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# 2023

# Global Quantum Communication & Security Industry Development Prospect

## Quantum Annual Series Report

February 2023

# Foreword

As the new generation of information technology develops, the amount of data grows rapidly. However, at the same time, the risk of data being stolen or altered by attackers through the internet increases. The occurrence of digital information leaks has also resulted in an increasing demand for information security from countries, organizations, and individuals. On the other hand, the continuous development of quantum computing technology poses unprecedented challenges to public-key cryptography systems based on large number factorization and discrete logarithms.

Cryptography is the cornerstone of network security technology. Quantum information security uses both quantum physics-based cryptography techniques (such as QKD, QT, and QSDC) and mathematics-based cryptography techniques (PQC). These new generation encryption technologies can be nested at different stages of the entire network, providing an additional layer of security to take on the heavy responsibility of information security in the quantum era. The physics-based QKD cryptography technique has some applications currently, but is still in the development stage. The mathematics-based modern cryptography system is well established and widely used, but cryptography cracking techniques are constantly challenging and stimulating the evolution of new generation cryptography techniques.

Although it may take ten years or even longer for the first quantum computer capable of breaking the current public-key cryptography to appear, there is a considerable amount of time for the deployment of quantum security devices by migrating from classical devices to quantum security devices. At the same time, the large amount of data that has been intercepted and stored currently has the risk of being deciphered by quantum computation in the future if new information confidentiality methods are not deployed promptly. National confidential information needs to be safe and confidential, not only now but also in the future.

The current research and application of quantum information security are of great practical significance and measures must be taken to protect important digital information from quantum attacks.

ICV Frontier Technology Consulting Director, Senior Vice President

Jude Green

Jude Green

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# Technical Advancement

To address the information security issues in the quantum era, various technologies and products have emerged. Both physical-based and mathematical-based methods aim to reduce the risks in transmitting existing network information. This chapter categorizes encryption technologies into physical-based and mathematical-based, and analyzes the advancements made in 2022 in terms of technology, applications, and standards.

## Advancements in Physical Encryption Technology

### The distance of the QKD line based on fiber transmission is refreshed, laying the foundation for the kilometer-scale terrestrial QKD.

In 2022, fiber-based transmission shone in both QKD and QSDC technologies, breaking records in length. The transmission distance of TF-QKD was refreshed to 833 km, a further step towards secure quantum communication over long distances on land. Additionally, TF-QKD is a key area of recent development, and its protocols have the advantage of having a key rate that decreases with the square root of the channel transmission rate, making it a promising direction for ultra-long-distance QKD. The transmission distance of QSDC was also updated to 100 km.

**The research on QKD based on satellites has been participated by many countries, with the aim of launching micro-nano satellites to verify network technology.**

Satellite transmission is an important mode of transmission besides fiber transmission and is currently the main development technology for quantum communication. The global quantum network composed of quantum communication satellites is further expanding experiments, and countries all hope to have sovereignty in network security and communication, and to develop the quantum secure communication network into an economical, compact, and commercial form through the verification of satellite networking programs. In 2022, countries such as China, the UK, Singapore, the Netherlands, Luxembourg, France, Canada, and India have made progress in satellite QKD:

China's Mozi satellite has refreshed the current farthest distance of 1200 km for QKD and the Jinan 1 micro-nano satellite has been successfully launched.

The UK has selected its existing satellite ground station to be used as a demonstration and testing ground station for optical satellite communications for quantum security. The UK is also working with companies in Singapore and the Netherlands to develop the Spectre satellite.

A 20-company alliance led by Luxembourg satellite company SES and supported by the ESA and the European Union Commission will design, develop, launch, and operate a secure end-to-end QKD system based on the low orbit satellite EAGLE-1.

French aerospace company Airbus claims to have developed a high-performance satellite capable of supporting high-throughput requirements for a QKD network based on satellites and plans to put the new payload system into use before 2026.

SpeQtral has signed a memorandum of understanding with Thales Alenia Space to research, develop, and demonstrate ground-to-space quantum communication, and will use the quantum satellite SpeQtral-1 being developed by SpeQtral and the quantum ground receiving station being developed by Thales Alenia Space for joint experiments.

Canada and the UK are collaborating on a trans-Atlantic quantum satellite link.

Indian start-up QNu Labs has signed a memorandum of understanding with the Indian National Space Promotion and Authorization Center to develop a domestic QKD product.

**The development of subsystems is characterized by the improvement of core upstream components such as high-performance light sources and quantum repeaters. These are among the important focuses of advancement.**

The improvement of QKD systems is not only focused on enhancing security, but also making efforts in the core component level, such as high-quality light sources. Besides being applied in QKD systems, quantum light source technology can also empower quantum computing and quantum precision measurement. Hence, the development of next-generation light sources and related devices will provide possibilities for multiple future applications. Germany has identified photonics technology as a key area of development.

In 2022, multiple teams attempted different approaches in quantum light sources by exploring different substrate materials, processes, and device technologies to enhance the quality of the light sources. For example, the University of Electronic Science and Technology of China, in collaboration with its partners, validated the frequency-multiplexed single-photon source on lithium niobate substrate. The UK-based quantum light source start-up, Aegiq, partnered with the University of Essex to develop quantum light sources for space communication. In addition, Amazon Web Services and the US Department of Energy's National Quantum Information Science Research Center (Q-NEXT) are working together to manufacture and develop quantum relay-related technologies, and they use nanoscale positioning to align the fiber tip with the relay receiver to address engineering challenges and advance the construction of quantum networks.

### The main direction of improvement for the cutting-edge technologies, DI-QKD MDI-QKD, still lacks the capability to be commercially applied.

DI-QKD and MDI-QKD protocols were important research directions demonstrated in academic papers in 2022. MDI solves the problem of an attacker controlling the detectors, while DI solves the problem of an attacker controlling all the devices. It's important to note that these technologies are experimental verifications assuming a very strong attacker capability, and they are still far from commercialization.

The Dutch company QuTech and Eurofiber have partnered to launch a quantum network testing platform connecting multiple data centers in the Netherlands. The platform, based on QuTech's MDI-QKD technology, will validate the operability of integrating MDI-QKD systems into commercial fiber networks.

### Interdisciplinary research is becoming a necessary step towards the practical implementation of quantum communication technology.

The combination of 5G and even 6G with quantum communication and security, as well as the integration of quantum communication and security with more fields such as computing networks, is based on existing mature technologies and aims to explore cross-disciplinary research. Regardless of the development of quantum communication and security technology itself, cross-disciplinary research with the entire industry is a necessary stage for the practical application of this technology.

For example, German network equipment provider UET and the Technical University of Dresden have launched the 6G-QuaS research project to demonstrate more secure communication and performance enhancement in industrial networks, and to integrate quantum technology with existing telecom infrastructure, showing the advantages of a quantum network with new encryption protocols compared to previous system designs.

In China, Origin Quantum and China Mobile Communications Research Institute are collaborating to explore quantum algorithms to address the computational bottleneck faced by 5G and 6G, with Origin Quantum providing quantum communication algorithms based on real-machine validation on a quantum computer.

In the US, Amazon AWS has established the AWS Quantum Network Center (CQN), which will develop new hardware, software, and applications for the quantum network. The CQN will supplement the advanced quantum science and engineering work already being done by the AWS Quantum Computing Center and the Amazon Quantum Solutions Lab.

## Advancements in PQC

**The three important tasks in the field of PQC are standardization projects by NIST, algorithm application R&D, and promotion and deployment.**

The main advancements in PQC in 2022 can be characterized in three aspects:

The standardization work of PQC by NIST (the National Institute of Standards and Technology) in the United States. Over the past 20 years, the development of PQC algorithms has been ongoing and is currently being selected and established as a standard by NIST and other standardizing organizations. Currently, four algorithms have been provisionally confirmed, including CRYSTALS-Kyber for general encryption and three schemes for digital encryption: CRYSTALS-Dilithium, FALCON, and SPHINCS+. The former ensures the confidentiality of message transmission, while the latter ensures the authenticity, integrity, and non-repudiation of message transmission.

PQC technology developers, based on the standard algorithms published by NIST, have developed and launched commercial products that are suitable for their use. For example, Castle Shield, a provider of zero-trust and network security solutions, has launched Typhos®, a secure communication mobile solution, which supports the PQC algorithms selected by NIST for audio and video calls. All of the features of Typhos® are protected by end-to-end PQC encryption.

PQC technology developers and cryptography users are conducting more learning, discussion, and promotion of the importance of PQC, preparing for the ultimate migration deployment. For example, SandBox AI and Google published an article in Nature entitled "Transitioning Tweet Organizations to Quantum-Resistant Cryptography," which provides a comprehensive explanation of the systematic nature of the transition.

### Companies in the field of network security, IoT, semiconductors, etc., entered the PQC field, launching their own research or collaborative research and development.

In 2022, more network security companies, IoT, and semiconductor companies entered the quantum communication and security market due to their strong application combinations, where their traditional businesses are heavily dependent on secure information transmission. For example, Swiss network security, AI, blockchain, and IoT company WISeKey joined forces with PQC start-up company to establish a new semiconductor quantum technology company, SEALSQ Corp. This allows them to widely integrate with the company's existing semiconductor applications, driving progress in the fields of communication, computing, healthcare, military systems, transportation, clean energy, and countless other applications. Semiconductor chip and solution provider Infineon launched a KeyShield platform module, protecting firmware updates from attack, mitigating the threat of firmware damage and enhancing the long-term performance of devices.

### The United States is a leading advocate for the advancement of PQC, with frequent actions in standardization and implementation.

The United States has been a major driving force behind the global development of Post-Quantum Cryptography (PQC). In 2022, the Biden Administration passed the National Security Memorandum and signed an agreement with the G7 group to further accelerate the pace of PQC development. Although the terms related to PQC appeared only four times (quantum-resistant protocols, quantum-resistant cryptography, quantum-resistant algorithms, quantum-resistant encryption) in the memorandum "Regarding Improving the National Security and Intelligence Community Systems," it is evident that the US government has embraced PQC and is taking practical steps to require some preparatory work for migration to be completed within a limited timeframe and to ask the EU to quickly advance the PQC migration work. Additionally, the White House, in its statement on the G7 group, openly confronts the People's Republic of China (PRC) in its title and the meeting emphasizes enhancing industrial chain resilience and strengthening cooperation to address challenges to national defense and security.

### PQC is not yet ready for commercialization and the transition from classical cryptography to quantum-resistant cryptography still presents challenges.

In the field of mathematical cryptography, PQC, as a general term for a series of algorithms, some specific algorithms have been experimentally proven to be not resistant to quantum computing capabilities. As a result, the algorithms are gradually evolving and optimizing towards more advanced levels. In addition to the algorithm technology itself, there are many situations that need to be verified and standardized. The public has not yet had a personal experience with the threat posed by quantum computers, which is also a major reason why the downstream industry applications are moving slowly.

However, for highly confidential information, such as long-term confidential national secrets, waiting until quantum computers are truly available to migrate would pose immeasurable risks. Therefore, in these fields, a mixed encryption method will be adopted in the short term, that is, the use of classical encryption systems and quantum-resistant cryptography systems. This application will first appear in special industries such as financial institutions.

Currently, some chip design companies are also participating in the research and development of PQC chips, and the engineering of PQC is also an imminent direction for development. This is because moving from a set of "academic" mathematical algorithms to a truly "practical" set that can serve society is not easy.

## Regardless of whether it's QKD or PQC, the commercial applications must take into account the arrival of quantum computing practicality.

Quantum Key Distribution (QKD) can be understood as an additional step in the network where the two parties verify the security of their communication through cryptographic authentication before transmitting information. On the other hand, Post-Quantum Cryptography (PQC) is a series of algorithms that have been verified for their security through mathematical methods. Currently, there is ongoing discussion among various parties to select the best and most secure algorithms. Once the algorithms are selected, the transition from classical cryptography to a combination of classical and PQC algorithms will begin, gradually replacing the former according to the level of information confidentiality required in various scenarios and stages. The ultimate goal is to complete this transition before the practical implementation of quantum computers, otherwise, information security will face significant threats.

## The opening of the largest access node quantum city network provides potential for realizing more application case scenarios.

In terms of practical QKD network construction, China's Hefei Quantum City Metropolitan Network (China's largest quantum metropolitan network, consisting of 8 core sites and 159 access sites, with a total fiber length of 1,147 km) provides quantum secure access services to nearly 500 party and government agencies at the city and district levels. China is currently the country with the most achievements in QKD network infrastructure construction globally. The opening of the quantum metropolitan network (connecting different regions and organizations within a city) and the connection to the quantum backbone network (inter-provincial and inter-city connections) and quantum local area network (access to multiple terminals within a unit or location) provide the necessary infrastructure for widespread application of confidential communication networks in more domains in the next step.

### QRNG, as a product that can be applied in QKD and other applications, is rapidly developing.

Currently, there are very few companies that have commercialized and integrated QRNG chips, as there are still areas of improvement in the manufacturing process of QRNG chips. Among the global companies that provide QRNG chips, Switzerland's IDQ stands out. IDQ's QRNG chips were used for the third time in the quantum 5G smart phone jointly released by Samsung and SKT in South Korea. SKT and IDQ have also collaborated with other downstream application partners to develop secure products for the Internet of Things, V2X, and financial sectors, and expect to make progress in terms of size, performance, and price to facilitate commercialization. IDQ has also teamed up with France's CryptoNext Security PQC company to develop QRNG+PQC technology for mobile phones. Canada's Quantum eMotion company has made progress in the development of its QRNG product in the blockchain application, and has completed the design of a hardware encrypted wallet.

### Mobile operators prioritize the development of downstream applications focused primarily on voice calls, which cannot be achieved without the construction of a QKD infrastructure.

More and more mobile operators are joining the field of quantum communication and security. Among them, Chinese and Korean operators show relatively positive performance, which is closely related to the current construction level of national quantum secure communication infrastructure. The three major mobile operators in China all made significant contributions in 2022. China Telecom launched the Tianyi Quantum HD Encrypted Call; China Mobile launched the Quantum Encrypted Call based on VoLTE and will be commercialized in Xiong’an and other regions; China Unicom released the "Cloud Era Quantum Communication Technology White Paper", and China Unicom stated that it will continuously promote the development and application of quantum communication standards and industrialization. SKT, one of the three major mobile operators in Korea, has also worked with Samsung for three consecutive years to launch the Quantum 5G Smartphone.

**Quantum communication has been tested in areas such as QaaS, blockchain applications, drones, stock trading, and smart power grids.**

The downstream applications of quantum communication are gradually expanding into a wider range of fields such as QaaS, blockchain, unmanned aerial vehicles, finance, and power grids, expanding the space for downstream development. For example, American companies EPB and Qubitekk have introduced a commercial quantum network, quantum-as-a-service, designed for private companies, governments, and university researchers to run quantum devices and applications on existing fiber.

Toshiba and its partners have established the first QKD network for protecting mission-critical blockchain applications in the US. Florida Atlantic University, Qubitekk, a US defense contractor, and IT service provider L3Harris are collaborating to develop the first mobile quantum communication network based on drones for the US Air Force. Nomura Holdings, Nomura Securities, and the National Institute of Information and Communications Technology in Japan tested a use case based on the exchange of keys between Toshiba's high-speed QKD device and NEC's QKD device, in combination with actual stock trading operations, to verify the practicality of the QKD system and various encryption methods. Oak Ridge National Laboratory and Qubitekk are collaborating on practical security authentication (including signature and verification) research and trials based on QKD for the smart power grid system, and China's QuantumCTeK is conducting "Quantum + 5G" applications in the power sector.

**Small-scale trials of post-quantum cryptography (PQC) have been conducted in areas such as VPN and IC cards.**

SK Telecom and SK Broadband in South Korea are expanding their anti-quantum cryptography to the global virtual network (VPN) that uses international networks, further improving the security level of their international network component. Japan's NICT and its partners have developed a PQC-based IC card and applied it to medical staff IC card authentication and access control in the long-term secure data storage and exchange system for electronic medical record data.

## Standardization Work

### The standards related to QKD and PQC are being advanced, and a new working group is being established to formulate the standards.

In 2022, the standardization work of QKD and PQC continued to advance, and the pace of standard release kept pace with the development of various sub-technologies within a reasonable timeframe. This means that many sub-technologies have not yet reached the necessary requirements for systematic standardization, while others that are mature and have a standardization foundation are being standardized in an orderly manner. In addition to the standards promoted by NIST and ISO/IEC, the UK GSMA has also established a working group with IBM in the US and Vodafone in the UK, and although there has not been a clear announcement that the content of the working group will form the industry standard, the work they are doing is actually a normative summary of the technical details of sub-fields.

### The standardization work for more specific technical fields is being established.

In addition to the standards for QKD and PQC, standardization work for specialized technologies and products has also been initiated. China has undertaken the standardization of lithium niobate crystals, which play a significant role in the high-quality development of quantum secure communication. This work reflects that China has accumulated a certain level of expertise in this field.

### China's standard documents in the field of quantum communication and security involve both communication and confidential domains.

As of January 2023, China has released 7 standards for quantum communication and security, with 5 of them in the communication (YD) field and 2 in the national secret (GM) field. China's national standards have expanded from the communication field to the national secret field, indicating a further widening of the coverage of quantum security communication technology in China's industry. Quantum security technology is not only an indispensable new technology in the communication field, but also an important new technology in the national cryptography system.

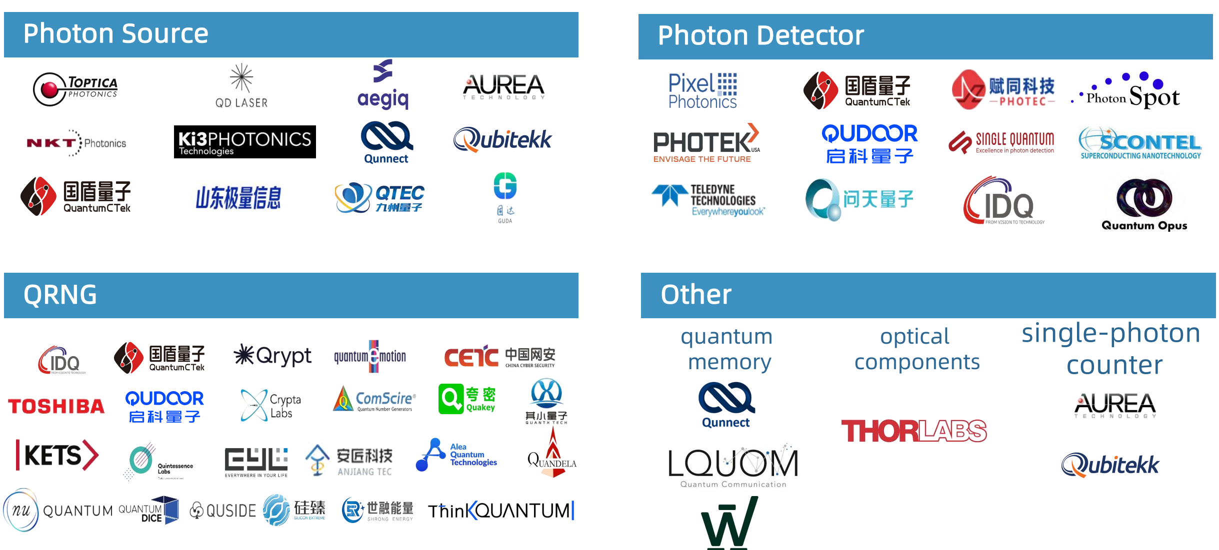
# 02

# Industry Ecosystem

The field of quantum communication and security has enriched the information security industry ecosystem, based on the current information communication and network security industry, due to the emergence of new technologies. At the same time, because quantum communication and security technologies are still cutting-edge technologies, scientific research instruments and equipment that serve as auxiliary industries for development, particularly some products that provide precise measurement and state stability (such as low-temperature equipment), also provide equipment for the industry. For example, in practical experiments, in pursuit of some extreme and special requirements, the quality or performance parameters of the light source are higher than those of the products in the actual QKD networking, and low-temperature thermostats will also be used as environmental assistance for experimental samples in some experiments. It should be noted that some precision instruments and equipment are indispensable hardware for quantum communication research and development (such as oscilloscopes, arbitrary waveform generators), which are mostly mature research and development equipment and therefore not included in this industry supplier map.

The upstream of the industrial chain in the field of quantum communication and security is the supplier of core equipment and components. Currently, the commercial form of PQC is estimated to be similar to that of the cryptography algorithm industry, with upstream providers possibly being software-based development tools and hardware-based testing equipment. Currently, a complete industrial chain for PQC has not yet been established, so it has not been included in this upstream research in the industrial chain. The building of QKD networks is currently mainly based on fiber and satellite, with the construction of the infrastructure for fiber-based QKD networks accounting for the majority. Therefore, classical optical communication products are also used in the QKD industrial chain, but these products are mature (such as power supply, fiber, broadband modulator, polarization splitter, PFGA, modulator, etc.) and widely used, so they have not been included in this industrial supplier map. This study focuses on the core and new quantum communication products. These companies provide light sources (such as lasers, entangled sources), photon detectors, QRNGs and other components (such as quantum memories which play an important role in long-distance quantum communication and quantum internet). These products collectively form QKD device products (such as quantum key distribution machines, quantum key receiver machines or integrated quantum key receiver machines).

Exhibit 2-1 Quantum Communication and Security Upstream - QKD Upstream Core Device




Note: The logo of some companies appears multiple times, with the intention of showing that the company is involved in business in different sections.

## Midstream

The middle-market companies in the industry chain serve as providers of comprehensive solutions in the fields of quantum communication and security. For example, they integrate upstream products and offer complementary software or platform systems, providing the most critical support for the implementation of QKD networks. Middle-market companies can be primarily divided into those that develop products and solutions primarily based on the principles of quantum physics (e.g. Toshiba and QuantumCTek, both providers of QKD equipment), those that develop products and solutions based on mathematical algorithms (e.g. PQ Shield in the UK and PQCTECH in China), and those that research key management and quantum security communication SaaS.

### Exhibit 2-2 Quantum Communication and Security Midstream

**QKD**

TOSHIBA, IDQ, Quintessence Labs, KEEQUANT, KETS, SPEQTRAL
国盾量子 QuantumCTek, HUAWEI, QUANTUM OPTICS JENA, Q→NU, QEYnet, QSpace Technologies
QUDOOR 启科量子, 中创为量子, Q*bird, ThinkQUANTUM, LUXQUANTA
问天量子, QTEC 九州量子, 国腾量子 NATIONAL-QUANTUM, 循态量子 XT Quantech, 国光量子, Quant LR

**PQC**

CRYPTO4A, CORNAMI Intelligent Computing, PQSHIELD, PQSecure
SANDBOXAQ™, Post-Quantum, CRYPTONEXT SECURITY, 量安科技 PQCTECH
Tomorrow's Cyber Security, Today IRONCAP, ISARA, HEAAN CRYPTO LAB, NXP

**Encryption Platform/Key Management/Quantum SaaS**

ARQIT, QUANTUMXCHANGE, quantropi, 量子网络 CAS QUANTUMNET, 国信量子
Aliro, QuSecure, evolutionQ, INFOSEC GLOBAL, QuBalt, 易科腾 EQTINFO

## Participant distribution

The participants in this quantum communication and security industry are mainly profit-oriented organizations, which are mostly startups. However, universities and research institutes also play a significant role in the development of the industry by contributing important technologies. Many of these startups are incubated from universities or research institutes, such as IDQ, a spin-off of the École Polytechnique Fédérale de Lausanne, QuantumCTek, a spin-off of the University of Science and Technology of China, Q-Bird, a spin-off of Delft University of Technology, and Quantum Dice, a spin-off of Oxford University. Traditional companies in the fields of network security and semiconductors are increasingly implementing quantum security technologies, such as NXP, Thales, Fortinet, and so on. In addition, IBM and Google are also involved in quantum information security, in addition to their research efforts in quantum computing.

