



CENTRE FOR SECURITY STUDIES | **ISSUE BRIEF**

MAY 2022

SCOPE OF QUANTUM TECHNOLOGY IN INDIA

IN LIGHT OF THE RECENT INDO-ISRAEL WORKSHOP ON
QUANTUM ENERGY

Hardika Dhanpuri

Edited by: Ishani Sharma

Introduction

Quantum technology is a new and possibly disruptive field that has the potential to influence a wide range of human activities. Quantum technologies are dual-use technologies, with defence and security industries, as well as military and government entities, being interested in them. Quantum technologies for military applications bring new capabilities, boosting efficacy and accuracy, resulting in ‘quantum warfare’, which necessitates the development of new military strategies, doctrines, policies, and ethics.¹

What is Quantum Technology?

The manipulation of neutrons, photons, electrons, and protons to execute a task is known as quantum technology. These particles, sometimes known as “qubits” are the fundamental elements of matter and comprehending how to use them is complicated by the fact that they do not always behave as one would anticipate. The operation of quantum technology depends on principles of non-classical physics. Classical physics had become widely accepted by the end of the 19th century, most notably Newton’s laws of mechanics, the electromagnetic theory of Maxwell, and thermodynamics, which was the basis of the machine and system design. The key quantum-specific concepts are ‘superposition’, ‘non-locality’, and ‘entanglement’.² Superposition means that an object behaves as if it has more than one value of some measurable property at once. Non-locality means that measurements on parts of a quantum system can tell us about properties that will be measured at some other place and time, no matter how far apart they are. The two objects in this example are said to be entangled. De-coherence is another germane concept associated with quantum technology. Its quantum information becomes spread out among a large number of particles, effectively making that information impossible to recover. The first quantum revolution happened at the turn of the century, as a result of

¹ Krelina, Michal. (2021). “Quantum Technology for Military Applications - EPJ Quantum Technology.” SpringerOpen. Springer Berlin Heidelberg, November 6. <https://epjquantumtechnology.springeropen.com/articles/10.1140/epjqt/s40507-021-00113-y>.

² Davies, Andrew, and Patrick Kennedy. (2017). “WHAT IS A QUANTUM TECHNOLOGY?” *From Little Things: Quantum Technologies and Their Application to Defence*. Australian Strategic Policy Institute, <http://www.jstor.org/stable/resrep16820.4>.

theoretical attempts to explain blackbody radiation tests.³ The essential notion of wave-particle duality came from this theory: in particular, the assumption that light waves acted like matter particles at times, and matter particles functioned like waves at other times. All of the scientific and technical discoveries linked with the first quantum revolution are based on this fundamental concept. The second quantum revolution has made key physical technological advances in the 21st century. The hallmark of this revolution is the realisation that we humans are no longer passive observers of the quantum world provided by nature.

Scope of Quantum Technology

As the subject matter is quite complicated, it is critical to understand the scope of national policy. The scope of quantum has great potential to grow in the future, especially being a relatively untapped technological sphere. Governments across the world are pumping money into this growing industry with special reference to the United States (US), China, and the European Union.⁴ India too, in the budget for 2021 announced the allocation of 8000 crore rupees towards the National Mission on Quantum Technologies and Applications (NM-QTA). Quantum technologies can be classified in a variety of ways, but there are three main categories: quantum computing, communication, and metrology.⁵

Quantum Computing

Quantum computing has sparked a lot of interest in these technologies since it promises to simplify computational difficulties that are currently unsolvable even by supercomputers. Quantum computers necessitate novel software techniques that make use of the quantum architecture to execute large amounts of work at once. For issues of great complexity and using enormous volumes of data, quantum computers outperform traditional computers. Quantum computing also offers a plethora of useful applications in a variety of fields. Short-term

³ Dowling, Jonathan P., and Gerard J. Milburn. (2003). “Quantum Technology: The Second Quantum Revolution.” *Philosophical Transactions: Mathematical, Physical and Engineering Sciences* 361, no. 1809: 1655–1674. <http://www.jstor.org/stable/3559215>.

