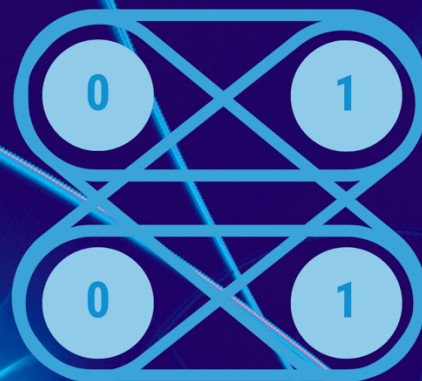
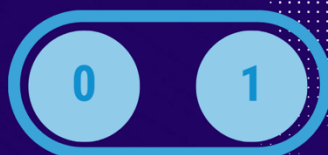




INTERNATIONAL TECHNOLOGY ENGAGEMENT STRATEGY QUANTUM

First Edition April 2025



India's International Technology Engagement Strategy for Quantum Science, Technology and Innovation

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Foreword



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The year 2025 has been designated as the International Year of Quantum Science and Technology (IYQST) by the United Nations and its member states, commemorating a century since the foundational developments of quantum mechanics. This global observance reflects both the historical significance and the tremendous future potential of quantum science and technology. IYQST provides an important platform to celebrate the scientific breakthroughs, global collaborations, and real-world applications that quantum technologies are beginning to unlock.

In this momentous year, the Office of the Principal Scientific Adviser to the Government of India is pleased to present the first edition of the *International Technology Engagement Strategy - Quantum (ITES-Q)* report, released on World Quantum Day, April 14, 2025. This report marks a significant step toward articulating India's outward-facing strategy in Quantum Science, Technology and Innovation (QSTI), with the intent to accelerate discovery, foster innovation, and catalyse adoption across critical sectors.

This inaugural edition of ITES-Q provides a comprehensive overview of both global and national quantum ecosystems, covering analysis of investments, talent development, institutional strengths, research publications, intellectual property, startups, supply chains, and industrial activity. It showcases India's vision, capabilities, and strategic interests in quantum technologies, while identifying avenues for meaningful international cooperation across various sub-domains of QSTI.

Notably, this edition refrains from prescribing specific engagement strategies or policy interventions. Rather, it offers a foundational landscape analysis, enabling stakeholders—within government, academia, and industry—to derive context-specific action points suited to their engagement goals. This flexible and data-driven approach aligns with our vision of enabling informed and adaptive international collaboration.

A unique and practical feature of this report is the inclusion of detailed information on India's National Quantum Mission (NQM)—including key researchers, institutions, and thematic areas—thereby making it easier for global stakeholders to identify potential collaborators. Our aim is to facilitate impactful partnerships, and we see this report as a valuable tool particularly for India's missions abroad, to strengthen bilateral and multilateral engagements in this strategic frontier.

As quantum science and its applications continue to evolve, future editions of ITES-Q will build upon this foundation, offering deeper insights and refined strategies that further enhance India's global partnerships and technological leadership.

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I. What should be India's outward-looking engagement strategy for QSTI?

Quantum technology leverages the principles of quantum mechanics (the physics of subatomic particles), such as superposition, entanglement and tunnelling, to perform tasks that are beyond the capabilities of classical systems. It enables unprecedented capabilities in computation, ultra-secure communication, and highly sensitive measurement systems. This includes quantum - computing, communication & cryptography, sensing & metrology, materials & devices, software & algorithms, optics, and photonics. For the purpose of this strategy document, more focus is given to the 4 verticals of India's **National Quantum Mission (NQM)** namely: quantum computing, quantum communication, quantum sensing & metrology, and quantum materials & devices. For India, Quantum holds strategic importance in enhancing technology security & competitiveness and India's position in the global technology landscape. NQM, launched in 2023, aims to help various sectors, including communication, health, finance, and energy with applications in drug design, space, banking, security, etc. The Mission provides a huge boost to National priorities like Digital India, Make in India, Start-up India, Aatmanirbhar India and Sustainable Development Goals (SDG) and provides complementarity to national missions such as National Supercomputing Mission (NSM), National Mission on Integrated Cyber-Physical Systems (NM-ICPS).

Quantum, being a pre-competitive field, India's international engagements with key partner countries should also keep in mind that quantum technologies have huge implications for national security and economic competitiveness. A well-planned strategy is necessary for India to engage with international partners in Quantum Science, Technology and Innovation (QSTI) to **accelerate and leapfrog towards the national objectives**. With an aim to complement and strengthen the ambitions of the NQM and other ongoing efforts by various agencies and stakeholders in the ecosystem, this strategy document (ITES-Q) focuses on QSTI to enable informed and adaptive international cooperation capturing the timely opportunities and help leverage a higher degree of impact for longer-term goals.

Employing multiple quantitative and qualitative indicators, this report provides a foundational landscape analysis, enabling stakeholders in government, academia, and industry to formulate context-specific action points aligned with their engagement goals. The analysis incorporates scientometric indicators, bibliometric analysis, patent analysis, industry ecosystem developments, talent mapping, investments, research and knowledge institutions mapping, and policies. This analysis extends to examining the ecosystems, initiatives, stakeholders, and specific focus areas within broader technology domains with the goal of identifying the hotspots in the selected technology areas for further engagement. Additionally, the strategy document assesses and pinpoints India's position within the global value chain of these technologies to provide specific insights. Expert consultations were also conducted to ensure a comprehensive coverage of the

quantum ecosystem, globally and domestically. These consultations have provided valuable insights that have been incorporated along with the in-house analysis, ensuring a multi-dimensional approach.

As part of the ITES-Q report, the India technology dossier has been incorporated, focusing on India's Quantum Science & Technology ecosystem. This India dossier lays out a snapshot of India's quantum ecosystem including investments, talent mapping, knowledge hotspots, state of quantum startups and collaboration on patents & publications. From a functional perspective of this report, detailed information on India's National Quantum Mission (NQM) - key researchers, institutions, and thematic areas-hubs and spokes have been included with an aim to streamline possible collaborations going forward. Quantum's critical importance for India's technology security was a key factor for this ITES report to focus on QSTI. Furthermore, the year 2025 being [designated](#) [1] as the [International Year of Quantum Science and Technology](#) [2] by the United Nations highlights the global recognition of the importance of quantum technologies. The ITES-Q is thought out to facilitate impactful partnerships and particularly add value to the efforts of Indian missions abroad in strengthening bilateral and multilateral engagements for QSTI.

II. Key Insights and Considerations

The field of quantum science and technology is evolving at a rapid pace and holds the potential to transform entire industries and economies. India, through its existing capabilities and ongoing initiatives, could gain tremendously from this technology. Through this report, analysis has been done to understand the state of the QSTI on a global level as well as in India. This has been done to gain some key insights into the ecosystem as well as to pinpoint the hotspots India should engage with to advance its capabilities in quantum.

The following are some of the key insights and domain specific gap-analysis derived from the analysis of the various metrics/indicators in the report as discussed in detail in the upcoming sections:

- Data from global and Indian publications and patents suggest that the vertical of material & devices constantly leads. This could suggest a possibly skewed representation. The large difference in the growth of this particular vertical can be attributed to the foundational nature of this sub-field and its relevance to the developments in the other three verticals. It may also be noted here that the developments of the entire sub-field of quantum materials and devices may not fully translate into applications in quantum technologies as not all researchers working on quantum materials & devices may be focusing on applications for quantum technology.
- From the data for the top funding agencies based on publications, it can be noted that the NSFC leads in all four quantum research verticals, with a particularly strong funding presence in Quantum Materials and Devices. It is this vertical that receives substantially more funding attention than other quantum domains globally, potentially indicating its foundational importance.
 - For the vertical of quantum computing specifically, the National Natural Science Foundation of China (NSFC) leads in funding for quantum computing research publications and is significantly ahead of the US National Science Foundation (NSF) by a ratio of 2:1.
- Even though global trends signify that the number of QSTI-related patent filings shows a rising trajectory, the possibility that organisations are not patenting all the innovations exists. Through expert consultations, it was pointed out that organisations may be waiting to achieve a certain internal threshold of innovation before patenting the technology. A possible reason for this may be attributed to the competitive nature of this field.

- IBM holds the highest number of quantum computing patents, more than double its nearest competitor, Microsoft. The heavy presence of large technology organisations in quantum computing patents suggests a concentration of patent ownership among the traditional technology giants (IBM, Microsoft, Google), specialised quantum companies (D-Wave, IonQ, Quantinuum), and companies like Red Hat which primarily specialise in open-source solutions.
- The category of Quantum Optics has the highest number of startups globally which is followed by Quantum Computing and Quantum Communications & Cryptography. Expert consultations highlighted the major focus of investors and commercial entities in quantum computing. This further correlates to the focus of startups in quantum computing and areas which feed into quantum computing like ASICs, Software and Optics as well. It is also noted that the US leads with the largest share of quantum startups globally with over 300 startups.
- The U.S. is getting the highest amount of private investments, corroborating with the large number of startups the country has. China, with only 63 startups accounts for a large amount of investments. American dominance is further visible through its lead through the most number of unicorns and acquisitions in quantum.
- Through analysis of PhDs and Postdocs researchers in India, it was highlighted that industry funding is at a limited stage currently with only 2.6% of the surveyed researchers highlighting they receive industry support for their research. It is also noted that in the case of a quantum-ready workforce, the talent extends beyond specialised graduates, encompassing talent from diverse fields like biochemistry, electronics, chemical engineering, mathematics, and statistics.
- For funding agencies based on research publications in India, the presence of foreign funding is also seen from countries like Japan, China, Germany and others. This suggests international funding in quantum research in India across verticals. The aspect of international funding flowing in research publications in India highlights collaboration between Indian and international counterparts, but may also point towards concerns regarding research security.
- For Indian collaboration in publication and patents, the US emerges as the top country for collaboration across all quantum verticals in both patents and publications. In joint publications, the collaboration with the US shows particularly strong numbers in Quantum Materials and Devices (758) and Quantum Computing (92). European countries, including

France and the UK, are also significant collaborators for India in both publications and patents, though their prominence varies across the verticals.

Based on the above takeaways and through insights from the expert consultations, a detailed **gap analysis** has been done to understand where India's priorities could lie going ahead:

R&D Participation of Early Adoption Sectors

1. Based on expert consultations and on the publications' meso and micro citations groupings data, several sectors emerged as early adopters of Quantum Science & Technology, namely Finance, BioMedical, and Logistics due to their reliance on high-complexity computations, optimisation challenges, and security demands. In finance, quantum computing enhances risk analysis, secure transactions, and post-quantum cryptography (PQC). In Biomedical, Quantum applications enhance drug discovery, molecular simulations, and medicine. In Logistics, the industry's complex optimisation problems, such as route optimisation, supply chain efficiency, and traffic management, benefit from quantum-enhanced combinatorial optimisation.

a. Finance

The challenge of ensuring secure communication is a priority for the financial sector due to its nature of protecting sensitive financial information. Through expert consultations and scientometric indicator-based analysis, the financial sector stands among the early adopters of quantum technologies. This is evident through various examples like Bank of America leading in patent ownership in quantum communication & cryptography, highlighting its focus on ensuring a secure network for financial transactions. HSBC partnering with the University of Edinburgh and becoming the [first bank](#) [4] to join the UK's commercial quantum secure metro network and its [partnership with Toshiba](#) [5] for developing their post-quantum cryptography strategy is also an example of a foreign bank advancing in quantum. While the Indian financial sector does not have much participation in the domain of quantum security and risks lagging behind. The participation of Indian financial service providers is currently limited in this regard, highlighting a [critical gap in the quantum readiness of the sector](#) [6]. Being the early adopter sector, involvement during the R&D phase of such technologies and applications is crucial for the Indian financial sector to become quantum-ready in terms of security, regulations, and industry competitiveness.

- i. Stakeholders: Reserve Bank of India (RBI); Ministry of Electronics and Information Technology (MeitY); National Payment Corporation of India (NPCI); International Financial Services Centres Authority (IFSCA); Securities and Exchange Board of India (SEBI); Society for Electronic Transaction and Security (SETS); Indian Statistical Institute (ISI); Fintech and Financial Services Industry

b. Biomedical

QSTI promises to revolutionise drug discovery, molecular simulations, and advanced diagnostic imaging. Roche is already collaborating with Cambridge Quantum Computing to explore molecular interaction simulations using quantum algorithms in drug discovery. Google's Sycamore quantum processor [demonstrated](#) [7] quantum-assisted protein folding simulations. UK-based Sir Peter Mansfield Imaging Centre, the University of Nottingham and the Wellcome Trust Centre for Human Neuroimaging, UCL used [quantum technology sensors to create a wearable brain scanner](#) [8] to measure activity. Based on the deeper analysis of patents and publications, research topics related to Quantum Imaging, Diagnostics, and Chemistry emerge as one of the top emerging trends in Quantum Computing topics citations. Further, this global trend matches partially (protein structures modelling; image scanning) with India's research focus in Quantum Sensing and Quantum computing. Despite India being one of the world's largest pharmaceutical producers, with major domestic companies having a strong global presence, India needs to advance its capabilities in developing advanced medical imaging and diagnostic technologies. A significant portion of high-end diagnostic equipment, such as MRI, CT scanners, and PET machines, is still imported.

- i. Stakeholders: Department of Science & Technology (DST); Department of BioTechnology (DBT); Indian Council of Medical Research (ICMR); Council of Scientific and Industrial Research (CSIR); All India Institute Of Medical Sciences (AIIMS); MedTech Industry

c. Logistics

The logistics sector is inherently complex due to its dependency on multiple variables like dynamic route planning, demand fluctuations, security concerns, and real-time tracking of assets. Quantum annealing can evaluate a huge amount of route variables in seconds, identifying the most efficient delivery paths. In 2019, Volkswagen partnered with D-Wave for a pilot project at the Web Summit in Lisbon, using [quantum computing to optimise traffic flow](#) [9] for a fleet of buses, demonstrating a real-world application of quantum technology. The teams at IBM Research and ExxonMobil Corporate Strategy Research have also collaborated to model [maritime inventory routing on quantum devices](#) [10], analysing the strengths and trade-offs of different strategies for vehicle and inventory routing. [Logistics cost in India is higher at 13% to 14% of GDP](#) [11] compared to 8% to 9% of GDP in other developed economies such as the US. High logistics costs hinder economic growth, trade competitiveness, and supply chain efficiency. The Government of India aims to reduce logistics costs to <9% of GDP under the PM Gati Shakti National Master Plan (2021), requiring next-gen technology interventions.

- i. Stakeholders: Ministry of Road Transport and Highways of India (MoRTH); Ministry of Housing and Urban Affairs (MoHUA); National Institute of Urban Affairs (NIUA); Directorate General of Civil Aviation (DGCA); Ministry of

Ports, Shipping and Waterways (MoSPW); Gati Shakti; Ministry of Railways;
Department of Science & Technology (DST)

Private Investment

2. Unlike global counterparts where deep-tech VCs play a major role, apart from government public funding, India's quantum technology ecosystem funding is primarily driven by angel investors, with limited participation from institutional investors such as venture capital (VC) firms, tech corporates and private equity (PE) funds. To achieve scalability, Indian quantum startups require long-term, patient capital, which institutional investors are better positioned to provide. Countries like the US, Germany, and the U.K. have leveraged government-backed VC funds, public-private partnerships (PPPs), and corporate-led investment consortia to derisk quantum investments and attract institutional capital.
 - a. Stakeholders: Department of Science & Technology (DST); Ministry of Electronics and Information Technology (MeitY); DPIIT; National Quantum Mission (NQM)

Collaboration between Quantum Researchers with other Scientific Disciplines

3. According to the [Economic Survey of India 2024-25](#) [3], India accounts for 28% of the global STEM workforce. Despite having a large workforce in STEM and a strong IT industry, there is a lack of Indian companies that primarily work on quantum related stacks (digital/data). Currently, all the popular quantum software stacks are primarily developed by global technology organisations such as IBM Qiskit, Google Cirq, Xanadu PennyLane, and Microsoft Q#. Expert consultations have further corroborated this integration gap between a large pool of software engineers and the production of quantum software and algorithms in India. It could be another international dependency as most of the available currently are open source and easily accessible but future export controls and restrictions by key organisations could lead to disruptions in the Indian quantum ecosystem.
 - a. Stakeholders: Ministry of Electronics and Information Technology (MeitY); Department of Science & Technology (DST); National Quantum Mission (NQM)

Mapping and Monitoring of Foreign Investments and Supply Chains

4. Mapping and monitoring of foreign direct investments (FDI) & overseas direct investment (ODI) and supply chains in QSTI are crucial for ensuring strategic autonomy, economic resilience, and technology security. Major economies like the US, EU, China, and Japan have already implemented stringent FDI screening. In January 2025, the EU [initiated](#) [12] a review of outward FDI in critical security technologies, with quantum among the top three areas under scrutiny. Similarly, France has already released [scrutinising](#) [13] FDI in specific strategic sectors. Without comprehensive mapping and tracking of FDI and supply

chains including a structured database of key suppliers, manufacturers, and dependencies, India risks strategic takeovers of deep-tech startups, turn-key solutions and over-reliance on foreign entities for critical quantum components such as photon source and detectors, lasers for NV sensing etc. The recent [report](#) [14] from NITI Aayog highlights that as quantum technologies become integral to national security, export restrictions on essential components including AWGs, DACs, microwave components, specialised lasers, and cryogenic dilution refrigerators could become increasingly stringent. Countries such as the US have already [conducted a survey](#) [15] in 2022 to assess the global quantum supply chain for vulnerabilities. Reports from the [Quantum Economic Development Consortium](#) [16] have also highlighted significant vulnerabilities in the global quantum supply chain. Through expert consultations and data analysis, a lack of comprehensive mapping of India's quantum ecosystem was highlighted as an issue, particularly in FDI, supply chain and trade statistics.

- i. **Stakeholders:** Reserve Bank of India (RBI); Directorate General of Commercial Intelligence and Statistics (DGCIS); Directorate General of Foreign Trade (DGFT); Department for Promotion of Industry and Internal Trade (DPIIT); Ministry of Commerce & Industry (MoCI); Ministry of External Affairs (MEA); Department of Science & Technology (DST); Securities and Exchange Board of India (SEBI)

Standardisation

5. Standardisation in quantum technologies has started to pick pace. The International Telecommunication Union (ITU), ISO/IEC JTC 3, IEEE, and ETSI are advancing standards for quantum technologies across verticals. The UK's BSI Group has been tasked with leading global standardisation efforts in quantum technologies, while the US National Institute of Standards and Technology (NIST) is spearheading post-quantum cryptography (PQC) standards. Without proactive participation, India risks being a late adopter of foreign-guided standards. India must actively engage in global quantum standardisation efforts to ensure strategic autonomy.

- a. **Stakeholders:** Bureau of Indian Standards (BIS); Department of Telecommunications (DoT); Telecommunications Standards Development Society (TSDSI); Telecommunication Engineering Centre (TEC); Department of Science & Technology (DST); Ministry of Electronics and Information Technology (MeitY)

Consortium Engagement

6. Based on the analysis of industry participation in QSTI in India (section 1.B.5), there is a growing industry presence and commitment in India by both Indian and Foreign MNCs.

This is seen through various programs and initiatives that these companies are engaging in and initiating in India to advance the QSTI ecosystem. By leveraging the existing strength and interest of these organisations, the government can facilitate a large-scale, industry-led quantum consortium to enable shared resources and to accelerate the pace of innovation in India. The sector specific use cases such as in healthcare, energy systems or in other strategic areas could motivate the industry stakeholders to increase their commitment, financially and otherwise. Further, this arrangement could be facilitated through one of the T-hubs of the NQM.

- ii. Stakeholders: National Quantum Mission (NQM); Industry

Research visibility and Global networking

7. Global QSTI conferences play a crucial role in knowledge exchange, networking, and collaboration. Based on expert consultation and qualitative scouring of major quantum-related conferences, it is observed that India has limited representation in key quantum-related conferences such as Optica, IEEE Quantum Week, and the APS March Meeting. India's limited presence means that Indian perspectives and technical inputs are underrepresented and reduce opportunities for strategic partnerships and research funding. Furthermore, the underrepresentation in global forums would also impact the involvement of global standardisation, and policy discussions.

- i. Stakeholders: Department of Science & Technology (DST); Department of Higher Education, Ministry of Education; Anusandhan National Research Foundation (ANRF)

III. Quantum Science, Technology and Innovation Landscape

1.A. Global QSTI Landscape

From enhancing computational power and secure communication to enabling ultra-precise measurements, Quantum Science and Technology is reshaping industries and fostering innovation worldwide. QSTI is not only driving advancements in technologies and industries across multiple sectors but also shaping international engagements, technology security, supply chains, economic competitiveness, and scientific collaboration.

The following table presents an overview of investments through national quantum initiatives in QSTI worldwide. Please note that these figures do not represent the full extent of investments in any given region or nation. Certain individual investments have not been included to ensure consistency in reporting.

Country	Public Investment	Quantum Initiatives / Policies / Strategies
China	USD 15.3 billion (CN¥ 108 billion)	Made in China 2025
Germany	USD 5.2 billion (EUR 4.9 billion)	Quantum Technology Plan, 2023
United Kingdom	USD 4.3 billion (GBP 3.9 billion)	National quantum strategy
USA	USD 4.1 billion	National Quantum Initiative Act, 2018
South Korea	USD 2.35 billion (WON 3.05 Trillion)	National Quantum Strategy
France	USD 2.3 billion (EUR 2.09 billion)	Quantum Plan, 2021

		1. Quantum Technology and Innovation Strategy, 2020: focus on R&D 2. Vision of Quantum Future Society, 2022: expanded on the initiatives for social innovation through quantum technology from the 2020 strategy. (with objectives to create opportunities for industrial growth and a carbon-neutral society and achieve SDGs) 3. Strategy for Quantum Industry Development
Japan	USD 1.8 billion (Yen 266 billion)	
Canada	USD 1.4 billion (CAD 1.88 billion)	National Quantum Strategy
Netherlands	USD 1 billion (EUR 965 million)	National Technology Strategy (NTS)
EU	USD 1.08 billion (EUR 1 billion)	European Declaration on Quantum Technologies
Russia	USD 790 million (RUB 72 billion)	The quantum technology concept
India	USD 735 million (INR 6003.65 crore)	National Quantum Mission (NQM)
Australia	USD 663 million (AUD 953 million)	National Quantum Strategy, 2023
Denmark	USD 605 million (DKK 4.1 billion)	National Strategy for Quantum Technology
Israel	USD 440 million (Shekel (₪) 1.4 billion)	National Quantum Initiative (INQI)
Taiwan	USD 282 million (NTD 8 billion)	Quantum Taiwan
Austria	USD 164 million (EUR 149.32 million)	Quantum Austria
Finland	USD 164 million (EUR 149.32 million)	The Finnish Quantum Agenda-
Sweden	USD 160 million (SEK 1.6 billion)	National Quantum Strategy
Qatar	USD 150 million (Riyal 541.5 million)	Quantum Policy

Singapore	USD 588 million (SGD 788.92 million)	National Quantum Strategy
Spain	USD 67 million (EUR 60 million)	Quantum Spain
New Zealand	USD 45 million (NZD 63.65 million)	Quantum Technologies Aotearoa
Philippines	USD 17.2 million (₱ (Peso) 860 million)	Quantum Technology Roadmap
Norway	USD 13 million (NOK 134.75 million)	National Quantum Initiative
Brazil	USD 12 million (BRL 60 million)	A Roadmap Towards Quantum Science & Technologies in Brazil
Switzerland	USD 11 million (CHF 10 million)	Swiss Quantum Initiative
Hungary	USD 11 million (HUF 3.5 billion)	Hungarian National Quantum Technology Programme (HunQuTech)
Ireland	USD 10 million (EUR 9.1 million)	National Quantum Technologies Strategy
Thailand	USD 6 million (Baht 200 million)	
South Africa	USD 3 million (R 54 million)	South African Quantum Technologies Initiative

Table 1: Global - Public Quantum Investments

Source: [McKinsey Quantum Technology Monitor 2024](#) [17] and [Annual Report: The Quantum Economy 2024](#) [18]

Note: Currency rates are based on the average exchange rate for the year in which the investments were made; if such data is unavailable, the exchange rate as of April 3, 2025, is used.

Global public investments in QSTI vary widely across countries. These investment figures highlight the global race for quantum advancements, with large investments playing a crucial role in securing technological and economic advantages. While major economies lead with large investments in QSTI overall, several small economies have made notable investments, such as the Philippines, Hungary, etc.

1.A.1. Capacity Building

Data from the [McKinsey Quantum Technology Monitor](#) [17] suggests the US and EU leading in terms of the number of study programs in QSTI. As of 2023, out of a total of [86 master's](#) [19]

programs in QSTI, Europe alone had more than 41 such programs suggesting its focus on developing a quantum-ready workforce. Furthermore, according to the [Landscape of Indian R&D in Quantum Technologies report](#) [106] by Itihaasa Research and Digital, there are 40 universities worldwide providing master's degrees in quantum science and technology, mostly concentrated in North America and Europe. The report also states that there are about 162 universities and institutions worldwide with educational programs and research activities in quantum technologies.

This further results in the EU leading with the concentration of talent for a quantum-ready workforce with India coming in at the second position with around 91,000 graduates as of 2021. It is to be noted here that this estimate is based on the quantum-relevant fields and not only on the specialised quantum fields. The quantum-ready workforce extends beyond specialised graduates, encompassing talent from diverse fields like biochemistry, electronics, chemical engineering, mathematics, and statistics.

1.A.2. Research Publications

An analysis of research publications has been carried out to gauge the research and institutional landscape across countries. For the analysis, a set of keywords and indicators have been used for an overall understanding of each vertical of quantum technology. These indicators and the overall glossary have been enclosed in the appendix for reference. The [Web of Science database](#) [20] has been used for this analysis.

Globally, the research publications have been compared and analysed on the following parameters:

- Top countries based on the number of publications
- Vertical-wise distribution of the number of publications
- Top Funding agencies based on the number of publications
- Countries based on the publications in Q1, Q2 journals, the Top 10% of Research Publications
- Organisations based on publications in Q1, Q2 journals and share in top 10% of publications

Leading countries based on number of publications

Data for the number of publications in the overall QSTI domain suggests that **China leads** with the highest number of publications over the past 10 years (2013-2023) with the **US ranking second** with a slight decline in the last two years. Meanwhile, **India** has consistently ranked **3rd** over the past 11 years.

