QUANTUM COMPUTING

A New Era of Future Computing

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Overview

- Computing Generations
- Quantum Computing
- Quantum Logics and Representation
- How It Works
- Present Status
- Future Research
- Conclusion
- Open Discussion

Computing Generations

- *First Generation (1940-1956)*
  - *Vacuum Tubes*
- *Second Generation (1956-1963)*
  - *Transistors*
- *Third Generation (1964-1971)*
  - *Integrated Circuits*
- *Fourth Generation (1971-Present)*
  - *Microprocessors*
- *Fifth Generation (Present and Beyond)*
  - *Artificial Intelligence*

Why Quantum Computing

"The number of transistors incorporated in a chip will approximately double every 24 months."

-- Gordon Moore, Intel Co-Founder

Why Quantum Computing

- By 2020 to 2025, transistors will be so small and it will generate so much heat that standard silicon technology may eventually collapse.

  Already Intel has implemented 32nm silicon technology

- If scale becomes too small, Electrons tunnel through micro-thin barriers between wires corrupting signals.

Quantum Computing

- A quantum computer is a machine that performs calculations based on the laws of quantum mechanics.

- A theoretical model is the Quantum Turing machine – Universal Quantum Computer.

Quantum Logics and Representation

- Quantum Computers use quantum mechanical phenomena-
  - Entanglement
  - Superposition

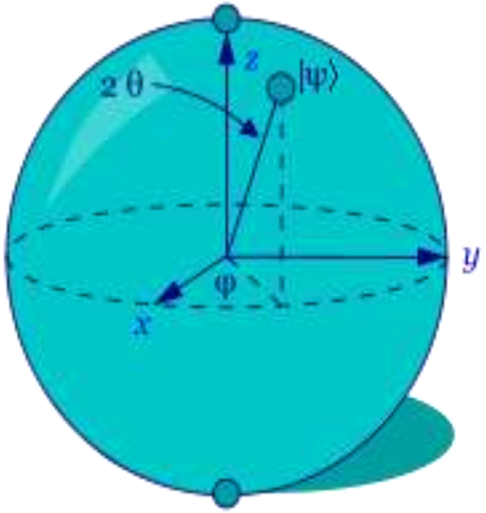
- Quantum computational operations were executed on a very small number of **Qubits** (quantum bits)

Quantum Logics and Representation

- A classical computer has a memory made up of **bits**. A quantum computer maintains a sequence of **qubits**.
- A single qubit can represent a one, a zero, or, crucially, any quantum superposition of these.
- Quantum computer with *n* qubits can be in an arbitrary superposition of up to 2^n different states simultaneously (this compares to a normal computer that can only be in *one* of

