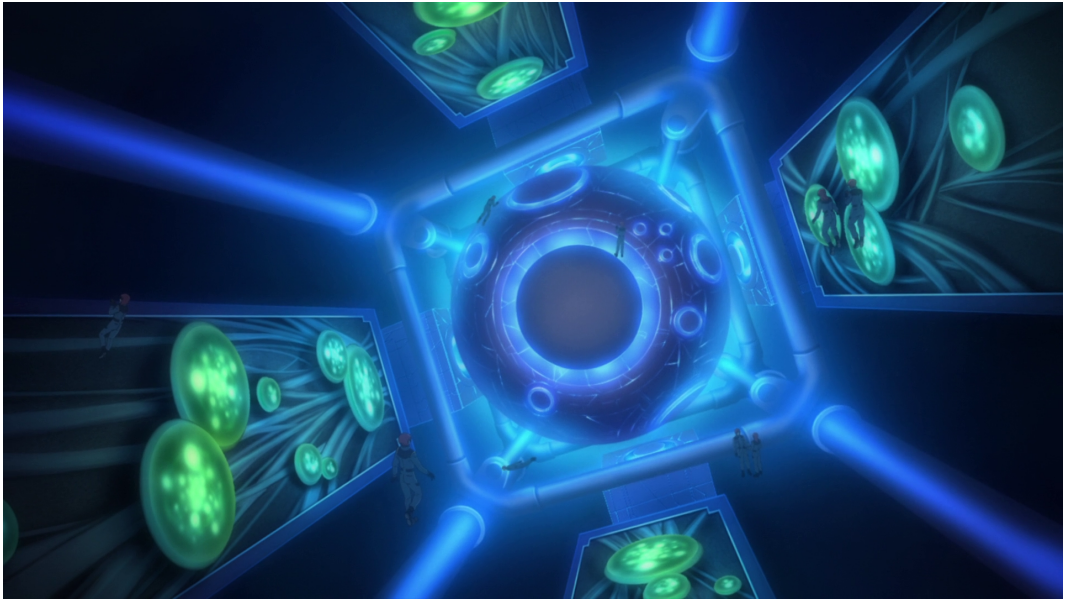
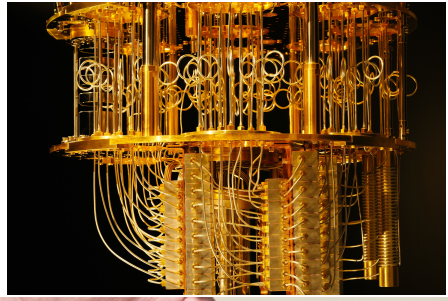
Open Source Quantum Computing

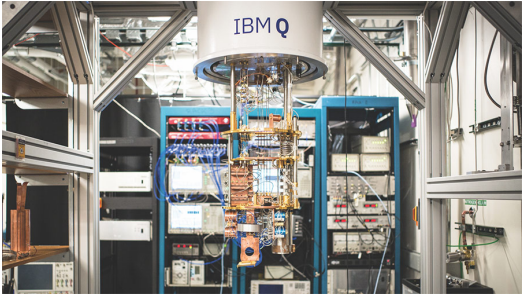
Matthew Treinish
Software Engineer - IBM Research
mtreinish@kortar.org
`mtreinish on Freenode`
https://github.com/mtreinish/open-source-quantum-computing

