CHALMERS
UNIVERSITY OF TECHNOLOGY

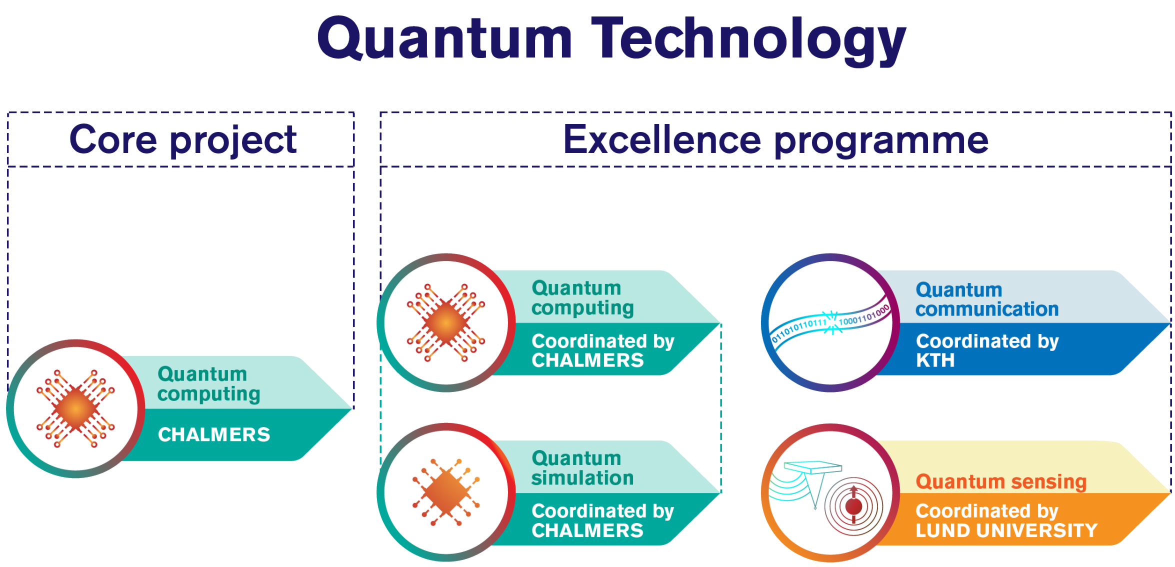
Research programme description:

Wallenberg Centre for Quantum Technology

A technology revolution – the second quantum revolution – is under way, with quantum computers, intercept-proof communications and hyper-sensitive measuring methods in sight. The research programme Wallenberg Centre for Quantum Technology is a decade-long SEK 1 billion investment programme that aims to take Swedish research and industry to the forefront of this technology revolution.

Quantum technology is based on the ability to control and manipulate individual quantum systems such as individual atoms and photons. Quantum technology is usually split into four sub-areas: quantum communications, quantum sensors, quantum computers and quantum simulators. Read more in *Quantum technology – popular science description*.

Wallenberg Centre for Quantum Technology, which is largely funded by the Knut and Alice Wallenberg Foundation, aims to develop and secure Swedish expertise in all four areas of this very rapidly expanding area of technology. The research programme therefore includes both a focus project with the aim of developing a quantum computer and an excellence programme in the four sub-areas. The research programme is managed and mainly located at Chalmers. The other participating universities are KTH Royal Institute of Technology and Lund University. The programme also has several industrial partners.



The five parts of the research programme *A quantum computer is being developed in a targeted project at Chalmers by specialists with permanent appointments and doctoral students/postdocs. The four sub-areas of quantum technology are being researched through an academic excellence programme with a significant input from industrial doctoral students to ensure that the knowledge will be rapidly put to use in industry.*

The research programme is headed up by Per Delsing, Professor of Quantum Device Physics at Chalmers. Delsing has also been on the steering committee of the EU's forthcoming flagship initiative on quantum technology.

Core project: Quantum computing

The aim of the focus project is to develop and build a quantum computer, based on superconducting circuits, with much greater computing power than the best supercomputers of today. In order to maintain an extremely high level of expertise throughout this challenging project, the development work will mainly be in the hands of specialist researchers with permanent appointments. Doctoral students and postdocs involved in the excellence initiatives on quantum computers and quantum simulators will contribute by studying specific issues of relevance to the construction of a quantum computer.