### Exhibit 2-3 Quantum Communication and Security Company


Note: This chart focuses mainly on companies with quantum technology as their core business, and does not take into account traditional companies entering the quantum field.

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In terms of the countries where the corporate headquarters are located, the United States, Canada, the European Union (such as Germany, France, Spain, Italy, Finland), the United Kingdom, and China are countries with a high concentration of participants in the quantum communication and security field. In addition, Russia, Israel, Japan, South Korea, India, Singapore, and Australia also have many start-up companies in the quantum communication and security field.

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In terms of the specific sub-businesses that companies are involved in within the quantum communication and security field, there are relatively few companies in the US that specialize in QKD hardware, but a larger number of companies that focus on PQC algorithm software and security platforms. Canadian companies are predominantly focused on algorithm software and security platforms as well. In China, hardware companies are more prevalent, with only one company in the PQC field. Companies in the UK and Switzerland tend to be hardware-focused, as are many companies in the EU member states. The core quantum security companies in Russia, Israel, India, Japan, South Korea, and Australia also tend to be hardware-focused.

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## Downstream

The downstream of the industrial chain consists of the demanders and users of quantum security products. Currently, the downstream application of quantum security technology is still in the exploratory stage of promoting the possibility of industry application.

The organizations displayed in this downstream quantum security industry are composed of two aspects:

One type is the organization that directly purchases quantum security products or services. For example, some state departments related to national defense were among the early purchasers of quantum security equipment;

The other type is the organization that has a demand for quantum security products but also collaborates with quantum start-up companies to develop products or services. For example, as most deployments of QKD are based on existing optical fiber communication networks, there is a cooperation between QKD suppliers and communication providers that own optical fiber communication infrastructure. Huawei and Spain's telecom once conducted a live trial of quantum cryptography on a commercial optical network using SDN. Therefore, companies related to communication will always be a major downstream application party.

Although the future usage of all infrastructure is still difficult to predict in full, the main applications have been basically determined. The downstream companies/organizations are mainly units with high demand for information security, such as national defense, military, financial information, energy networks, data centers, intelligent driving, mobile operators, individual consumers, etc. Currently, the downstream purchasers/suppliers are still government and military departments, large companies, and individuals. As the development of QKD network technology advances, terminal devices tend to become more compact and mobile, and QKD will also expand to broader applications such as telecom networks, enterprise networks, individuals and families, cloud storage, etc.

## Exhibit 2-4 Quantum Communication and Security Downstream - Applications

Defense

Energy Grid

V2X

Finance

Telecom

Office/Industrial Internet/Smart Phone

Other

# 03

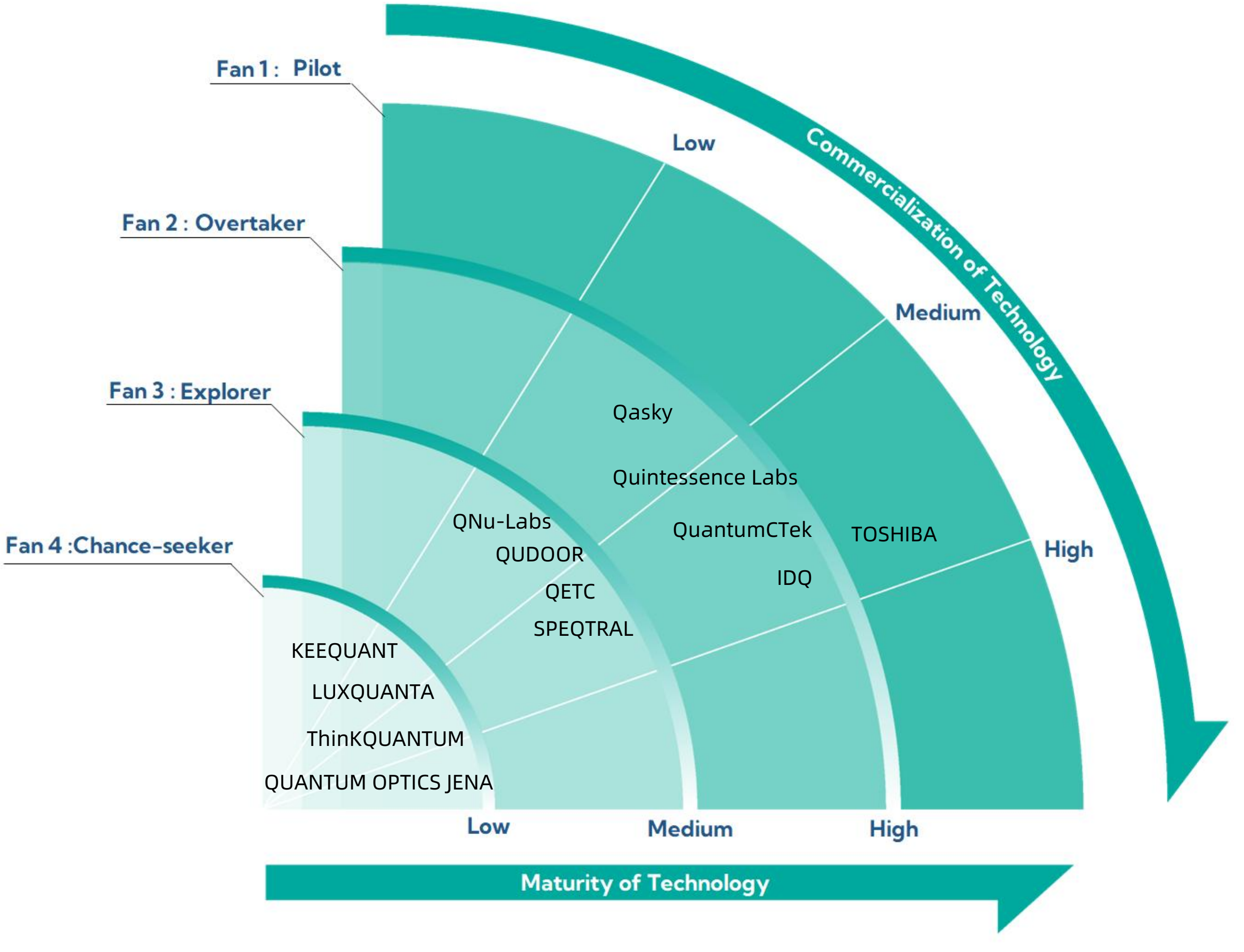
## Company Analysis

QKD has been applied in many countries and industries. Although many technical suppliers have emerged, the standardization of the PQC algorithm is still in progress and market feedback for actual products is still needed after the standard is published. This evaluation is mainly focused on suppliers who have the ability to provide a complete QKD system solution.

## Analysis of QKD Vendors

Based on the definition of the four tier segments according to the CTF model, the following is the evaluation of QKD field suppliers:

Exhibit 3-1 QKD Vendors Evaluation




Note: The purpose of the supplier evaluation is to provide information on the current state of the company to the purchasing party and wide-ranging industry participants (such as investment organizations) to aid decision making. The Cutting-edge Tech Fan (CTF) model of future technology evaluation is used to assess suppliers from multiple dimensions including technology (including technology readiness and R&D technology reserves), market (market development and market share), and comprehensive accumulation of the enterprise.

**Pilot**

“Pilot" represents a company with a "pioneering" spirit in the industry. Without a doubt, Toshiba Europe Research Company is the largest in all QKD companies, with deep accumulations in semiconductors, information, electricity, industry and other fields. Since 2003, it has co-developed QKD-related technologies with the Cambridge University Research Institute and conducted QKD-related businesses in many countries such as Europe and Japan.

**Overtaker**

"Overtaker" refers to companies that have strong "overtaking" abilities in their respective field, such as Swiss company IDQ, China's QuantumCTek and Qasky, and Australia's Qunatessence Labs, which are main suppliers in this field. Their products are used in building the infrastructure of QKD networks in their own countries and even some foreign countries, and their reliability has been proven in practical scenarios. However, the internationalization of the two Chinese companies is clearly not as developed as Toshiba and IDQ, which may be due to the current international competition and blockade environment in China. Compared to Toshiba's European company, the companies in Overtaker need more time to accumulate in terms of supply chain, marketing channels, and R&D personnel. But in the competition for QKD products and technologies, they are now on par with Toshiba, which is the result of their rapid development.

**Explorer**

"Explorer" refers to suppliers that have entered the field but still have limited scale, with acceptable technology and some supply experience, but there is still much untapped market for QKD. These companies lack marketization and still have room for improvement in technology. For example, Singapore's SpeQtral company is currently focused on satellite QKD, which has fewer competitors compared to fiber QKD companies. The company needs to have the ability to operate in the space field. If there is a large-scale deployment of QKD satellites in low orbit in the future, SpeQtral's business will grow significantly. The company's satellite plan will be launched in 2024, which represents more commercialization processes in the following time.

**Chance-seeker**

"Chance-seeker" refers to participants with keen business acumen who have just entered the industry. Currently, companies in the field of quantum communication and security have been supported by the key state in many major quantum technology countries, and their technology is derived from top universities or scientific research institutes in their respective countries. These companies are seeking opportunities in the market and trying to establish a foothold in the industry.

To provide a broader analysis of the development of global core QKD suppliers, the following companies - Toshiba Europe, IDQ, and QuantumCTek are analyzed as follows:

## Technology

•Toshiba Europe in the UK has quantum communication technology derived from its Quantum Information Group (QIG) at its Cambridge laboratory. The company's current business involves semiconductor and storage solutions, rechargeable batteries, digital solutions, railway systems, etc., and quantum technology has yet to develop as the company's main business.

•IDQ in Switzerland has technology derived from the Applied Physics Laboratory at the University of Geneva, founded by a professor in the field of quantum cryptography at the university. The company's current three major products still revolve around QKD and related technologies.

•QuantumCTek in China had technology derived from the University of Science and Technology of China during its inception, with the initial product being quantum cryptography applications. However, the company now has a quantum computing prototype, providing an important foundation for the future integration of quantum communication and quantum computing. QuantumCTek has also developed in the quantum cryptography product field, with the development of core components, networking supporting products, and quantum science education products in addition to QKD system equipment.

## Market Channel

•Toshiba Europe can rely on a large amount of resources accumulated in the past in government public relations, supply chain construction, and distribution channel construction. The longstanding TOSHIBA (listed company) brand can provide significant help to the company in promoting its products.

•IDQ has developed global influence among quantum technology enterprises over the past twenty years and has sales offices, engineering, development, and research laboratories in Geneva (headquarters), Boston, and Seoul, South Korea. After being acquired by the listed company SKT in Korea, it can expand its business and technology by leveraging SKT's commercial layout。

•QuantumCTek, which has been developing for more than 10 years, was listed on China's Science and Technology Innovation Board in 2020, becoming China's first pure quantum technology listed company and attracting great market attention. Since both Toshiba Europe and IDQ are European companies, they inevitably need to expand their product sales outside their home markets and seek broader markets on the European continent, North America, and even globally. QuantumCTek currently has a wide network of cooperative relationships in China, including upstream suppliers and downstream industry application partners. Additionally, China has a large domestic market, providing QuantumCTek with ample room for development.

It should also be noted that QKD products are currently classified as cryptographic products in some countries. The import and export control regulations for cryptographic products in countries such as the United States, the United Kingdom, and China are not entirely the same. As a new generation of cryptographic products, the regulatory requirements for QKD may lag behind in some countries or regions, which may also be a factor in the inability to promote products across borders.

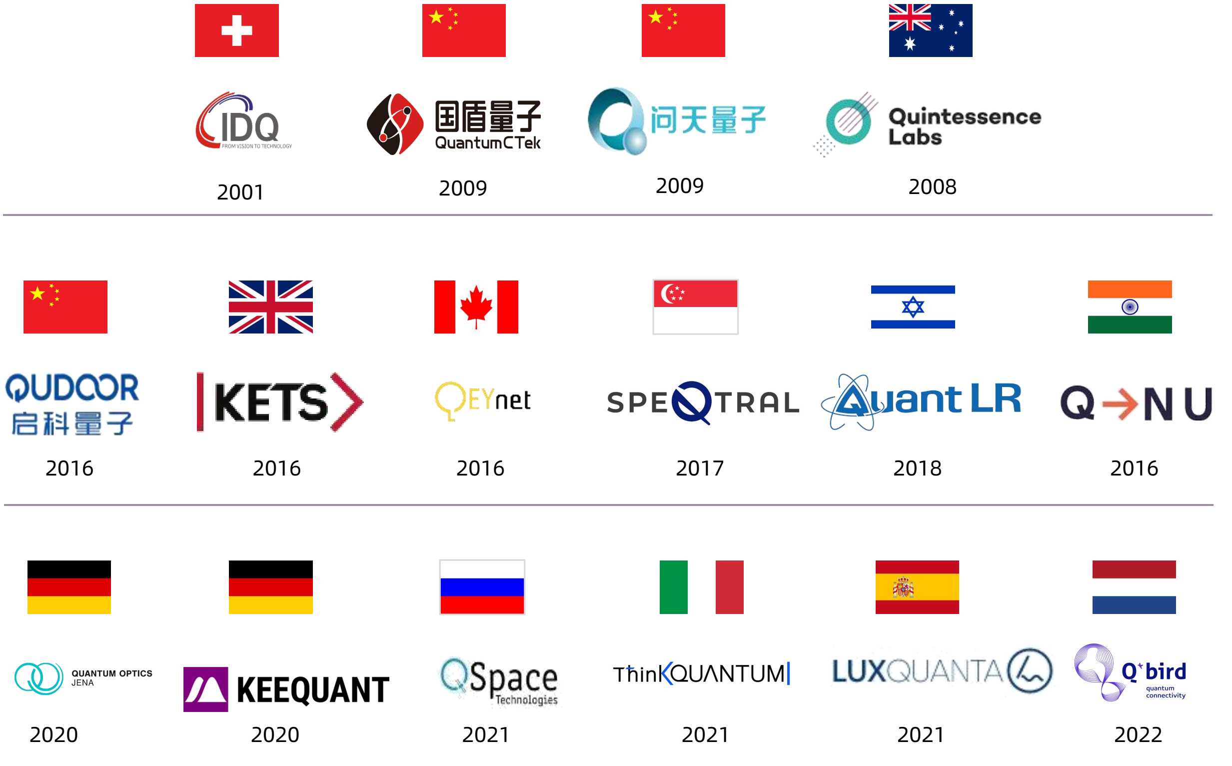
In addition to the three QKD companies analyzed above, there are many start-ups that focus on QKD technology. Comparing the countries where they are located and their founding dates, it can be seen that they were roughly founded in three time periods:

The first stage was when QKD technology achieved success in the experimental demonstration stage and QKD engineering machines began to take shape;

The second stage was when the US, UK, and EU widely launched national plans for quantum implementation;

The third stage was when quantum communication and security technology began to be applied in a certain range.

### Exhibit 3-2 QKD Company Comparison




Note: The above-mentioned companies only refer to those established for the purpose of quantum technology. QKD is only one of the businesses of Toshiba Europe and is not within the scope of comparison.

## Toshiba Europe Limited

TEUR, short for Toshiba Europe Ltd., was founded in the UK in 1998 as a global R&D organization established by the Japanese company Toshiba. It consists of two labs, the Cambridge Research Laboratory (CRL) in the UK, which focuses on basic and applied research in physics, engineering, and computer science, and the Telecommunications Research Laboratory (TRL) in Bristol. TEUR is a partner of the UK Quantum Communications Hub and is involved in establishing the UK Quantum Network (UKQN) and developing quantum communication industry standards for the European Telecommunications Standards Institute (ETSI). In addition to QKD-related fields, Toshiba leads the ISCF-funded AQuaSec project in the PQC field. TEUR has established a quantum technology business division to commercialize its quantum communication technology, and in October 2020, it released its first QKD product, which has been deployed in networks in the UK, Europe, the US, Japan, and South Korea.

In 2022, Toshiba and its affiliated companies, together with organizations such as BT and EY in the UK, KT in South Korea, JPMorgan Chase and Ciena in the US, Nomura Holdings and Nomura Securities in Japan, and the National Institute of Information and Communications Technology in Japan, achieved significant progress in building and testing QKD systems, downstream application testing and development, and played a role in promoting the release of the international standard for QKD (in the QoS field).

## ID Quantique SA

IDQ, short for ID Quantique, was established in 2001. Its main products include QKD equipment, QRNG chips, and single-photon detectors. In 2022, IDQ made progress in all three product areas. In the QKD field, it launched the Clavis XG series, with a product key generation rate of >100 kb/s and a maximum code distance of 150 km, serving as a long-distance and backbone network QKD solution. In the QRNG field, it plans to continue its collaboration with SKT and release smaller, cheaper, and higher-performance products in 2024, compared to the current chip size of 2.5mm x 2.5mm x 0.8mm, for development and application in IoT, V2X, finance, and other fields. It also launched QRNG chips for space, capable of withstanding extreme space radiation. QRNG also combined with the technology of France's PQC company CryptoNext Security to develop a solution for mobile users to provide effective and long-term quantum-safe communication for various types of government, business, and organizations to manage sensitive communication for specific groups (such as execution teams and/or specific projects).

IDQ also provides QKD products for fiber optic networks to the French telecommunications company Orange, which is part of the Paris Region Quantum Communication Infrastructure (ParisRegionQCI) project.

## KETS Quantum Security Limited

The company was founded in 2016 and is located in Bristol, UK. It is a spin-off company of the Quantum Engineering Technology Labs (QETLabs) at the University of Bristol and an industrial partner of the UK National Quantum Technology Programme's Quantum Communications Hub. The company's main products are QKD equipment and QRNG (currently in non-chip form). The company has an international office in Paris and is involved in the Thales Cyber@Station program and the ParisRegionQC located in France, collaborating with French telecommunications companies Orange and Thales to build the Paris Quantum Security Network.

QuantumCTek, founded in 2009, is the first quantum technology company in China to go public on the Science and Technology Innovation Board. The company's current business is not limited to quantum secure communication, and it has also developed an engineering prototype of a quantum computer. The company's secure communication products mainly include four categories: quantum secure communication network core equipment (QKD products, quantum satellite miniaturized ground receiving stations, channel and key networking exchange products, etc.), quantum security application products (fixed network encryption application products, mobile encryption application products, etc.), core components (single photon detectors, quantum random number sources, etc.), and quantum secure communication network management and control software.

In 2022, the company's important events in the field of quantum communication are as follows: the development of a prototype of the "New Generation Quantum Satellite Ground Receiving Station" was completed, and experiments were conducted with the "Jinan No.1" micro-nano satellite; the development of high-performance encoding optical chips was completed. The company participated in the formulation of Chinese standards for "Key Devices and Modules for Quantum Key Distribution (QKD) Based on BB84 Protocol Part 1: Light Source", "Key Devices and Modules for Quantum Key Distribution (QKD) Based on BB84 Protocol Part 2: Single Photon Detector", "Terms and Definitions for Quantum Communication", "Quantum Secure Communication Network Architecture", "Technical Requirements for Network Management of Quantum Key Distribution (QKD) Network Part 1: Network Management System (NMS) Function" and "Technical Specification for Quantum Secure Communication Application Equipment Based on IPSec Protocol"; and participated in the formulation of the international standard ISO/IEC "Security Requirements, Testing and Evaluation Methods for Quantum Key Distribution".

QUDOOR was founded in 2019 and is the first ion trap quantum computing company in Asia. QUDOOR is dedicated to the development and application of ion trap quantum computers and quantum communication technology, providing products and services to meet the needs of users in the processing of massive data and secure information transmission. The company has applied for and been granted over 350 patents and has participated in the development of more than 20 national and industry standards in the field of quantum information, such as "Technical Requirements for Quantum Key Distribution (QKD) System Part 1: QKD System Based on Deception State BB84 Protocol" and "Test Method for Quantum Key Distribution (QKD) System Part 1: QKD System Based on Deception State BB84 Protocol".

In the field of quantum communication, QUDOOR currently provides users with more than 20 products and solutions, including quantum secure communication terminals (QKD), quantum random number generators (QRNG), key management, network switching/routing, quantum servers, quantum gateways, mobile encryption devices, core components, etc. In 2022, a new generation of QKD, PCIe-QRNG, API gateways and other products have completed development and certification. QUDOOR has already established business partnerships with leading companies in various industries such as communication, cloud computing, infrastructure construction, energy, information security, and finance, including China Broadcasting Network, ZTE, Shenzhen Digital Kingdom, Alibaba Cloud Eco-Partners, China Financial Authentication Center, State Grid, GAC Group, and more, around quantum computing, quantum cryptography applications, secure cloud infrastructure, etc.

## QNU Labs Private Limited

QNuLabs was founded in 2016 at the IIT-Madras research park and began commercial operations in Bangalore in 2017. It is India's first company to offer quantum network security products. QNuLabs has three main product lines: QKD (Armos), QRNG (Tropos), and PQC (Hodos). The company also sells its Qosmos product (Quantum Key Generation as a Service, Entropy as a Service) on the AWS Marketplace.

In 2021, the company demonstrated differential phase-shift quantum key distribution at a distance of 105 km from its Bangalore R&D lab, generating 10-15 secure AES keys per second. In 2022, the company successfully entered the Indian Army's procurement list. In addition to its operations in India, the company established a subsidiary, QNu Labs Inc, in Massachusetts, USA in 2019 through a partnership with QuantumBlockchains in Poland, with plans to expand its business to Europe and the US and establish partnerships for satellite-based QKD technology. QNuLabs' partners include Let's Solve, airticle, Quantum Allance, Cystel, CISCO, Thales Accelerate, Urban Matrix, among others.

## ThinkQuantum SRL

The company was established in 2021 and is located in Sarsego, Italy. It is a spin-off company of the University of Padua and was founded by academic founders, including Officina Stellare Spa (a company that designs and manufactures complex optical and aerospace instruments for ground and space applications). Most of the founders come from the QuantumFuture research group, which has a 20-year background in quantum optics, photonic quantum information processing, quantum communication, quantum key distribution, and quantum random number generation. QuantumFuture is the only partner in Italy of the OPENQKD project, which implements various QKD test platforms and use cases throughout Europe, and is supported by the Italian Space Agency, the European Space Agency, and the European Commission. The company has access to resources such as Padua University's laboratory and related intellectual property. Its main business is to provide fiber-based QKD, free-space QKD (the only solution for communication with moving platforms such as drones, high-altitude platforms, aircraft, and ships), satellite QKD, and payloads and ground stations, as well as QRNG. The company can provide batch QKD products, with a fully EU27 supply chain, and its QKD and QRNG systems were launched in the market in 2022. The company is collaborating with the leader in the protected multi-cloud storage field, fragmentiX Storage Solutions, on QKD.

