Part 6

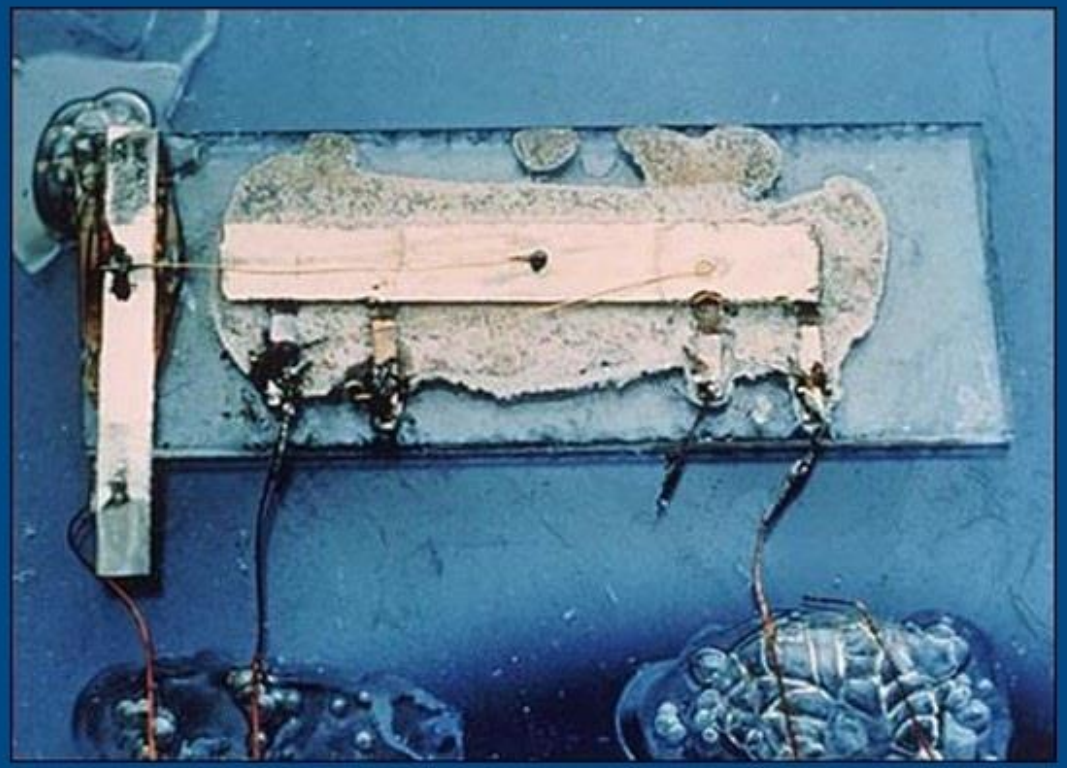
QND

- **Quantum NonDemolition** (**QND**) **measurement** is a special type of measurement of a quantum system in which the uncertainty of the measured observable does not increase from its measured value during the subsequent normal evolution of the system.
- This necessarily requires that the measurement process preserve the physical integrity of the measured system. In
- QND measurements are the "most classical" and least disturbing type of measurement in quantum mechanics.

