

THE QUANTUM TECHNOLOGY WAR BETWEEN CHINA AND THE UNITED STATES



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Abstract:

This study examines the technological conflict between China and the United States, with a particular focus on quantum technology. This rivalry has escalated in recent years, especially following Joe Biden's presidency, which aimed to curb China's advancements in quantum technology. Despite these efforts, the study finds that China has emerged as a leading force in quantum technology, surpassing Western nations, even in the face of critical restrictions imposed by the United States, particularly on key quantum components.

key words: Technology Conflict; Quantum Technology; technological cold war; China; United States of America.

ملخص:

تهدف هذه الدراسة إلى التركيز على موضوع الصراع التكنولوجي بين الصين والولايات المتحدة الأمريكية وخاصة في تكنولوجيا الكم والذي تزايد في السنوات الأخيرة وخصوصا بعد تولي جو بايدن الرئاسة للحد من قدرة الصين على تطوير تكنولوجيا الكوانتم واستخدامها. وتوصلت الدراسة إلى أن الصين استطاعت ان تفرض نفسها كقوة تكنولوجية في تكنولوجيا الكوانتم على الدول الغربية بالرغم من التضييق الذي فرض عليها من الولايات المتحدة الامريكية وخاصة في المكونات الحيوية لتكنولوجيا الكوانتم.

الكلمات المفتاحية: الصراع التكنولوجي؛ تكنولوجيا الكوانتم؛ حرب تكنولوجيا باردة؛ الصين؛ الولايات

المتحدة الأمريكية.

Introduction:

The Sino-American conflict is one of the most pressing issues in global politics today, encompassing a range of interconnected challenges influenced by various factors. Over the past few decades, China's rise has intensified competition between the two powers. Initially cantered on political influence—through efforts to win over countries, particularly in Africa, or exert control over international affairs—this competition has since expanded to economic and industrial rivalry. Both nations are now vying for dominance in the global economy. A particularly crucial aspect of this struggle is in the technological arena, notably in quantum technology. This competition could shape the future of global dominance and influence the course of world affairs for decades to come.

In 2017, China initiated a secretive quantum program that remained undisclosed for three years. In late October 2020, the Chinese government finally unveiled this program as part of its 14th Five-Year Plan during the 19th Central Committee meeting of the ruling Communist Party. The plan highlighted key goals related to research and development—areas that have become the central battleground between China and the United States. Among the seven priority fields in science and technology, the first is China's "National Quantum Program," housed at a massive research facility in Hefei. The importance of this initiative was further underscored when Chinese President Xi Jinping met with senior Chinese quantum physicists, emphasizing that the program is a critical component of the national strategy. He likened quantum research to an "advanced piece on the board" in a game of Go—one of the most complex strategic games in the world—where a seemingly insignificant piece can later turn the tide of the game. Xi envisioned China's quantum program playing a similar role on the global stage. With the unveiling of this advanced Chinese quantum program, a fierce cold war over quantum research began between the U.S. and China.

This study seeks to explore the key questions emerging from the post-2020 quantum technology war. Central to this inquiry is the question: **Why does the United States perceive China's technological advancements as a threat—so much so that in January 2024, the U.S. declared a national emergency? And how has China managed to outpace the United States in the field of quantum technology?**

Importance of the Study: The significance of this study stems from its attempt to shed light on a critical aspect of the ongoing struggle for future global dominance between the United States and China. The central question is which nation will ultimately be able to assert its control over the world in the next 10 to 15 years. This paper aims to highlight the quantum technology conflict as one of the newest and most critical arenas of competition, made evident through the

sanctions imposed on Chinese tech companies. These sanctions coincide with the declining prestige of American power in economic and technological domains, especially in contrast to China's remarkable strides in quantum technology and its integration across various sectors.

Study Objectives: This research aims to provide an analytical examination of the technological competition in the field of quantum technology between the United States and China. It seeks to outline the current state of this emerging technology in China, presenting numerous indicators that suggest China's growing superiority in quantum technology. Additionally, the study explores how the United States has responded to China's technological achievements and its emergence as a parallel power.

