

Quantum Computing: Global Trends, Key Challenges and Strategic Directions

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Abstract

Quantum technology represents a paradigm shift in computing capacity, offering exponential speed and fresh solutions to problems that classical systems cannot decipher. The present treatise analyses the rapid development of quantum technologies, stresses their global search momentum, technological superiority over classical AI, as well as innovative capabilities in medical aid, financing, and climate science. We analyze roadblocks such as decoherence, scalability, and expertise deficit and propose a calculated roadmap to achieve quantum advantage by 2030. Understandings from Elsevier's Quantum Technology Inquiry Report, Field Events Research and Technical White Papers underpin this comprehensive study and provide achievable recommendations for interested parties.

Keywords: Quantum Computing, Post-Quantum Cryptography, Hybrid Systems, NISQ Era, Quantum Advantage.

Introduction

The race for harnessing quantum information is growing worldwide, along with administrations, corporations, and universities funding countless efforts to unlock its potential. Unlike a classical computer, which processes binary numbers (0s and 1s), a quantum computer uses qubits, which exist simultaneously as both 0s and 1s. This enables parallel processing of huge datasets, solving optimization, cryptographic analysis, and imitation problems exponentially faster. However, problems with qubit uncertainty and error correction remain, limiting the short-term objective.

This paper is structured into five sections:

1. **Global Momentum:** Investments, research trends, and geopolitical competition.
2. **Technical Superiority:** Quantum's edge over classical AI and large language models (LLMs).
3. **Industry Transformations:** Real-world applications in healthcare, finance, and climate science.
4. **Challenges:** Technical, ethical, and workforce barriers.
5. **Future Roadmap:** Strategic priorities for 2025–2030.

1. Global Momentum in Quantum Research

1.1 Explosive Growth in Research

Quantum Mechanics Computer Research has owned Billow since the 1990s, together with over 48,000 publications by 2021. After 2015, breakthroughs in qubit design e.g. A 300 % increase in annual publication is due to superconducting circuits, trap ions, photonics, and error correction processes [1].

- Scalability is demonstrated by IBM's 433-qubit Osprey processor and Google's 70-qubit Bristlecone framework [2].

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