Article

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Quantum technology — glimpses of potential technological advancements

Quantum theory's most significant contribution to technology is arguably its contribution to semiconductor technology. Quantum theory allowed us to describe and understand semiconductor crystals, which enabled the development of semiconductor devices. It would not be an exaggeration to say that this is one of the main technological achievements that enabled our modern society. A natural question is: what will be the next big technological advancement? This article gives a brief overview of what quantum technology is and where it came from.

The four categories of quantum technology

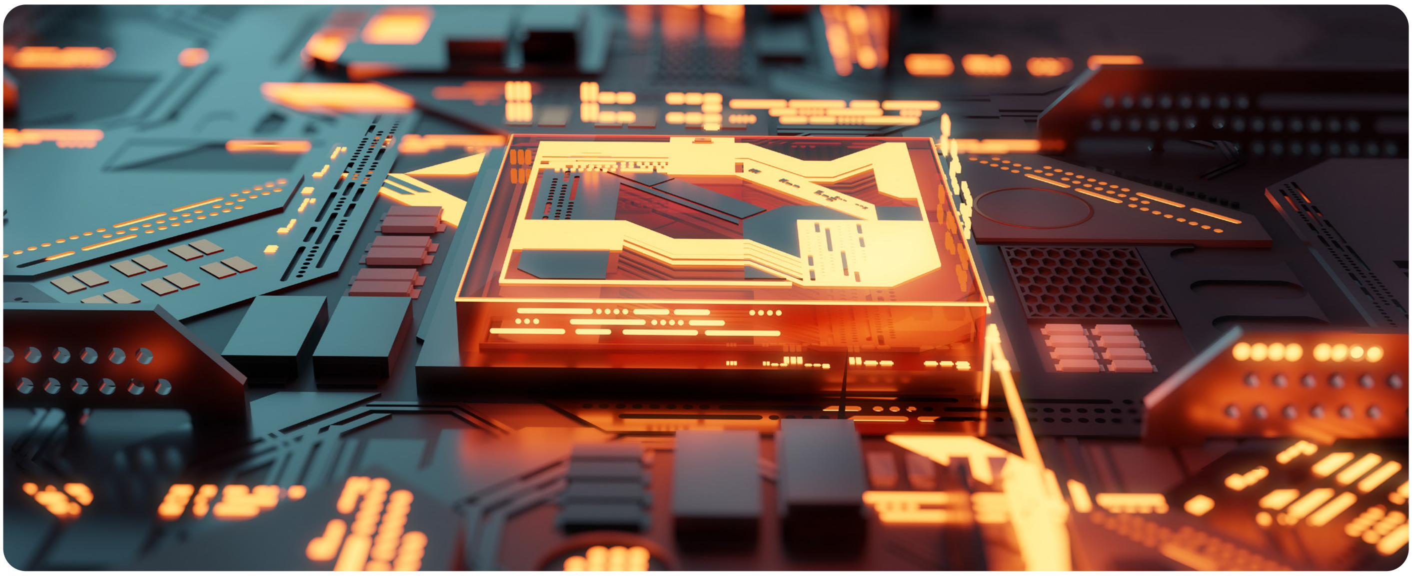
In the last few decades, research in quantum theory has taken an information-theoretic approach. This combination of quantum theory and information theory has provided us with glimpses of potential technological advancements, and this is what is referred to as quantum technology. Quantum technology is commonly divided into four different categories: quantum simulation, quantum sensing, quantum communication, and quantum computation.

Quantum simulation

Computer simulations of quantum systems are important for studying new materials, new drugs, and other different processes in nature. However, using regular computers to simulate complex quantum systems is intractable. In quantum simulation, the idea is to use another large quantum system (a quantum simulator) that we can control, and then use that simulator to mimic the behavior of the system that we want to study. The rationale is that a computer built from the same building blocks as the system we want to study will have an advantage.

Quantum sensing

Quantum systems are incredibly fragile and susceptible to external influences. This sensitivity is usually seen as a drawback in the other three categories, but in quantum sensing, one instead intends to exploit this extreme sensitivity to build sensors and measurement devices. The goal is to detect smaller signals than what is possible with regular sensors. Potential use cases range from scientific explorations to defense applications.



Quantum communication

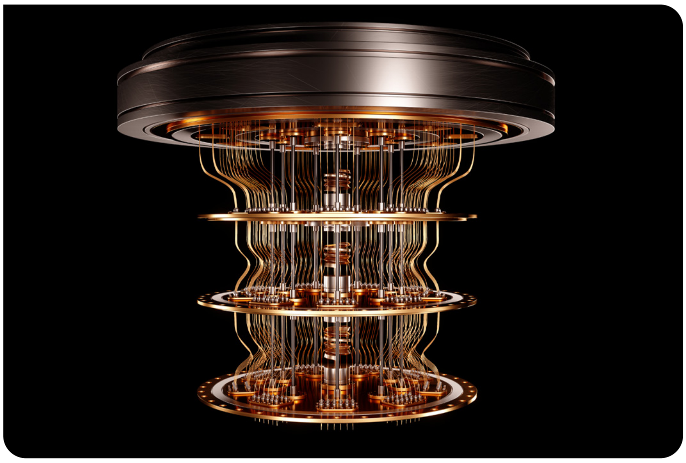
The main applications here aim to secure communication channels by protecting against an eavesdropper. A quantum system can neither be copied nor read-off without disturbing it. With clever protocols, we can ensure that an eavesdropper has to alter the data in the communication channel. This alteration, and in turn the eavesdropper, can then be detected. These protocols can be used to distribute a secret key between two parties, a secret key that could then be used to encrypt data.

Quantum computation

Quantum computation emerged with the theoretical development of quantum algorithms. These algorithms could solve certain computational problems fast. This needs to be emphasized; a quantum computer does not provide an overall speedup; it is only for when we have a quantum algorithm with better performance than the best know algorithm on a regular computer. A good way of thinking about the speedup from quantum computers is as a software speedup: there are new faster algorithms, but these require hardware that has yet to be built. The most famous quantum algorithm is Shor's algorithm, which can efficiently solve integer factorization and discrete logarithm problems. An efficient solution to these two problems would be detrimental for many widely used cryptographic protocols, which has prompted a search for replacement protocols.

With the intention to achieve a technological advantage

There is a common approach in the above four categories. Instead of using quantum theory to describe and understand an existing system, one aims to engineer controllable systems at the quantum level — with the intention to make direct use of quantum phenomena to achieve a technological advantage. As in the beginning of every new technological paradigm — quantum technology is no exception — there is little knowledge of how large the impact of the new technology will be and where it will find applications. If quantum technology will have an impact on the same magnitude as semiconductor technology, or if it will be contained to a small niche of applications, that remains to be seen.



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