Quantum computing. Quantum information technologies as the basis for future learning platforms

Oleksandr Hnatenko*

Kharkiv National University of Radio Electronics

**Corresponding author e-mail: oleksandr.hnatenko@nure.ua*

Abstract

This paper presents the place of quantum technologies in the modern information world. The technique of quantum computing is described. Also presented is a new model of a qubit based on a nanolaser with frequency stabilization, which emits at different wavelengths, which corresponds to its different states. Thus, the work proposes a scheme of a qubit, which underlies quantum technologies and quantum computers. Quantum computing is a thousand times faster than existing ones. In the future this technology will be able to solve problems that are beyond the power of modern computers, which means it will become the basis for learning and understanding the world more broadly.

Keywords: qubit, nanolaser, quantum computer.

1 Introduction

With the advent of high-performance computing, algorithms and mathematical models are used to solve problems in many sciences: physical, biological and computer sciences.

Quantum theory has proven to be a highly successful description of physical reality and has led, since its inception in the early 20th century, to advances such as lasers, transistors, and semiconductor microprocessors. The quantum computer uses the most efficient algorithms, using operations that are not possible in classical machines. Quantum processors do not run faster than classical computers, but they work in a completely different way, they achieve unprecedented speedups, avoiding unnecessary computation. For example, calculating the total electron wave function of the average drug molecule on any modern supercomputer using conventional algorithms is expected to take longer than the full age of our universe [1], while a small quantum computer can solve this problem in a few days. Encouraged by such a promise of quantum advantage, engineers and scientists are continuing their quest to build a quantum processor. However, the technical difficulties in manufacturing, managing and protecting quantum systems are incredibly complex, and the first prototypes have only appeared in the last decade.

It is important to note that the technical problems of building quantum computers did not stop the development of quantum computing algorithms. Even in the absence of hardware, algorithms can be analyzed mathematically, and the advent of high-performance quantum computer simulators as well as early prototypes in the past few years has allowed further research to advance.

Recent claims of quantum supremacy from Google [2], which are disputed by IBM [3], indicate that the era of quantum computing is near. The first processors using quantum effects to perform computations impossible for classical computer technology are expected within the next decade [4].

2 Quantum computing

In classical information, the fundamental unit of information is the bit, a system with two identifiable states, often denoted 0 and 1. The quantum analog, the qubit, is a two-state system, the states of which are labeled $|0\rangle$ and $|1\rangle$. We use Dirac's notation, where $|\ *\rangle$ identifies a quantum state. The main difference between classical and quantum information is that a qubit can be in any superposition of states $|0\rangle$ and $|1\rangle$:

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle, \alpha, \beta \in \mathbb{C} \quad (1)$$

The complex coefficients α and β are known as the amplitudes of states, and they are related to another key concept in quantum mechanics: the effect of the physical dimension. Since qubits are physical systems, you can always come up with a protocol to measure their state. If, for example, the states $|0\rangle$ and $|1\rangle$ correspond to the states of the spin of an electron in a magnetic field, then measuring the state of a qubit is simply measuring the energy of the system. The postulates of quantum mechanics dictate that if the system is in a superposition of possible measurement results, then the act of measurement must change the state itself. The superposition system will fall apart at the measurement stage, the measurement thus destroys the information carried by the amplitudes in the qubit. Important computational implications arise when we consider systems of multiple qubits that can experience quantum

I2127 transition 8-4 P (10), then the nanolaser will emit at wavelengths 612, 633, 640 nm, respectively, and these are already three different states. Therefore, this idea can be used as a qubit.

4 Conclusion

A quantum computer can store and manipulate vast amounts of information and execute algorithms exponentially faster than any classical computing technology [7-8]. The potential of even small quantum computers can surpass the best supercomputers in existence today, and ultimately, within the framework of certain tasks, can have a predominant impact on scientific and educational computing, which promises to move problems from unsolvable to difficult. The first quantum processors that can solve useful problems are expected to appear within the next decade. Therefore, understanding what quantum computers can and cannot do is a priority for every computer scientist.

References

[1] Attila Szabo, Neil S. Ostlund. *Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory*. 1999, **466** p.

[2] Arute, F., Arya, K., Babbush, R. et al. *Quantum supremacy using a programmable superconducting processor*. Nature **574, 505–510** (2019). https://doi.org/10.1038/s41586-019-1666-5

[3] Pednault, Edwin & Gunnels, John & Nannicini, Giacomo & Horesh, Lior & Wisnieff, Robert. (2019). *Leveraging Secondary Storage to Simulate Deep 54-qubit Sycamore Circuits*.

[4] Preskill, J., "*Quantum Computing in the NISQ era and beyond"*, vol. **2019**, 2019.

[5] Gnatenko, A.S., Machekhin, Yu.P., Kurskoy, Yu.S., Obozna, V.P. et al., (2018) *Ring fiber lasers for telecommunication systems*, Telecommunications and Radio Engineering, **77(6),** pp. **541-548.**

[6] Machekhin, Yu.P., Gnatenko, A.S., and Kurskoy, Yu.S., (2018) *Photonic crystal nanolasers as optical frequency standards*, Telecommunications and Radio Engineering, 77(13), pp. **1169-1177**. DOI: 10.1615/TelecomRadEng.v77.i13.50.

[7] Machekhin Yu. P.; Kurskoy Yu. S.; Gnatenko A. S.; Tkachenko V. A. *Nanolaser superradiation in information and measuring procedures*. Telecommunications and Radio Engineering, 2018, Vol.**77**, Issue **13**, pp.**1179-1186**.

[8] Gnatenko A. S.; Machekhin Yu. P.; Kurskoy Yu. S.; Obozna V. P.; Vasianovych A. V. *Ring fiber lasers for telecommunication systems.* Telecommunications and Radio Engineering, 2018, Vol.**77**, Issue **6**, pp.**541-548**.