

# The Second Quantum Revolution: Unexplored Facts and Latest News

Subjects: **Quantum Science & Technology**

Contributor: Kimberly Intonti , Loredana Viscardi , Veruska Lamberti , Amedeo Matteucci , Bruno Micciola , Michele Modestino , Canio Noce

The Second Quantum Revolution refers to a contemporary wave of advancements and breakthroughs in the field of quantum physics that extends beyond the early developments of Quantum Mechanics that occurred in the 20th century. One crucial aspect of this revolution is the deeper exploration and practical application of quantum entanglement. Entanglement serves as a cornerstone in the ongoing revolution, contributing to quantum computing, communication, fundamental physics experiments, and advanced sensing technologies. Here, we present and discuss some of the recent applications of entanglement, exploring its philosophical implications and non-locality beyond Bell's theorem, thereby critically examining the foundations of Quantum Mechanics. Additionally, we propose educational activities that introduce high school students to Quantum Mechanics by emphasizing entanglement as an essential concept to understand in order to become informed participants in the Second Quantum Revolution. Furthermore, we present the state-of-art developments of a largely unexplored and promising realization of real qubits, namely the molecular spin qubits. We review the available and suggested device architectures to host and use molecular spins. Moreover, we summarize the experimental findings on solid-state spin qubit devices based on magnetic molecules. Finally, we discuss how the Second Quantum Revolution might significantly transform law enforcement by offering specific examples and methodologies to address the evolving challenges in public safety and security.

Second Quantum Revolution

quantum technology

entanglement

modern physics

molecular chemistry

quantum cryptography

The evolution of Quantum Mechanics (QM) is a fascinating story that spans the 20th century and leads to revolutionary discoveries and fundamental technological applications <sup>[1]</sup>. Here, we present a summary of the key facts and concepts of QM from the beginning up to the current day:

- Planck's Quantum Theory (1900) <sup>[2]</sup>: the starting point of QM was Planck's proposal that the energy of harmonic oscillators, such as those emitting electromagnetic radiation, cannot take any value save for discrete values called quanta.
- Bohr's Atomic Model (1913) <sup>[3]</sup>: Bohr extended these concepts to atomic structure, proposing a model where electrons have quantized angular momentum and travel on quantized orbits.

- Schrödinger's Wave Equation (1925) <sup>[4]</sup>: Schrödinger developed the wave equation, a fundamental equation describing the time-dependent evolution of a quantum state.
- Heisenberg's Uncertainty Principle (1927) <sup>[5]</sup>: Heisenberg formulated the Uncertainty Principle, stating that it is impossible to simultaneously know with precision both the position and linear momentum of a particle.
- Einstein–Podolsky–Rosen Paradox (EPR) (1935) <sup>[6]</sup>: the EPR Paradox is based on quantum entanglement, a state where the properties of two particles are closely correlated even at large distances, thereby highlighting implications on the nature of reality.
- Bell inequality (1964) <sup>[7]</sup>: Bell formulated an inequality to establish limits on the correlations that can exist between measurements of entangled particles.

From its inception to current developments, QM has gone through various stages, culminating in the so-called Second Quantum Revolution <sup>[8]</sup>, which is where quantum entanglement is the key feature, with advanced and promising applications that are shaping the future of technology and science. The Second Quantum Revolution represents an epochal phase in the evolution of technology, with significant impacts across various sectors. At the heart of this revolution lies quantum computing, a mode of information processing that harnesses the principles of QM to outperform the most powerful classical computers in solving specific problems. Specifically, a quantum device is able to perform certain computational tasks in a feasible amount of time while the same task would have been impractical or impossible for even the most advanced classical supercomputers. However, this quantum advantage does not mean that quantum computers will replace classical computers for all tasks. Instead, it highlights their potential to excel in specific computations, such as complex simulations or cryptography-related problems. Despite achieving quantum advantage in certain contexts, the practical implementations of quantum computers for widespread use are still in the early stages of development, and ongoing research has focused on refining the technology and exploring its full capabilities <sup>[9]</sup>.

One of the most revolutionary aspects is the use of quantum bits (qubits), quantum information units that can exist in a state of superposition, which allow the simultaneous handling of multiple possibilities. This characteristic makes quantum computing particularly effective in solving complex problems, such as factoring very large numbers or simulating molecular systems for the development of new drugs. However, the scope of the Second Quantum Revolution extends beyond computation. It reaches into sectors like cryptography, with the threat posed by quantum computers to current cryptographic security techniques, and quantum metrology promising levels of precision previously thought unattainable. Furthermore, the Second Quantum Revolution paves the way for new frontiers in quantum communication, with the possibility of transmitting information completely securely through the indestructibility characteristic of quantum states.

Since a plethora of the scientific literature has been dedicated to the Second Quantum Revolution <sup>[10]</sup>, in this work, we present some unexplored facts and the latest news on this topic.

## References

1. Greenberger, D.; Hentschel, K.; Weinert, F. (Eds.) *Compendium of Quantum Physics*; Springer: Berlin/Heidelberg, Germany, 2009.
2. Planck, M. Ueber das Gesetz der Energieverteilung im Normalspectrum. *Ann. Phys.* 1901, 309, 553–563.
3. Bohr, N.I. On the constitution of atoms and molecules. *Lond. Edinb. Dublin Philos. Mag. Sci.* 1913, 26, 1–25.
4. Schrödinger, E. Quantisierung als Eigenwertproblem. *Ann. Phys.* 1926, 384, 361–376.
5. Heisenberg, W. Über den anschaulichen Inhalt der quantentheoretischen Kinematik und Mechanik. *Z. Phys.* 1927, 43, 172–198.
6. Einstein, A.; Podolsky, B.; Rosen, N. Can quantum-mechanical description of physical reality be considered complete? *Phys. Rev.* 1935, 47, 777.
7. Bell, J.S. On the Einstein Podolsky Rosen paradox. *Phys. Phys. Fiz.* 1964, 1, 195.
8. Dowling, J.P.; Milburn, G.J. Quantum technology: The second quantum revolution. *Phil. Trans. R. Soc. A* 2003, 361, 1655–1674.
9. Bennett, C.H.; Bernstein, E.; Brassard, G.; Vazirani, U. Strengths and Weaknesses of Quantum Computing. *SIAM J. Comput.* 1997, 26, 1510–1523.
10. Jaeger, L. *The Second Quantum Revolution: From Entanglement to Quantum Computing and Other Super-Technologies*; Springer International Publishing: Berlin/Heidelberg, Germany, 2019.

---

Retrieved from <https://encyclopedia.pub/entry/history/show/127250>