MARCH 2023

QUANTUM

VIBES

Bi-monthly newsletter on Indian Quantum Technology Activities

KEY
DEVELOPMENTS

In the field of Quantum technologies in India

INSIDE THE MINDS

Prof. Apoorva Patel & Prof. R.P Singh

Breaking the Limits

Exploring the capabilities of Quantum Computing

Editor's Note

We are excited to introduce the inaugural edition of Quantum Vibes! Get ready to be immersed in the world of quantum and stay updated with the most exciting developments in the field.

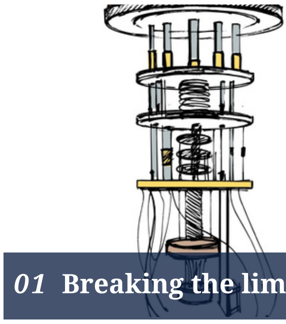
Quantum technology offers new possibilities in computing, cryptography and communication, which could potentially solve problems that are difficult to tackle with classical technology.

Therefore, governments and companies worldwide are making significant investments in the research and development of quantum technology to leverage its potential benefits.

We are delighted to present a diverse range of happenings and developments in quantum technologies across India through this newsletter. We are excited about "Expert Insights", that presents the thoughts and perspectives of domain experts. The "Inside the Minds" section, offers exclusive interviews with some of the most renowned quantum technology researchers in India. It provides our readers with a unique perspective on the latest trends and developments, straight from the minds of those leading the charge. We are confident that it will be a valuable resource for anyone interested in staying informed and up-to-date on the latest happenings in the quantum technology world. Furthermore, our newsletter highlights a diverse range of publications from India to keep readers informed about the latest developments bi-monthly.

We welcome your feedback and suggestions. Our goal is to continue providing you with high-quality content that is informative, engaging, and relevant in Quantum Technologies. We look forward to bring you more exciting developments in quantum technology in our upcoming issue. We welcome Indian experts in the field of quantum technology to be a part of our editorial board. You may please reach us at quantum-outreach-blr@cdac.in

DR. S.D SUDARSAN
Editor



** In our next newsletter, we will be publishing the editorial committee and advisory committee.

Breaking the limits

Exploring the capabilities of Quantum Computing, Challenges and Opportunities

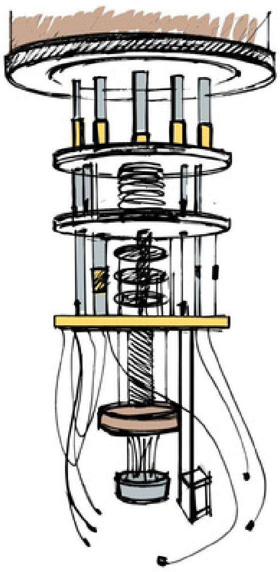


Image courtesy: **quantumzeitgeist.com**

Quantum computing, an emerging technology, employs quantum mechanics to carry out tasks that are too complicated for ordinary computers. The use of quantum phenomena like superposition and entanglement in computations is known as quantum computing. The way we manage and keep data may be radically changed, opening the door for advancements in fields like machine learning, cryptography, and medical research.

A quantum computer's fundamental building block is the quantum bit (or qubit, for short). Such examples are the spin of electrons or the polarisation of photons, which are quantum features of subatomic particles. In contrast to today's digital computers, which employ binary bits to represent values of either zero or one, qubits can simultaneously represent zero and one (or some mixture of the two). Superposition is the name for this phenomenon.

A unique connection between two or more groups of quantum components is known as quantum entanglement. No matter how far apart the entangled elements are, changing the state of one causes the other entangled elements to change immediately. The processing speed of calculations increases exponentially as the number of qubits increases. To match the power of a single qubit, two conventional binary bits are needed; for two qubits, four bits are needed; for three qubits, eight bits are needed; and so on.

When compared to digital computers that operate according to classical physics, quantum computers are capable of performing orders of magnitude better. According to Nobel Prize-winning scientist William Phillips, the transition from current technology to quantum mechanics is akin to the development of the digital computer. The so-called quantum advantage or quantum "supremacy" was only an idea up until recently. In contrast, Google employed a quantum computer in 2019 to complete a task in under 200 seconds.