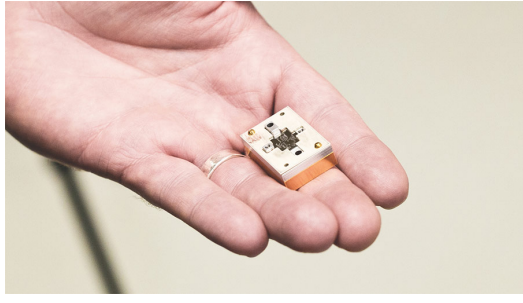
January 25, 2019



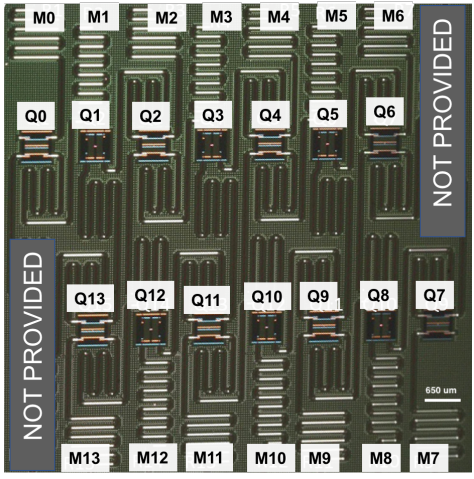
Real Quantum Computer

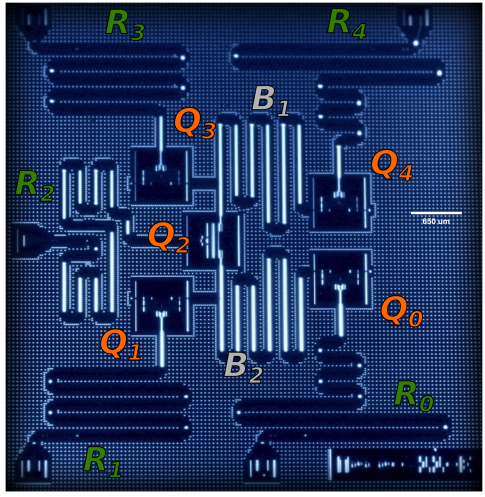




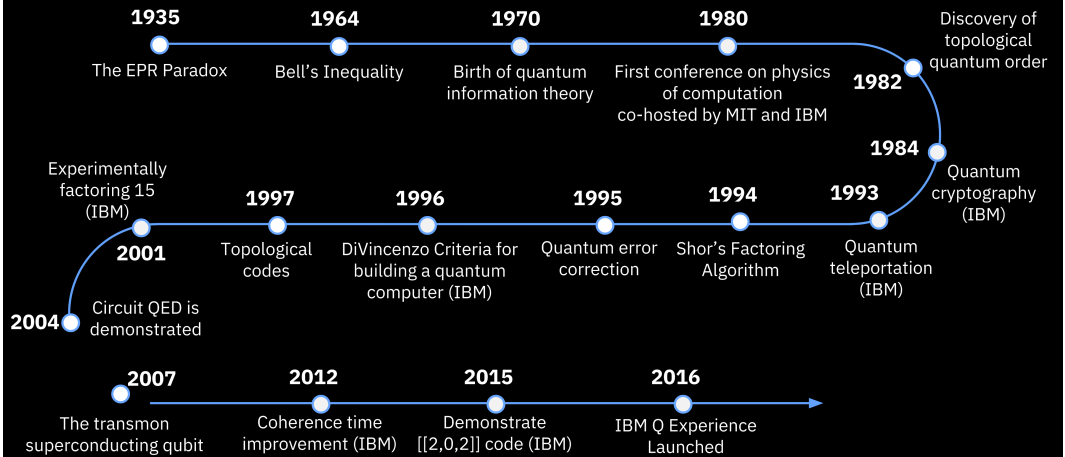


Quantum Chips



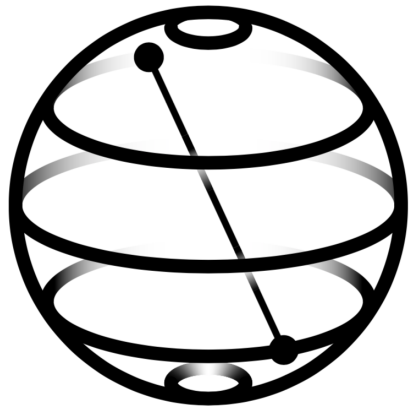


History of Quantum Computing

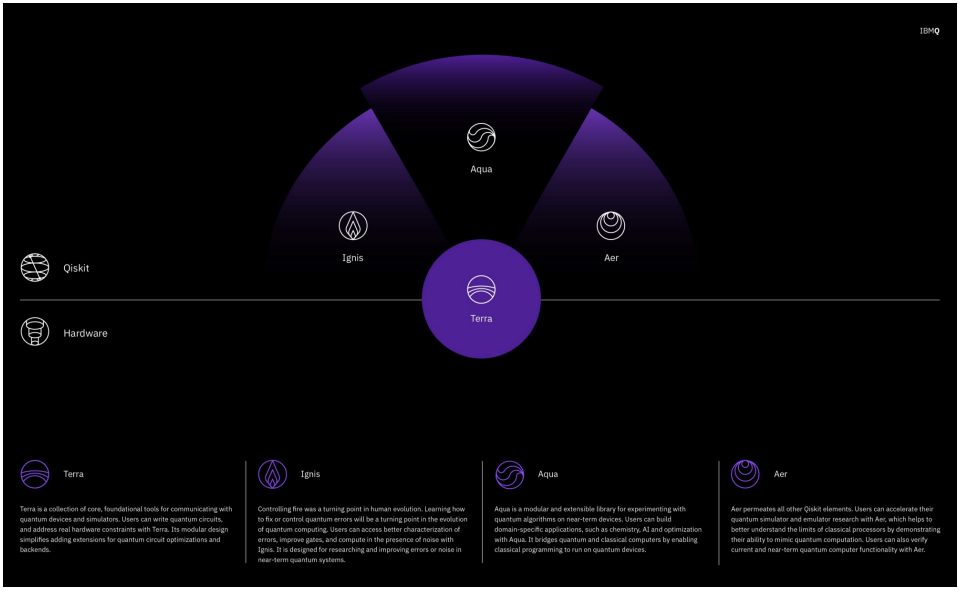


What is Qiskit?