No. of Web of Science Documents

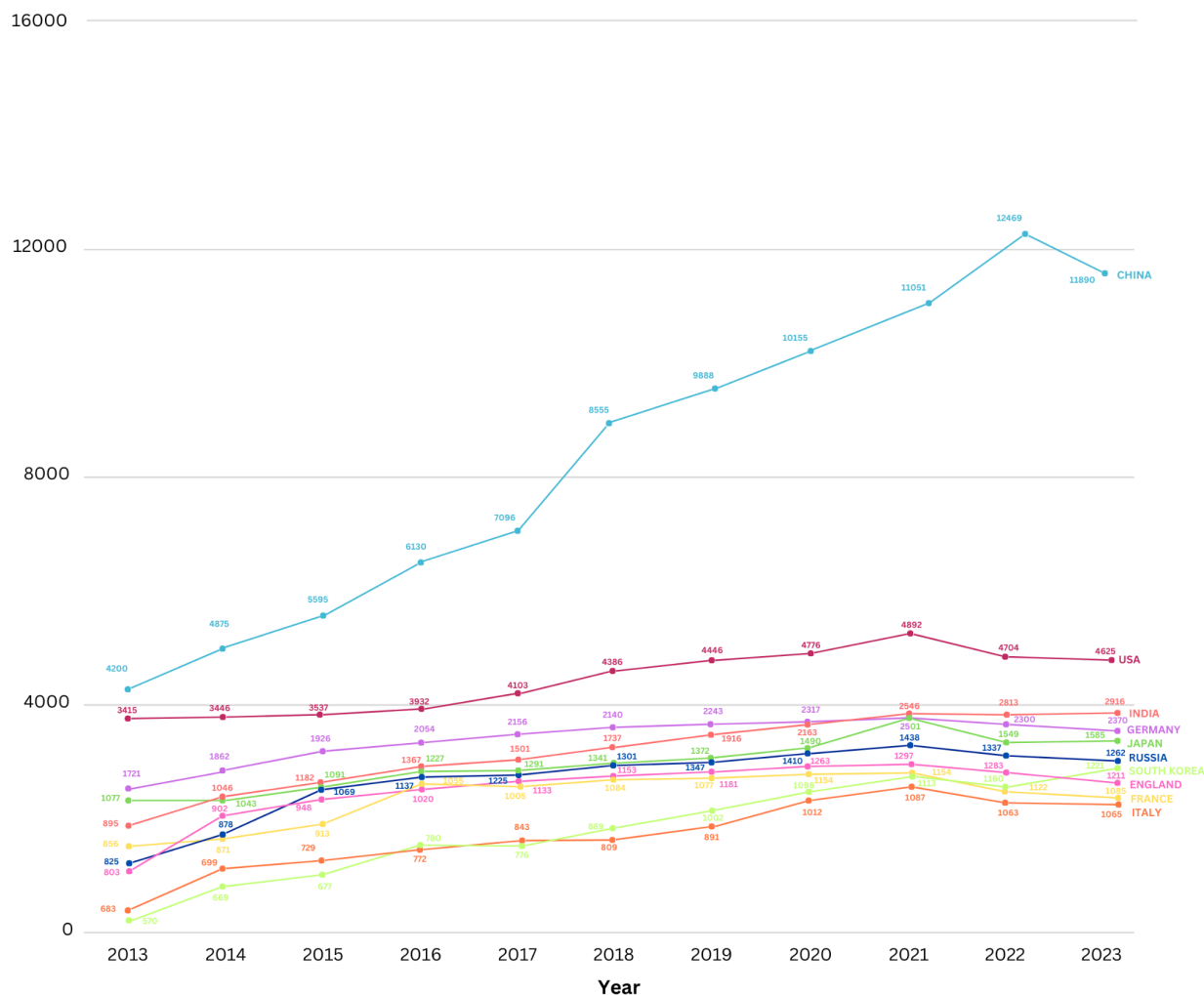


Figure 1: Overall publications in QSTI of Top 10 countries (2013-23)
 Source: Web of Science Core Collection, Clarivate Analytics [20] (Date accessed: 04/03/2025)

Vertical-wise distribution of the number of publications

Globally, the number of publications in the QSTI field has seen significant growth across verticals. The vertical of **quantum materials and devices** lead this growth with the highest share in the number of publications. The large difference in the growth of this particular vertical can be attributed to the foundational nature of this sub-field and its relevance to the establishment of the other three verticals. It is to be noted here that the developments of the entire sub-field of quantum materials and devices may not fully translate into applications in quantum technologies as not all researchers working on quantum materials & devices may be focusing on applications for quantum technology.

No. of Publications

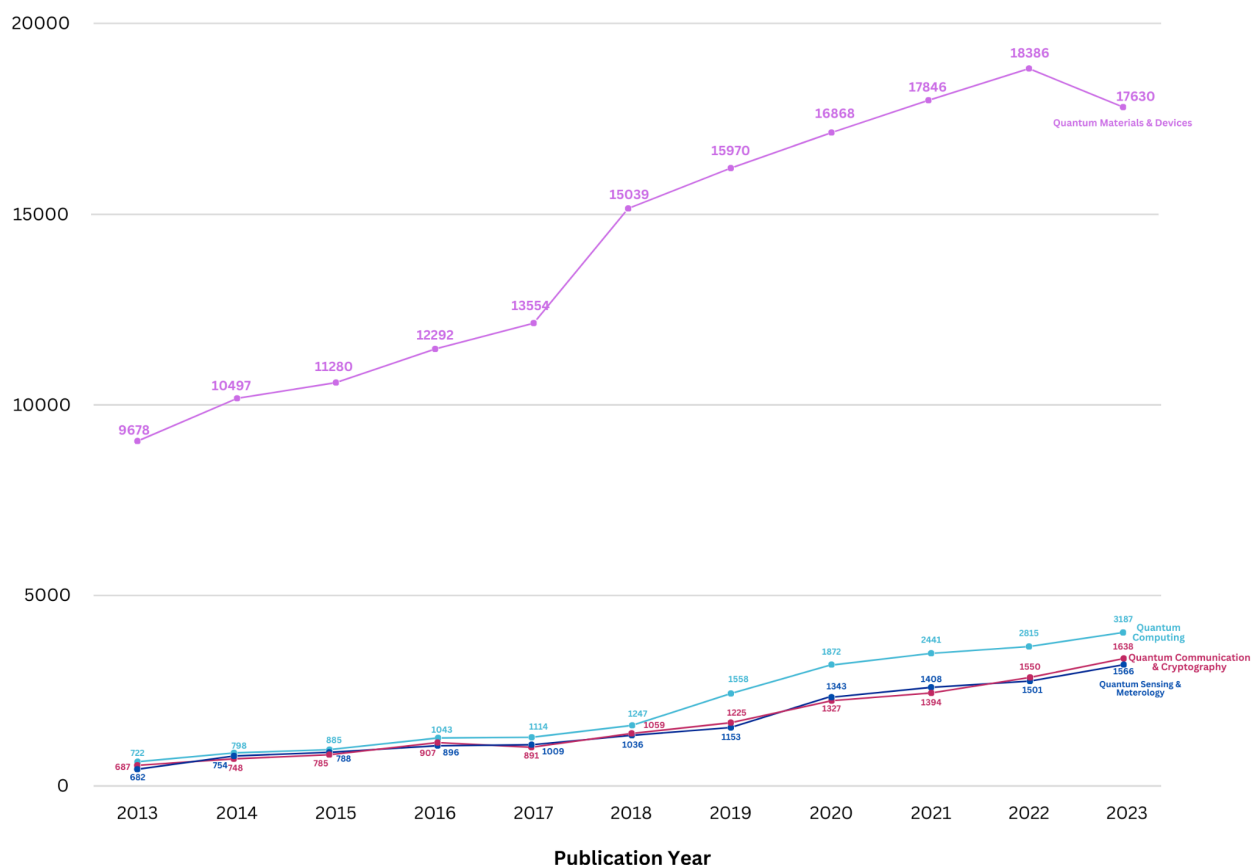


Figure 2: Vertical-wise distribution of QSTI publications globally (2013-23)
Source: Web of Science Core Collection, Clarivate Analytics (Date accessed: 04/03/2025)

The verticals of quantum sensing and quantum communication can be seen to be growing at a slow pace at nearly the same growth rate, with both having around 1600 publications in 2023. For quantum computing, however, steady and consistent growth can be seen in publications, possibly due to the increasing advancements by major tech companies and the availability of cloud-based quantum processors.

Funding agencies based on the number of publications globally

An analysis of the research publications by funding data reveals the top funding agencies in each of the verticals in QSTI. Here, the analysis has been done on the total number of publications in each field to arrive at the agencies funding the research publications.

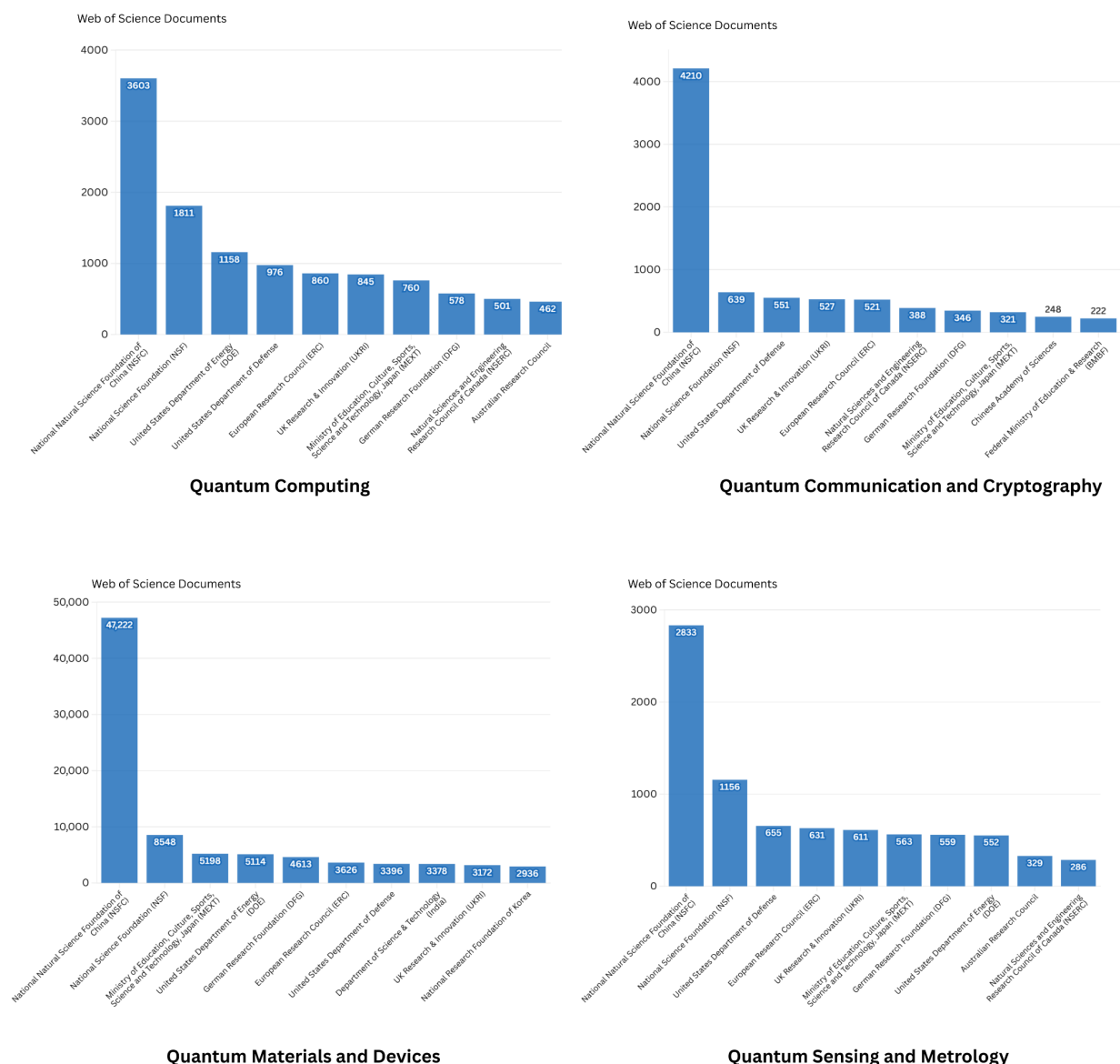


Figure 3: Funding agencies globally based on Number of Publications - vertical-wise
Source: Web of Science Core Collection, Clarivate Analytics (Date accessed: 04/03/2025)

Quantum Computing

- The **National Natural Science Foundation of China (NSFC)** leads in funding for quantum computing research and is significantly ahead of the US National Science Foundation (NSF) by a large margin. This represents a difference of approximately 2:1 ratio, indicating China's substantial investment in this field.

- U.S. federal funding is distributed across multiple agencies like the Department of Energy and the Department of Defense (through the Air Force Office of Scientific Research). Together with the NSF, these three U.S. agencies collectively exceed China's NSFC output.
- NSF Directorates with significant QSTI funding presence are: NSF - Directorate for Mathematical & Physical Sciences (MPS); NSF - Directorate for Computer & Information Science & Engineering (CISE); NSF - Directorate for Engineering (ENG); NSF - Division of Electrical, Communications & Cyber Systems (ECCS)
- European funding can be seen to be fragmented across several entities. It could be noted here that, collectively, these European agencies contribute significantly to the global quantum computing research landscape.

Quantum Communications & Cryptography

- The **NSFC leads** funding in this vertical too (with 4,210 publications), creating an even wider gap with other funding agencies in this vertical. This is approximately **6.6 times** the research publication funding of the European Union (639) and the NSF (639).
- China's emphasis on quantum communication is further evidenced by additional Chinese funding through various programs and academies like the Chinese Academy of Sciences, NKRDP, NBRP; Fundamental Research Funds for the Central Universities and the China Postdoctoral Science Foundation.
- The UK (through the UKRI) and the European Union (through the European Research Council), both showcase a focus for funding in this vertical by being one of the leading funders.

Quantum Materials & Devices

- The NSFC (along with China's other programs and agencies like the NKRDP, NBRP and the China Postdoctoral Science Foundation) leads the funding with more than 47,000 publications, substantially higher than the second-placed NSF with around 8,500 publications.
- Japan shows significant investments in this area with the Ministry of Education (along with its agencies like the Japan Society for Promotion of Science) which could suggest a strategic focus on materials science as a foundation for quantum technologies by Japan.
- The U.S. agencies like the Department of Energy (DOE) and National Science Foundation (NSF) are also among the top funders, suggesting a focus on fundamental materials research by the US.
- Korea, through the National Research Foundation of Korea is also a significant funder in this vertical, suggesting South Korea's specific focus on this vertical.

Quantum Sensing & Metrology

- Similar trends follow in this vertical as well with the NSFC leading followed by the US's NSF, with a ratio of about 2.5:1 between the two.
- Following similar trends, the UK (through the UKRI) and the European Union (through the European Research Council), both showcase a focus for funding in this vertical by being one of the leading funders along with Japan's Ministry of Education.

For funding agencies, it can be noted that the NSFC leads in all four quantum research verticals, with the NSF, the UKRI and ERC being the top funders across the spectrum. The NSFC has a particularly strong funding presence in materials and devices and this vertical also receives substantially more funding attention than other quantum domains globally, potentially indicating its foundational importance. Another point to note here is that, the presence of defence agencies across all domains, signifying the strategic importance of quantum technologies.

Global knowledge-producing countries based on research publications quality analysis

For the purposes of avoiding a possibly skewed understanding through the analysis of only the number of publications, comparison based on the quality of publications is essential. A comparison of the quality is done by analysing the publications in Q1 & Q2 journals as well as the top 10% of highly cited publications in each vertical globally.

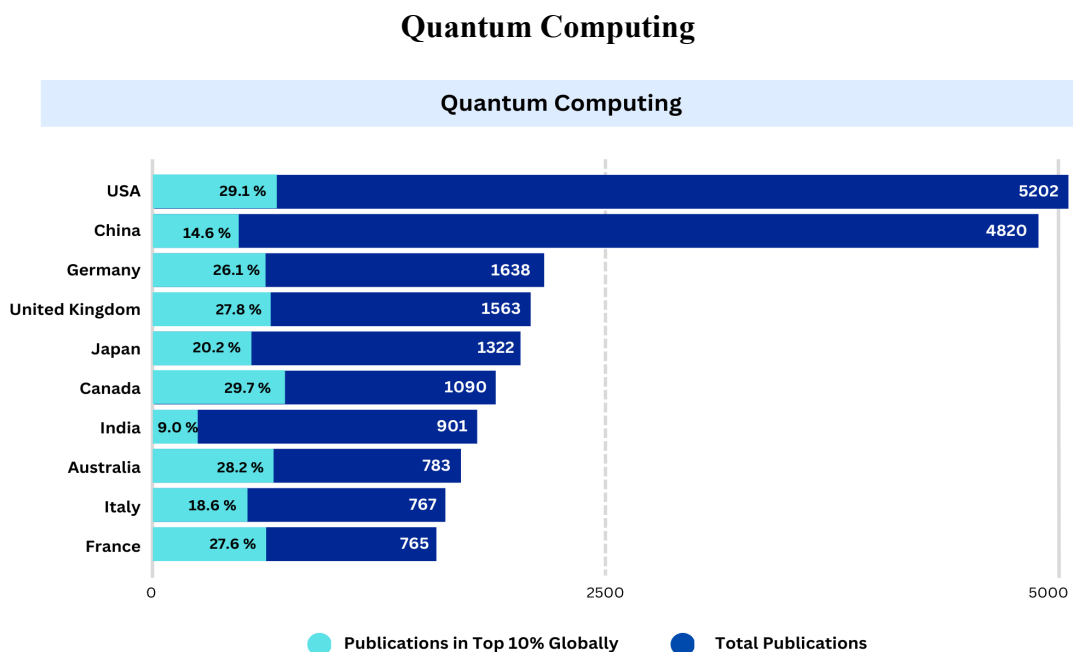


Figure 4: Countries based on number of publications in Q1, Q2 journals as Top 10% publications globally in Quantum Computing

Source: Web of Science Core Collection, Clarivate Analytics (Date accessed: 04/03/2025)

For quantum computing, between 2013 and 2023, even though the US **leads** on the basis of the number of publications, **the Netherlands** has the highest ratio of quality publications. Meanwhile, India has a share of 80 quality publications out of its total of 901 publications. Hence, it does not figure in the leading countries in terms of quality.

It is to be noted here that, even though the US leads in terms of the total number of publications, its ratio of quality over quantity stands at around 29% which is comparable to other countries like Canada and Australia which come lower in terms of number of publications.

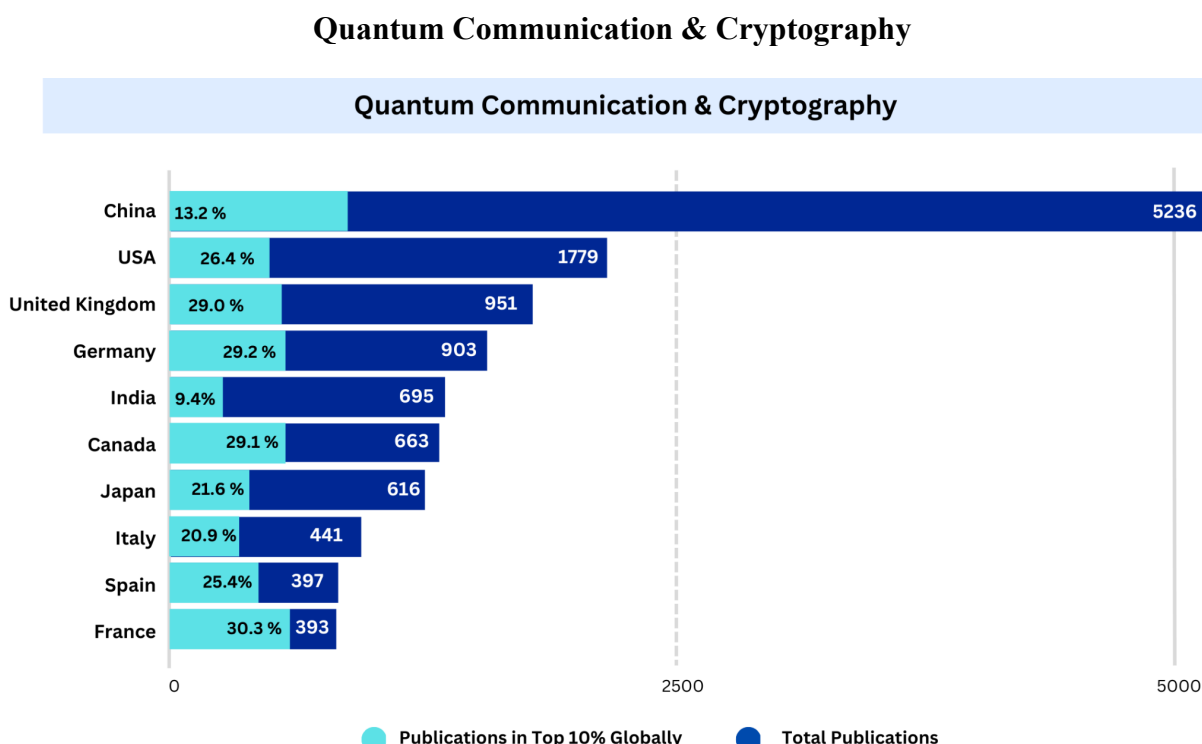


Figure 5: Countries based on number of publications in Q1, Q2 journals as Top 10% publications globally in Quantum Communication & Cryptography
Source: Web of Science Core Collection, Clarivate Analytics (Date accessed: 04/03/2025)

For quantum communications & cryptography, between 2013 and 2023, even though **China leads** on the basis of the number of publications, **Austria and the Netherlands** have the highest ratio of quality publications. Meanwhile, India has a share of 65 quality publications out of its total of 695 publications. Hence, it does not figure in the leading countries in terms of quality.

It is to be noted here that, even though China leads in terms of the total number of publications, its ratio of quality over quantity stands at around 13% which is lesser than that of Denmark for example which has a much lesser number of publications.

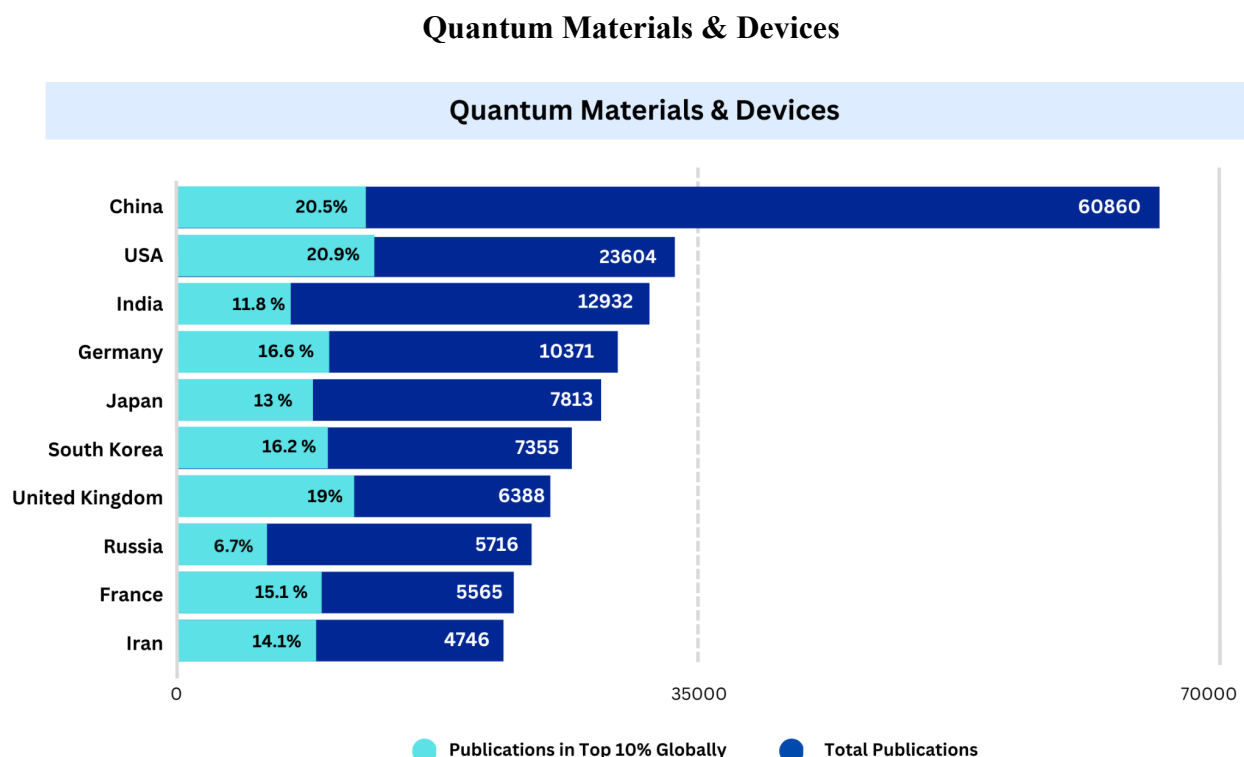


Figure 6: Countries based on number of publications in Q1, Q2 journals as Top 10% publications globally in Quantum Materials & Devices

Source: Web of Science Core Collection, Clarivate Analytics (Date accessed: 04/03/2025)

For quantum materials and devices, between 2013 and 2023, even though China **leads** on the basis of the number of publications, **Singapore, Switzerland and Australia** demonstrate the highest ratio of quality publications. Meanwhile, India has a share of 65 quality publications out of its total of 13,000 publications. Hence, it does not figure in the leading countries in terms of quality.

It is to be noted here that, even though China leads in terms of the total number of publications, its ratio of quality over quantity stands at around 20% which is less than that of Switzerland for example which has a much smaller number of publications.

