ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

DECEMBER 2014 ISSUE

PRESIDENT'S SELECTION

The Newsletter from the ETH Zurich President

www.ethz.ch

QUANTUM ENGINEERING

In the workshop of the future

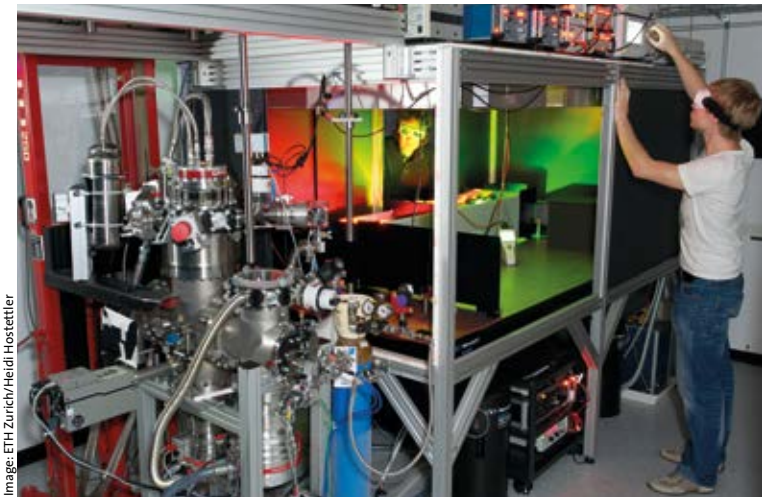

Image: ETH Zurich/Heidi Hostettler

Nano world experiments call for very low temperatures and elaborate electronic instrumentation: View into professor Andreas Wallraff's laboratory

Simple quantum computers already exist. The involvement of engineers is now needed in order to build more powerful quantum computers and realise the dream of the computer of the future.

"Quantum technology is coming. That much is clear." Klaus Ensslin, professor of physics at ETH Zurich leaves no room for doubt here. His colleagues Lukas Novotny and Andreas Wallraff also talk of "a technical necessity". How can they be so sure? Today's electronics are becoming ever smaller, faster and cheaper. Larger and larger quantities of data can be stored and processed in an ever-smaller space. Computer chips, for example, now operate in the nanometre range, on the scale of millionths of a millimetre. This minuscule world is already relatively well-researched. However, engineers are increasingly coming up against limiting factors. The technology must therefore go one level deeper, into the world of the extremely small: the quantum world. Here, the classic laws of physics no longer apply: a body can, for example, exist at two locations simultaneously.

New tools are needed to be able to investigate this world. Conventional hammers and screwdrivers will not get you very far here. Moreover, very low temperatures are also required. Ensslin's team, which researches novel semiconductor structures, achieves this using a special refrigerator, whose temperatures almost reach absolute zero. Furthermore, the experiments call for elaborate electronic instrumentation and components, which cannot simply be bought in a supermarket. "We have to put a lot of it together ourselves," says Ensslin. Another key requirement, however, is teamwork. Collaboration between physicists, mathematicians and engineers is needed in order to achieve the ultimate aim of driving forward quantum technology.

ETH Zurich and indeed Switzerland as a whole offer an exceptional body of research groups, investigating a wide range of quantum systems. The country boasts an internationally renowned research group in almost every specialist area of quantum physics. "Switzerland invests heavily in this area, including within the framework of the QSIT National Centre of Competence in Research. But it is important that we do so, because the competition never sleeps," says Ensslin. Singapore, the Netherlands, the US – they have all provided hundreds of millions in funding for research into this new world. In addition, large companies such as IBM and Google are also investing heavily in this direction.

> "To build more powerful quantum computers a greater involvement of engineers is needed"
> Professor Andreas Wallraff

But in which direction exactly? What products will the workshop of the future make? Many dream of a quantum computer that would be streets ahead of today's computers. This is a topic of research for the team of Andreas Wallraff, a professor of physics at ETH Zurich. He develops superconducting electrical circuits – the future

Continued on page 2

EDITORIAL

At the forefront

Dear readers,

Zurich is one of the hotbeds of quantum mechanics. Albert Einstein, Walter Heitler, Erwin Schrödinger and Wolfgang Pauli: they all taught and researched here at ETH Zurich and the university over a century ago. Today, the theory is widely proven, and it is used in applications in the processing and transmission of data. However, it is still far from realising its full potential. Quantum sensors with ultimate sensitivity, quantum cryptography and quantum computers are still in their infancy. ETH Zurich is at the forefront of all of these fields – with researchers in the departments of Physics, Information Technology and Electrical Engineering, Mechanical and Process Engineering and Computer Science. ETH Zurich operates the Binnig and Rohrer Nanotechnology Center in Rüschlikon in collaboration with IBM's research centre and is open to further partnerships. It will be interesting to see what the future will bring.