## SpeQtral Pte Limited

The company was founded in Singapore in 2017, with a focus on designing and manufacturing satellite-based quantum communication QKD systems. It originated from a team at the Centre for Quantum Technologies (CQT) at the National University of Singapore, and currently has over 20 full-time members. The team previously demonstrated a miniaturized entangled photon source in space.

In 2022, the company's main activities revolve around QKD satellite communication and collaborations with various organizations. They have also conducted some ground-based QKD tests and demonstrations, including announcing the upcoming launch of the QKD satellite SpeQtral-1 in 2024; partnering with Belgian company RHEA System Luxembourg to demonstrate intercontinental QKD; launching Southeast Asia's first quantum network experience center (QNEX) in Singapore in collaboration with Toshiba Digital Solutions Corporation; conducting experiments using Singapore ST Engineering's quantum encryptor and Toshiba Digital Solutions Corporation's QKD system on the fiber network of Singaporean telecom company SPTel; signing a memorandum of understanding with German company Rivada Space Networks to demonstrate the communication security and technical compatibility of a low Earth orbit satellite constellation with SpeQtral-1 added, and to verify the space and ground station terminals required to support QKD encryption traffic on the Rivada Space Networks constellation; and signing a memorandum of understanding with Antaris, a US-based space startup that provides software-defined satellite platforms, to host SpeQtral's airborne quantum security software sandbox in Antaris' technology demonstration satellite mission.

## KEEQuant GmbH

KEEQuant was established in 2020 and is based in Bavaria, Germany. The company's main business is QKD products, including continuous variable quantum key distribution systems (CV-QKD) based on optical fibers and key management systems (KMS) in networks, serving the data center, network, defense, and security fields. The company's funding comes entirely from the EU27 (the 27 member states of the European Union). KEEQuant is a participant in the EuroQCI (European Quantum Communication Infrastructure) project and is coordinating the SEQRET project. It has also participated in the standardization and certification work of the EU's OpenQKD project.

## LuxQuanta Technologies S.L.

LuxQuanta was founded in 2021 and is headquartered in Barcelona, Spain. It is a spin-off from ICFO (The Institute of Photonic Sciences in Spain) and was incubated there for over four years. The team currently consists of 14 people, with most of the company's shareholders coming from Europe, giving Europe full control over the company. LuxQuanta's main product is the CV-QKD system, which provides QKD systems and technology to be integrated into existing network infrastructures, providing quantum-safe security layer mathematical encryption technology on top.

LuxQuanta is part of the EU Digital Project, which aims to achieve the digital transformation of European society and economy through advanced digital technologies such as supercomputing, artificial intelligence, and network security. A part of the Digital Project is to develop and mature QKD technology, deploy European QKD links, and build European quantum communication infrastructure.

The company's QKD system was first tested in 2022, with a 30km point-to-point fiber optic quantum communication link established between ICFO headquarters (Castelldefels) and the Catalan government CTTI headquarters (Hospitalet de Llobregat). This was the first step in deploying a quantum network in Barcelona.

## QEYnet INC.

QEYnet was founded in 2016 and is located in Toronto, Canada. The company was created by spacecraft engineers and quantum communication experts and focuses on the development of QKD small satellites with the aim of establishing a global, low-cost, and micro-satellite-supported quantum key distribution network. QEYnet's QKD technology is derived from the Institute for Quantum Computing at the University of Waterloo, which has received funding of over $7 million from the Canadian government.

## Quantum Optics Jena GmbH

Quantum Optics Jena was founded in 2020 and is located in Jena, Germany. Leveraging years of research experience in quantum optics, as well as accumulated expertise in precision optics, mechanics, and optoelectronics in applied science and industry, the company offers high-performance entangled photon sources, fiber-based and satellite-based QKD systems, quantum imaging systems, and photonic components and systems for quantum networks (polarization analysis modules), providing solutions for communication, biomedical imaging, and the scientific community.

Located in the state of Thuringia, Jena is renowned for photonics and optical technology, home to the Fraunhofer Institute for Applied Optics and Precision Engineering (Fraunhofer IOF), providing favorable geographical positioning for the company's technological development. In terms of business expansion and partnership network, the company is a member of the Quantum Business Network (QBN), the European quantum business network.

## Q.Bird B.V.

QBird was founded in 2022 and is located in Delft, Netherlands. It is a spin-off of QuTech, a Dutch quantum computing company, providing basic building modules for quantum communication infrastructure in the Netherlands and Europe. QBird is also part of the Quantum Delft and Quantum Delta NL ecosystems and a participant in the National Quantum Network Plan (Quantum Delta NL) and Quantum Internet Alliance (QIA). The company mainly provides QKD technology.Q*Bird's technology team has years of experience in delivering next-generation quantum prototype systems and projects to industrial and commercial partners. They operated as an engineering team within QuTech for three years, during which they designed and built next-generation QKD prototype systems. These systems have been tested with industrial partners in relevant fields.

QBird is currently deploying QKD prototype systems with commercial partners in finance, telecommunications, and data centers across the Netherlands, including Eurofiber's Utrecht regional network. The testing platform is open to new partners to explore the possibility of quantum-secured communication. QBird's next-generation system will be launched at the Port of Rotterdam, connecting users to the port's data sharing platform Portbase and two to three other maritime logistics companies located in Rotterdam. The project is two-thirds funded by the Quantum Delta NL SME program and one-third by the Port of Rotterdam, and Q*Bird is collaborating with Dutch superconducting nanowire single-photon detector company Single Quantum in this project.

## Arqit Quantum INC.

Arqit was founded in 2017 and is headquartered in the UK with a subsidiary in the US. It went public on the NASDAQ through a SPAC merger in 2021, becoming one of the few quantum technology companies to be publicly traded. The company's product is the QuantumCloud™ quantum encryption cloud platform software, developed in collaboration with the UK government, BT, and Virgin Orbit over four years.

In the 2022 fiscal year, the company had a revenue of $20 million, with $7.2 million coming from five contracts for QuantumCloud™ and $12.8 million from other business revenue from contracts with the European Space Agency. Administrative expenses for the year were $72.2 million ($14.6 million in 2021), with employee costs accounting for a significant portion of the increase due to a growth in headcount from 73 to 145 employees. The operating loss was $52.1 million ($172.6 million in 2021), but Arqit also gained $21.3 million in cash from the exercise of warrants.

Arqit has expanded its business by collaborating and deploying its products in private cloud infrastructure, cloud storage platforms, and hardware. This includes integration with Fortinet's next-generation firewall Fortigate series, a contract with UK cybersecurity solution provider Nine23 to provide services on Nine23's UK Sovereign Secure Private Cloud Infrastructure Platform Flex through the G-Cloud 13 framework, deployment on Amazon Simple Storage Service (Amazon S3) for use by AWS customers, and pre-installing products on selected Dell hardware devices for sale as a single SKU.

# 04

# Infrastructure Development

In 2022, the development of quantum communication network infrastructure in countries such as the United States, Canada, United Kingdom, France, South Korea, China, Poland, India, and others has further progressed. The following is a summary of related developments.

## USA: Despite the absence of a large-scale national infrastructure plan, the development of QKD application research is still unaffected.

In May, the Brookhaven National Laboratory (BNL) in the United States Department of Energy launched a new quantum network facility that provides researchers with the tools and capabilities needed to make large-scale quantum entanglement distribution networks a reality. The new facility already has one of the most advanced regional quantum networks in the United States and is part of the longest quantum network in the US, spanning 98 miles and connecting the two institutions' affiliated campuses, which is being completed by BNL and Syracuse University. In June, the Chicago Quantum Exchange (CQE) at the Pritzker School of Molecular Engineering at the University of Chicago connected Chicago city and suburban laboratories to the quantum network, building a 200-kilometer QKD network that distributes quantum keys at a rate of over 80,000 quantum bits per second via fiber optic cable. The Chicago network, which will be one of the first publicly available quantum security technology test platforms open to the academic and industrial communities, is expected to become one of the first public quantum security technology test platforms in the United States. The entire network currently consists of 6 nodes and transmits particles carrying quantum-encoded information between two buildings in Argonne National Laboratory and the south side of Chicago (the headquarters of the CQE near the University of Chicago campus and Hyde Park). In June, the Illinois Rapid Quantum Network (IEQNET) research team deployed a quantum network between two Energy Department laboratories located 50 kilometers apart in Illinois and simultaneously transmitted a conventional clock signal and a quantum signal on the network. The two signals remained synchronized within a window of less than 5 picoseconds, an important step towards building practical multi-node quantum networks.

## Canada: The Quebec government opens a new fiber quantum communication testing platform for industry and researchers.

In June, the non-profit organization Numana in Quebec, Canada opened a quantum communication infrastructure in Sherbrooke's Quantum Innovation Zone. The facility provides a fiber quantum communication testing platform for industry and researchers. The project cost 3.75 million Canadian dollars and was supported by a 2.5 million Canadian dollar grant from Quebec's Department of Economy and Innovation and technical support from the communications company Bell. The Quebec government plans to establish networks in Montreal and Quebec City, gradually deploying an infrastructure quantum ecosystem connecting the entire province of Quebec.

## Germany: A 75 km fiber QKD connection has been established between research institutes in Frohnau and Erfurt.

In September, the construction of quantum communication network infrastructure was carried out in the state of Thuringia (one of the 16 federal states in Germany) with the support of Thuringia Science Department with an allocation of 11 million euros. The Institute of Applied Optics and Precision Engineering (IOF) and its partners, with the support of the Federal Ministry of Education and Research (BMBF), built and tested the first-ever quantum communication network over a 75 km fiber QKD. This line connected the IOF in Jena and the Center for Bioelectronics and Optical Systems (MEOS) in Erfurt. Over 300,000 quantum keys were sent between the two locations. This experiment was also the first phase of the construction of QuNET (Quantum Communication Network), a research program funded by the BMBF and participated in by four core research institutes: IOF, the Heinrich Hertz Institute (HHI), the Communication and Navigation Research Institute (DLR-IKN), and the Max Planck Institute for Light Physics.

## UK: The North region implements the first quantum communication network, connecting York and Manchester.

In February, the Quantum Communications Center funded the first quantum communication network project in northern England. The project will use CV-QKD technology to deploy a quantum secure network between four strategic interconnection points between York and Manchester via Leeds and Halifax.

## France: Connection tests between some nodes in Paris have been completed in a quantum communication infrastructure project.

In October, the ParisRegionQCI (Quantum Communication Infrastructure project) led by French telecom operator Orange deployed a quantum communication network for testing secure communication solutions between Saclay, Châtillon and Paris. The network will be established between large groups, start-ups, LIP6 (Paris Computer Science Laboratory), optical institutes, and Paris Telecom. The project was funded with 1 million euros by the Île-de-France region and is the first quantum communication network in the region. The project relies on ID Quantique's QKD solution, Thales's IPsec Mistral encryption gateway, and collaborations with institutions such as the École Polytechnique.

## Poland: A 380 km QKD inter-city infrastructure link has been built between Warsaw and Poznan.

In September, a 380 km inter-city QKD link was established between the cities of Warsaw and Poznań. The link is part of the National Quantum Communication Infrastructure Project developed by the National Laboratory of Photonics and Quantum Technologies (NLPQT) and is a collaboration between Poznań Supercomputing and Networking Center (PSNC) and the Swiss company IDQ. The link will serve multiple applications including remote healthcare, medical data transmission, data storage and public services. PSNC aims to further integrate its subway QKD infrastructure developed in Poznań in 2021 with this new long-distance Poznań-Warsaw QKD link, with the ultimate goal of connecting all of Poland's high-performance computing centers and establishing a general access layer for QKD services.

### China: The Hefei Quantum Secure Communication Metropolitan Area Network is now open, with a total length of 1147 kilometers and 159 access points.

In August, the Hefei Quantum Metropolitan Area Network was launched, which is currently the largest, most user-friendly, and comprehensive quantum secure communication metropolitan area network. The network was constructed by China Telecom Quantum and the core equipment was provided by QuantumCTek. The network consists of 8 core sites and 159 access sites, with a total fiber length of 1147 km. It provides quantum secure access services to nearly 500 party and government organizations at the city and district levels. The network will also serve the financial, energy, medical, and technology industries in the future and is expected to expand to four counties and one city, connecting to the national quantum backbone network.

### Korea: The first phase of the QKD Network Infrastructure project is complete, connecting 48 government organizations.

In July, SK Broadband and IDQ successfully completed the first phase of the construction of an 800-kilometer long QKD network infrastructure in South Korea. This network connects 48 government organizations in the country, providing secure protection for sensitive information and communications. It is the largest quantum cryptography network outside of China.

### India: The Army Ground Fiber Infrastructure has successfully achieved over 150 kilometers of quantum key distribution.

In August, the Indian army successfully trialed the distribution of secure keys over 150 km via the QKD system from QNu Labs. The Indian army has added QNu Labs to its procurement list and begun purchasing the Armos QKD system developed by the company.

# 05

# Investment Overview

Currently, the field of quantum communication and security is still a future technology, and this chapter focuses more on the start-ups established for this purpose. Many traditional network and information security companies have ventured into quantum communication and security research and business, but these companies have accumulated sufficient capital through long-term continuous operation, and they hardly need venture capital injection. Quantum start-ups, especially companies focused on hardware research and development, have few collateral assets in the early stages of their establishment, and research and development carries risks. Therefore, bank loans are less common, and they mainly rely on venture capital and government funding to support their initial development.

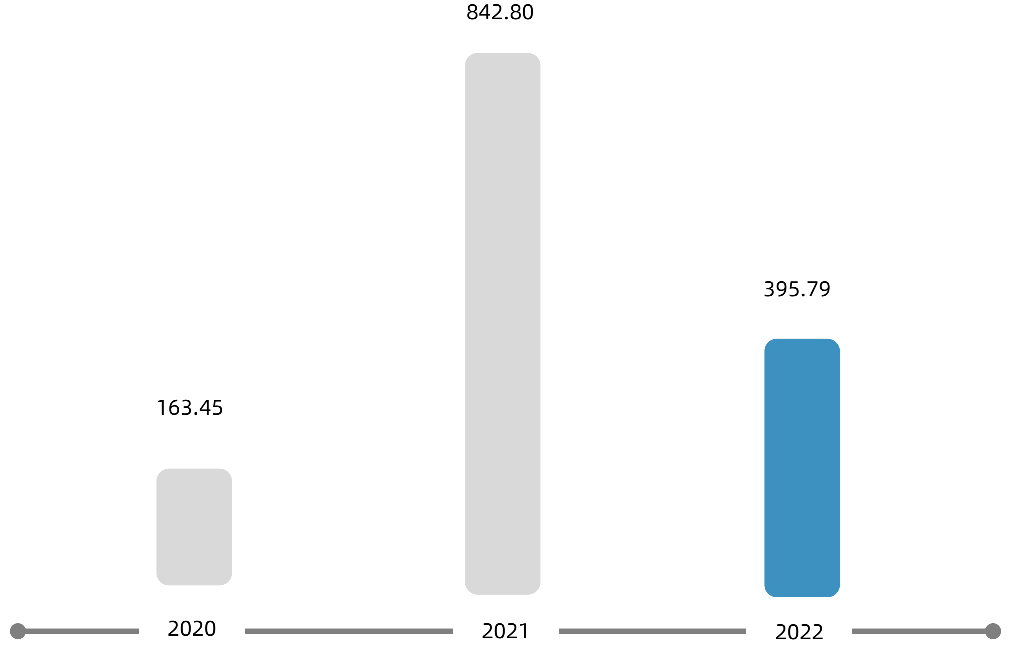
Regarding the scope of the statistical amount, in addition to funds from venture capital firms (this chapter does not delve into whether venture capital is government industry guidance funds), start-ups also obtain investments from the government through projects organized by the government (for example, the US Department of Energy or the UKRI provides funding/prizes, etc.). These two types of funding sources sometimes exist in a single round of financing, and it is impossible to distinguish them in detail. Therefore, investments from venture capital firms and funds directly invested by the government into companies are included in this calculation. This financing data is based on public information, and some companies do not disclose their investment situation or investment amount, which will not be included in the calculation scope. Some companies' technologies and businesses not only involve quantum communication and security but may also involve quantum computing or quantum precision measurement, and the disclosed investment amount often does not split into exact research directions. The currency of funds is mainly in US dollars, and there are also euros, pounds, Australian dollars, RMB, Korean won, and rupees. The calculated amount does not consider inflation and exchange rate fluctuations. In summary, there may be deviations in the actual investment amount received by the quantum communication and security industry, and the above situations should be considered when using the data.

The main characteristics of financing in 2022 are as follows:

## Compared to 2021, the financing in the field of quantum communication and security significantly decreased in 2022.

In 2022, a total of 21 startups in the field of quantum communication and security raised approximately $396 million in funding, including three companies (India's QNu Labs, China's Hefei Guizhen Quantum, and China's Xanadu Quantum) whose funding amounts were not disclosed. This represents a significant decline in funding compared to 2021 (approximately $843 million), which was boosted by two large fundraising rounds from UK-based Arqit and China's QuantumCTek, accounting for 74.14% of the total funding for the year. However, in 2022, no company in this field went public, and the highest amount of funding came from US-based Sandbox AQ, a spin-off of Alphabet (Google's parent company), which raised a nine-figure sum (exact amount undisclosed, assumed to be $100 million). In addition to the impact of these high-value funding rounds, other factors may also be at play, such as delayed delivery of funding and slower sales due to the ongoing COVID-19 pandemic.

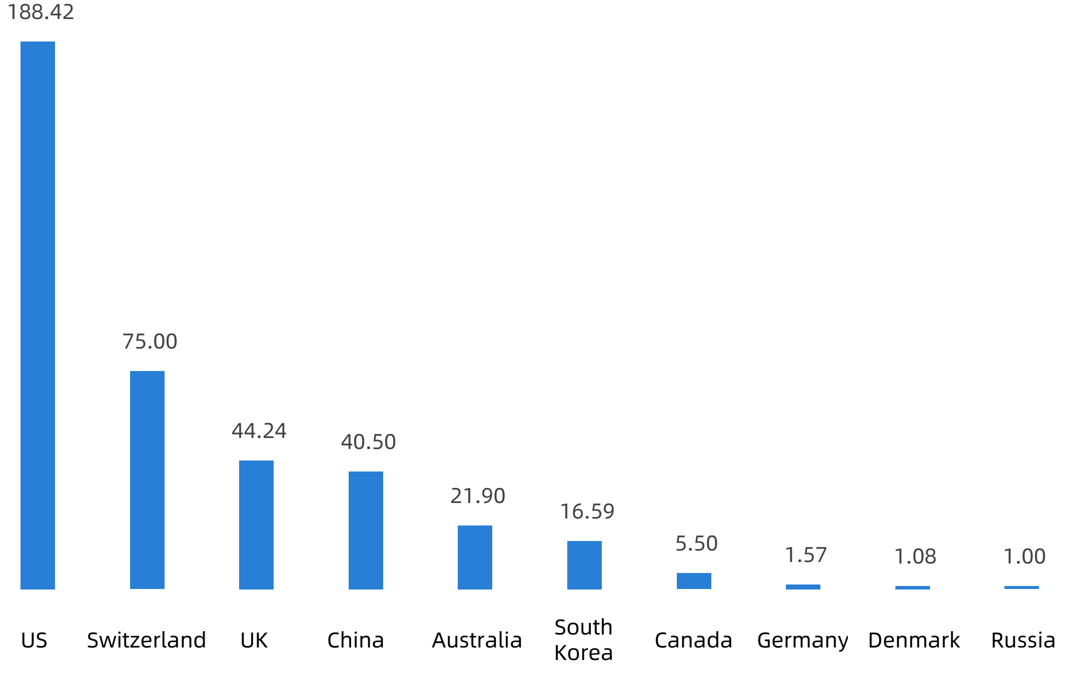
Exhibit 5-1 The total amount of financing in the global quantum communication and security field (2020-2022)
(Unit: Million USD)



## The funds are primarily invested in US companies, followed by Switzerland, the UK, China, and Australia.

In 2022, funded companies in the quantum communication and security industry came from 11 countries, including the United Kingdom, Denmark, the United States, Canada, South Korea, Germany, India, Russia, Australia, Switzerland, and China. Based on disclosed funding amounts (funding amount for India's QNu Labs was undisclosed), the highest funding amount went to companies in the United States (approximately $188 million for 6 companies), followed by Switzerland (approximately $75 million for 2 companies), the United Kingdom (approximately $44 million for 4 companies), and China (approximately $41 million for 4 companies). This may be due to a higher number of quantum communication and security startups in the United States, greater policy releases in the US network security sector, and more open and active capital markets in Europe and America.

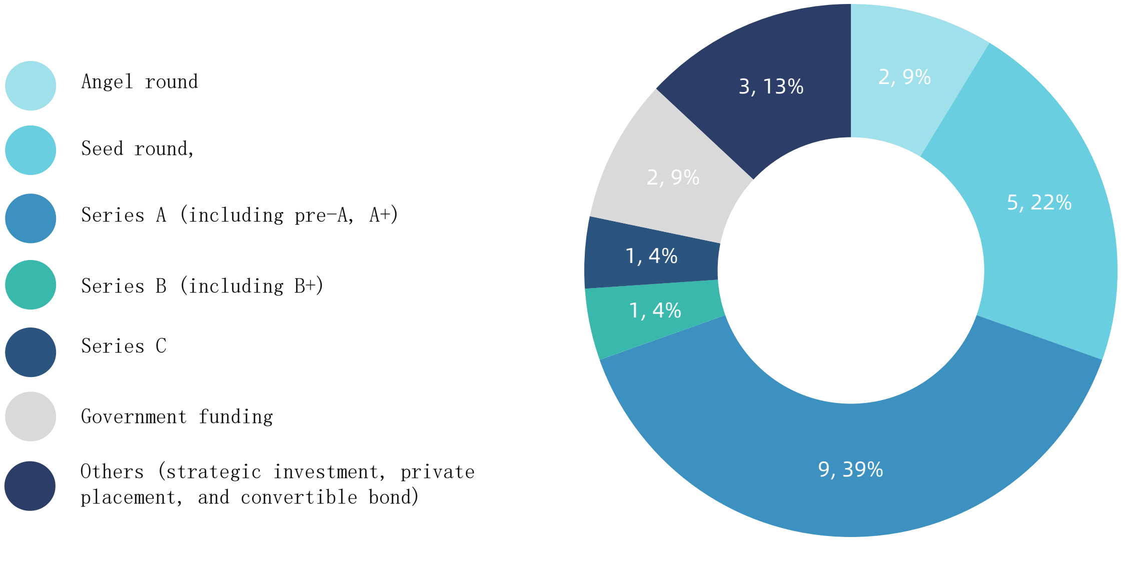
Exhibit 5-2 Funding amount quantum communication and security sector in 2022 (by country)
(Unit: Million USD)



## The financing types are still mainly in the early stages, with seed and Series A rounds having the highest proportion.