Quantum Sensing & Metrology

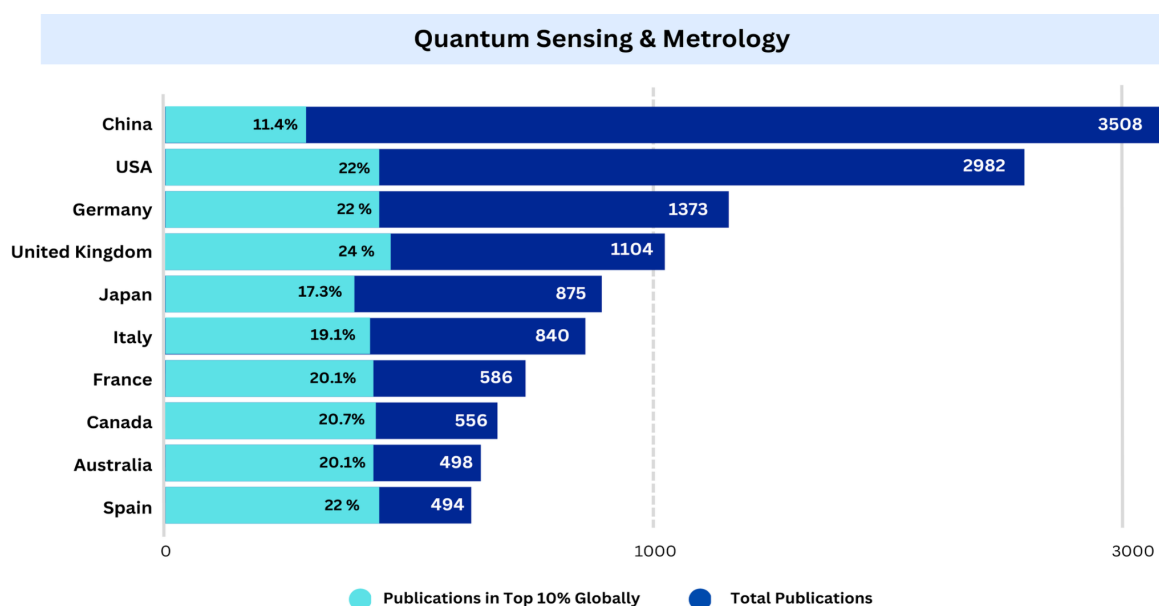


Figure 7: Countries based on number of publications in Q1, Q2 journals as Top 10% publications globally in Quantum Sensing & Metrology

Source: Web of Science Core Collection, Clarivate Analytics (Date accessed: 04/03/2025)

For quantum materials and devices, between 2013 and 2023, even though China **leads** on the basis of the number of publications, **Switzerland, Austria and the U.K.** demonstrate the highest ratio of quality publications. Meanwhile, India has a share of 41 quality publications out of its total of 483 publications. Hence, it does not figure in the leading countries in terms of quality.

It is to be noted here that, even though China leads in terms of the total number of publications, its ratio of quality over quantity stands at around 20% which is lesser than that of Switzerland for example which has a much lesser number of publications.

Global knowledge hotspots based on the publications in Q1 & Q2 Journals and Top 10% global publications

An analysis of the Q1 & Q2 journals and the top 10% of the research publications has been carried out to identify the knowledge hotspots with the highest share of quality research publications across the quantum verticals.

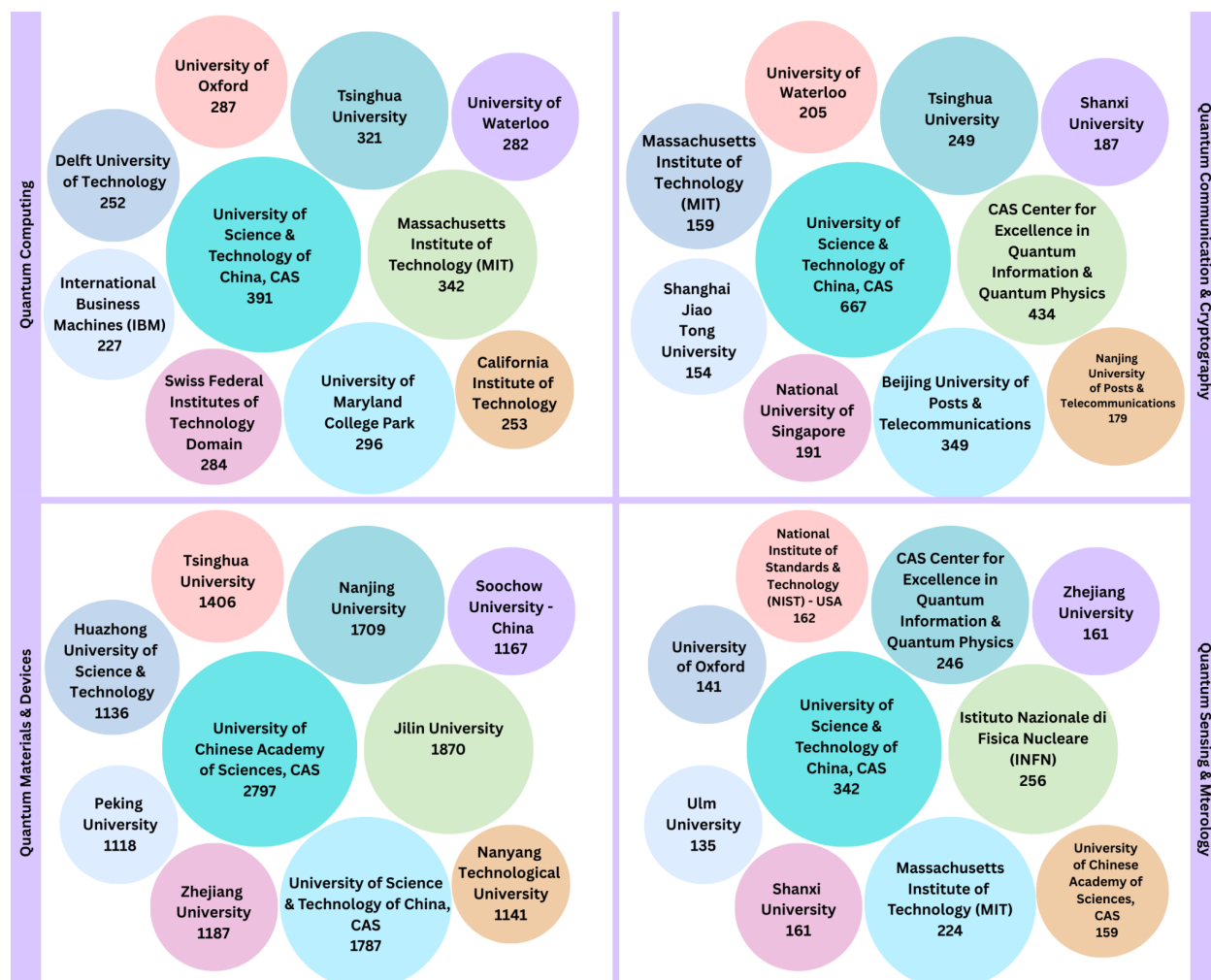


Figure 8: Organisations globally based on the Number of Publications in Q1 and Q2 journals and Global Top 10% publications - vertical-wise
Source: Web of Science Core Collection, Clarivate Analytics (Date accessed: 04/03/2025)

Looking at knowledge hotspots based on their share in the quality publications, it is evident that the majority of these hotspots are spread across verticals and are concentrated in countries like **China**, the **US**, **Japan** and the **UK**.

- Across all four quantum subfields, **Chinese organisations** (especially CAS entities, Tsinghua, and Peking University) frequently occupy the highest ranks. This signifies China's large-scale focus on quantum research.
- Institutions from **the US** like the Massachusetts Institute of Technology (MIT) figure as the knowledge hotspot in all the verticals.
- Entities like **CNRS** (France), **Max Planck Society** (Germany), **Riken** (Japan), through their entities show consistently high publication counts in the quality publications. The

presence of the national labs (e.g., Oak Ridge, Argonne in the US) is also seen across the verticals.

- University systems in the US (California, Texas, Illinois, Maryland, etc.), Canada (Toronto, British Columbia), Europe (Cambridge, Oxford, ETH Zurich), and Asia (NUS, NTU, University of Tokyo) appear across verticals, suggesting broad research portfolios that span several quantum domains.
- Notably, in Quantum Communications and Cryptography, **China leads with most institutions basis the quality**. This signifies China's strong research ecosystem in all four verticals of quantum with a stronger hold in quantum communication and cryptography.

Quantum computing, being a field with high commercial interest, apart from research institutions, the following technology corporations are also leading in the publications in this domain: Google Incorporated, IBM USA, Microsoft.

In **Quantum Computing**, the following research institutes/universities have a large number of publications:

- Massachusetts Institute of Technology (MIT), USA
- Delft University of Technology, Netherlands
- California Institute of Technology, USA
- University of Maryland College Park, USA
- Harvard University, USA
- University of Science & Technology of China, China
- University of Oxford, UK
- Tsinghua University, China
- Yale University, USA

In **Quantum Communication & Cryptography**, the following research institutes/universities have a large number of publications:

- University of Science & Technology of China, CAS, China
- CAS Centre for Excellence in Quantum Information & Quantum Physics, China
- Tsinghua University, China
- Delft University of Technology, Netherlands
- Beijing University of Posts & Telecommunications, China
- Massachusetts Institute of Technology (MIT), USA
- National Institute of Standards & Technology (NIST), USA
- University of Waterloo, Canada
- National University of Singapore, Singapore

- University of Geneva, Switzerland

In **Quantum Materials & Devices**, the following research institutes/universities have a large number of publications:

- University of Chinese Academy of Sciences, CAS, China
- Jilin University, China
- University of Science & Technology of China, CAS, China
- Nanjing University, China
- Tsinghua University, China
- Zhejiang University, China
- Massachusetts Institute of Technology (MIT), USA
- Nanyang Technological University, Singapore
- Soochow University, China
- Zhengzhou University, China
- Harvard University, USA

In **Quantum Sensing & Metrology**, the following research institutes/universities have a large number of publications:

- Massachusetts Institute of Technology (MIT), USA
- University of Science & Technology of China, CAS, China
- CAS Centre for Excellence in Quantum Information & Quantum Physics, China
- National Institute of Standards & Technology (NIST), USA
- Harvard University, USA
- Istituto Nazionale di Fisica Nucleare (INFN), Italy
- University of Oxford, UK
- Ulm University, Germany
- RIKEN, Japan
- University of California Berkeley, USA

Across the verticals, the following academic systems/government departments/research societies have a large number of publications through their affiliate/subsidiary organisations:

- United States Department of Energy (DOE) - System of institutes including Oak Ridge National Laboratory, Lawrence Livermore National Laboratory among others.
- University of California System - System of institutes including University of California, Berkeley, University of California, Los Angeles among others.

- Chinese Academy of Sciences - System of institutes including University of Science and Technology of China, University of Chinese Academy of Sciences (UCAS) among others.
- Centre National de la Recherche Scientifique (CNRS) - System of institutes including CNRS Chemistry, CNRS Physics among others.
- International Business Machines (IBM) - System of entities including IBM USA among others IBM entities.
- University System of Maryland - System of institutes including University of Maryland, College Park, University of Maryland, Baltimore among others
- Swiss Federal Institutes of Technology Domain - System of institutes including ETH Zurich, EPFL, Paul Scherrer Institute among others.
- Max Planck Society - System of institutes including Max Planck Institute for Physics, Max Planck Institute for Chemistry among others.
- University of London - System of institutes including King's College London, University College London among others.

1.A.3. Patents

Patent data has been analysed to comprehensively understand intellectual property capital across the QSTI ecosystem. The rise in the number of QSTI-related patent filings globally reflects growing efforts to secure intellectual property in this competitive field. It may be noted here that, globally, even though the number of QSTI-related patent filings shows a rising trajectory, the possibility that organisations are not patenting all the innovations exists. Through expert consultations, it was pointed out that organisations may be waiting to **achieve a certain internal threshold of innovation before patenting the technology**. A possible reason for this may be attributed to the competitive nature of this field.

Vertical-wise distribution of patent filings

The following figure analyses the YoY growth of patents being filed and granted across verticals globally:



Figure 9: QSTI-related patent filings trend (2013-23) vertical wise
Source: [Lens.org](#) [21] (Date accessed: 03/03/2025 - 04/03/2025)

Quantum Computing

- The patent filings for quantum computing show a growing trend from 2013-2018, followed by acceleration from 2019 onwards. Patent filings increased from 798 in 2019 to 2,951 in 2023, nearly quadrupling in just four years.
- The sharp increase from 2019-2020 coincides with [Google's quantum supremacy claim](#) [22] in 2019 when they announced their 53-qubit Sycamore processor. An increased commercial interest and investment could have resulted from this announcement. The continued steep rise from 2020-2023 also corresponds with [IBM's quantum roadmap announcement](#) (2020) [23] and the entrance of more commercial players seeking to establish intellectual property positions.

Quantum Communications & Cryptography

- The patents from this vertical signal consistent growth with a particular rise starting from 2018-19. The news of secure communication surfaced around the same time by China's [Micius](#) [24] claiming to have conducted the '[world's first quantum-encrypted virtual teleconference](#)' [25].

Quantum Materials & Devices

- The patents from this vertical have the highest absolute number of patent filings, reaching over 6500 patents filed by 2023. Unlike the other verticals, this growth in this vertical is more linear instead of exponential, without a sudden inflection point.
- The significantly higher baseline (starting at ~1,500 patents in 2013 vs. lower numbers for other verticals) may indicate that this area builds upon existing semiconductor and materials science IP portfolios.

Quantum Sensing & Metrology

- The patents from this vertical have the lowest absolute numbers but show a notable spike around 2021-2022 around which many countries launched their national programs/strategies on quantum.

The constantly increasing patent activity across verticals may also suggest that organisations are racing to secure intellectual property in anticipation of commercial applications.

Inventor Countries

An analysis of the patents across quantum verticals has been used to understand the top patent inventor countries. It may be noted here that the country information for some patents in each vertical was incomplete due to limitations at the data collection source. Hence, the following analysis may be limited in its insights.

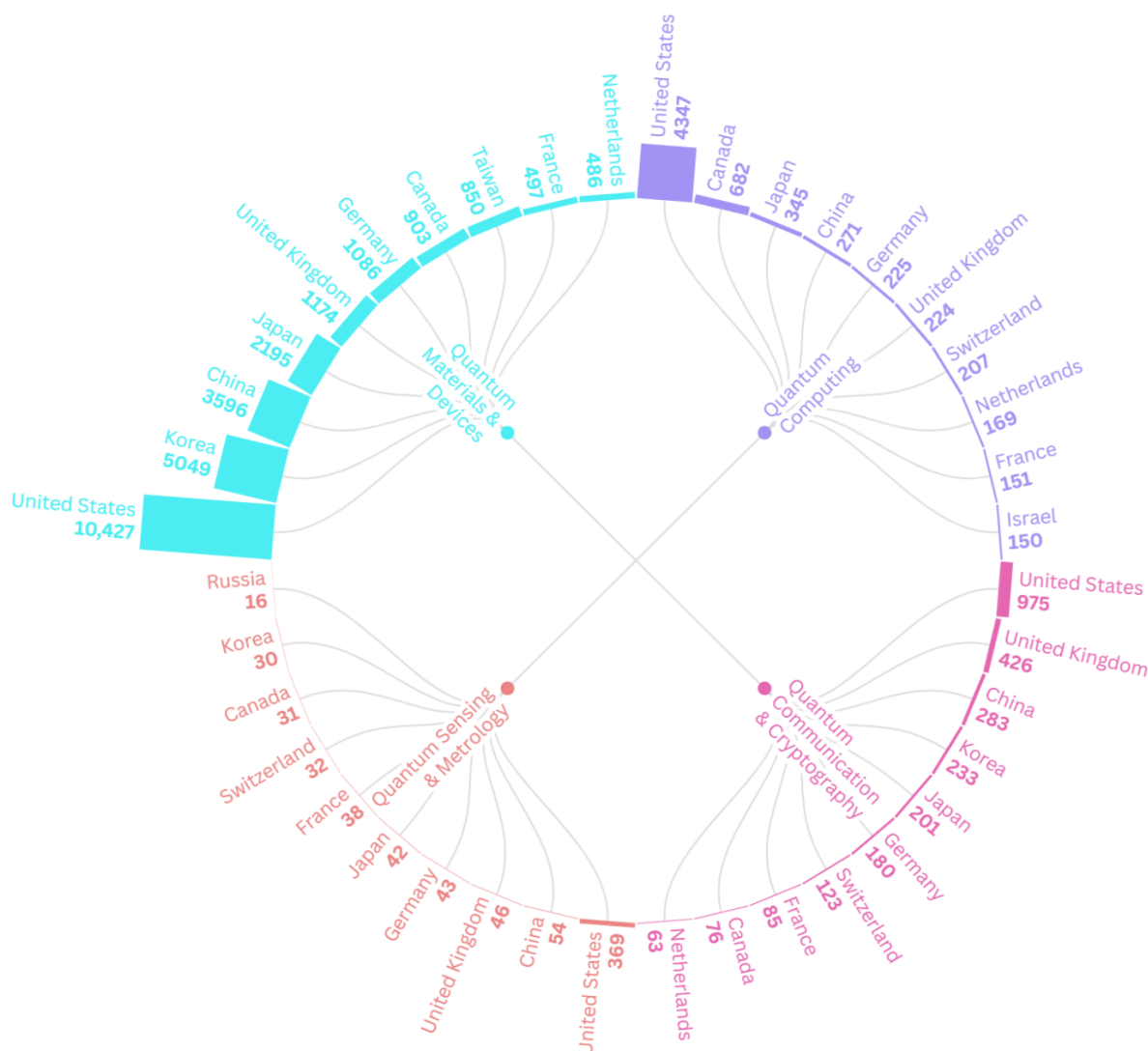


Figure 10: Inventor countries based on Patent filings - vertical-wise (Cumulative 2013-23)
Source: Lens.org (Date accessed: 03/03/2025 - 04/03/2025)

- **The U.S.** comes as the top inventor country in all four quantum technology categories, with particularly large numbers in Quantum Computing (4,347 patents) and Quantum Materials & Devices (10,427 patents). This may suggest that the US has built a substantial advantage across the quantum technology landscape. **Canada** can be seen as having capabilities across verticals with particular emphasis on quantum computing.
- While not appearing in the top 5 inventor countries, **India** appears in the top rankings for all categories except in sensing & metrology.
- Countries like **South Korea** could be focusing on specific verticals (like quantum materials and quantum communication) more while others (the US and China) are competing across the full spectrum of quantum technologies.

- Other Asian countries like China, Japan and South Korea collectively signify **particular** strength in **materials as well as communications** while **Europe demonstrates distributed innovation** across multiple countries like France and Germany rather than concentration in a single country.
- **The U.K.** consistently ranks in the top 5 in nearly all verticals which showcases its strength across domains of quantum.

Patent Owner Countries

An analysis of the patents across quantum verticals has been used to understand the leading countries owning the patents. It may be noted here that the country information for some patents in each vertical was incomplete due to limitations at the data collection source. Hence, the following analysis may be limited in its insights.

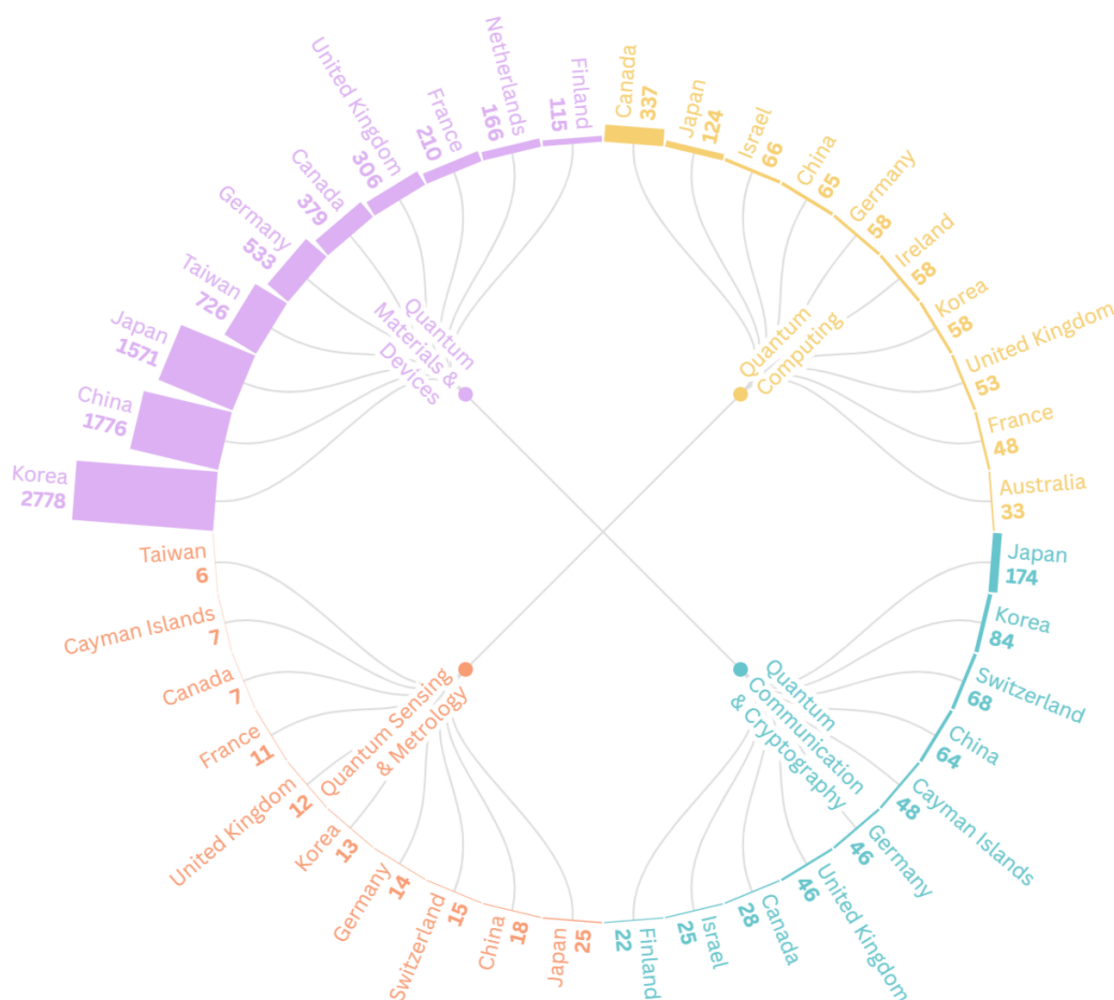


Figure 11: Patent owner countries - vertical-wise (Cumulative 2013-23)
 Source: Lens.org (Date accessed: 03/03/2025 - 04/03/2025)

- **The U.S.** does not appear among the top patent owners in any of the four categories, despite leading in inventor countries. This could be due to missing country data for patents at the data collection source. It is also to be noted that American organisations lead in almost all verticals in the following section which analyses patent owner organisations. It is also to be noted that the US has its presence based on analysis of the inventor countries as highlighted in the preceding section.
- Canada leads in Quantum Computing while South Korea leads in both Quantum Communication and Quantum Materials and Japan leads in Quantum Sensing.
- Japan maintains strong positions across all four verticals (ranking 2nd in Computing, 1st in Communication, 3rd in Materials, and 1st in Sensing).
- A notable owner region here is the Cayman Islands which appears in all four categories, suggesting it may be a location for intellectual property holding companies.

Patent Owner Organisations

An analysis of the patents across quantum verticals has been used to understand the organisations owning the patents. It may be noted here that the country information for some patents in each vertical was incomplete due to limitations at the data collection source. Hence, the following analysis may be limited in its insights.



Figure 12: Patent owner organisations globally - vertical wise (Cumulative 2013-23)
Source: Lens.org (Date accessed: 03/03/2025 - 04/03/2025)

Quantum Computing

- **IBM** holds the highest number of quantum computing patents, more than double its nearest competitor, Microsoft. The heavy presence of large technology organisations suggests a concentration of patent ownership among the traditional technology giants (IBM, Microsoft, Google), specialised quantum companies (D-Wave, IonQ, Quantinuum), and open-source contributors (Red Hat).
- Even though, some companies don't show up in patent ownership but have breakthrough inventions as reported by [Quantum Insider](#) [107], companies such as **Origin Wukong** [], has 72-qubit superconducting chip with more than **80 percent** of its hardware and software

components **domestically produced**, which has completed over 339,000 quantum computing tasks serving users from 139 countries.

Quantum Communication & Cryptography

- Kabushiki Kaisha Toshiba owns the highest number of patents in this vertical as well followed by Wells Fargo and Alibaba Group.
- The presence of multiple banks like Wells Fargo indicates significant investment in quantum-resistant cryptography by financial institutions concerned about future threats to classical encryption.
- Telecommunications companies like Nokia and AT&T only appear in this particular vertical. This may suggest the investments in R&D by the telecom companies to aid network security. Nokia owning patents in this field corroborates with the [recent developments](#) [26] in the deployment of quantum secure networks to protect Korea Hydro and Nuclear Power's IT infrastructure.

Quantum Materials & Devices

- Samsung holds the highest number of patents in this vertical with its two entities (**Display Co LTD and Electronics Co LTD**) collectively holding ownership over 2,100 patents. South Korea's focus on Materials & Devices through patent inventor and patent owner country data is further corroborated by Samsung's extensive patent portfolio.
- China's BOE Technology Group is also a major owner of patents in this vertical with 698 patents, suggesting China's focus on quantum materials & devices.
- The presence of display companies (**Samsung Display, BOE, LG Display**) indicates investments in quantum materials for display technologies. Electronic companies also own a considerable amount of patents in this vertical (Samsung Electronics, Osram Opto, Intel), possibly suggesting quantum materials's importance for advanced semiconductor development.

Quantum Sensing & Metrology

- Companies like IBM, Equal1 Labs and Microsoft lead patents owned in this vertical. Also notable is the presence of financial institutions like Wells Fargo and government entities, which may suggest quantum sensing applications in security and measurement systems for financial and governmental domains.

- Academic institutions like MIT and Southern Methodist University rank considerably higher in this vertical than in others, indicating the research stage of quantum sensing, with significant R&D still occurring in research settings.

1.A.4. Industry

Based on patenting landscape and analysis, the global tech giants can be seen playing a major role in shaping the quantum technology landscape with major legacy technology firms such as Google, IBM, Intel and Microsoft competing to achieve quantum advantage. Startups like Rigetti Computing, IonQ, D-Wave, Xanadu and PsiQuantum are pioneering novel approaches for trapped ion, photonic, and quantum annealing etc. Companies like Origin Quantum are working towards 1024-Qubit Quantum Computer.

1.A.4.i. Startups

An analysis of the quantum technology based startups on a global scale reveals the following insights on their YoY growth and distribution among verticals.

