

# Research on International Competition Situation of Quantum Information Technology Based on Patent

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**Abstract:** As a new subject combining quantum physics and information technology, quantum information involves many fields, such as quantum superposition and interference, quantum teleportation, quantum key distribution, precision measurement and so on. Based on the patent data collected in patsnap, this paper analyzes the innovation in the field of global quantum information technology. The results show that the papers in the field of quantum information are a comprehensive cluster of quantum computing, quantum communication and quantum measurement; The global quantum information theory has experienced a long period of development. Quantum computing has become a research hotspot from 2010 to 2019, and its advantages have been reflected; The life cycle of quantum computing is in a growing period and is the most perfect; The United States leads the world in quantum computing research, and China is the most mature in quantum communication research; Beijing, Shanghai, Jiangsu and Guangdong are the key provinces of quantum information theory patent application in China, and universities or research institutions are the key patent applicants.

**Keywords:** Quantum information, Quantum computing, Quantum communication, Patent analysis.

## 1. Introduction

In the 20th century, relying on the most basic principle of quantum mechanics, human launched the combination of quantum mechanics and classical information science, form a new discipline "quantum information science", mainly including quantum computing, quantum communication and quantum measurement, can play a huge advantage in specific application scenarios or field, involving artificial intelligence, financial analysis, biological medicine, materials, energy, communication network, precision measurement, and other aspects.

In quantum information technology, Quantum computation is a class of quantum computing techniques based on the controlled evolution of quantum states, Using the two major characteristics of particle quantum superposition states and quantum entangled states, Expected to become a "new engine" for accelerating development in almost all technological fields; Quantum communication mainly includes quantum key distribution, quantum state invisible transmission, quantum network, etc., Using the new transmission of the entanglement or superposition effect of quantum states; Quantum measurements have two characteristic features, The microscopic particle systems are the observation objects, Quantum states can change, The technical principle is to break through the "Heisenberg" limit by using quantum entanglement, coherence and statistics, Quantum gravity measurement, magnetic field measurement, time reference and other high-precision measurement<sup>[1-2]</sup>。

At present, quantum information technology has become the focus of the future world development of science and

technology, the world attaches great importance to it, have increased policy and financial support, including the United States, China, Australia, eu, Russia, Israel, Japan, South Korea and other countries actively carry out the top planning, technology strategy and research application layout, seize the emerging information technology strategic commanding heights, as shown in table 1.

This paper is based on the wisdom bud patent database system, With quantum computing, quantum communication, quantum computer, quantum superposition state, quantum entanglement state and other retrieval keywords, Since quantum technology mainly involves physics and electricity, Therefore, the IPC classification number is set to departments G and H, The retrieval type is: TA\_ALL: quantum computing {quantum computer (quantum computer), quantum superposition state (quantum superposition state), quantum state (quantum state), quantum algorithm (quantum algorithm), quantum software (quantum software), qubit (qubit), ion trap (ion trap) ANDIPC: (G OR H)}, TA\_ALL: Quantum communication {Quantum Key Distribution (QKD, Quantum Key Distribution), quantum state stealth transmission (QT, Quantum Teleportation), quantum secure direct communication (QSDC, Quantum Safe Direct Communication) and quantum secret sharing (QSS, Quantum Secret Sharing), quantum entanglement (quantum entanglement)}, Quantum measurement {Quantum sensing (quantum sensing), quantum energy levels (quantum energy level), quantum image processing (quantum image processing), quantum precision measurement (quantum precision measurement)}, A total of 14,331 articles were obtained.

**1Table 1.** Global Quantum Information Theory Policies and Strategies

nationality	date of issue	filename	Release agency
America	In 2018,	The National Quantum Initiative Act, or a	United States House of Scientific Committee
	In 2018,	An Overview of the National Strategy for Quantum Information Science"	The White House Office of Science and Technology Policy (OSTP), the National Science and Technology Council (NSTC)
	In 2018,	The National Quantum Initiative Act, or a	Capitol Hill
	In 2020,	The Strategic Concept of American Quantum Networks	White House
	In 2020,	The "The Quantum Internet Initiative"	The United States Department of Energy (DOE)
	In 2020,	"Establish laboratories across the country"	O STP, National Science Foundation (NSF), D OE
Australia	In 2020,	"Quantum frontier"	The White House Office of Science and Technology Policy, the National Science Foundation (NSF), and the U. S. Department of Energy
	In 2021,	"Future research and development and industry"	the White House
	In 2020,	Growing Australia's QuantumTechnology Industry	Australia's National Science Agency
EU	In 2020,	Midterm Report of the Quantum Technologies Flagship	E.U.
	In 2020,	Quantum Information Processing Technology Layout 2020: UK Defense and Security Prospects	The British Defence Science and Technology Laboratory, etc
Russia	In 2018,	Quantum Technology	The British House of Commons Science and Technology Committee
	In 2019,	"The National Quantum Technology Development Roadmap"	The Russian government
Israel	In 2020,	The National Science and Quantum Technology Program	The Israeli government
Japan	In 2019,	Japan's quantum technology innovation and development strategy	Government of Japan
Korea	In 2019,	Five-year development plan for quantum computing Technology	Ministry of Science and Communication Technology
	In 2021,	The 14th Five-Year Plan;	Chinese Government
China	In 2019,	The Outline of the Regional Integrated Development Plan of the Yangtze River Delta	Chinese Government
	In 2017,	Notice on Organizing and Implementing the New Generation Information Infrastructure Construction Project in 2018	National Development and Reform Commission
	In 2016,	The 13th Five-Year Plan;	Chinese Government
	In 2016,	The National Science and Technology Innovation Plan during the 13th Five-Year Plan Period	Chinese Government
	In 2011,	The 12th Five-Year Plan is established in	Chinese Government