This financing round is categorized by funding types, including angel round, seed round, Series A (including pre-A, A+), Series B (including B+), Series C, government funding, and other types of funding (strategic investment, private placement, and convertible bond). According to the funding types, Series A received the most funding (9 times, accounting for 39%), followed by the seed round (5 times, 22%). This indicates that most of the funded companies are in the early stage and still have some distance to go before going public. This aligns with the fact that the quantum communication and security field is still in the early stage of development as a cutting-edge technology.

Exhibit 5-3 2022 Global Quantum Communication and Security Financing Types

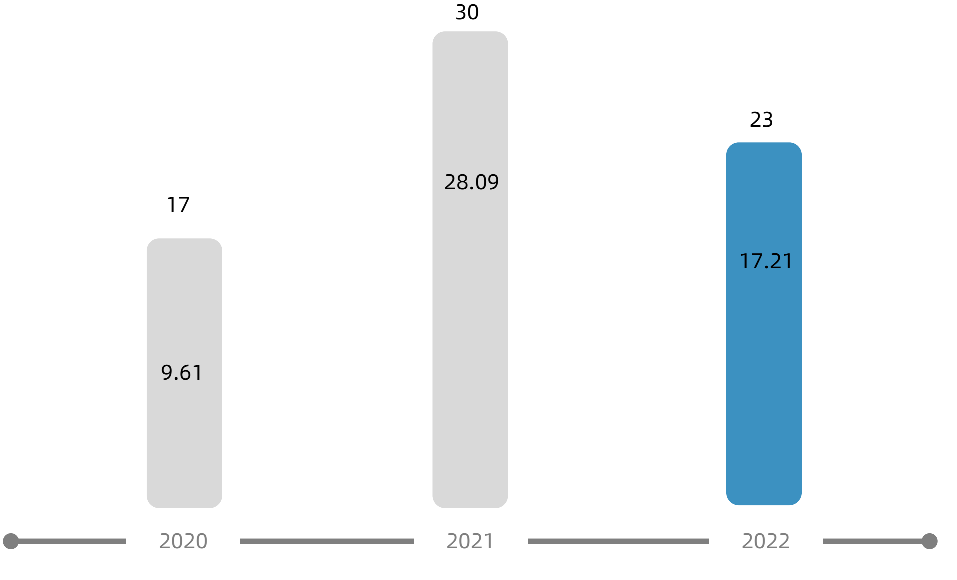


## The number of financing events in 2022 decreased from 30 in 2021 to 23.

In 2022, a total of 23 financing events occurred in the global quantum communication and security field, which is lower than the number in 2021. Additionally, the average financing amount per event was around 17.21 million USD, lower than in 2021 but higher than the average in 2020.

The total financing amount, number of financing events, and average financing amount per event in 2022 were all lower than in 2021. This is likely due to the impact of COVID-19 and the slowdown of macroeconomic growth. Governments around the world have invested a large amount of funds to deal with the pandemic, which inevitably affects the funding for technological innovation and industrial development. As the pandemic entered its third year, this consumption had already reached a certain peak. In 2022, there were fewer cases of companies going public and large investment deals.

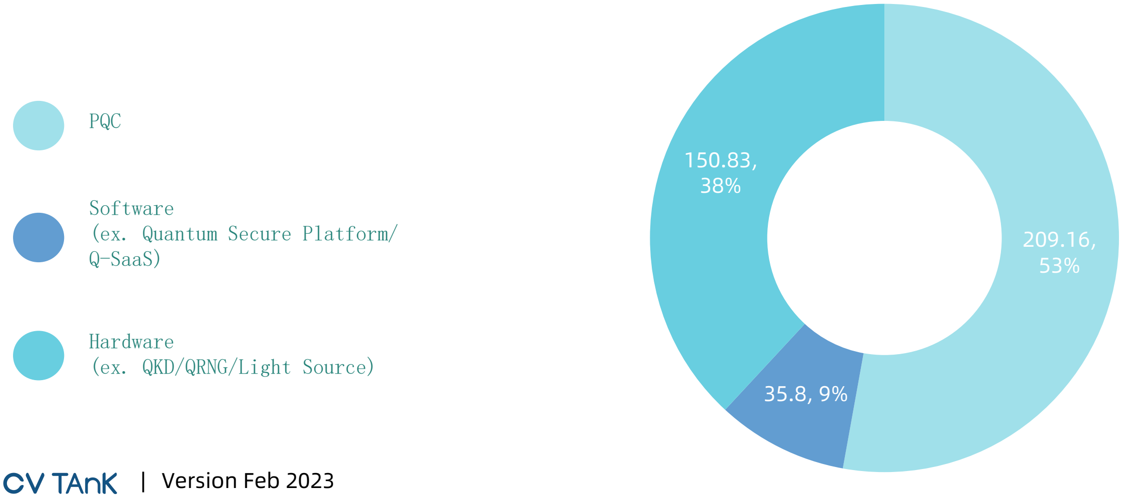
Exhibit 5-4 Number of Quantum Communication Investment and Financing Events and Average Event Amount Worldwide (2020-2022)
(Unit: million USD)



## The total financing amount for hardware-based enterprises such as QKD and QRNG is higher than that of PQC enterprises.

The companies in the quantum communication and security field can be mainly classified into three categories: those that develop products based on quantum physics (such as QKD, QRNG, and light sources), those that develop quantum cryptographic platform products (Q-SaaS, cryptographic management platform), and those that develop products based on mathematical algorithms (fully homomorphic encryption algorithm). According to disclosed investment data, in 2022, 6 PQC companies received investment, including Cornami (USA), HEAAN CRYPTO LAB (South Korea), PQSecure Technologies (USA), PQShield (UK), Sandbox AQ (USA), and Hangzhou Liangan Technology Co., Ltd. (China), receiving a total investment of approximately $209 million. In 2022, 11 quantum physics encryption companies received investment, including Aegiq (UK), Alea-quantum (Denmark), Pixel Photonics (Germany), QNU Labs (India), QSpace Technologies (Russia), QuintessenceLabs (Australia), Qunnect (USA), Terra Quantum (Switzerland), Hefei Guizhen Quantum (China), Shanghai Xianhai Quantum (China), and Zhejiang Jiuzhou Quantum (China), receiving a total investment of approximately $151 million. In 2022, three quantum software platform companies received three financing deals, including Arqit (UK), evolutionQ (Canada), and QuSecure (USA), receiving a total investment of approximately $36 million. In the future, as PQC algorithm standardization becomes more prevalent, there may be some start-up companies in PQC algorithm applications, and the investment ratio in PQC, QKD, QRNG, and other hardware fields may undergo new adjustments.

Exhibit 5-5 Investment Distribution of Quantum Communication and Security in 2022



## Governments of multiple countries continue to invest in the field of quantum communication and security, focusing on industry, academic discipline development, and talent cultivation.

In 2022, countries including China, the United States, Canada, Finland, Australia, Singapore, Germany, the United Kingdom, and South Africa are actively investing in the quantum field, including quantum communication and security, to support the development of quantum technology. Major governments have invested approximately $1.203 billion in the field, covering areas such as infrastructure construction, quantum education, talent cultivation, innovation districts, national quantum programs, and industrial development.

Some policies are specifically aimed at quantum communication and security, such as Singapore's National Quantum Security Network, which is part of the Quantum Engineering Program and aims to conduct experiments on quantum security communication technology across the country, evaluate security systems, and develop guidelines to support the adoption of such technology by companies. The project plans to deploy 10 nodes and will receive SGD 8.5 million over three years.

Funding policies also target quantum talent, such as the Australian Labor Party's commitment to providing AUD 4 million to support the cultivation of quantum talent, including AUD 3 million for the training of quantum technology PhD students and AUD 1 million for the establishment of a national quantum research and education partnership based on the Sydney Quantum Academy model. In addition, the K12 Quantum Talent Development Program, operated by the George Mason University Quantum Science and Engineering Center in the US, has received $650,000 in funding from the House Appropriations Bill to pilot quantum physics courses in Fairfax and Loudoun County public schools and cultivate diverse quantum talent in Northern Virginia.

National science and technology departments, national industry departments, national innovation departments, national quantum research centers, national quantum research programs, national standards and technical research institutions, and local governments are the main policy makers in the release of funding policies.

**Diversifying the sources of funding for the quantum industry can unlock its innovative and entrepreneurial potential, thereby contributing to the development of the industry.**

In addition to national and local governments and investment companies, professional societies also encourage the development of quantum technology by setting up awards. For example, the Institute of Physics (IOP) in the UK has partnered with the investment firm Quantum Exponential to launch the qBIG innovation award, which offers a cash prize of £10,000 and guidance from academic and industry experts to the winners. These initiatives demonstrate the capital's eagerness to invest in quantum targets and provide another funding channel for start-up companies.

# 06

# Policy Release

As a guiding document for industrial development, policies serve as a compass for the direction of industry and are highly influential and widely promoted. In other words, once policies are released, they need to gradually affect all aspects of the industry. This chapter will summarize guiding and funding policies in chronological order, from the perspective of the national or international organization.

**Quantum Information**

**Policies related to quantum communication and security are still mostly covered under the term "quantum information".**

Currently, most policies still use the comprehensive term "quantum information", with relatively less attention to the specific field of quantum communication and security. There may be two reasons for this: first, the three major technologies of quantum communication, quantum computing, and quantum precision measurement that are widely categorized in the field of quantum technology are highly technically related. Based on the future development vision of current technology, the three major technologies will complement each other and merge to form a comprehensive era of quantum Internet. Therefore, it is not easy to separate them too much in actual development. Second, even though the three major technologies of quantum communication, quantum computing, and quantum precision measurement have already had a lot of development, there are still many "branches" to explore. It may be more targeted to separate policies when the branches are flourishing.

**Nationwide Promotion**

**The United States is leading the way in promoting the development of quantum information through legislative means, which remains unique among other countries.**

In 2022, countries such as the United States, China, Finland, Singapore, Canada, the United Kingdom, Germany, Japan, the Netherlands, Spain, Australia, South Korea, and South Africa all issued policies to promote the field of quantum communication and security. The form and tendency of policy releases vary among different countries. The United States tends to use legislation to drive scientific development, technology research and development, and industrial development from top to bottom by publishing bills with different themes. Except for the United States, other countries have not yet introduced such legislation. This approach is not only related to the governance and legislative habits of the United States but also related to the goal of the United States to always maintain a leading position in quantum technology. In addition to national policies, the European Union and NATO also issued policies in 2022 to support the development of quantum communication and security. Overall, the field of quantum communication and security has continued to develop sustainably with the support of policies, and this technology continues to be supported at the national and international organization levels.

**Advancing in an Alliance**

**The EU and NATO have both released policies supporting the development of quantum communication, but the EU has made greater overall progress in advancing these policies than NATO.**

In the EU, an investment of 6 billion euros was announced to establish satellite constellation infrastructure and connect the European quantum communication infrastructure. Ireland signed the EuroQCI declaration, and all 27 EU member states have completed signing it. Preliminary strategic research and industry agenda have been released (expected to be updated and finalized in 2023). In NATO, the establishment of a quantum testing center and laboratory at the Niels Bohr Institute in Denmark was announced for the development and testing of quantum technology (including quantum encryption). Quantum technology has been identified as a critical emerging technology, and integrated technologies for QKD and PQC are being researched to protect information infrastructure for the alliance in the best and most comprehensive way.

**Continuous Release**

**In China, many policies supporting the development of quantum are continuously being released by the eastern and central provinces and cities.**

From an economic and geographic perspective, China's quantum policies have been mainly concentrated in the eastern coastal provinces and municipalities, with only Tianjin not releasing any quantum-related policies in 2022. The last wave of quantum policy releases occurred in 2021, when local "14th Five-Year Plans" were released by provinces and cities nationwide. Provinces and municipalities in central and southwestern regions with a certain amount of technological accumulation and industrial foundation have also released quantum policies. Key policy keywords include digital economy, future industries, commercial cryptography applications, network and digital security, advanced manufacturing, etc., which are also applicable to the global policy development direction of the quantum communication and security industry.

While local government policies related to quantum technology have been frequently introduced in China, the actual implementation of these policies has been limited. Considering that the quantum information industry is still in its early stages and the industry scale is very limited, local government investment in quantum technology has been relatively low.

**Quantum Workforce**

**The workforce developing quantum technology is receiving policy attention.**

Policies from various countries have more or less mentioned the importance of quantum talent. The United States, in particular, has released the report "Quantum Information Science and Technology Workforce Development National Strategic Plan" through the influential publication body NSTC, showing its attention to the workforce to the public. Quantum policies have gradually expanded their focus from science and technology to the people researching and developing them. Current policies concerning labor force mainly aim to cultivate reserve forces for quantum research through curriculum settings and other means. However, quantum education should not be limited to university education, especially as it currently focuses mainly on the doctoral level. It should gradually infiltrate K12 education and consider professional education in the quantum product manufacturing process, where such talent is essential.

**Various Forms**

**The quantum policy of the United States takes on the most diverse forms, releasing its leadership and cooperation signals through G7, roundtable meetings, and other means.**

In addition to the cooperation signed by the G7, the United States has also signed agreements with countries such as Finland, Sweden, India, Denmark, and South Korea through bilateral and multilateral dialogues, as well as through public statements by government officials, to signal its collaboration with other countries in the field of quantum technology, constantly emphasizing its important position in the quantum field, and promoting the commercialization of quantum technology in the United States.

# 07

# Industry Analysis & Forecast

The products and technical services in the field of quantum information and security mainly belong to the network security industry, which is a core and fundamental sub-industry within the vast industry of network security. This industry can extend downstream to various security products in multiple industries.

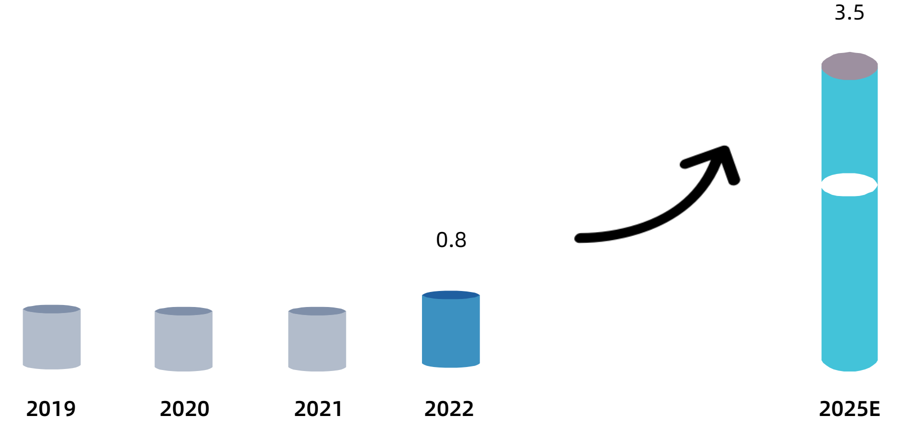
From the current form of development, the quantum information and security industry is mainly driven by the industrial value brought by quantum physics encryption products and technologies (such as QKD), PQC, QRNG, etc.

## QKD

QKD products have been available for many years and are currently mainly upgraded and iterated to gradually replace components in existing products, making them more superior in performance, more cost-effective, and smaller in size. QKD products do not replace traditional products in similar industries.

In 2022, the global QKD market is expected to decrease compared to 2021, reaching around $800M. Many projects that were previously supported by government funds have been affected by the COVID-19 pandemic, and many have been suspended or progressed slowly due to the pandemic and economic slowdown. As the global economy gradually recovers and the pandemic becomes normalized, the market size is expected to reach $3.5B by 2025, approximately five times that of the end of 2022.

Exhibit 7-1 Global QKD Industry Scale (2019-2025E)
(Unit: Billion USD)



Compared to 2022, the overall market application proportion is similar in 2025. The defense and military sector remains the main market, slightly decreasing from 29.75% in 2022 to 26.11%. The power grid sector has the largest decrease, dropping from 21.88% in 2022 to 16.41%. The market share of telecommunications, government services, finance, railways, and other industries has all slightly increased.

Exhibit 7-2 Global QKD forecast (2022-2025E, by application)

| Segment Share | 2022 | 2023E | 2024E | 2025E |
|---|---|---|---|---|
| Defense & Military | 29.75% | 25.65% | 25.85% | 26.11% |
| Telecommunications | 9.38% | 10.05% | 10.42% | 10.53% |
| Government Affairs | 11.38% | 10.05% | 10.22% | 11.70% |
| Power Grid | 21.88% | 22.53% | 21.36% | 16.41% |
| Finance | 16.50% | 15.94% | 16.41% | 17.55% |
| Rail | 8.63% | 12.31% | 12.64% | 15.41% |
| Others | 2.50% | 3.47% | 3.10% | 2.28% |

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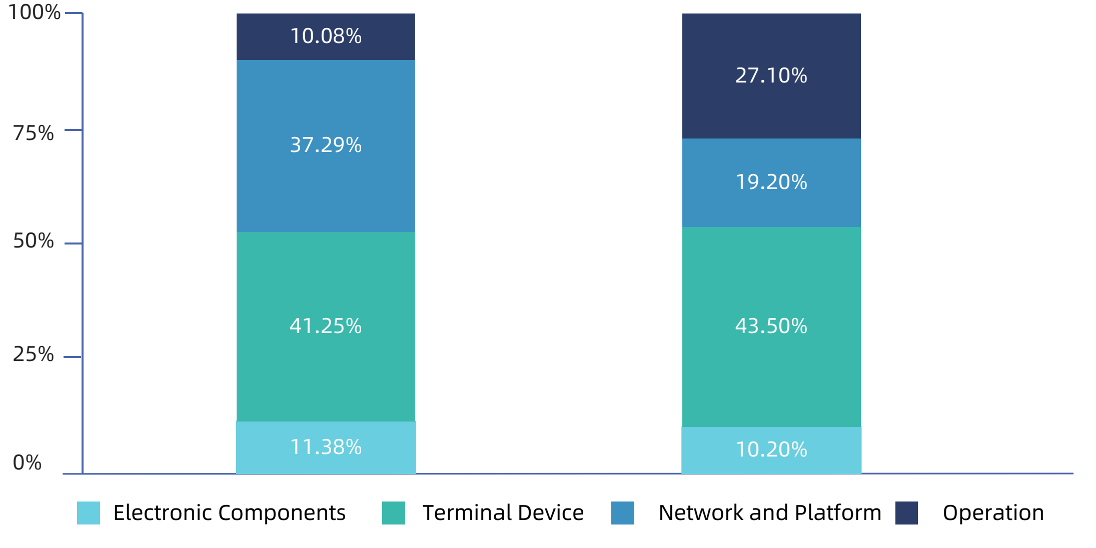
Looking at the proportions of the main links in the industry chain, as one of the most important links in the upstream of the industry chain, components have tended to stabilize in supply as the industry develops, and their proportion in the entire industry structure is expected to slightly decrease from 2022 to 2025. The proportion of terminal equipment in the industry structure is expected to slightly increase from 2022 to 2025. The proportion of network and platform construction is expected to significantly decrease from 2022 to 2025, as most infrastructure construction work has already been carried out on a large scale. As QKD infrastructure gradually improves, its proportion in the industry structure will significantly increase. By 2025, a large number of network platforms will have been built, and operational activities will enter a peak period, with more downstream applications launching into operation.

Exhibit 7-3 Global QKD Industrial Structure (2022-2025E)



## QRNG

The quantum random number generator (QRNG) is a component-level product, unlike QKD equipment which requires multiple components to be assembled. For entrepreneurs who want to enter the quantum industry, QRNG is an area that can be quickly accessed. Furthermore, QRNG has a wide range of applications, not only in the field of quantum information, but also in computing simulation, financial payments, and biological implants, among others. As the performance and economies of scale of QRNG products improve, they are expected to gradually replace some existing random number products.

QRNG is a research and application field recognized and supported by governments. For example, the UK's AQURAND project and the EU's QRANGE project, which are joint industrial collaborations led by national units and primarily supported by national funds.

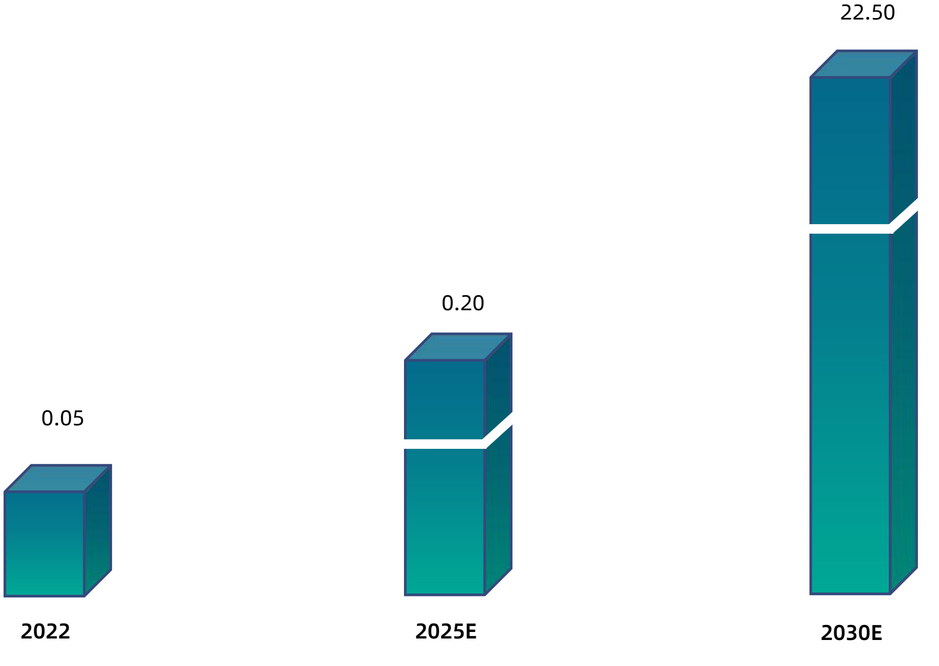
The growth of QRNG applications is related to the flourishing development of the quantum information age. Although classical RNGs can currently meet most application needs, they may not be able to provide higher security as new technologies emerge. When the cost of using QRNG drops to a level where it can be replaced or applied on a large scale, it will experience explosive growth during this period. Especially in the 5G/6G era, a large number of mobile devices can use QRNG to increase security. At present, the main application scenarios are for situations that require high security but are not sensitive to cost and scale, mainly for exploratory experiments. With the iteration and upgrading of QRNG, the product is expected to enter the lives of individual consumers on a large scale in recent years. For example, QRNG may appear on a large scale in mobile phones, bank U-disks, unmanned driving (drones, unmanned ships, unmanned vehicles), internet-connected cars, and other IoT products. This means that the development of QRNG products is mainly in the form of chips, which are small in size, fast in speed, more reliable, and more economical.

Currently, the gambling industry is one of the downstream markets for QRNG. This is because hackers successfully made millions of dollars by locking and invading slot machines in 2014, causing losses to casinos in the United States, Romania, and Macau. Casinos in the United States and Macau have used QRNG to provide a fair environment for participants in games.

It is estimated that the QRNG industry will reach a market size of approximately $51M in 2022. This market is expected to experience a robust growth trajectory, with the industry projected to expand to $203M by 2025, and exceeding an impressive $22.5B in market size by 2030. This represents a significant opportunity for businesses operating in this space, as the demand for quantum technology continues to surge and investments in this industry grow.

