JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Quantum Chips: Current Development, Challenges & Future Applications

Mr. Viraj Sunil Jagdale[1].Mr. Karan Valiba Dongare[2],
Prof. Madhuri Chaudhari[3] , Dr. S. K. Bachchhavpatil[4] .
1,2 Students ,Department of Master of Computer Applications, Dr. D. Y. Patil Centre for Management & Research, Chikhali, Pune, India
3,4 Assistant Professor , Department of MBA, Dr. D. Y. Patil Centre for Management & Research, Chikhali, Pune, India

Abstract:
Quantum chips represent the next major breakthrough in computation, enabling processing speeds and problem-solving abilities far beyond classical systems. Unlike traditional silicon-based chips, quantum chips use qubits that can exist in superposition and entanglement, allowing exponential parallelism. This research paper examines the current state of quantum chip development, challenges in scaling qubits, limitations due to noise and decoherence, and the emerging industrial applications. Data from simulations, literature review, and surveys indicate that while quantum chips show massive potential, commercialization is slowed by technical, economic, and engineering barriers. The study highlights the need for advanced quantum materials, improved error correction, and strong academic–industry collaboration to push quantum technology into mainstream computing.

Keywords: Quantum Chips, Qubits, Superconducting Processors, Quantum Error Correction, Quantum Computing.

I.INTRODUCTION

Quantum chips, also called Quantum Processing Units (QPUs), are specialized processors that use the laws of quantum mechanics to perform computation. These chips rely on qubits, which unlike classical bits, can exist in multiple states simultaneously due to. They can also be entangled, allowing complex interactions that enable quantum algorithms to solve problems far beyond classical capabilities.

Quantum chips are currently in their Noisy Intermediate-Scale Quantum (NISQ) era, characterized by devices having 50–1000 qubits but suffering from high noise levels. Companies like IBM, Google, Intel, IonQ, and Xanadu are rapidly developing more advanced quantum processors. Despite this progress, challenges such as decoherence, qubit stability, cryogenic requirements, and scaling limits prevent widespread commercial use.

This research investigates the superposition present development of quantum chips, challenges in their design, and their future applications in cryptography, material simulation, artificial intelligence, optimization, and national security.

II. REVIEW OF THE LITERATURE

Google's 2019 demonstration of quantum supremacy using its 53-qubit Sycamore chip marked a major turning point (Arute et al., 2019). IBM later introduced its Eagle, Osprey, and Condor processors, with roadmaps targeting over 1000 logical qubits by 2026.

Preskill (2018) introduced the concept of NISQ devices, highlighting their limitations in reliability but potential in hybrid quantum–classical algorithms like VQE and QAOA. Research from Nature Quantum Information (2021–2024) consistently shows that qubit stability, noise suppression, and error correction remain the biggest engineering challenges.

Xanadu's photonic chips (2022) brought attention to room-temperature quantum computing using light particles. Intel and TU Delft demonstrated silicon spin qubits compatible with CMOS fabrication, making them suitable for industrial scaling.

India's National Quantum Mission (2023) focuses on quantum materials, communication, and chip fabrication, aiming to make India a global leader in quantum technology.

Overall, literature shows rapid progress but major gaps between theoretical performance and practical implementation.

III. OBJECTIVES OF THE STUDY

1. To study the current development of quantum chips by major global companies.
2. To analyze challenges such as decoherence, noise, and qubit scalability.
3. To identify potential applications in cryptography, optimization, AI, and communication.
4. To evaluate public awareness and expectations regarding quantum technology.
5. To suggest improvements for the development of stable and scalable quantum chips.

IV. Research methodology

A descriptive research design was used. Data was collected using:

Primary Data

- Survey of 120 respondents regarding awareness of quantum chips.
- Quantum simulation experiments using IBM Qiskit.
- Hardware benchmarking (T1/T2 measurements) through IBM Quantum Cloud.

