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Materials and Methods used for the formation of qubit in quantum computing

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Abstract: The article reviews the basic concept of methods and materials in the formation of Qubits in Quantum computing. Qubits have mainly different types such as superconducting qubits, trapped ion qubits, photonic qubit and spin qubits. They are mainly synthesized by different physical processes. Not only that, effort has been made to review the materials and formation methods but also on advantages and challenges faced. In this review article mainly, the work published in last few years have been considered. We do believe that this work will be a valuable addition in the related literature.

Keywords: introduction, superconducting qubit, trapped ion qubit, photonic qubit, spin qubits.

Introduction

Quantum computer is a new technology that uses special rules of quantum physics. Normal computers use bits — tiny switches that are either 0 or 1. Every website, app, or game is made using these bits. But quantum computers use something different called qubits (short for *quantum bits*). Qubits are different because qubit can be 0, 1, or both at the same time which is known as superposition. Two qubits can be connected in a special way called entanglement, if we change one instantly change another. Because of this, quantum computers can do multiple calculations at single time, which makes them powerful for solving certain complicated problems — like understanding molecules, improving medicines, or breaking secret codes.

Formation of Qubits

Qubits are formed by **very tiny particles**, like, electrons, atoms, or even light particles (photons). Scientists use special tools to control these particles so they can behave like qubits.

Here are some common ways to make qubits:

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Superconducting Qubits

Those Qubit which are made from electrical circuits that are cooled down to very, very low temperatures which is close to absolute zero (-273°C or 0 Kelvin) are known as Superconducting qubits. At this temperature, the materials become superconductors, meaning electricity flows with no resistance. These circuits act as like tiny artificial atoms, and their energy levels can be used to store and control quantum information.

The process of formation of superconducting qubits starts with superconducting materials like aluminium or niobium; these materials become superconductor at low temperature. These materials build a very small circuit which is called a Josephson junction. This is made by putting a very thin insulator between two super conductors. The whole circuit is placed in a dilution refrigerator, which cools it down to near absolute zero temperature so it becomes superconducting. The energy states are control by sending microwave signals into the circuit and these energy states (like high and low levels) act like the 0 and 1 of a qubit. The qubit can be set to 0, 1, or a mix of both (superposition) by adjusting the microwaves. They also measure the state of the qubit using sensitive electronics. The advantages of superconducting qubits are Fast operations (nanoseconds), Scalable which is easier to make many of them on a chip, used by companies like IBM, Google, and Intel. But they also have challenges, like Need to be extremely cold; Sensitive to noise (can easily lose information).

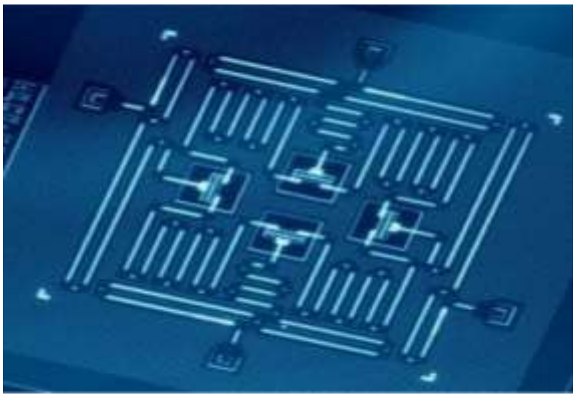

Figure 1: A device consisting of four superconducting transmon qubits, four quantum buses, and four readout resonators fabricated by IBM and published in npj Quantum Information in January 2017

Trapped Ion Qubit

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Those qubits which are made by using charged particle called ions are known as Trapped ion qubits. Electric and magnetic fields are used for trapping the ions at a place inside a special machine. Then, lasers are used to control and read their quantum states. These act as a qubit (the basic unit of quantum computer).