> **“Although it is still in its infancy, quantum computing is widely believed to have the potential to dramatically revolutionize how we process and store data.”**

MYTHS VS FACTS

Myth: ‘Quantum Supremacy’ spells the beginning of the end for classical computing

Fact: Classical computers won’t be completely swept aside by Quantum Computers. Quantum computers have limited I/O capability and will thus not be good at solving big data problems. However, the area where quantum systems does excel is large compute problems on small data. This includes chemistry, materials science, for game-changing solutions like designing better batteries, new catalysts, quantum materials, countering climate change etc., The company claims that the identical process would have taken 10,000 years to accomplish on the most potent digital supercomputer available at the time. We produce vast amounts of data every day. We need a lot more processing capacity to adequately process it all and derive sense from it. Quantum computers come to the rescue in this situation. In 1997, IBM's Deep Blue computer beat out Garry Kasparov as it had an aggressive benefit with the aid of using inspecting two hundred million capability actions in line with second. A quantum computer can calculate his 1 trillion movements per second. Comparing quantum computing to traditional computing has various benefits, including:

- **Speed**: Compared to conventional computers, quantum computers perform a variety of calculations far more quickly.
- **Processing in parallel**: Quantum computers are able to perform several calculations at once, producing faster results.
- **Handling massive volumes of data**: Quantum computers are well suited for processing complicated algorithms since they can handle enormous volumes of data with ease.
- **Reduced power consumption**: Instead of using more power, quantum computers promise to reduce power consumption by a factor of 100-1000 because they use quantum tunneling.

Complex computational tasks are analogous to navigating a maze. A typical computer would look for a way out by going down each path in order until it discovered one. A quantum computer can concurrently test all the paths thanks to superposition, though. Numerous sectors have already adopted quantum computing for a variety of purposes. The most prominent ones are as follows:

- **Cryptography**: Because quantum computers are far faster than conventional computers at carrying out complex mathematical operations, difficult cryptography problems are now much easier to resolve.
- **Artificial intelligence**: Quantum computers can enhance the field of artificial intelligence by digesting massive amounts of data and spotting patterns that are challenging for traditional computers to recognise.
- **Drug discovery**: Quantum computers can hasten the creation of new drugs by the pharmaceutical sector by simulating and predicting complex chemical reactions.
- **Financial modelling**: Complex financial simulations and risk assessments can be carried out by quantum computers, improving prediction accuracy and decision-making.
- **Supply chain optimization**: Quantum computers can aid in the optimization of supply chains, lowering costs and boosting productivity.
- **Climate modelling**: Complex simulations of the Earth's climate can be run on quantum computers to better understand the effects of climate change.

Although it offers many advantages, quantum computing is still in its infancy and has a number of disadvantages, including:

Lack of software: Due to the dearth of quantum-friendly software and algorithms, it is currently difficult to fully exploit the potential of quantum computers.

Lack of hardware: Numerous companies are competing to construct the most cutting-edge systems in order to produce the hardware required to run quantum computers, which are currently being developed.

Correction of errors: The accuracy of calculations may be harmed by the error-prone nature of quantum computers. The fragility of quantum computers is extreme. A qubit may fall out of superposition before finishing its task if it interacts with an external stimulus like a vibration or temperature change. New robust error correction techniques should evolve to do large-scale quantum computing.
Although it is still in its infancy, quantum computing is widely believed to have the potential to dramatically revolutionize how we process and store data. In general, research into quantum computing's possibilities is an interesting and quickly developing topic, with many new developments and breakthroughs still to come. In the following years, we might expect the accessibility and availability of quantum computers to grow, leading to improvements in fields like machine learning, cryptography, and drug discovery.

Prof. Amlan Chakrabarti

A Full Professor of Information Technology in the A.K. Choudhury School of Information Technology at the University of Calcutta.

Inside the Minds

Apoorva D. Patel is a professor at the Centre for High Energy Physics, Indian Institute of Science, Bangalore. He is notable for his work on quantum algorithms, simulators, and the application of information theory concepts to understand the structure of genetic languages.