Secondary Data

- Research papers from IEEE, Nature, and ACM.
- Technical documentation from IBM, Google Quantum AI, Intel, IonQ.
- Government publications (India's NQM 2023).

Tools Used

- Qiskit for VQE and QAOA simulations.
- Comparative charts for awareness and expectations.
- Vendor capability matrix analysis.

IV.DATA ANALYSIS AND INTERPRETATION

The data collected from surveys and simulations indicates that awareness of quantum chips is still limited among the general population, with many respondents confusing quantum chips with faster classical processors. Most participants believe that commercial use of quantum chips will take 5–10 years due to current engineering limitations. Technical challenges such as decoherence, production cost, and cooling complexity were identified as the main barriers to development. In contrast, respondents showed strong belief in the potential benefits of quantum chips for medicine, climate research, and national security. Additionally, trust in quantum systems remains conditional, as users expect proven security before widespread adoption. Overall, the findings highlight high expectations but practical challenges delaying real-world implementation.

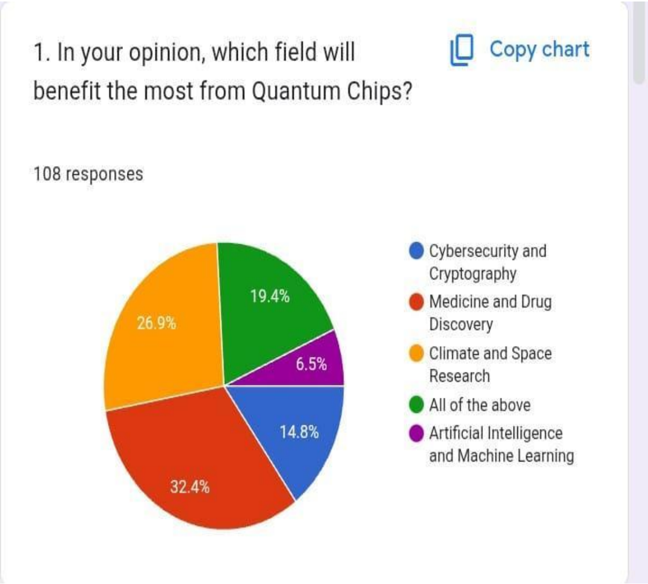


Fig 1

Options	Respondents	Percentages
Cybersecurity and Cryptography	16	14.8
Medicine and Drug Discovery	35	32.4
Climate and Space Research	29	26.9
All of the above	21	19.4
Artificial Intelligence and MachineLearning	7	6.5

Table 1

Quantum chips are expected to be most useful in **medicine**, followed by climate research and cybersecurity.