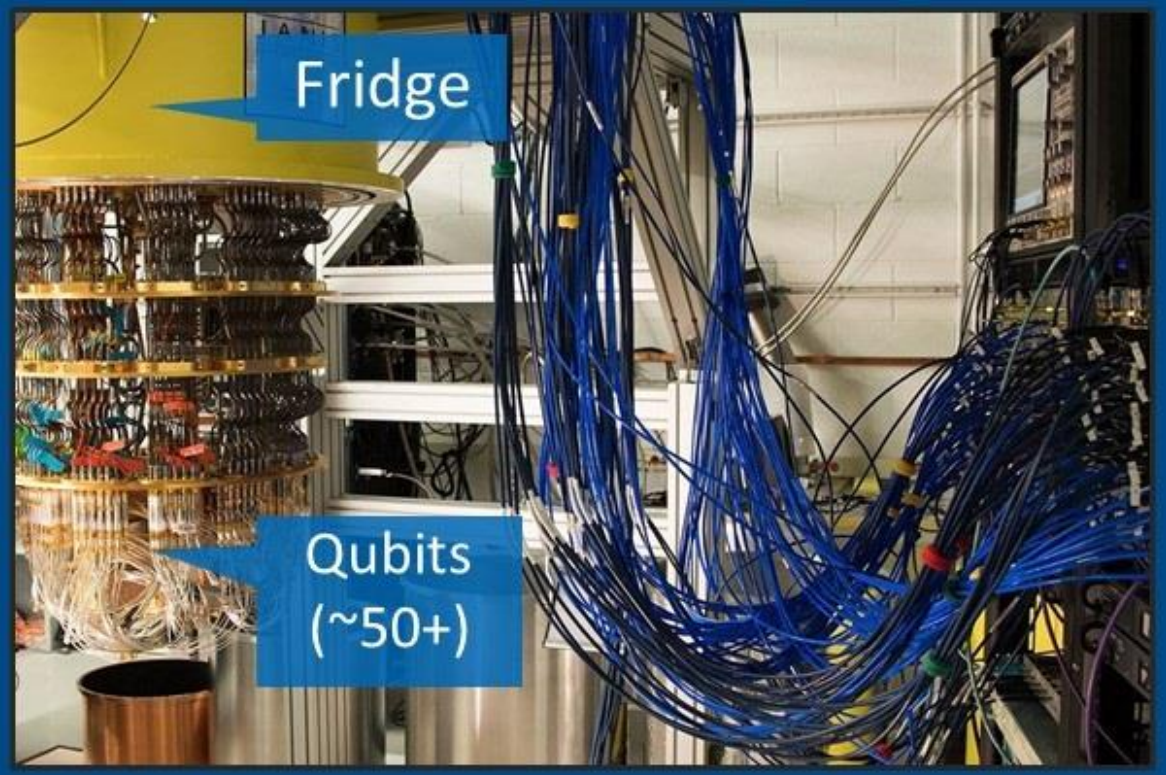
Summary of Qubit Approaches

Qubit type	Advantages	Weaknesses
Ion/atom Trap	-Extremely good quantum state control -Little interaction with environment -All ions are identical	-Difficult to scale up the number of qubits
Superconducting	-Compatible with current lithography procedures -Electrical control	-Each qubit is slightly different due to fabrication imperfections
Spins	**Depending on the system:** -Potentially long coherence times -Optical and/or electrical control possible -Room temperature operation	-Each qubit may be slightly different -Difficult to isolate from the environment
Topological	-Insensitivity to noise in the environment	-Forming topologically protected states is difficult -No demonstrated qubits yet

First Integrated Circuit (1958)

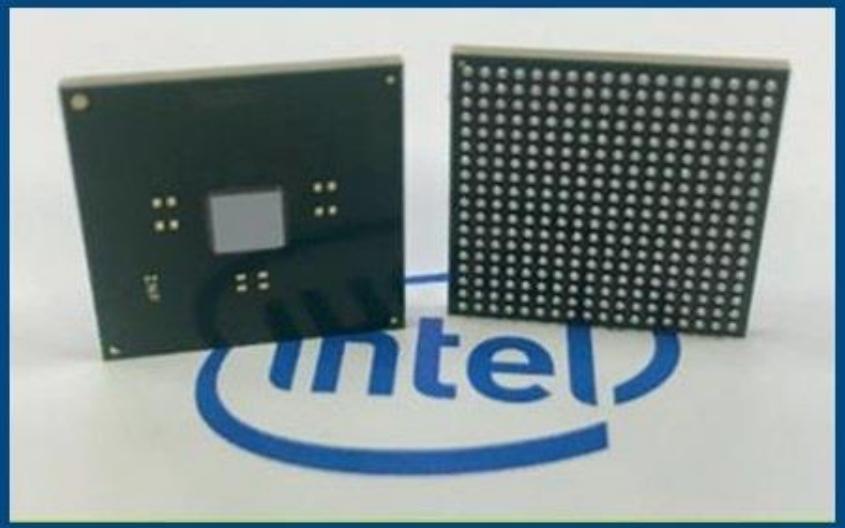


Quantum Supremacy (2019)

