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EDUCATION SYSTEM OF ENGINEERS AND SCIENTIFIC PERSONNEL IN THE SPHERE OF QUANTUM INFORMATION TECHNOLOGIES, QUANTUM ROBUST ARTIFICIAL INTELLIGENCE AND QUANTUM RESILIENCE

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Abstract. Currently, quantum technologies are the driving force behind technological progress (Industry 4.0/5.0/6.0 or Society 6.0). The development of quantum information technologies gives rise to new quantum threats to information security. The requirements of the federal project "Personnel for the Digital Economy or the Data Economy" for the key information technology – "Quantum Technologies" (Priority 1) – can be fulfilled only by developing an appropriate training system for engineering and scientific personnel in the fields of quantum information technologies, quantum robust artificial intelligence and quantum resilience. The creation of a vertically integrated education system, which includes not only basic higher education, but also the training of scientific personnel and upskilling for already employed professionals, will contribute to the development of innovative technologies in general. The paper presents the results of joint efforts of the Sirius University of Science and Technology together with the Quantum Consortium of Business and Universities to train personnel in the sphere of quantum information technologies for the development of such an education system.

Keywords: quantum computing, quantum information technology, information security, educational program, new quantum security threat, quantum and post-quantum cryptography, quantum robust artificial intelligence

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СИСТЕМА ОБРАЗОВАНИЯ ИНЖЕНЕРОВ И НАУЧНЫХ КАДРОВ В СФЕРЕ КВАНТОВЫХ ИНФОРМАЦИОННЫХ ТЕХНОЛОГИЙ, КВАНТОВО-СИЛЬНОГО ИСКУССТВЕННОГО ИНТЕЛЛЕКТА И КВАНТОВОЙ УСТОЙЧИВОСТИ

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Аннотация. В настоящее время квантовые технологии являются двигателем технического прогресса (промышленности 4.0/5.0/6.0 или общества 6.0). Развитие квантовых информационных технологий порождает новую квантовую угрозу информационной безопасности. Требования федерального проекта «Кадры для цифровой экономики или экономики данных» к ключевой информационной технологии – «Квантовым технологиям» (приоритет 1) могут быть выполнены только путем разработки соответствующей системы подготовки инженерных и научных кадров в области квантовых информационных технологий, квантово-сильного искусственного интеллекта и квантовой устойчивости. Создание вертикально интегрированной системы образования, предусматривающей не только получение базового высшего образования, но и подготовку научных кадров и повышение компетенций уже работающих специалистов, будет способствовать развитию инновационных технологий в целом. В статье представлены результаты совместной деятельности научно-технологического университета «Сириус» совместно с Квантовым консорциумом бизнеса и университетов по подготовке кадров в области квантовых информационных технологий для развития такой системы образования.

Ключевые слова: квантовые вычисления, квантовые информационные технологии, информационная безопасность, образовательная программа, новые угрозы квантовой безопасности, квантовая и постквантовая криптография, квантово-сильный искусственный интеллект

Финансирование: Результаты получены при финансовой поддержке проекта «Технологии противодействия ранее неизвестным квантовым киберугрозам», реализуемого в рамках государственной программы федеральной территории «Сириус» «Научно-техническое развитие федеральной территории “Сириус”» (Соглашение № 23-03 от 27 сентября 2024 г.).

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Introduction

Currently, quantum technologies are the driving force behind technological progress (Industry 4.0/5.0/6.0 or Society 6.0). They have already irreversibly changed the world and have spread not only in the scientific community, but also in various fields of human activity, including manufacturing, the military-industrial complex, ecology, medicine and information security [1–11].

The development of quantum information technologies gives rise to new quantum threats to information security [10].

In the Russian Federation, the development of quantum technologies is receiving the closest attention [10, 11]. For instance, in early 2024, the government roadmap for the development of the

high-tech field of Quantum Computing, prepared by the Rosatom State Corporation for 2020, was updated as part of the new federal project "Quantum Technologies as a component of the National Project Data Economics". This federal project replaced the "quantum roadmap", which was set to run until the end of 2024 and was coordinated by Rosatom. The strategic goal of the new policy document is to create a quantum industry by 2030, involving not only scientists and specialists, but also entrepreneurs and a wide range of future consumers of quantum technologies as active participants.