## 2. The Overall Situation and Technology Direction of Global Quantum Information Technology Patents

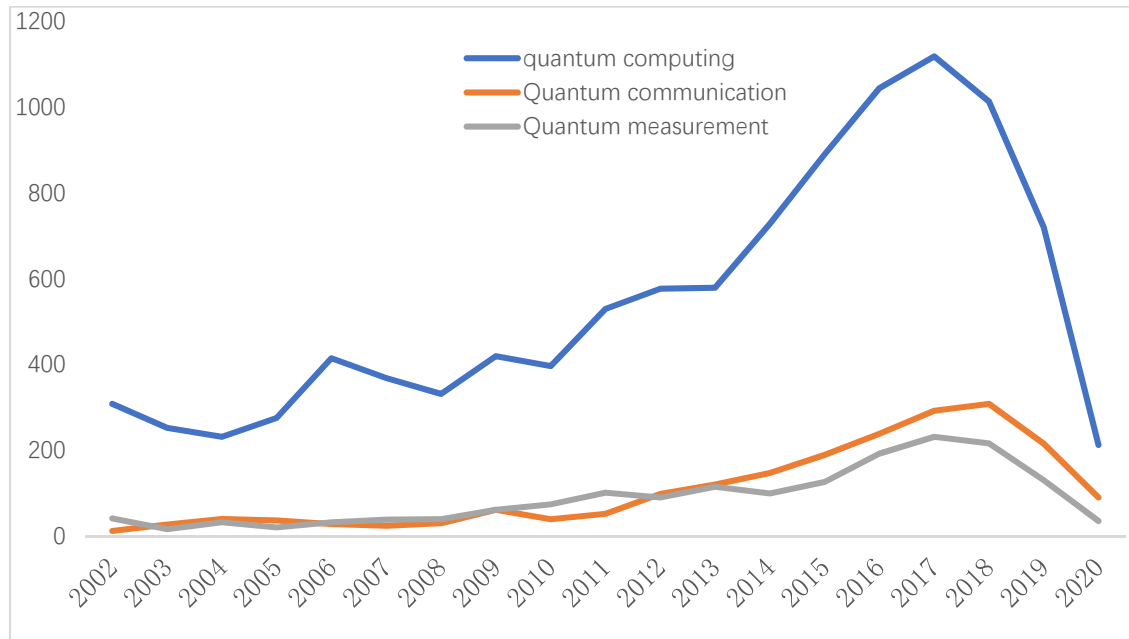
### 2.1. Analysis of the development trend of quantum information patent

From the perspective of the trend of patent application, related patents appeared as early as the 1980s. As the quantum information theory involved relatively little in this period, more theoretical exploration and experimental exploration were the main ones. Figure 1 shows that the number of global quantum information patents is dominated by quantum computing. In terms of the evolution trend, the global quantum computing patents from 2000-2020 have experienced three stages: slow fluctuation period (2002-2014), rapid rise period (2014-2017), and decline period (2017-2020), among which the highest number of global quantum computing patents is 1,118, the lowest is 232, and the height difference is nearly 4 times. Global has been

quantum technology as an important strategic development field, quantum computing as the most important branch in the field of quantum technology, in many directions such as quantum state, quantum superposition, quantum particle, quantum compression, quantum semiconductor, superconducting route, by strong attention, patent application situation rising, there is still software to hardware development path of quantum computing, quantum computer computing problems, challenges but also frontier opportunities, need governments, professional institutions, enterprises and other joint efforts<sup>[3-4]</sup>.

The global number of patent applications for quantum communication and quantum measurement is relatively small, among which the number of quantum communication patents is distributed in 13 to 239, and the number of quantum measurement patents is distributed in 17 to 232, with no more than 300 applications. Quantum communication has gradually shifted from theory to practical and commercialization, such as the total number of QKD and QT technology patent applications is the largest. The number of patents in quantum measurement or quantum measurement is

relatively small, and spin qubits are a new field of quantum measurement.