The project is located at Chalmers where the right expertise and necessary infrastructure in the form of an advanced clean room and cryotechnology are available. The focus project's principal investigators have worked on superconducting qubits for many years and have made many contributions to expand knowledge in the field. They were among the first in the world to create a superconducting qubit, and have explored a completely new area of physics through wide-ranging experiments on single qubits. One of the cornerstones of the successes is the unusually strong cooperation between experimentalists and theoreticians.

The first milestone for the quantum computer project is to build two interlinked blocks each containing ten qubits within four years. This will make it possible to demonstrate basic quantum simulations of small systems, such as a small molecule.

The final goal is to develop a 100-qubit quantum computer within ten years (the current world record is 16 qubits). Such a quantum computer should be capable of performing calculations which surpass those of a normal computer. For example, it will be possible to use the quantum computer to improve machine learning and to calculate the characteristics of larger molecules, thus assisting the more efficient design of medicines and materials.

Quantum physics conflicts with ordinary human intuition, and the quantum computer will certainly have many more applications than we can imagine today. Part of the project therefore also involves further research into the best uses of a quantum computer. The various areas of applications will be developed in cooperation with the research programme's industrial partners.

Principal investigators

The experimental parts are headed up by Professor Per Delsing and Associate Professor Jonas Bylander in the Quantum Device Physics Laboratory, Chalmers. The theoretical work is led by Professor Göran Johansson at the division of Applied Quantum Physics, Chalmers. Professor Göran Wendin, Applied Quantum Physics, Chalmers, is the senior adviser.

Excellence programme

The largest component of the research programme is an excellence initiative which includes a graduate school with 60 doctoral students, 20 of whom are industrial doctoral students, a postdoc programme with 30 postdocs, a guest professor programme to attract world-leading scientists to come and do research for a shorter period (1–12 months) and funding to recruit 12 assistant professors. This will ensure that Sweden has a long-term supply of expertise in the field of quantum technology, even when the programme has ended.

The excellence initiative is taking place in all the sub-areas of quantum technology: quantum computing, quantum simulation, quantum communication and quantum sensing.

Quantum computing and quantum simulation

This part of the excellence programme is integrated with the focus project and will mainly be located at Chalmers. Doctoral students, postdocs, assistant professors and visiting researchers will support the development of the focus project's quantum computer by investigating specific issues, related both to the design of the hardware, the implementation of error correction and how best to program and use the quantum computer.

The quantum simulator sub-area is closely related to quantum computers. A quantum simulator is essentially a simpler type of quantum computer which has been specifically designed to solve a certain type of problem. In the course of the project, the researchers will also build a quantum simulator. Using the quantum simulator, they expect to be able to demonstrate what is known as quantum supremacy, which means solving a problem that is beyond the reach of a traditional computer.

The quantum computer and quantum simulation sub-areas are being managed from Chalmers, by the same principal investigators as for the focus project.

Quantum communication

Quantum communications involves the secure transmission of encrypted data. It is completely intercept-proof, but currently limited to a distance of around 100 kilometres due to the lack of amplifiers for quantum signals, known as quantum repeaters. In order to guarantee the security of the next generation of communications systems, a global quantum network needs to be developed, which can rapidly and securely transmit data between many different points.

One of the aims of this project is to develop a quantum repeater that can amplify and transmit quantum information. Another goal is to find good photon sources to generate the individual photons which are the data carriers of quantum communications – they have to be fast, and you need to be able to select both the wavelength and shape of the light pulse. A third challenge is to develop a quantum memory that can store data in a photon for a certain period, and then read off the data.

The quantum communications sub-area is for the most part based at KTH and Stockholm University and is led by Gunnar Björk, Professor of Photonics, KTH.

Quantum sensing

The quantum sensor sub-area uses individual particles, such as atoms and photons, to facilitate more sensitive detection than traditional measuring methods can achieve. The work will focus on developing quantum sensor technologies which are based on what are known as spin qubits or optomechanics. (Optomechanics is a combination of optics and nanomechanics.)
In addition, completely new avenues will be researched by, for example, using materials in which the speed of light can be increased or reduced for greater measurement sensitivity. An important element also involves shifting the unavoidable measurement uncertainty to a variable other than the one you want to measure.

In the longer term, it is expected that there will be highly sensitive sensors for use in fields such as medicine and that can be used to locate mineral deposits or warn about earthquakes or volcanic eruptions by extremely precise gravitational measurements.

The quantum sensor sub-area is led by Stefan Kröll, Professor of Atomic Physics, Lund University.