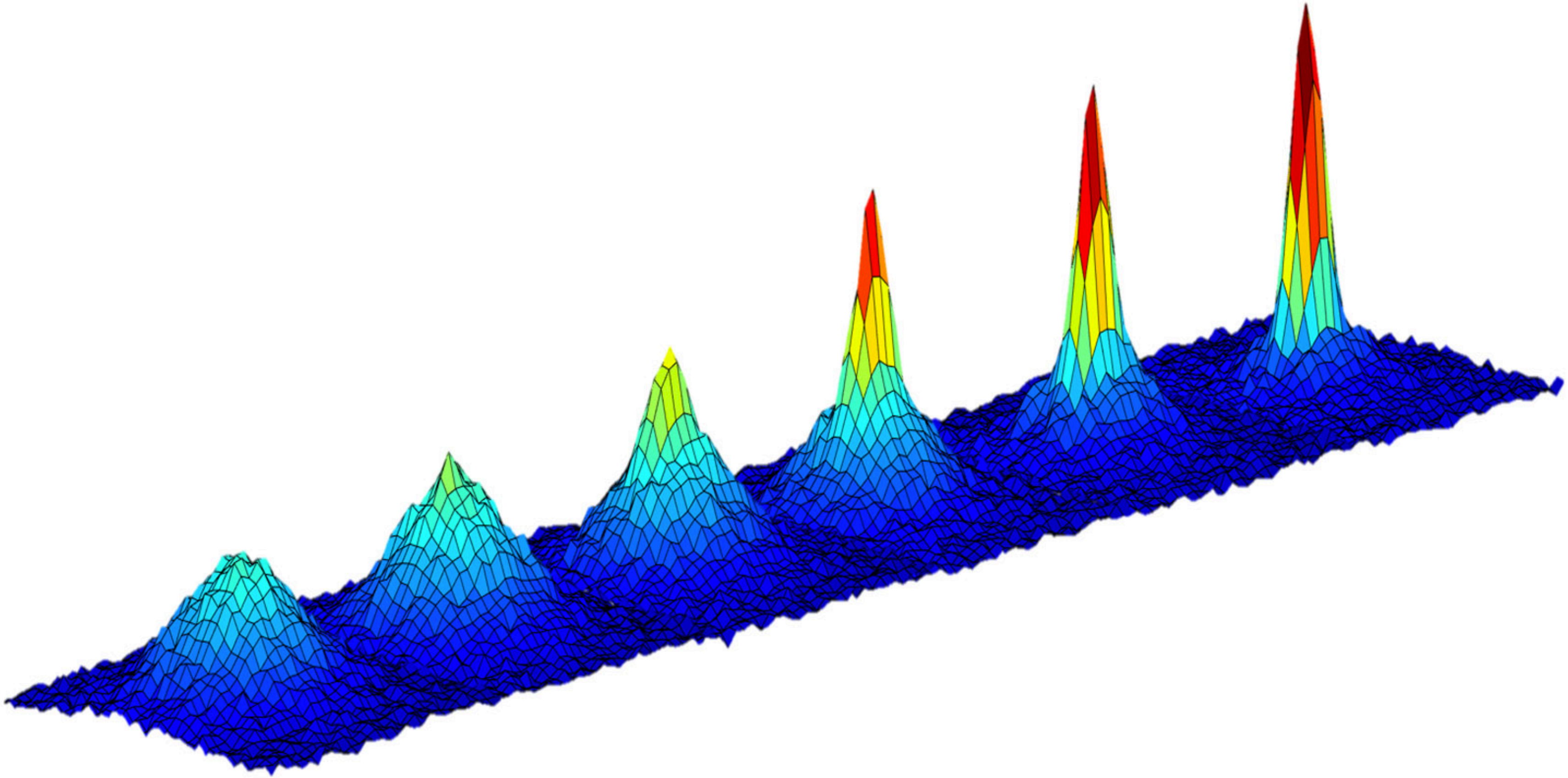
Quantum Programming 101

April 29th 2019

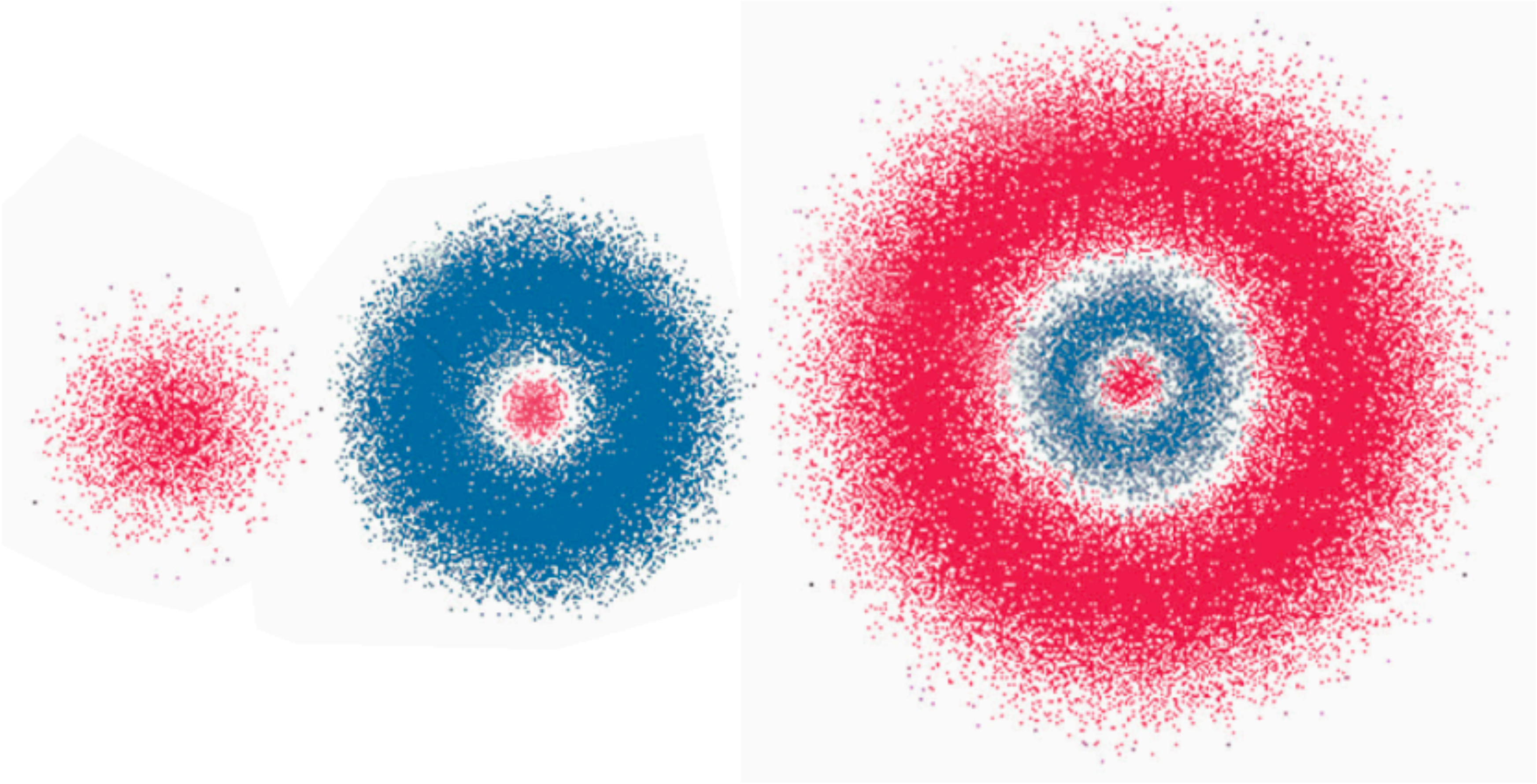
Guen Prawiroatmodjo

goto; chicago

"Galton Board" by Four Pines Publishing



[Source](): NASA/JPL-Caltech, Mission: Cold Atom Laboratory (CAL)