The study [11] examines initiatives to develop a new educational program – "Quantum informatics: Information security". It proposes directing the training of specialists in this field toward two categories of students:

1) developers of core technologies: students will acquire fundamental systems knowledge and a deep understanding of the core technologies in the field, will be capable to develop system components for the technology stack and will be competent enough to contribute to international projects;

2) developers of applied solutions: this category will unite "applied engineers" who will be able to create trusted and secure solutions for various domains (fintech, telecommunications, defense, medical technologies, management, retail, logistics etc.), will have knowledge about existing technology stacks and will be capable to design and develop applied solutions based on them.

The implementation of this initiative in 2024–2025 at the Sirius University of Science and Technology (Sirius University) together with the Quantum Consortium of Enterprises and Universities for training personnel in Quantum Information Technology (Quantum Consortium), has highlighted the need to establish vertically integrated education system for engineers and researchers in quantum information technology, quantum robust artificial intelligence (AI) and quantum resilience of information systems.

Related work and background

According to [11], quantum informatics and information security is a relatively new and rapidly developing field of scientific research that arose at the intersection of quantum mechanics, information theory, programming and information security. Its main branches are quantum computing, quantum communication and quantum information theory.

A bibliometric analysis of academic literature on quantum technologies for 1990–2020 revealed [2, 12] the dynamic growth of the field, high degree of concentration of research and international scientific relations, as well as the involvement of not only universities and academic institutions, but also large corporations (especially from Japan) and military research structures (primarily from the USA). At the same time, Russia exhibits the following characteristics:

- high concentration of research in metropolitan areas and significant international collaboration;
- leading contribution of the Russian Academy of Sciences (RAS), which ranks sixth among scientific organizations in the world in terms of the number of publications in the field of quantum technologies for 1990–2020 [1];
- growing role of universities in the development of the scientific base of quantum and quantum information technologies;
- still limited involvement of the Russian commercial sector in research.

In accordance with the conclusion made in [12], since 2020, the number of scientific publications on the research results in quantum and quantum information technologies has increased exponentially, partly driven by efforts to address information security challenges arising from new quantum threats.

At the same time, the broader landscape is characterized by the absence of mass-production technology for quantum chips and the fact that a dominant physical platform for quantum computers has yet to be established. In parallel, development efforts are underway to create quantum computers

based on more than 10 platforms, the main ones being superconductors, ions, neutral atoms and photons [12].

In Russia, scientific research and engineering studies are also being conducted to create the first domestic quantum computers [3, 4, 10, 12]. Cooperation and consortia are being formed on the basis of domestic centers of competence in quantum technologies, quantum information technologies and quantum communications [12]. Quantum processors with 2–10 qubits and quantum simulators with 10–20 qubits have been developed, and the first domestic quantum processors with 50–100 qubits are expected to appear by the end of 2025.

In order to fulfill the directive of the President of the Russian Federation to create a fundamentally new University of Quantum Technologies dedicated to studying advanced developments in quantum computing and quantum information technologies, as well as to engage school students in the educational process, a new research group "Technologies for Countering Previously Unknown Quantum Cyber Threats" (research group) was established in 2024 at Sirius University under the supervision of prof. S.A. Petrenko (Grand PhD in Engineering).

The main objective of the research group is to create a promising world-class technology to ensure quantum resilience of leading national digital platforms and blockchain ecosystems of the digital economy of Russia, which, unlike existing technologies, will prevent significant or catastrophic consequences in the face of previously unknown cyberattacks carried out by malicious actors using quantum computer [12].

Task statement

From its inception, the research group began to implement the initiatives outlined in [11]. Consequently, in the drafted Concept of ensuring the resilience of operation of national digital platforms and blockchain ecosystems under the new quantum threat to security [12], one of the key tasks is the development of a set of interrelated training programs in quantum information technologies and quantum resilience of national digital platforms and blockchain ecosystems, including supplementary professional education and/or upskilling.

