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REVIEW ARTICLE

QUANTUM COMPUTING-NOVELTY& RESEARCH CHALLENGES

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ABSTRACT

The idea of Quantum computer is different from classical computing methodologies. Presently, we work to resolve a problem on digital computers which is based on binary values. Quantum computers work on the qubit which is quantum bits based on quantum entanglement to solve a problem. There exists some algorithm for Quantum computers like Shor's algorithm which is used to find the prime factors of a number. There is D-wave computer which is based on 128 – qubit processor (Rainer).

INTRODUCTION

In the 21st century, can we build a computer that can work on the principle of quantum computing and can store, transmit and process information that exhibit unique quantum properties? Answer is yes. Now-a-days many ambitious researchers around the world are working to build a physical quantum computer, which would dramatically improve computational power for particular tasks. Quantum computing is one of the recent research immersing trends in the field of quantum information science. This article introduces the basic concepts behind quantum computing, quantum dot, recent developments in quantum searching and challenges.

In 1982, a Nobel prize-winning physicist Richard Feynman, thought up the novelty of a 'quantum computer' a computer that uses the effects of quantum mechanics to its advantage. The feature of quantum computers is to provide dramatic speed-up in information processing as compared to the fastest classical machines. During long decades the notion of a quantum computer was primarily of theoretical interest only, but recent developments have bought the idea to everybody's attention. The development initiative was taken by Peter Shor at Bell Laboratories. He developed an algorithm to factor large numbers on a quantum computational model. By using this algorithm, a quantum computer would be able to crack codes much more quickly than any ordinary (or classical) computer could. In fact a quantum computer capable of performing Shor's algorithm would be able to break current cryptography techniques in a matter of seconds. With this motivation from Shor's development the topic of quantum computing has gathered momentum and researchers around the world are trying to develop a physical quantum computer.

The Generation of Quantum Dot

The word *quantum* derived from the Latin word *quantus* which means "how much". Quantum is a discrete quantity of energy proportional in magnitude to the frequency of the radiation it represents. An analogous discrete amount of any other physical quantity, such as momentum or electric charge is known as *quantum*.

The only comprehensible unit by the computer is a *bit* (binary digit either 0 or 1) which is the smallest. So bit is the basic unit of the classical computer. One of the most intuitive representations of bit is an open(on) or closed (off) switch of the circuit.In today's modern computer, this representation remains in transistors, with a high voltage possibly denoting a 1 and low voltage possibly denoting a 0. A two state system ($0 \rightarrow 1$) is the building block of classical computational device.

A classical computer is made up by transistors and diodes whereas a quantum computer is very much different from the classical computer in design. In order to build one, a new type of technology is needed, a technology that enables 'quantum bits' to exist as coherent superposition of 0 and 1 state. A *quantum bit* or simply *qubit* is a unit of quantum information. Qubit represents both the state memory and the state of entanglement in a system. *Quantum entanglement* is experimentally verified property of nature. It happens when the particles such as photon, electron, molecules interacts physically and then become separated. This interaction is known as *entanglement*. The superposition of states by quantum bits can be represented as

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$$

where α, β represent *complex numbers* satisfying $|\alpha|^2 + |\beta|^2=1$ and $|\psi\rangle$ is called a superposition. Any state measurement results in $|0\rangle$ with probability $|\alpha|^2$ and $|1\rangle$ with probability $|\beta|^2$. Moreover, quantum entanglement is a form of quantum superposition which shows the photons are highly mobile in nature.

An example of an implementation of the qubit is the *quantum dot* which is the first step taken by the researchers for building a quantum computer. In this phenomenon a single electron is trapped inside a cage of atoms as shown in Fig.1. When the dot (i.e. the electron) is exposed to a pulse of laser light of certain frequency λ for the time interval T, the electron is raised to an excited state: a second burst of laser light causes the electron to fall back to its ground state. The ground and excited states of the electron can be thought of as the 0 and 1 states of the qubit and the application of the laser light can be regarded as a controlled NOT function as it knocks the qubit from 0 to 1 or from 1 to 0 i.e. $\alpha|0\rangle + \beta|1\rangle$ is changed to $\alpha|1\rangle + \beta|0\rangle$ and vice versa.