The driving force behind the growth of the QRNG industry comes from the maturity of chip technology and the widespread recognition of the product by downstream applications.

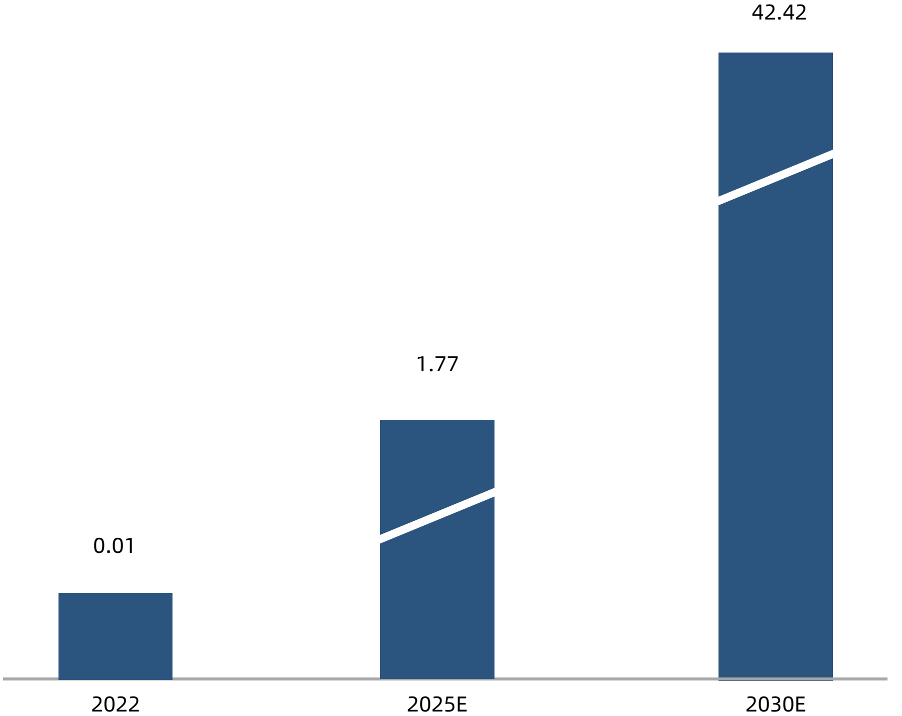
Exhibit 7-4 Global QRNG Industry Scale (2022-2030E)
(Unit: Billion USD)



The form of PQC products can be classified as software or hardware. Software products (including algorithms) may be applied to applications such as web browsers, while hardware products may gradually be installed in IoT devices in the form of chips or embedded chip modules. As PQC is an upgrade or addition of a "line of defense" to current algorithms, it may replace some traditional security software or chips.

The growth of the PQC market is closely related to the standardization process of PQC and the practicality of quantum computers. It is expected that the PQC industry will still be in the initial stage in 2022, with a market size of about 10 million US dollars, but will see significant growth by 2025, reaching about $1.77B, and reaching $42.42B by 2030.

Exhibit 7-5 Global PQC Industry Scale (2022-2030E)
(Unit: Billion USD)



# 08

## Perspective View

## 01 The Battle for the Best Solution Continues Between QKD and PQC.

In the era of quantum technology, network information security will use QKD and PQC cryptography techniques. Both aim to address the security challenges posed by the quantum era, but differ in their protection mechanisms. QKD is based on physical hardware while PQC relies on algorithm software. While QKD is already widely deployed in many countries, PQC is still in the standardization stage. As both serve new quantum-era information security technology, they are constantly compared. QKD and PQC may not necessarily replace each other, as they each have their own advantages and disadvantages. QKD may have hardware vulnerabilities and increase deployment costs, while PQC may be cracked at some point. In the future, different security level requirements, application scenarios, and other factors may determine the choice between QKD or PQC, or a combination of both.

## 02 The development goal of QKD remains to expand communication distances to a practical scale.

In practical applications, the communication range of ground-based QKD links is currently limited to around 800 kilometers, which is the maximum distance for ground-based fiber optic QKD communication. This limitation means that QKD is still primarily confined to urban areas or regional ranges, and is far from meeting actual usage needs. To enable long-distance quantum communication, the development of quantum relays and satellite networks is necessary. This trend has been confirmed by actual actions in 2022. For example, the Q-NEXT quantum research organization, led by Amazon and the US Argonne National Laboratory, is collaborating to develop quantum relays. Additionally, the US and South Korea have established a quantum relay cooperation center jointly operated by the Korea Advanced Institute of Science and Technology and Harvard University. Currently, companies such as Qunnect in the United States, supported by the Department of Defense, are dedicated to the development of quantum relays. The development process of quantum relays will reflect the progress of practical quantum networks.

Furthermore, the opening of China's QKD metropolitan area network has opened up a new path towards practical-scale quantum secure communication networks. In addition to China, South Korea, EU countries, and the US are also continuing to advance their own QKD network construction. Although the US National Security Agency has expressed concerns about unverified issues in QKD, actual actions show that US national laboratories and other countries researching quantum technologies have not stopped researching QKD technology and verifying the usability of QKD networks.

Although QKD currently has attractive performance parameters, there is still room for improvement. To meet the broader practical goals of quantum communication, new solutions will continue to emerge. As experiments continue, existing QKD application technologies will be iteratively upgraded and new products released in parallel.

## 03 The development of QRNG is proceeding independently with ongoing technical iteration and expansion of its application scenarios.

Quantum Random Number Generator (QRNG) is a relatively mature product that is known to the general public through Quantum Key Distribution (QKD). Unlike QKD, which is a comprehensive application with a certain system scale, QRNG is a quick entry field for some entrepreneurs who want to enter the quantum field. Meanwhile, QRNG is widely used and has its value not only in the fields of quantum communication and quantum computing, but also in fields such as computational simulation, financial payment, and biological implants. The UK and the EU have established projects for QRNG, such as AQURAND in the UK and QRANGE in the EU. These projects aim to accelerate the commercial and industrial development of QRNG, and are supported primarily by national funding with the collaboration of industrial partners and led by national units.

The smartphone market and the smart driving car market are the closest and most popular QRNG downstream applications to the general public. Samsung has been releasing quantum 5G smartphones with QRNG chips for three consecutive years, and although the size of the chips has not changed in three years, the number of protected smartphone applications has increased. LG and 360 have begun to test and research QRNG applications for smart driving. On the other side that the general public may not see, data center and cloud applications may be a larger market as the underlying data transmission is derived from it. In the future, QRNG products in the form of small devices and chips will continue to serve data center/cloud applications and mobile applications respectively. Mobile applications include smartphones, networked cars, etc. and economically priced QRNG chips will gradually be applied to these products.

## 04 The development of PQC algorithms is underway, but its application planning is still in its early stages

According to an announcement from NIST, a draft of PQC standardization could be released in 2023, with the goal of publishing a set of standards by 2024. The US has notified federal agencies to begin migrating to PQC before running quantum computers. This action is expected to be followed by many countries worldwide, and the transition to PQC standards is expected to occur between 2024 and 2030, as practical quantum computers are anticipated by 2030.

The transition to post-quantum encryption algorithms depends on both the development and adoption of such algorithms. The NIST process of creating new post-quantum cryptography standards is currently underway. China has not yet publicly disclosed any institutions that are working on post-quantum encryption algorithms, but based on China's past efforts in cryptography and related projects, it may begin in the two years following NIST's release.

The recent years' PQC standardization conferences hosted by NIST have involved the participation of many countries, including the US, China, Japan, the Netherlands, Switzerland, Germany, the UK, France, Italy, Canada, South Korea, Russia, Brazil, Australia, Spain, Norway, Belgium, Finland, Denmark, Singapore, Israel. This indicates that these countries are among the first participants and are also the top 15 economies in the world, demonstrating that PQC has gained recognition among major global economies.

## 05 Adopting a classical and hybrid approach before standardization is complete may reduce risk.

What preparations should participants in the industry chain make before the PQC standardization work is finished? As an algorithm application research team, you can choose a currently highly demanded candidate key negotiation algorithm from the standardization projects in which you participate, but as technology evolves, this algorithm may be attacked in the next few years. However, if the PQC algorithm is introduced after the standardization project is completed, security issues still persist. Currently, a mix of classical and quantum-resistant solutions can be used to reduce potential risks. This is because, if quantum computers eventually become a reality, they cannot directly break through information encrypted with post-quantum keys. If security issues are discovered in quantum-resistant algorithms during the transition from classical to quantum-resistant encryption, solutions can be proposed as soon as possible.

## 06 Global cooperation can aid in complementing each other's strengths and accelerate the timeline for technology to reach practical application.

In 2022, there was frequent global cooperation in the field of quantum communication and quantum information science. These collaborations mainly aim to complement each other's weaknesses with each other's strengths or to draw each other into building global, regional, or allied industrial chains in order to combat uncertainties caused by changes in international relations. There are various forms of collaboration, including:

Establishing research centers in fields such as science and technology. For example, the National Research Foundation of South Korea (NRF) invested in the Pritzker Molecular Engineering at the University of Chicago in the United States to jointly lead the creation of a South Korea-United States joint research center dedicated to quantum error correction. Currently, there are five quantum field collaborations within the Korea-United States Science Cooperation Center (KUSCO), including the Entangled-Based Quantum Network Center co-founded by the Korean Standards Scientific Research Institute (KRISS) and the University of Illinois at Urbana-Champaign and the Quantum Relay Center co-founded by the Korean Institute of Science and Technology and Harvard University.

A platform for connecting quantum researchers has been established. For example, a roundtable conference was held in London by twelve countries, including Australia, Canada, Denmark, Finland, France, Germany, Japan, the Netherlands, Sweden, Switzerland, the UK, and the US, to advance the multilateral dialogue on quantum. The conference, called Entanglement Exchange, was initiated by the cooperation of the twelve countries and followed the previous roundtable conference, Pursuing Quantum Information Together, held in Washington in May.

Agreements on quantum technology have been signed between countries. For instance, the US and France signed a quantum technology agreement, which clearly identifies quantum information science as a recognized field for continued research cooperation.

By various forms of cooperation, both parties can complement each other's strengths and technology, which can accelerate the advancement of this new technology.

## 07 Investments in the fields of quantum communication and security will gradually recover and new targets will emerge.

From a macroeconomic perspective, 2022 was the third year in which the global pandemic swept the world. Major economies gradually relaxed pandemic restrictions, which injected timely momentum into the entire economic cycle.

On a meso-level, the QIS budget in the United States declined for the first time since 2019, while news of a decrease in government investment in pre-determined quantum projects in Russia also emerged. This outcome may be related to increased expenses from the 2022 Russia-Ukraine conflict and the economic downturn caused by the COVID-19 pandemic. However, more countries still support quantum communication and security.

At the micro level of businesses, the 2022 Nobel Prize in Physics was awarded in the field of quantum information, which is a great recognition of quantum information science. In this wave of information, a large number of people began to know and pay attention to quantum, and then chose quantum information science in their future education and careers, which has a positive impact on future talent reserves. However, this positive impact is not enough for investment institutions, which are rational. Startups' performances are inevitably discounted to some extent during the pandemic in the past three years, and the original financing plans may be delayed, with a slow growth in the number of investment targets.

## 08 The main technological nations are all nurturing their industrial ecosystems by focusing on quantum technology.

In addition to the alliance of scientific and technological research, many governments consider quantum technology to be a key industry driving future economic growth in their countries. As a result, industry alliances and associations that are guided by the development of industry are gradually being established. Among these, the US QED-C Core Alliance is particularly interesting, as its membership continues to expand and its website and other information are becoming increasingly refined. The alliance's planning is gradually becoming evident. Other countries have also established industry alliances or associations in 2022, such as the Quantum Information Network Industry Alliance (QIIA) established in Beijing in July, sponsored by the China Academy of Information and Communications Technology and guided by the Ministry of Industry and Information Technology; the Quantum Science and Technology Innovation Alliance established in Hefei in September; the UKQuantum Alliance established in the United Kingdom in October; the Australian Quantum Software Network (AQSN) Alliance established in Sydney by the Australian Federal Scientific and Industrial Research Organization in November; and the Anhui Commercial Cryptography Industry Association established in Hefei in December.

Among these, the alliance in Australia, the AQSN, has integrated non-local organizations such as Google Quantum Artificial Intelligence, Okinawa Institute of Science and Technology in Japan (OIST), and the University of Oulu in Finland, in order to promote cooperation and partnerships in quantum hardware and software. In terms of international cooperation in cutting-edge technology, China is clearly unable to compare with the alliances of the United States and Australia.

## 09 Improved communication through industry conferences and other means is beneficial for the development of new quantum technologies.

Despite the impact of COVID-19, which has limited travel and offline meetings, industry conferences related to quantum communication have still taken place in countries such as the United States, China, and Spain, promoting communication between enterprises, governments, and academic organizations within the industry. For example, the International Conference on Quantum Communication, Measurement and Computing (QCMC 2022) was held in Lisbon, Portugal in July, the 17th Conference on the Theory of Quantum Computation, Communication, and Cryptography (TQC 2022) was held at the University of Illinois Champaign in the United States, the 2nd Quantum Industry Conference was held in Hefei, China in September 2022, and the 4th Guangdong Hong Kong Macau Greater Bay Area (Guangdong) Quantum Cryptography and Information Security Summit (CFQCIS) was held in Guangzhou in December. However, these exchanges are still influenced by regional, international, and language factors, such as the limited attendance of guests from outside China in the conferences held in China.

Industry conferences are relatively effective ways of communicating within a regional or industrial alliance, which can help to shorten the process of industry development. Quantum technology is still in a stage where only a small portion is practical and a large amount is in the experimental verification and engineering trial phase. While quantum technology has the potential to create new markets, it remains a challenge for companies already in the field of quantum communication and security, especially for start-ups. This is because many application scenarios are innovative and not yet accepted, some are substitutes for traditional ones, but high R&D costs lead to high product prices, making it difficult for many downstream users to purchase or make large-scale purchases. If companies do not receive enough funding from the government and investment institutions, there will be a lack of motivation for product iteration and cost reduction, inadequate science popularization, and social rejection, making it difficult for the market to grow, slowing the entry of new industry participants, and resulting in a lack of market activity. All of this will fall into a vicious cycle. Therefore, it is called upon for the government and large enterprises to actively participate in supporting the development of the quantum industry, by supporting enterprises, promoting public awareness, reducing the high cost of R&D and production, and promoting the development of the industry.

## 10 Blind optimism is of no benefit to the development of the industry and must continuously solve practical problems in order to continue moving forward.

From a high point of view, where technology drives the progress of society, the quantum information industry is undoubtedly another great progress for human society, but it will take time and even several generations to achieve a peak of expectation. There will be many problems along the way that need to be avoided.

As the quantum information technology is the arena of the world's major technological powers, there will always be some risk no matter how much cooperation there is. For example, in August, Australian quantum company QuintessenceLabs was appointed as the first private sector member of the US Quantum Security Alliance (QSA) Strategic Information Sharing Partner (SISP). The current cooperation between Australia and the US in this field is going smoothly. However, there are also times when cooperation is not smooth, as in November, due to doubts about the UK's willingness to provide reciprocal access to UK projects for EU researchers and to abide by intellectual property rules, the EU excluded the UK from the sensitive quantum projects within the European Horizon Europe in October, and UK companies that have already received funding will not be able to participate if they cannot find a replacement in time. The attitude and outcome of these bilateral cooperation events are a worthy aspect to note for both sides who are in a cooperation relationship or are about to enter into one. Quantum projects often require huge financial and human resources, and projects are rarely completed in a short period. Especially for quantum startups, it is important to learn from the problems that have arisen in others and avoid these problems from happening again.

Despite the fact that many countries around the world have relaxed entry and exit restrictions caused by the pandemic to some extent in 2022, the international situation has not improved. Especially in the field of strategic and cutting-edge science and technology, although countries all hope to cooperate, they also maintain a cautious attitude and the border sense of communication and cooperation is implicit.

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GUANGZIHE was founded in February 2020, as a quantum industry service platform, GUANGZIHE is dedicated to becoming the most trustworthy service institution in the Chinese quantum technology industry by pushing the frontier of quantum technology news, popularizing quantum knowledge, interpreting quantum technology, publishing annual and special reports, etc.

Jan.

Istituto Nazionale di Ricerca Metrologica, the National Institute of Physics, Beijing Academy of Quantum Information Sciences, Toshiba Europe, the University of Leeds and the University of York
Nature Communications
Coherent phase transfer for real-world twin-field quantum key distribution

For the first time, quantum metrology technology, optical frequency combs, has been introduced into quantum communication using dual-band phase stabilization technology. A successful demonstration of precise coherent phase transmission over a 206-kilometer fiber-optic transmission line in three locations in Italy, Bardonecchia, Torino, and Santhià, has solved the need for phase stability in the two-field protocol and provided an efficient and practical solution for twin-field quantum key distribution (TF-QKD).

University of Science and Technology of China
Nature Photonics
Twin-field quantum key distribution over 830-km fibre

By achieving quantum key distribution over 833 km of optical fiber, the record for secure transmission distance has been extended by over 200 km and the secure key rate has been improved by 50-1000 times.

Apr.

Nanjing University
PRX Quantum
Breaking the Rate-Loss Bound of Quantum Key Distribution with Asynchronous Two-Photon Interference

Proposed an asynchronous MDI-QKD protocol that breaks the rate-distance limit and overcomes the rate-distance limit of the dual-rail MDI-QKD. Using the general MDI-QKD technology, the asynchronous protocol achieves time multiplexing through classical post-processing to construct a two-photon Bell state, greatly improving the key rate for intercity transmission and establishing a bridge between MDI-QKD and TF-QKD

Beijing National Research Center for Information Science and Technology, Tsinghua University
Light-Science & Applications
Realization of quantum secure direct communication over 100 km fiber with time-bin and phase quantum states

A new quantum direct communication system, which combines phase quantum states and time stamp quantum states, was cooperatively designed, and successfully achieved secure quantum communication over 100 km, making it the longest quantum direct communication distance in the world so far.

University of Science and Technology of China, Shanghai Center for Quantum Sciences of the CAS
Physical Review Letters Quantum State Transfer over 1200 km Assisted by Prior Distributed Entanglement

Using the "Micius" quantum science experimental satellite, important experimental progress has been made in long-distance quantum state transmission, setting a new record for ground-based quantum state transmission of 1200 kilometers.

May

University of Science and Technology of China, Jinan Institute of Quantum Technology Research
Physical Review Letters
Quantum Key Distribution over 658 km Fiber with Distributed Vibration Sensing

An experimental system that integrates quantum key distribution (QKD) and fiber-optic vibration sensing has been implemented, achieving both long-distance (658 km) fiber-optic sensing with a positioning accuracy of 1 km and successful fiber-optic time-frequency QKD. This breakthrough greatly exceeds the traditional 100 km limit of fiber-optic vibration sensing technology.

QuTech, Kavli Institute of Nanoscience, and Delft University of Technology.
Nature
Qubit teleportation between non-neighboring nodes in a quantum network

Have achieved quantum teleportation between remote non-adjacent nodes in a quantum network. This network employs three optical connection nodes based on solid-state spin qubits. This work demonstrates a key building block for future quantum networks and opens the door for exploring multi-node protocols and applications based on teleportation.

Jul.

Chinese University of Electronic Science and Technology, National Research Council of Canada - Energy, Materials and Telecommunications Center
Photonics Research
Spectrally multiplexed indistinguishable single-photon generation at telecom-band

A collaborative effort proposed and experimentally verified a scheme for frequency-division multiplexing heralded single-photon sources on lithium niobate chips, achieving for the first time fiber-optic communication band frequency-division multiplexing heralded single-photon generation.

University of Science and Technology of China
Physical Review Letters
Toward a Photonic Demonstration of Device-Independent Quantum Key Distribution

We have achieved the first international demonstration of device-independent quantum key distribution (DI-QKD) based on all-optical technology. The achieved bit rate is 466bps (bits per second), and the security of the system was verified at a fiber length of 220 meters.

Aug.

University of Science and Technology of China
Optica
Unbalanced-basis-misalignment-tolerant measurement-device-independent quantum key distribution

A high-stability and high-security error-tolerant MDI-QKD protocol was proposed, and its strong tolerance to non-ideal source-side characteristics was demonstrated through both security analysis and experimental verification.

Sep.

Tsinghua University, Shenzhen University of Technology
ACS Nano
Large-Scale, High-Yield Laser Fabrication of Bright and Pure Single-Photon Emitters at Room Temperature in Hexagonal Boron Nitride

By combining the controllability of laser processing for large-scale manufacturing with the excellent properties of two-dimensional wide-bandgap semiconductor material hexagonal boron nitride (hBN), several key issues with current single-photon sources were resolved, and high-purity and high-brightness single-photon sources were manufactured on a large scale with spatial controllability.

Oct.

Nanjing University, Matrix Time Digital Technology Co., Ltd.
National Science Review
Experimental quantum secure network with digital signatures and encryption

For the first time, non-repudiable transmission of megabit-level images was successfully achieved over a distance of over 100 kilometers using asymmetric quantum cryptography. The research team creatively proposed a "one-time one-hash" approach and constructed a commercially viable quantum digital signature framework by combining the key asymmetric properties of secret sharing and the "one-time one-secret" encryption principle. For example, when signing a megabit file, the signature rate is increased by several hundred million times. This practical quantum digital signature protocol requires only several hundred bits of asymmetric quantum key to achieve information-theoretic secure digital signatures for almost any length of file, ensuring the authenticity, integrity, and non-repudiation of file transmission. This quantum digital signature framework is compatible with various quantum secret sharing and quantum key distribution protocols.

Dec.

University of Science and Technology of China, Jinan Institute of Quantum Technology, Shanghai Institute of Microsystem and Information Technology, Chinese Academy of Sciences, University of Würzburg, University of Oldenburg, University of Kassel, New York University Shanghai
Advanced Photonics
Quantum interference with independent single-photon sources over 300 km fiber

The first successful undeniable transmission of megabit images over a distance of more than 100 kilometers based on asymmetric quantum cryptography. The research group creatively proposed "one-time-one-hash", combined with the asymmetric characteristics of secret shared keys and the encryption principle of "one-time pad" to construct a commercially available quantum digital signature framework. Taking signing a megabit file as an example, the framework increases the signing rate hundreds of millions of times. This practical quantum digital signature protocol only needs to consume hundreds of bits of asymmetric quantum keys to implement information-theoretic secure digital signatures on almost arbitrarily long files, thereby ensuring the authenticity, integrity and non-repudiation of file transmissions. The quantum digital signature framework is compatible with various quantum secret sharing and quantum key distribution protocols.