Representatives of the research group participated in the final panel discussion at the 3rd All-Russian Forum "Trusted Quantum Technologies and Communications (Quantum-2025)", dedicated to the specialists training and human resources potential of the industry, on January 30, 2025. The discussion also included representatives of leading universities and training centers – ANO "NTC CC", MISIS, NIO "Quantum Center" MTUSI, TUSUR and the Quantum Consortium, who highlighted the critical shortage of specialists trained in quantum information technologies and quantum robust AI.

In early 2025, Sirius University joined the Quantum Consortium alongside prof. S.V. Ulyanov (Grand PhD in Physics and Mathematics) and A.G. Reshetnikov (PhD in Engineering), the co-authors of a number of works on quantum robust AI and cognitive robotics [8, 9]. This collaboration led to the formulation of the task of developing educational programs spanning from school students to top manager and/or qualified end-users for work in quantum computer science and quantum robust AI.

The jointly defined objective is to establish a vertically integrated education system for engineers and research personnel in quantum information technologies, quantum robust AI and quantum rsilience. This system will range from organizing introductory career guidance events in educational institutions to providing advanced training for existing IT professionals and/or systems engineers in robotics.

In other words, the task entails integrating the educational system (universities) with industry (business) to create a university-based scientific and industrial complex. This complex will serve as the foundation for implementing the innovative "education–science–production" project. At the same time, the vertical integration spans from foundational education systems to specialized retraining centers ans research institutions in active cooperation with production companies implementing quantum information technologies in the product life cycle.

Currently, the task of developing quantum processors or quantum information technologies depends not only on a shortage of engineering personnel with the requisite competencies, but also on the absence of specialists trained to serve as qualified end-users in industry, who could form a request for the development and/or implementation of such technologies in production and their further practical application.

Establishing a vertically integrated education system, which provides not only foundational higher education, but also research training and upskilling for current professionals, enables meeting the requirements of the federal project "Personnel for the Digital Economy or Data Economy" for the key information technology "Quantum Technologies" (priority 1), and will contribute to the development of innovative technologies in general. It is noteworthy that upon acquiring the necessary skills and competencies for solving complex trans-computational problems, the next significant step would be the emergence of quantum AI, that is, AI created on the basis of a quantum computer.

Components of a vertically integrated system and the main stages of its implementation

The first component of the vertically integrated system (Fig. 1) is the implementation of introductory career guidance activities for educational institutions of the "Sirius" federal territory, implementing educational programs of basic general and secondary general education.

The core of this component is the educational and outreach program "New threats to information security using AI technology and quantum computers", which includes the following set of lectures:

- Blockchain ecosystems and their role in the digital economy of Russia;
- Challenges to the resilience of national blockchain ecosystems in the context of emerging quantum security threat;
- Methods and algorithms for the synthesis of quantum-resilient blockchain ecosystems and platforms of the digital economy of Russia;
- Methodology for addressing the synthesis of technologies and programs to ensure quantum resilience of national blockchain ecosystems and platforms of the digital economy of Russia;
- Models for ensuring quantum resilience of national blockchain ecosystems and platforms of the digital economy of Russia.

Holding these events on a regular basis will help engage school students during their studies and attract their interest in pursuing relevant specializations at Sirius University (Fig. 2).

The next component of the vertically integrated system in terms of importance is the training of research and teaching staff, which will enable the recruitment of specialists with higher education in