Q: What realistic advancements do you anticipate in the field of quantum computing in the near future, considering the widespread interest and enthusiasm around it?

In anticipating future advances, attention must be paid to the following four criteria:

1. Quantum theory was invented not because classical explanations of observed natural phenomena became too complicated, but because classical theory could not explain certain observations at all. Quantum technology can be advantageous when these phenomena are at the core of the problems to be tackled; they include superposition, entanglement, squeezing and tunnelling of quantum states.
2. Quantum dynamics is highly fragile against environmental disturbances, and so can work well in cooperative and protected settings, but not in hostile ones. The same property makes quantum technology expensive.
3. Many of our practical problems do not involve genuine quantum phenomena; tackling them with classical methods would be more robust, cheaper and efficient. So quantum technology would be worthwhile in special purpose devices to tackle specific problems or in hybrid systems, and would not replace many general purpose information processors.
4. Classical technology will keep on evolving together with developments in quantum technology. So the comparison between the two (for judging advantage) would remain time-dependent and would not be absolute.

Q: Could you shed some light on the role of quantum dynamics in natural processes, particularly in information processing by living organisms, based on your extensive research in this area?

Quantum dynamics plays a role in processes of molecular biology, but in a manner that would remain advantageous at a macroscopic scale in spite of environmental disturbances. Living organisms are driven by a supply of free energy, and molecules of life continuously vibrate. Non-equilibrium processes and wave dynamics can enhance underlying quantum features, but how that really happens is open to future investigations.

Q: Is there a specific field of quantum technology that you are particularly excited to see develop in the future, given your work across multiple areas in physics?

1. Quantum technology has already started to improve sensing and high precision measurements. They span a variety of physical observables - time, space, movement, electric field, magnetic field, gravitational field, imaging-with applications ranging from navigation and engineering to surveillance and medical diagnostics.
2. On the verge of appearing are advances in quantum communications that would improve the signal-to-noise ratio and distribute entanglement, as well as quantum simulators that would study a variety of atomic and molecular phenomena by mapping them into quantum hardware. Applications would range from a quantum internet to design of novel materials.
3. Improved technology would feed back to better understanding of science at some stage.

Q: What would you say to young people who are considering pursuing a career in quantum technologies?

Stay away from the hype in the social media about what quantum technology would do. Learn some quantum physics, to figure out the possible areas of quantum advantage. Keep in mind that the real challenges are in design, and not in use of readymade systems.

Q: What upcoming advancements in quantum technologies are you most excited to witness, considering your extensive experience in the field?

Quantum technology for sensing & high precision measurements and simulators for atomic & molecular phenomena.

Inside the Minds

R. P Singh is a professor at the Physical Research Laboratory, Ahmedabad. He is notable for his work on Quantum Information Science, Quantum Optics and Nonlinear Optics, Orbital Angular Momentum States of Light and their Applications.

Q: What led you, as a hands-on experimental physicist, to pursue research in quantum physics? Was it a deliberate choice or a serendipitous opportunity that presented itself?

For me, it was a deliberate choice as I found the concept of entanglement quite intriguing and it could also be observed in the laboratory.

Q: What potential opportunities do you anticipate arising from the proliferation of quantum computers and networks?

It will generate new employment opportunities across the sector. The moment one sector is able to garner the advantage of quantum computer, horde of others will follow, it will be a kind of avalanche. The network is going to make quantum computing more potent through cloud quantum computing along with secure transmission of the data.

Q: What advancements in the field of quantum optics are you eagerly anticipating after your extensive experience working in this area?

A quantum detector that would be able to detect the superposition of states. Anyway, we do quantum state tomography to reconstruct a superposition state, then why not a detector using AI or any other means could measure a superposition state? I think, it will change the way quantum algorithms are being written and subsequently the quantum computing itself.

Q: How easy do you think it is for young people to follow a career in quantum science and technology? What advice would you give to young people who want to get involved in physics, particularly quantum physics, and to get to where you are today?

It is just the matter of willingness. Like any other subject, if one really wants to learn, he or she can learn it. The onus is on us, we seniors, we have to show them that it is really interesting and it is going to be useful in our day-to-day life to get them involved in the subject. If by starting at the age of 45, I could reach here, then for you, the young lot, sky is the limit.