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| Infineon | Feb. | Introduced the world's first OPTIGA™ TPM (Trusted Platform Module) SLB 9672 with PQC protected firmware update mechanism, a future-proof security solution with post-quantum cryptography and XMSS signature protected firmware update mechanism. This mechanism counteracts the threat of firmware corruption by an attacker with access to a quantum computer and increases the long-term survivability of the device by enabling a quantum-resistant firmware upgrade path. |
| Institute of Electrical Communications, Tohoku University and Nippon Telegraph and Telephone Corporation | | Jointly developing PQC technology, the technology developed this time eliminates the concern of physical attack when implementing international standard candidates (8 out of 9 types) in software or hardware, and it is expected to contribute greatly to international standardization activities. |
| SandboxAQ;Google Nature Transitioning organizations to post-quantum cryptography | May. | Presents an organizational perspective for PQC transition; discusses transition timelines, key strategies for protecting systems from quantum attacks, and ways to integrate pre-quantum cryptography with PQC to minimize transition risk; recommends criteria for starting trials now , and provides a range of other recommendations to enable organizations to achieve a smooth and timely PQC transition. |
| QuSecure | | Introduced QuProtect™, a quantum orchestration platform, a software platform specifically designed for solutions that use quantum secure channels to protect encrypted communications and data with quantum resilience. |
| SK Telecom,SK Broadband | Sep. | It has extended its commercial-grade PQC to use the global virtual network (VPN) of the international network, further improving the security level of the international network part. This marks the first international PQC commercialization by a Korean company. |
| Nippon Toppan Printing Co., Ltd., Japan National Institute of Information and Communications Technology (NICT) | Oct. | Developed PQC's IC card "PQC CARD®" and applied it to medical personnel IC card authentication and access control of electronic medical record data in long-term secure data storage and exchange systems. |
| LG Electronics , LG Uplus ,CryptoLab | | Signing a memorandum of understanding, the three parties will jointly develop PQC technology to enhance automotive network security. |
| WISeKey | Nov. | Introducing QUASARS, a quantum-resistant secure architecture, a radically innovative solution based on the new WISeKey Secure RISC V platform. |
| Mercury Workspace | | Released a Unified Communications and Collaboration (UCC) platform that integrates post-quantum cryptography to protect client data from future quantum computers. |
| Google | | Google Cloud in the United States has enabled the algorithm transmission security ALTS protocol at the application layer of the encryption protocol in Google's internal transmission to ensure that communications on the company's internal infrastructure are authenticated and encrypted. |
| Xiphera | Dec. | Introduced the new xQlave™ product family of IP cores for PQC. The product family offers a comprehensive collection of quantum-secure key exchange and digital signatures implemented as intellectual property (IP) cores in FPGA (Field Programmable Gate Array) and ASIC (Application Specific Integrated Circuit) hardware. |
| Castle Shield | | Announced that its Typhos® secure communications mobile solution now supports the PQC algorithm chosen by NIST for audio and video calls. With this update, all Typhos® functions are protected by end-to-end PQC encryption. |
| Monash University, Oceania Cyber Security Center | | Will operate the Post-Quantum Cryptography in the Indo-Pacific Program (PQCIP) funded by the US government. PQCIP will help participating organizations and government entities conduct detailed assessments of their current quantum-resistant cybersecurity capabilities, and will provide tailored education, planning, and cyber threat assessments. The goal of the program is to give participants an in-depth understanding, a comprehensive understanding of relevant tools, and the ability to develop a plan to protect their organizations from the threat of quantum computing. |

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| Japan Nomura Holdings Co., Ltd., Japan Nomura Securities Co., Ltd., Japan National Institute of Information and Communications Technology | Jan. | Japan's Toshiba Corporation and Japan's NEC Corporation, using stock trading operations as a use case, jointly verified the effectiveness and practicability of quantum cryptography in the implementation of future society. Based on the key exchanged by the high-speed QKD device developed by Toshiba and the QKD device developed by NEC, a test case was carried out in combination with actual stock trading operations, and the response time of several different data encryption methods in the process of large-capacity data transmission was measured, and QKD was verified. System and availability of each encryption method. |
| JP Morgan, Toshiba, Ciena | Feb. | Built the first QKD network for securing mission-critical blockchain applications, demonstrating the full viability of the first QKD network for a metropolitan area. The network is resistant to quantum computing attacks and capable of supporting 800 Gbps data rates for mission-critical applications under real-world environmental conditions. |
| Samsung Electronics, SK Telecom | Apr. | Launched the Galaxy Quantum 3, a Quantum 5G smartphone equipped with IDQ's QRNG chip. This is the third consecutive year that Samsung Electronics and SK Telecom have launched quantum 5G smartphones. The QRNG chipset supports reliable authentication and encryption of messages, enabling smartphone users to use apps and services more securely and in a more secure manner by generating true random numbers without patterns. |
| BT, Toshiba, Ernst & Young | | Together they launched the world's first trial of a commercial quantum-secure metro network. The infrastructure will be able to connect numerous customers across London, helping them secure the transfer of valuable data and information between multiple physical locations using QKD over standard fiber optic links. |
| Florida Atlantic University (FAU), Qubitekk, L3Harris | May. | Developing the first UAV-based mobile quantum communications network for the U.S. Air Force, allowing UAVs to seamlessly move between buildings, adverse weather and terrain, and quickly adapt to changing environments, such as combat environments. |
| Blue Bear | | Using its UAV command and control system to carry out information monitoring and reconnaissance mission simulation flight, the mission and target data of this system are protected by symmetric encryption using Arqit's symmetric key agreement platform. During the mission, image data of potential targets was encrypted and securely relayed using Arqit's quantum-safe communication tunnels. In addition, through active authorization of endpoints and frequent rotation of symmetric keys, the attack surface of the system is limited, and complete confidentiality of data is realized. |
| China Mobile | | Held the "Quantum Digital Intelligence, Harmonious Future" achievement conference, released the VoLTE-based quantum encryption call service, and will promote commercial use in Xiong'an and other places. China Mobile (Xiong’an) Industrial Research Institute will jointly develop "quantum + DICT" fusion products with the government and enterprise business department, technology department, integration company, terminal company, and industrial partners such as Xintong Quantum, Weishitong, and TD Bridge. Provide services for government affairs, finance, energy, medical care and other industries. |
| Errol Airport | Jun. | Its Satellite Ground Station Facility has been selected as the newest Optical Ground Station (OGS) to demonstrate and test satellite quantum secure communications. The new facility will enable UK and associated international research teams to connect to satellites with quantum-safe communication payloads to provide quantum security at all distances, including intercontinental security via satellites. The research facility will be funded by the UK's National Quantum Technologies Program as part of the Quantum Communications Hub. |
| Amazon AWS | | AWS Quantum Network Center (CQN) was established to develop products for the quantum network market to realize a global quantum network. While specific products have yet to be announced, AWS will develop new hardware, software and applications for the quantum network. CQN will complement the advanced quantum science and engineering work already underway at the AWS Center for Quantum Computing and the Amazon Quantum Solutions Lab. |
| Fortinet, National University of Singapore | | Signed a Memorandum of Understanding to support Singapore's National Quantum Security Network (NQSN) project in collaboration with the Singapore Quantum Engineering Program (QEP) hosted by NUS. The collaboration will support a proof-of-concept for QEP and explore use cases for quantum-safe communications. NQSN is funded by the National Research Foundation of Singapore (NRF). |

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| Oak Ridge National Laboratory, Qubitekk | Jul. | The QKD-based security authentication (including signature and verification) research and experiment is carried out on the actual smart grid numerical control system. Tests have shown that the authentication based on GMAC (Galois Message Authentication Code) encoding is significantly more efficient than the traditional scheme, and the calculation time is RSA2048>AES256>GMac. The results were published in Scientific Reports. |
| Institute of Microsatellite Innovation, Chinese Academy of Sciences | | The low-orbit quantum key distribution test satellite "Jinan No. 1" developed by Zong Zong successfully entered orbit through a solid launch vehicle "Lijian No. 1" independently developed by the Chinese Academy of Sciences. "Jinan-1" is the second quantum communication satellite launched by China and the world's first quantum micro-nano satellite. The "Low-orbit Quantum Key Distribution Test Satellite" will complete the satellite-to-earth quantum key distribution business, and at the same time carry radiation source detection, supercomputing platform, and space environment detection loads, and use non-toxic liquid ammonia to propel it for later de-orbiting operations. |
| Netherlands QuTech, Eurofiber, etc. | | The collaboration launched a quantum network testbed connecting multiple data centers in the Netherlands. The testbed is based on measurement device-independent quantum key distribution (MDI-QKD) technology developed by QuTech, integrating a corresponding proof-of-concept MDI-QKD system into a commercial fiber optic network. |
| Toshiba US, US Safe Quantum | | Establishing partnerships in the fields of QKD and quantum communications will help meet the growing interest of potential users in North America. |
| Quantum eMotion | Aug. | Announced significant progress in the development of the first blockchain application of its quantum random number generator QRNG2 technology, in particular the completion of the design of a hardware cryptocurrency wallet integrated with QRNG2, enabling the hardware encryption wallet to store encrypted data offline in a quantum encryption device The private key of the currency to prevent hackers from stealing it. |
| SandboxAQ,evolutionQ | | announced a partnership. SandboxAQ will promote evolutionQ's BasejumpQDN software, which is used to manage and secure QKD's key delivery, and optimize the use of QKD to improve efficiency, network adaptation and reduce latency; evolutionQ will integrate and distribute SandboxAQ's security suite and services, and Tap into the company's business, product and technical expertise. |
| 2022 China-ASEAN Satellite Application Industry Cooperation Forum | Sept. | Held in Nanning, Guangxi. The world's first "Beidou Quantum Mobile Phone" was released at this forum. |
| 20 European companies led by Luxembourg SES | | A consortium, with the support of the European Space Agency (ESA) and the European Commission, will design, develop, launch and operate an end-to-end secure QKD system based on the low-orbit satellite EAGLE-1, with the aim of improving Europe's cybersecurity and communications autonomy. |
| Singapore SpeQtral, France Thales Alenia Space | | Sign a memorandum of understanding to research, develop and demonstrate satellite-to-earth quantum communication. The quantum satellite SpeQtral-1 being developed by SpeQtral and the quantum ground receiving station being developed by Thales Alenia Space will be used to conduct joint experiments to demonstrate the feasibility of long-distance transmission of quantum information and demonstrate the inter-city quantum networks currently under construction. interconnection. |
| SKT | | Said to have applied NIST's PQC algorithm to SK Broadband's global VPN system. SKT also stated that after obtaining the KCMVP certification for 10Gbps~100Gbps encryption modules in December last year, it has completed the development of quantum communication encryption equipment hybrid key combination technology in August 2022. The key is combined with the quantum key generated by QKD and used as a key for existing encryption devices. |
| Harvard University, AWS | | Initiate strategic alliances to advance fundamental research and innovation in quantum networking. The work, which provides substantial funding for faculty-led research at Harvard, will support Harvard Quantum Initiative (HQI) research programs in the areas of quantum storage, integrated photonics and quantum materials. |
| JPMorgan | | Announced to join the Q-NEXT Quantum Research Center in the United States, and will cooperate with Q-NEXT to promote the application of quantum technology in basic algorithms, including applications in the financial field. |

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| Oct. | Aliro Quantum | Announced the launch of AliroNet, an entanglement-based full-stack quantum network software solution, which can be used in three different modes, namely: simulation mode, which can be used to simulate, design and verify quantum networks; pilot mode, which can be used to realize small-scale quantum network experiments platform; a deployment model that can be used to expand quantum networks and integrate end-to-end applications. Each mode directly corresponds to one of the three necessary stages of building a quantum network, and the deliverable of the deployment mode is a user-deployed entanglement-based full quantum network. |
| | QuTech | It will use its spin-off company Q*Bird to deploy a new quantum-safe network based on MDI-QKD technology. The central node of the network will be located at the Port of Rotterdam Authority. The Port of Rotterdam Authority, the port base and some nautical service providers will be involved in the test, and data will be exchanged between multiple users in the port in a closed environment. Users will share keys generated by quantum technology and used to implement classical message encryption. |
| Nov. | Arianespace | The EAGLE-1 satellite supporting the European end-to-end security (QKD system) will be launched by Arianespace on a Vega C rocket for the European satellite operator SES as early as the fourth quarter of 2024, completing a three-year in-orbit mission. In the European Space Agency With the support of the European Commission, a consortium of 20 European institutions, led by SES, will jointly design, develop, launch and operate an end-to-end QKD system for the EAGLE-1 satellite to test and verify the space-based security of encryption keys Transmission, and construction of Europe's first sovereign end-to-end space-based QKD system, development and operation of dedicated LEO satellites, while establishing a state-of-the-art QKD operations center in Luxembourg. |
| | China Telecom, China Telecom Quantum | Newly upgraded Tianyi Quantum Secret Voice (Secret Voice 2.0), expanding the high-security instant messaging function integrating graphic security, voice security, video security, and disappearing after reading. Secret Talk 2.0 secure instant messaging system provides integrated mobile office information security protection covering "device-edge-network-cloud", effectively solving users' information security problems in mobile communication office. |
| | EPB,Qubitekk | Launch of the first industry-led commercial quantum network in the United States, designed for private companies, as well as government and university researchers, to run quantum devices and applications in established fiber-optic environments. EPB Quantum NetworkSM is a quantum-as-a-service to accelerate their process of bringing quantum technology to market. |
| | CAS QUANTUMNET | The "Star-Integrated" Quantum Network around Hainan Island (Haikou-Wenchang) and the "Wenchang International Aerospace City Quantum Satellite Ground Station" have completed construction and are now operational. These developments will provide independent and controllable security measures for the safe and secure flow of cross-border and cross-domain data for Hainan Free Trade Port. |
| | IBM, Vodafone Group | Collaborate on quantum-safe cybersecurity to validate and advance potential quantum use cases in telecommunications. |
| | Singapore SpeQtral, Luxembourg RHEA | A strategic partnership has been established whereby the parties will establish the first satellite-based quantum secure links between Singapore and Europe. RHEA will demonstrate intercontinental quantum key distribution and exchange encryption keys between Singapore and ESA member states using SpeQtral-1, SpeQtral's satellite, scheduled for launch in 2024. SpeQtral announced the launch of Southeast Asia's first Quantum Network Experience Center (QNEX) in partnership with Japan's Toshiba Digital Solutions. QNEX is a collaborative technology demonstration platform that will be open to strategic partners, including government agencies and private companies, to support the exploration and prototyping of commercial QKD-based quantum cryptography use cases. |
| | Amazon Web Services(AWS) | It will deepen the quantum communication cooperation with the National Quantum Information Science Research Center (Q-NEXT) of the U.S. Department of Energy, manufacture and develop quantum repeater-related technologies, and use the nanopositioner to connect the fiber tip and the repeater to receive photons. Parts are aligned to address engineering challenges and advance the construction of quantum networks. |

Dec.

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| China Telecom, Huawei, HKUST QuantumCtek , China Telecom Quantum. | The "OTN Quantum Encryption Dedicated Line" was released to enable high-level security and confidentiality of business transmission, and effectively promote the commercialization of quantum encryption on the transport network. |
| Germany UET, Dresden University of Technology | Launch of the 6G-QuaS research project with the goal of demonstrating applications in industrial networks for more secure communications and performance enhancements, and enabling the integration of quantum technologies with existing telecommunication infrastructure, showing how quantum networks with new encryption protocols compare to previous systems advantage of design. The project is funded by the German Federal Ministry of Education and Research as part of the "Innovation Center for Quantum Communications" program and is expected to run until 2025. |
| Aegiq, University of Exeter, Luxmoore Laboratories | The collaboration launched the U-Quant project, which aims to develop economical intercontinental quantum links. This project will take advantage of true quantum light sources to provide improved space communication capabilities and explore new materials for single-photon generation. The project, led by Aegiq and funded by Innovate UK, will bring to market an integrated quantum communication system with low loss and low SWaP (size, weight and power). |
| Aegiq, University of Exeter, Luxmoore Laboratories | Launch the U-Quant project, which will take advantage of true quantum light sources to improve space communication capabilities and explore new materials for single-photon generation. The project aims to develop an economical intercontinental quantum link (traditional digital communication mainly uses submarine optical cables, but due to loss, it is not suitable for quantum links). Satellite-based communications offer a near-term solution without the physical vulnerability of undersea communications. |
| Indian National Center for Space Promotion and Empowerment (IN-SPACe), QNu Labs | Signing of a memorandum of understanding to develop indigenous satellite QKD products. QNu Labs, with support from the Indian Space Research Organization ISRO and IN-SPACe, will demonstrate satellite-based QKD quantum-safe communication over unlimited distances. |

## Current Status of Quantum Communication and Security Industry/National Standards in China.

| Standard Number | Standard Name | Industry Field | Approval/Implementation Date |
|---|---|---|---|
| YD/T 3907.2-2022 | Part 2: Single-photon detectors for quantum key distribution (QKD) based on the BB84 protocol | Communication | 2022-09-30<br>2023-01-01 |
| YD/T 3907.1-2022 | Part 1: Light sources for quantum key distribution (QKD) based on the BB84 protocol | Communication | 2022-09-30<br>2023-01-01 |
| GM/T 0114-2021 | Specification for detection of Trojan-horse BB84 quantum key distribution (QKD) products | National Cryptography | 2021-10-19<br>2022-05-01 |
| GM/T 0108-2021 | Technical specification for Trojan-horse BB84 quantum key distribution (QKD) products | National Cryptography | 2021-10-19<br>2022-05-01 |
| YD/T 3907.3-2021 | Part 3: Quantum random number generators (QRNG) for quantum key distribution (QKD) based on the BB84 protocol | Communication | 2021-05-17<br>2021-07-01 |
| YD/T 3835.1-2021 | Part 1: Test methods for QKD systems based on the Trojan-horse BB84 protocol. | Communication | 2021-03-05<br>2021-04-01 |
| YD/T 3834.1-2021 | Part 1: Technical requirements for QKD systems based on the Trojan-horse BB84 protocol. | Communication | 2021-03-05<br>2021-04-01 |

Source: China Industry Standards Information Service Platform,2023.01

## US Documents Released for PQC Migration

| Date | Name (English/Chinese) | PQC Related Content |
|---|---|---|
| 2022.01 | Memorandum on Improving the Cybersecurity of National Security Department of Defense and Intelligence Community Systems | The National Security Agency (NSA) should revise and provide advisory memos to the Chief Information Officer, including post-quantum protocols, and plan to use post-quantum cryptography (PQC) when necessary. A timetable should be developed to transition systems to using compliant encryption, including post-quantum cryptography. |
| 2022.05 | National Security Memorandum | NIST has established a "Migration to Post-Quantum Cryptography Project" and an industry-open working group within the National Cybersecurity Center of Excellence to study and promote the widespread and equitable adoption of quantum-resistant cryptography standards and technologies. Recognizing the complexity, cost, and time required for a complete transition to post-quantum cryptography standards, the NSM provides agencies with a roadmap for taking stock of their IT systems and requires them to set and meet specific milestones. This will help ensure that federal agencies have the necessary support to effectively and fully protect their networks from future exploitation. |
| 2022.06 | United States Continues to Strengthen Cooperation with G7 on 21st Century Challenges, including those Posed by the People's Republic of China (PRC) | Strengthen G7 network collaboration to deploy PQC technology, ensuring secure interoperability between ICT systems and promoting digital economic growth. |

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| | Jul. | |
| NIST | | The first batch of PQC algorithms has been announced to be part of NIST's post-quantum cryptography standard. These four algorithms are CRYSTALS-Kyber for key encapsulation mechanisms (KEMs), and CRYSTALS-Dilithium, FALCON, and SPHINCS+ for digital signatures. |
| | Sep. | |
| ISO/IEC | | The Enquiry stage voting for DIS 23837-1: Information security — Security requirements, test and evaluation methods for quantum key distribution — Part 1: Requirements, and DIS 23837-2: Information security — Security requirements, test and evaluation methods for quantum key distribution — Part 2: Evaluation and testing methods has ended, with the current progress at 40.60%. These standards provide detailed requirements and testing methods for QKD protocols, quantum optical components in QKD transmitter and receiver modules. It is expected to provide guidelines for QKD manufacturers to improve the security of QKD module design and implementation, as well as guide evaluators to test and assess QKD modules, thereby reducing the risk of security operation failure. |
| GSMA,IBM ; Vodafone | | A working group for post-quantum telecom networks has been established to help define policies, regulations, and operational business processes to enhance the protection of telecommunications from the future of advanced quantum computing. The new working group will support the roadmap for post-quantum cryptography and its adoption in the global telecommunications supply chain. |
| | Nov. | |
| NIST | | NIST has announced the fourth round of submissions, and has selected four algorithms (three of which were developed with the help of IBM) to be part of the standardization protocol by 2024. IBM Quantum Safe is taking the lead in understanding and preparing for this risk in telecommunications. |
| | Dec. | |
| Jinan Institute of Quantum Technology, Shandong University, Nanjing University, Nankai University, Nanjing Nanzhi Advanced Optoelectronic Integrated Technology Research Institute Co., Ltd. | | The Chinese national standard "Optical Near Stoichiometric Lithium Niobate Single Crystal Used in Quantum Information" has been approved for a 12-month project cycle. This standard will establish technical requirements, provide testing methods, and quality assessment procedures for the commonly used near-stoichiometric lithium niobate single crystal in the field of quantum information technology, filling the gap in related standards in China. |

**The CTF model is an evaluation and analysis model for future industry participants. ICV TAnK's CTF model helps the public understand the development of cutting-edge technology fields and corresponding companies. Cutting-edge technology has many characteristics, such as un-converged technical roadmaps, high uncertainty in technological development, and early stage commercialization. With the continuous development of technology, a reasonable model is needed to evaluate the comprehensive evaluation of the cutting-edge technology suppliers in a specific period and form a consensus.**

**The CTF model is presented with four different size fan-shaped areas in depth and is composed of three-dimensional coordinates. The horizontal coordinate is the Maturity of Technology (the technical level, such as the supplier's technology, R&D, team, etc.), the lateral coordinate is the Commercialization of Technology (the commercial level, such as the supplier's revenue, customers, use cases, etc.), and the implicit variable (the underlying level, such as the factors accumulated by the supplier in the long-term operation that can promote the development of the enterprise). The CTF model divides the suppliers into the following four fan areas based on their comprehensive performance in different dimensions: Pilot, Overtaker, explorer, and chance-seeker.**

**Due to the high uncertainty in the fast-growing emerging technology, the CTF charts of various sub-fields need to be updated periodically.**

**Fan1 - Pilot: The companies in this sector are characterized by their large scale and have accumulated many experiences in the previous technological development cycle, laying a solid foundation for their entry into the new cutting-edge technology field. These companies have the ability and resources to become the pioneers of the new round of cutting-edge technology and may have a profound impact on the future development direction of the industry.**
**Fan2 - Overtaker: The companies in this sector have developed to a certain extent after a period of time and have a strong new technology R&D strength. Based on the accumulation they have achieved in a specific technology field, these companies have the ability to overtake other companies in the competition and lead the future development of the industry.**
**Fan3 - explorer: The companies in this sector are in the early stage of development and have not yet formed a scale. They are full of potential for development and are characterized by their willingness to take risks and innovation. These companies have the opportunity to become the pioneers of new technologies and lead the future development of the industry.**
**Fan4 - chance-seeker: The companies in this sector are characterized by a lack of strength in both technology and commercialization. They are in a wait-and-see mode and may not have a clear development direction. These companies may miss the best opportunity to participate in the cutting-edge technology field and may face greater risks in the future.**