Electron probability density of Hydrogen atom S-orbitals

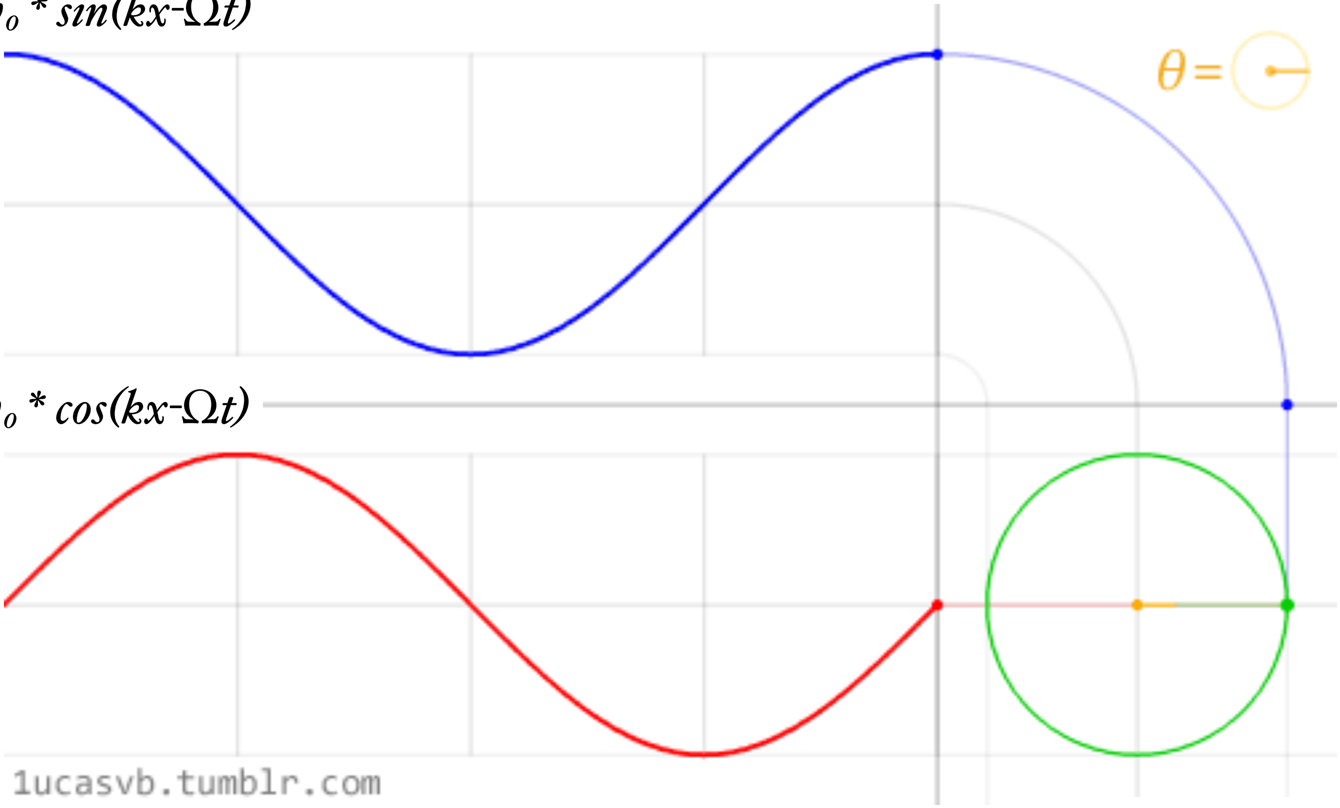
Photo credit: [101 cats]

