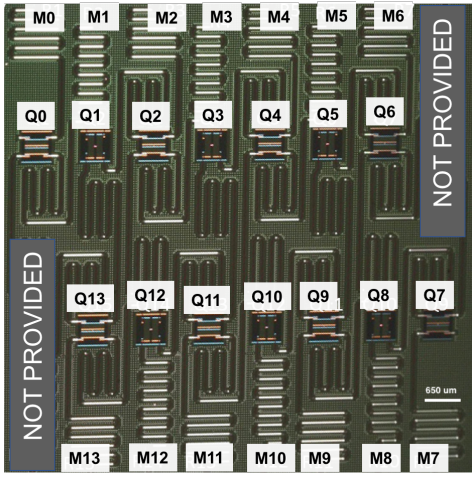
Real Quantum Computer

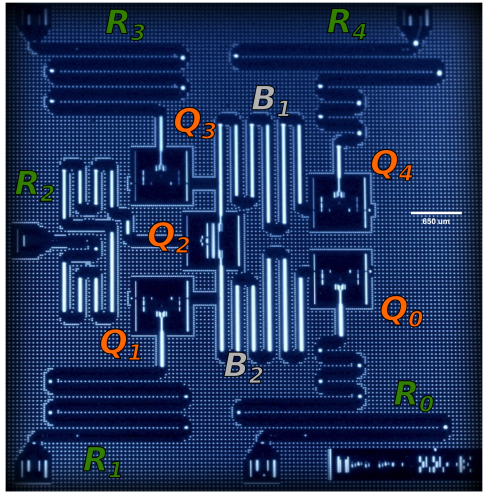




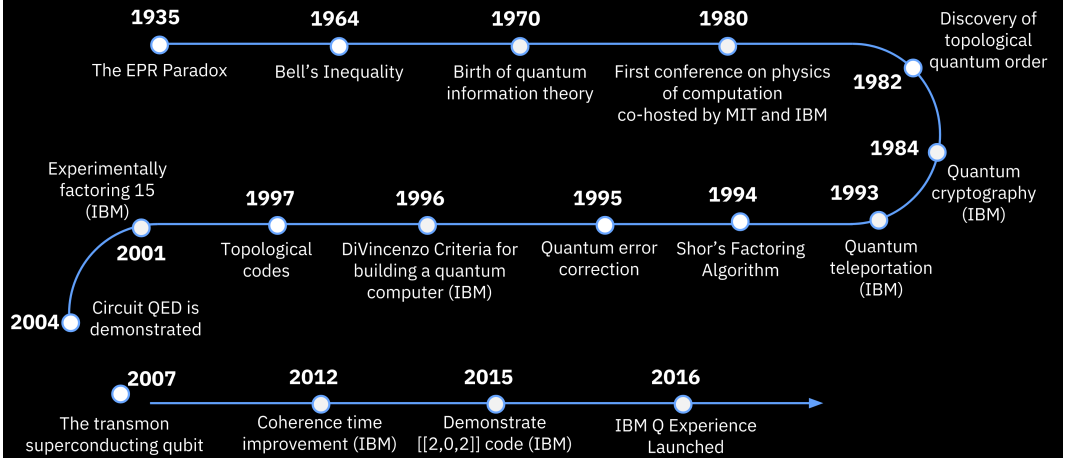


Quantum Chips





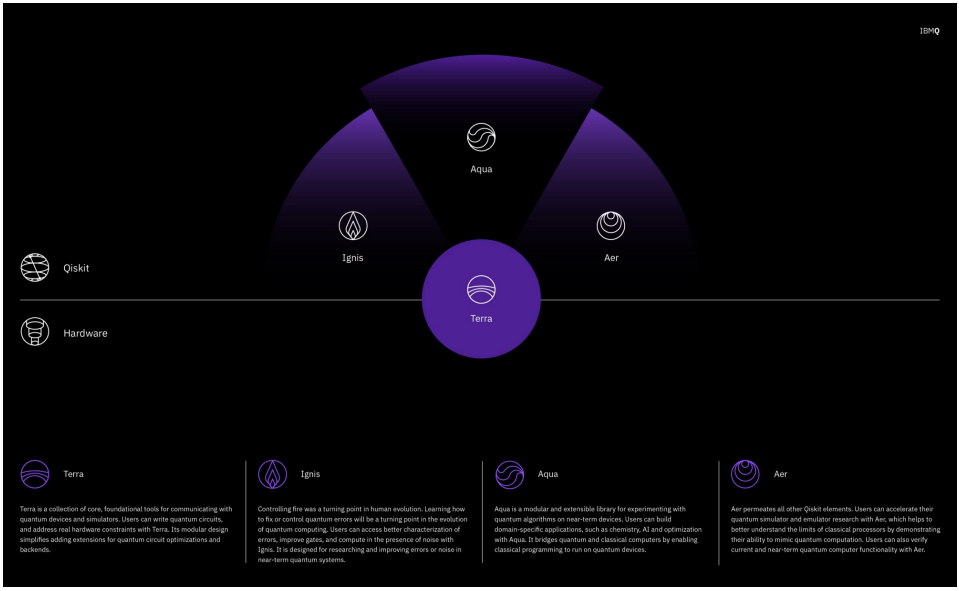
History of Quantum Computing



What is Qiskit?