⁴ Goled, Shraddha. (2021). “Top Countries Pumping Money into Quantum Computing Technology.” *Analytics India Magazine*, August 24. <https://analyticsindiamag.com/top-countries-pumping-money-into-quantum-computing-technology/>.

⁵ Dowling, Jonathan P., and Gerard J. Milburn. (2003) “Quantum Technology: The Second Quantum Revolution.” *Philosophical Transactions: Mathematical, Physical and Engineering Sciences* 361, no. 1809: 1655–1674. <http://www.jstor.org/stable/3559215>.

quantum computer applications aim to help natural scientists by providing a platform for strong models of chemical and biological processes, allowing them to get a better understanding of how these systems work. Quantum computing has the potential to drive medical breakthroughs, smart city development, artificial intelligence, and big data analytics advancements. Businesses expect application in financial analysis and planning. Improved weather forecasting and traffic management systems, where quantum computers can manage and optimise huge volumes of real-time data to deliver superior insights, are examples of socially beneficial uses.

Quantum Communication

It is the second branch of the technologies and has the potential to transform communications by improving the security and privacy of data in motion. These approaches rely on entangled systems to convey information since changing the quantum state of one particle in an entangled pair causes the other to change as well. By allowing various devices to be linked in quantum networks, quantum communication systems create new possibilities. A ‘quantum internet’ might have many social benefits, including increased security, improved access to and power of quantum computers, and the ability to support astrophysical research. Though pilot programs exist, such as those supported by national governments in Chicago, the Netherlands, and China, building a quantum internet would need extensive research and development to enhance and scale-up such projects.

Quantum Metrology

Often known as quantum sensing, it is the last, broad category of quantum technologies that use quantum mechanics principles to do high-sensitivity measurements. These applications get beyond the limitations of standard sensors, which lose sensitivity around quantum mechanical limits. Instead, hypersensitive systems, such as discrete energy states of atoms or other particles, and ‘tricks’ from quantum events, are used in these technologies to improve accuracy within traditional boundaries. Quantum metrology devices have a variety of civilian uses, including improved medical diagnostic imaging, more powerful sensors onboard driverless cars, and geological mapping for building and oil exploration. Similar technologies might help with open-water navigation even if a GPS signal is not available.

India in the Race to Quantum Supremacy

Quantum technologies are gaining traction in the business world. The world's first integrated quantum communication network, which combines ground optical fibers with two ground-to-satellite links to provide quantum key distribution (QKD) spanning 4,600 kilometers, was launched in China in 2021.⁶ China is the obvious world leader in quantum communication. It is the only country in the world with a satellite capable of ground-to-ground quantum communication, and the Chinese have established an enormous fiber-optic network for quantum communication between Beijing and Shanghai. Much of the country's prosperity may be traced back to a single factor. Jian-Wei Pan is a Chinese physicist who has worked on virtually all of China's quantum communication and photonics discoveries. Banks, local electricity grids, and e-government websites can all benefit from it. The United States is the obvious world leader in quantum computing. Google (2018), IBM (2019), and a start-up called IonQ have constructed the world's biggest quantum computers (with 50 or more high-quality qubits) (2018). Honeywell, Microsoft, and several start-ups such as Rigetti, ColdQuanta, and PsiQuantum are among the other prominent commercial participants in the United States. D-Wave Systems of Waterloo, Canada, is another notable quantum computing company. However, many academic researchers in quantum computing are sceptical of the D-Wave computer's performance because its qubits are of much lower quality than the qubits in other computers. Google, Lockheed Martin, and the National Aeronautics and Space Administration (NASA) have all purchased D-Wave machines with more than 2,000 qubits. Quantum computing might begin to give quantum advantage on real financial applications over the next five years, according to a Goldman Sachs projection from 2021.⁷ In total, 23% of firms said they are working with quantum technologies or intend to work with them in the future. Many, on the other hand, have yet to reach the testing/piloting stage. Investment in quantum technologies is increasing, with 43% of businesses working on them expecting them to be available for use in at least one important commercial application over the next 3–5 years.⁸

⁶ Parker, Edward. (2021). *Commercial and Military Applications and Timelines for Quantum Technology*. Santa Monica, CA: RAND Corporation. https://www.rand.org/pubs/research_reports/RRA1482-4.html.