Trapped ion qubits are formed by first ionizing neutral atoms, such as ytterbium or calcium, to create charged ions. These ions are then confined in space using electromagnetic fields within a device called a Paul trap. To ensure precise control, the trapped ions are cooled to extremely low temperatures using laser cooling techniques, reducing their motion to near the quantum ground state. A qubit is encoded in two stable internal energy levels of each ion, which represent the quantum states $|0\rangle$ and $|1\rangle$. The qubits are initialized into a known state using optical pumping, and quantum logic operations are performed using laser or microwave pulses that drive transitions between the qubit states or entangle multiple ions via shared motional modes. Finally, the qubit states are measured using state-dependent fluorescence, where the presence or absence of emitted light reveals the ion's quantum state.

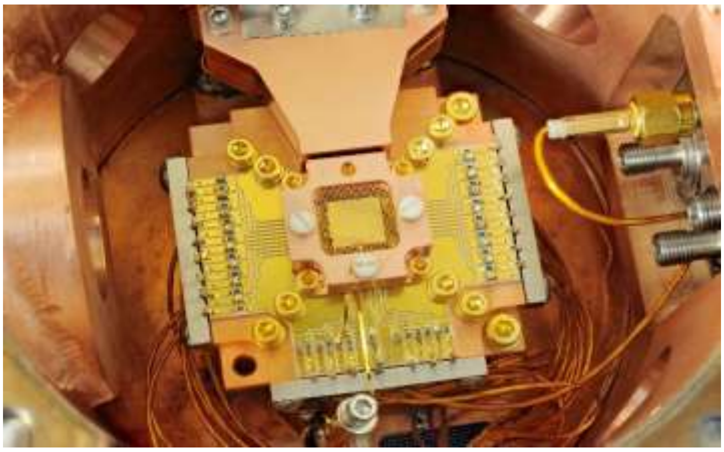

Figure 2: Chip ion trap for quantum computing from 2011 at NIST

Photonic qubits

Photonic qubits are qubits made from light particles, called photons. A photon is the smallest unit of light like a tiny packet of energy. Photonic qubits store and carry quantum information using different properties of photons, such as Polarization, Path, Time, and Frequency. Photons are great for sending quantum information over long distances like in quantum communication and quantum internet.

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The process of formation of photonic qubits starts with First creation of photons. This is done using by Lasers (produce controlled light), Nonlinear crystals (special materials that produce single photons). The quantum information is stored in a property of the photon. The most common is Polarization, Light can be polarized in different directions like: Horizontal (→) = represents 0, Vertical (↑) = represents 1, A mix of both directions = superposition. Other properties can also be used: Path – which direction the photon takes, Time-bin – whether the photon arrives early or late, Orbital angular momentum – the "twist" of the light wave. Beam splitters, Wave plates, Mirrors and phase shifters are used to control or change the photonic qubit. These tools help put the photon in superposition or entangle it with other photons. To read the state of a photonic qubit, detectors like photodiodes or avalanche photodetectors are used. They "click" when they detect a photon and show whether it was in state 0, 1, or both. The advantages of photonic qubits are fast, low noise, perfect for quantum communication, work at room temperature. But the challenges are Harder to store or delay, Generating single photons on demand is still challenging.

Figure 3: Quantum Computing Modalities: Photonic QC

Spin qubits

Spin qubits are made by using the spin of tiny particles like electrons or atomic nuclei. Spin-up = represents 0, Spin-down = represents 1 and it can be both at once in quantum terms which is known as superposition

Semiconductors or quantum dots (tiny particles) to trap a single electron. This particle will be used to store the qubit. use the spin of electron as a qubit and the direction of spin is represented as Spin up (↑) = 0, Spin up (↑) = 0. The spin can also be in a superposition — both up and down at the same time. Magnetic fields or microwave pulses are used to change the spin direction. These pulses can flip the spin, rotate it, or put it into a superposition state. When you have more than one spin you can entangle them. To measure the spin (find out if it's 0 or 1), a technique called spin-to-charge conversion is used if the spin is up, the electron stays in place, if it's down, it moves and this change is detected by sensors. The advantages are Very small, Stable, Works with existing semiconductor technology. But the challenges are Controlling and reading spin is very delicate, Harder to scale compared to some other qubit types