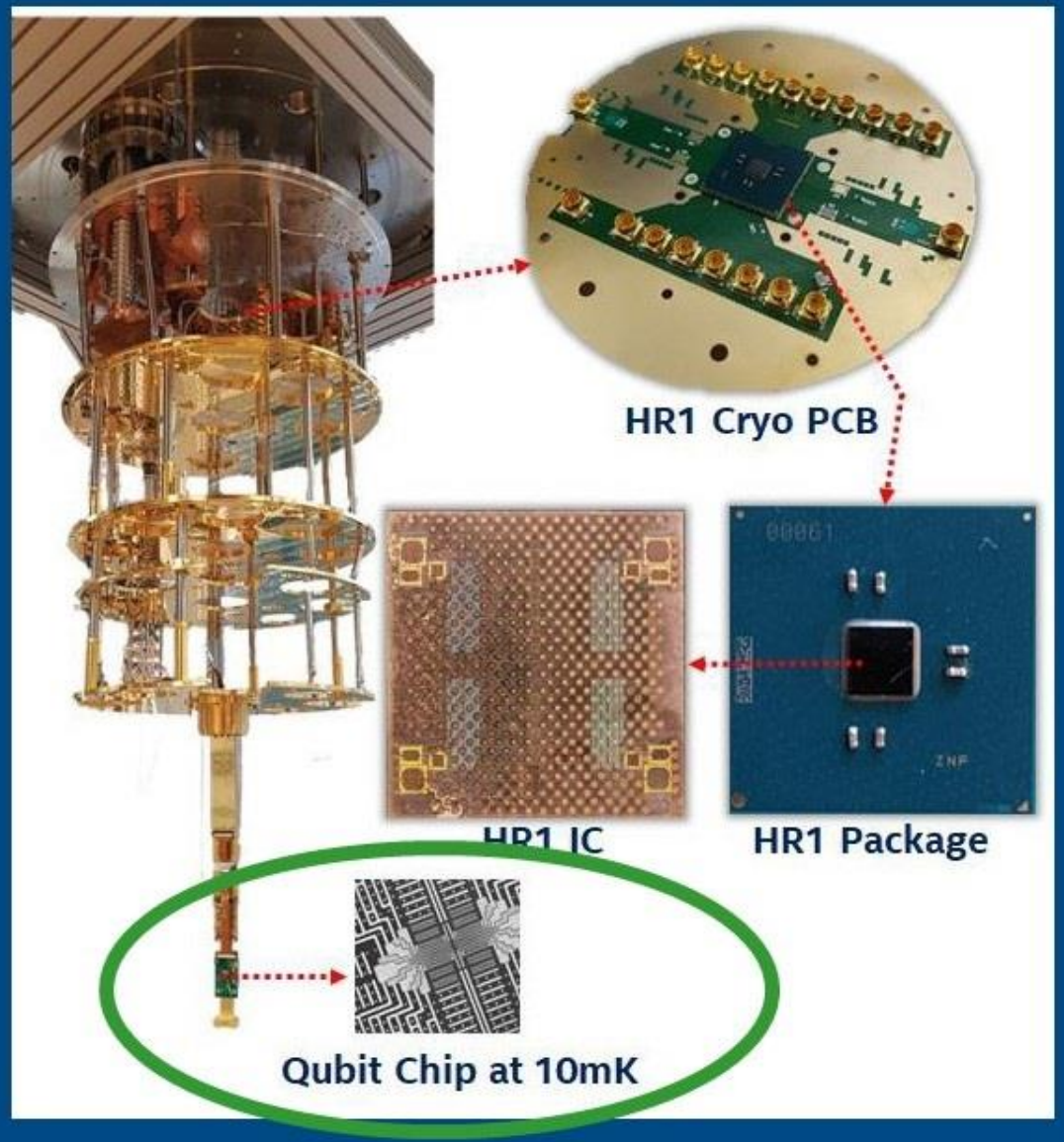


Brute Force Interconnects Work for a Few Devices – but NOT Millions

Horse Ridge Integration



Horseridge RFIC Fabricated
in Intel 22nm FinFet CMOS Technology



Quantum Computing: Key Concepts

Superposition

Classical Physics

Heads OR Tails

Quantum Physics

Heads AND Tails

Entanglement

1) 

2) 

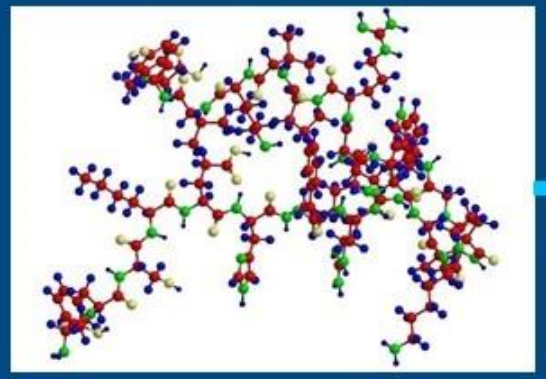
3) 