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$$

The Qubit: a two-level quantum system

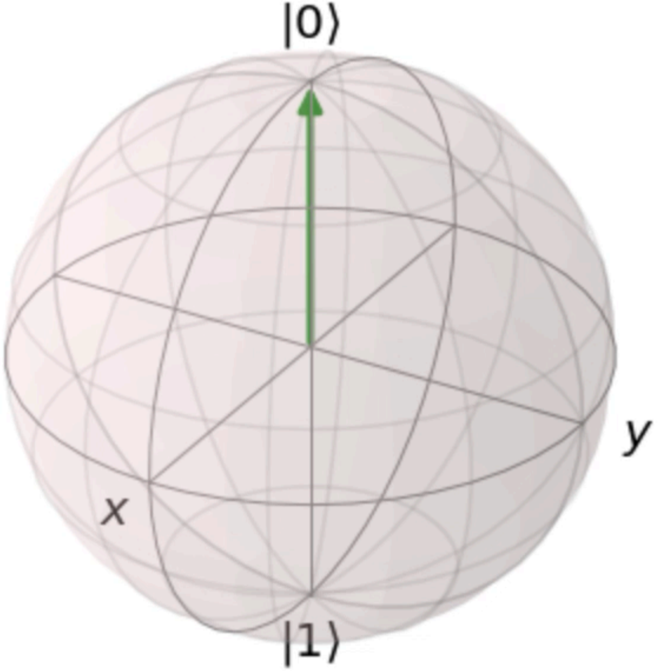
Quantum State

$$Im(\psi(t)) = \psi_o * sin(kx\text{-}\Omega t)$$

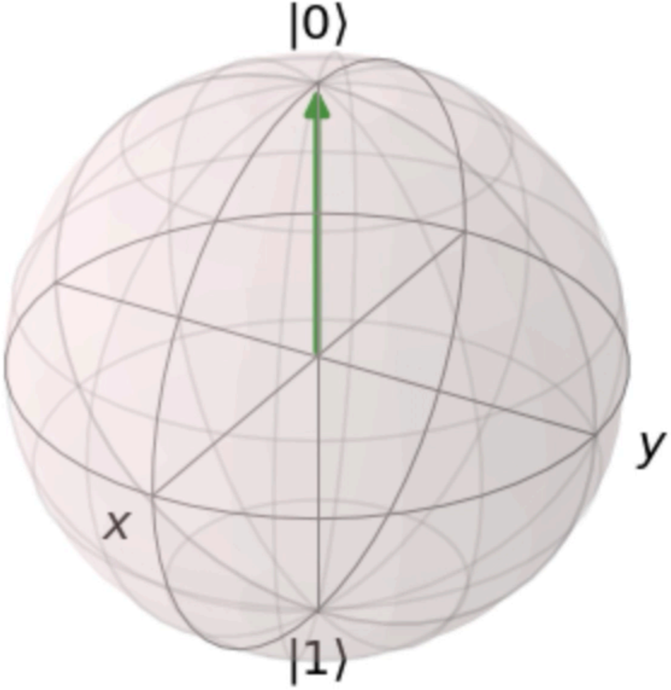


$$Re(\psi(t)) = \psi_o * cos(kx\text{-}\Omega t)$$

$$\psi(t) = \psi_o \, e^{i(kx\text{-}\Omega t)}$$

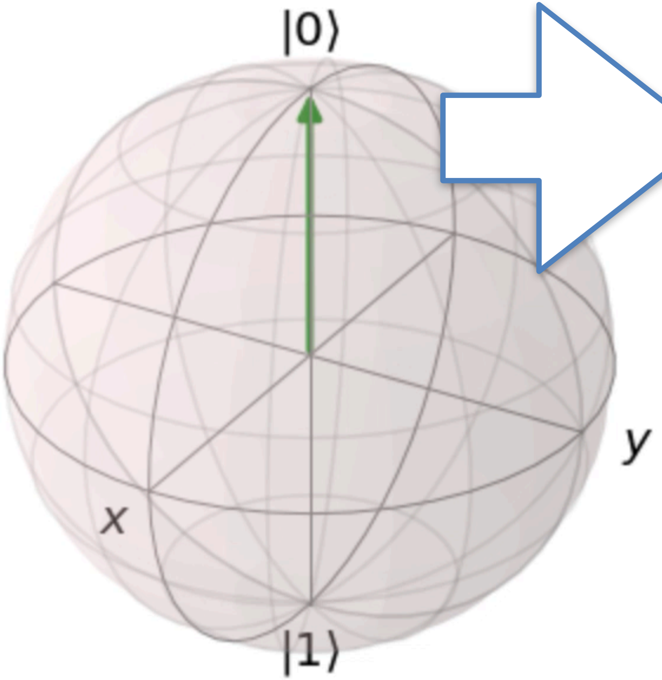


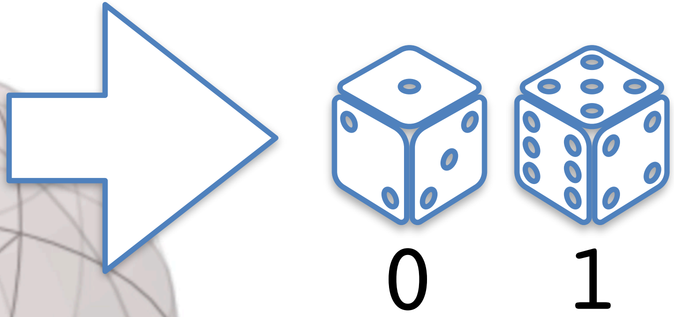
Bloch sphere representation of a qubit running X(π) |0>