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| 10 million euros | In January, VTT, the Finnish state-owned technology research center, announced the launch of the Quantum Technologies Industrial (QuTI) project to accelerate the development of quantum technology in Finland. The QuTI project will coordinate the development of new components, manufacturing and testing solutions, and algorithms in areas such as quantum computing, communication, and sensing devices to meet the needs of quantum technology. The alliance consists of 12 partners, partially funded by the Finnish Ministry of Commerce, with a total budget of approximately €10 million. |
| 8.5 million Singapore dollars | In February, the Quantum Engineering Program (QEP) in Singapore will begin testing quantum-secured communication technology nationwide for three years to provide strong network security for critical infrastructure and companies processing sensitive data. The new National Quantum Security Network (NQSN) will deploy commercial technology to conduct tests with government and private companies, conduct in-depth security system assessments, and develop guidelines to support companies adopting this technology. The project is initially planned to deploy 10 nodes and will receive SG$8.5 million (approximately CNY 40 million) in funding over three years. |
| 435 million Canadian dollars | In February, Canada launched the Sherbrooke Quantique quantum innovation zone in Sherbrooke, Quebec, focusing on the field of quantum information applications, with over CAD 435 million in investment raised. |
| 137.9 million Canadian dollars | In March, the Minister of Innovation, Science and Industry announced a total investment of CAD 137.9 million through the Collaborative Research and Training Experience (CREATE) grant from the Natural Sciences and Engineering Research Council of Canada (NSERC) and the Alliance grant, representing an important step in advancing the national quantum strategy. These grants will strengthen Canada's research advantage in quantum science and support the development of talent pipelines to enable the growth of a strong quantum community. |
| 4 million Australian dollars | In May, the Australian Labor Party pledged AUD 4 million to support the cultivation of quantum talents, with AUD 3 million dedicated to training quantum technology PhD students and an additional AUD 1 million to "kickstart" national quantum research and education cooperation based on the Sydney Quantum Academy model, promising to develop this strategically important industry. |
| 650,000 US dollars | In May, the K12 Quantum Talent Development Program, operated by George Mason University's Center for Quantum Science and Engineering, received $650,000 from the $3.5 trillion US House Appropriations bill and will serve as a pilot for quantum physics courses in Fairfax and Loudoun County public schools. The program aims to inspire the next generation of students to pursue this field while cultivating diverse quantum talent in northern Virginia. |
| 2.08 million US dollars | In May, NIST allocated $300,000 to support quantum technology, and the National Institute of Standards and Technology (NIST) of the US Department of Commerce allocated $2.08 million to seven organizations in six states to develop manufacturing technology roadmaps to strengthen innovation and productivity in the entire industry sector in the United States. |

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|  | 1.15 million Canadian dollars | In June, the Canadian government (GoC) is seeking "pre-commercialization prototypes" proposals in three rapidly developing quantum-related technology fields: quantum sensing, quantum communication, and quantum computing. The Canadian innovation solution may provide funding of up to CAD 1.15 million for eligible innovators. |
|  | 23 million Canadian dollars | In June, the government of Alberta and the University of Calgary announced the establishment of a world-class quantum hub, Quantum City, in Alberta. Quantum City will further establish Alberta as a leading technology center and accelerate the development of Calgary's quantum ecosystem. The Alberta government, along with the University of Alberta and the University of Lethbridge, has formed a strategic partnership to provide CAD 23 million for the development of the University of Calgary's Quantum City. |
|  | 23 million Canadian dollars | In June, the Federal Economic Development Agency for Southern Ontario (FedDev Ontario) Minister of State, Helena Jaczek, announced that businesses can now apply to the Regional Quantum Initiative (RQI) in southern Ontario, and FedDev Ontario will provide over CAD 23 million over the next six years to support eligible companies in advancing and commercializing their quantum products and solutions in domestic and global markets. This program is an important step in promoting Canada's national quantum strategy. |
|  | 1 billion Australian dollars | In August, the new Australian federal government plans to use a AUD 1 billion Critical Technology Fund to develop Australia's quantum industry and plans to formulate a national quantum strategy by the end of 2022. |
|  | 11 million euros | In September, the Ministry of Science of the state of Thuringia provided EUR 11 million for the development of quantum communication network infrastructure in Thuringia. |
|  | 54 million rand | In October, the National Alliance led by the University of Johannesburg received a startup fund of 54 million South African Rand (approximately 21.6 million RMB) from the Department of Science and Innovation (DSI) in South Africa to coordinate the establishment of the South African Quantum Technologies Initiative. The initiative will establish quantum nodes in five universities, including the University of Johannesburg, and increase the number of national quantum centers by identifying and supporting emerging quantum leaders. The funds will be used for human capital development, the development of emerging leaders, the use of quantum computers, promotion, and support for quantum communication, quantum sensing, and metrology deployment through start-ups. |
|  | 15 million euros | In November, six research institutions in Catalonia launched a new quantum technology research program, with the ultimate goal of applying it to the future European quantum internet. The program will receive EUR 15 million in funding over the next three years, with EUR 9.7 million coming from the EU's Recovery Fund and the remaining EUR 5.3 million from the Ministry of Science and Innovation. The participating institutions in the program include the Institute of Photonic Sciences (ICFO), the Catalan Institute of Nanoscience and Nanotechnology (ICN2), the Institute of High Energy Physics (IFAE), the University of Barcelona (UB), the Polytechnic University of Catalonia (UPC), and the Autonomous University of Barcelona (UAB). |

## 2022 QIST Cooperation Statement signed by the United States and other countries

| Date | Country | | Event |
|---|---|---|---|
| 2022.04 | US | Finland | Signed the Joint Statement of the United States and Finland on Cooperation in Quantum Information Science and Technology |
| 2022.04 | US | Sweden | Signed the Joint Statement of the United States of America and Sweden on Cooperation in Quantum Information Science and Technology |
| 2022.06 | US | Denmark | Signed the Joint Statement of the United States of America and Denmark on Cooperation in Quantum Information Science and Technology |
| 2022.11 | US | France | Signed the Joint Statement on Cooperation in Quantum Information Science and Technology |



## 2022 International Collaborative Events

| Date | Partner | | Event |
|---|---|---|---|
| 2022.04 | India | US | Decided to promote cooperation in emerging technologies such as communications and quantum science, and urged private companies of the two countries to jointly develop and produce defense equipment. |
| 2022.09 | South Korea | US | Opened the Korea-US Quantum Technology Cooperation Center in Washington |
| 2022.10 | European Commission | Canada NSERC | Co-funding €2.8 million to fund the Hyperspace Research Project (HYPERSPACE) on Satellite-based Quantum Entanglement Distribution. The project will focus on research on integrated quantum photonics and optical space communications, with the goal of building an intercontinental satellite-based quantum network. The research content covers the research and innovation of the entire process chain of optical quantum communication. Eight partners from Europe and Canada, including the Fraunhofer Institute for Applied Optics and Precision Engineering (Fraunhofer IOF), participated in the research project. Among them, Fraunhofer IOF received 300,000 euros in funding. |
| 2022.12 | Ireland | EU | Announced a €10 million investment in a new network designed to protect sensitive data transfers and prevent cyberattacks. The Quantum Communications Infrastructure (QCI) network is the first of its kind in Ireland and will be deployed by IrelandQCI over the next two years. The pilot network is part of a European initiative: to create a secure quantum communication infrastructure across the European Union. The Irish government has committed €5 million to the initiative, matching €5 million in EU funding received by IrelandQCI. |

The United States

| Month | Agency | Policy |
|---|---|---|
| Feb. | National Science and Technology Commission | The Critical and Emerging Technologies List Update has added quantum information technology to its list. In response, the Quantum Information Science and Technology Workforce Development National Strategic Plan has been released, proposing several actions to assess the workforce status and prospects of Quantum Information Science and Technology (QIST), strengthen STEM education at all levels, accelerate the exploration of quantum frontiers, and expand the talent pool for future industries. |
| | White House Office of Science and Technology Policy<br>National Quantum Coordination Office<br>National Science Foundation | The Executive Order on Enhancing the National Quantum Initiative Advisory Committee has been signed to create the National Quantum Initiative Advisory Committee under the National Quantum Initiative Act. The aim is to ensure that the NQI plan and the nation can benefit from evidence, data, and viewpoints from various experts and stakeholders, and provide advice to the President, the Quantum Information Science Committee (SCQIS), and the Economic and Security Impact of Quantum Science Committee (ESIX) on the NQI plan. |
| May | President Biden | The National Security Memorandum on Promoting United States Leadership in Quantum Computing While Mitigating Risks to Vulnerable Cryptographic Systems outlines the current policies and measures related to quantum computing by the US government. It identifies key steps required to maintain America's competitive edge in quantum information science and reduce the risks of quantum computers to the US networks, economy, and national security. |
| | President Biden | The National Security Memorandum on Promoting United States Leadership in Quantum Computing While Mitigating Risks to Vulnerable Cryptographic Systems outlines key steps to maintain U.S. competitiveness in quantum information science and reduce risks to networks, the economy, and national security. |
| Sep. | National Security Agency | The Commercial National Security Algorithm Suite 2.0 (CNSA 2.0) Cybersecurity Ad visory (CSA) has been released to notify National Security System (NSS) owners, o perators, and suppliers of future requirements for Post-Quantum Cryptography (P QC) used in all NSSs. |
| Nov. | White House Office of Management and Budget | The Migrating to Post-Quantum Cryptography statement requires federal agencies to migrate to PQC before running quantum computers and report on high-risk information assets and systems. |
| Dec. | President Biden | The Quantum Computing Cybersecurity Preparedness Act has been signed, involving the transition of executive branch information technology systems to Post-Quantum Cryptography. The Act requires the Office of Management and Budget to prioritize post-quantum cryptography for federal agencies when purchasing or transitioning to new IT systems. |
| | President Biden | The NDDA (National Defense Authorization Act) has been signed, authorizing $768.2 billion in defense spending. The Act mentions "accelerating activities for the development and deployment of dual-use quantum technology," "modifying appropriations programs to support STEM education for primary reserve officer training corps in quantum information science," and "establishing an Economic and Security Impact Committee for Quantum Information Science." |
| | National Quantum Information Science Research Center | Q-NEXT has released A Roadmap for Quantum Interconnects, outlining the resear ch and scientific discoveries needed to develop quantum information distribution technology over the next 10 to 15 years. The roadmap includes three sections, foc using on the applications of quantum interconnects in quantum computing, com munication, and sensing. Each section identifies the scientific and technological t asks needed to advance the research field in the next ten years, lists the compone nts and systems used, proposes problems that the community needs to solve, an d outlines the steps to translate this technology into practical benefits. |

## Appendix 6-3 : Key Words of 2022 China's Quantum Communication and Security Policy

### China Central Government

digital economy, financial data security, high-tech industry, National Natural Science Foundation, future industry technology park, and expanding domestic demand, reflect important areas of focus for promoting technological development and economic growth

### West China, Central China

Sichuan: Digital economy, High-tech industry development
Chongqing: strategic emerging industries

Hubei: Innovation and Development of the Semiconductor Industry, Digital economy

Henan: Future industry layout, construction of new infrastructure, development of scientific and technological innovation, medium-to-long term planning

### North China

Beijing: digital economy

Hebei: Digital Economy Promotion Regulations

Shandong: advanced manufacturing

Liaoning: Structural Adjustment Action Program


### Southeast China

Guangdong: Ten-year plan for basic and applied basic research, strategic emerging industrial clusters, future industrial development, cultivation and expansion of market players, integrated development of innovation chain and industrial chain

Fujian: Funding for high-level overseas talents returning to China

Jiangxi:Future Industrial Development, Digital economy

Hainan: Commercial cryptographic applications, network and data security

Taiwan: Quantum R&D Direction, Quantum Industry Development

### Yangtze River Delta

Anhui: Integrated development of the Yangtze River Delta, Science and technology innovation plan, Development plan for development zones, Development plan for metrology, Construction of world-leading science and technology parks

Shanghai: Digital economy, Future industrial innovation highland

Jiangsu: Circular Development Economic System

Zhejiang: Digital economy

## China

**Jan.**

**State Council of PRC, "14th Five-Year Plan for the Development of Digital Economy"**

Aiming to enhance research and development capabilities in cutting-edge areas such as target sensors and quantum information, and to strengthen self-reliance in critical product assurance, with a focus on advancing digital technology foundations.

**Wuhan Government, "Opinions on Promoting Innovative Development of the Semiconductor Industry"**

Our efforts include supporting the research and industrialization of optical quantum chips, such as single-photon sources, lasers, and detectors; establishing production projects for quantum sensors and precision measuring devices; and advancing common cutting-edge technologies for quantum communication, quantum imaging, quantum navigation, quantum radar, and quantum computing chips.

**Jiujiang Government, "Guiding Opinions on Accelerating the Development of Future Industries in Jiujiang"**

Looking to the future, Jiujiang will concentrate on the three cutting-edge technologies and industrial transformation areas of new energy, life and health, and quantum communication, while also taking into account the cutting-edge technologies required for future scenario applications. We will synergistically cultivate fields such as artificial intelligence, blockchain, flexible electronics, future networks, cutting-edge new materials, advanced equipment manufacturing, and metaverse, and organize the implementation of future industry incubation and cultivation. Additionally, we will plan the layout of a number of future industrial projects and gradually construct a future industrial development system.

**Jiangsu Provincial Government, "Implementation Opinions on Accelerating the Establishment of a Sound Green, Low-carbon and Circular Development Economic System"**

We will actively develop strategic emerging industries, such as the new generation of information technology, new materials, and new energy vehicles, to enhance the new driving forces for the bright orange economy. Our goal is to create a self-controlled, secure, and efficient green industrial chain and supply chain. We will vigorously improve the development level of green environmental protection industries, build a number of green environmental protection industrial bases, create large leading green environmental protection enterprises, and foster "specialized, refined, unique, and innovative" small and medium-sized enterprises. Furthermore, we will proactively plan for future green industries such as virtual reality, additive manufacturing, quantum communication, hydrogen energy, solid-state batteries, and others.

**Anhui Provincial Development and Reform Commission, "Action Plan for Implementing the 14th Five-Year Plan for the Integrated Development of the Yangtze River Delta in Anhui Province"**

We will promote the construction of a "quantum center", accelerate the layout of future industries such as "quantum technology", and advance the research and development of quantum computers.

**Henan Provincial Government, "Action Plan for Accelerating the Layout of Future Industries in Henan Province"**

Our key focus is to cultivate future industries such as quantum information, and to initially establish a national advanced manufacturing cluster in the field of quantum information. Exploring the development of the quantum information industry is one of our main priorities. Specifically, we will concentrate on breakthroughs in the core devices and equipment preparation for quantum communication, quantum computing, and quantum precision measurement. Additionally, we plan to construct a star-to-ground integrated quantum communication network hub and scheduling center in Zhengzhou, as well as establish the Henan section of the national wide-area quantum secure communication backbone network and a Zhengzhou metropolitan quantum communication network.

**Feb.**

**Anhui Provincial Government, "Anhui Province's 14th Five-Year Plan for Science and Technology Innovation"**

We will promote the advancement of industry fundamentals. We will enhance technological innovation in future industries such as quantum information, bio-manufacturing, and advanced nuclear energy, and drive technological transformations in fields such as neuromorphic computing, big data, cloud computing, industrial internet, and blockchain to cultivate and develop a number of future industries. We will fully leverage the R&D advantages in quantum communication, quantum computing, and quantum precision measurement to support the commercial development of the quantum technology industry.。

# Appendix 6-4 : The policy related to quantum communication and security released by China in 2022

China

| | | |
|---|---|---|
| PBC, State Administration for Market Regulation, China Banking and Insurance Regulatory Commission, CSRC, "Development Plan for Financial Standardization in the 14th Five-Year Plan" | | Enhance the standard system for network security and data security in the financial industry. Establish and improve the standard system for protecting critical information infrastructure in the financial industry, and support the enhancement of security capabilities. Emphasize the exploration of application standards for new technologies such as quantum communication. |
| Henan Provincial Development and Reform Commission, "Plan for the Construction of New Infrastructure in Henan Province during the 14th Five-Year Plan" | Feb. | Deploying future networks such as quantum communication networks in advance, accelerating the construction of quantum communication networks and satellite ground stations, and building a national dispatch center for integrated quantum communication networks. Actively introducing research resources from the national laboratory of quantum communication, establishing an internationally top-tier research infrastructure for quantum communication, and exploring the demonstration applications of quantum security in fields such as government affairs. Enhancing the research of cutting-edge technologies such as quantum computing. |
| Liaoning Provincial Government | | Promote and strengthen the development of future industries such as additive manufacturing, flexible electronics, quantum technology, energy storage materials, and others through nurturing and support. |
| Fujian Provincial Human resources and Social Security Department, "Notice on the Pilot Work of Supporting High-level Overseas Study Talents to Return to China in 2022" | | This year, the focus will be on providing support for cutting-edge areas and fundamental research fields such as artificial intelligence, quantum information, integrated circuits, life and health, biological breeding, and aerospace technology. |
| Jiangxi Provincial Government, "Opinions on Further Promoting the Digital Economy to Improve and Strengthen the "Number One Development Project"" | Mar. | We will deepen the transfer and transformation of achievements in the national "03 project," accelerate breakthroughs in key common technologies in the Internet of Things industry, such as intelligent perception, new short-range communication, and high-precision positioning. We will coordinate the planning and layout of major cutting-edge technologies such as quantum communication, neuromorphic intelligence, and 6G. We will carry out major scientific research projects and develop more core technologies with independent intellectual property rights. |
| Anhui Provincial Development and Reform Commission, "Plan for High-Quality Development of Development Zones in Anhui Province during the 14th Five-Year Plan" | | Promote the development of the future industry of quantum technology. In the creation of the 'new generation of information technology industry clusters', it is proposed that development zones in cities such as Hefei and Wuhu should leverage their leading advantages in quantum computing, quantum communication, and quantum precision measurement to accelerate the occupation of the commanding heights of quantum technology and the development of the industry. Make every effort to promote the construction of national laboratories, accelerate the cultivation and development of provincial leading enterprises such as QuantumCTek, CIQTEK, and Origin Quantum, establish a 'quantum center', promote demonstration applications, and build a gathering area for the development of the quantum information industry. |
| Digital Economy Development Office of Zhejiang Province, "Key Points for Promoting the High-Quality Development of the Digital Economy in Zhejiang Province in 2022" | | Accelerate the construction of a batch of future industry pilot zones, including the layout of quantum information industry. |

# Appendix 6-4 : The policy related to quantum communication and security released by China in 2022

China

| Policy | Month | Content |
| --- | --- | --- |
| Shenzhen Government, "Implementation Opinions on Accelerating the Cultivation and Growth of Market Entities" | Apr. | Propose to focus on the development direction of strategic emerging industries such as quantum technology, precisely identify enterprises with "hard-core" technologies and explosive growth potential, and establish a unicorn enterprise cultivation database. |
| Guangzhou Government, "14th Five-Year Plan for the Development of Strategic Emerging Industries in Guangzhou" | | Propose to aim at a group of cutting-edge industries such as quantum technology, and concentrate breakthroughs towards the future. Build Guangzhou as a global and vital source of future industries. This includes planning to establish a quantum internet and quantum communication industrial park, promoting the widespread application of quantum technology in commercial and civil fields, and striving to create a complete quantum information industry chain that spans the upstream, midstream, and downstream. |
| Shenzhen Government, "Implementation Opinions on Accelerating the Cultivation and Growth of Market Entities" | | Propose to focus on the development direction of strategic emerging industries such as quantum technology, accurately target enterprises with "hardcore" technology and explosive growth potential, and establish a unicorn enterprise cultivation system. |
| Chengdu Development and Reform Commission, "14th Five-Year Plan for the Development of Digital Economy in Chengdu City" | | The proposal is to focus on the future trends of the six major digital economies, including quantum technology and 6G communication, and to construct national innovation platforms such as the Sichuan branch of the National Laboratory of Quantum Information Technology. Efforts will be made to expedite access to the national backbone network of quantum secure communications, open the "Chengyu main line" of the national wide-area quantum secure communication backbone network, and launch pilot projects for quantum communication applications. Special emphasis will be placed on the development of quantum communication application schemes, quantum computing software systems, and quantum information materials. In addition, products and services such as IDC based on quantum security technology, quantum switches, and network transmission systems integration will be vigorously developed. We will actively participate in the formulation of national quantum communication technology standards and integrate super applications to boost the quantum communication industry chain. |
| Beijing Municipal Bureau of Economy and Information Technology, "Action Plan for the Open Development of the Full Industrial Chain of Digital Economy in Beijing" | May | It is proposed to enhance the supply capacity of digital technology, including advanced layout in frontier fields such as quantum computing, striving to achieve major original innovations and disruptive achievements. |
| Anhui Provincial Government, "Work Plan for Implementing the Measurement Development Plan (2021-2035) in Anhui Province" | | The main goal proposed is to significantly improve the level of innovation in metrology technology by 2035, with a focus on quantum measurement as the core, leading the country in this field. Specific measures include strengthening research and innovation in measurement basic theory, quantum standards, quantum sensing, and precision measurement. Anhui province's leading advantages in research and development of quantum communication, quantum computing, and quantum precision measurement should be fully utilized to promote the "quantum measurement and standardization" plan, and carry out research on quantum measurement and measurement standard device technology. |
| Shenzhen Government, "Opinions on Developing and Strengthening Clusters of Strategic Emerging Industries and Cultivating Future Industries" | Jun. | Emphasis is placed on the development of quantum computing, quantum communication, quantum measurement, and other fields, with the establishment of world-class R&D, open-source, and standardized public service platforms. The aim is to make breakthroughs in quantum operating systems, quantum cloud computing, and medium-scale quantum processors with noise, as well as the establishment of the Guangdong-Hong Kong-Macau Greater Bay Area Quantum Science Center. |