4) 

N Quantum Bits or **Qubits** = 2^N States

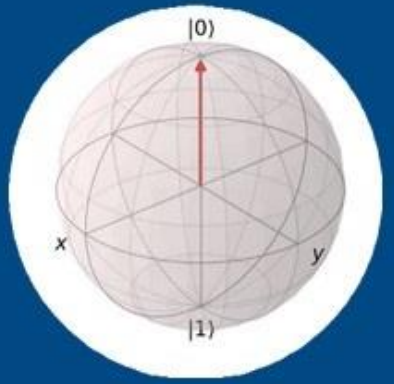
The Power of Quantum Computing

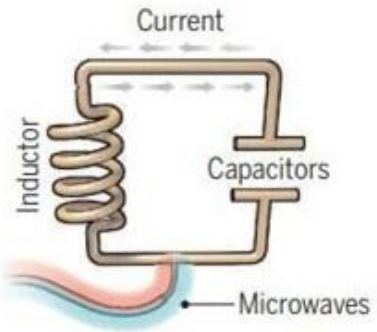
Nearer Term	Longer Term
Quantum simulation ▪ Chemistry ▪ Materials ▪ Drug discovery	▪ Machine learning ▪ Artificial Intelligence (AI) ▪ Optimization ▪ Cryptography



Quantum computers will let us do things we can't do today

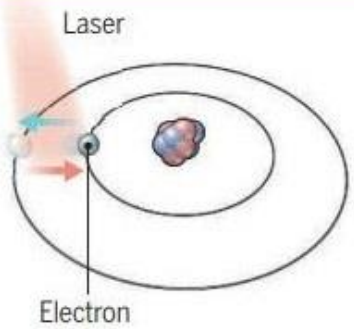
A Quantum Bit





Superconducting Loops

Google, IBM, Rigetti, DWave



Trapped Ions

Honeywell, IonQ

Silicon Quantum Dots

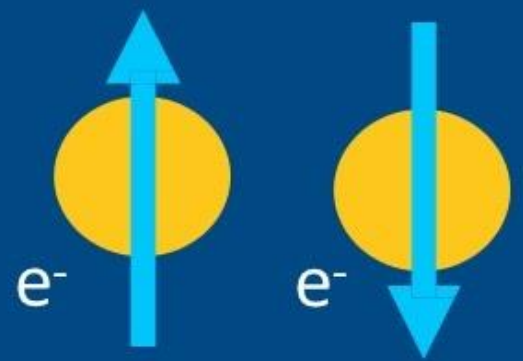
Intel Corporation, HRL

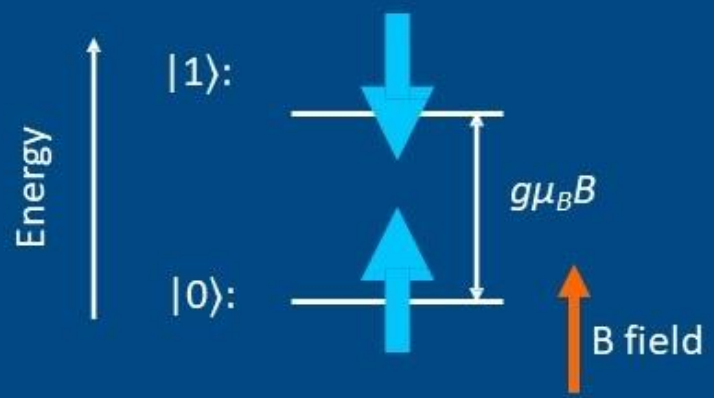
Only One of These Qubits is Built on the Technology of Transistors

