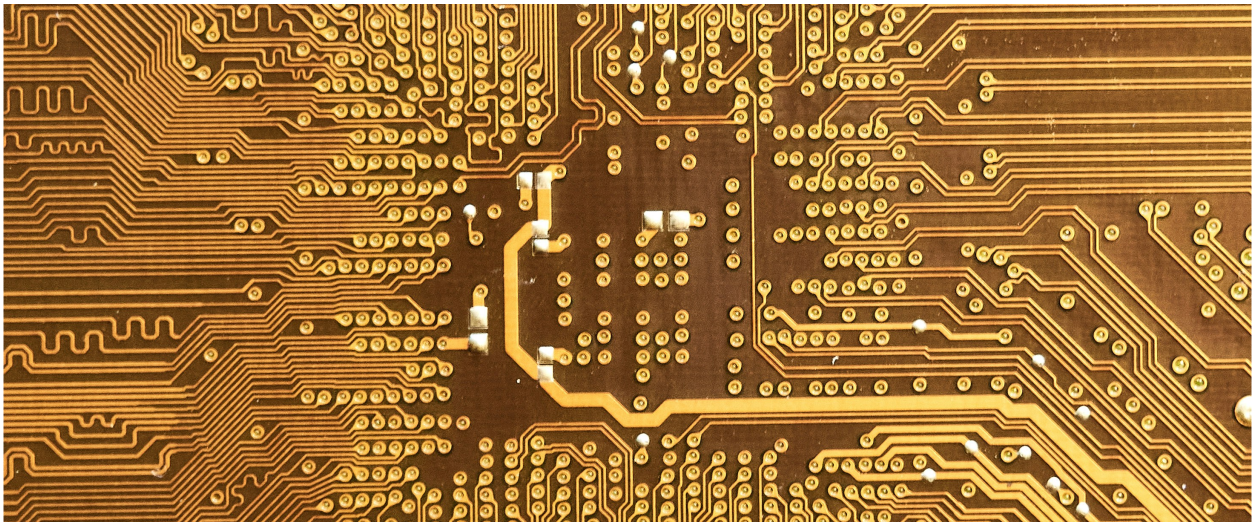

How Cool are Quantum Computers?

Or How Does Quantum Computer Stays Cooler Than the Outer Space

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Everyone knows Isaac Asimov—the science fiction genius who transported readers to futuristic worlds filled with groundbreaking ideas. One of his most famous stories,
The Last Question, featured Multivac, an Earth-bound supercomputer, and later the Cosmic AC, an all-knowing, universal intelligence. While humanity isn't quite there yet, did you know we already have something that feels like something right from Asimov's stories?

Meet the Quantum Computer.

Quantum computing is a mind-blowing leap in technology. Unlike the computers we use every day, which think in simple 0s and 1s (bits), quantum computers use **qubits**, which can represent 0, 1, or even both at the same time, thanks to a phenomenon called **superposition**. Think of qubits like spinning coins: instead of just heads or tails, they can exist as a mix of both, which makes quantum computers incredibly powerful for solving complex problems that can have multiple outcomes.

But wait! Don’t rush to throw out your laptop just yet. Quantum computers aren’t faster than classical computers for everything. They excel in areas where the data is unbelievably complex. Imagine unraveling a tangled ball of yarn versus unwinding a neat spool. Quantum computers thrive on the tangled mess.

One of the coolest things in quantum computing is **entanglement**. This is the process when two qubits that are so deeply connected that when you change one, the other instantly reacts, even if they’re light years apart. Pretty cool, right? Einstein himself called this “spooky action at a distance.”

Entanglement is exactly why quantum computers uniquely suited to tackle challenges that traditional computers can't.

How Does Quantum Computer Work?

At its core, quantum computing works by controlling qubits in a highly controlled environment at *extremely* low temperatures to minimize interference. Why? Because qubits are ridiculously delicate. Even the tiniest vibration or bit of heat can cause them to lose their special quantum properties — a process known as **decoherence**. To keep qubits stable, quantum computers operate at temperatures close to absolute zero, around -269°C.

These qubits are then manipulated using quantum gates—basically, tools that let scientists build algorithms by exploring multiple possibilities simultaneously.

> Depending on the gate, you could change its state in all kinds of weird ways—like flipping it, mixing it, or entangling it with another qubit. These operations can happen at the same time for multiple qubits, thanks to quantum properties like *parallelism.*

Cooling is the solution?

One of the key challenges is keeping the quantum computer cool enough to operate properly, which is very hard since the temperature should be about 4 Kelvin (-269°C), the same as the outer space! Lowering the temperature helps suppress thermal noise or vibrations and allows qubits to maintain their quantum coherence for a long time.