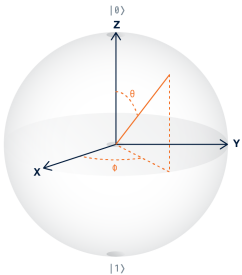
- Toolkit

Qiskit


IBMQ
Aqua
Ignis
Aer
Qiskit
Terra
Hardware
Terra
Terra is a collection of core, foundational tools for communicating with quantum devices and simulators. Users can write quantum circuits, and address real hardware constraints with Terra. Its modular design simplifies adding extensions for quantum circuit optimizations and backends.
Ignis
Controlling fire was a turning point in human evolution. Learning how to fix or control quantum errors will be a turning point in the evolution of quantum computing. Users can access better characterization of errors, improve gates, and compute in the presence of noise with Ignis. It is designed for researching and improving errors or noise in near-term quantum systems.
Aqua
Aqua is a modular and extensible library for experimenting with quantum algorithms on near-term devices. Users can build domain-specific applications, such as chemistry, AI and optimization with Aqua. It bridges quantum and classical computers by enabling classical programming to run on quantum devices.
Aer
Aer permeates all other Qiskit elements. Users can accelerate their quantum simulator and emulator research with Aer, which helps to better understand the limits of classical processors by demonstrating their ability to mimic quantum computation. Users can also verify current and near-term quantum computer functionality with Aer.

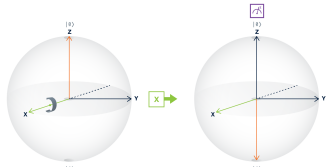
The Qubit

- Bloch
- Measure along Z

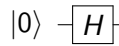


Multiple Qubits

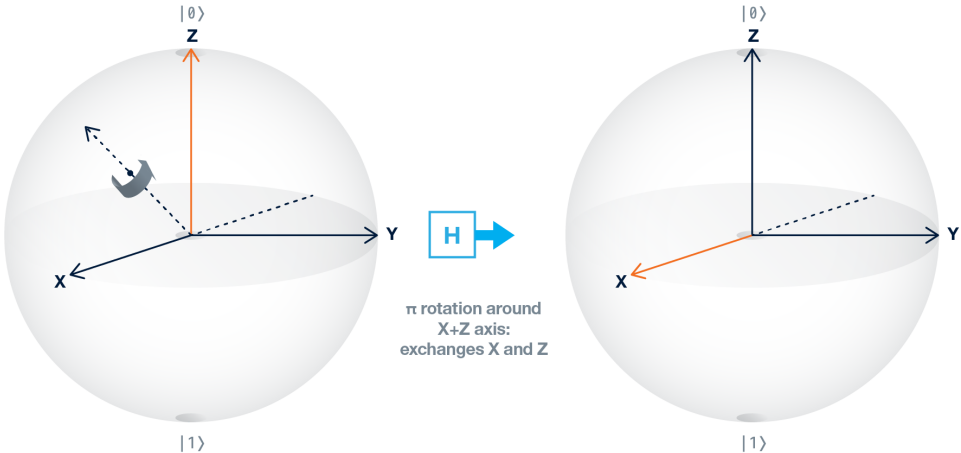
Quantum Gates

Gate	Matrix Form	Bloch Sphere
$\|0\rangle$ — X —	$\begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$	
$\|0\rangle$ — Y —	$\begin{bmatrix} 0 & -i \\ i & 0 \end{bmatrix}$	
$\|0\rangle$ — Z —	$\begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$	

Superposition and Hadamard Gate

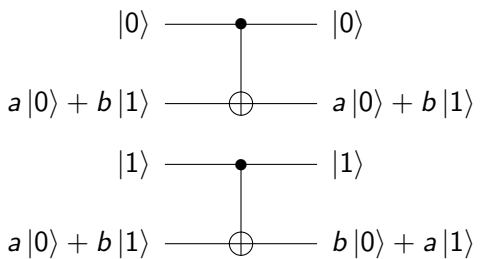


$$\frac{1}{\sqrt{2}}\begin{bmatrix}1 & 1\\ 1 & -1\end{bmatrix}$$



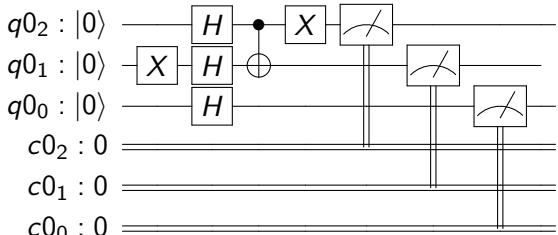
Phase

Controlled Not Gate



CNOT flips the *target* bit if the *control* bit is 1

Quantum Circuits



Bernstein-Vazirani Algorithm[1]

The Oracle

Input (query)
$\Longleftarrow X_{n-1} \cdots X_1 X_0$

Secret Bitstring
$\boxed{S_{n-1} \cdots S_1 S_0}$

Output (result)
$\Longrightarrow X_{n-1} S_{n-1} \oplus \cdots X_1 S_1 \oplus X_0 S_0$

[1] E. Bernstein & U. Vazirani, STOC, 93

Classical Oracle

O(n)

Quantum Oracle

$O(1)$

Phase Kickback

Implementing a Quantum Oracle

Live Demo

Open Source in Quantum Computing

Other Open Source Tools

- https://github.com/rigetticomputing/pyquil
- https://github.com/ProjectQ-Framework/ProjectQ
- https://github.com/quantumlib/Cirq
- https://github.com/qutip/qutip
- https://github.com/XanaduAI/strawberryfields

A lot more out there: https://github.com/topics/quantum-computing

Conclusions

- Quantum Computing is about solving problems that we can't with classical computers
- It's not just in labs anymore, quantum computing is accessible by everyone now
- It's still very early for quantum computers
- Open source software is playing a key role early on

Where to get more information

- Overview and Comparison of Gate Level Quantum Software Platforms: https://arxiv.org/abs/1807.02500
- Qiskit: https://qiskit.org/
- IBM Q Experience: https://quantumexperience.ng.bluemix.net/qx
- Tutorials on Quantum Computing and Qiskit: https://github.com/Qiskit/qiskit-tutorials