DOI: 10.1126/science.354.6316.1090

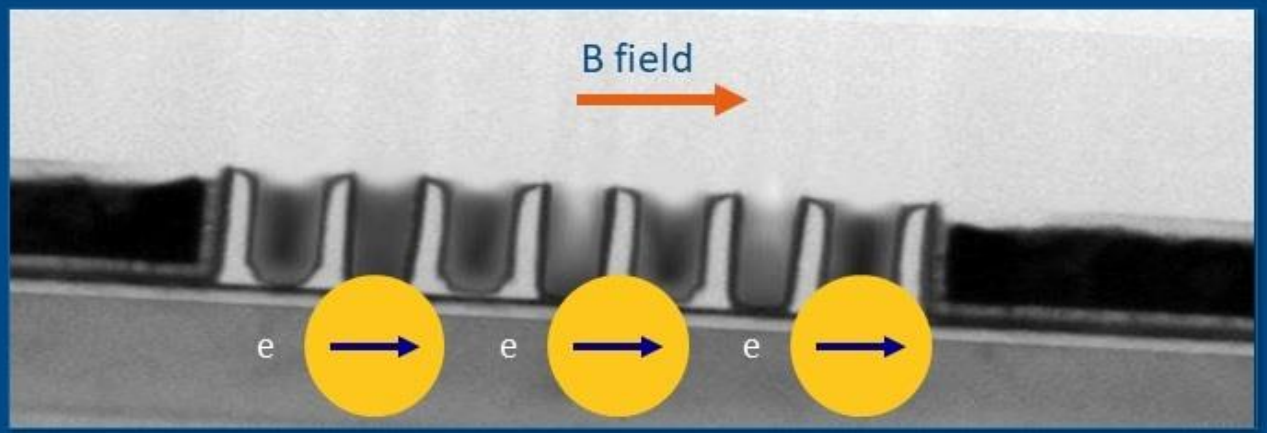
Spin qubits

2 basis states:



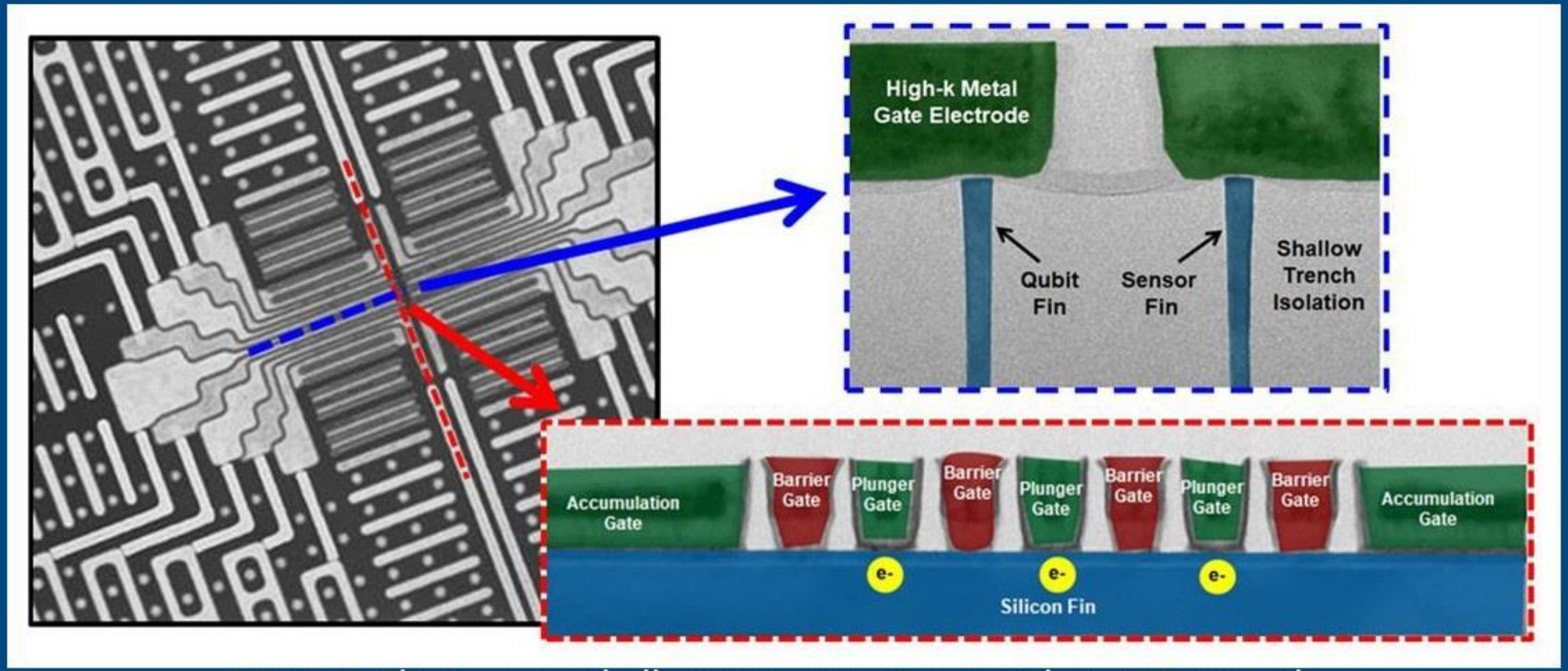


- Spin is a fundamental property of electrons
- Spin behaves like a tiny magnet that can be manipulated using magnetic fields