While both classical and quantum computers require a cooling system, it is quite different than in quantum computers.

There are different types of cooling systems for quantum computer:

- **Dilution Refrigeration:** The most common cooling methods for qubits with multiple stages, reaches temperatures close to absolute zero (around 10 mK or -273.14°C). They use a mixture of helium-3 (^3He) and helium-4 (^4He) and a helium dilution process to achieve and maintain very low temperatures. This cooling method is suitable for superconducting qubits and some types of trapped ions. These dilution refrigerators are bulky, complex and expensive.
- **Adiabatic Demagnetization Refrigeration (ADR): M**agnetic substance that undergoes heat-exchange-free demagnetization to reduce paramagnetic material temperature. This technique can achieve temperatures below 2 K by applying a strong magnetic field to align the atomic magnetic moment, followed by its subsequent reduction. The material's thermal energy surpasses magnetic interactions, which cools the system.
- **Pulse Tube Refrigeration (PTR):** A mechanical method that creates oscillating pressure waves to cool the system. To achieve temperatures below 4 K, PTR uses a mechanical device to generate a high-frequency pressure wave within a sealed gas circuit or closed-cycle cryostats. This oscillating pressure wave stimulates the gas to alternate between expansion and contraction, leading to temperature fluctuations, which generate low temperatures for cooling purposes. This type of cooling technique is generally suitable for superconducting qubit implementations.
- **Laser Cooling:** Laser cooling is a technique that uses frequency and laser light to reduce the speed of the movement of atoms and other particles. When an atom traps a light photon, it gains momentum in the direction of its travel to be

manipulated with more precision. The laser cooling technique is suitable for trapped ions to control the individual ions within the trap. In short, by slowing down particles using focused light, this technique is perfect for trapping ions.

At room temperature, thermal energy causes chaos — atoms bump into each other, creating noise that wrecks the delicate balance of quantum states like superposition and entanglement. Lowering the temperature helps suppress thermal noise or vibrations, allowing qubits to maintain coherence for much longer.

This superconductivity is very important for maintaining stable qubits and preventing energy loss.

Low temperatures help reduce decoherence, which is when qubits lose their quantum properties due to environmental interactions. Specialized cooling systems, like dilution refrigerators, keep these machines cold, sometimes even colder than outer space so they can perform their computations accurately.

Who makes this come true

So now we know why it is important to keep things cool, but cooling these tiny quantum particles isn't as simple as plugging in a fan. Thankfully, there are companies out there solving the problem in innovative ways.

One of the major players in this space is **Bluefors**, known for their **dilution refrigerator systems** that can chill quantum systems to an unfathomable **10-20 millikelvin (mK)**—that's colder than outer space itself. This ultra-cold environment is essential to keep qubits stable and prevent them from losing their quantum properties.

Quantum computing is growing fast, and the need for scalable cooling solutions is critical. The Bluefors' *KIDE Cryogenic Platform* is designed to handle over **1,000 qubits**. Here's what makes it so cool (pun intended):

- Increased Cooling Capacity and longer cooling cycles.
- Accommodation of more qubits and equipment without breaking a sweat (or a frost).

- Enhanced Wiring Infrastructure, which ensures that signals to and from qubits remain reliable, minimizing errors.

Bluefors has also teamed up with **Linde**, a giant in cryogenics, to tackle large-scale quantum computing projects.

Another major company is **Kiutra**. Their magnetic cooling systems unlike traditional cryogenic systems, doesn't rely on critical helium supplies, which makes it scalable and sustainable. It eliminates helium-3, reducing costs and environmental impact, which is perfect for the growing demands of quantum computing.

One standout feature of Kiutra's systems is a *Continuous cooling at sub-Kelvin temperatures.* This is a rare gem in the world of commercial magnetic refrigerators and a game-changer for keeping qubits stable.

Kiutra's systems are versatile enough to support a variety of quantum technologies, with temperature ranges tailored to specific needs. Their cryogenic systems are designed to be user-friendly, even for non-experts with their automated systems and Python based interfaces.

On of my favorite features from them is Kiutra's **L-Type Rapid System.** It can achieve temperature range of 100 mK to 300 K in under 3 hours and is ideal for rapid testing and characterization of quantum devices.

So, while quantum computers push the boundaries of science, these companies ensure their environment stays as cool as the tech itself. Together, they're building systems that could make massive quantum computers a reality.

Quantum computing is still in its infancy, but it's already reshaping fields like cryptography, material science and AI. While it might not yet rival Asimov's Cosmic AC, the possibilities are endless.

Sound like science fiction? Give it a few decades or even less. The future is closer than you think.