Bloch sphere representation of a qubit running X(-π/2) Z(π/2) Y(π/2) |0>

Quantum vs *Classical*

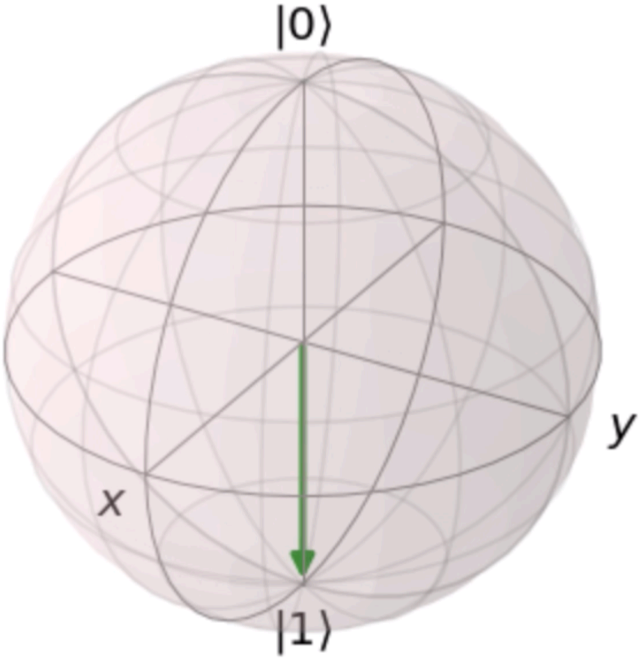




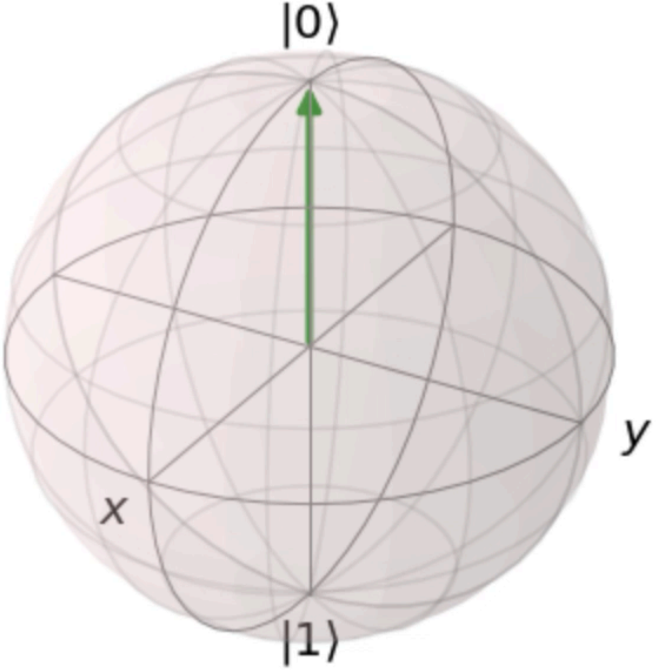
$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$$