Each Qubit is Encoded as a Single Electron Spin in a Silicon Substrate

Spin Qubit Device Integration



Many similar process challenges to transistors such as: CD control, VT variation, gate dielectric interface/bulk quality, defects, traps

Advantages of Quantum Computers

- **Faster computations:-**
- These type of computers can perform computation at a much faster rate than normal computers. Quantum computers have computation power higher than supercomputers also. They can process data at 1000 times faster than normal computers and supercomputers. Some calculations if performed by a normal computer can take 1000 years is done by quantum computers in a few seconds.
- **Best for simulation:-**
- Quantum computers are best for doing data simulation computing. There are many algorithms created that can simulate various things like weather forecasting, chemical simulation etc.
- **Medicine creation:-**
- These type of computers can work better in the medical field. They can detect diseases and can create a formula for medicines. Different type of diseases can be diagnosed and tested in scientific laboratories using these computers.

- **Google search:-**
- Quantum computers are used by Google to refine searches. Now every search on Google can speed up by using these computers. Most relevant results can be populated using quantum computing.
- **High privacy:-**
- These computers can make high encryption and is good at cryptography. It is impossible to break the security of quantum computers. Recently China has launched a satellite that uses quantum computing and china claimed that this satellite cannot be hacked.
- **Used in radar making:-**
- Quantum computing is also used in making radar missiles. The accuracy of radar weapons can be improved by using this technology.

- **Used in artificial intelligence:-**
- These type of computers perform well in artificial intelligence. They can make decisions more precisely than normal computers. Scientists can do better research using these computers.
- **Machine learning:-**
- Quantum computing is applied nicely by using machine learning techniques. Users can use less code and uses machine learning process for improving outcome.

Disadvantages of Quantum Computing

- **1. They emanate noise**
- An average Quantum Computer has about 10,000 times more noise than a standard computer. The noise is understood to be the main reason these computers make mistakes.
- Interference, environmental noise, and unwanted interactions between qubits are all potential causes of undesirable quantum-to-classical transitions. A "quantum circuit," a sequence of operations known as quantum gates, is used to perform computations on a quantum computer.

- **2. Power requirement is one of the major cons of quantum computer**
- Traditional computers use bits to represent either a 0 or a 1. Quantum computers, on the other hand, use qubits. Qubits can represent a 0, a 1, or both simultaneously. This allows much more data to be processed at once, but it also requires more power. Traditional computers use algorithms that are based on logic gates. Quantum computers, on the other hand, use algorithms that are based on quantum mechanics. These algorithms are much more complex and require more processing power.

- **3. They're very expensive**
- With more form factors such as power requirement, maintenance, and complex processing, the cost of setting up is initially high. Quantum computers are extremely expensive to build and maintain. Most of the cost goes into keeping them cool because they need to operate in near-absolute-zero temperatures.

- **4. They're delicate**
- A quantum computer is a delicate machine that its environment can easily disrupt. Even a small amount of heat or light can cause it to lose its quantum state and become useless. Despite investing substantially in large projects, companies or research facilities may have to face such **cons of quantum computer**.

- **5. Limited application**
- Quantum computers are only good for certain tasks, such as data simulation and machine learning. They are not well-suited for other tasks, such as general-purpose computing or everyday tasks like word processing or web browsing. Because they are so expensive, they also aren't available for public use. Furthermore, because these computers are still in the early phases of development, their mistakes are significant. So far, the most powerful quantum computers are available only in research labs.

6. **Quantum computers are expensive and difficult to build:**

Creating a quantum computer requires specialized equipment and expertise, and the costs of building and maintaining a quantum computer can be high.

7. Quantum computers are difficult to program:

Programming a quantum computer is a complex and specialized task that requires a deep understanding of quantum mechanics. There are also few tools and resources available for programmers to work with, which makes it difficult for developers to create new quantum algorithms.

8. **Quantum computers are not yet fully developed:**

- Quantum computers are still in the early stages of development, and many of their capabilities are not yet fully understood. This makes it difficult to predict how they will be used in the future, or what their limitations might be.