The Prospect of Quantum Technology in Indonesia and the Korean Company's Investment Opportunities

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Quantum technology could transform almost every industry. Quantum computing will revolutionize healthcare, economics, logistics, and artificial intelligence by performing computations significantly more quickly than classical computers and creating unbreakable communication protocols. Indonesia is only starting to develop quantum technologies. However, the government has prioritized quantum research and development. The National Research and Innovation Agency (BRIN) and other Indonesian institutions have also opened quantum research facilities. Quantum technology in Indonesia provides employment opportunities for Indonesians with the necessary skills and attracts international investment and collaborations. Korea has been at the forefront of quantum technology research and development. The Korean government is also actively promoting collaboration with other countries in the field of quantum technology, including Indonesia. The potential for collaboration between Korean and Indonesian companies could result in significant quantum technology advancements that would benefit both countries.

Introduction

The term "industrial game changer" is often used to characterize quantum technology. It has the potential to revolutionize computation, communication, and even medicine. One of the most promising of quantum technology is quantum computing. Classical computers store and process information using binary bits, whereas quantum computers utilize quantum bits, or qubits, which can exist in both the 0 and 1 states at the same time[1]. This allows quantum computers to conduct calculations exponentially faster than classical computers. IBM, Google, Microsoft, Amazon, Rigetti, and other technology leaders offer cloud-based platforms for users to study and experiment with quantum algorithms. For instance, IBM Quantum with their superconducting qubit-based systems, and a user-friendly interface called Qiskit[2]. And Google developed a cloud-based quantum processor known as the Google Quantum Processor Unit (QPU) and

provides access to it via its Cirq platform[3]. While quantum technologies are beginning to expand with potential benefits for a variety of industries. Every country should begin by defining the framework of the strategy, identifying the most impactful quantum technologies for the country, and support funding for quantum technologies. In these few years, the leaders in the development of quantum technology, such as the United States, the United Kingdom, Canada, France, South Korea, China, Australia, and India, have built the strategies and frameworks of this technologies.

Indonesia, as a rapidly developing country and the largest population in South Asia, must be aware of quantum technology to preserve the ability to compete and keep up with global technological advances. Indonesia must have a clear road map and strategy to cash in on the quantum technologies and establish itself as a leader in this field in South Asia. The Indonesian government and expert community should address issues of knowledge at an early stage and start to move on. This requires a collaborative effort between the government, industry, and academic institutions. This also can be accomplished via partnerships with other countries, such as South Korea. In this article, the prospect of quantum technology in Indonesia and the investment opportunities of a Korean company are discussed.

Quantum strategy development

Quantum technology supports the organization and management of complex systems that belong to the laws of quantum physics, or quantum mechanics[1]. This is in contrast with classic technology, which can be explained using classical mechanics. Quantum technology primarily relies on quantum superposition and quantum entanglement[4]. Quantum superposition is the principle that a quantum system can exist in multiple states simultaneously until it is observed or measured, whereas quantum entanglement refers to the phenomenon where two or more particles become connected in such a way that their states become dependent on each other despite being separated by large distances. These principles serve as the foundation for numerous quantum technologies, such as quantum computing, quantum sensors, and quantum cryptography[4,5].

There are five primary ways to advance this technology[6] as shown in Figure 1. First, it is necessary to identify and support priority research areas, such as quantum computing, algorithms, and simulation. Second, highly qualified human resources and talent. Third, the ecosystem and infrastructure for research and development with research centers. This R&D is essential for establishing partnerships and collaborations with the fourth strategy, industry and supply chain, in order to advance quantum technology readiness. Lastly, market opportunities and the adoption of this technology should be supported to ensure that businesses benefit from new opportunities and that investors recognize the potential for development and return on investment.