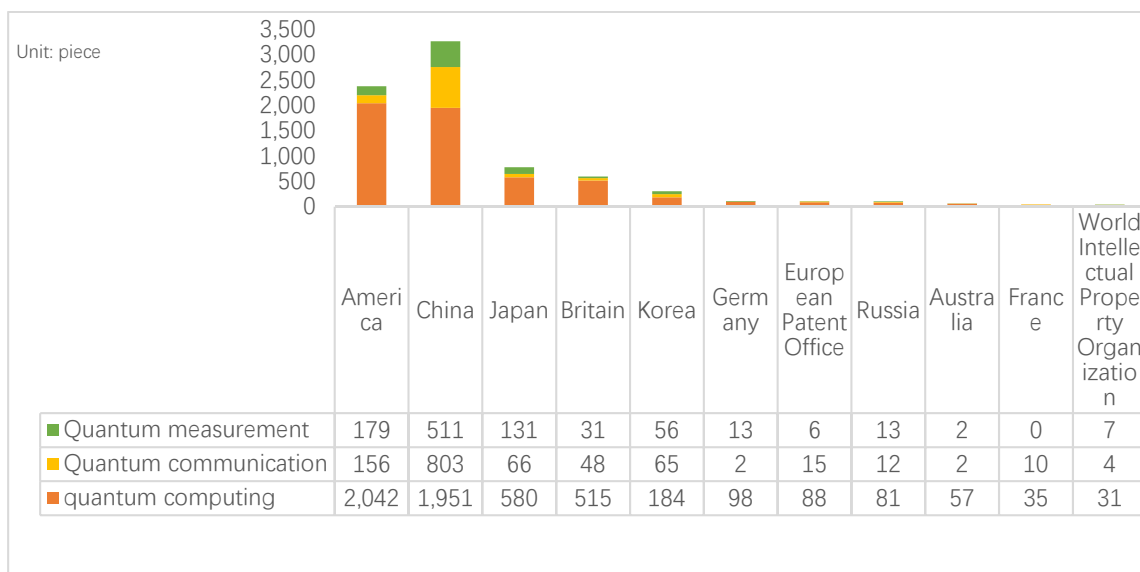


Source: Wisdom Sprout patent database  
**Figure 1.** Global quantum information patent application trend

In terms of the number of quantum information patent applications in the world, the United States has the largest number of quantum computing patent applications, with 1,951 patent applications. In the field of quantum communication and quantum measurement, China has the largest number, with 803 and 511 global patent applications, respectively. It reflects that in the global research progress in quantum computing, the United States has good advantages in the field of quantum computing and has a strong scientific research field. In the global research progress in quantum communication and measurement, China has good international advantages and has the strongest scientific innovation ability. In terms of national quantum information patent invention and innovation ability, the top 10 countries

and organizations in the world are the United States, China, Japan, The United Kingdom, South Korea, Germany, the European Patent Office, Australia, France and the World Intellectual Property Organization.

In terms of the country level, The United States mainly has IBM, Intel, Microsoft, Amazon, Rigetti, Google, MIT and many other quantum research institutions; China mainly has Huawei, Baidu, Alibaba, Tencent, Origin quantum, Science power shield and other institutions; Japan mainly has NTT, NEC, Hitachi, Fujitsu, Sharp and other quantum enterprises; The UK mainly has Isis Innovation, Element Six, River lane, etc.; Canada mainly has D-Wave, IQbit, Quantum Valley, Qoherence Instruments, etc.

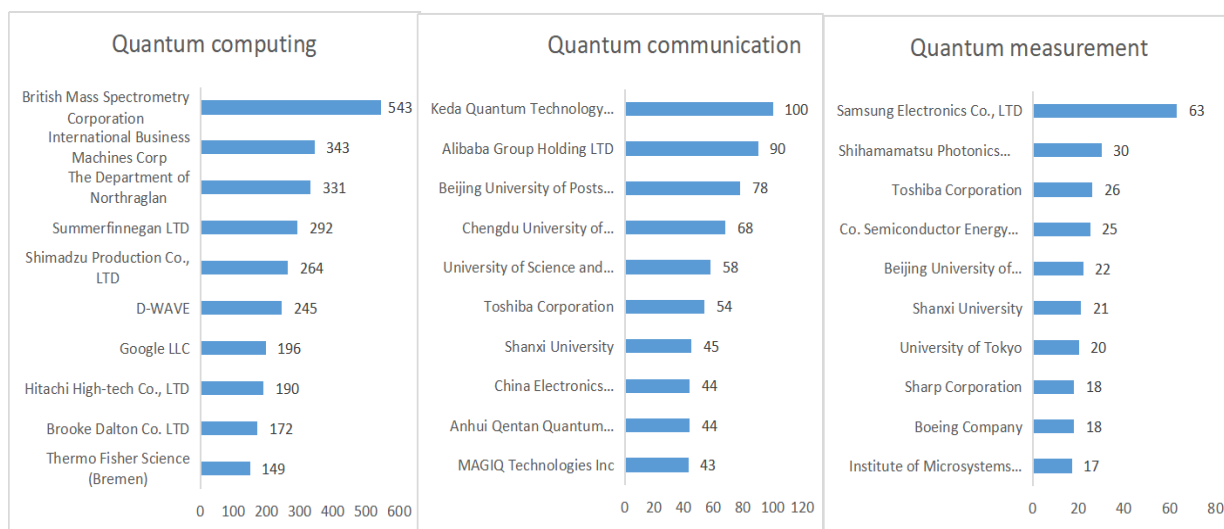


Source: Smart Bud patent Data  
**Figure 2.** Number of quantum information patent applications around the world