Bloch sphere representation of a qubit running H |o>

Two qubit gate: CX

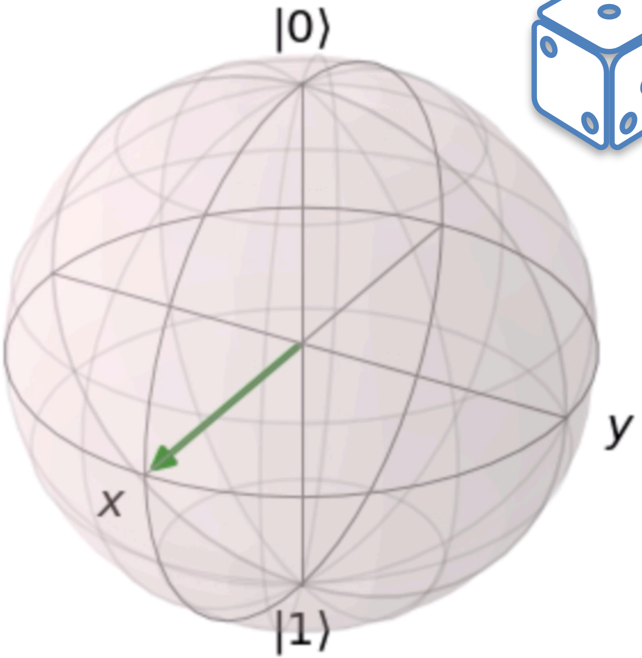


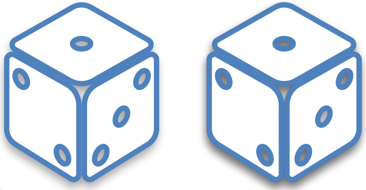
Control qubit

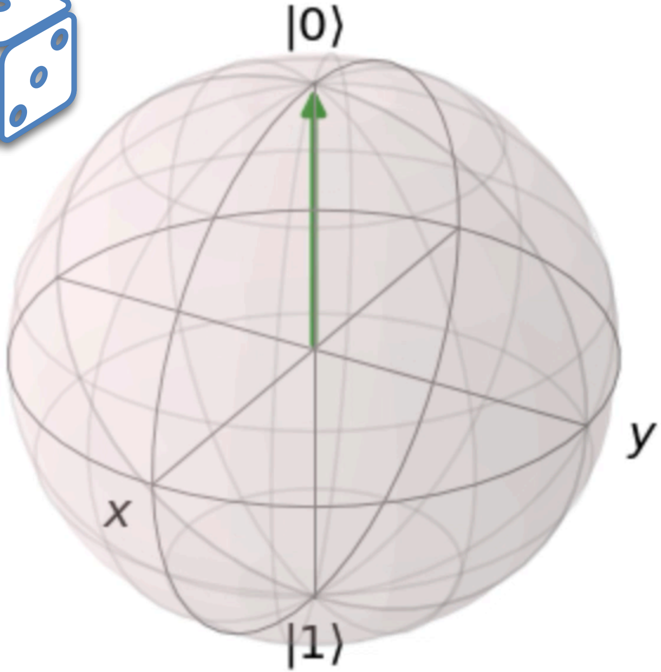


Target qubit

Two qubit gate: CX





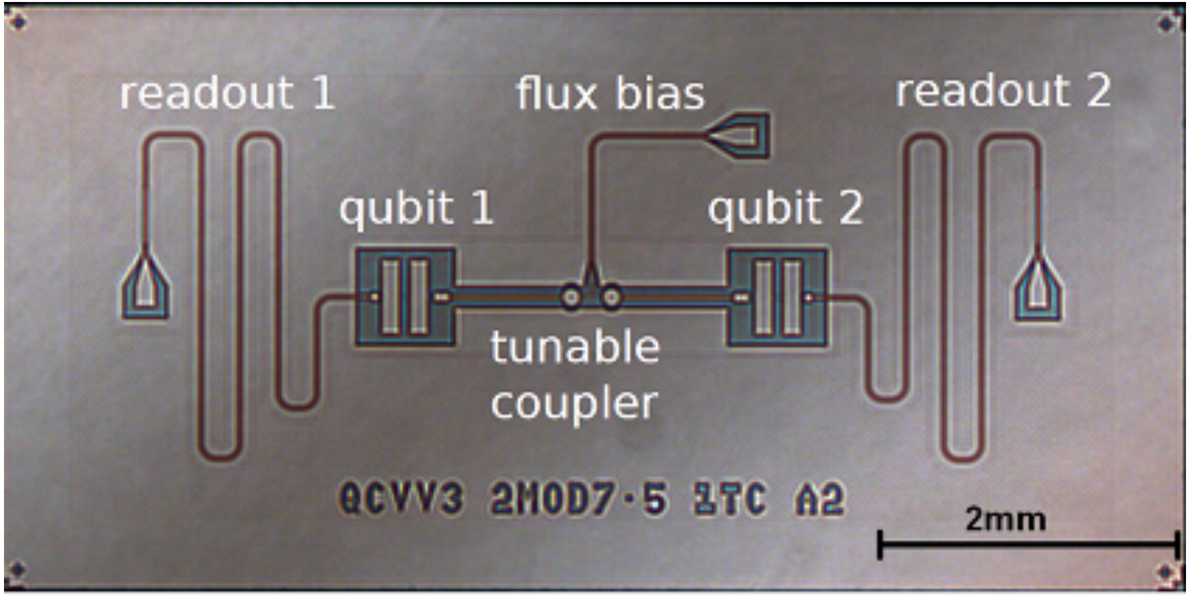


Control qubit **Bell state** *Target qubit*

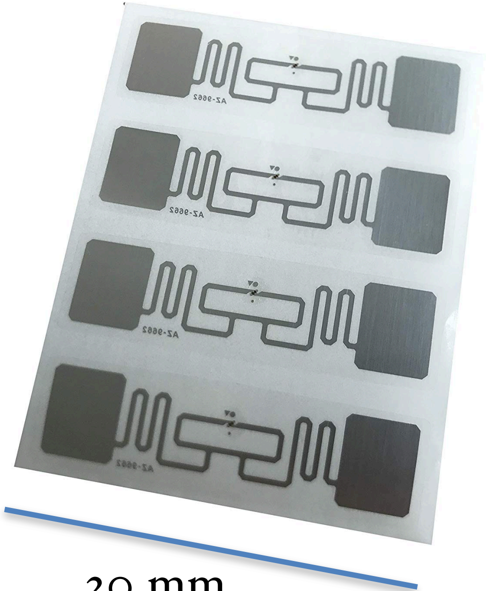
Quantum programming

- Create and run quantum circuits using gates such as I, X, Y, Z, H, CX, CY, CZ
- *Classical* vs. *Quantum* registers
- Built-in quantum simulators
- Some can be run on real prototype hardware

Quantum engineering



Superconducting qubit device with two transmon-type qubits
IBM Research - Zürich
Frequency: 5-7 GHz

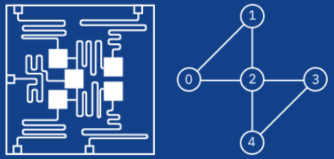


20 mm

RFID tags
Frequency: 860-960MHz

IBM Q 5 Tenerife [ibmqx4]

ACTIVE: USERS

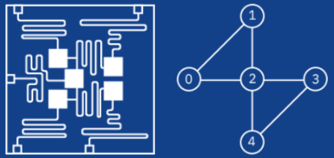


Last Calibration: 2019-04-26 18:56:34

	Q0	Q1	Q2	Q3	Q4
Frequency (GHz)	5.25	5.30	5.34	5.43	5.17
T1 (μs)	45.70	42.70	50.10	55.50	38.10
T2 (μs)	21.30	11.60	56.20	28.90	5.40
Gate error (10^{-3})	0.86	1.55	1.12	1.55	1.37
Readout error (10^{-2})	6.30	7.60	4.30	18.10	24.60
MultiQubit gate error (10^{-2})		**CX1_0**	**CX2_0**	**CX3_2**	**CX4_2**
		2.72	2.16	5.09	5.93
			CX2_1	**CX3_4**	