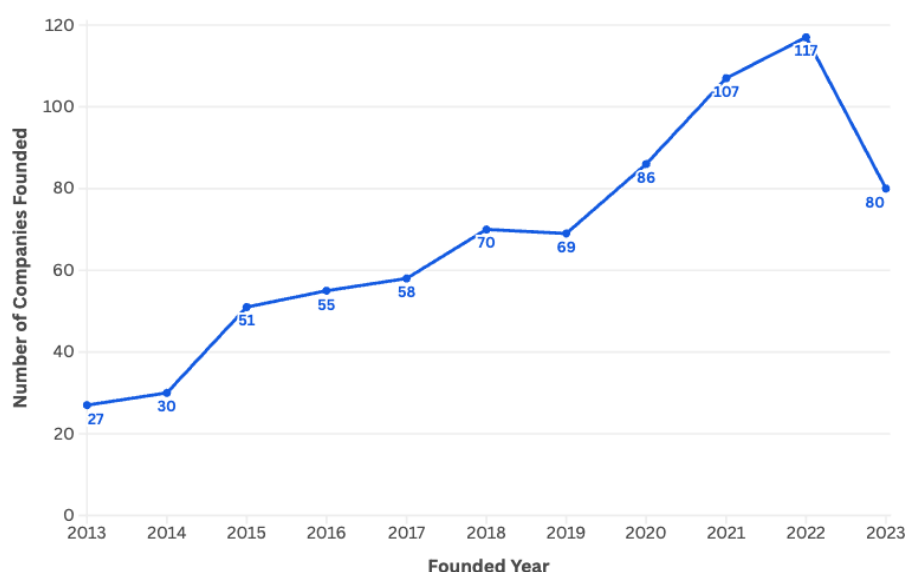


Figure 13: Number of QSTI companies founded YoY globally
Source: Tracxn [27] (Date accessed: 10/03/2025)

The data shows a **general upward trajectory** in quantum company formations from 2013 (~30 companies) to a peak in 2022 (~117 companies), with some fluctuations over the years. It is also to be noted that after the 2022 peak, there's a decline in new company formations in 2023 which is consistent with the fluctuations in global private investments.

Sectoral Categorisation

Globally, quantum technology startups are working in various sectors of quantum which may not necessarily equate with the four verticals as defined by India's National Quantum Mission (NQM). Following is an analysis of the sectoral categorisation of these startups:

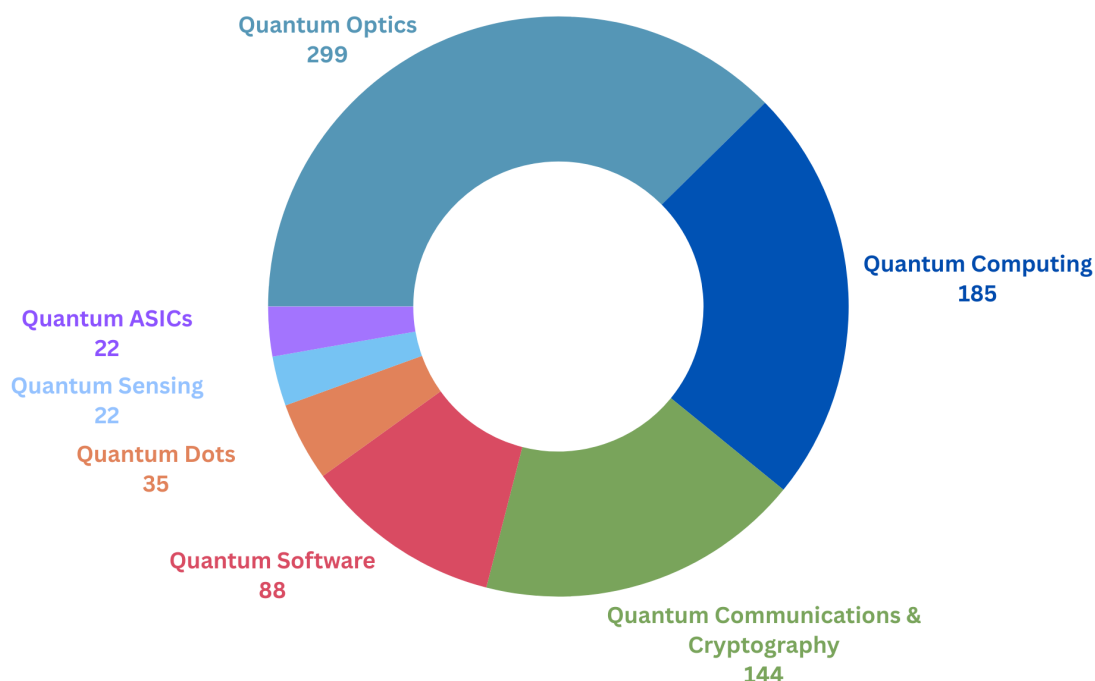


Figure 14: QSTI Startups sectoral categorisation globally
 Source: Tracxn (Date accessed: 10/03/2025)

The category of **Quantum Optics** has the highest number of startups globally which is followed by Quantum Computing and Quantum Communications & Cryptography.

- The Quantum Optics category has applications in a wide range of sectors including Quantum Computing among others, suggesting a specialisation of startups in this domain.
- The presence of startups working in the field of quantum dots also corroborates with the patent and research publication analysis in section 1.A.2 and 1.A.3 signifying a large number of patents in the field of quantum materials & devices.
- The Quantum ASICs category of startups suggests a significant category of startups working on specialised quantum tasks while quantum software which is another category for startups suggests a focus on software specific commercialisation in quantum.

- Export consultations highlighted the major focus by investors and commercial entities in quantum computing. This further correlates to the focus of startups in quantum computing and areas which feed into quantum computing like ASICs, Software and Optics as well.

Note: To ensure coherence to other data points and analysis, the following categories of startups have been combined for analysis purposes:

- The startups with categories of ‘Quantum Computers’, ‘Quantum Computing in Cybersecurity’ and ‘Quantum Computing in Healthcare’ are combined to be ‘Quantum Computing’.
- The startups in ‘Quantum Communication’ and ‘Quantum Cryptography’ are combined as ‘Quantum Communication and Cryptography’

Country-wise startup distribution

The U.S. leads with the largest share of quantum startups globally while **India ranks in the top 10 countries** on the basis number of startups. This suggests the US’s lead in the quantum startup ecosystem with over 300 startups.

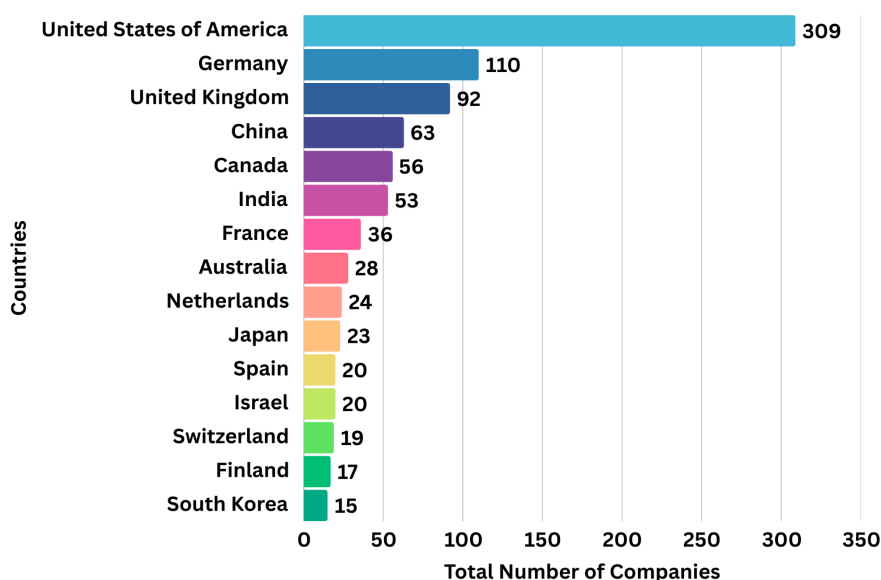


Figure 15: Distribution of QSTI Startups globally
Source: Tracxn (Date accessed: 10/03/2025)

1.A.4.ii. Investments/Funding

Data for investments and funding reveal a growing investment trend with a **peak in 2021** with nearly \$2.3 Billion in investments. This indicates a substantial increase in investments from the 2013 levels.

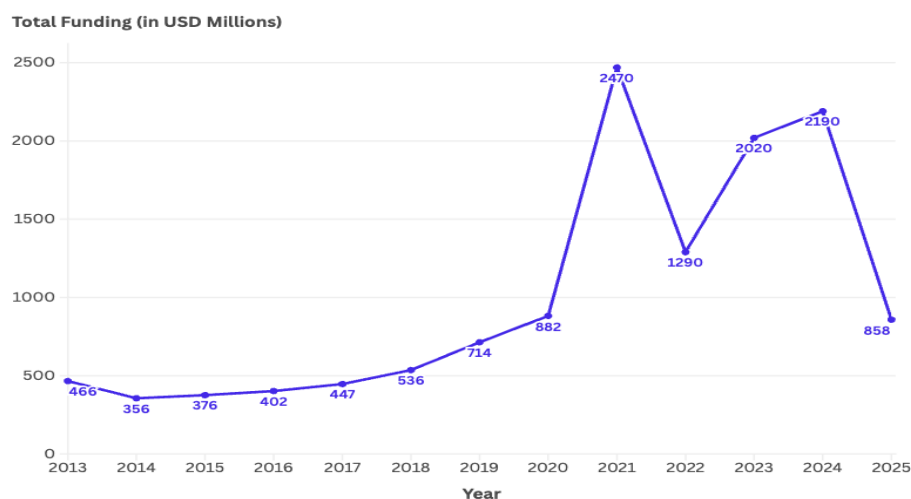


Figure 16: YoY funding of QSTI startups globally
Source: Tracxn (Date accessed: 12/03/2025)

The year 2022, however, witnessed a decrease in funding. Expert consultations and recent announcements by companies like [Google](#) [28], [Microsoft](#) [29], and [Amazon](#) [30] suggest that companies have been investing in internal R&D through the period of declines in investments. The data may also suggest a possible decline only from a VC/Funding investments point of view and not necessarily private funding by companies to focus on internal R&D. Insights from expert consultations also revealed that the overall investment decline in 2022 was matched by the launch of several national missions and programs by countries around the world, giving rise to public funding.

Country-wise funding distribution

An analysis of country-wise founding/investments distribution suggests **the US getting the highest amount of private investments**, corroborating with the large number of startups the country has. **China**, with only 63 startups accounts for a large amount of investments. Meanwhile, European countries leading with the Netherlands signify substantial investments in this space.

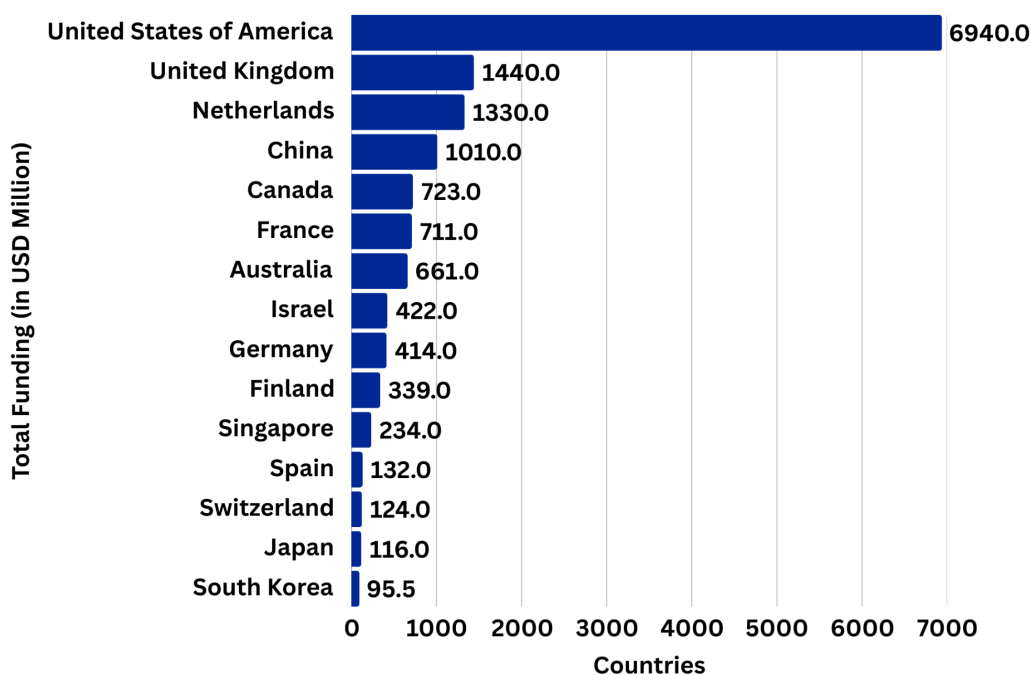


Figure 17: Total funding in QSTI - Global distribution
Source: Tracxn (Date accessed: 12/03/2025)

- The U.S. has received approximately **USD 6.94 billion** in quantum funding. This represents more than **4.5x the investment of the second-highest country (the U.K.)** and depicts the concentration of investments in the US
- India with its approximate investments of USD 30 million does not rank in the top 10 countries.

1.A.4.iii. Unicorns

The unicorns (companies valued at \$1 billion or more) in the QSTI field are analysed to understand the geographic concentration and sectors of quantum these unicorns are distributed in.

- The quantum technology sector consists of **13 unicorns**, with **7 publicly listed companies** and **6 private companies**. This distribution suggests that a significant portion of quantum companies has transitioned to public markets, which may reflect growing investor interest and confidence in the sector's maturity.
- **The U.S. leads with 7 quantum unicorns** (54% of the total), indicating its strong ecosystem for quantum technology commercialisation. This is corroborated by expert consultations and the analysis of publications, patents and investments in the previous sections.

- Aligning with the analysis of investments and startups, **Quantum computing remains the leading field for unicorns as well**, accounting for **9 out of 13** unicorns globally (nearly 70%). This includes both public companies like IONQ and D-Wave as well as privately held companies like Quantinuum and PsiQuantum.
- China hosts 3 unicorns (23%), including QuantumCTek, which has the **highest market value** among publicly listed companies at \$4.075 billion.

Publicly listed unicorns in QSTI			
Company	Market Value (in Billion USD)	Field	Country
QuantumCTek	3.63 (26.33 CNY)	Quantum Computing	China
Qtec	3.39	Quantum Materials	China
IONQ	5.45	Quantum Computing	USA
Rigetti Computing	2.33	Quantum Materials	USA
Quantum Computing Inc	1.16	Quantum Computing	USA
D-Wave	2.21	Quantum Computing	Canada
Arqit	0.209	Quantum Materials	UK

Unicorns in QSTI				
	Post Money Valuation (in USD Billion)	Total Equity Funding (in USD million)		
Quantinuum	5	300	Quantum Computing	USA
SandboxAQ	4	500	Quantum Computing	USA
PsiQuantum	3	1000	Quantum Computing	USA
XtalPi	2	786	Quantum Pharmaceuticals	China
Xanadu	1	231	Quantum Computing	Canada
Quantum Metric	1	226	Quantum Computing	USA

Table 2: Unicorns and publicly listed unicorn enterprises in the QSTI
Source: Crunchbase, Yahoo Finance, Nasdaq 2024 (Date accessed: 31/03/2025)

1.A.4. iv. Acquisitions

The U.S. dominates the global acquisition landscape with 29 deals (58% of the global total), followed by Germany with 7 acquisitions. Asian countries (Japan, South Korea, and China) have low acquisition counts. Unlike the US and Germany, China has only 1 acquisition. It could be also because Chinese acquisitions are often undisclosed due to government restrictions.

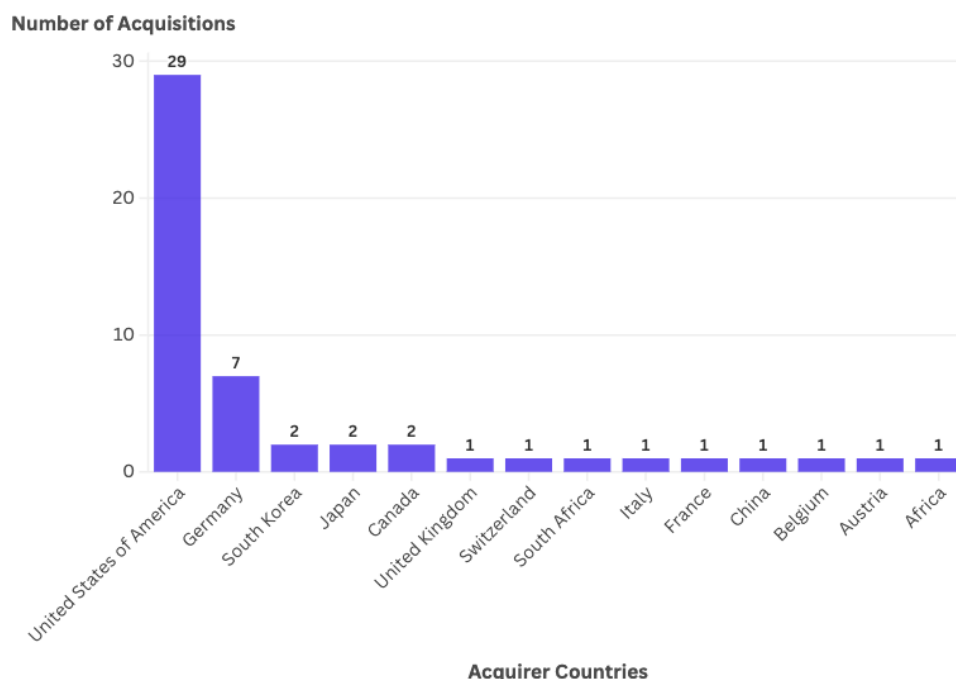


Figure 18: Number of acquisitions of QSTI companies - Global distribution
Source: Tracxn (Date accessed: 12/03/2025)

The industry has started to exhibit signs of maturation through strategic mergers and acquisitions (M&A), as seen in [IonQ's acquisition of Qubitekk](#) [32], [Kipu Quantum's purchase of Anaqor](#) [33], and [SandboxAQ's acquisition of Good Chemistry](#) [34], indicating the early stages of market consolidation. The U.S. lead in acquisitions is further shown through recent reports of IonQ making several acquisitions. [IonQ has also entered into partnership with SK Telecom](#) [35] and is in talks to [acquire Geneva-Based ID Quantique](#), This acquisition will strengthen IonQ's position in quantum networking, adding 300 patents to its portfolio.

1.A.5. Supply Chain

Given the emerging nature of the field of QSTI, an analysis of the supply chain components and their dependencies is necessitated. Due to a lack of comprehensive mapping of supply chain dependencies in the Indian context, a reference from the Netherlands Organisation for Applied Scientific Research's work has been taken. The following figure depicts the mapping of supply chain dependencies.

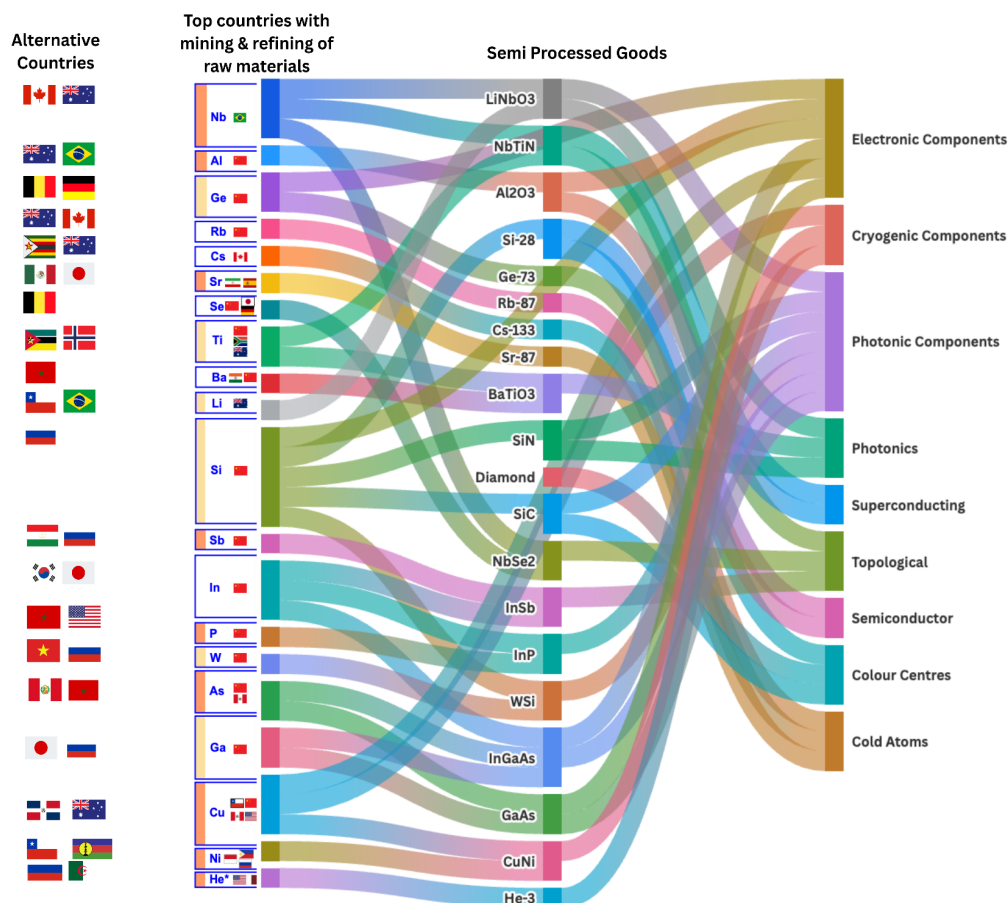


Figure 19: Overview of the materials that are required for quantum technology R&D

Source: Reproduced based on [Critical raw materials for quantum technologies](#), Netherlands Organisation for Applied Scientific Research (TNO)

Figure 19 depicts an overview of the materials that are required for quantum technology R&D prepared by the [Netherlands Organisation for Applied Scientific Research](#) [36]. From left to right: raw elements, semi-manufactured goods¹ and isotopes, and components for quantum processors and enabling technologies. The country flags indicate the top countries that together currently hold >50% of global mining & refining capacity. The yellow and orange indicators denote which materials (Nb: niobium; Al: aluminium; Ge: Germanium; Rb: rubidium; Cs: caesium; Sr: strontium; Se: selenium; Ti: titan; Ba: barium; Li: lithium; Si: silicon; Sb: antimony; In: indium; P: phosphorus; W: tungsten; As: arsenide; Ga: gallium; Cu: copper; Ni: nickel; He: helium) are earmarked as strategic and critical raw materials respectively by the European Commission.

¹ *He-3 is mostly produced from H-3 (tritium). NbTiN: Niobiumtitaniumnitride, Al₂O₃: Aluminium Oxide, Si-28: Silicon-28, Ge-73: Germanium-73, Rb-87: Rubidium-87, Cs-133: Cesium-133, Sr-87: Strontium-87, BaTiO₃: Barium titanate, LiNbO₃: Lithium niobate, SiN: Silicon Nitride, SiC: Silicon Carbide, NbSe₂: Niobium Diselenide, InSb: Indium Antimonide, InP: Indium Phosphide, WSi: Tungsten Disilicide, InGaAs: Indium Gallium Arsenide, GaAs: Gallium Arsenide, CuNi: Cupronickel, He-3: Helium-3

- From the above supply chain mapping, it can be seen that China's dominant presence is not only in raw materials supply but in the refinement process as well, suggesting an overall dependency on Chinese supply.
- Lithium is required in the manufacturing of photonics and photonics components and is a critical component for photonics. Hence, reducing a possible dependency of Lithium would be a step in the right direction to secure India's supply chain. On that front, India in 2023 [discovered](#) [37]² 5.9 million tons of Lithium in Jammu & Kashmir, which could be a key asset for quantum photonic components.
- Cryogenic components are critical for quantum technologies, superconducting qubits, and ultra-sensitive quantum sensors. Seeing the enabling technologies, the supply chain of cryogenic components is dominated by a few countries, India has an opportunity to position itself as a key player in this domain by leveraging its existing expertise in cryogenic engineering from ISRO, DRDO, and national research institutions such as the Inter-University Accelerator Centre (IUAC), Tata Institute of Fundamental Research (TIFR), Institute for Plasma Research (IPR), and the Variable Energy Cyclotron Centre (VECC).

Alternate Producers/Suppliers of Elements

- [Nb](#): Canada, Australia; however, Brazil has 98%.
- [Al](#): China (58%), Australia (14%), Brazil (8%), India (5%), Russia (2%), UAE (1.7%), Ireland (1.34%).
- [Ge \(metal\)](#): China (54%); Belgium (30%); Germany (8%).
- [Rb](#): Australia, Canada, China, Namibia.
- [Cs](#): Canada, Zimbabwe, China, [Australia](#).
- [Sr](#): Spain (200,000 metric tons/MT), Iran (200,000 metric tons), China (80,000 metric tons), Mexico (35,000 metric tons); and Argentina (700 metric tons); [Turkey](#) is also said to have some deposits.
- [Se](#): China, 1,400 metric tons; Japan, 710 metric tons; Germany, 300 metric tons. Several [other countries](#) such as [Belgium](#) are involved since it often occurs as a byproduct of copper refining.
- [Ti](#): China, Mozambique, South Africa, Australia, Norway, Canada, etc.
- [Ba](#): India, China and Morocco are the largest producers.
- [Li](#): Australia, Chile, China, Argentina, Brazil are the top 5 producers.
- [Si](#): After China, Russia is the second largest producer at 520,000 metric tons.
- [Sb](#): China (47%), Tajikistan (23%), Russia (17%), Myanmar (4%).
- [In](#): The top 5 producers are China, South Korea, Japan, China, Belgium.
- [P](#): China (41%), Morocco (16%), the US (9%), Russia (6%).

² It is to be noted here that the discovery done is a preliminary one (G3) and quantities with the deposit can be estimated only with a low level of confidence.

- **W:** China (67,000 MT), Vietnam (3,400 MT), Russia (2,000 MT), North Korea (1,700 MT), Bolivia (1,600 MT).
- **As:** Peru (45%), China (40%), and Morocco (13%), largely derived during the refining of Cu and other ores.
- **Ga:** China, Japan, Russia and South Korea.
- **Cu:** Chile (5.3 million MT), Democratic Republic of Congo (3.3 million MT), Peru (2.6 million MT), China (1.8 million MT), Indonesia (1.1 million MT), United States (1.1 million MT), Russia (930,000 MT), Australia (800,000 MT), Kazakhstan (740,000 MT), Mexico (700,000 MT).
- **Ni:** Indonesia (20%), The Philippines (11%); **other** countries include Russia and New Caledonia.
- **He:** USA, Qatar, Russia, Algeria.