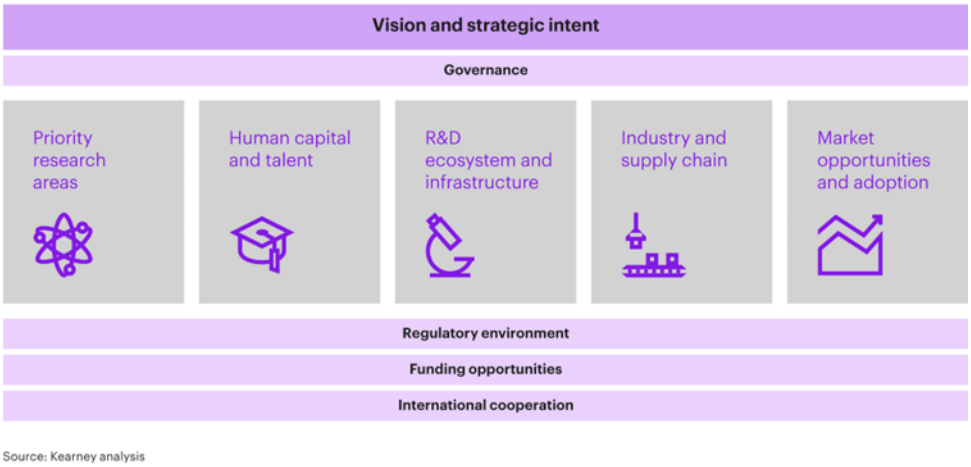

Figure 1. National quantum strategy framework[6]

The current state of quantum technology development in Indonesia

The development of quantum technology in Indonesia is still in its infancy, and significant progress in this area has not yet been made. Nevertheless, the government has recognized the importance of quantum technology and established programs to promote research and development in this area. The Ministry of Research and Technology, for instance, launched the Quantum Indonesia Program in 2020, which aims to develop quantum technology capabilities and applications in Indonesia. The program includes initiatives such as the establishment of a national quantum laboratory and fostering the development of quantum-based solutions for multiple industries. In addition, several universities in Indonesia have begun to offer courses in quantum technology and conduct related research. In 2020, the Bandung Institute of Technology established the Quantum Computing and Devices Laboratory, which focuses on developing quantum devices using superconducting qubits. At the same time, SpeQtral, the School of Electrical and Informatics Engineering, Bandung Institute of Technology (STEI-ITB), and Kennlines Capital Group have signed an official memorandum of understanding to develop a quantum-based secured network in Indonesia[7]. And, the University of Indonesia has established the Quantum Information and Computing Research Group, which focuses on research in quantum information theory, quantum algorithms, and quantum hardware. In 2022, the National Research and Innovation Agency (BRIN) established the Research Center for Quantum Physics with the main goal of exploring the fundamentals of quantum physics and its applications for near-future technology[8]. And Sepuluh Nopember Institute of Technology (ITS) launches the Quantum Computing and Information Group with focus to develop computers based on the principles of quantum theory[9]. On the other hand, the Chairman of Innovator 4.0, Budiman Sudjatmiko, encourages Indonesia to be qualified in the field of quantum computing technology, which is included in the five main sectors that

are the focus of Indonesia's Fourth Industrial Revolution. These initiatives show Indonesia's commitment to advancing the technological capabilities and competitiveness in the global market, particularly in the field of quantum computing.

In the roadmap of Indonesia's Fourth Industrial Revolution[10], five industries are the focus of implementation, specifically the food and beverage industry, automotive industry, electronics industry, chemical industry, and textile industry. Quantum technology is expected to have a substantial impact on these five industries. For example, quantum computing could improve the efficiency of supply chain management in the food and beverage industry by optimizing transportation routes and minimizing waste. In the automotive industry, quantum computation could advance artificial intelligence (AI) and machine learning to optimize flexible production processes in Industry 4.0, and the planning of routes for electric buses. Quantum computing can simulate the behavior of electrons and atoms, allowing for the creation of more effective and powerful chips in the electronic industry. The chemical industry in Indonesia get benefit from the potential of quantum computing, such as the simulation of the properties and behavior of new molecular structures. In the textile industry, we could use quantum computing to optimize the production of fibers and textiles, resulting in more efficient and eco-friendly products.