Fig. 1. Vertically integrated education system

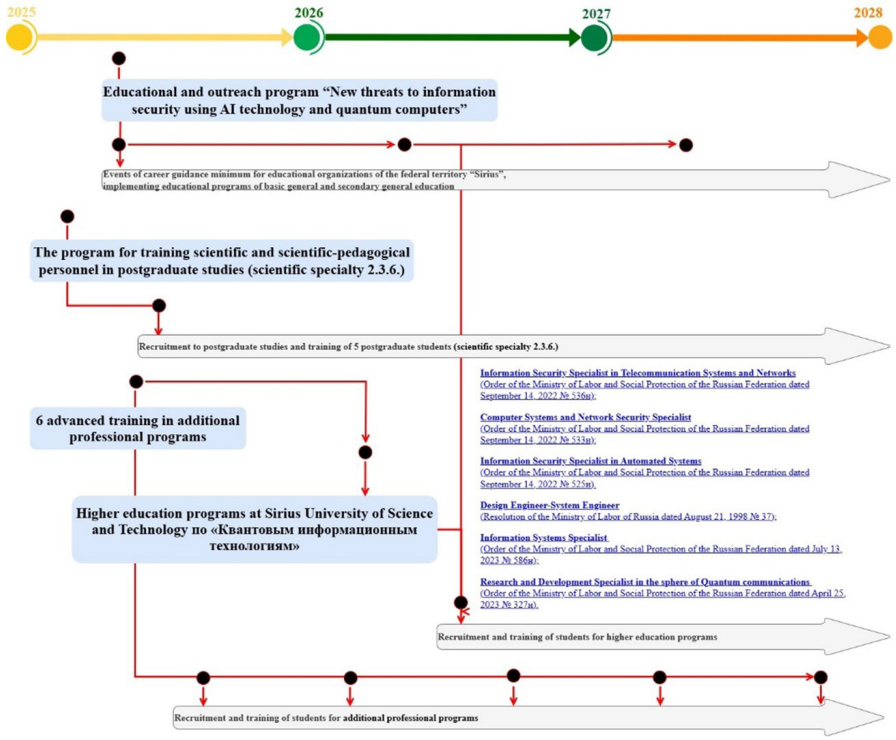

Fig. 2. Relationship between the components of a vertically integrated system and the timing of their implementation

other related IT fields to work in quantum information technologies. Taking into account the importance of ensuring the quantum resilience for digital platforms and blockchain ecosystems, the first program for training research and teaching staff was developed in specialization 2.3.6 "Methods and systems of information protection, information security".

Also of significant importance is accelerated retraining through additional professional programs for professionals and end-users of information technologies. Six additional professional training programs have been developed for the following specialist profiles:

- information security specialist in telecommunication systems and networks (requirements approved by Order No. 536n of the Ministry of Labor and Social Protection of the Russian Federation, dated September 14, 2022);
- computer systems and network security specialist (requirements approved by Order No. 533n of the Ministry of Labor and Social Protection of the Russian Federation, dated September 14, 2022);
- information security specialist in automated systems (requirements approved by Order No. 525n of the Ministry of Labor and Social Protection of the Russian Federation, dated September 14, 2022).
- design engineer/systems engineer (qualification outlined in Decree No. 37 of the Ministry of Labor and Social Protection of the Russian Federation, dated August 21, 1998);
- information systems specialist (requirements approved by Order No. 586n of the Ministry of Labor and Social Protection of the Russian Federation, dated July 13, 2023);
- research and development specialist in quantum communications (requirements approved by Order No. 327n of the Ministry of Labor and Social Protection of the Russian Federation, dated April 25, 2023).

The list of additional professional programs is given in Fig 3.

The final and key component of the vertically integrated system is necessarily a program for training qualified specialists in quantum information technologies to fully and adequately meet the demand for

Fig. 3. List of programs of additional professional education and acquired competencies

experts among end-users and manufacturers. Such training is planned to be carried out in accordance with the higher education program “Quantum Information Technologies”.

Graduates of this program will be qualified specialists in the fields and with the qualifications previously outlined for additional professional training programs.

First results

At a meeting of the Quantum Consortium held at the Russian Union of Industrialists and Entrepreneurs on April 24, 2025, its President, Alexander Shokhin, noted in his welcoming speech that the field of quantum technologies has been developing in Russia for several decades:

“We have formed an expert consensus on key issues and clearly understand that in the coming years, the field of quantum technologies, alongside AI, will be one of the main drivers of development of industry and the Russian economy. There is a lot of work ahead. Together with universities, we need to train teachers and engineers and create favorable conditions for the development of the industry”.

During the meeting, Sirius University presented educational programs for targeted training of personnel in quantum engineering and quantum industrial AI (Fig. 3).

The discussion focused on cultivating demand among industrial companies for highly qualified personnel capable of developing and implementing innovative solutions, including industrial ones, based on end-to-end quantum information technologies.

The participants of the discussion explored the possibilities of training a new generation of engineering personnel to meet the needs of industrial customers on the basis of technical universities in problem-oriented areas, taking into account international practice. Particular attention was paid to the potential for establishing new specialized profiles in quantum information technologies under the umbrella of “Quantum Engineering”.