Production of specialised components

- NITI Aayog Frontier Tech Hub's [recent report](#) [14] highlights the increased focus on the production of cryogenic systems, specialised lasers and ultra-high purity materials for quantum computing. It also notes some of the key players in this field like Quantum Silicon, Materion, SigmaAldrich, American Elements, Kyocera, Oxford Instruments, Bluefors, Cryoconcept, Sumitomo Heavy Industries, Cryomech, Samtec, Lake Shore Cryotronics, Toptica Photonics, NKT Photonics, Zurich Instruments, Tektronix, and Quinstar Technology.
- The establishment of specialised fabrication facilities is also taking place for making components and quantum chips. The report mentions the following players in this sphere: Seeqc, Rigetti Foundry Services, VTT, IQM, IMEC, CEALeti, AQT, QuiX Quantum, and LioniX International.

1.A.6. Standards

The International Electrotechnical Commission (IEC) and International Organization for Standardization (ISO) Joint Technical Committee (JTC) 3 is [focused](#) [38] on Quantum technologies. The scope includes standardisation in the field of quantum technologies, including quantum information technologies (quantum computing and quantum simulation), quantum metrology, quantum sources, quantum detectors, quantum communications, and fundamental quantum technologies. It is based out of its secretariat at the [British Standards Institution \(BSI\)](#) [39].

There are 7 working groups under the IEC/ISO JTC 3:

1. Strategic Planning
2. Quantum terminology and metrics

3. Quantum sensors (sensing, devices, and imaging)
4. Quantum secure communication
5. Quantum computing and simulation
6. Quantum random number generator (QRNG)
7. Quantum enabling technologies

The work programme for the IEC/ISO-JTC 3 is stated as below:

- a. Quantum technologies – Terminology and quantities – General quantities ([PNW JTC3-59 ED1](#) [40])
- b. Quantum technologies – Terminology and quantities – General vocabulary ([PNW JTC3-62 ED1](#) [41])
- c. Characterization and Measurement of the Frequencies of Optical Frequency Standards ([PNW JTC3-68 ED1](#) [42])
- d. Characterization and measurement of the performance of single-photon sources ([PNW JTC3-69 ED1](#) [43])
- e. Information technology — Introduction to quantum computing is under development ([ISO/IEC AWI TR 18157](#) [44])
- f. Quantum Photonics Vocabulary is under development ([IEC/ISO 63622 ED1](#) [45])

The following are relevant ISO standards to Quantum technologies:

- g. Information technology — Quantum computing — Vocabulary (Published in 2024). This document defines terms commonly used in the field of quantum computing. ([ISO/IEC 4879:2024](#) [46])
- h. Information security — Security requirements, test and evaluation methods for quantum key distribution – Part 1: Requirements (Published in 2023). This document specifies a general framework for the security evaluation of quantum key distribution (QKD) ([ISO/IEC 23837-1:2023](#) [47]) and Part 2: Evaluation and testing methods (Published in 2023). This document specifies test and evaluation methods for the security evaluation of quantum key distribution (QKD) ([ISO/IEC 23837-2:2023](#) [48]).

1.A.7. Open-source projects developments

Open-source development in QSTI is transforming the field by making software, algorithms, and simulators, accessible to researchers, developers, and startups. It reduces the redundancy in research efforts and provides a common platform for global collaboration. The Quantum Open Source Foundation (QOSF) provides a detailed [list of Open Quantum Projects](#) [49]. Following are some of the major ones:

- Open-source software platforms like [IBM's Qiskit](#) [50], [Google's Cirq](#) [51], [Xanadu's PennyLane](#) [52], [Rigetti's Forest](#) [53], and [Open Quantum Safe](#) [54] provide researchers, developers, and startups access to quantum algorithms and quantum hardware simulators.

- [Open Quantum Design announced the world's First Open-Source Trapped-Ion Quantum Computer Platform](#) [55].

1.A.8. Consortiums / Alliances

In the global QSTI landscape, consortiums and alliances play a critical role in fostering collaboration, pooling resources, and accelerating technological advancements. The following lists some of the consortiums and alliances for quantum technologies globally:

- [Quantum Economic Development Consortium \(QED-C\)](#), United States
- [Chicago Quantum Exchange](#), United States
- [Open Quantum Institute \(OQI\)](#), Geneva Science and Diplomacy Anticipator (GESDA)
- [European Quantum Industry Consortium \(QuIC\)](#)
- [UK Quantum Hubs](#)
- [Quantum Industry Canada \(QIC\)](#)
- [Quantum Strategic Industry Alliance for Revolution \(Q-STAR\)](#), Japan
- [Quantum Internet Alliance](#), Delft, Netherlands
- Linux Foundation - [Post-Quantum Cryptography Alliance](#)
- [Munich Quantum Valley](#)
- [C-DOT India Quantum Alliance](#)

1.A.9. Conferences

Some of the key global conferences focused on quantum technologies:

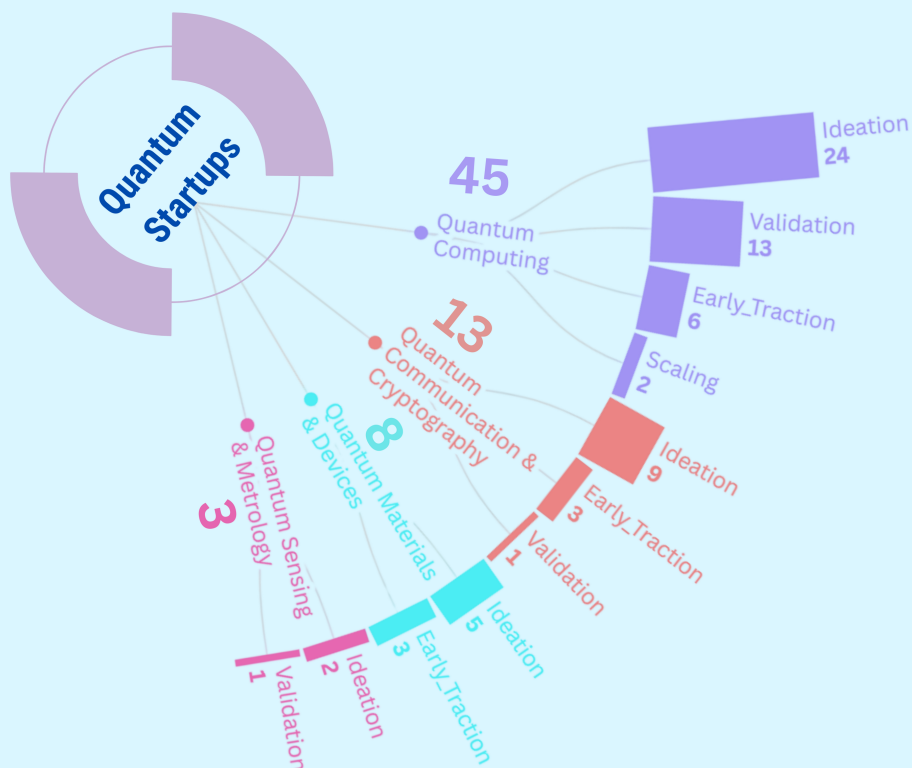
- [Joint March Meeting and April Meeting: Global Physics Summit 2025 | American Physical Society](#)
- [Optica Quantum 2.0 Conference and Exhibition](#)
- [International Conference on Quantum Technologies for High-Energy Physics \(20-24 January 2025\)](#)
- [Quantum.Tech](#)
- [Q2B – Quantum Computing Business Conference](#)
- [IEEE Quantum Week](#)
- [CERN Quantum Technology Initiative](#)

1.B. India's QSTI Landscape

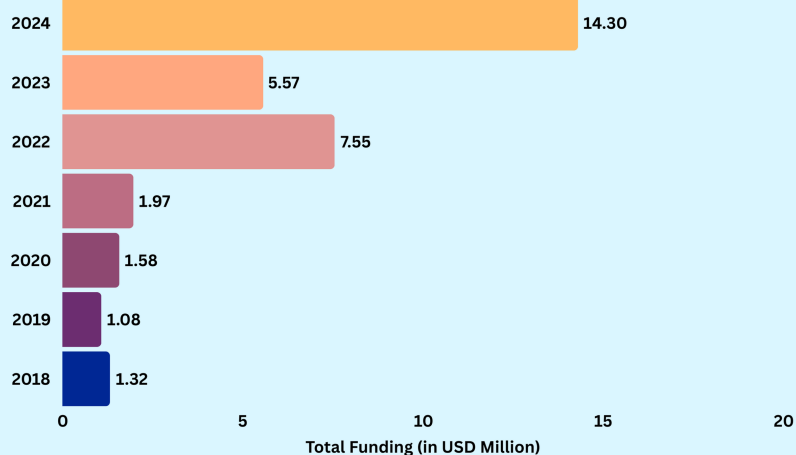
India has long maintained a strong emphasis on fundamental sciences, which serves as a robust foundation for research and development in the field of quantum science and technologies. India is emerging as a significant player in a field that has traditionally been led by countries like the US, EU and China. India's growing digital economy and initiatives like the National Supercomputing Mission, IndiaAI mission and Digital India underscore the importance of the development of Quantum Science & Technology for national initiatives. As a country with a growing interest in technology-driven developments across sectors and the [vision of Techade](#) [56], India stands to benefit significantly from advancements in Quantum science & technology.

India's quantum ecosystem is mapped through the indicators of the talent ecosystem, research and institutional landscape, intellectual property, corporate and startup ecosystem and India's existing international collaborations.

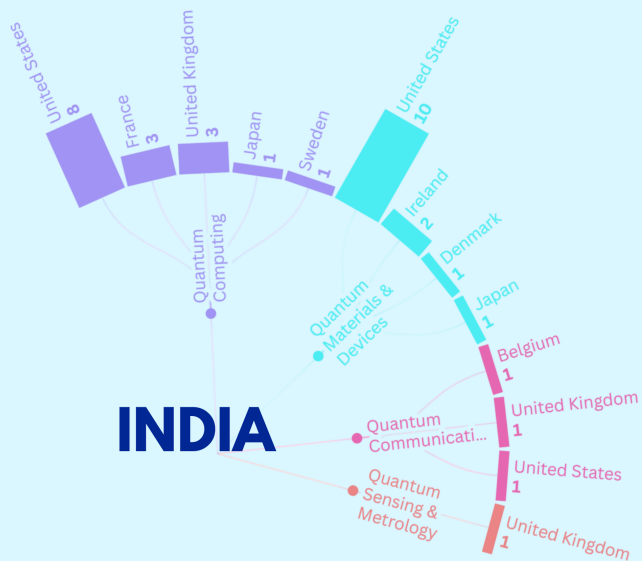
A snapshot of India's QSTI ecosystem is presented below providing an overall analysis into the ecosystem:



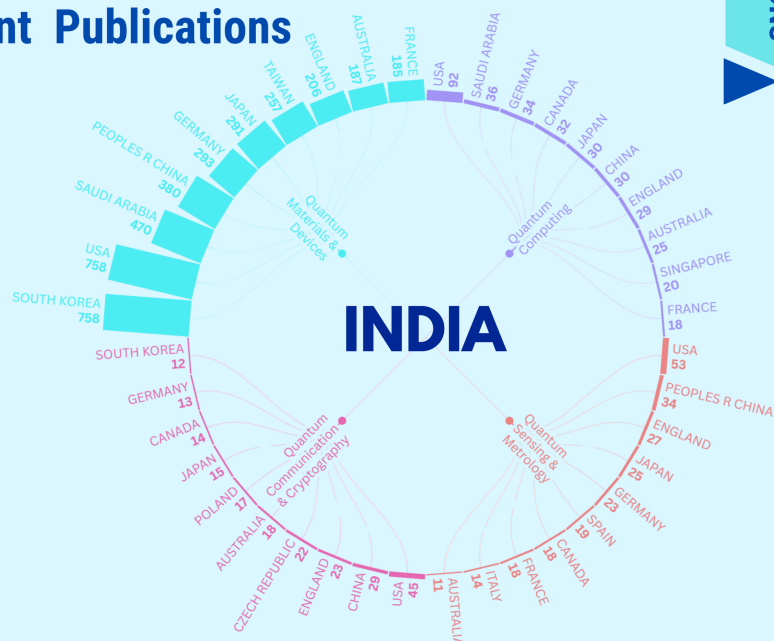
Funding trend of QST startups in India



Joint Patents



Joint Publications



17



3

IndianOil



3

QCWARE



cognizant®

3



भारतीय विज्ञान संस्थान

661



677



572

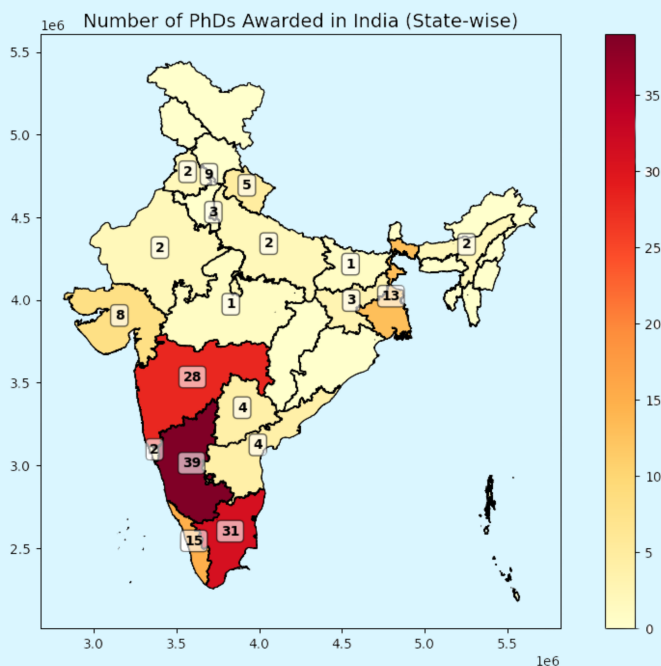


616



517

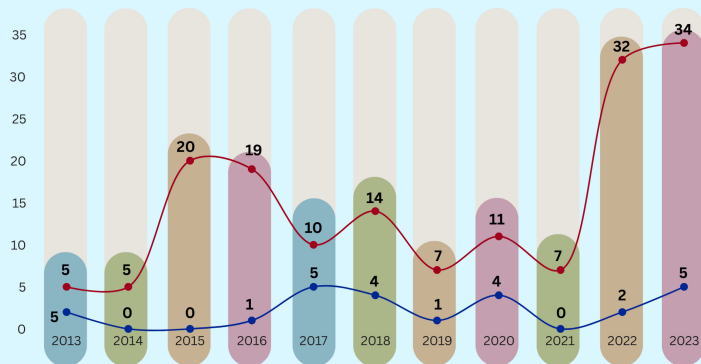
State/UT wise distribution of researchers in India



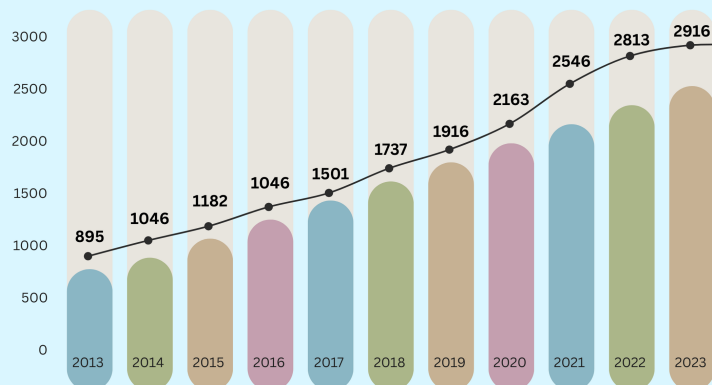
Total Patents India Level



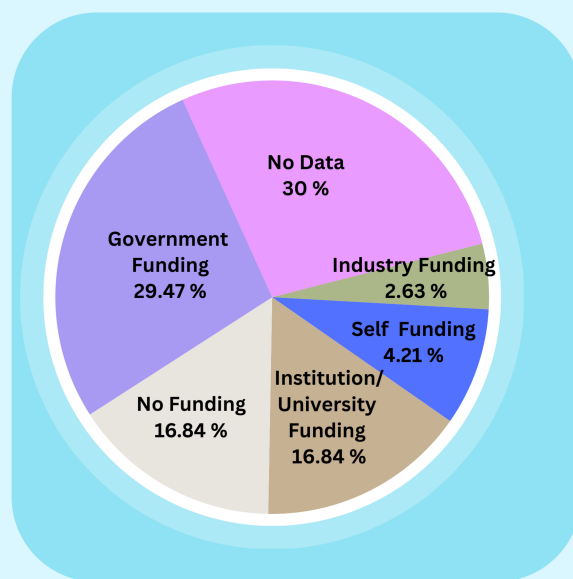
Overall Patents - India Level



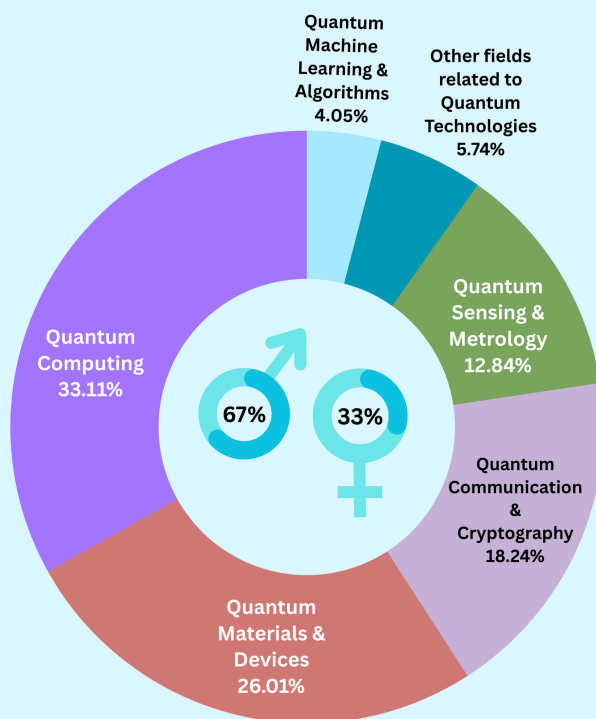
Overall Publications - India Level



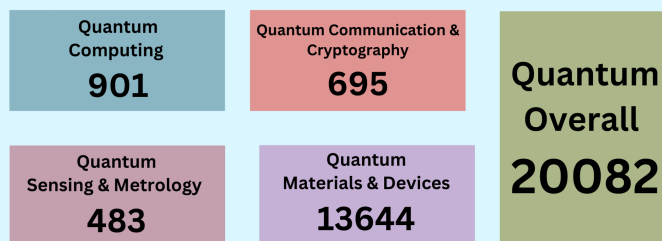
Funding Distribution among researchers



Domain Categorisation under QST for PhD/Post Doc/Early Career Researchers



Total Publications - India Level



1.B.1. Capacity Building

The role of capacity building in advancing the competencies in an evolving field like QSTI is crucial for India. For measuring India's current capabilities in this field, the state of the current capacity building measures, graduate-level courses and industry's contribution to capacity building is depicted below.

There exist various programs in quantum technologies in universities/institutions across India. A 2023 [report](#) [57] by QETCI suggests around **50** such programs around India. Complementing the academic institutions, there are various companies that are working to add value to quantum education in India. The following lists some of these institutions offering QSTI courses and companies focusing on quantum education across the country:



Figure 20: Institutions in India offering QSTI-related courses
 Source : QETCI Quantum Value Chain Report 2023

India is pushing for the development of a skilled workforce in quantum technologies through various academic programs and research collaborations. The recently launched [undergraduate curriculum by DST and AICTE](#) [58] under the NQM aims to impart training in all four spheres of quantum technology.

1.B.1.i. Analysis of PhDs and Postdocs in QSTI

The quantum technology research ecosystem spans diverse interconnected domains. An analysis of the research details provided by the researchers reveals the following aspects of QSTI in focus:

- Researchers are working to advance quantum computing algorithms while addressing error correction challenges.
- Materials scientists are developing improved quantum hardware through superconducting circuits, trapped atoms/ions, and engineered quantum dots.
- Quantum communication researchers are focusing on secure protocols and satellite-based systems.
- Researchers in quantum sensing are leveraging specialised quantum systems for precision measurements.

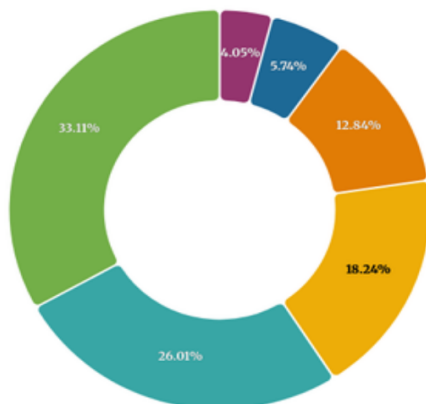
This interdisciplinary field integrates computer science, materials science, electronics, and biology through both experimental and theoretical approaches. Further, researchers are trying to address challenges in qubit coherence, system scalability, and commercialisation across healthcare, communications, energy, and security sectors.

Additionally, according to NITI Aayog Frontier Tech Hub's recent [report](#) [14], the workforce involved in the field of QSTI in India includes a total of over **170** professors who are currently working in related domains related to Quantum science and technology.

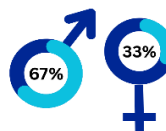
Data was collected through a primary survey of PhDs and Post Docs for inputs on the sub-domain of specialisation, gender representation, funding patterns and other parameters. Analysis was done on a total of **189** respondents.

Domain Categorisation under QST for PhDs/Post Docs

■ Other fields related to Quantum Technologies ■ Quantum Communications & Cryptography
■ Quantum Computing ■ Quantum Machine Learning & Algorithms ■ Quantum Materials & Devices
■ Quantum Sensing & Metrology



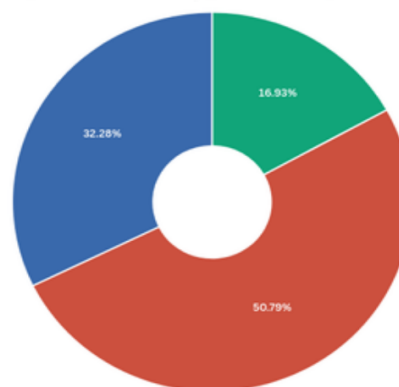
The major chunk of respondents are focusing on the sub field of **Quantum computing**, which is closely followed by **Quantum communication & cryptography** and others. This also aligns with the insights from derived by expert consultations and analysis of funding data



The gender representation shows males being the majority in the field with a split of **66%** and **33%** with the females

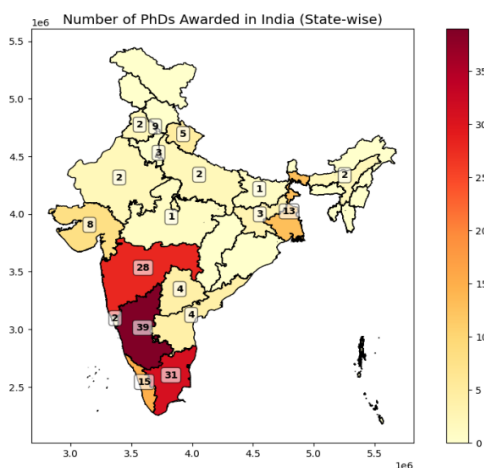
Industry Collaboration among PhDs/Post Docs

■ Collaboration with Industry ■ No Collaboration ■ No Data



Nearly **17%** of respondents had collaborated with industry in the past or were collaborating for their research in various areas of quantum technologies.

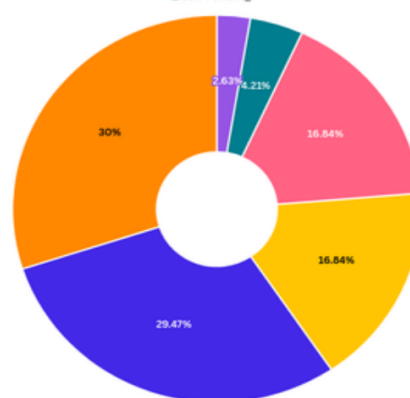
State/UT wise distribution of PhDs/Post Docs in India



Most number of respondents are concentrated in the state of **Karnataka**, followed by Tamil Nadu and Maharashtra

Funding Distribution among PhDs/Post Docs

■ Government Funding ■ Industry Funding ■ Institution/University Funding ■ No Data ■ No Funding ■ Self Funding



Analysis of funding sources for PhDs/Post Docs reveal that most respondents are funded either by their host institutions or via various government programs. Only **2.63%** of the respondents claimed to have been funded by the industry. This is further corroborated by expert consultations highlighting that there is a lack of industry funding. Another point to be noted is, a substantial percentage of respondents have no funding at all, causing difficulties in research activities

Figure 21: Analysis of PhD/ Post-Doc/ Early Career Researchers in India in QSTI
Source: Primary Survey (Time Period: 12th February - 6th March 2025)

Here, 'Other fields related to Quantum Technologies', refer to the following fields with low representation of researchers: CO₂ Adsorption and reduction, Data storage devices, Experimental solid state, Gravitation and Cosmology - QFT on curved spacetime, Molecular Modelling and Computational Chemistry, Nonlinear Optics, Power Integration and optimization, Quantum bit development, Quantum Error Correction, Quantum Foundations, Quantum Game Theory, Quantum Information, Quantum Measurements, Quantum Chaos, Quantum Shannon Theory, Green Supply Chain sustainability

1.B.1.ii. Collaborations between academia and industry

Apart from academic programs by universities/institutions, collaboration among various industry players and academia is also taking place. Some of them are mentioned below:

- [Collaboration](#) [59] between **IBM** and **IITM** for research in Quantum Computing.
- [Collaboration](#) [60] between **Tech Mahindra** and **Mahindra University** for research in Quantum Computing.
- [Collaboration](#) [61] between **Qkrishi** and **IIIT Kottayam** for research in Quantum Finance.
- [Collaboration](#) [62] between **Qkrishi** and **SRM University** to establish SRM Qkrishi Centre of Excellence in Quantum Information and Computing to work jointly with industry on real industry problems.
- [Collaboration](#) [63] between **Artificial Brain** and **CHRIST** (Deemed to be University), Lavasa, Pune for quantum research.
- The Centre for Quantum Engineering, Research and Education at **TCG CREST**, a private entity, in [collaboration](#) [106] with the **Academy of Scientific and Innovative Research (AcSIR)** offers a PhD in Science program with an emphasis on quantum computing and quantum sensing.