⁷ Parker, Edward. (2021). *Commercial and Military Applications and Timelines for Quantum Technology*. Santa Monica, CA: RAND Corporation. https://www.rand.org/pubs/research_reports/RRA1482-4.html.

⁸ "Quantum Technologies - Capgemini." Quantum technologies: How to prepare your organization for a quantum advantage now. Capgemini Research Institute. Accessed June 9, 2022. <https://www.capgemini.com/wp-content/uploads/2022/03/Final-Web-Version-Quantum-Technologies.pdf>.

In this field, India's research was evaluated from a worldwide perspective. India contributed 4946 papers to the global total of 92,004 publications in the field between 2000–2019. India's performance in terms of quantity and quality of research in the field is still quite poor when compared to China and the United States, the top two ranking countries.

The newly created National Mission on Quantum Technologies and Applications (NMQTA) would receive 8,000 crores (\$ 1.2 billion) in the Union Budget 2020-21, while the National Mission on Interdisciplinary Cyber-Physical Systems will receive 3660 crores (NM-ICPS) as a part of India's current approach to Quantum Technology.

In its budget for 2020, the government announced a National Mission on Quantum Technologies and Applications (NM-QTA), which would be handled by the Department of Science and Technology and will cost Rs 8000 crore over five years (DST). In her Union Budget 2020 address, Finance Minister, Smt. Nirmala Sitharaman, stated that “the new economy is centered on innovations that challenge traditional business models. Artificial intelligence, the Internet of Things (IoT), 3D printing, drones, DNA data storage, quantum computing, and other technologies are reshaping the global economy”.⁹ The Mission will be able to meet society's ever-increasing technical demands while also taking into account international technology trends and road maps for developing next-generation technologies. It aims to give a solid research base and workforce foundation to enable industries to innovate in the field of quantum mechanics.

Cyber-Physical Systems (CPS) are a new type of designed system that combines computing and physical processes in a dynamic environment. Cybernetics, Mechatronics, Design and Embedded Systems, the Internet of Things (IoT), Big Data, Artificial Intelligence, and many more technical disciplines are covered by CPS. Agriculture, water, energy, transportation, infrastructure, security, health, and manufacturing are all projected to benefit from the CPS systems, which are intelligent, autonomous, and efficient. The Union Cabinet approved the launch of the National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS) by the Department of Science and Technology (DST) with a total outlay of Rs. 3660 Crore for five years to harness the potential of this new wave of technology and make India a leading

⁹ “Draft Concept Note National Mission on Quantum Technology ... - TIFAC.” Accessed June 9, 2022. https://www.tifac.org.in/images/nmqta/concept_note12.06.19.pdf.

player in CPS.¹⁰ A network of 15 Technology Innovation Hubs (TIHs), 6 Sectoral Application Hubs (SAHs), and 4 Technology Translation Research Parks will carry out the goal (TTRPs). Each hub and technology park will take a technology life cycle approach, addressing all stages, such as research and development. The estimated budget for each TIH would be about Rs. 115 crores for five years. Depending on the domain area, intended mandate, targets/deliverables, and other factors, funding assistance for each TIH may vary. The Mission Governing Board would finalise and approve the entire monetary assistance (MGB)

To ensure India's long-term progress, the Prime Minister's Science, Technology, and Innovation Council (PMSTIAC) have identified nine national research objectives.¹¹ Every STIAC mission will be directed by a ministry and will include global and national institutional partners as well as aspiring scientists. The PMT at Invest India assists the implementation and advancement of the PM - "9 STIAC's National Missions". Under its second mission on Quantum Frontier, they focus on the main contemporary problems in basic science and technology. This mission intends to start work on understanding and control of quantum mechanical systems with a large number of degrees of freedom. It is critical for national security and the development of quantum computers, quantum chemistry, quantum communication, novel materials, quantum sensors, and quantum cryptography to achieve excellence in the quantum frontier through this objective. Beginning in October 2018, the PSA's office hosted four PMSTIAC meetings, and significant national missions developed from the talks are being led by the PSA's office. Each mission will be headed by a lead Ministry, with participation from international and national institutional partners, as well as young scientists and industry.