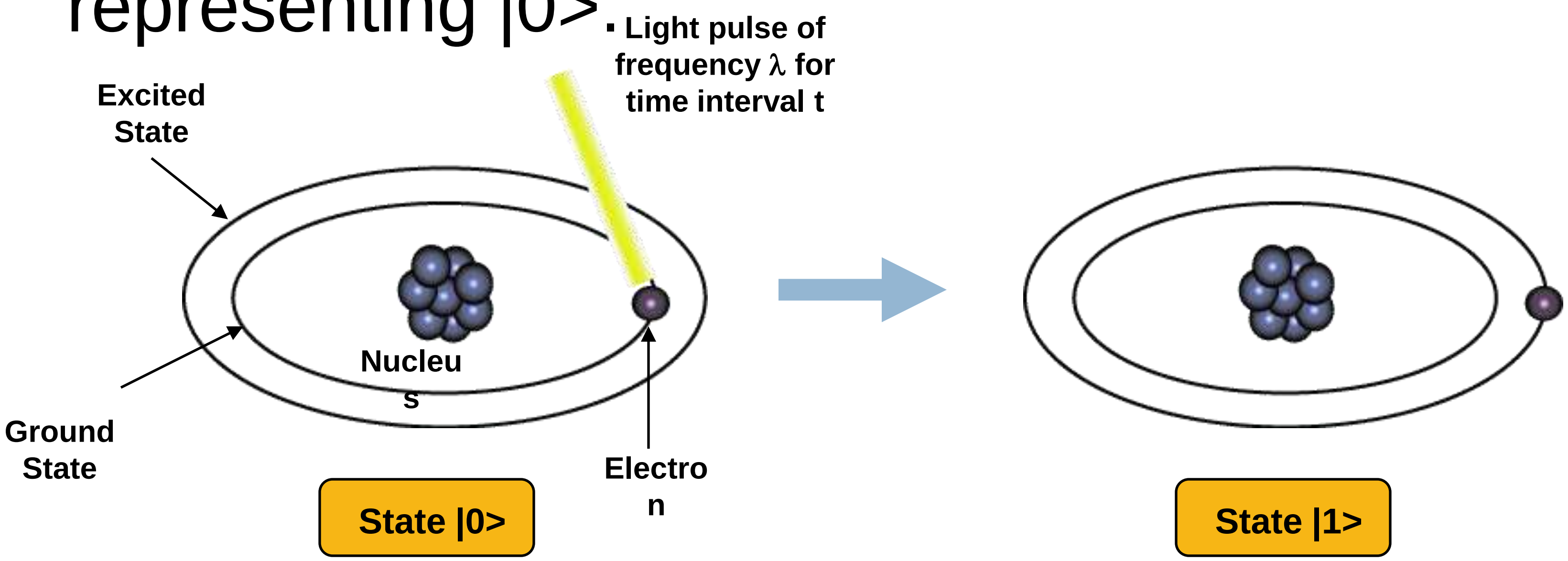
Qubit

- This sphere is often called the *Bloch sphere*, and it provides a useful means to visualize the state of a single qubit.



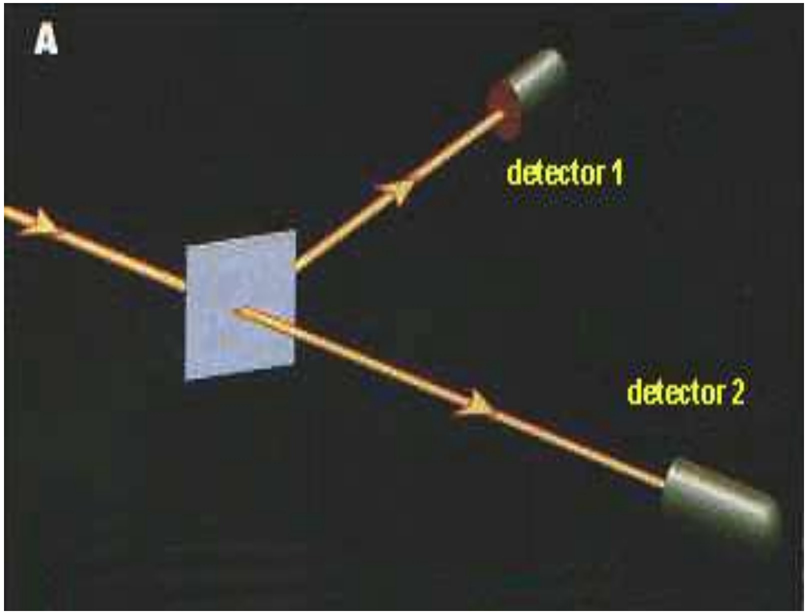
Qubit: How It Works

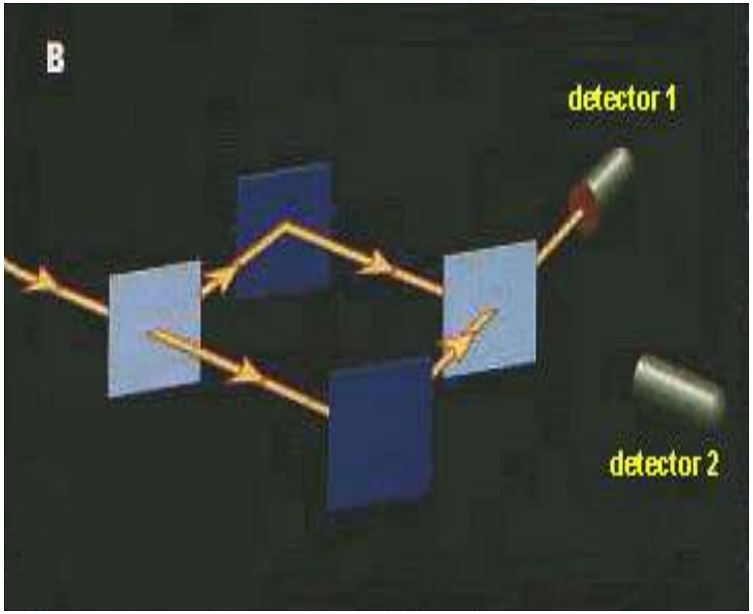
- A physical implementation of a qubit could use the two energy levels of an atom. An excited state representing |1> and a ground state representing |0>.