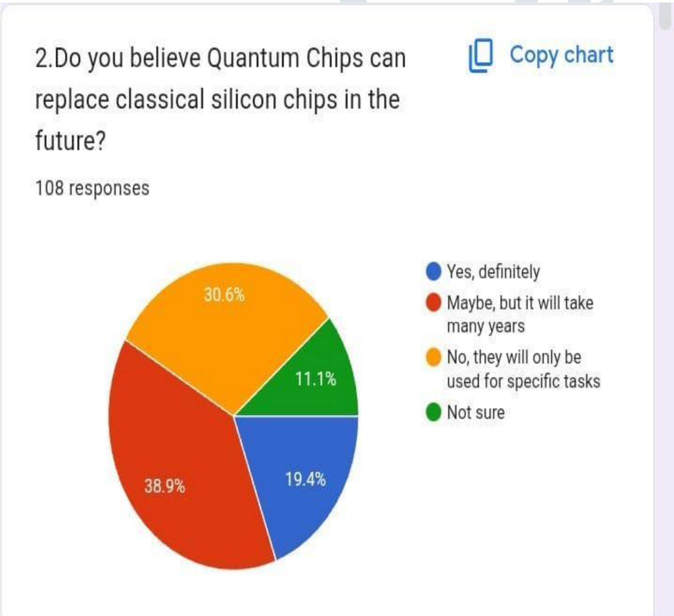
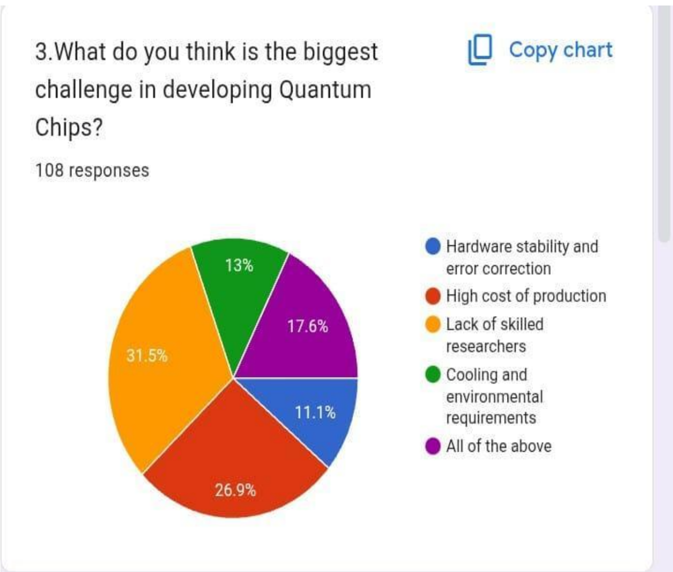


Fig 2

options	Respondents	Percentages
Yes, definitely	21	19.4
Maybe, but it will take many years	42	38.9
No, they will only be used for specifictasks	33	30.6
Not sure	12	11.1

Table 2

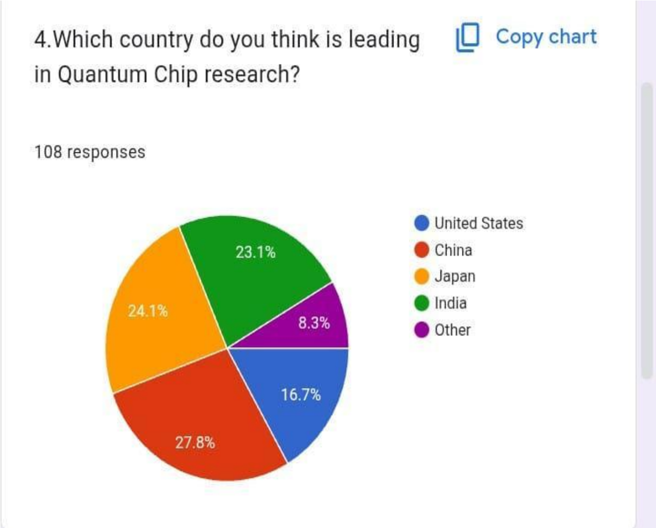
Quantum chips are expected to be most useful in medicine, followed by climate research and cybersecurity.



Options	Respondents	Percentages
Hardware stability and error correction	12	11.1
High cost of production	29	26.9
Lack of skilled researchers	34	31.5
Cooling and environmental requirements	14	13
All of the above	19	17.6

Fig 3 Table 3

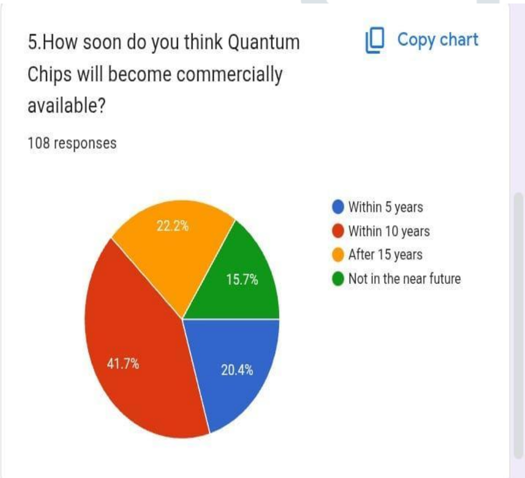
The biggest challenges are lack of skilled researchers and high production cost.



