
Switzerland:
At the Quantum
Crossroads

Quantum Technology will…

… accelerate machine learning, material discovery, process optimization and improve our understanding of nature at the atomic scale.

… lead to a quantum enhanced internet.

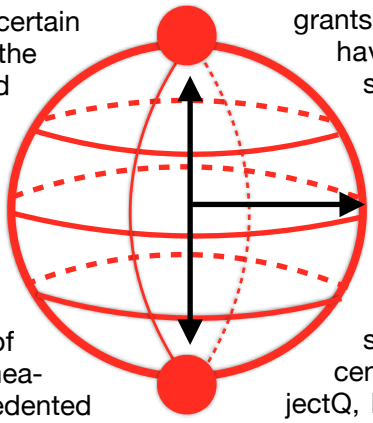
… enable detection of motion, light, gravity, electric and magnetic fields with an accuracy that surpasses conventional technologies.

… create an innovation chain for Swiss high tech companies exploring the limits of technology.

Quantum Technology Revolution

Quantum mechanics is probably the most successful theory to describe how nature behaves. Understanding quantum mechanics led to the inventions which underly much of modern technology, including transistors, lasers and fibre optics. Now, in the ongoing **second quantum revolution**, researchers and research organizations worldwide are striving to go a step further and **build systems with functionality rooted in the fundamental laws of quantum physics.**

Quantum technology promises ground-breaking improvements in computation, communication and sensing. For instance, a **quantum computer** would be able to perform certain tasks within minutes for which the fastest classical computer would require the lifetime of the universe. This is because of the fundamentally different nature of quantum information where in only 300 quantum bits (known as qubits) more numbers can be stored than there are atoms in the universe. **Quantum sensing** makes use of quantum mechanical systems to measure very weak signals with unprecedented accuracy only limited by quantum mechanics itself. **Quantum Communication** will allow the transmission of data with guaranteed encryption - a technology that is likely to lead to a more secure internet.



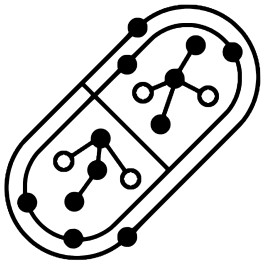
Internationally many countries have invested in quantum research initiatives (Australia, Austria, Canada, China, Denmark, Germany, Japan, Netherlands, UK, USA) with significant involvement of large enterprises (Google, IBM, Intel, Microsoft) and many smaller companies worldwide. The European Union recently announced 1 billion Euro of funding for a new Quantum Technology Flagship that will start in 2019.

Switzerland is very well positioned in the field of quantum technology. The Swiss National Science Foundation has supported quantum science and technology since the point when the field started to take off around the year 2000. A major boost came with the NCCR in Quantum Science & Technology (QSIT) in 2011. It has generated a successful collaborative and interdisciplinary research environment for more than 34 research groups working on different aspects of quantum science and technology, with a continuous world-class output. More than 30 young professors were recruited over the last 10 years and more than 30 highly prestigious ERC grants from the European research council have been obtained by Swiss researchers in this field.

Joint efforts between academic and industrial partners are required to realize the promises of the second quantum revolution. In Switzerland, quantum technology is key to the success of companies such as idQuantique and several recent startup companies (Qnami, ProjectQ, MicroRsystems, IRsweep) that were founded by quantum research teams. Other companies like Zurich Instruments or Specs Zurich are actively collaborating with researchers in this field to develop products needed to control quantum systems. At the IBM Zurich Research Lab, researchers collaborate with academic partners on the long-term goal of building a large scale universal quantum computer.

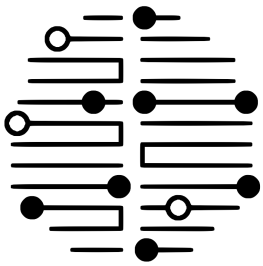
A Swiss strength is to be successful in a complex interdisciplinary field. Quantum technology will lead to significant market opportunities for Swiss companies, similar but complementary to the field of nanotechnology.

Quantum Research Topics in Switzerland



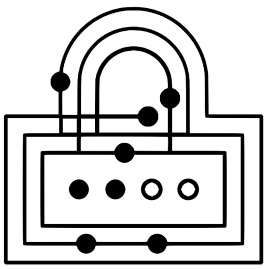
Quantum Computing & Simulation

Perform computational tasks that are intractable using classical computers.



Quantum Sensing & Imaging

Quantum systems obtain ultimate limits of measurement.