Superposition: How It Works

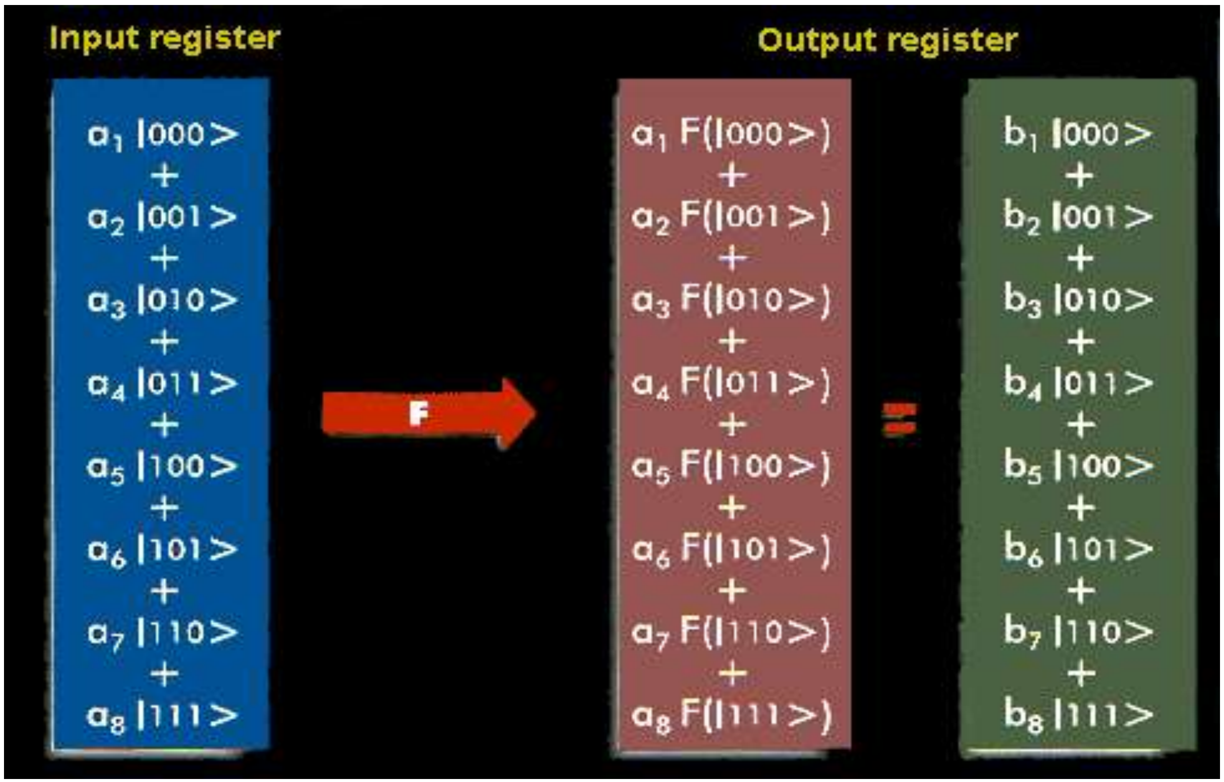
- A qubit in superposition is in both of the states |1> and |0> at the same time.