## 2.2. Analysis of the patent licensor

Figure 3 reveals that the leading applicants in the global fields of quantum information, In the field of quantum computing, Main applicants for the British mass spectrometry, international commercial machine company, gracorporation, sammer funigan co., LTD., corporation, D-WAVE system, Google, LTD., corporation Hitachi high-tech, brooke Dalton co., LTD., sermo Fisher science (Bremen) co., LTD., The patents of the top five applicants were 543,343,331,292 and 264, respectively; In the field of quantum communication, Main applicants for big shield quantum technology co., LTD., alibaba group holding co., LTD., Beijing university of post and telecommunications, Chengdu university of information

engineering, the university of science and technology of China, Toshiba, Shanxi university, Anhui quantum technology co., LTD., China electronics technology group company electronics research institute, MAGIQ technology company, The top five applicants were 100,90,78,68 and 58 patents respectively; In the field of quantum measurement, The main applicants are Samsung Electronics Corporation, Hamamatsu Toshiba, Toshiba, 7, Semiconductor Energy Research Institute, Beihang University, Shanxi University, Tokyo University, Sharp Corporation, Boeing, Shanghai Institute of Microsystems and Information Technology, Chinese Academy of Sciences, The number of the top five patent applications were 63,30,26,25 and 22, respectively.



Source: Wisdom Sprout patent database  
**Figure 3. Major applicants for global quantum information patents**

## 2.3. Patent distribution of the main technology directions of quantum information

From the perspective of the patent distribution in the main technology directions of quantum information technology, the global quantum information technology hotspot mainly includes H 01J49, H 04L9, G 06N99, G 04B10, G 01N27, G 06N10, H 01L39, H 01L 29, C 09K11, H01L27. In the H 01J49 direction, The United States number is 967 pieces, For 38.6% of the global mainstream countries, In the H 04L9 direction, The China number is 1,275 pieces, For 59.9% of the global mainstream countries, In the G 06N99 direction, The United States, for 643 pieces, For 54.2% of the global mainstream countries, In the H 04B10 direction, China has 570 pieces, For 60.3% of the global mainstream countries, In the G 01N27 direction, There are 376 pieces in Japan, For 45.5% of the global mainstream countries, In the G 06N10 direction, The USA has 432 pieces, For 53.3% of the global mainstream countries, 383 in H 01L39, H 01L29 direction in the US, 276, Accounting for 60.1%, 64.4% of the global mainstream countries, In the C 09K11 direction, In China,

with 361 cases, Accounting for 70.9% of the global mainstream countries, In the H 01L27 direction, The USA has 235 items, It accounts for 52.8% of the global mainstream countries.

The newly announced development direction of quantum information science reveals the latest progress direction of quantum scientific research, and it is also the future development path of quantum information technology.among, The H 01J49 refers to the basic electrical elements, H 04L9 refers to the quotient density algorithm, G 06N99 refers to a quantum computer, That is, using the quantum superposition, correlation, dedispersion, entanglement, non-localization, long-distance transfer for information processing, G 04B10 refers to a transport system that uses divergent particle bundles, G 01N27 refers to the testing or analysis of materials by quantum electric, quantum electrochemical, or magnetic methods, G 06N10 refers to superconducting circuit structures, quantum chips, quantum computers, H 01L39 refers to the preparation method of Josephson knots, H 01L 29 refers to multi-element semiconductor devices.