Quantum Communication

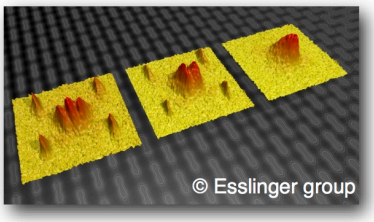
Transmission of information in an intrinsically secure way.

Quantum in Switzerland:

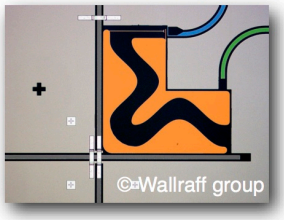
Quantum science and technology in Switzerland plays a unique role internationally. Swiss researchers lead in many qubit implementations as well as in pushing the frontiers of quantum computing and quantum cryptography. Switzerland is already investing in this field via the National Centre of Competence in Research "Quantum Science and Technology" NCCR QSIT which started its operation in 2011, and has a yearly budget from the Swiss National Science Foundation of about 5 Mio CHF. In addition, contributions to this endeavour by the involved institutions sum to more than twice this amount per year. Participating groups are located throughout Switzerland (ETHZ, EPFL, University of Basel, University of Geneva, University of Bern, Università della Svizzera Italiana and the IBM Research laboratory). Swiss research institutions such as PSI and CSEM and also IBM have developed unique expertise in areas relevant to quantum technologies. Smaller Swiss companies such as idQuantique, Specs Zurich and Zurich Instruments are already selling products in this field. Business opportunities in this area are expected to grow at a similar rate as the current Information and Communication Technology market.

NCCR QSIT and its quantum partners:

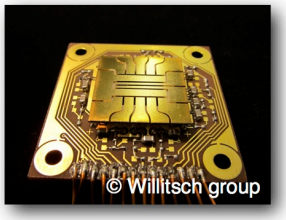
Quantum Simulation



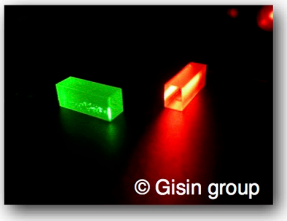
Superconducting Qubits



Ion Traps



Quantum Memory



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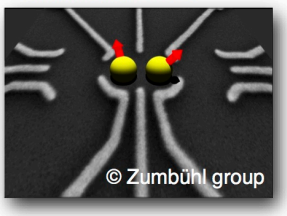
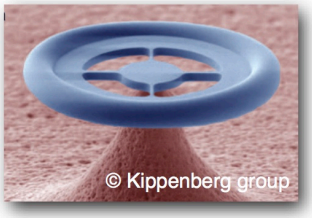
Quantum Dots