Methodology: To address the research topic and answer the central questions, this study employs both descriptive and analytical methods. We present the key concepts related to quantum technology and assess its current state in China. Furthermore, we examine the nature of the conflict between the United States and China over quantum technology.

Structure of the Study: The research paper is divided into three main sections. The first section provides an explanation of what quantum technology entails, including its most important applications and fields. The second section focuses on the current state of quantum technology in China. The third section examines the nature of the ongoing conflict over quantum technology between the United States and China, as well as how the U.S. is responding to China's superiority and technological achievements.

I. The Concept of Quantum Technology

Through this element we will try to clarify what is quantum technology.

1. Definition of Quantum Technology:

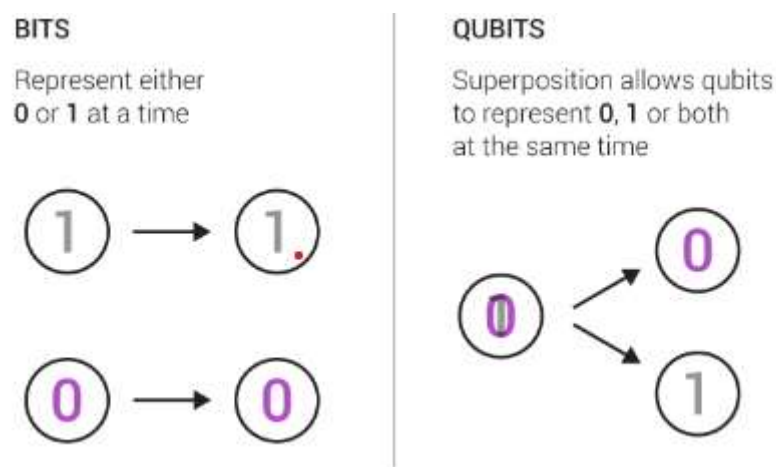
Quantum technology is a complex field within physics that seeks to explore the behaviour of particles smaller than atoms, the fundamental building blocks of all matter (Dylan Duan, 2022). By leveraging principles of quantum mechanics, such as superposition and entanglement, it aims to develop powerful systems with remarkable capabilities across three primary applications:

A. Quantum Computing: Classical computers, which range from smartphones, laptops, and desktop computers to massive servers driving the artificial intelligence revolution, are fundamentally different from quantum computers. Classical computers perform calculations one at a time, and their basic unit of information is the bit, which represents either a 0 or 1 (Dylan Duan,

2022). In contrast, quantum computing is based on a different fundamental unit called the qubit. Qubits are made from atoms and subatomic particles and have the flexibility to represent 0, 1, or both simultaneously through the principle of superposition, allowing quantum computers to process multiple calculations simultaneously.

The incredible properties of qubits give quantum computers extraordinary processing power. For example, a classical computer might take thousands of years to decrypt a highly complex code using its maximum capabilities. In contrast, a quantum computer could solve the same problem in a fraction of a second.