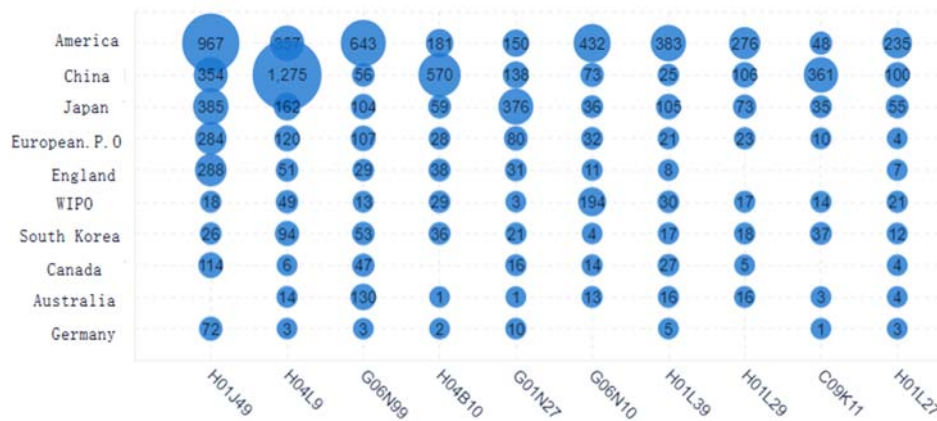


Figure 4. Quantum Information Technology Hotspot

From the point of technology life cycle, quantum computing is relatively flat, in the possibility of growth is relatively large, in recent years, the increasing quantum computing research institutions, quantum cloud platform, quantum processor, quantum, quantum coding, quantum algorithm, quantum software is also quantum computing patent application important technology direction, and the most perfect the quantum computing technology life cycle, technology development frontier, is the quantum information technology industrialization direction<sup>[5]</sup>; The life cycle of quantum communication technology has not yet formed a scale effect. Although the number of research institutions has increased, the patent trend of combining key technologies and industries is relatively developing, such as quantum trunk line, quantum confidentiality, public exchange telephone network, quantum encryption terminal, automobile intelligent charging network, digital signature, etc. Quantum measurement space has a broad prospect, and a complete technical system has not been formed. The patent applications are mainly distributed in quantum gyroscope, quantum clock source, quantum synchronous system, electromagnetic field, gravity, acceleration, angular velocity, etc. The technology life cycle is not yet mature, and there is no complete practical application case.

## 2.4. Quantum information key word analysis

From the perspective of the number of quantum information SCI papers, the number of published papers in various fields of quantum information fluctuated. Through the Web of Science database, more than 40,000 research papers were climbed through the data screening and clarity, and 200 keywords were selected for analysis<sup>[6-7]</sup>. Cluster results are as follows, quantum information keywords can be divided into blue, light yellow, green, red four clusters, light yellow part covers quantum entanglement, quantum communication, quantum password, quantum channel, such as keywords, green part covers quantum information, quantum system, information theory, blue part covers quantum computing, quantum bit, quantum algorithm keywords, red part covers diamond color core, quantum dots, quantum correlation, quantum element and other keywords. Can simply think that quantum information main keywords consists of the following four clusters, the light yellow part represents quantum information communication field, blue part represents quantum information computing field, red part represents quantum information measurement field, from the perspective of research of quantum information field is quantum computing, communication, measurement of three fields.

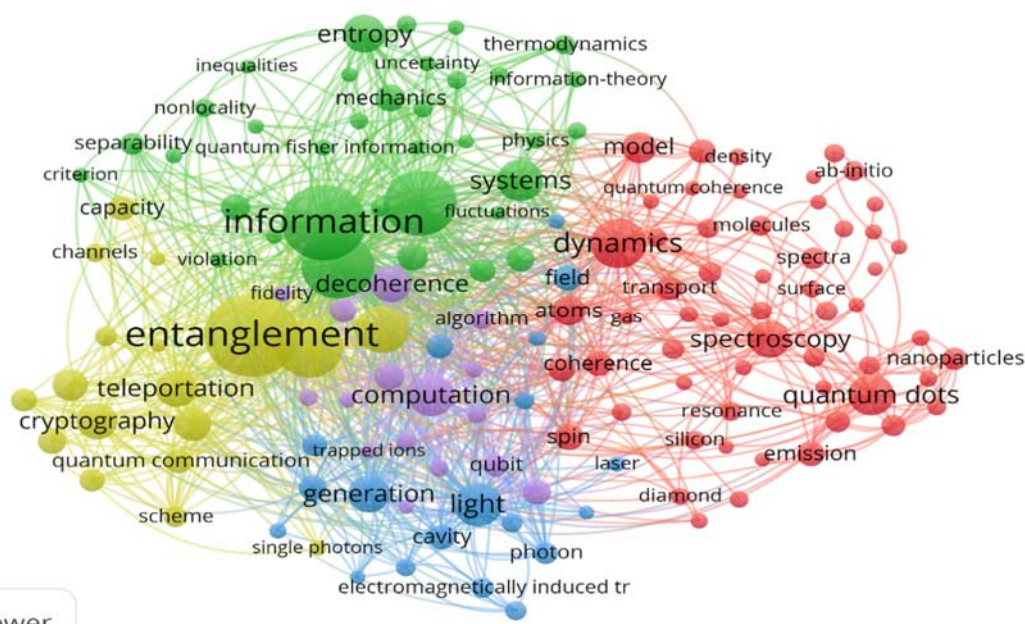


Figure 5. Keyword analysis of quantum information technology topics

From the network diagram of quantum information cooperative institutions, Mainly divided into five clusters, Among them, the blue cluster includes University of Science and Technology, China Academic Journal, Shaanxi University, Anhui University, Nankai University, South China Normal University and other universities; The shallow blue cluster includes the University of Tokyo, Osaka University, Kyoto University, Japan Telecom and Telephone Corporation, the National Institute of Chemistry and other universities or institutions; Dark green includes MIT, Stanford University, Princeton, The University of Washington, Harvard University

and other universities; The red cluster includes the University of Berkeley, Russian Academic Council, University of Paris, University of Copenhagen and other institutions; The purple cluster includes the University of Oxford, the University of Waterloo, Singapore National University, and others. It can be believed that the world is committed to the research of quantum information technology, and a large number of high-level research institutions in the Americas, Asia and Europe are deeply cooperating to form a quantum information research network in the pan-international sense.

