Summary of Key Concepts

Quantum Hardware

Week of February 18th, 2024

Resources

- QXQ YLC Week 17 Homework Notebook [STUDENT].ipynb
- QXQ YLC Week 17 Lab Notebook [STUDENT].ipynb
- 5. QXQ YLC Noisy Simulations Cheat Sheet
- Quantum Virtual Machine | Cirq (Example Notebook)
- Hardware | Cirq | Google Quantum AI

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Key Terms

Key Term	Definition
Superconducting Qubit	The most common type of qubit. Qubits are made up of superconducting circuits and the quantum state is determined by the direction of electrical current in the circuit. Gates are applied by firing microwaves at the qubits, changing the current.
Trapped-Ion Qubit	The second most common type of qubit. Qubits are made of ions. Ions are trapped by an electromagnetic field, and the qubit state is determined by the vibration of the ion. Gates can be applied by shining lasers on the qubit. A similar type of qubit known as neutral-atom qubits behave in a similar way, but use uncharged atoms rather than ions.
Photonic Qubit	These are qubits made by light particles with qubit states determined by the polarization of the light. Gates can be applied using optical elements to change the polarization. These are the qubits we worked with in the Quantum Flytrap.
Topological Qubits	These are theoretical qubits made using anyons, a type of quasiparticle. Quantum states are determined by the configuration of anyons, and quantum gates are applied by rearranging anyons.
Nitrogen-Vacancy Center Qubits	This is a type of qubit made from an unpaired electron in a flawed diamond. The quantum state is determined by the spin of the electron and quantum gates are applied by applying electromagnetic waves to change the electron's spin.
Noise	Unintentional influences on qubits which cause errors in quantum computing.
Error	Unexpected measurement results.

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Decoherence	Loss of information of a qubit. There are two types of decoherence: • Relaxation, or the loss of energy. • Dephasing, or the loss of phase information.

Lecture

Learning Objectives

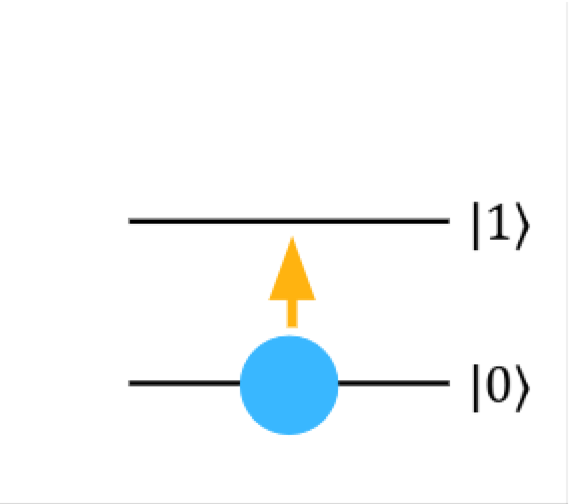
1. *Recognize* the current landscape of qubits: superconducting, trapped ion, photonic, topological, and nitrogen-vacancy center.

2. *Recognize* what noise and errors are and how they hinder the implementation of quantum computing.

3. *Recognize* the current landscape of quantum hardware.

Key Ideas

1. The qubit landscape is fragmented, so there are many different options, all of which are being pursued by different groups.
2. Every qubit type has its own unique set of advantages and disadvantages, but they all have certain things in common:
    a. They all have a 0 and 1 state.
    b. They can produce a superposition.
    c. They can produce interference.
    d. They can produce entanglement.



3. Quantum computers do not have many bits yet. The largest quantum computers have only a little more than 1,000 bits **and** they are very error prone.

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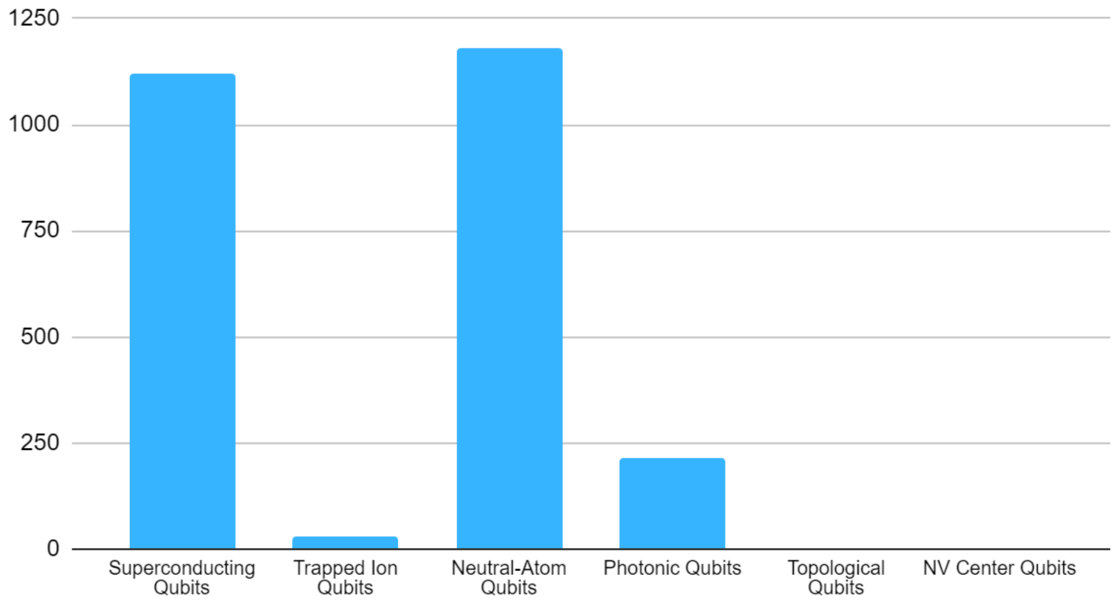

4. Some proposed qubits have not been used to construct quantum computers yet, such as topological qubits and NV Center qubits. Their applications are still only theoretical.
5. Noise and error are the main hindrance to building useful quantum computers (more on this next week). The three proposed ways to combat noise are:
    a. New qubits.
    b. Error correction.
    c. Better, more insulated hardware.

6. The current quantum hardware landscape has a lot of players from a lot of

backgrounds. Many of them are pursuing different solutions, and much progress has been made, but most predictions do not have useful quantum computers for **at least** a decade.