Figure 1: Difference between Bits and Qubits

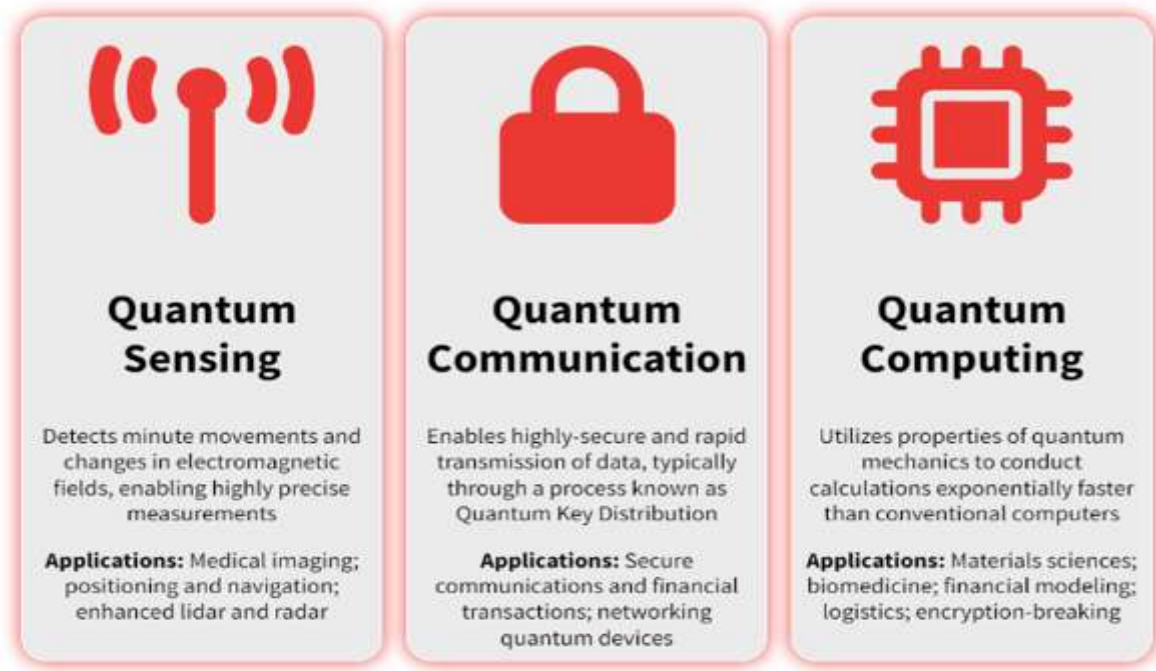


Source : Dylan Duan, "Quantum technology: how it works, applications, and why the US and China are racing to achieve supremacy," 02/01/2022, from the website (<https://www.scmp.com/news/china/science/article/3161830/quantum-technology-how-it-works-applications-and-why-us-and>)

B. Quantum Sensing: Quantum sensing is a technology capable of detecting or measuring minute changes in motion, electromagnetic fields, and physical disturbances with unprecedented precision. Applications of quantum sensors include airborne devices that can detect a submarine hidden hundreds of meters below the ocean's surface or navigation systems that can operate independently for months without relying on GPS signals.

C. Quantum Internet: Quantum internet is a technology that will enable ultra-secure communications by using entangled particles to transmit messages. This would make eavesdropping virtually impossible, as any attempt to intercept the messages would cause changes in the particles, alerting the users.

Figure 02: Quantum Technology Applications



Source: Brian Hart, Bonny Lin, Samantha Lu, Hannah Price, Yu-jie Liao, Matthew Slade,

"Is China a Leader in Quantum Technologies?" from the website:
<https://chinapower.csis.org/china-quantum-technology>.

Chinese quantum physicist Pan Jianwei, regarded as the mastermind behind China's efforts to achieve global leadership in quantum technology and the founder of China's quantum satellite program, spoke after a 2020 meeting between President Xi Jinping and Chinese quantum physicists. In an article published in the official newspaper of the Ministry of Science and Technology of China, Pan stated, "China has been striving to develop three disruptive applications of quantum technology: quantum computing, quantum sensing, and quantum internet."

2. The Relationship between Quantum Technology and Various Challenges:

In general, quantum research is expected to lead to ground-breaking scientific discoveries. Once quantum computers, with their incredible processing power, are fully operational, they will revolutionize nearly every industry, including aviation, automotive, clean energy production, and pharmaceuticals. For instance, quantum computing could pave the way for treatments for diseases like cancer and Alzheimer's. According to a June 2021 report by management consulting firm McKinsey & Company, quantum computing's ability to simulate larger and more complex molecules at faster rates will significantly aid drug development. Consequently, pharmaceutical companies will likely become game-changers, and companies should begin considering their strategic stance toward this promising new technology.