Korean Companies Investment Opportunities and Challenges

There are seven research areas that become part of the National Research Master Plan (Rencana Induk Riset Nasional) of Indonesia for 2017–2045: (1) food security; (2) new and renewable energy; (3) health and medicine; (4) transportation; (5) technology information and communication (ICT); (6) defense and security technology; and (7) advanced materials. And quantum technology is included in information and communication technology (ICT) and advanced materials. The first step was taken by the government to get to know quantum technology was to create the topic research about lasers and optics as a sub area of advanced material, which is supported by the Ministry of Industry and the Agency for the Assessment and Application of Technology (BPPT)[11].

The Making Indonesia 4.0 program specifically aims to promote the adoption of advanced technologies such as artificial intelligence, robotics, and the Internet of Things, all of which could benefit from advances in quantum technology. The Ministry of Energy and Mineral Resources, the Ministry of Industry, the Ministry of Finance, and the Ministry of Trade work togethe to fulfill Agenda 4.0[10]. The collaboration aims to increase the competitiveness of Indonesian industrial products in the global market, including the processing raw materials for natural resources such as minerals and rare earth elements that are essential to producing components for quantum technology. For instance, Indonesia is the largest producer of nickel in the world. The Ministry of Energy and Mineral Resources has set a goal of generating

23% of the country's energy from renewable sources by 2025. This mineral is a crucial component in the production of batteries, which are essential to the advancement of quantum technology.

To improve the quality of human resources, the Indonesian government invests 20% of Indonesian state budget in this goal, through: (1) scholarships, the LPDP scholarship, and International Student Mobility Awards (IISMA). Especially for students in STEM disciplines, the skills demanded by quantum technology. (2) Opening positions in institutions and institutes for international scientists. (3) Providing post-doctoral research in universities and R&D institutions. (4) Encouraging the mobility of research personnel between institutions and universities. (5) Encouraging collaboration between universities and research institutions[11].

Korean companies have been pioneering in technological innovation for decades, including their interest in quantum technology. The Ministry of Science and ICT of the Republic of Korea has announced their vision of "Digital to Quantum by 2035." The purpose is to promote industry-wide innovation, enhance national security, and develop ICT infrastructure and semiconductor capabilities. Over the next five years, the Korean government will invest 44.5 billion won (US$39.8 million) in the development of core quantum computing technology[12]. In addition, they have formed partnerships with major Korean companies such as Samsung Electronics, Hyundai Motor, SK Telecom, and LG Electronics, all of which are actively researching the quantum field. Hyundai Motor has utilized quantum computing to identify less expensive alternatives to platinum for catalyzing the essential reaction required to run hydrogen fuel cells. The company SK Telecom has created a quantum random number generator (QRNG) chip. In addition, the Korean steel POSCO is utilizing quantum technology to identify new cathode materials.

The challenges that Indonesian companies and the government may face in implementing and adopting quantum technology are significant, but the potential rewards are equally substantial. (1) lack of skilled personnel to support quantum research. However, some universities started to show positive results on the topic of quantum technology; for example, the Bandung Institute of Technology (STEI-ITB) published a few papers in Nature publications[13]. Korean government could have cooperation to train talent in the field of technology, they call Indonesian students who want to register in the department of semiconductors universities in Korea. (2) The high cost of equipment and production fees may pose a significant barrier to entry for Indonesian company that wish to access the quantum technology market. This is particularly for smaller businesses with limited resources. (3) Lack of infrastructure. High-quality qubits are needed for quantum computers. Superconducting qubits require cooling equipment to reach extremely low temperatures and to prevent interference, shielding and control systems are needed. Indonesia could begin with photonics technology, which does not require as much cooling and isolation as

superconducting qubits, making it affordable for countries like Indonesia. In this section, Korea may be able to assist Indonesia in acquiring the necessary equipment, as Korea is already well-equipped in the field of photonic technology.

Conclusion

Quantum technology has not yet made significant advancements in Indonesia. However, the government has shown a commitment to investing in quantum technology, which could further stimulate growth in the semiconductor industry. And several universities in Indonesia have started to get positive results in a few publications. As quantum technology becomes more extensively adopted and integrated across a variety of industries, there is expected to be an increase in demand for semiconductors to support these advancements. In the beginning stages, the Korean government and Korean companies will be urged to share knowledge and prepare talent in this field. Then participate actively in the production of raw materials.

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