The Quantum Computing Toolkit Project is one of the country's initial efforts to strengthen India's quantum computing research frontiers. The project is being carried out by diverse teams of academics, scientists, engineers, and industry representatives from some prestigious institutions, including IISc, IIT-Roorkee, and C-DAC.¹² The QSim serves as a playground for

¹⁰ "Science and Engineering Research Board Established through an Act of Parliament: Serb Act 2008 Department of Science & Technology, Government of India." National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS), Department of Science & Technology, Government of India. Accessed June 9, 2022. <http://serb.gov.in/nm-icps.php>.

¹¹ "Prime Minister's Science, Technology and Innovation Advisory Council ..." Accessed June 9, 2022. <https://archive.pib.gov.in/documents/rlink/2019/mar/p20193601.pdf>.

¹² "QSim Is the Gateway for Indian Scientists to Take Us in Direction of Future Demands of Computing Power, Mos It Shri Rajeev Chandrasekhar." Press Information Bureau. PIB Delhi. Accessed June 9, 2022. <https://pib.gov.in/PressReleasePage.aspx?PRID=1749667>.

those interested in learning about or experimenting with quantum computing, regardless of whether they are students, staff, or researchers. The toolkit QSim enables researchers and students to build and debug Quantum Code, which is required for the development of Quantum Algorithms. Researchers may use QSim to investigate Quantum Algorithms in a virtual environment and design experiments to execute on real Quantum Hardware.

The Centre for Development of Telematics (C-DOT), a premier telecom research & development organisation under the Department of Telecommunications, Government of India, is leading the effort in the Quantum Communications vertical of NM-QTA. C-DOT has developed a product in one of the most promising applications of Quantum Communications viz. Quantum Key Distribution (QKD) and is continuing to pursue research in this area. The development of the QKD solution will address the threat that rapid advancement in Quantum Computing poses to the security of the data being transported by the current communication infrastructure.¹³ C-DOT is actively looking to collaborate with other national & international institutes and organisations working in the area of Quantum Communications to synergise efforts in this nascent field.

In the sphere of developing technology domains, the Indian Army is making gradual but considerable progress. The Army has built the Quantum Lab at Military College of Telecommunication Engineering, Mhow (MP) MCTE, with cooperation from the National Security Council Secretariat (NSCS), to drive research and training in this crucial emerging subject. During his recent visit to Mhow, the Chief of Army Staff, Gen MM Naravane, was briefed on the facilities. The Indian Army's quantum technology research will aid in leapfrogging into next-generation communication and transforming the Indian Armed Forces' present cryptography system into Post Quantum Cryptography (PQC).¹⁴ Quantum Key Distribution, Quantum Communication, Quantum Computing, and Post Quantum Cryptography are key focus areas.

¹³ “Secretary Telecom Shri K. Rajaraman Visits C-Dot; Inaugurates Futuristic Quantum Communication Lab.” Press Information Bureau. Accessed June 9, 2022. <https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1762590>.

¹⁴ “Indian Army Establishes Quantum Laboratory at Mhow (MP).” Press Information Bureau. Accessed June 9, 2022. <https://pib.gov.in/PressReleasePage.aspx?PRID=1786012>.

Quantum Alliances

Quantum technologies have the potential to have a profound impact on a wide range of human activities. This is particularly true in the defence industry. Quantum technologies offer a wide range of applications in modern warfare.¹⁵ With the second quantum revolution, there will be increased sensitivity, efficiency, provision of new capabilities and sharpening of present military techniques.