Q: What upcoming advancements in quantum technologies are you most excited to witness, considering your extensive experience in the field?

Materials that could generate entangled photons and single photons at GHz or more, quantum memories which can store the state for longer times with better fidelity, and finally the advancement in photonic quantum computing integrating the quantum network, secure communication and the cloud computing.

DID YOU KNOW?

Some of the Quantum computers require extremely cold temperatures, as sub-atomic particles must be as close as possible to a stationary state to be measured. These quantum computers operate at -460 degree Fahrenheit, or -273 degree Celsius, which is very close to absolute zero.

AN OVERVIEW OF CURRENT ADVANCEMENTS

Quantum Technology in India

Breaking New Grounds

> **"Quantum Computing will be at the core of the growth and expansion in India's Techade."**
>
> *Shri. Rajeev Chandrasekhar*
> *Minister of State for Electronics & Information Technology and Skill Development & Entrepreneurship*

I-Hub Quantum Technology Foundation

Jul 2022: The I-Hub QTF at IISER Pune has a mission to expedite quantum technology research and facilitate collaboration between academia and industry. In 2022, they issued a call for proposals to fund quantum technology research and development for both academic institutions and startups. Additionally, the I-Hub QTF has organized various events to promote and engage the quantum community in India. As a result, they have become the most significant advocates for the growth of the quantum ecosystem in India.

ISRO Demonstrates 300 Metre QKD

Jan 2022: Researchers from India’s Department of Space, specifically the Space Applications Centre (SAC) and the Physical Research Laboratory (PRL) located in Ahmedabad, have successfully demonstrated real-time Quantum Key Distribution (QKD) using quantum entanglement. This breakthrough was achieved over an atmospheric channel spanning 300 meters.

Source: isro.gov.in

IIT-Madras becomes first Indian institution to join IBM Quantum Network

IIT-Madras has become the first institution in India to join the IBM Quantum Network. This collaboration aims to promote the development of quantum computing skills and research in India. Researchers from IIT Madras will work alongside IBM Research India to advance research in the application of quantum computing, particularly in domains that are relevant to India.

Emerging Trends in Quantum Research and Development in India

India and Finland agree to set up Virtual Centre of Excellence for technical cooperation

April 2021: During the visit of the Minister of Economy, Finland - Mika Lintilä - to India in April 2022, both countries agreed to establish a Virtual Centre for Excellence in Quantum Computing. Delegates from India and Finland held discussions on identifying areas for potential collaboration in quantum computing and establishing a roadmap for the Virtual Centre of Excellence.

Source: dst.gov.in

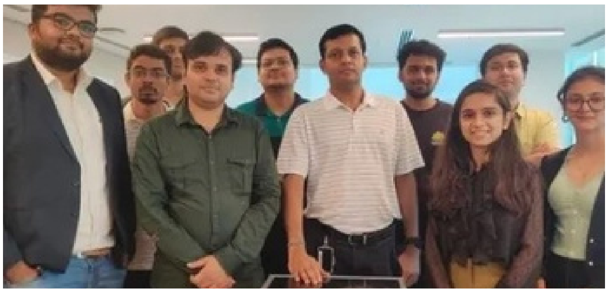
> **“A national quantum mission having four verticals, quantum computing, quantum communication, quantum sensors and metrology, and quantum materials and devices, would be launched very soon”**
>
> *Prof. Ajay Kumar Sood*
> *Principal Scientific Adviser to the Government of India and an Indian Physicist*

QSim: A Toolkit for researchers & students

August 2021: Shri Rajeev Chandrasekhar, Minister of State for Electronics & Information Technology, launched QSim – Quantum Computer Simulator Toolkit, to enable Researchers and Students to carryout research in Quantum Computing. This is one of the first initiatives in the country to address the common challenge of advancing the Quantum Computing research frontiers in India. This project is being executed collaboratively by IISc Bangalore, IIT Roorkee and C-DAC with the support of Ministry of Electronics and Information Technology (MeitY), Government of India.