The presentation of these programs aroused great interest among members of the Quantum Consortium.

In July 2025, the first cohort of postgraduate students was enrolled in specialty 2.3.6 with dissertation research aimed at applying quantum information technologies, quantum algorithms and post-quantum algorithms to address the problem of ensuring the resilience of national digital platforms and blockchain ecosystems.

The enrollment and training of students for the higher education programs are scheduled to commence in the summer of 2026.

Conclusion

The development and most importantly, the implementation of the proposed vertically integrated education system for engineers and research personnel will meet the requirements of the federal project "Personnel for the Digital Economy or Data Economy") concerning key information technology – "Quantum Technologies" (priority 1), and will also contribute to the development of innovative information security technologies and the use of quantum robust AI in industry and robotics.

The postgraduate, master's and additional professional education programs included in the system are aimed primarily at training specialists in developing universal libraries of quantum algorithms regardless of quantum platforms and chips used. Quantum algorithms can be created without deep understanding of quantum physics. It is significant that developers who have the skills to program quantum computers will gain a competitive advantage as "quantum hardware" technology matures.

REFERENCES

1. **Terekhov A.I.** On the Development of the Scientific Base of Quantum Technologies. *Economics of Science*, 2022, Vol. 8, No. 1, Pp. 58–72. DOI: 10.22394/2410-132X-2022-8-1-58-72

2. **Terekhov A.I.** Bibliometric Analysis of Academic Literature on Quantum Information Processing. *Photonics*, 2024, Vol. 18, No. 4, Pp. 296–312. DOI: 10.22184/1993-7296.FRos.2024.18.4.296.312

3. **Holevo A.S.** *Vvedenie v kvantovuiu teoriiu informatsii* [*Introduction to Quantum Information Theory*]. Moscow: MTsNMO, 2002. 128 p.

4. **Holevo A.S.** *Veroiatnostnye i statisticheskie aspekty kvantovoi teorii* [*Probabilistic and statistical aspects of quantum theory*]. Moscow: MTsNMO; NMU, 2020. 364 p.

5. **Bogdanov Y.I., Valiev K.A., Kokin A.A.** Quantum computers: achievements, implementation difficulties, and prospects. *Microelectronics*, 2011, Vol. 40, No. 4, Pp. 243–255. DOI: 10.1134/S1063739711040032

6. **Nielsen M.A., Chang I.L.** *Quantum Computation and Quantum Information: 10th Anniversary ed*. Cambridge: Cambridge University Press, 2011. 702 p.

7. **Bennett C.H., Shor P.W.** Quantum information theory. *IEEE Transactions on Information Theory*, 1998, Vol. 44, No. 6, Pp. 2724–2742. DOI: 10.1109/18.720553

8. **Borovinsky V.V., Kapkov R.Yu., Reshetnikov A.G., Ulyanov S.V.** *Intelligent cognitive robotics*, 2nd ed. Moscow: KURS, 2024. 557 p.

9. **Dobrynin V., Reshetnikov G., Sacharov Yu., Ulyanov S.** Quantum and soft computational intelligence technologies in intelligent control processes design. *Systems analysis in science and education*, 2010, No. 2, Pp. 1–19.

10. **Skiba V.Yu., Petrenko S.A., Murzina A.A., Popova K.R.** New types of threats and assessment of quantum stability of information systems in the field of foreign trade activity. *Computing, Telecommunications and Control*, 2024, Vol. 17, No. 4, Pp. 16–34. DOI: 10.18721/JCSTCS.17402

11. **Petrenko S.A., Petrenko A.S., Ozhiganova M.I.** On the development of a new educational program "Quantum information science: information security". *Zaŝita informacii. Inside*, 2024, Vol. 118, No. 4, Pp. 17–23.

12. **Skiba V.Yu., Petrenko S.A., Gnidko K.O., Petrenko A.S.** Concept of ensuring the resilience of operation of national digital platforms and blockchain ecosystems under the new quantum threat to security. *Computing, Telecommunications and Control*, 2025, Vol. 18, No. 2, Pp. 56–73. DOI: 10.18721/JCSTCS.18205

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