## Appendix 6-4 : The policy related to quantum communication and security released by China in 2022

China

| Month | Policy | Content |
| --- | --- | --- |
| Jun. | Shenzhen S&T Innovation Commission, "Action Plan for Cultivating and Developing Future Industries in Shenzhen (2022-2025)" | The plan points out that Shenzhen's industrial development has a relatively sound foundation, a relatively complete industrial chain, and four future industries, including quantum information, are in the incubation stage. It is expected that they will become a cornerstone force in strategic emerging industries within 10 to 15 years. |
| | Shenzhen Government, "Opinions of the People's Government of Shenzhen City on Developing and Strengthening Clusters of Strategic Emerging Industries and Cultivating Future Industries" | Indicate that quantum information, including quantum computing, quantum communication, and quantum measurement, is one of the eight key directions for cultivating future industries. Efforts should be made to promote breakthroughs in areas such as quantum operating systems, quantum cloud computing, and medium-scale quantum processors with noise. In addition, the Guangdong-Hong Kong-Macao Greater Bay Area Quantum Science Center should be established. |
| | Shanghai Government, "14th Five-Year Plan for the Development of Digital Economy in Shanghai City" | It is proposed to strengthen the deployment of new network infrastructure, technology research and development, and application innovation, in order to build a network ecosystem for the future. Emphasis will be placed on advanced research and deployment in 6G, IPv6, Wi-Fi6, and quantum communication, and to build a third-generation internet technology application ecosystem that enables interconnectivity of data. |
| Jul. | The 13th Standing Committee of Hebei Province, "Regulations on Promoting the Digital Economy in Hebei Province" | According to the regulations, Hebei Province will support the cultivation of industries such as blockchain, quantum information, and virtual reality. With the legislative protection, the innovation of emerging industries and the development of traditional industries are expected to accelerate in the future. |
| | Hainan Provincial National Cryptography Administration, "Several Policy Measures to Promote the Application and Industrial Development of Commercial Cryptography in Hainan Province" | 15 policy measures have been proposed to safeguard the network and data security of the Hainan Free Trade Port, consolidate the foundation of Hainan's smart security, and promote the digital development of the economy and society. The government, universities, scientific research institutions, and enterprises are encouraged to carry out theoretical research on post-quantum cryptography, lightweight cryptography, and privacy computing through methods such as announcement and appointment to promote major technological innovations and demonstration applications in areas such as autonomous and controllable maritime communication security, integrated management and control of land, sea, and air, cross-border data security, and blockchain. |
| Aug. | Henan Provincial Government, "Work Plan for Accelerating the Construction of Infrastructure in Henan Province to Stabilize the Economy" | It is proposed to focus on cutting-edge fields such as quantum information and plan to build a number of significant science and technology infrastructure. At the same time, the construction of network security infrastructure will be implemented, including the advanced deployment of a quantum communication network, and the construction of the Henan section of the national wide-area quantum communication backbone network and the Zhengzhou quantum communication network. |
| | Zhengzhou Government, "14th Five-Year Plan for Science and Technology Innovation Development in Zhengzhou City" | Encourage leading universities and research institutions to plan major scientific and technological infrastructure such as the basic support platform for quantum information technology. At the same time, implement the action plan to cultivate future industries, including the development of cutting-edge technologies such as quantum chips and superconducting quantum devices in the field of future networks. |

China

| | | |
|---|---|---|
| Guangzhou Government, "Action Plan for Promoting the Integrated Development of Innovation Chain and Industrial Chain in Guangzhou City (2022-2025)" | Aug. | The statement expressed the commitment to leverage innovation as a driver for economic and social development by focusing on emerging pillar industries, emerging advantageous industries, and future industries, including quantum technology. Efforts will be made to seize the initiative in the development of emerging industries and to achieve the deep integration of the innovation chain and industrial chain, in order to support high-quality economic and social development. |
| Shanghai Government, "Action Plan for Developing and Strengthening Future Industry Clusters and Building a Hub of Future Industry Innovation in Shanghai" | Sep. | Clarify the goal of building future industry clusters. Among them, in the construction of future intelligent industry clusters, for quantum technology, it is proposed to actively cultivate the quantum technology industry around quantum computing, quantum communication, and quantum measurement, and promote the application of quantum technology in fields such as finance, big data computing, healthcare, resources and environment. |
| Hefei High-tech Zone, "Action Plan for the Construction of a World-Leading Science and Technology Park in Hefei High-tech Zone" | | Hefei High-tech Zone will take the construction of the Future Industry Innovation and Reform Pilot Zone as its core, and implement eight leading actions to strive to reach the global leading level in partial fields by 2025. By 2035, it aims to have basically built the "World Quantum Center", with the output value of the quantum information industry exceeding 20 billion yuan and the total number of related enterprises exceeding 100. |
| Hubei Provincial Government, "The Three-Year Action Plan for Hubei Province to Become a Stronghold of Digital Economy (2022-2024)" | | It is proposed to implement the Strong Network Foundation Action and focus on building central hub nodes for new infrastructure, accelerating the deployment of quantum scale, and supporting Hubei CAS QUANTUMNET, Hubei Jiaotou Quantum, and Wuhan CAS QUANTUMNET companies to accelerate the construction of the "Wuhe trunk line," "Jinghan trunk line," "Hanguang trunk line" Hubei section, as well as the construction of Hubei Province's quantum secure communication backbone network. By the end of 2024, Wuhan is expected to have basically completed the national "Star-Earth Integrated" quantum communication network core hub node. |
| Henan Provincial Government, "Designing the Mid-to-Long-term Plan for Henan Province Construction (2022-2035)" | | In terms of quantum information research and design, active participation in international and domestic quantum information field standard-setting is proposed, with a focus on breaking through the key technology research and design for core devices and equipment preparation in the directions of quantum communication, quantum computing, and quantum precision measurement. Additionally, exploring and developing quantum communication application products and core equipment, as well as exploring the pilot demonstration of integrated innovation applications such as "quantum + secure government affairs" and "quantum + mobile government affairs." |
| Ministry of Science and Technology of PRC, "14th Five-Year Plan for the Development of National High-tech Industrial Development Zones" | Nov. | The plan proposes to deepen the layout of the quantum industry by focusing on providing science and technology-driven and future-oriented scenarios around quantum technology. It also suggests forward-looking deployment of future industries in areas such as quantum information and other cutting-edge technologies and industrial transformations.。 |
| Ministry of Science and Technology of PRC, Ministry of Education of PRC, "Reply on Pilot Construction of Future Industrial Science and Technology Park" | | The list of pilot projects for the construction of future industry science and technology parks was approved, and the Quantum Information Future Industry Science and Technology Park was selected as a pilot project for cultivation. The University of Science and Technology of China and the Hefei National High-tech Industrial Development Zone will be responsible for the construction of the park |

## Appendix 6-4 : The policy related to quantum communication and security released by China in 2022

China

### Nov.

National Natural Science Foundation of China, "Development Plan of the National Natural Science Foundation of China for the 14th Five-Year Plan Period"

The plan puts forward a total of 115 priority development areas, of which the quantum field accounts for 8 items. This includes conducting relevant research in important areas such as quantum computing, quantum communication, quantum sensing, and quantum precision measurement, as well as studying network security, involving new technologies such as quantum cryptography and IoT security.

The 15th Standing Committee of Beijing, "Beijing Municipal Regulation on the Promotion of the Digital Economy"

According to Article 10 of Chapter 2 of the Regulation, the construction of information network infrastructure should give priority support to new generation high-speed fixed broadband and mobile communication networks, satellite internet, quantum communication, and so on, to form a high-speed and ubiquitous, space-ground integrated, cloud-network converged, and secure and controllable network service system.

Shandong Provincial Government, "Action Plan for Building a Strong Province in Advanced Manufacturing (2022-2025)"

The document proposes an active forward-looking layout for future industries. It emphasizes aiming at cutting-edge areas and key breakthroughs, focusing on life sciences, quantum information, gene technology, future networks, deep sea and space development, hydrogen and energy storage, etc. The document emphasizes efforts to create future technological application scenarios, accelerate innovation breakthroughs, and promote integrated applications.

### Dec.

State Council of PRC, "Outline of the Strategic Plan for Expanding Domestic Demand (2022-2035)"

It is required to systematically layout new infrastructure guided by demand and enhance the service capability of the national wide-area quantum secure communication backbone network. It is also necessary to accelerate the development of new industries and products and implement a number of forward-looking and strategic major national science and technology projects in cutting-edge fields such as artificial intelligence, quantum information, and brain science.

Jinan Government, “Work Report of the Jinan Government”

Jinan Mayor Yu Haitian delivered a work report on behalf of the Jinan Municipal People's Government, emphasizing the need to focus on breaking through in future industries and seizing the development opportunities of the quantum information industry. The city will leverage its position as an important node on the "Beijing-Shanghai trunk line" of quantum secure communication to support the growth of Shandong Quantum and Guoxun Quantumchip, expand the "quantum +" application demonstration, and accelerate the industrialization process of quantum technology. Jinan will also accelerate the construction of an electronic government quantum application research laboratory to provide strong support for public data security.

Sichuan Provincial Science and Technology Department, "Development Plan for High-tech Industries in Sichuan Province during the 14th Five-Year Plan Period (2021-2025)"

In the ten key areas outlined in the "Plan", the sections on electronic information and the digital economy both emphasize the forward-looking layout of cutting-edge scientific research and technological development in the field of quantum technology, the establishment of research and development platforms for quantum technology, and the construction of industrial bases to promote the development of new technology industries in Sichuan province.

# Appendix 6-5 : 2022 Policies Related to Quantum Communication & Security Released

## The United Kindom

| | | |
|---|---|---|
| UK Research and Innovation | Mar. | The UKRI strategy for 2022 to 2027, "Transforming Tomorrow Together," aims to vigorously develop seven technology sectors where the UK has a global advantage. These sectors include advanced materials and manufacturing, artificial intelligence, digital and advanced computing, bioinformatics and genomics, engineering biology, electronics, photonics, and quantum technologies, energy, environment and climate technologies, robotics and intelligent machines. |
| Institute of Physics | Nov. | The release of "A Vision for Quantum Technologies in the UK" aims to support the UK government's quantum strategy. The report presents the UK's quantum vision and 10 recommendations for achieving it. Key focus areas include a roadmap for commercializing quantum products and services, supporting ecosystem development and scaling capabilities, establishing a strong skills base to support the quantum industry, and broader driving factors such as partnerships and communication. |

## Germany

| | | |
|---|---|---|
| Bundesministerium für Bildung und Forschung（BMBF） | Jun. | Germany hopes to increase investment in cutting-edge key technology fields such as artificial intelligence and quantum technology, and work with EU partners to expand Europe's technological sovereignty. The Ministry of Economic Affairs has invested 740 million euros in quantum technology. |
| Bundesministerium für Bildung und Forschung（BMBF） | Aug. | Approximately 28 million euros will be invested to support the QYRO project, a collaboration between the quantum technology start-up Q.ANT, Bosch, Thales Group, and the German Aerospace Center (DLR), to develop attitude sensors that meet the requirements of space. The project will use these quantum-based sensors to achieve high-precision attitude control of small satellites and improve global data communication. The QYRO project plans to launch the first satellite with quantum technology attitude control in 2027. |

## Australia

| | | |
|---|---|---|
| Government 2021 National Research Infrastructure (NRI) Roadmap | Apr. | To guide Australia's 2022 research infrastructure investment plan, it includes supporting the construction of quantum technology infrastructure. |
| National Quantum Strategy: issues paper | Jun. | This document will be used to assist in the development of the national quantum strategy. The development of this strategy will provide information for the Quantum Commercialization Centers and the Australian Quantum Prospectus. |

## Netherlands

| | | |
|---|---|---|
| Quantum Application Laboratory(QAL) | Mar. | The Quantum Applications Lab (QAL) has been launched. QAL is a newly established public-private research and development partnership that provides a unique team of scientists, researchers, engineers, application developers, and software and hardware experts on its leading platform to explore the advantages of quantum computing and bring it to the market. QAL will initially focus on optimizing, simulating, and machine learning applications, which aligns with the roadmap of the Quantum Delta NL Foundation (QDNL). QAL will evaluate and support its partners in moving towards "quantum value" and "quantum advantage", help them develop research strategies, and make investment decisions. |
| PhotonDelta | Apr. | With a total of 1.1 billion euros in public and private investments over six years, including 470 million euros obtained through the National Growth Fund, PhotonDelta and its partners will be able to further invest in photonics startups and expand their scale, production and research facilities, attract and train talent, drive applications, and develop world-class design libraries. PhotonDelta is currently composed of 26 companies, 11 technical partners, and 12 research and development partners, and officials say "the development of photonics technology will open the door to many new applications, including quantum computing." |
| Dutch Research Council(NWO) | May | A total of 142.7 million euros in funding has been provided to seven academic groups in the Netherlands, with the "Quantum Age Materials (Qumat)" project receiving 21.5 million euros to develop prototype materials with stable coherent quantum states. |
| Quantum Delta NL | Sep. | The winners of the first "Quantum SME Call" have been announced, and ten selected quantum SMEs will receive a total of 7.87 million euros in funding. Quantum Delta NL plans to provide 35 million euros in funding to Dutch quantum SMEs over the next seven years, with companies required to provide 17 million euros in matching funds. |
| Quantum Delta NL | Oct. | The Quantum Internet Alliance (QIA), led by the QuTech quantum technology research institute, has launched a seven-year plan to develop a full-stack prototype network connecting cities hundreds of kilometers apart to further establish an innovative quantum internet ecosystem in Europe. The first phase of the project will begin in October 2022 and last for three and a half years, with a total budget of 24 million euros. |
| Quantum Delta NL | Nov. | The Quantum House will become the world's first national quantum campus, consisting of multiple multi-tenant buildings of quantum companies throughout the Netherlands. The Quantum House provides membership to local and international companies, investors, and researchers to work, meet, collaborate and develop their business for future quantum technology. QDNL will establish the Quantum House as a separate program aimed at expanding the technology ecosystem, creating synergies among all expertise surrounding major knowledge institutions in the Netherlands and between quantum hardware and software, and introducing non-technical stakeholders to support the national quantum ecosystem. This is a core goal of the Dutch national growth program, with 615 million euros allocated for this purpose. |

## Spain

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| Spain The first major quantum computing project in the country on a national and business level, CUCO | Jan. | This project is funded by the Spanish National Industrial Technology Development Agency (CDTI) and supported by the Ministry of Science and Innovation as part of the recovery and transformation plan. Currently, seven companies, five research centers, and Valencia Polytechnic University have joined the CUCO project to work together on empowering Spain's strategic industries, including energy, finance, space, defense, and logistics, with quantum computing technology. |

## Japan

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| Government | Jan. | Japan is modifying its national quantum technology strategy to achieve self-sufficiency in this field. The current strategy focuses on basic research at universities and other institutions, but it will now nurture industry by supporting start-ups and other measures. A panel of experts has begun planning and developing the modification plan, and the Japanese government plans to approve these changes by June. |
| Government | Apr. | At a meeting of the Comprehensive Innovation Strategy Promotion Conference at the Prime Minister's Official Residence, a new strategy was formulated for quantum technology and artificial intelligence, emphasizing the importance of these two fields for the country's economic security and disaster warning. With regards to quantum technology, the aim is to develop Japan's first "domestically produced" quantum computer this fiscal year and increase the number of users of quantum technology to 10 million by 2030, in order to accelerate its dissemination in Japan. |
| The Ministry of Defense of Japan Self-Defense Forces<br>"Defense White Paper (2022 Defense White Paper)" | Jul. | The word "quantum" appears 36 times in the document, and topics related to communication include NICT's main collaborative areas with the national information and communication technology research institute and technology in the electronic information and communication field, such as network security technology and quantum cryptographic communication. |
| Japanese Defense Minister | Aug. | According to Yasuichi Hamada, the government will work to fundamentally strengthen defense capabilities to firmly protect the lives and livelihoods of the people, facing various challenges such as ensuring ammunition, researching and developing artificial intelligence, unmanned aerial vehicles, and advanced technologies such as quantum, as well as strengthening defense production and technological infrastructure to maintain the ability to continue fighting. |
| Committee for the Promotion of Comprehensive Innovation Strategy established by the Japanese government | Nov. | A proposal to establish an international quantum technology cooperation center at the Okinawa Institute of Science and Technology Graduate University (OIST) has been made as part of its "Quantum Future Society Vision". The center is now one of Japan's ten innovation centers for quantum technology. The OIST Quantum Technology Center (OQT) was launched on October 31, 2022, to promote research and innovation at the international quantum technology cooperation center. Kae Nemoto, a professor in the OIST Quantum Information Science and Technology Unit, has been appointed as the director of OQT. |

## Korea

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| Ministry of Science and Information Communication Technology (MSIT) | Jan. | The opening ceremony of the Korea Quantum Industry Center, K-QIC, was held in Banqiao to foster quantum technology. The center also shared its commercialization efforts and technological development achievements, and supports collaboration among various industries. Attendees included Samsung Electronics, LG Electronics, KT, SKT, and LGU+.<br>The Ministry of Science and ICT will double the budget for quantum technology to nurture talent, establish a business model using this technology, and develop core quantum technologies. In addition, it will formulate follow-up measures for a memorandum of understanding signed by the Korea Institute of Science and Technology Information (KISTI) and the US Argonne National Laboratory. |
| Meeting chaired by the President of South Korea<br>Ministry of Science and ICT in South Korea<br>National Strategic Technology Fostering Program | Oct. | The plan proposes 12 national strategic technologies, including semiconductors and displays, power batteries, high-tech transportation, new generation nuclear energy, high-tech biotechnology, space and oceans, hydrogen energy, network security, artificial intelligence, new generation communication, high-tech robotics and manufacturing technology, and quantum technology. The South Korean Ministry of Science and ICT has selected these 12 strategic technologies, taking into account factors such as the global competitiveness of the industry, the impact on future industries, diplomatic and security value, and the likelihood of achieving results.<br>The South Korean government plans to increase R&D investment for the aforementioned strategic technologies by 10% from KRW 37.4 trillion in 2022 to KRW 41.2 trillion (approximately RMB 21 billion) and to allocate KRW 2.651 trillion in the 2023 budget specifically for the research and development of technologies such as system semiconductors, small modular reactors (SMRs), 5G open wireless access networks (Open RAN), quantum computing, and sensors. |

## Ireland

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| Tindall National Research Institute, Irish Centre for High-End Computing (ICHEC) | May | The two sides are seeking collaborative partnerships to develop end-to-end quantum technology, particularly in quantum computing and quantum communication for the quantum internet, dedicated to developing quantum computing and quantum internet platforms, software, applications, and services closely integrated with high-performance computing systems. |

## Russia

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| Russian Railways | Aug. | They propose to develop national standards for quantum communication technology and the quantum internet. This will be jointly developed by Russian Railways, the National Technological Initiative (NTI) Skolkovo-based competence center, Technical Committee for Cyber-Physical Systems (TC 194), and Technical Committee for Cryptographic Information Protection (26). |
| Russia's latest memorandum of intent for the high-tech sector roadmap | Dec. | The content involving quantum communication includes ensuring the construction of over 2,500 kilometers of quantum network by 2023 and over 7,000 kilometers by 2024 to achieve the main goals of the quantum network length roadmap. |

## India

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| | Apr. | India held an Indo-Israel Bilateral workshop on Quantum Technologies, attended by 175 experts and scientists from the Indian Institute of Science (IISc), Tata Institute of Fundamental Research (TIFR), IIT Bombay, IIT Madras, IIT Kanpur, IIT Kharagpur, IIT Tirupati, Indian Institutes of Science Education and Research (IISER), Jaypee Information Technology Research Institute (JPIT) Noida, Bharat Electronics Limited (BEL), Centre for Development of Advanced Computing (CDAC), Centre for Development of Telematics (CDoT), and the Department of Space. The workshop discussed areas such as photonic quantum computing, quantum sensing, quantum encryption, quantum magnetometry, atomic clocks, and free-space quantum communication. The workshop agenda also included developing a joint quantum technology roadmap and joint development plans between the two countries. |

## Finland

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| National Quantum Office, VTT Technical Research Centre, IQM Quantum Computing Company, CSC Science Information Technology Centre | Aug. | They have signed a memorandum of understanding to explore and promote research and development cooperation in the field of quantum technology. The two sides aim to accelerate the development of quantum technology hardware components, algorithms, and applications, and to collaborate in high-performance computing for quantum acceleration and ground and satellite quantum communication. The memorandum of understanding will also pave the way for knowledge exchange in the national strategic roadmap for quantum technology. |

## NATO

| Month | Content |
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| Apr. | NATO will establish a new quantum technology center at the Niels Bohr Institute in Copenhagen, Denmark. The center will include a testing center and laboratories for the development and testing of quantum technology, including components for quantum sensors, quantum encryption devices, and quantum computers. |
| Sep. | At the NATO Madrid Summit, the allies reached a consensus to support quantum technology through the Science for Peace and Security (SPS) research program. SPS will focus on integrating QKD and PQC to protect information infrastructure in the best and most comprehensive way for the alliance. |

European Union

Feb. The European Union (EU) has announced plans to establish a satellite constellation infrastructure that will integrate with the European quantum communication infrastructure to provide secure communication for member states in areas such as economy, security, and defense through quantum encryption technology. The total investment for the project is approximately €6 billion, of which the EU will allocate €2.4 billion over five years. According to officials, the initial development and deployment may begin in 2023, with the provision of quantum cryptography services and in-orbit testing in 2025, and full deployment of integrated quantum cryptography technology by 2028 to achieve comprehensive services.

Jul. All 27 EU member states have agreed to jointly develop a quantum communication infrastructure (EuroQCI) covering the entire EU with the support of the European Commission and the European Space Agency.

Sep. The European Commission has positively evaluated the Netherlands' recovery plan and will allocate €4.7 billion under the Recovery and Resilience Facility (RRF) to support its key investment and reform measures. The Netherlands plans to use 26% of the funds to support measures for digital transformation, including investments in quantum technology, artificial intelligence, digital education, and digital government. Of this, €270 million is expected to be allocated to promote the innovative application of quantum technology to support digital transformation.

Nov. The European Commission has positively evaluated the Netherlands' recovery plan and will allocate €4.7 billion under the Recovery and Resilience Facility (RRF) to support its key investment and reform measures. The Netherlands plans to use 26% of the funds to support measures for digital transformation, including investments in quantum technology, artificial intelligence, digital education, and digital government. Of this, €270 million is expected to be allocated to promote the innovative application of quantum technology to support digital transformation.

The Institute of Photonic Sciences (ICFO), the Catalan Institute of Nanoscience and Nanotechnology (ICN2), the Institute for High Energy Physics (IFAE), the University of Barcelona (UB), the Polytechnic University of Catalonia (UPC), and the Autonomous University of Barcelona (UAB) are conducting research on quantum technology with the ultimate goal of applying it to the future European quantum internet. The project has received €15 million in funding over the next three years, including €9.7 million from the European Union's Recovery and Resilience Mechanism funded by the Ministry of Science and Innovation and €5.3 million allocated by the Catalan Government to research institutions.

The Strategic Research and Industry Agenda has released preliminary content that covers and coordinates the "Quantum Flagship Strategic Research Agenda" (SRA), "Strategic Industrial Roadmap for Quantum Chips" (SIR), EuroQCI and EuroQCS projects, and chip legislation, among other European quantum technology industry and research programs, to comprehensively promote the quantum technology (QT) strategy. In the field of quantum communication, the goal is to deploy multiple metropolitan quantum key distribution (QKD) networks, large-scale QKD networks with trusted nodes, QKD manufacturing based on the European supply chain, and the sale of QKD services by telecom companies by 2026, gradually achieving regional, national, European, and satellite-based quantum secure communication network deployment. The long-term goal is to develop a quantum network throughout Europe.

The EAGLE-1 satellite, which supports end-to-end secure quantum key distribution (QKD) systems in Europe, is scheduled to be launched by Arianespace on a Vega C rocket in the fourth quarter of 2024 for the European satellite operator SES. With the support of the European Space Agency and the European Commission, a consortium of 20 European institutions led by SES will jointly design, develop, launch, and operate an end-to-end QKD system on the EAGLE-1 satellite to test and validate the secure transmission of encryption keys from space, and build Europe's first sovereign end-to-end space-based QKD system. The consortium will also develop and operate dedicated LEO satellites and establish a state-of-the-art QKD operation center in Luxembourg.

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