One of the most pressing challenges the world currently faces is climate change. High-speed quantum simulations could help scientists develop more efficient batteries and fertilizers, or even discover innovative ways to reduce carbon emissions.

3.The Relationship between Quantum Technology and Artificial Intelligence:

The current revolution in artificial intelligence (AI), which is rapidly evolving and barely grasped by the human mind, is heavily dependent on massive computational power. Systems like ChatGPT, a form of generative AI, are improving dramatically by the day, fuelled by classical computers. However, if AI systems were to be placed in quantum computers, it would be like adding rocket fuel to the engine. This could lead to a complete transformation of AI systems to the point where we might call it a "technological doomsday."

These are just a few examples of the revolutionary potential of quantum technology, even though it remains in its early stages. Nonetheless, both China and the United States have recently made significant discoveries and inventions in this field.

II.The Current State of Quantum Technology in China

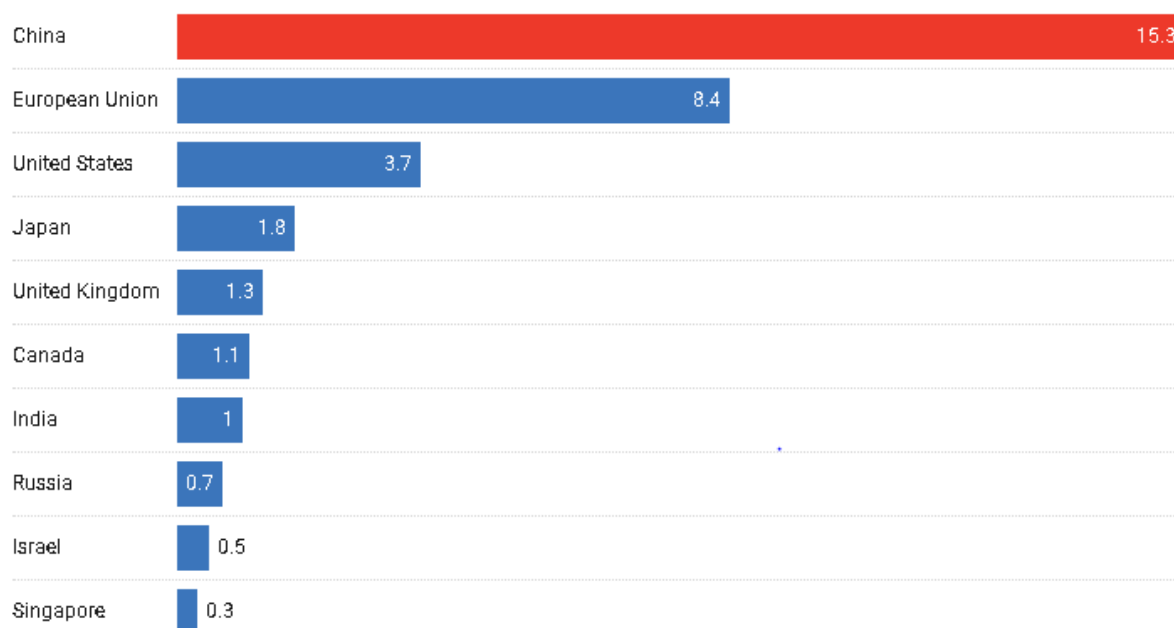
At present, quantum computers operate in extremely complex environments. They require protected settings, can only run for short periods, and are limited to very specific tasks, often making numerous errors. Scientists are still facing significant challenges in stabilizing qubits long enough to perform tasks due to their fragile nature. Quantum entanglement and superposition states are currently very delicate, and without extremely low temperatures and precise environmental conditions, they quickly lose their properties and behave chaotically. For a qubit to function correctly, it must be stored in specialized refrigerators at temperatures near absolute zero, the point at which atomic movement nearly ceases (Dylan Duan, 2022). Thus, studying quantum computing requires vast material and human resources. This is where the competition between China, the United States, and Western countries becomes particularly intense.