			5.07	4.77	

IBM Q 5 Yorktown [ibmqx2]

ACTIVE: USERS



Last Calibration: 2019-04-26 04:07:35

	Q0	Q1	Q2	Q3	Q4
Frequency (GHz)	5.29	5.24	5.03	5.30	5.08
T1 (μs)	87.50	60.00	68.90	63.60	61.70
T2 (μs)	66.30	46.90	58.60	28.00	38.00
Gate error (10^{-3})	2.15	2.15	4.55	3.52	8.17
Readout error (10^{-2})	23.10	30.50	1.40	2.20	10.60
MultiQubit gate error (10^{-2})	**CX0_1**	**CX1_2**		**CX3_2**	**CX4_2**
	3.58	3.57		5.88	6.99
	CX0_2			**CX3_4**	
	4.84			7.88	

IBMQ: available QPUs

Q#

Quil [01⟩

ProjectQ

Qiskit

Cirq

docker

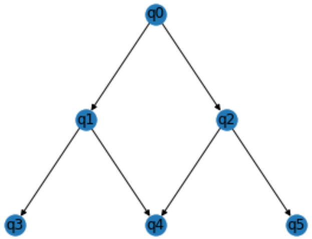
binder

python™

matplotlib

QuTiP

Quantum Toolbox in Python



demo

http://goto2019.guen.pw

More resources

- CS 269Q: Quantum Computer Programming course: (https://cs269q.stanford.edu)
- http://www.quantummadesimple.com
- https://algassert.com/quirk
- Play around with quantum gates: http://demonstrations.wolfram.com/SingleQubitQuantumGatesOnABlochSphere

Thank you;

All notebooks used in this presentation:
[*http://goto2019.guen.pw*](http://goto2019.guen.pw)

Credits//thanks for your help ❤️
@cgranade (Q#)
@QuantumRic (quantum information)
@stylewarning (Quil QVM & cat memes)

@guenp *linkedin.guen.pw* *guenp* *hi@guen.pw*

goto; chicago

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