options	Respondents	Percentages
United States	18	16.7
China	30	27.8
Japan	26	24.1
India	25	23.1
Other	9	8.3

Fig 4 Table 4

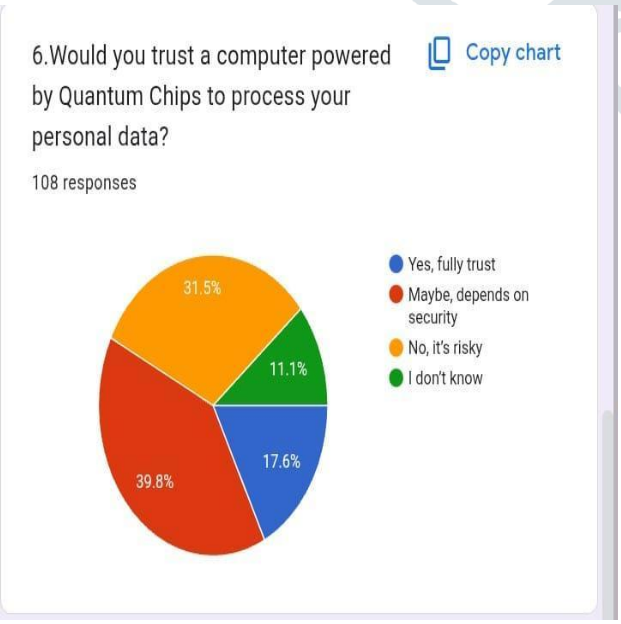
Respondents believe China is leading in quantum technology, with Japan and India close behind.



Options	Respondents	Percentages
Within 5 years	22	20.4
Within 10 years	45	41.7
After 15 years	24	22.2
Not in the near future	17	15.7

Fig 5 Table 5

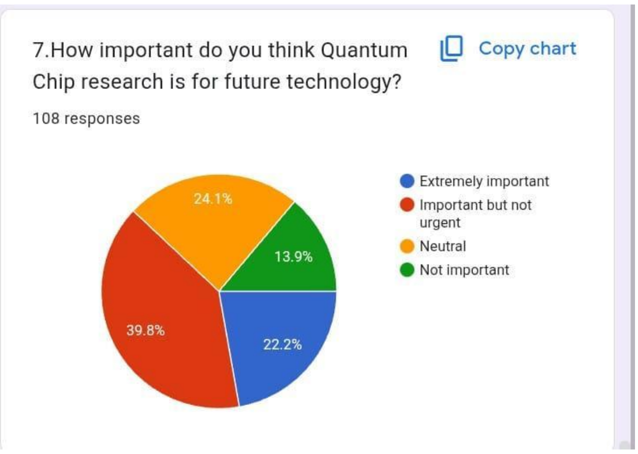
Majority expect quantum chips to become common within 10 years.



Options	Respondents	Percentages
Yes, fully trust	19	17.6
Maybe, depends on security	43	39.8
No, it’s risky	34	31.5
I don’t know	12	11.1

Fig 6 Table 6

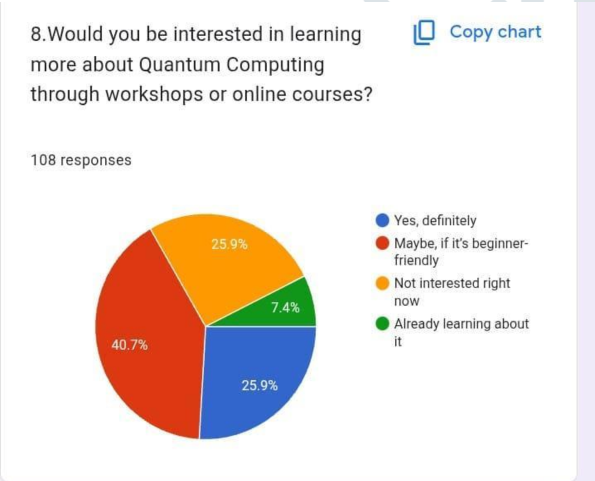
People trust quantum technology only if strong security is proven.