1.B.1.iii. Nonprofit Organisations

Some of the major nonprofit organisations working in the field of QSTI are listed below for reference:

1. [SheQuantum](#): eLearning platform aiming to simplify quantum computing education to encourage women's participation.
2. [Quantum Research and Centre of Excellence \(QRACE\)](#): Nonprofit focused on quantum technology research, through collaborations with Hyundai on quantum-inspired vehicle routing problems and Agra University on quantum Schrödinger channels.
3. [Quantum Ecosystems Technology Council of India \(QETCI\)](#): Nonprofit think tank dedicated to improving India's quantum technology ecosystem by offering policy recommendations, education initiatives, and ecosystem-building activities.
4. [QIndia](#): The nonprofit aims to engage and educate newcomers in quantum technology through hands-on practical training sessions to strengthen India's quantum talent base. It conducted structured workshops (QBronze) in 2021–2022 to teach fundamental quantum computing skills, focusing on core quantum algorithms like Grover's and Shor's.

1.B.2. Research Publications

An analysis of research publications has been carried out to gauge the research output and institutional landscape in India. For the analysis, a set of keywords and indicators have been used for an overall understanding of each vertical of quantum technology. These indicators and the overall glossary have been enclosed in the appendix-B for reference. The Web of Science (Incites) database is used for this analysis.

In India, the research publications have been compared and analysed on the following parameters:

- Vertical-wise analysis of India's research publications
- Knowledge hotspots based on number of publications in Q1, Q2 journals and share in top 10% of publications
- Major funding agencies based on number of publications in India

Vertical-wise analysis of India's research publications

In India, the number of publications in the QSTI field has seen significant growth across verticals. Aligning with the global trends, the vertical of **quantum materials and devices** leads this growth with the highest share in the number of publications. The large difference in the growth of this particular vertical can be attributed to the foundational nature of this sub-field and its relevance to the establishment of the other three verticals. It is to be noted here that the developments of the entire sub-field of quantum materials and devices may not fully translate into applications in quantum technologies as not all researchers working on quantum materials & devices may be focusing on applications for quantum technology.

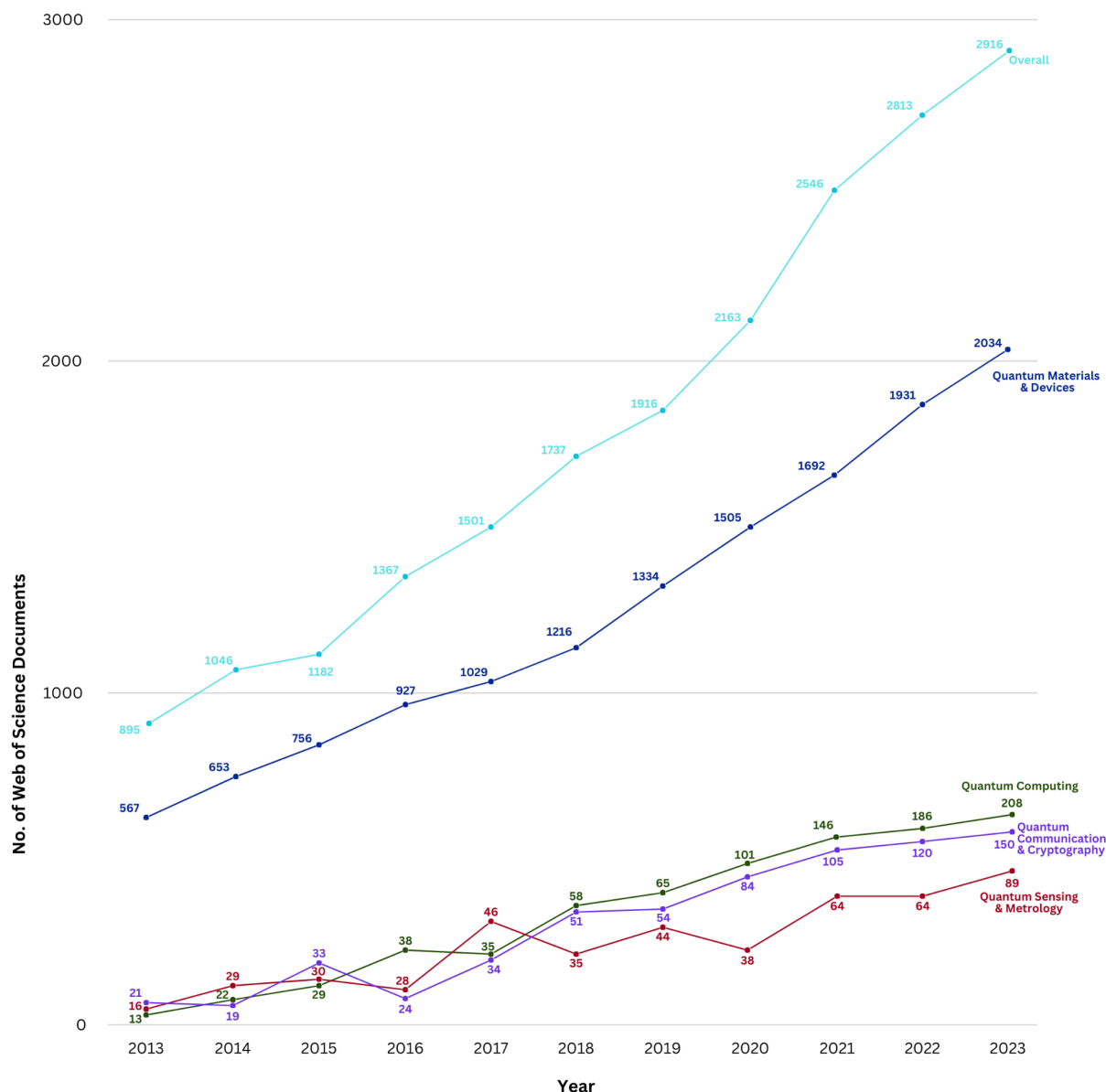


Figure 22: Vertical-wise distribution of India's QSTI publications (2013-23)
Source: Web of Science Core Collection, Clarivate Analytics (Date accessed: 04/03/2025)

The overall quantum research publications have shown significant growth from 2013 to 2023, with total publications increasing from 895 in 2013 to 2916 in 2023—a **226% increase** over this decade, with the vertical of "**Quantum Materials and Devices**" leading the number of publications in the field (increasing from 567 to 2034 publications, representing about 70% of total quantum publications in 2023), while three other quantum subfields (Quantum Computing, Quantum Communication & Cryptography, and Quantum Sensing & Metrology) show much smaller but steadily growing publication counts from 2013 to 2023, with Quantum Computing showing the most notable growth among these three.

An analysis of each vertical reveals India's contribution to the top 10% of research publications globally. As inferred by the data on the number of publications previously, it is the domain of materials & devices that leads here as well.

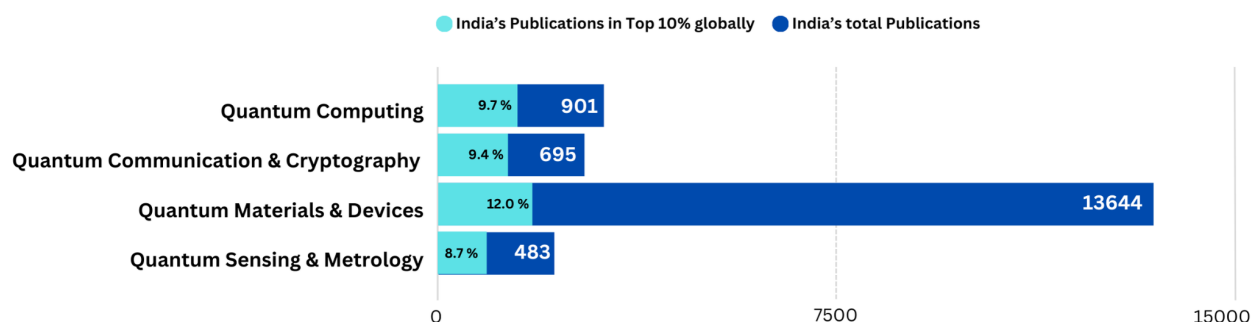


Figure 23: India's publications in the top 10% globally in QSTI vertical-wise
Source: Web of Science Core Collection, Clarivate Analytics (Date accessed: 04/03/2025)

- India's representation in the top 10% globally cited quantum research publications varies by subfields, with "Quantum Materials & Devices" having the highest percentage (around 12% of India's publications in this area are in the top 10% globally).
- This is followed by "Quantum Computing" (9.7%), "Quantum Communication and Cryptography" (9.4%), and "Quantum Sensing & Metrology" (8.7%), suggesting that while India's quantum research output is growing across all subfields, its highest-cited work relative to global quality publications is in materials & devices.
- The lag by the vertical of quantum sensing & metrology here aligns with the results of the global publication analysis as well.

A key point to note here is that based on the analysis of the number of publications, India ranks in the top 10 countries globally in all verticals of quantum except quantum sensing (where it ranks 11th). This could highlight that India is an emerging hotspot for R&D in quantum. However, a deeper analysis of the top 10% of publications reveals the absence of India in any of the four verticals in quantum except that of materials.

Knowledge hotspots in India based on the publications in Q1 & Q2 Journals and Top 10% global publications

India is home to several emerging and established knowledge hotspots in the field of Quantum Science and Technology, spanning national research institutes, academic institutions, and science agencies.

Analysis of the research publications in Q1 and Q2 journals and contribution to top 10% of the global research publications has been carried out to understand the knowledge hotspots with the highest share of quality research publications across the quantum verticals in India.



Figure 24: Organisations in India based on Number of Publications in Q1+Q2 Journals and Global Top 10% publications - vertical-wise

Source: Web of Science Core Collection, Clarivate Analytics (Date accessed: 04/03/2025)

Quantum Computing

- Indian Institute of Technology (IITs) are the major contributor to quantum computing research in India, with 171 publications in Q1 and Q2 journals across 19 IITs. Leading IITs in this vertical include IIT Bombay, IIT Madras, IIT Delhi, IIT Kharagpur, IIT Roorkee, and IIT Kanpur.
- Apart from IITs, individual research universities and institutions like the Indian Institute of Science (IISc), Indian Institute of Science Education & Research (IISER) Kolkata, National Institute of Science Education & Research (NISER), Saha Institute of Nuclear

Physics, Indian Institute of Tropical Meteorology (IITM) leads in terms of publications in Q1 and Q2 journals as top 10% globally.

- Private institutions like Thapar Institute of Engineering & Technology, Jaypee Institute of Information Technology (JIIT), SRM Institute of Science & Technology Chennai and Vellore Institute of Technology (VIT) also contribute significantly,
- The 21 National Institute of Technology (NITs) collectively contributed 61 publications, with prominent NITs in quantum computing research are NIT Kurukshetra, NIT Jaipur, MANIT Bhopal, and NIT Tiruchirappalli, NIT Silchar.
- The Department of Science & Technology (DST), India, has supported research efforts with 10 publications, while research institutions such as the SN Bose National Centre for Basic Sciences (SNBNCBS) and the Indian Association for the Cultivation of Science (IACS), Jadavpur.
- Department of Space (DoS) and its affiliated bodies - such as the Physical Research Laboratory (PRL), Space Applications Centre (SAC), Vikram Sarabhai Space Center (VSSC), and the Indian Institute of Space Science and Technology (IIST)

Quantum Communication & Cryptography

- Based on scientometric indicators, the Jaypee Institute of Information Technology (JIIT)³ stands out as the leading institution in the Quantum Communication and Cryptography vertical.
- Other key contributors include the Homi Bhabha National Institute, Harish Chandra Research Institute, Indian Institute of Science Education & Research (IISER) Kolkata, Tata Institute of Fundamental Research (TIFR) Mumbai, Indian Statistical Institute (ISI) Kolkata, and Indian Institute of Engineering Science and Technology (IIEST) Shibpur.
- The Indian Institute of Technology (IITs) collectively contributes to a large share of high-quality publications in this field, with 18 IITs actively involved. Leading among them are IIT Madras (NQM Hub for Communication), IIT Delhi, IIT Jodhpur, and IIT Kanpur.
- Similarly, the National Institutes of Technology (NITs) have made notable contributions, with 21 NITs contributing 38 publications to the growing corpus of publications. Institutions such as NIT Jamshedpur, NIT Patna, and NIT Silchar are among the active NITs.
- The Department of Science and Technology (DST) has collective publication of 49 with the institutes such as the SN Bose National Centre for Basic Sciences (SNBNCBS), Bose Institute, and Raman Research Institute (RRI).
- Other scientific agencies such as the Department of Space (DoS) and Physical Research Laboratory (PRL) with NQM Hub and Spokes of Quantum Communications, including

³ For JIIT's leading position, the contribution of [Prof. Anirban Pathak \(FNASc\)](#), HoD, Department of Physics and Materials Science and Engineering, JIIT could be attributed, who has made sustained contributions to the field over the years with over 4,481 citations (Google Scholar)

IIT Madras and Raman Research Institute (RRI) are exploring quantum communication for satellite-based secure networks, reflecting national security relevance.

Quantum Materials & Devices

- Based on scientometric indicators such as publication output and citations in globally top-ranked journals, IITs and CSIR laboratories lead the vertical in the global top 10%, followed by the Department of Science & Technology and NITs.
- IISc Bengaluru with 369 publications is one of the top performing research institutions. **Bhabha Atomic Research Centre (BARC)** follows closely with 351 publications. As one of the major nuclear research institutions under the Department of Atomic Energy (DAE) has far-reaching implications for national security, and advanced sensing.
- The IITs feature prominently, with 23 IITs, notable institutions include: IIT Delhi (NQM Hub for Quantum Materials and Devices), IIT Bombay, IIT Kharagpur, IIT Guwahati and IIT BHU Varanasi.
- The Council of Scientific and Industrial Research (CSIR) is another key player, with 34 labs (as per the WoS dataset) contributing to advancements in quantum materials. Major CSIR labs include the National Physical Laboratory (NPL), National Chemical Laboratory (NCL), Central Scientific Instruments Organisation (CSIO), Central Electrochemical Research Institute (CECRI), and Indian Institute of Chemical Technology (IICT). Many of the publications are collaborated in part through the Academy of Scientific and Innovative Research (AcSIR).
- Department of Science and Technology (DST) have a combined number of 883 publications in Q1 and Q2 journals because of the several autonomous research institutes like the **Indian Association for the Cultivation of Science (IACS) in Jadavpur, the Institute of Nano Science & Technology (INST), SN Bose National Centre for Basic Sciences (SNBNCBS), Institute of Advanced Study in Science & Technology (IASST), and Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR).**
- Additionally, the National Institutes of Technology (NITs) have emerged as important contributors, with 29 NITs conducting research in materials and devices. Prominent among them are **NIT Rourkela, SVNIT Surat, NIT Tiruchirappalli, MNIT Jaipur, and NIT Durgapur.**

Quantum Sensing & Metrology

- Based on scientometric analysis, research institutes under the Department of Atomic Energy (DAE) like the **Harish Chandra Research Institute (54) and Homi Bhabha National Institute (47),** Tata Institute of Fundamental Research (TIFR), Mumbai (30) are the major contributors in Quantum Sensing and Metrology.

- **Indian Institute of Science (IISc)**, Bengaluru, leads with 35 publications in research universities. Apart from IISc, the Indian Institutes of Science Education & Research (**IISERs**) have a strong collective presence, with contributions from IISER Kolkata, Mohali, Thiruvananthapuram, Bhopal, and Pune, indicating a distributed active network. Additionally, central universities such as **Jawaharlal Nehru University (JNU)**, New Delhi and **Jamia Millia Islamia** also have research publications in quantum sensing.
- Indian Institute of Technology (IITs) are a critical driver, with 16 IITs actively engaged in quantum sensing research. Indian Institute of Technology System (IIT System) including the **NQM Hub for Quantum Sensing - IIT Bombay**, and other IITs such as **IIT Madras**, **IIT Jodhpur**, and **IIT Gandhinagar**.
- Based on the scientometric data, the Department of Space (DoS), with its Indian Institute of Space Science & Technology (IIST), is actively exploring quantum-based sensing applications for space navigation, satellite-based measurements, and precision instrumentation.
- Department of Science & Technology has collectively 37 publications with its autonomous institutes such as Raman Research Institute (RRI), SN Bose National Centre for Basic Science (SNBNCBS), Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR) and Bose Institute, etc.
- The National Institute of Technology (NITs), with 13 NITs contributions—such as NIT Patna, NIT Tiruchirappalli, and Motilal Nehru National Institute of Technology suggests expansion in the regional footprint.

Funding agencies based on the number of publications in India

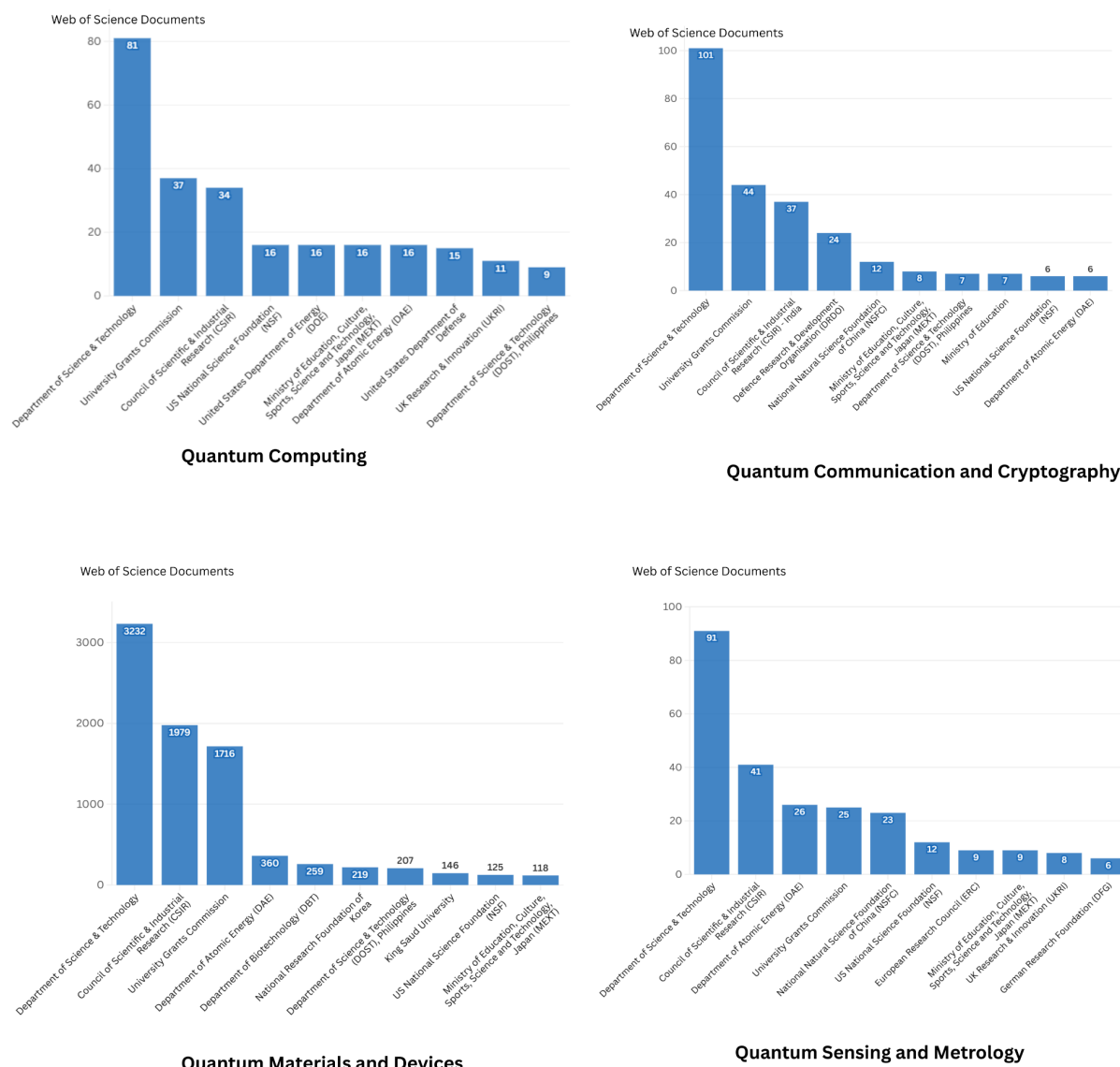


Figure 25: Funding agencies for Indian publications in QSTI vertical-wise based on the number of publications
Source: Web of Science Core Collection, Clarivate Analytics (Date accessed: 04/03/2025)

- **Department of Science & Technology (DST), University Grants Commission and Council of Scientific & Industrial Research (CSIR)** are the major funders for QSTI-related research publications across all 4 verticals in India.
- **Department of Science Technology (DST)** furthermore leads across all four quantum research verticals in India, in terms of funding. Some part of DST funding has been through the Science Engineering Research Board (SERB) which is now subsumed under the Anusandhan National Research Foundation (ANRF).

- Apart from DST, other major Indian government departments and agencies funding for QSTI include **Department of Atomic Energy (DAE), Department of Biotechnology (DBT), and Defence Research & Development Organisation (DRDO)**, suggesting the interest of other key scientific agencies of India, particularly in areas like quantum-enabled biomedical sensing, and security applications.
- From the research publications analysis, it is evident that the primary funding comes from government departments and agencies rather than the private sector. This is further corroborated by analysis of the data from researchers and their funding sources and through expert consultations.
- Apart from Indian funding agencies, the strong presence of funding from countries/regions like **the US, Japan, China, the UK, EU, Germany** and others suggests international funding in quantum research in India across verticals. The aspect of international funding flowing for research in India highlights collaboration between Indian and international counterparts but in some cases may also point towards concerns regarding **research security**.
- Some countries have multiple funding counterpart engagements with India such as Japan: **Ministry of Education, Culture, Sports, Science and Technology, Japan (MEXT), Japan Society for the Promotion of Science**, and United States of America: **National Science Foundation (NSF), United States Department of Energy (DOE), United States Department of Defense**.
- In addition to countries with well-established quantum initiatives, the **Philippines (through Department of Science & Technology (DOST))** ranks among the top 10 international funders contributing to quantum research publications in India across all four verticals.

1.B.3. Patents

To analyse the patent landscape and IP capital of QSTI in India, patents filed with India as the priority jurisdiction have been considered, along with those where the applicant's filing jurisdiction is in India, to broaden the scope of the collection and to ensure a comprehensive view of India's competency via patents. The analysis includes only active or pending patents, excluding inactive or expired ones.

Patent Record Analysis (YoY)

The following is an analysis of YoY growth of patents in the QSTI field in India. Please note, this data is for overall QSTI and does not relate to any particular vertical within QSTI.

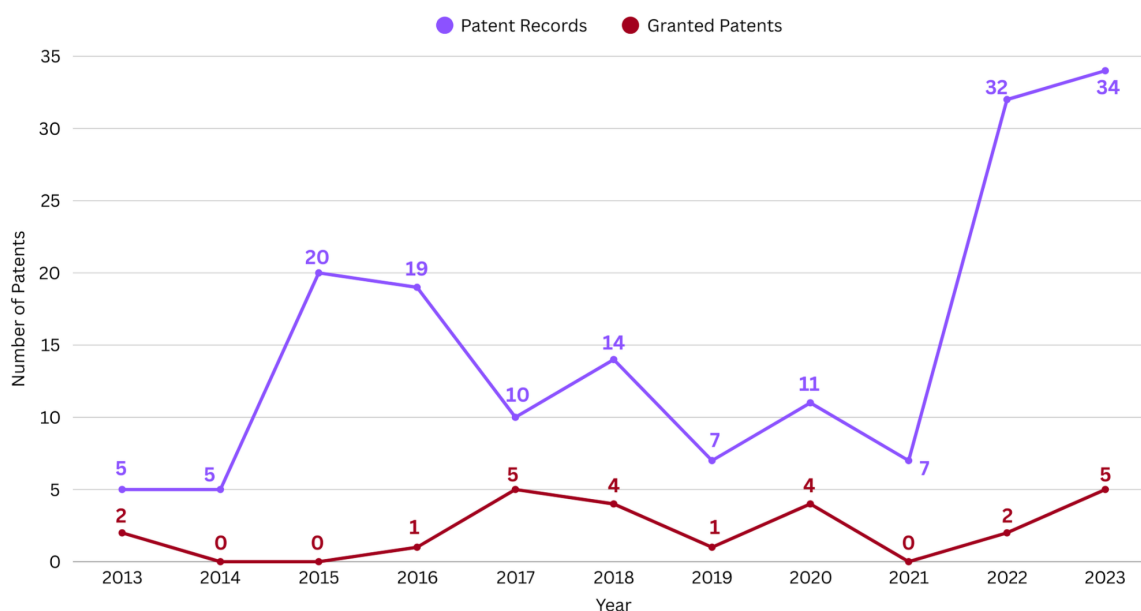


Figure 26: Indian Patents Records and Granted in overall QSTI
Source: Lens.org (Date accessed: 03/03/2025 - 13/03/2025)

India's overall QSTI patent landscape shows a prominent acceleration in recent years, with patent records increasing from **5** in 2013 to **34** in 2023, while granted patents have been fluctuating over the years, the latest being 5 granted patents in 2023.

Patent Jurisdiction

The patent jurisdiction data shows which countries the patent owners prefer to protect their intellectual property.

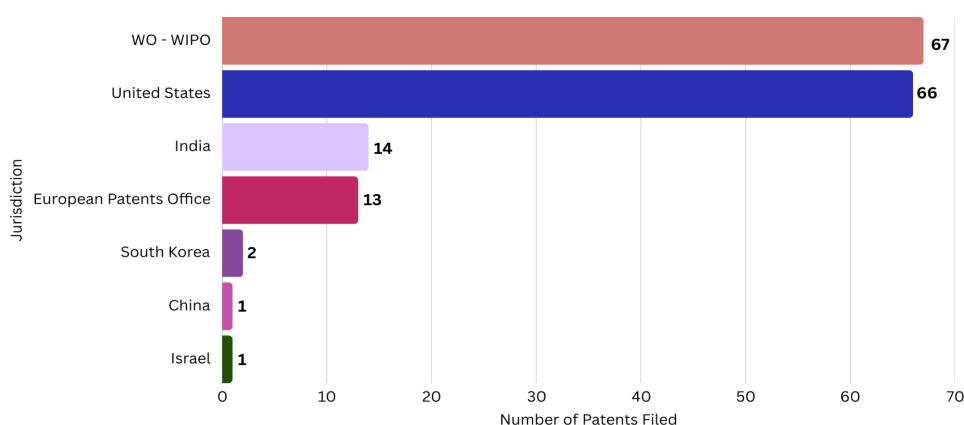


Figure 27: Jurisdiction of Patents with India as Priority Jurisdiction
Source: Lens.org (Date accessed: 03/03/2025 - 13/03/2025)

On the basis of jurisdiction, most patents with India as a priority jurisdiction are filed in the WO-WIPO⁴ (67 patents). This means the inventors or patent holders are choosing to internationally protect their Indian-filed inventions by using WIPO's global system. This suggests a strong interest in seeking international patent protection across multiple countries through the WIPO system. The United States follows closely with 66 patent filings, indicating its significance as a key market and jurisdiction for patent protection.