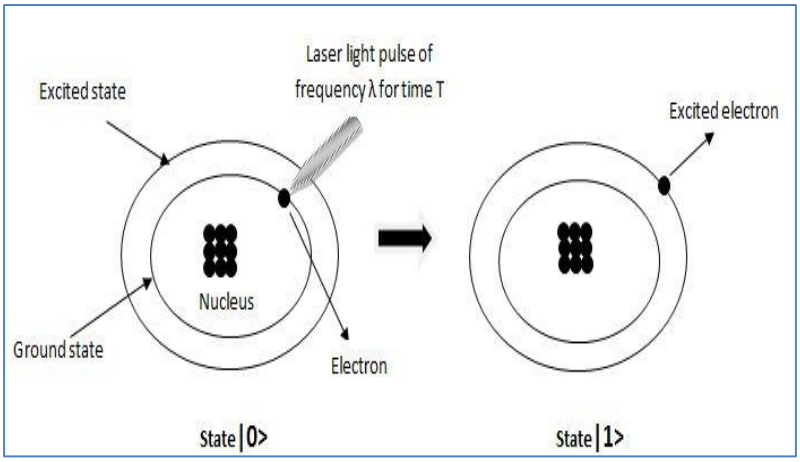

Fig.1:Transition of States in an Atom

Limitations of Quantum Dot

It seems that quantum dots are a suitable thing for building a quantum computer. However unfortunately many practical problems are obstructing this to happen. The serious drawback is the electron remains only about few microseconds in its excited state before it falls to the ground state. On the other hand there is a limit to the number of computational steps.Therefore making a quantum computer from the concept of quantum dot seems to be a verytedious task. A typical quantum dot measures just 10 atoms (1 nanometer) across. The technology needed to build a computer from these dots doesn't yet exist.

Recent Developments and Challenges

In the year 2011, D-Wave Systems a Columbia based company demonstrated the world's first commercially quantum computer known as *D-Wave* one. It operates on 128 qubit processor named as Rainier (Fig.2). This coputer only performs single mathematical operation named discrete optimization. The computer uses quantum annealing (which is a general strategy for finding the global minimum of a given objective function over a given set of candidate solution) to solve optimization problems. Later some researchers found that this system provides no speedup compared to classical computers.

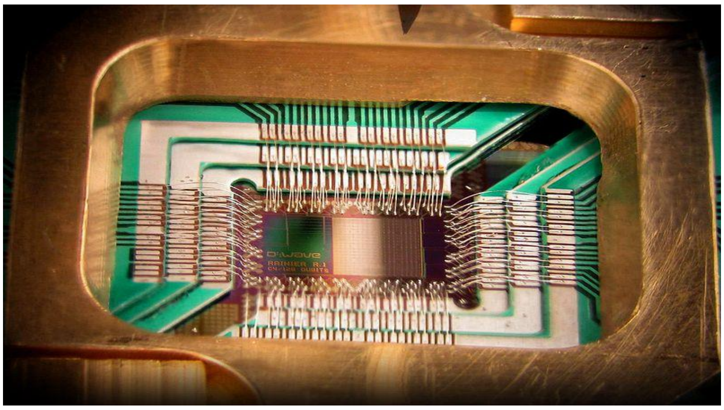

Fig.2: 128 bit Processor Rainier

In 2012, Six researchers from *University of Vienna developed a new model of a quantum computer called "boson sampling computer" on the basis of computational power of photons.* They inserted photons into a complex optical network where they could propagate along many different paths and they found the photons seem to take all possible paths at the same time which obeys the laws of quantum physics (Fig. 3). This is known as superposition.

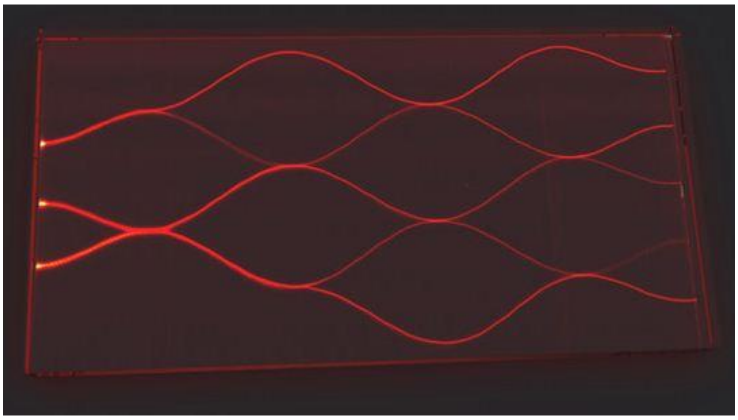

Fig.3:Optical Network of Boson Sampling Computer

CONCLUSION

Quantum computers not only promise a dramatic increase in speed over classical computers in a variety of computational tasks but also designed to complete tasks that even a supercomputer would not complete in a specific time period. Although, in recent years, there has been a rapid development in quantum technology the realization of a fully-fledged quantum computer is still very challenging. Most research in quantum computing is still in fantasy. While it is still an exciting debate which architecture and quantum objects will finally lead to the outperformance of conventional supercomputers.

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