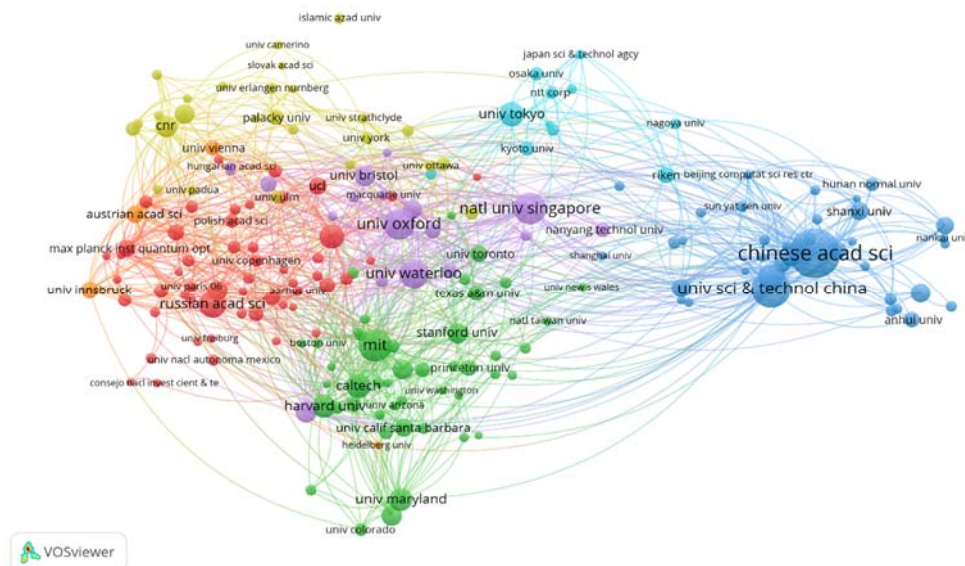


Figure 6. Global Quantum Information Cooperative Network diagram

### 3. Overall Situation and Technology Direction of China's Quantum Information Technology Patents

The search results show that, From the evolution trend of the number of patents in the field of quantum information technology in China, The number of applications in China is consistent with the global situation, Quantum computing is the most important patent technology application direction, It peaked at 325 and 327 units in 2017 and 2018, The average annual growth rate of patents is 0; In the context of patent application directions for quantum computing, 77 Original quantum patents, Baidu network news patents, the number of

17, Alibaba (including Alipay) has 12 patents, Huawei, 12 pieces, Wave of 11 pieces; In the patent application direction for quantum communication, Mainly distributed in Alibaba, Beijing University of Posts and Telecommunications, Shield, Chengdu University of Information Engineering, University of Science and Technology of China, China Electronics Technology Group and other research institutions; In the patent application direction for quantum measurement, The relatively low number of patents, It is mainly distributed in 33 universities and research institutions, including Beihang University, University of Science and Technology of China and China Third Academy of Aerospace Science and Technology<sup>[8]</sup>.