On February 15, 2024, the Centre for Strategic and International Studies (CSIS), a well-known American think tank, published a significant research paper that delivered a shock to the United States regarding the ongoing quantum technology battle with China. The report indicated that the U.S. might already be falling behind China in quantum technology (Seth & Palmer, 2024), despite recent U.S. efforts to restrict China's access to quantum technology components—similar to the measures imposed on semiconductors. However, the situation in quantum technology is different. China has already achieved

significant advances and, in some areas, has surpassed the U.S. in quantum technology applications. China also invests more in quantum research than the U.S., as shown by a study from McKinsey & Company. Among the world's nine leading nations in quantum research funding, China is the highest, while Singapore ranks lowest. The following figure illustrates global quantum research funding.

Figure. 03: Government Investment in Quantum Technologies through 2022

Billions of US\$



Source : Brian Hart, Bonny Lin, Samantha Lu, Hannah Price, Yu-jie Liao, Matthew Slade, "Is China a Leader in Quantum Technologies?", from the website: (<https://chinapower.csis.org/china-quantum-technology>).

As shown in the figure, China has committed more than \$15.3 billion to global quantum research—double the combined commitment of European governments and eight times more than the United States. According to McKinsey, this substantial Chinese investment has fostered the rapid development of dozens of Chinese quantum research institutes and the establishment of the first PhD program in quantum technologies in China. This focus has cultivated a research culture that has led to China's rapid progress in the field. Within just a few years, China has started reaping the benefits, as it now holds more than half of the world's quantum technology patents—53.8%, compared to 11.2% for the European Union and 10% for the United States. This is a direct result of China's prioritization of quantum technology as a key aspect of national security.

The Chinese government periodically issues directives to scientists and researchers, encouraging them to achieve breakthroughs in quantum technology

and other advanced technologies. The most recent directive was on January 29, 2024, when a document was released by the Ministry of Industry and Information Technology, the Ministry of Science and Technology, the Chinese Academy of Sciences, and other government bodies. The document called on the entire nation to focus its resources on achieving technological breakthroughs in areas such as quantum computing, graphics processing units (GPUs), brain-computer interfaces, and other cutting-edge technologies, with the goal of dominating future industries. The new guidelines set targets for breakthroughs in at least 100 core technologies by 2025 (Feng, 2024), with China aiming to become a global leader in specific fields by 2027. Shortly before the release of these guidelines, in early January 2024, China stunned the world with a new quantum computing breakthrough. The Chinese company Origin Quantum Computing Technology (Hefei), based in Hefei, announced the third generation of its superconducting quantum computer, the "Origin Wukong." The company had previously delivered its first and second-generation superconducting quantum computers to the Chinese market in 2020 and 2021 (Global Times, 2024), respectively. The third-generation system is several times more efficient than its predecessors, making China the third country, after the U.S. and Canada, to offer a complete quantum computing system.

While classical computers that the world relies on today use silicon chips, quantum computers are different. According to a joint statement from the Anhui Quantum Computing Engineering Research Centre and the Key Laboratory of Quantum Computing Chips in Anhui, the third-generation quantum computer is powered by a superconducting quantum chip named "Wukong." This chip contains 198 qubits (Global Times, 2024) and is currently the most advanced and programmable superconducting quantum computer delivered in China.

2.1 Chinese Companies Leading in Quantum Technology:

Origin Quantum, the Chinese company behind this major achievement, is now competing with tech giants IBM and Google, who also produce superconducting quantum computers. While the number of qubits in IBM and Google's systems may be higher, they have been working on quantum computing since the 1990s. In contrast, Origin Quantum was founded in 2017 by quantum physicists Gue Guoping and Guo Guangcan from the University of Science and Technology of China (USTC). Despite its relatively recent founding, the company has developed China's first quantum chip production line, first quantum computer operating system, and first quantum computing measurement and control system. It also holds numerous patents, making it the top patent holder in quantum computing in China and the sixth globally, following its announcement of the third-generation "Origin Wukong" quantum computer in January 2024.

