Analyzing Qubits on the Bloch Sphere

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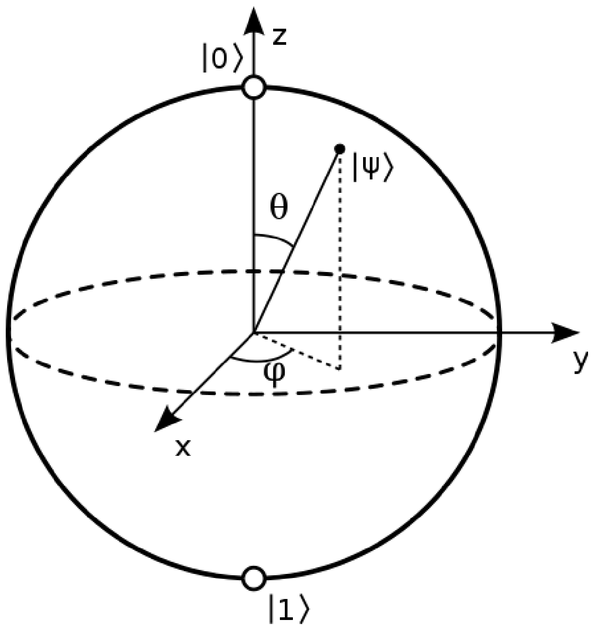


What is the Bloch Sphere?

The Bloch Sphere allows one to visualize the state of a qubit (a quantum bit)

Why is this necessary?

- Qubits do not operate with classical probability (where the probability of something happening and not happening adds up to 1)
- Instead, qubits can exist in **superpositions** (the ability to exist in multiple states simultaneously)
  - The 2 poles represent the 2 states (0 and 1)
- When measured, the qubit collapses into either 0 or 1. The Bloch Sphere helps visualize what the qubit really looks like.

How to read the Bloch Sphere:

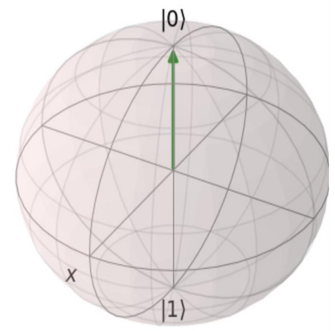
- θ determines probability
- ϕ determines phase

General Quantum State: $|\psi\rangle=\alpha|0\rangle+\beta|1\rangle$

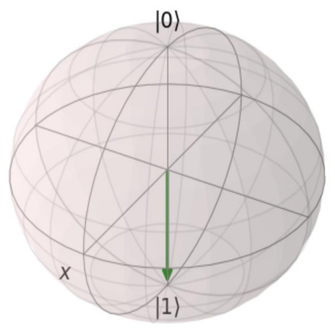
It can also be written as:

$$|\psi\rangle = \cos(\theta/2)|0\rangle + e^{i\phi}\sin(\theta/2)|1\rangle = \cos(\theta/2)|0\rangle + (\cos\phi + i\sin\phi)\sin(\theta/2)|1\rangle, \text{ where } 0 \le \theta \le \pi \text{ and } 0 \le \phi < 2\pi$$