- SDK for working with Noisy Intermediate-Scale Quantum (NISQ) computers
- Provides a Python interface to write quantum programs
- Apache 2.0 License
-



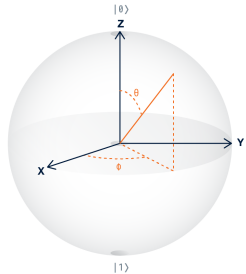
Qiskit Elements



The Qubit

- The bloch
- Measure along Z
-

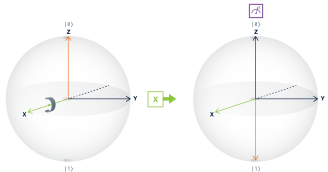
Bloch Sphere:



Multiple Qubits

The Complexity and Power of Quantum Information

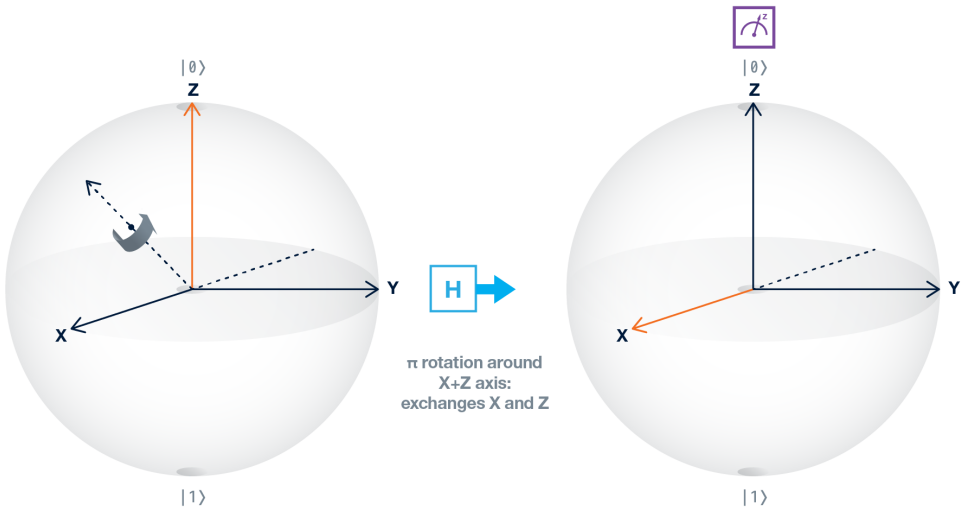
Quantum Gates

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

Superposition and Hadamard Gate

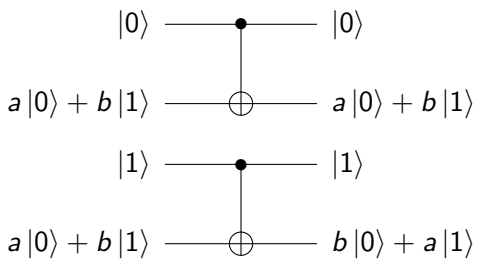
$|0\rangle$ — H —

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



Qubit Phase

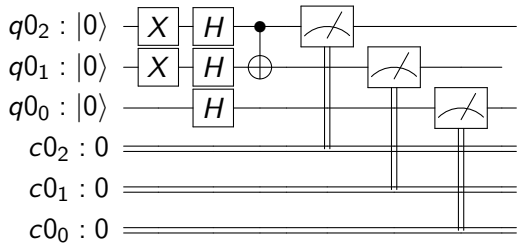
Controlled Not Gate



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

Quantum Circuits

Putting all together you build a circuit like:



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

Optimal Classical Oracle

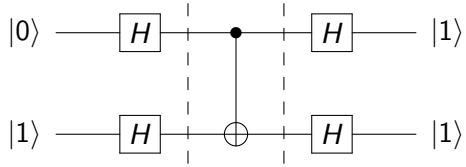
$$\begin{cases} X = 1\,0\cdots0\,0 & (2^{n-1}) \\ X = 0\,1\cdots0\,0 & (2^{n-2}) \\ \vdots & \\ X = 0\,0\cdots1\,0 & (2) \\ X = 0\,0\cdots0\,1 & (1) \end{cases}$$

The ideal classical oracle is $\mathcal{O}(n)$

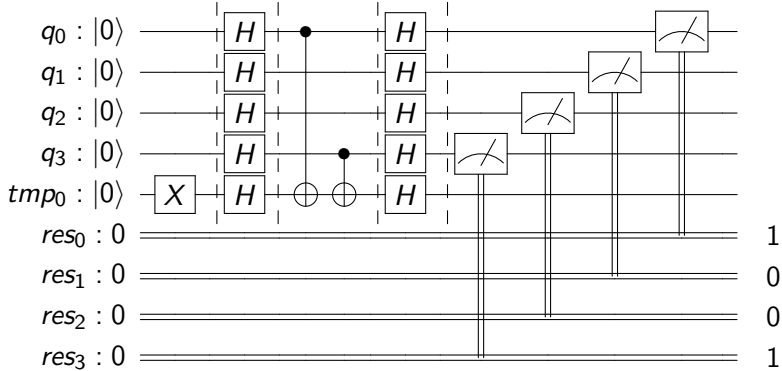
Quantum Oracle

$O(1)$

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