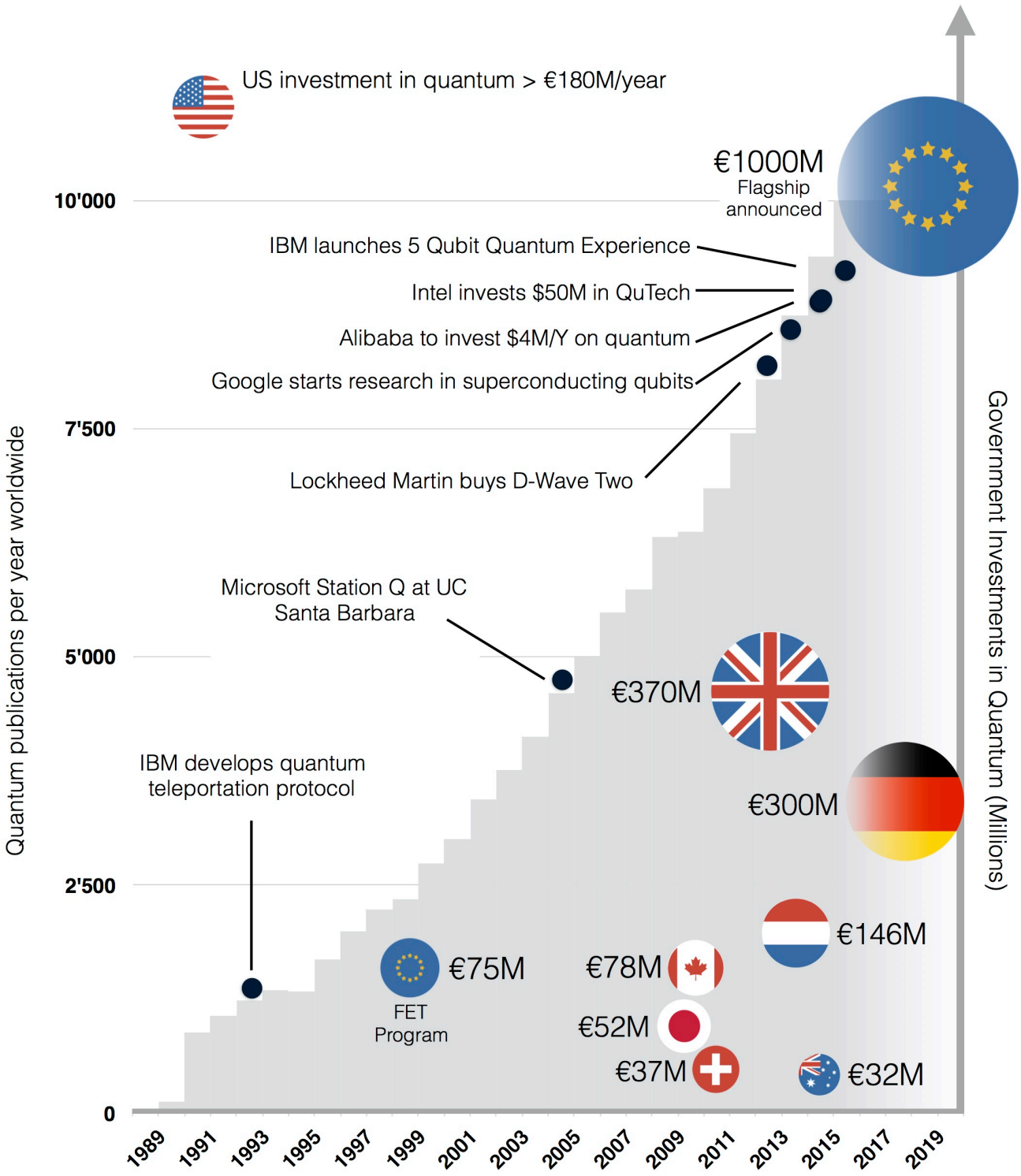
Quantum "Mechanics"