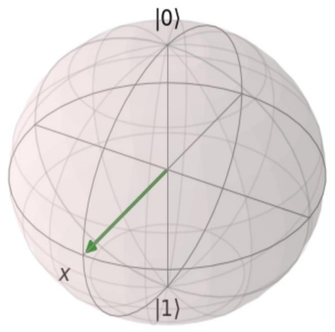
0 State



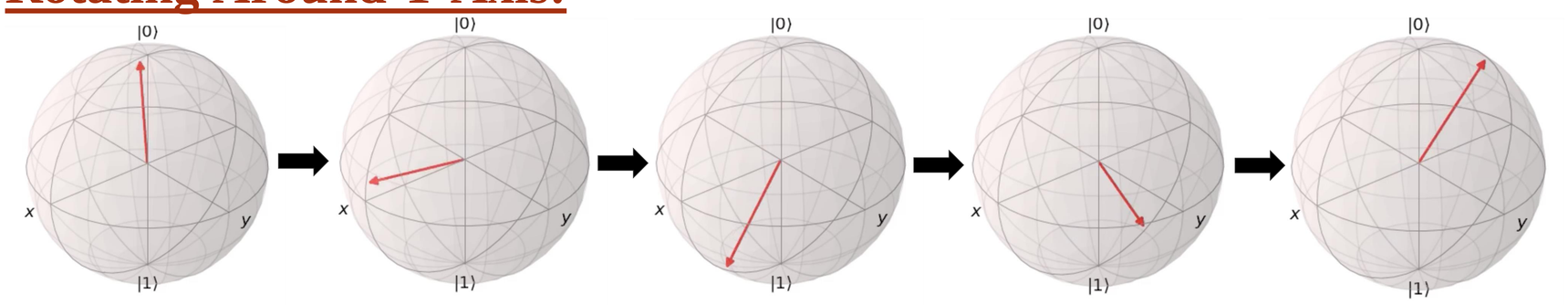
1 State



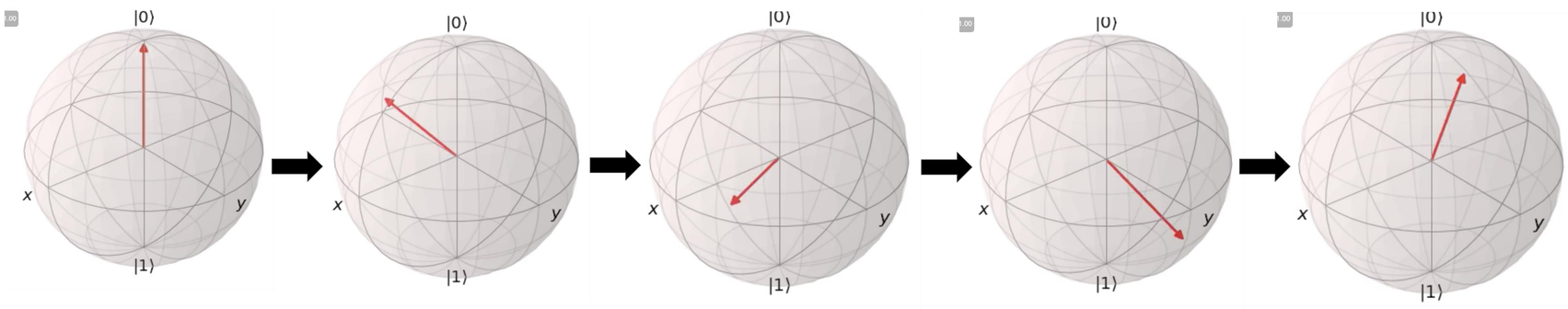
0+1 State



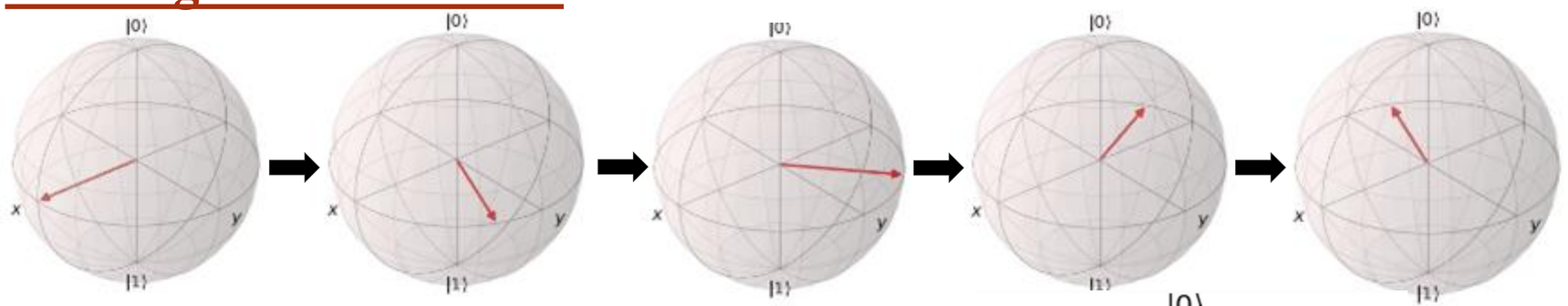
Rotating Around Y Axis:



Rotating Around X Axis:



Rotating Around Z Axis:



Quantum Operations

Quantum operations are used to change a system from one quantum state to another

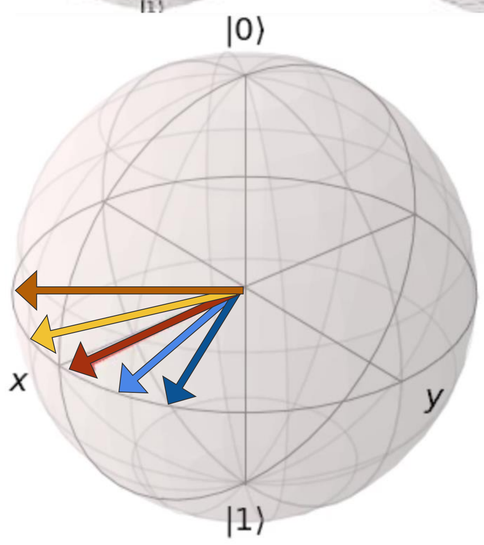
Rotations are defined by the axis of rotation and the angle the vector is rotated

Operations on the bloch sphere model a laser pulse on qubits

Spreading Out

Spreading out occurs when there are many two-level systems which have slightly different frequencies

When the systems are not at either of the poles, they are rotating around the z axis at a frequency corresponding to the difference in energy between the states which leads to spreading out



Correcting Spreading Out

Spin Echo Sequence: applies a 180° inversion electromagnetic radiation pulse

Because of the variation in the frequency, the systems refocus back to the initial direction

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