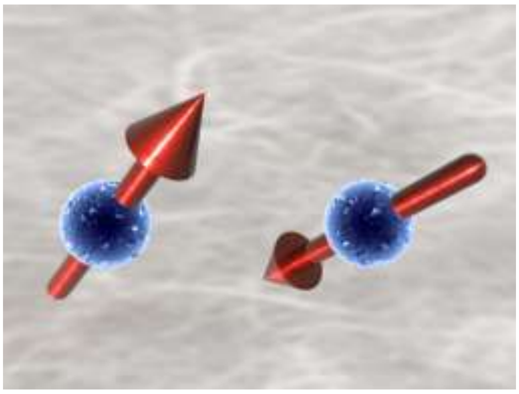

Figure 4: Two-qubit exchange gate between adjacent electron spins

Conclusion

Quantum computers are very powerful machines that use special bits called *qubits* instead of normal bits. Qubits can be 0, 1, or both at the same time, which helps them solve very hard problems much faster than ordinary computers.

There are different ways to make qubits such as superconducting qubits, trapped ion qubits, photonic qubits, and spin qubits. Each type is made using different materials and techniques. Superconducting qubits use very cold circuits, trapped ion qubits use charged atoms, and photonic qubits use light, and spin qubits use tiny electron spins.

All these methods have their own benefits and challenges. Some are faster, some are more stable, and some are easier to connect together. Scientists are still working to find the best materials and methods to make qubits more reliable and easier to use. In the future, better qubit technology will help make quantum computers more practical and powerful for solving real-world problems.

Reference

1. Arute, F., et al. (2019). *Quantum supremacy using a programmable superconducting processor*. **Nature**, 574(7779), 505–510. https://doi.org/10.1038/s41586-019-1666-5
2. Kjaergaard, M., Schwartz, M. E., Braumüller, J., Krantz, P., Wang, J. I., Gustavsson, S., & Oliver, W. D. (2020). *Superconducting qubits: Current state of play*. **Annual Review of Condensed Matter Physics**, 11, 369–395,https://doi.org/10.1146/annurev-conmatphys-031119-050605
3. Bruzewicz, C. D., Chiaverini, J., McConnell **Nature**, 453(7198), 1008–1015. https://doi.org/10.1038/nature07125, R., & Sage, J. M. (2019). *Trapped-ion quantum computing: Progress and challenges*. **Applied Physics Reviews**, 6(2), 021314. https://doi.org/10.1063/1.5088164
4. Blatt, R., & Wineland, D. (2008). *Entangled states of trapped atomic ions*.
5. O'Brien, J. L., Furusawa, A., & Vučković, J. (2009). *Photonic quantum technologies*. **Nature Photonics**, 3(12), 687–695. https://doi.org/10.1038/nphoton.2009.229
6. Wang, J., Sciarrino, F., Laing, A., & Thompson, M. G. (2020). *Integrated photonic quantum technologies*. **Nature Photonics**, 14(5), 273–284. https://doi.org/10.1038/s41566-019-0532-1
7. Loss, D., & DiVincenzo, D. P. (1998). *Quantum computation with quantum dots*. **Physical Review A**, 57(1), 120. https://doi.org/10.1103/PhysRevA.57.120
8. Zwanenburg, F. A., et al. (2013). *Silicon quantum electronics*. **Reviews of Modern Physics**, 85(3), 961. https://doi.org/10.1103/RevModPhys.85.961
9. Nayak, C., Simon, S. H., Stern, A., Freedman, M., & Das Sarma, S. (2008). *Non-Abelian anyons and topological quantum computation*. **Reviews of Modern Physics**, 80(3), 1083. https://doi.org/10.1103/RevModPhys.80.1083
10. Karzig, T., Knapp, C., Lutchyn, R. M., Bonderson, P., Hastings, M. B., Nayak, C., ... & Freedman, M. H. (2017). *Scalable designs for quasiparticle-poisoning-protected topological quantum computation with Majorana zero modes*. **Physical Review B**, 95(23), 235305