Quantum Computing in the Cloud

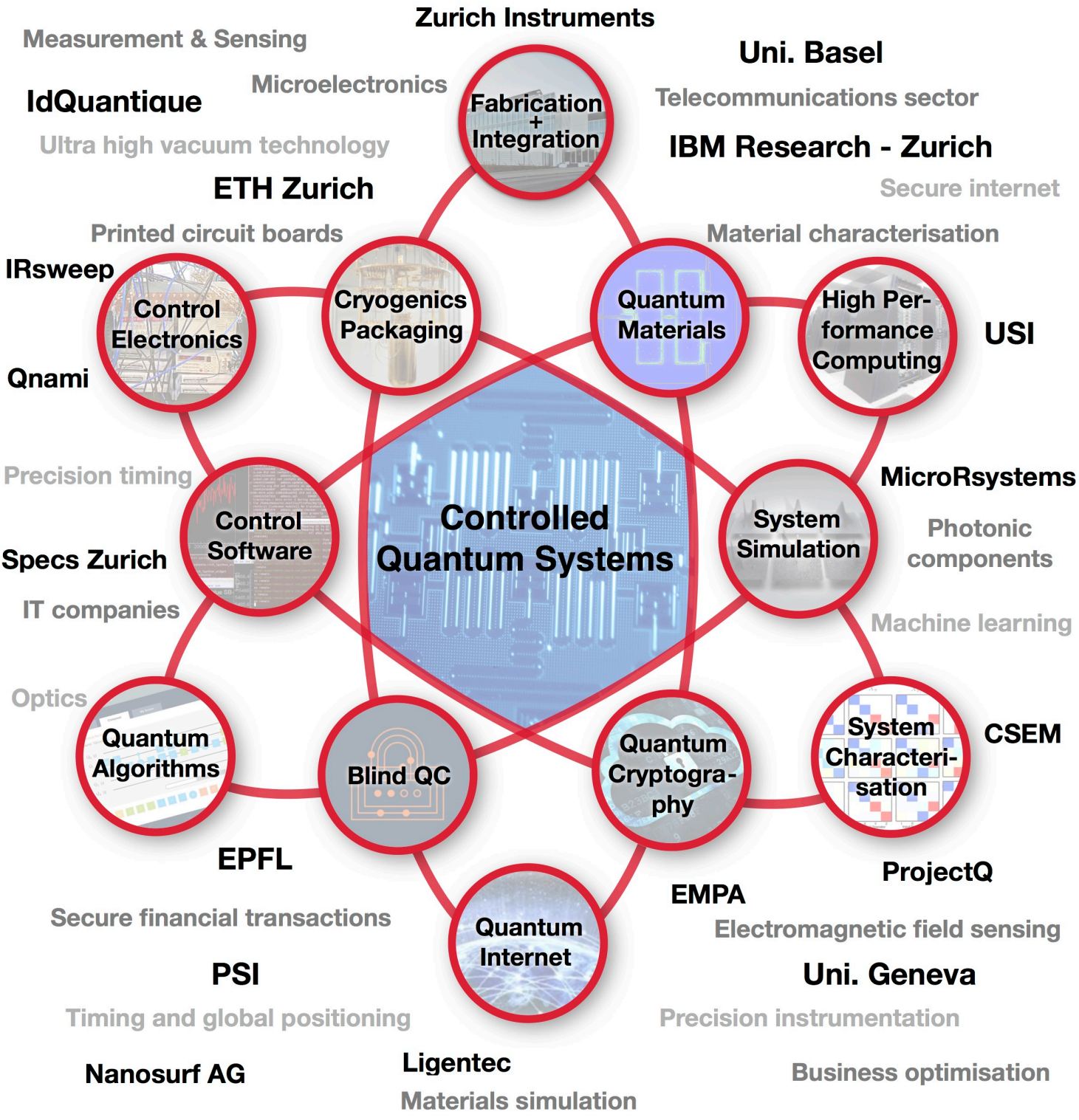
Public Private Partnerships in Quantum

The number of scientific publications worldwide in the field of quantum information technology has increased tremendously in the last decade. This growth in academic output (including contributions from IBM Research) has been matched by an upswell in industry investment which recently accelerated due to the entry of Google, Intel and Microsoft. In the quantum field, industry strongly collaborates with academic partners. As market opportunities become closer to reality, the pace and the quantity of the funding is increasing rapidly. In order for Swiss quantum efforts to stay at the leading edge of this new sector of technology, Switzerland must make a substantial investment, matching or surpassing that of other countries.



Quantum Ecosystem

The goal of building a useful quantum computer can only be reached in a concerted effort between academic and industrial partners. This requires a strong quantum ecosystem with a network of interactions that serve the common goal to create something unique. The strength of the industrial landscape in Switzerland relies on small and medium-sized companies that work in the high-tech environment needed for such an undertaking. In order to foster the transition from laboratory to market, advances are required in sophisticated classical control electronics and optics, including cryogenic amplifiers, low-noise multiplexed microwave and radio-frequency signalling and high efficiency optical networks. These will be the key technologies which underly quantum computers and communication devices at an industrial scale. Combining world-leading research with the specialist engineering present across all disciplines in Switzerland provides an ideal starting point for these endeavours.



Quantum Opportunity in Switzerland

Switzerland has a history in being at the forefront of technological developments, both in the form of scientific discoveries as well as in using technology for industrial leadership. Quantum technology is a fast-developing field which plays to many Swiss strengths. Research in quantum science and technology will continue to strive for excellence and international leadership. It is essential to strengthen the efforts in developing real-world quantum applications through close collaboration with industry, creation of start-up companies and education of future quantum engineers. Swiss policymakers need to support a quantum ecosystem that is attractive for all the stakeholders involved.

We are at a crossroads for quantum technology.

Now is the time to invest!

"Wenn wir wollen, dass hier investiert wird und hier die Arbeitsplätze gesichert werden: Dann dürfen wir nie selbstgefällig werden. Sondern wir müssen unseren Trümpfen Sorge tragen."

Federal Councillor Johann N. Schneider-Ammann

quantum marketplace

Job creation in a new industrial wave

Develop awareness of quantum opportunities

E.g. advantages of secure quantum cryptography for banking.

quantum innovation

Ensure Swiss quantum leadership leads to industrial outcomes

Create a start-up friendly quantum ecosystem

Establish "Paper to patent" path for young Swiss entrepreneurs

quantum expertise

Retain and strengthen Swiss leadership in research and education

Guarantee a continued stream of experts for the quantum technology ecosystem

Attract top talent

"Already, about 7,000 researchers around the world are working in the field of quantum computing. Annual research spending is on the order of $1.7 billion."

European Commission Workshop
May 6, 2015

"... it seems that the laws of physics present no barriers to reducing the size of computers until bits are the size of atoms and quantum behavior holds dominant sway."

Richard Feynman
Optics News,
***11**, 11 (1985)*

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