Visit: qctoolkit.in

QpiAI's First AI-enabled platform for quantum computing



QpiAI announced an AI-enabled platform for quantum computing. The QpiAISense system enables controlling of room temperature qubits to more easily control quantum computing systems.

Source: qpiai.tech

DID YOU KNOW?

One of the first applications of quantum computer will be in materials modelling — not as dry as it sounds. Your future iPhone may not be a quantum computer, but its battery may be designed by one.

Symposium on Quantum Computing Ecosystem: Basic Building Blocks

Jan 2023: C-DAC organized a symposium to explore the technologies, systems and subsystems (including software stack, error correction etc.) that make quantum computers' building blocks. The symposium brought together the stakeholders from the Indian and global quantum computing ecosystem on a single platform.

The symposium was officially inaugurated by the Hon. Minister of State for Electronics & Information Technology and Skill Development & Entrepreneurship, Shri. Rajeev Chandrasekhar, through his online presence.

The symposium saw the participation of over 67+ speakers and panelists who covered various topics related to quantum computing, including quantum processor development using different technologies, control and measurement electronics, error correction, cryostat and dilution refrigerators, system software stack, algorithms, and standardization efforts.

> **Quantum computing and other quantum technologies are crucial areas of focus for the entire world. Indian science and industry have a tremendous opportunity to contribute significantly in this area with many favourable conditions.**
>
> *Prof. R Vijayaraghavan*
> *Department of Condensed Matter Physics & Materials Science*
> *Tata Institute of Fundamental Research*

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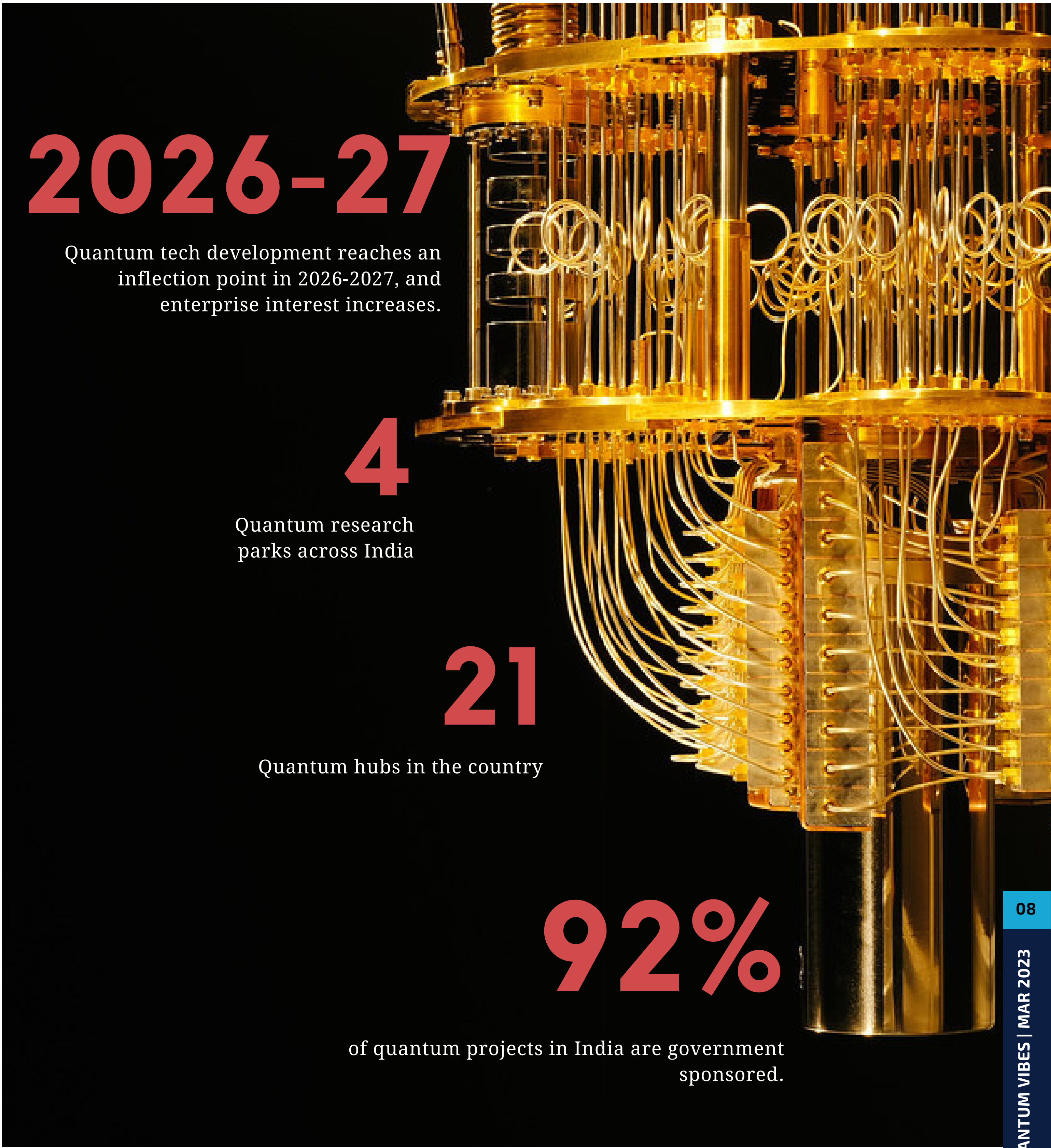
GOI budget allocation for National Mission on Quantum Technologies and Applications