India and Finland signed a joint statement on Tuesday, April 18, 2022, to construct a virtual network center for quantum computing. It intends to expand training, research, and commercial applications such as quantum algorithms, hardware devices, and quantum architectures, among other things. India's first target area for the relationship is free space communication (or satellite communication), along with creating quantum simulators, parametric amplifiers, cryogenic electronics, and other technologies.¹⁶ The Indo-Israel bilateral workshop on Quantum Technologies was the next phase in the Bilateral Innovation Agreement (BIA) signed in November 2021 between India's DRDO and Israel's Directorate of Defence Research and Development (DDR&D) to foster innovation and expedite R&D in both nations' start-ups and Micro, Small and Medium Enterprises (MSMEs). The goal of the MoU was to foster cooperation in development activities on a variety of technologies, including quantum technology, between the DRDO in India and the Directorate of Defence Research and Development (DDR&D) in Israel. Both nations will be permitted to use the technology created under BIA for domestic purposes. Many Indian start-ups and MSMEs took part in the event and displayed their work. Representatives from Israel's Ministry of Defence as well as delegates from Israel Aerospace Industries (IAI) attended the workshop discussions.¹⁷ During the two-day workshop, many technical workshops in the specified technological areas were held. Photonics-based quantum computing, sensing, encryption, quantum magnetometry, atomic clocks, and free-space quantum communication were among the topics discussed. The workshop's joint research ideas will aid in the development of technology solutions for a variety

¹⁵ "Updated May 6, 2022, Defence Primer: Quantum Technology - Congress." Accessed June 9, 2022. <https://crsreports.congress.gov/product/pdf/if/if11836>.

¹⁶ Naik, Amit Raja. "[Exclusive] India Fast-Tracks Quantum Research, Joins Hand with Finland." Analytics India Magazine, May 21, 2022. <https://analyticsindiamag.com/exclusive-india-fast-tracks-quantum-research-joins-hand-with-finland/>.

¹⁷ "Ministry of Defence." Home | Ministry of Defence. Ministry of defence. Accessed June 9, 2022. <https://www.mod.gov.in/>.

of applications. Quantum technology offers a wide range of applications, including scientific research, secure communication, gravimetry, and navigation, among others.

Defence Minister Rajnath Singh announced that India and the United States have decided to advance cooperation in emerging technologies such as communication, artificial intelligence, quantum science, semiconductors and biotechnology, urging both countries' private industries to collaborate on the development and production of defence equipment.¹⁸ The sector would aim to mobilise funding and identify particular initiatives to improve technical collaboration in a presentation to members of the American Chamber of Commerce in India.

Conclusion

With recent developments in the field, the government seems to be targeted at making India a 'quantum power house'. The realisation of this vision has been gradual, especially concerning China- Asia's Quantum Giant. To enable the desired growth and innovation, production power is necessary and so is an 'open-source environment'. On the way ahead, to become a technology exporter, India has to boost its investor ecosystem and push the semiconductor industry. Therefore, India's 'Quantum Dream' can only be fulfilled if the state intervenes and heavily supports this research and experiment-driven field.

¹⁸ Pubby, Manu. (2022). "India, US to Advance Ties in Quantum Science, Biotech & Chips: Rajnath Singh." The Economic Times. The economic times; Print Edition, April 22. <https://economictimes.indiatimes.com/news/defence/india-us-to-advance-ties-in-quantum-science-biotech-chips-rajnath-singh/articleshow/90988560.cms?from=mdr>.

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<https://economictimes.indiatimes.com/news/defence/india-us-to-advance-ties-in-quantum-science-biotech-chips-rajnath-singh/articleshow/90988560.cms?from=mdr>.

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"Updated May 6, 2022, Defence Primer: Quantum Technology - Congress." Accessed June 9, 2022. <https://crsreports.congress.gov/product/pdf/if/if11836>.