According to one study, between 2010 and 2022, China's National Intellectual Property Administration (CNIPA) received 1,554 patent applications related to quantum communications—nearly double the number submitted to the U.S. Patent and Trademark Office (USPTO) and four times more than those submitted to the Japan Patent Office (JPO). CNIPA also received over 900 quantum computing patent applications during the same period, fewer than half the number submitted to the USPTO, but twice as many as Japan received (Brian Hart, Bonny, Lu, Price, & Liao, 2024).

Figure 04: Patent Applications Received by Patent Offices (2010–2022)

Patent Office	Quantum Communication	Quantum Computing
China	1,554	908
United States	803	1,838
Japan	372	449
South Korea	207	122
Europe	162	161

Source : Brian Hart, Bonny Lin, Samantha Lu, Hannah Price, Yu-jie Liao, "Is China a Leader in Quantum Technologies?" from the website: (<https://chinapower.csis.org/china-quantum-technology>).

In a surprising move, China recently hosted a forum that allowed anyone worldwide to use its third-generation quantum computer for free for 10 days. During this period, 350,000 visitors from 61 countries accessed the ultra-fast quantum computer, with the majority of users coming from the United States. The system completed around 34,000 quantum computing tasks during this short timeframe. Notably, American quantum computers are not available for use by China, so through this forum, China demonstrated its strength and progress in quantum technology, even surpassing the U.S. in some aspects. China emphasized that this was "just the beginning."

In November 2023, South China Morning Post, a government-backed newspaper, reported that Chinese company SpinQ's QPU, specializing in quantum computing, had delivered the first domestically developed superconducting quantum chip, named "QPU", to a research institute in the Middle East (Tong, 2023), though the exact country or institute was not disclosed.

Founded in 2018 in Shenzhen, southeastern China, SpinQ Technology is one of the fastest-growing Chinese quantum computing companies. It has independently established a research and development centre for superconducting quantum computers and a quantum chip production line. SpinQ

supplies quantum computing products to five continents, including the United States and its allies like Canada, Australia, the UK, Germany, Switzerland, Norway, Japan, Brazil (Shenzhen & Guangdong, 2023), and many other countries, highlighting China's growing influence in the global quantum computing industry.

III. The Sino-American Conflict over Quantum Technology

China has not only continued to make progress but has also dealt a significant blow to the United States, led by Pan Jianwei, the “godfather” of quantum technology in China. Pan spearheaded a research team that achieved a ground-breaking breakthrough in quantum computing, as detailed in a research paper published in *Physical Review Letters* in October 2023. This breakthrough involved the development of the fastest quantum computer to date, named Jiuzhang 3.0, which utilized photons—particles that travel at the speed of light—as a physical medium for computations (Deng, et al., 2023).

Named after an ancient Chinese mathematics textbook, Jiuzhang solved a highly complex mathematical problem in just a fraction of a millionth of a second. In comparison, the world's fastest classical supercomputer, FRONTIER, developed by the United States and crowned the most powerful computer in mid-2022, would take 20 billion years to solve the same problem that Jiuzhang 3.0 solved in a millionth of a second. This quantum leap is both astonishing and ground-breaking.

These Chinese breakthroughs, which have been regarded as a significant blow to the U.S., left American leaders stunned. A report by *The Diplomat* on the quantum technology race between China and the United States stated that in this high-stakes race, coming in second means losing entirely. The first country to master quantum technology will possess tools that will allow it to outpace unprepared competitors. This includes the ability to break current encryption, build unbreakable quantum communication networks, and develop more precise sensors (Howell, 2023).

The leading country in quantum technology will be able to map out the IT infrastructures of companies, armies, and governments faster than they can defend themselves. Despite the stringent restrictions imposed by the U.S. to halt China's progress in this area, China continues to make unprecedented strides. The latest set of restrictions came in August 2023, when President Joe Biden declared a national emergency in response to the Chinese threat. He stated that this move was a response to "the threat posed by advances made by countries of concern in sensitive technologies with military, intelligence, surveillance, or cyber capabilities." While the declaration didn't mention specific countries, it was clearly aimed at China, along with its territories, Hong Kong and Macau. The new restrictions targeted U.S. investments in Chinese companies within three key sectors: quantum technology, semiconductors, and artificial intelligence.