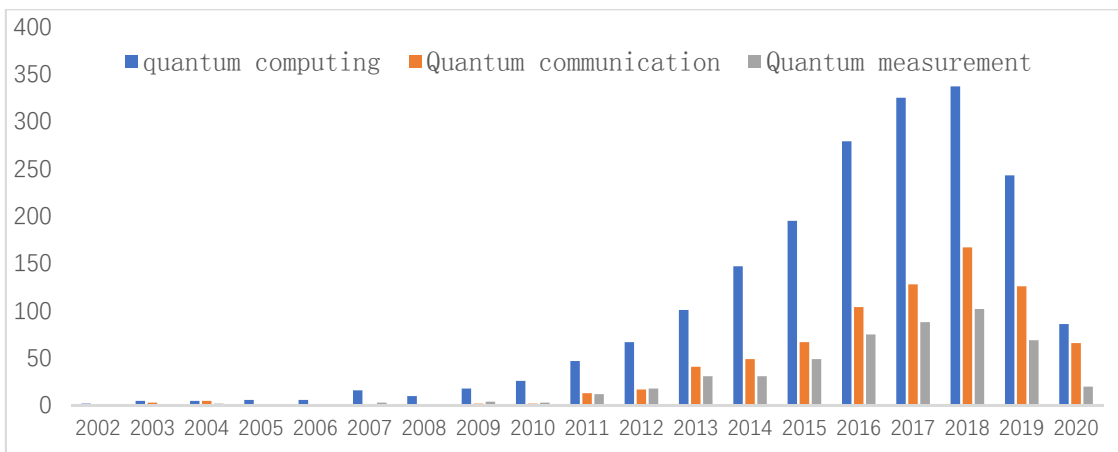


Figure 7. Patent Application Situation of Quantum Information in China

In terms of the number of quantum information technology patents in each province, Beijing, Shanghai, Jiangsu and Guangdong have applied for 911,487,530 and 521, which is the most major quantum information technology patent application provinces in China. In addition, Anhui, Zhejiang, Sichuan, Shaanxi, Hubei and Shandong were the second. In the industrialization pilot, China launched the world's first quantum communication satellite, Micius in 2016. In 2017, China built the world's first commercial quantum secure communication line, the "Beijing-Shanghai Thousand Line", running for 2 kilometers long. At the end of 2018, the state

added two city nodes, Wuhan and Guangzhou, on the basis of the Beijing-Shanghai trunk line, forming the Beijing-Han-Guangdong quantum communication trunk line. New Beijing-Wuhan-Guangzhou line and Wuhan-Hefei-Shanghai line. In 2019, the Plan proposed to build a quantum secret trunk ring network covering 16 major cities; In some cities, distributed in more universities or research institutions, such as Peking University, BPI, Shanghai Jiao Tong University and the University of China continuous key distribution innovation research is very perfect.

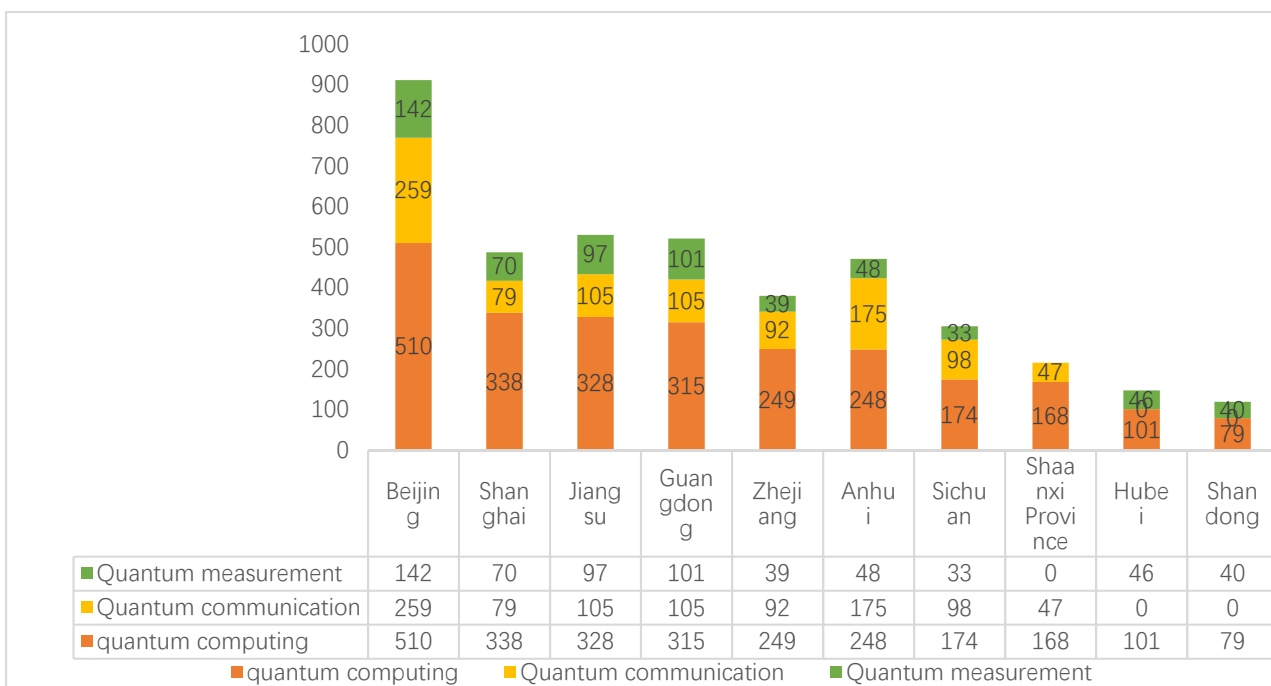


Figure 8. Major provinces for quantum information patent application

In the distribution of keywords in various fields of quantum information, quantum computing is mainly reflected in quantum bits, quantum bits, ion trap, quantum computing, quantum dots, quantum state, mass spectrometer, computer, semiconductor, quantum circuit, in quantum communication, quantum communication, quantum communication, quantum secret key distribution, receiving end, quantum entanglement, quantum state, secret key distribution, beam splitter; in quantum measurement, quantum dots, semiconductor, quantum trap, sensor, light emitting layer, light emitting device, quantum dot layer.