Figure 28: Trend of QSTI related patent filed and granted with India either as Priority Jurisdiction or Applicant Filing Jurisdiction (2013-23) vertical-wise

Source: Lens.org (Date accessed: 03/03/2025 - 13/03/2025)

- Analysis by subfield reveals distinct patterns: **Quantum Computing** show high growth in recent times, with Computing reaching 14 patent records in 2023 (from nearly zero before 2019); **Quantum Communication and Cryptography** shows an increase in patent filings after 2021; **Quantum Materials and Devices** displays a more mature but cyclical patent

⁴ WIPO administers 26 international treaties including the Patent Cooperation Treaty (PCT) and the Paris Convention.

landscape with filings fluctuating between 3-15 annually over the decade, showing a recent resurgence after a 2019-2021 dip; meanwhile, **Quantum Sensing and Metrology** remains the least-patented vertical with nearly no filed patents throughout the period and only a small peak of 4 patents applications in 2022-23.

Patent Owner Organisations

An analysis of the patents across quantum verticals has been used to understand the organisations owning the patents in India.



Figure 29: Patent owner organisations with India as Priority Jurisdiction and Applicant Filing Jurisdiction- vertical-wise
Source: Lens.org (Date accessed: 03/03/2025 - 13/03/2025)

- While CSIR leads in Quantum Materials & Devices, its patents may not be translating into commercialisation, as there are only a few startup players in this vertical. (refer section 1.B.5)

- The presence of **Indian Oil Corporation Limited (3 patents)** and **Indian Council of Medical Research (2 patents)** indicates **cross-sectoral applications** of quantum materials & devices, possibly in energy storage, medical diagnostics, and industrial chemistry.
- It is to be noted that a clear industry segmentation exists within the quantum ecosystem - technology companies (**Infosys, Cognizant, Ericsson, TCS**) dominate the computing vertical, while research institutions (**CSIR, ICMR, IIT, TIFR**) lead in materials/devices research.
- The quantum sensing vertical significantly lags in patenting compared to other quantum domains, with only **Mphasis Limited** and **Society for Electronic Transactions and Security (SETS)** holding identifiable patents, which could suggest this field remains early in its development of the IP capital.

1.B.4. Collaborative Research Networks

1.B.4.i. Publications & Patents

The data analysis of the four verticals of quantum on the basis of the top countries that Indian researchers are collaborating with highlights research partnerships India has cultivated with specific countries in different areas of quantum technology with varying stages of research and development.

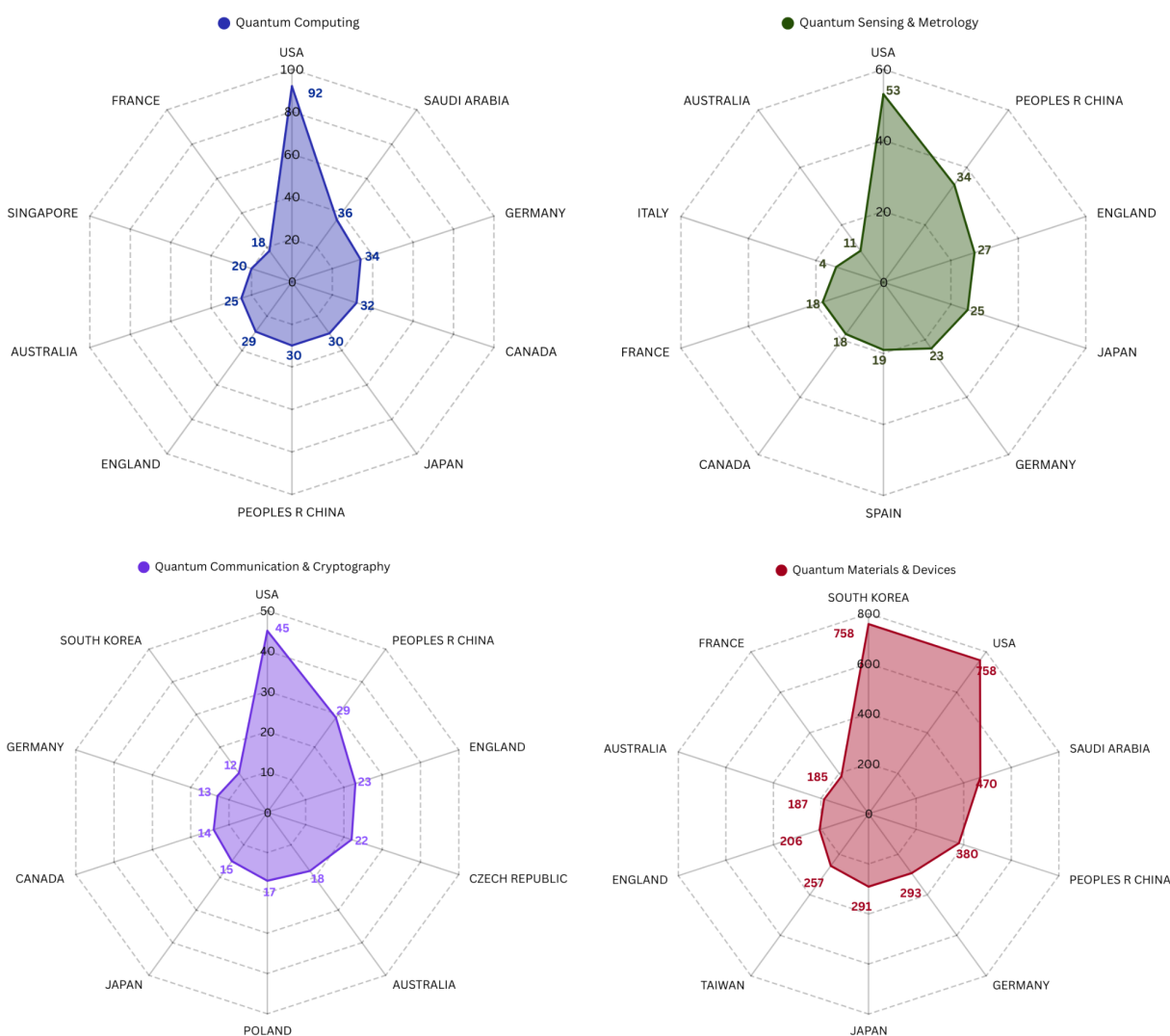


Figure 30: India's joint publications worldwide in QSTI vertical-wise (Cumulative 203-23)
Source: Web of Science Core Collection, Clarivate Analytics (Date accessed: 04/03/2025)

- **The U.S. emerges as the top country for collaboration** across all quantum verticals in both patents and publications. In joint publications, the US shows particularly strong numbers in Quantum Materials and Devices (758) and Quantum Computing (92).
- In Publications, **Quantum Materials and Devices** emerge as the most collaborative domain, with significantly higher publication numbers than other fields and broader international participation. Collaboration with South Korea leads here with 758 joint publications.

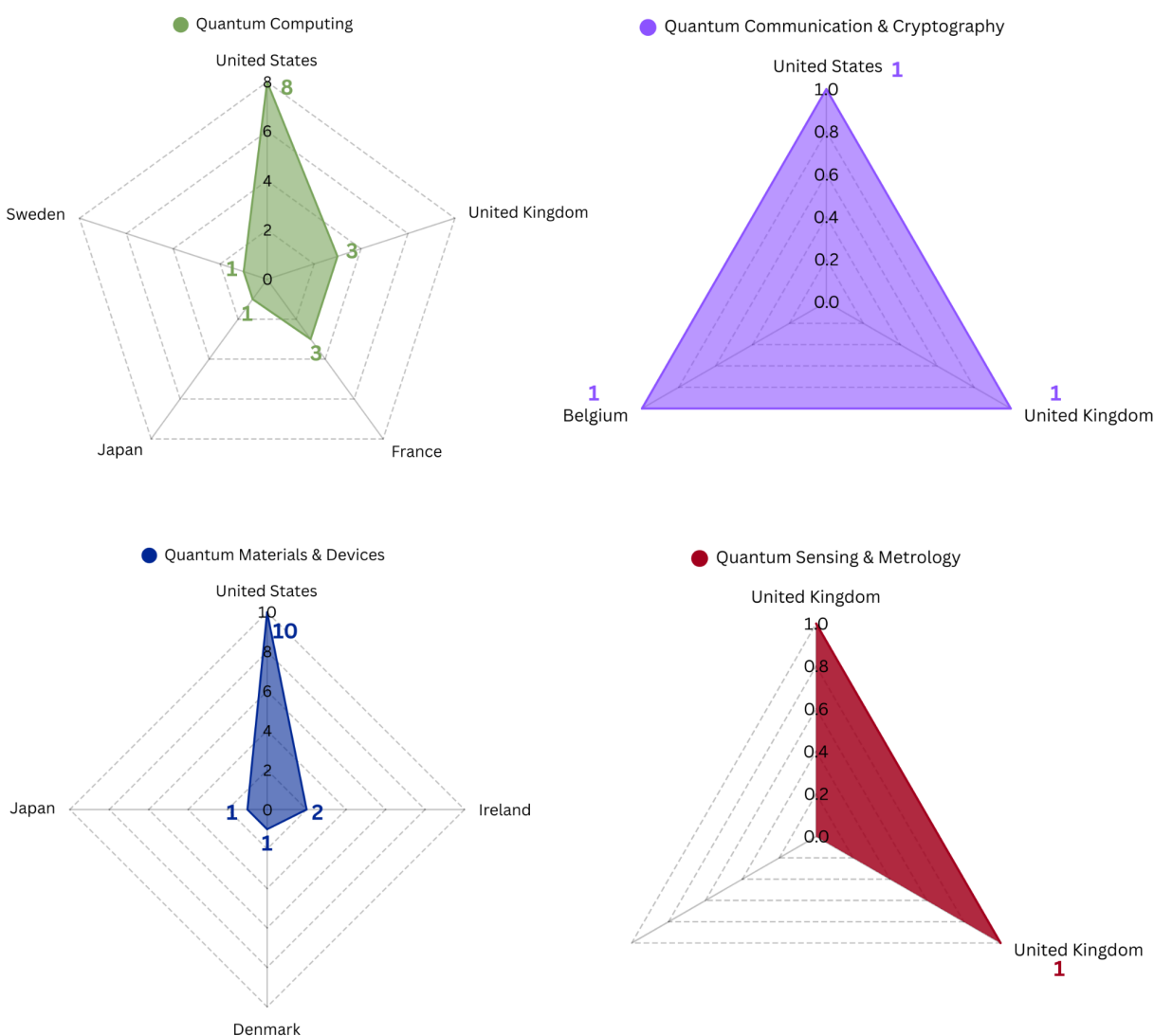


Figure 31: India's joint patents worldwide in QSTI vertical wise
Source: Lens.org (Date accessed: 03/03/2025-13/03/2025)

- European countries, including **France** and **the U.K.**, are significant collaborators for India in both publications and patents, though their prominence varies across the verticals.
- Quantum Communication & Cryptography show an equal number of partnerships in patents (UK, US, Belgium) but more distributed international collaboration in publications, with countries such as the Czech Republic, Australia and England showing significant activity.
- Quantum Computing also shows distributed collaboration levels with a wider fragmentation of collaborating countries. European partnerships (France, UK, Sweden) are more visible in patents than in publications.

- Quantum Sensing & Metrology appears to be the least collaborative vertical for patents, the UK is the only partner for joint patents but shows healthy publication networks. The high number of joint publications with England (27 publications) and Japan (25 publications) strongly indicates significant collaborative research efforts in quantum sensing and metrology. The absence of patent data for these collaborations could imply that the research is at an earlier stage of translation into patentable inventions.

1.B.4.ii. Conferences

Conferences play a vital role in collaboration and networking among researchers which could further lead to collaboration on publications and patents. Currently, conferences focused on quantum technologies are limited in India. Expert consultations and interviews have also revealed a similar picture with an understanding that Indian participation in international conferences is also limited. With 2025 being the International Year of Quantum, conferences could be a way of accelerating collaborative research in this field. Some of the conferences focused on quantum technologies in India are highlighted below for 2025:

- IIT Madras [hosted](#) [64] the International Conference on Quantum Communication, Measurement & Computing (QCMC24) for the first time in India.
- Workshop on Quantum Technologies ([WQT](#) [65]), Bengaluru.
- [Workshop](#) [66] on Quantum Machine Learning in Signal Processing and Artificial Intelligence in Hyderabad.
- International Symposium on Quantum Information and Communication ([ISQIC](#) [67]), 2025 in Kolkata.
- [Conference](#) [68] on Quantum Sensing & Metrology in Kolkata.
- [Conference](#) [68] on Quantum Computing and Algorithms in Kolkata.

1.B.5. Industry

The Indian technology sector, driven by a strong IT industry, is increasingly recognising the transformative potential of quantum technologies. Indian corporations are increasingly investing in quantum technologies, with companies like TCS, Bharat Electronics Limited (BEL), and Indian Oil Corp., L&T to name a few. Some examples of such investments are:

- [Infosys recently announced](#) [69] a partnership with Australian quantum cybersecurity firm QuintessenceLabs to work in the area of Quantum security. Infosys is also working with Amazon Web Services, QuintessenceLabs and QCWare to set up **Quantum Living Labs**.

- Similarly, [TCS announced](#) [70] that it will collaborate with IIT Bombay to develop India's first Quantum Diamond Microchip Imager.
- [INOX Group partnered](#) [71] with IISc to establish India's first quantum materials laboratory, the INOX Quantum Materials Lab, at IISc's Centre for Nano Science and Engineering. The lab aims to develop topological semiconductors essential for fault-tolerant quantum computing, building an indigenous Molecular Beam Epitaxy (MBE) unit to make quantum technology more accessible and affordable in India.
- [Mphasis](#) [72] partnered with IIT Madras to establish a Quantum Lab to advance quantum computing research addressing real-world challenges.
- Coforge (formerly NIIT Technologies) has established a [Quantum lab](#) [73] conducting multiple experiments to foster innovation by training a quantum-ready workforce, solving complex cryptography and machine learning challenges, and collaborating with major quantum cloud providers like Azure and Amazon Bracket.
- In 2023, HCL Technologies joined forces with Microsoft Azure Quantum, integrating [HCLTech Q-Labs into the Azure network](#) [74] to drive client exploration of practical quantum applications through pilot programs. It currently offers Quantum Inspire Services via Azure Marketplace, structured around QC Foundation Services, QC Fluidic Capability Centres, and QC Pilot Planning.

Multinational corporations with non-Indian origins are also making forays into the Indian ecosystem. Some examples include:

- [Microsoft announced](#) [75] in 2020 its project to ready a quantum computing workforce through its 'Train the Trainer' program.
- [IBM announced](#) [59] its recent 'Quantum Innovation Centre' in India in collaboration with IIT Madras. [IBM also announced](#) [76] a collaboration with LTIMindtree to advance the quantum ecosystem.
- Canadian company [D-Wave Systems](#) [77] expanded its Leap quantum cloud service to India in 2020 offering real-time access to commercial quantum computing resources.
- [Capgemini launched](#) [78] quantum laboratories (Q-Labs) in 2022 across the UK, Portugal, and India to drive industry-specific quantum research, anticipating widespread commercial adoption within a decade.
- [Fujitsu launched](#) [79] Fujitsu Research of India Private Limited (FRIPL) in Bengaluru in 2022 to drive AI, ML, and quantum software innovation in collaboration with leading Indian research institutions.
- On March 17, 2025, [NTT Data announced](#) [80] investments in India's digital infrastructure, expanding its AI Innovation Centre in Bengaluru, focusing on AI, digital twin, and quantum computing.
- Samsung Electronics has the [Samsung Semiconductor India Research](#) [81], which partnered with IISc in 2023 to establish a Quantum Technology Lab focused on advanced semiconductor innovations and quantum reliability solutions.

1.B.5.i. Startups

The quantum startup ecosystem shows the evolution from minimal activity in 2010 to accelerated growth beginning in 2018, with **peaks in the years 2021 and 2023** (9 companies each).

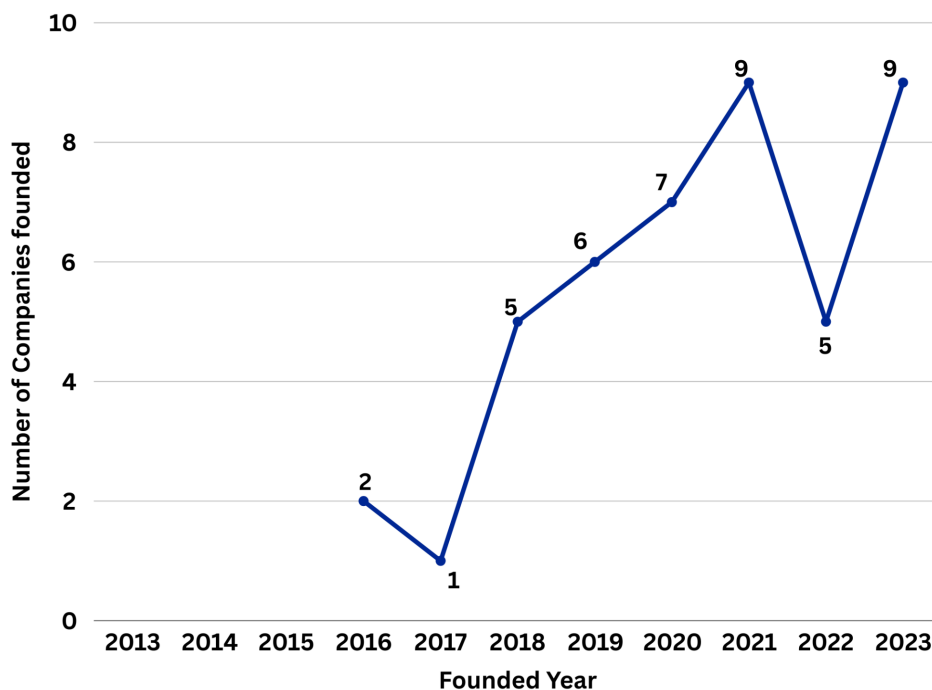


Figure 32: Number of QSTI companies founded YoY
Source: Tracxn (Date accessed: 10/03/2025)

The startups focused on quantum technologies are analysed, based on the categories they are focusing on and the stage they are in. These categories are according to the four verticals as described by NQM and the ‘stage of startup’ here refers to the stage each startup is in at the time of data collection. These stages can vary from Ideation, Validation, Early Traction and Scaling.

Sectoral Categorisation & Stage Analysis

Data from Startup India was collected for the analysis of the sectoral categorisation of startups in the QSTI field.

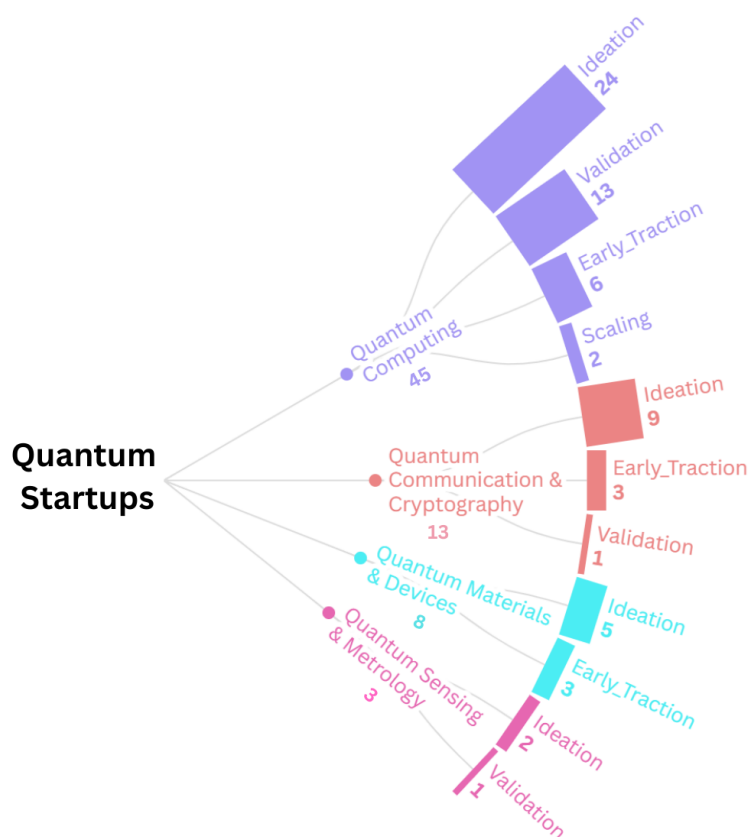


Figure 33: QSTI Startups sectoral categorisation in India
Source: Startup India (Date Updated till: 31/01/2025)

Quantum Computing startups (45) lead the sectoral landscape, followed by Quantum Communications & Cryptography. indicating stronger market interest in these verticals as compared to verticals of quantum materials and quantum sensing.

- As for the stages these startups are in, nearly half of quantum computing startups are still in the early conceptual phase i.e. ideation. This could indicate that this is an emerging area with significant focus but is not yet mature. Also, very few of these startups have reached the scaling stage, highlighting the nascent state of quantum computing commercialisation in India.
- There is a possible funnel effect with numbers consistently decreasing at later stages (15 in validation, 12 in early traction, and only 2 in scaling). This may highlight possible bottlenecks in commercialising quantum technologies and the high technical barriers to progress.

- A point to be noted here is that, across all verticals, 40 out of 69 startups (~58%) are in the ideation stage, revealing that India's quantum startup ecosystem is in early stages. From an international collaboration perspective, this could suggest significant potential for collaboration.

The government, along with funding various programs in this field, is funding startups focusing on various aspects of quantum technology. In November 2024, [DST selected the following 8 startups](#) [82] for support under the National Quantum Mission and the National Mission on Interdisciplinary Cyber-Physical Systems:

- QuNu Labs Private Limited (Bengaluru), focuses on spearheading advancements in quantum communication by developing end-to-end quantum-safe heterogeneous networks.
- OpiAI India Pvt Ltd (Bengaluru), focuses on building a superconducting quantum computer, marking a milestone in quantum computing.
- Dimira Technologies Pvt Ltd (IIT Bombay), focuses on indigenous cryogenic cables essential for quantum computing.
- PrenishQ Pvt Ltd (IIT Delhi) focuses on developing precision diode-laser systems that are vital for the sector's growth.
- QuPrayog Pvt Ltd (IISER Pune), focuses on innovating optical atomic clocks and related technologies.
- Pristine Diamonds Private Limited (Ahmedabad) focuses on creating diamond materials for quantum sensing.
- Quanastra Pvt Ltd (Delhi), focuses on developing advanced cryogenics and superconducting detectors.
- Quan2D Technologies Pvt Ltd (IISc Bengaluru) focuses on advancing superconducting Nanowire Single-photon Detectors

1.B.5.ii. Investments/Funding

- Investment trends correlate with the founding of companies, showing modest funding from 2018-2020 (\$1.32M, \$1.08M, and \$1.59M respectively) before acceleration in 2021 (\$1.97M) and 2022 (\$7.55M), a temporary decline in 2023 (\$5.57M) following the global trend, and a substantial peak in 2024 (\$14.3M). **This represents a 10.8x increase from 2018 levels and approximately 157% growth from 2023 to 2024.**

- This pattern could suggest a quantum technology sector transitioning from experimental beginnings to commercial viability, with emphasis on software applications being more explored commercially than fundamental hardware.

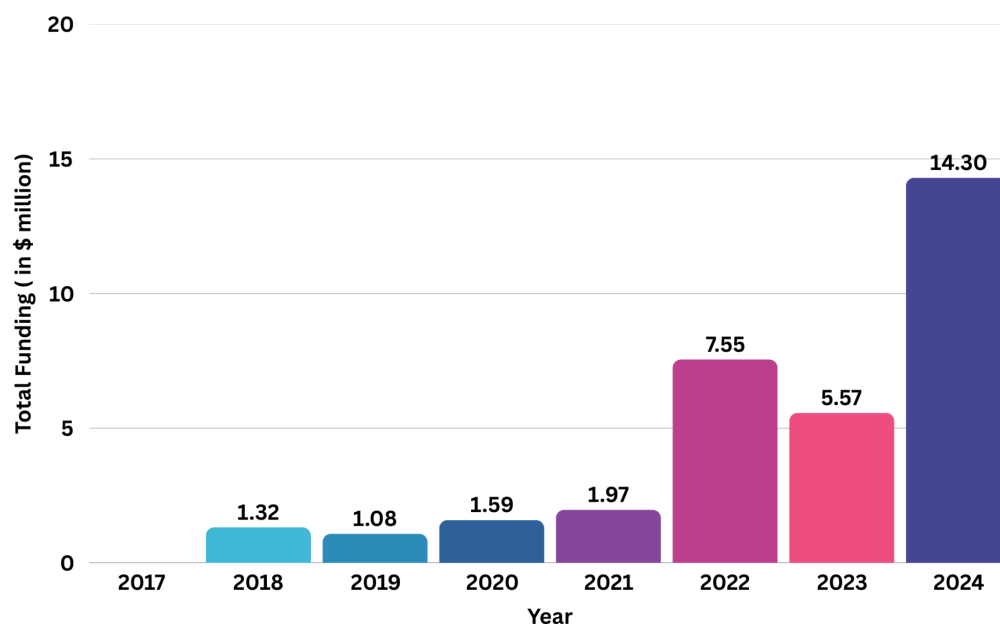


Figure 34: YoY Funding of QSTI startups in India
Source: Tracxn (Date accessed: 12/03/2025)

1.B.6. Government Initiatives

1.B.6.i. National Initiatives

The Government of India has launched several initiatives to support the development of quantum technologies, with the **National Quantum Mission (NQM)** with an outlay of Rs. 6003.65 crores being the flagship initiative. Additionally, government programs like the National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS) and the erstwhile QUEST program are working to integrate quantum technologies into India's broader digital infrastructure, including cybersecurity systems. Other initiatives by the Department of Science & Technology, Ministry of Electronics & Information Technology, Department of Telecommunications and Office of the Principal Scientific Adviser are also contributing to the advancement of the quantum ecosystem in India.