2026-27

Quantum tech development reaches an inflection point in 2026-2027, and enterprise interest increases.

4

Quantum research parks across India

21

Quantum hubs in the country

92%

of quantum projects in India are government sponsored.

Source
NASSCOM and Avasant 2022 Report: https://avasant.com/report/the-quantum-revolution-in-india-betting-big-on-quantum-supremacy/
PSA Office: https://www.psa.gov.in/technology-frontiers/quantum-technologies/346

Quantum Outreach

C-DAC's Quantum Outreach Program is an initiative from C-DAC Bangalore to conduct a series of outreach and educational workshops, short-term certification programs, and tech conclaves, showcasing the research and development activities in the field of Quantum Computing & Communication technologies.


Prof. Urbasi Sinha, RRI launched the Quantum Outreach Initiative on 2nd June 2022


Prof. Apoorva Patel, IISc launched the Quantum webinar series and delievered talk on 15th June 2022


Prof. Anil Prabhakar, IITM inagurated the training program and delivered the talk on 27th June 2022.


Prof. Arindam Ghosh, IISc, innagurated the training program and delivered talk on 21st July 2022

> **Quantum technology is extraordinary. It is the science of the young**
>
> *Prof. Ajay Kumar Sood*
> *Principal Scientific Adviser to the Government of India and an Indian Physicist*

DID YOU KNOW?

The BB84 protocol, one of the earliest proposed QKD protocols was first published in the proceedings of a conference held in Bangalore in 1984 by Charles Bennett and Gilles Brassard.

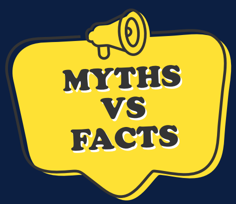
PUBLICATIONS

List of selected publications in various Quantum Technologies by Indian researchers during the last year**.