In the number of patent applications for quantum information, the main number of quantum computing patent applications are H 01J-49, G 06N-99, H 04L-9 and G 01N-9, and the number of quantum information patent applications is relatively concentrated. In the direction of quantum communication patent application, mainly concentrated in H 04L-9, H 04B-10, H 04L-29, G 02F-1, the involved direction is relatively concentrated. In the quantum measurement patent applications, the main directions are G 09-11, G 01N-21 and H01L-51, and the number of patent applications is 245,205,178 and 172, respectively.

Table 2. Number of Quantum Information patents in China



Notes: From left to right: quantum computing, quantum communication&quantum measurement

## 4. Summary and Enlightenment

Through analyzing the global patent development trend of quantum information technology, quantum information technology involves encryption algorithm, quantum dots, accelerator, quantum hardware, quantum software, new drug development, key distribution, repeater, quantum entanglement, quantum measurement, quantum sensing, quantum network, and other fields, has a strong strategic leading position. From the analysis of technology application trend, technology area, main applicant, technology mainstream direction, cooperation network map, the following conclusions are obtained, in order to discuss the development of quantum information technology and technology research trend in China.

Global quantum information technology is still in the initial development, as the forefront of the field of quantum information technology, quantum computing involves quantum system simulation, machine learning, image recognition, aerospace, specific computing and other scenarios, ecological use is still a distant concept. According to the patent search results, from 2002 to 2020, there were about 14,000 quIT patents worldwide, with quantum computing accounting for 73 percent<sup>[9]</sup>.

The industrialization or commercialization of quantum information technology is a hot spot, and there are still some problems in key technologies that have not been broken through. For example, the realization of "quantum superiority" is easily subject to interference by external factors such as raw materials, temperature environment and noise to form a decoherence effect. Quantum key distribution, invisible transmission of quantum states and the initial industrialization of quantum network still need to be explored. Quantum precision measurement, spin qubits, quantum clock sources, quantum sensors should be more short push chip, practical.

In the global research on the frontier field of quantum information technology, the United States is at the forefront of quantum computing. During the research period, the number of patents reached 2,071 patents, accounting for about 36% of the global proportion. The United States is one of the earliest countries in the field of quantum computing in the world. In the field of quantum communication, China has 803 patents, accounting for about 67% of the global total. In the field of quantum measurement, China has 511 patents, accounting for 53% of the global quantum information field, Beijing, Shanghai, Jiangsu and Guangdong, accounting for 59%.

With the exploration of basic research of quantum information technology, quantum information technology will become one of the important fields of scientific and technological development in various countries in the world.

The international integration in the field of quantum information technology is closer, and the competition trend of scientific research papers and patent layout will become more and more prominent. In the future, the direction of quantum computing will be possible to develop a general quantum computer, through the coherent manipulation of hundreds of qubits, its computing power exceeds the current supercomputer; quantum communication direction, to create an integrated wide-area quantum information system, to realize the security intersection of national defense, transportation, finance, energy and artificial intelligence<sup>[10-11]</sup>.

## References

- [1] China Information and Communication Institute. Research Report on the Development and Application of Quantum Information Technology [M]. Beijing: China Academy of Information and Communications Technology.2020
- [2] Zhang Qian, Li Wenyu. Global Research on Quantum Information Technology Innovation and Development [J]. Information and Communication Technology and Policy, 2020 (12): 81-85...
- [3] Zhang Qian. Research on the International Competition Situation of Quantum Communication Based on Patent [J]. Information and Communication Technology and Policy, 2019 (10): 10-13.
- [4] Tang Chuan, Fang Junmin, Wang Lina, Zhang Juan. The Development Trend and Planning Analysis of Quantum Information Technology [J]. World Science and Technology Research and Development, 2017,39 (05): 448-456.
- [5] Yuan Pengbin, Tong Hefeng, Zhao Yunhua. Research on Global Blockchain Technology Competition Situation based on Patent Analysis [J]. Global Science and Technology Economic Outlook, 2018,33 (03): 69-76.
- [6] Zhang Zhiqiang, Chen Yunwei, Tao Cheng, Xu Jing, Tian Yanfei. Analysis of International Competition Situation in Quantum Information Research Based on bibliometric measurement [J]. World Science and Technology Research and Development, 2018,40 (01): 37-49.
- [7] Liu Xiaoping, Li Zexia. Analysis of Quantum Interest Based on Common word Analysis [J]. Scientific Observation, 2014,9 (05): 13-22.
- [8] IPR index number. Global Quantum Computing Technology invention patents list [EB / OL].2020(09)
- [9] The White House National Quantum Coordination Office.Quantum Frontiers[EB/OL].2020-10
- [10] OSTP.National Strategic Overview for Quantum Information[EB/OL].2020-09.  
<http://www.whitehouse.gov/ostp/nstc> .
- [11] National congress.Endless Frontier Act[EB/OL].2021-05.  
<https://www.congress.gov/bill/116th-congress/senate-bill/3832>