- One example of a two-state quantum system is the polarization of a single photon

Multiple computations simultaneously

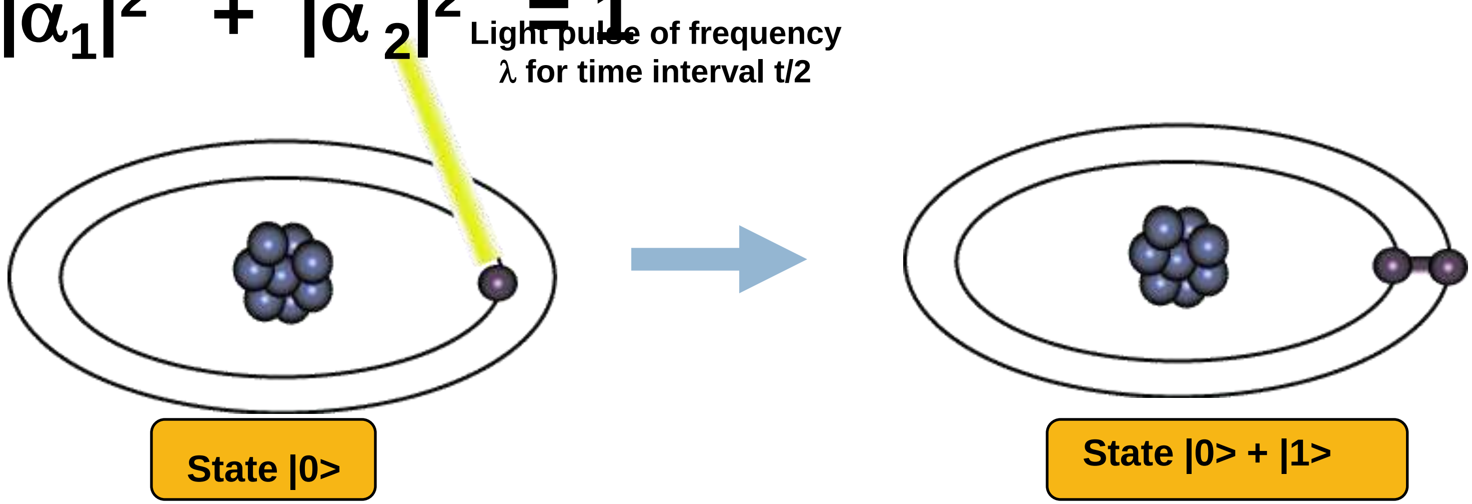


Superposition: How It Works

- A single qubit can be forced into a superposition of the two states denoted by the addition of the state vectors:

$$|\psi\rangle = \alpha_1|0\rangle + \alpha_2\,|1\rangle$$

- Where α_1 and α_1 are complex numbers and $|\alpha_1|^2 + |\alpha_2|^2 = 1$



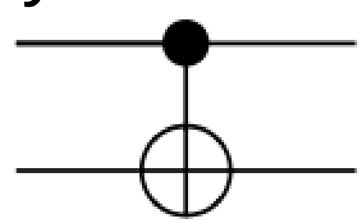
Quantum Logic Gates

- Commonly used gates
  - Hadamard gate
  - Pauli-X gate
  - Pauli-Y gate
  - Pauli-Z gate
  - Phase shift gates
  - Swap gate
  - **Controlled gates**

Controlled Gates

- Controlled gates act on 2 or more qubits. For example, the controlled NOT gate (or CNOT) acts on 2 qubits, and performs the NOT operation on the second qubits only when the first qubit is **|1>** , and otherwise leaves it unchanged. It is represented by the matrix-

$$\mathrm{CNOT} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{bmatrix}$$



Circuit representation of controlled NOT gate

Present Status

- Quantum physicists from the University of Innsbruck have set another world record: They have achieved controlled entanglement of 14 quantum bits (qubits) and, thus, realized the largest quantum register that has ever been produced. *ScienceDaily (Apr 1, 2011)*

- Researchers at Delft University of Technology have succeeded in carrying out calculations with two quantum bits. *ScienceDaily (June.17, 2010)*

- December 19, 2001 – IBM performs Shor's Algorithm

Future Research

- If large-scale quantum computers can be built, they will be able to solve certain problems much faster than any classical computer using the best currently known algorithms (for example integer factorization using Shor's algorithm or the simulation of quantum many-body systems).

- Desktop Quantum computers expected by many within 10 years

Conclusion

References

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Thanks!