Following the national emergency declaration, an October 2023 congressional committee focused on China launched investigations into Sequoia Capital, a venture capital firm, for its investments in Chinese quantum computing companies, AI firms, and semiconductor businesses. Sequoia was not the only firm under investigation. Other venture capital firms such as GGV Capital, GSR Ventures, Walden International, and Qualcomm Ventures were also scrutinized. These measures were part of a broader U.S. effort to limit China's access to quantum technology (Dylan Duan, 2022). In fact, since 2019, the U.S. Department of Commerce has been consulting with allied countries to block sales of critical quantum technology components to Chinese firms, such as the ultra-low-temperature refrigeration systems used to control qubits. The three largest global manufacturers of these refrigerators are Finland's Blue Fors, the UK's Oxford International, and the U.S.-based Janisult, which together control 70% of the global market for dilution refrigerators in 2021. The U.S. administration had considered imposing a total ban on selling these refrigerators to China. However, China responded swiftly. On February 28, 2024, Chinese media reported that China had begun mass production of a refrigerator called EZ-Q, designed for cooling superconducting quantum computer chips. Chinese reports stated that despite the technological blockade imposed by Western countries, which restricted China's access to essential components for quantum computing research, Chinese researchers at the Anhui Quantum Computing Engineering Research Centre and QuantumCTek Corp.—a leading Chinese company specializing in quantum communication encryption—developed a commercially available dilution refrigerator for global customers (Swayne, 2024). Delivery to clients began in the second quarter of 2023, ending China's dependence on international manufacturers from Finland, the UK, and the U.S.

China has become the U.S.'s biggest nightmare in quantum technology, a source of deep anxiety. This fear is so intense that U.S. officials have distanced themselves from anything related to China. For instance, Katherine Tai, the U.S.

Trade Representative, told the BBC that the sharp decline in trade with China could be seen as a positive, not a negative. In 2023, trade between the world's two largest economies dropped by 20% (Jonathan & Hashmi, 2024), amid a global economic divide causing significant losses. According to a study by the World Trade Organization (WTO), the division between China and the U.S. could cost the global economy 5% of its GDP (Goes & Bekkers, 2022). The role of the WTO has significantly diminished in recent years, and it is now unable to manage trade rule violations between the two largest economies. During the 13th WTO Ministerial Conference in Abu Dhabi, discussions focused on reforming the organization and updating global trade rules, as it has become increasingly ineffective. With potential changes in leadership in the U.S., such as the possible return of Donald Trump to the White House in 2025, there could be further tariffs imposed on China and retaliatory Chinese tariffs, which would heighten the trade war and severely impact the global economy.

Conclusion:

This research paper demonstrates that China's goal is not to steal or imitate American quantum technology but to create an independent technology ecosystem that relies on internal resources, particularly since the imposition of technological sanctions by the United States and its allies. These sanctions, in fact, have accelerated the development of quantum technology in China. Chinese scientists have increasingly turned to domestic patents and quantum research papers following the restrictions on the export of critical components for quantum technology. According to the Offset-X report from the Competitive Studies Project—a bipartisan panel of American experts—the failure of U.S. efforts to decisively win the technological race, especially in quantum technology, against the achievements of China, signals a potential shift in the global balance of power. The statistics and indicators confirm this trend. Based on the discussion of the key issues, it is now evident that the United States and China have entered a new technological cold war, one that could last for an extended period and potentially lead to the creation of a new international order. In this emerging system, the country that controls technology will dominate and shape the global order. This has driven both nations to fiercely compete in the field of quantum technology, aiming to achieve the highest level of technological advancement in order to exert influence over other sources of power.

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