Abstract

Quantum computers, which harness the principles of quantum physics, are advancing at an unprecedented pace. These systems represent a transformative leap in computing, enabling the solution of complex and challenging problems that lie beyond the reach of classical computers. In recent years, significant progress has been made across the entire quantum computer stack, from hardware and software to system integration, interaction with classical computers, and practical applications in research and industry.

This presentation explains the core concepts of quantum computing, discusses the current state of the field, and explains the prerequisites for developing a robust tool for solving real-world problems.

In order to increase performance—number of qubits, quality, and speed of the system—as quickly as possible, improvements are needed in all areas. An overview of the challenges, recent advances in development, and the technology roadmap will be discussed. Furthermore, examples of quantum applications in chemistry, physics and optimization are presented.

Biography

Dr. rer. nat. Dr. h.c. Heike Riel is an IBM Fellow, Head of Science for Quantum and Information Technologies, and Lead of IBM Research Quantum EMEA. She is dedicated to shaping the future of computing through pioneering scientific and technological advancements in quantum computing, quantum technologies, the physics of artificial intelligence, nanoscience, and nanotechnology—exploring novel paradigms that redefine computation.

She holds a Master's degree in Physics from Friedrich-Alexander University Erlangen-Nürnberg, a Ph.D. in Physics from the University of Bayreuth, and an MBA from Henley Business School.

Dr. Heike Riel has received numerous prestigious honors and awards, e.g., elected member of the Leopoldina – German National Academy of Sciences and the Swiss Academy of Engineering Sciences; she was awarded the APS David Adler Lectureship Award in the Field of Materials Physics, the Applied Physics Award of the Swiss Physical Society, and the 2022 IEEE Andrew S. Grove Award. She was honored as Fellow of the American Physical Society, and with an honorary doctorate by Lund University. In February 2022 she was elected to the National Academy of Engineering and in 2023 to acatech, the National Academy of Science and Engineering Germany.