1. **National Quantum Mission**: The Union Cabinet approved the National Quantum Mission (NQM) [83] in 2023 with a total budget of Rs.6003.65 for the time period of 2023-24 to 2030-31, aiming to seed, nurture and scale up scientific and industrial R&D and create a vibrant & innovative ecosystem in Quantum Technology. The following four verticals were chosen as areas of focus for the mission:

- a. Quantum Computing
 - b. Quantum Communication
 - c. Quantum Sensing & Metrology
 - d. Quantum Materials & Devices
- The operationalisation of NQM is spearheaded by the Department of Science and Technology (DST), led by Prof. Abhay Karandikar (Secretary, DST – dstsec@nic.in) and team including that of Dr. JBV Reddy (Scientist-F, DST – jbvreddy@nic.in)
 - The mission governing board (MGB) of NQM is chaired by Dr. Ajai Chowdhry (Chairman MGB and Founder HCL Technologies – ajaichowdhry@epicfoundation.co.in) and the advisory board is chaired by Prof. Ajay Kumar Sood (Principal Scientific Adviser to the Government of India – sood.ajay@gov.in). The mission is also shaped by Dr VK Saraswat, Member, S&T, NITI Aayog (vk.saraswat@gov.in).
 - For the NQM, the Mission Coordination Cell (MCC) has been setup at IIT Kanpur to ensure streamlined coordination with the mission secretariat at DST as well as with the four T-Hubs and will also connect NQM to other missions and initiatives.

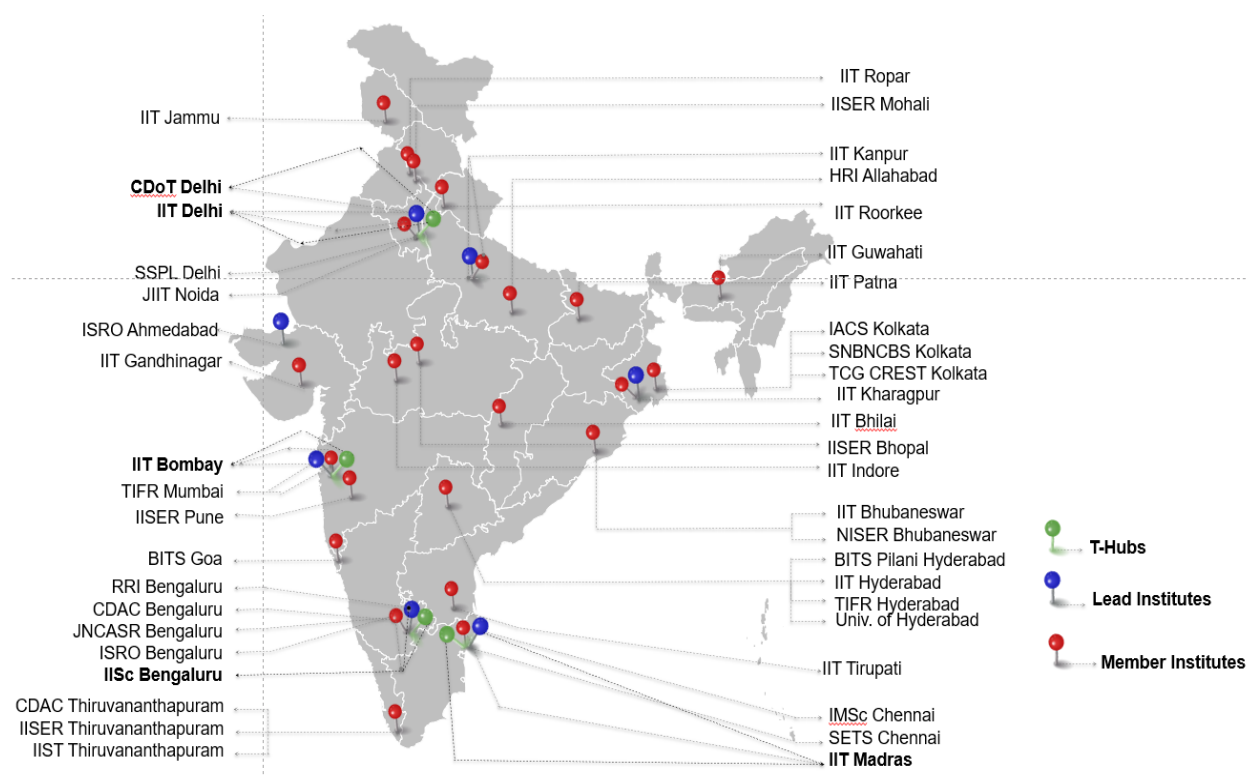


Figure 35: NQM Thematic Hubs and Technical Groups
Source: National Quantum Mission



NQM T-Hubs

In a major step for India's National Quantum Mission (NQM), premier institutions were [selected](#) [84] to establish Thematic Hubs (T-Hubs). Each T-Hub operates under the Hub-Spoke-Spike model, supporting a cluster-based network of research projects (Spokes) and individual research groups (Spikes).

Quantum Computing

Thematic Hub for Quantum Computing: Indian Institute of Science, Bengaluru

Institutions Involved: IIT Delhi, IIT Kanpur, IIT Roorkee, IIT Bombay, IIT Madras, IIT Ropar, IIT Guwahati, IIT Patna, BITS Hyderabad, IMSc Chennai, IIIT Noida, SETS Chennai, CDAC Bengaluru, IIT Indore, IISER Thiruvananthapuram, IISER Pune, RRI Bengaluru, NISER Bhubaneswar, TIFR Mumbai, TIFR Hyderabad and JNCASR Bengaluru

Objective: Develop intermediate-scale quantum computers with 20-50 physical qubits (3 years), 50-100 physical qubits (5 years) and 50-1000 physical qubits (8 years) in various platforms like superconducting and photonic technology.

Contacts for Quantum Computing T-Hub

- For the technical group focusing on photonics quantum processor development / programmable photonic quantum computing using qubits encoded in different degrees of freedom of a photon, the following leads can be contacted:

- Prof. Shankar Kumar Selvaraja / Prof. Chandrashekar C M - Indian Institute of Science, Bangalore

Email Id: shankarks@iisc.ac.in / chandracm@iisc.ac.in

- For the technical group focusing on design and demonstration of a highly scalable quantum computer using semiconducting qubits / development of a 50-qubit quantum information processor with electron spins in silicon, the following leads can be contacted:

- Prof. Abhisek Dixit - IIT Delhi / Dr .Suddhasatta Mahapatra - IIT Bombay

Email Id: adixit@ee.iitd.ac.in / suddho@phy.iitb.ac.in

- For the technical group focusing on quantum computing with neutral atoms, trapped ions and related hybrid systems, the following leads can be contacted:

- Dr. Saptarishi Chaudhuri - Raman Research Institute

Email Id: srishic@rri.res.in

- For the technical group focusing on quantum computers with superconducting qubits, the following leads can be contacted:
 - Dr. Rajamani Vijayaraghavan - TIFR Bombay

Email Id: rvijay26@gmail.com

Quantum Communication

Thematic Hub for Quantum Communication: Indian Institute of Technology, Madras

Institutions Involved: ISRO Ahmedabad, ISRO Satellite Centre, IIT Delhi, IIT Kanpur, IIT Kharagpur, IIT Bhilai, IIT Roorkee, IIT Jammu, IIT Tirupati, IIT Patna, IIT Indore, IIT Hyderabad, IISc Bengaluru, IISER Bhopal, IISER Mohali, RRI Bengaluru, HRI Prayagraj, IIST DOS Thiruvananthapuram, CDAC Bengaluru, C-DAC Thiruvananthapuram and SETS Chennai

Objective:

- Develop satellite-based secure quantum communications between two ground stations over a range of 2000 kilometres within India as well as long-distance secure quantum communications with other countries.
- Develop inter-city quantum key distribution over 2000 km with trusted nodes using wavelength division multiplexing on existing optical fibre.
- Develop a multi-node Quantum network with quantum memories, entanglement swapping and synchronised quantum repeaters at each node (2-3 nodes).

Contacts for Quantum Communication T-Hub

- For the technical group focusing on quantum internet with local access - QuILA, the following leads can be contacted:
 - Prof. Anil Prabhakar - IIT Madras

Email Id: anilpr@ee.iitm.ac.in

- For the technical group focusing on the development of tamper-proof SCA/FI resistant 10Gbps post-quantum In-line IP network encryptor, Post-Quantum TLS ASIC (PQ-TLS), TLS Accelerator PCIe card using PQ-TLS ASIC for TLS offloading in servers, the following leads can be contacted:
 - Mr. Deepak Gaur - Centre for Development of Telematics

Email Id: dgaur@cdot.in

- For the technical group focusing on trusted-node-free hybrid quantum secure communication networks - TAHQEECAT, the following leads can be contacted:

- Dr. Bhaskar Kanseri - IIT Delhi

Email Id: bkanseri@physics.iitd.ac.in

- For the technical group focusing on a multi node quantum repeater network for entanglement distribution based quantum communication, the following leads can be contacted:

- Prof. Urbasi Sinha - Raman Research Institute

- Email Id: usinha@rri.res.in

- For the technical group focusing on satellite based quantum key distribution systems, the following leads can be contacted:

- Dr. Senthil Kumar M - Space Application Centre (ISRO)

Email Id: senthilist@gmail.com , senthil@sac.isro.gov.in

Quantum Sensing and Metrology

Thematic Hub for Quantum Sensing and Metrology: Indian Institute of Technology, Bombay

Institutions Involved: IISc Bengaluru, IIT Madras, IIT Delhi, IIT Kanpur, IIT Gandhinagar, IISER Bhopal, IIT Ropar, TCG CREST Chennai, TIFR Bombay, TIFR Hyderabad, HRI Prayagraj, IACS Kolkata, BITS Goa, University of Hyderabad and SN Bose NCBS

Objective: Develop magnetometers with 1 femto-Tesla/sqrt (Hz) sensitivity in atomic systems and better than 1 pico-Tesla/sqrt (Hz) sensitivity in Nitrogen Vacancy-centers; Gravity measurements having sensitivity better than 100 nano-meter/second² using atoms and Atomic Clocks with 10⁻¹⁹ fractional instability for precision timing, communications and navigation.

Contacts for Quantum Sensing and Metrology T-Hub

- For the technical group focusing on diamond quantum defects-based sensing, the following leads can be contacted:

- Dr.Kasturi Saha - IIT Bombay

Email Id: kasturis@ee.iitb.ac.in

- For the technical group focusing on field-deployable quantum-enhanced sensors on integrated hybrid platform / design and development of quantum entanglement-enhanced imaging systems, the following leads can be contacted:

- Dr. Saikat Ghosh / Prof.Anand Kumar Jha - IIT Kanpur

Email Id: gsaikat@iitk.ac.in / akjha@iitk.ac.in

Quantum Materials and Devices

Thematic Hub for Quantum Materials and Devices: Indian Institute of Technology, Delhi

Institutions Involved: IIT Bombay, IIT Madras, IIT Kanpur, IIT Roorkee, IIT Kharagpur, IIT Bhubaneswar, SSPL- DRDO Delhi, IACS Kolkata and IISER Pune

Objective: Novel materials for the fabrication of quantum devices for the development of qubits for quantum computing and quantum communication applications, single photon sources/detectors, and entangled photon sources for quantum communications, sensing and metrological applications.

Contacts for Quantum Materials and Devices T-Hub

- For the technical group focusing on the development of on-demand single photon emitters, single photon avalanche detectors, high-frequency devices and nanowire quantum devices utilising GaAs and InP-based epitaxial semiconductors, the following leads can be contacted:
 - Prof. Rajendra Singh - IIT Delhi
Email Id: rsingh@physics.iitd.ac.in
- For the technical group focusing on reconfigurable and scalable photonic qubit architecture for quantum computing, heterogeneous and monolithic approaches - RASPAC, the following leads can be contacted:
 - Dr. Shailendra Kumar Varshney - IIT Kharagpur
Email Id: skvarshney@ece.iitkgp.ernet.in
- For the technical group focusing on wafer-scale emitter and detector arrays for multi-wavelength room temperature photonic quantum technologies, the following leads can be contacted:
 - Prof. Saurabh Lodha - IIT Bombay
Email Id: saurabh.lodha@gmail.com

2. The Department of Science & Technology had set up [Quantum-Enabled Science & Technology \(QuEST\)](#) [85] – a research program to build quantum capabilities. As a part of the program, DST invested a sum of USD 11.2 million (Rs 80 crore) over three years to facilitate research in this field.
3. [Mission on Nano Science & Technology Mission](#) [86]: The **NPNST** (National Programme on Nano Science and Technology) is a culmination of the erstwhile ‘Mission on Nano Science & Technology’ which was launched in 2007 as an “umbrella capacity-building program” and stands completed as of 2017. The mission’s main objective was to advance

R&D and build infrastructure and human resources in the field of Nano Science and Technology. The [Institute of Nano Science and Technology \(INST\)](#) [87] was established at Mohali in 2013 by DST under the Nano Science & Technology Mission to boost research and development in the field of Nanoscience and Nanotechnology.

4. [National Mission on Interdisciplinary Cyber-Physical Systems \(NM-ICPS\)](#) [88]: IISER Pune hosts the [I-Hub Quantum Technology Foundation](#) [89] which is working in the area of Quantum Technologies under the National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS) of DST through Technology-Innovation-Hub (TIH) Programme.
5. [MeitY Quantum Computing Applications Lab](#) [90]: Launched in 2021 in collaboration with AWS, the MeitY Quantum Computing Applications Lab identifies quantum computing problem statements for experimentation from central and state government ministries, government agencies, research institutions, and academia and aims to put quantum computing in the hands of every developer and scientist to build algorithms, conduct advanced simulations, and run experiments.
6. [C-DOT India Quantum Alliance](#) [91]: C-DOT has formed the India Quantum Alliance under the guidance of the Department of Telecommunications. The Alliance has multiple consortiums for bringing together industry, academia, and startups to develop indigenous quantum communication technologies.
7. [DRDO Young Scientist Laboratory - Quantum Technology \(DYSL-QT\)](#) [92], Pune: The mission of DYSL-QT is to explore Quantum Technologies and improve the TRL from 1 to 5 and subsequently to 9 in Quantum Computing, Communications and Sensing technologies.
8. [Metro Area Quantum Access Network \(MAQAN\)](#) [93]: India's first Metro Area Quantum Access Network (MAQAN) is proposed between IITM, IITM Research Park, Society for Electronic Transactions Security (SETS) and the National Informatics Centre (NIC). This is conceived as a testbed with multiple short-haul links to explore implementations of quantum communication and develop standards around them.

1.B.6.ii. Existing outward-looking efforts and engagements related to QSTI

In addition to the government strategies and national quantum initiatives, India has established partnerships with international research organisations, universities, and tech companies, reflecting India's growing commitment to advancing quantum technologies through global partnerships.

Below are some of the key collaborations and initiatives India has engaged in quantum science and technology.

- **US-India Engagement:**

- [US-India initiative on Critical and Emerging Technology \(US-India iCET\)](#) [94], announced in May 2022, aims to elevate and expand the strategic technology partnership and defence industrial cooperation between the governments, businesses, and academic institutions of the two countries.
 - Within this, the US-India Quantum Coordination Mechanism is facilitating bilateral cooperation in Quantum Information Science and Technology, including workshops on post-quantum cryptography and quantum hardware, and enabling visits of Indian technical experts to U.S. quantum institutions and national laboratories. Led by the National Security Advisors of both sides.
 - [U.S.-India Transforming the Relationship Utilizing Strategic Technology \(US-India TRUST\)](#) [95] initiative was announced in February 2025, which aims to catalyse government-to-government, academia and private sector collaboration to promote the application of critical and emerging technologies in areas like defence, artificial intelligence, semiconductors, quantum, biotechnology, energy and space.
- [UK-India Technology Security Initiative](#) [96] (UK-India TSI), launched in July 2024, builds upon the ambitious bilateral cooperation agenda set out in the India-UK Roadmap 2030 and focuses on quantum technologies as part of broader cooperation in critical and emerging technologies.
 - The TSI is being coordinated by the NSAs of India and the U.K. through both existing and newly established dialogues. Progress on the initiative will be reviewed every six months at the Deputy NSA level.
 - [EU-India Trade & Technology Council \(EU-India TTC\)](#) [97], launched in February 2023, also prioritises quantum technologies under Working Group-1 (Strategic technologies, digital governance and digital connectivity), particularly in collaboration with High-Performance Computing research and development projects to address global challenges.
 - [Australia-India Cyber and Critical Technology Partnership \(AICCTP\)](#) [98], established in 2020, supports Australia-India collaborations on cyber and critical technology issues and deepens institutional, research, business, and government linkages. Initiatives include research grants, policy exchanges, information sharing and awareness-raising activities.

- [QUAD QUIN's Quantum Information Sciences Center of Excellence \(QCoE\)](#) [99]: The Quad Investors Network ("QUIN") was created to accelerate investment in critical and emerging technologies among the Quad countries: India, Japan, Australia, and the United States. In November 2023, the QUIN launched the Quantum Center of Excellence (CoE)'s Task Forces covering quantum computing, communications, sensing, and ecosystem & workforce development.
 - The QCoE Co-Chairs include Dr. Cathy Foley (Chief Scientist of Australia), Prof. Ajay Kumar Sood (Principal Scientific Adviser to the Government of India), Prof. Hiroaki Aihara (Executive Vice President of the University of Tokyo), and Dr. Celia Merzbacher (Executive Director, Quantum Economic Development Consortium).
- India's participation in the [Chicago Quantum Exchange](#) [100] and in the [Quantum Economic Development Consortium](#) [101] is also an example of existing international collaborations.
 - Indian Institute of Technology (IIT) Bombay joined the Chicago Quantum Exchange as an international partner, and S.N. Bose National Centre for Basic Sciences, Kolkata, became a member of the Quantum Economic Development Consortium.
- India is also engaged internationally through various memorandums of understanding (MoUs), Joint S&T Committees, and working groups with [Canada \(2022\)](#) [102], [France \(2023\)](#) [103], [Israel \(2023\)](#) [104], and [Japan \(2024\)](#) [105] each aiming to promote collaboration in quantum science and technology.

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List of Conferences

1. [Joint March Meeting and April Meeting: Global Physics Summit 2025 | American Physical Society](#)

2. [Optica Quantum 2.0 Conference and Exhibition](#)
3. [International Conference on Quantum Technologies for High-Energy Physics \(20-24 January 2025\)](#)
4. [Quantum.Tech 2025](#)
5. [Q2B](#)
6. [IEEE QCE](#)
7. [CERN QTI](#)

List of Non-Profits in India

1. [SheQuantum](#)
2. [Contact Us - Quantum Research and Centre of Excellence](#)
3. [Quantum Ecosystems and Technology Council of India](#)
4. [QIndia - QWorld](#)

List of Consortiums / Alliances

1. [The Quantum Economic Development Consortium](#)
2. [Chicago Quantum Exchange](#)
3. [The Open Quantum Institute](#)
4. [European Quantum Industry Consortium](#)
5. [Five hubs launched to ensure the UK benefits from quantum future – UKRI](#)
6. [QCS Hub](#)
7. [Quantum Industry Canada](#)
8. [Q-STAR Quantum STRategic industry Alliance for Revolution](#)
9. [Quantum Internet Alliance](#)
10. [Post-Quantum Cryptography Alliance](#)
11. [Munich Quantum Valley](#)
12. [C-DOT India Quantum Alliance.](#)

List of Alternate Producers/Suppliers of Elements

1. [Germanium metal](#)
2. [Mineral Commodity Summaries 2024](#)
3. [Cesium Metal Market](#)
4. [Power Metals' Rare Find: Cesium | INN](#)
5. [Mineral commodity summaries 2024](#)
6. [Strontium Price, Occurrence, Extraction and Use | Institute for Rare Earths and Metals](#)
7. [Selenium global production volume by country | Statista](#)
8. [Selenium Metal Market](#)
9. Government of India. Indian Mineral Year Book 2021. [Selenium and Tellurium.](#)
10. [Global titanium production by country 2024 | Statista](#)
11. [Barium - Minerals Education Coalition](#)
12. [This chart shows which countries produce the most lithium](#)
13. [Silicon production worldwide by country 2024 | Statista](#)
14. Government of India. [Indian Minerals Yearbook 2020](#)
15. [Global indium production by country 2023 | Statista](#)
16. [Global-to-Local Dependencies in Phosphorus Mass Flows and Markets: Pathways to Improving System Resiliency in Response to Exogenous Shocks](#)
17. [Top 10 Tungsten-producing Countries | Nasdaq](#)
18. [The Global Biogeochemical Cycle of Arsenic - Schlesinger - 2022](#)
19. [What are Gallium and Germanium and which countries are producers? | Reuters](#)
20. [Top 10 Copper Producers by Country | INN](#)
21. [Top 10 nickel-producing countries in 2023 - Mine | Issue 139 | April 2024](#)
22. [Top 9 Nickel-producing Countries | INN](#)
23. [Helium | 2020 Minerals Yearbook](#)

Appendices

Appendix - A: Indicators used in this document

Research Publications (using the Glossary) - Number of publications yearly -> country-wise -> Top Organisations - Quality Indicators - Top 10% publications globally -> country-wise -> Top Organisations - Citation Topics - Number of publications -> country-wise -> Top Organisations Funding Agencies - Meso Topics - Number of publications -> country-wise -> Top Organisations Funding Agencies - Micro Topics - Number of publications -> country-wise -> Top Organisations Funding Agencies - Collaboration Network - co-authorship in research papers	Patents (using the Glossary) - Yearly Patents Applications Granted -> Top countries - Top Applicants - Top Applicants Country - Top Owners - Top Owners Country - Patent Jurisdictions - Top Agents & Attorneys - Top Agents & Attorneys Country - Joint Patents based on co-inventor countries - Legal Status YoY - Title, Abstract, Claims
Workforce - Number of PhDs/Post-Doc/early career researchers - Primary research areas - Gender Ratio - Institutes / Geography - Industry collaboration - Funding sources for the PhDs/Post-Doc/early career researchers - University programs & specialised tracks	Industry - Distribution Sectoral/Business-vertical - Startups - Unicorns - Publicly exited-Unicorns - Mergers & Acquisitions
- Investments - Investment distribution Sectoral/Business-vertical - Public Investments - Private Investments (Venture capital, private equity, etc.)	Other indicators - Conferences - Quantum alliances / consortiums - Standardisation efforts (participation in quantum standards development by bodies, e.g., ISO, ITU, IEEE) - Open source developments in Quantum Science and Technology

Appendix - B: Glossary

Compiled glossary of keywords (about 120 keywords) into 5 categories - based on the 4 NQM verticals and 1 overarching category encompassing the overall QSTI domain including the 4 verticals. It is compiled from the multiple common glossaries prepared by startups, universities, and tech companies, as well as from research papers. Additionally, OpenAlex was used to identify relevant keywords based on broad search queries for each vertical. The categorisation is based on the definitions of each term rather than search queries or any other source.

Overarching Quantum Science and Technology	Quantum computing	Quantum communication & cryptography	Quantum sensing & metrology	Quantum materials & devices
qubit	quantum computing	quantum communication	quantum sensing	quantum dot
quantum state	Quantum computer	quantum transmission	quantum metrology	spintronic
quantum entanglement	quantum computation	quantum network	quantum sensor	quantum material
quantum superposition	quantum processing unit	quantum repeaters	quantum radar	majorana fermions
quantum tunnelling	qpu	quantum internet	quantum imaging	josephson junction
quantum information	quantum processor	quantum optical communication	quantum measurement	quantum device
von neumann mutual information	quantum annealer	quantum key distribution	quantum gravimeter	quantum liquid
quantum mutual information	quantum automata	qkd	quantum magnetometer	graphene for quantum
quantum science technology	quantum compiler	quantum crypto	quantum accelerometer	graphene quantum
quantum science	quantum software	quantum cryptography	quantum atomic clock	quantum graphene
quantum technology	quantum circuit	post-quantum cryptography	quantum clock	trapped ions

quantum information science and technology	quantum reservoir computing	quantum encrypt	quantum tomograph	quantum storage
quantum information science	quantum approximate optimization algorithm	quantum encryption	quantum diamond magnetometry	quantum hardware
quantum optimization	quantum approximate optimisation algorithm	quantum decrypt	quantum inertial navigation	neutral atom quantum
quantum optimisation	quantum parallelism	quantum decryption	quantum positioning systems	neutral atom technology
rydberg blockade	quantum volume	quantum cybersecurity	quantum coherence	quantum simulators
quantum algorithm	quantum supercomputing	quantum fidelity	quantum decoherence	quantum yield
quantum application	quantum logic gate	diffie-hellman key exchange	quantum entropy	quantum optics
bloch sphere	variational quantum algorithm	quantum teleportation	quantum fisher information	quantum photonics
quantum simulation	variational quantum algorithm	quantum state transmission	quantum noise	quantum cascade laser
quantum field theory	shor's algorithm	no-cloning theorem		
quantum lattice system	divincenzo criteria	quantum random number generation		
quantum control	quantum phase estimation	qrng		
quantum optimal control	quantum error correction	quantum network modelling		
quantum state control	quantum convolutional code			

quantum coherent control	noisy intermediate-scale quantum			
quantum chemistry	noisy intermediate scale quantum			
quantum walk	quantum register			
pauli exclusion principle	qubit fidelity			
quantum electrodynamics	grover's algorithm			
	quantum machine learning			
	quantum artificial intelligence			
	quantum AI			
	quantum cellular automaton			

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International Technology Engagement Strategy

In a time when emerging technologies are reshaping the contours of geopolitics, trade, security, and sustainable development, India's international engagements in science and technology must be strategically calibrated, evidence-informed, and resilient to future challenges. The International Technology Engagement Strategy (ITES) is an initiative of the Office of the Principal Scientific Adviser to the Government of India, designed to strengthen and elevate India's Technology Diplomacy efforts across critical and emerging domains.

India's global technology partnership approach is rooted in the principle of "meaningfully balancing competition with collaboration for equitable development." ITES aspires to provide a structured, pragmatic, and forward-looking framework for India's international technology engagements—building on existing bilateral and multilateral platforms, while identifying new strategic opportunities for co-development and cooperation.

The ITES captures the opportunities and challenges at the global technology landscape and analyses it with the Indian ecosystem. As the global technology landscape becomes increasingly complex and competitive, ITES offers a mechanism to ensure that India's international engagements are aligned with national interests, technological priorities, and long-term strategic autonomy.

This strategy not only underscores India's position as a trusted global technology partner, but also reaffirms our commitment to leveraging technology for inclusive, sustainable, and human-centric progress—both at home and globally.

Dr. Parvinder Maini

**Scientific Secretary
Office of the Principal Scientific Adviser to the
Government of India**





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