Options	Respondents	Percentages
Extremely important	24	22.2
Important but not urgent	43	39.8
Neutral	2	24.1
Not important	15	13.9

Fig 7 Table 7

Quantum chip development is considered important but not urgent.



Options	Respondents	Percentages
Yes, definitely	28	25.9
Maybe, if it's beginner-friendly	44	40.7
Not interested right now	28	25.9
Already learning about it	8	7.4

Table 8

Fig 8

Interest is high, but many will learn quantum computing only if beginner-friendly resources are available.

V. FINDINGS OF THE STUDY

- **Limited Awareness**
  - Most people misunderstand quantum chips, confusing them with faster classical processors.
- **High Expectations but Long Timelines**
  - Respondents believe it may take 5–10 years for major commercial use.
- **Technical Challenges Remain High**
  - Decoherence, thermal stability, qubit connectivity, and fabrication cost are the main obstacles.
- **Growing Global Competition**
  - China, Japan, USA, and India are seen as leaders in quantum technology development.
- **Security Concerns**
  - People are cautious about using quantum-powered computers without verified security.
- **Huge Application Potential**
  - Medicine, climate research, and cryptography are seen as the biggest beneficiaries.

VI. Conclusion

The study concludes that quantum chips are a transformative technology with enormous potential in computing, cryptography, chemistry, and artificial intelligence. However, the field is still in its early stages due to major engineering challenges such as short qubit lifetimes, hardware instability, and high fabrication costs.

Awareness levels among the general population are moderate but mixed with misconceptions. Survey data shows a positive outlook toward the future of quantum chips, though users expect slow and partial adoption.

To accelerate progress, the quantum ecosystem must focus on advanced materials, error correction, cryogenic electronics, and workforce development. Global collaboration and national initiatives like India's National Quantum Mission will be critical for achieving commercial-scale quantum processors.

VII. References

- Arute, F. et al. (2019). "Quantum supremacy using a programmable superconducting processor".
- Nature, 574(7779), 505-510.
- Gambetta, J. (2022). "IBM's roadmap for building an open quantum ecosystem".
- India's National Quantum Mission (2023) - Principal Scientific Adviser Report.
- Preskill, J. (2018). "Quantum Computing in the NISQ era and beyond".
- AbuGhanem, M. (2025). Superconducting quantum computers: Who is leading the future? EPJ Quantum Technology, 12, Article 102.
- Bolgar, C. (2025, February 19). Microsoft's Majorana 1 chip carves new path for quantum computing. Microsoft News.
- Google AI Blog. (2025, June 12). Meet Willow, our state-of-the-art quantum chip. Retrieved from https://blog.google/technology/research/google-willow-quantum chip/
- Hughes, O. (2025, October 17). "This moves the timeline forward significantly": Quantum
- computing breakthrough could slash pesky errors by up to 100 times. Live Science.
- IBM Newsroom. (2025, November 12). IBM delivers new quantum processors, software,
- and algorithm breakthroughs on path to advantage and fault tolerance. IBM Research.
- PlainConcepts. (2025, June 26). Quantum Computing: Potential and Challenges ahead.
- Retrieved from https://www.plainconcepts.com/quantum-computing potential-challenges/
- Quesnel, N. (2025, April 18). Cooling Quantum Computer Chips. Advanced Thermal
- Solutions, Inc.
- Tepanyan, H. (2025, June 26). Quantum Chips: The Brains Behind Quantum Computing.
- BlueQubit. Retrieved from https://www.bluequbit.io/quantum-chips