Upper bounds on device-independent quantum key distribution rates in static and dynamic scenarios	Physical Review Applied, 18(5), 054033 *Kaur, E., Horodecki, K., & Das, S*
Time-Bin Superposition Methods for DPS-QKD	IEEE Photonics Journal, 14(5), 1-7 *Shaw, G., Sridharan, S., Ranu, S., Shingala, F., Mandayam, P., & Prabhakar, A*
Quantum-noise-limited microwave amplification using a graphene Josephson junction	Nature Nanotechnology, 1-6 *Sarkar, J., Salunkhe, K.V., Mandal, S., Ghatak, S., Marchawala, A.H., Das, I., Watanabe, K., Taniguchi, T., Vijay, R. and Deshmukh, M.M*
Silicon Photonic Wires for Broadband Polarization Entanglement at Telecommunication Wavelengths	Physical Review Applied, 18(4), 044043 *Sharma, S., Venkataraman, V., & Ghosh, J*
Spatial Profile and Polarization Entanglement in Partially Spatially Coherent Qubits	Laser Science (JTu4A.40) *Sharma, P., Rao, S., & Kanseri, B*
A Review of Developments in Superconducting Quantum Processors	Journal of the Indian Institute of Science, 1-37 *Mamgain, A., Khaire, S.S., Singhal, U., Ahmad, I., Patel, L.A., Helambe, K.D., Majumder, S., Singh, V. and Suri, B*
A Decade of Advancement of Quantum Sensing and Metrology in India Using Cold Atoms and Ions	Journal of the Indian Institute of Science, 1-24 *Maurya, S. S., Biswas, K., Rapol, U. D., Dutta, P., Mangaonkar, J., Sarkar, S., & Patel, K*
NMR Quantum Information Processing: Indian Contributions and Perspectives	Journal of the Indian Institute of Science, 1-21 *Dorai, K*
Direct determination of arbitrary dimensional entanglement monotones using statistical correlators and minimal complementary measurements	Quantum Science and Technology, 7(4), 045037 *Ghosh, D., Jennewein, T., & Sinha, U. (2022)*
Thermodynamic Signatures of Genuinely Multipartite Entanglement	Physical Review Letters, 129(7), 070601 *Puliyil, S., Banik, M., & Alimuddin, M*

***Latest being first*

Myth:
Quantum Computing will destroy cybersecurity



Fact:
Some of the widely used Public-Key Cryptography (PKC) algorithms are vulnerable to security attacks launched from sufficiently powerful quantum computers. However realizing such powerful quantum systems is still a distant task. Nevertheless cryptologists worldwide are already working and shortlisting multiple Post Quantum Cryptographic (PQC) algorithms which can offer sufficient cryptographic strength, even with the advent of powerful quantum computers.

Non-uniform magnetic field as a booster for quantum speed limit: faster quantum information processing	New Journal of Physics, 24(8), 085001 *Aggarwal, S., Banerjee, S., Ghosh, A., & Mukhopadhyay, B*
Quantum speed limits for information and coherence	New Journal of Physics, 24(6), 065003 *Mohan, B., Das, S., & Pati, A. K*
Benchmarking Noise and Dephasing in Emerging Electrical Materials for Quantum Technologies	Advanced Materials, 2109671 *Islam, S., Shamim, S., & Ghosh, A*
BBM92 quantum key distribution over a free space dusty channel of 200 meters	Journal of Optics, 24(7), 074002 *Mishra, S., Biswas, A., Patil, S., Chandravanshi, P., Mongia, V., Sharma, T., Rani, A., Prabhakar, S., Ramachandran, S. and Singh, R.P*
Achieving fault tolerance against amplitude-damping noise	Physical Review Research, 4(2), 023034 *Jayashankar, A., Long, M. D. H., Ng, H. K., & Mandayam, P*
An intelligent approach towards quantum error reduction	ACM Transactions on Quantum Computing, 3(4), 1-18 *Basu, S., Saha, A., Chakrabarti, A., & Sur-Kolay, S*
Asymptotically improved circuit for a d-ary Grover's algorithm with advanced decomposition of the n-qudit Toffoli gate	Physical Review A, 105(6), 062453 *Saha, A., Majumdar, R., Saha, D., Chakrabarti, A., & Sur-Kolay, S*
Quantum emitters and detectors based on 2D van der Waals materials	Nanoscale, 14(14), 5289-5313 *Dastidar, M. G., Thekkooden, I., Nayak, P. K., & Bhallamudi, V. P*
A software simulator for noisy quantum circuits	International Journal of Modern Physics C, 33(08), 2250103 *Chaudhary, H., Mahato, B., Priyadarshi, L., Roshan, N., Utkarsh, & Patel, A. D.*
Thirty-six entangled officers of Euler: Quantum solution to a classically impossible problem	Physical Review Letters, 128(8), 080507 *Rather, S. A., Burchardt, A., Bruzda, W., Rajchel-Mieldzioć, G., Lakshminarayan, A., & Życzkowski, K*
Quantum key distribution with multiphoton pulses: an advantage	Optics Continuum, 1(1), 68-79 *Biswas, A., Banerji, A., Lal, N., Chandravanshi, P., Kumar, R., & Singh, R. P*

***Latest being first*

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