R. Eichler

Prof. Ralph Eichler,
President of ETH Zurich

THE QUOTE

"Quantum physics is revolutionising the encryption of data"

Professor Renato Renner,
Institute for Theoretical Physics, ETH Zurich

IN THE WORKSHOP OF THE FUTURE

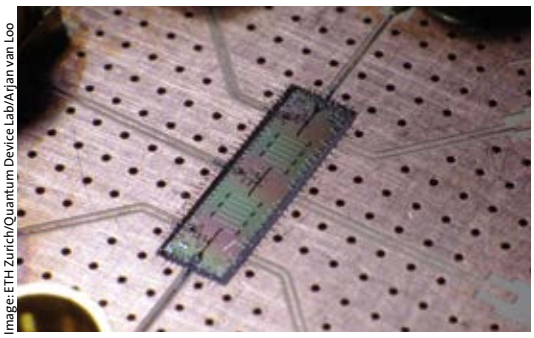

Image: ETH Zurich/Quantum Device Lab/Arjan van Loo

Ever-smaller computer chips: Superconducting electrical circuits are the future building blocks of quantum computers

Continued from page 1

building blocks of quantum computers. These elements can be used for the storage, processing and retrieval of information. “Simple quantum computers already exist,” says Wallraff. However, they are still inferior to the conventional computer. “Building bigger quantum computers will require greater involvement of engineers.” A corresponding centre is to be established at ETH Zurich in order to master these technological challenges.

But is this just about quantum computers? “In my view, there are many other areas that could benefit from quantum technology,” says Ensslin. Similarly, when the first transistor was developed more than 50 years ago, no one could have imagined that this tiny component would one day pave the way for the computer. Ultimately, it might turn out the same way as at CERN, where hundreds of researchers were looking for the Higgs boson and, in the process, invented the internet. “Applications tend to develop in a direction that no one predicted,” says Ensslin. For example,

> “Applications often tend to develop in a direction that no one predicted”
> Professor Klaus Ensslin

Andreas Wallraff and his team are also researching a quantum amplifier with noise suppression that is 100 times better than that of conventional amplifiers. These novel amplifiers could be used in a wide range of applications. Where exactly they will be used, however, is barely possible to say: mobile telephony, radar, radio telescopes?

In any event, we are not at that stage yet. At the moment, quantum researchers are primarily grappling with technical challenges, with achieving sufficiently low temperatures, and with the complexity of the quantum systems. In future, the aim will be to realise and control not just individual quantum systems, but rather a large number of interconnected systems, with a view to potentially finding completely new states of matter.

INTERVIEW

Glass beads in the nano world

Professor Novotny, with your experiments, you're attempting to reach into the quantum world, into the world of the extremely small. How are you going about this?

We want to cool down a glass bead to such an extent that quantum mechanics comes into play. An analogy helps here: the glass bead is like a snowboarder moving back and forth in a half-pipe. If there were no friction, he would sway from side to side indefinitely. So, we now try to progressively restrict the snowboarder’s movement, by delivering a counterimpulse at the right point in time. The oscillation becomes smaller and smaller. In this way, we can reduce the temperature substantially, almost down to absolute zero. Then, the snowboarder – i.e. the glass bead – is no longer subject to the laws of the macroscopic world, which we can see with the naked eye, but rather to the laws of quantum mechanics.

Lukas Novotny, professor of photonics at the Department of Information Technology and Electrical Engineering

What does that mean?

For example, it means that the bead can be present at two locations at the same time. Only by taking a measurement it materializes at an exact location. It would be the first time that a visible body reacted in this way. I hope that we'll be able to reach the low temperature we need for this in five years’ time. There are still some technical barriers to overcome.

What could one deduce from an experiment of this kind?

For example, we could investigate how the transition from the macroscopic world to the quantum world works. Then, it would also be possible to use a system of this kind to store information. Should the need arise, this would constitute a key piece in the puzzle of constructing a quantum computer.

What fascinates you about the nano world?

It is an intermediate world, between the macroscopic and atomic worlds, that was still relatively unresearched 20 years ago. Today, many exciting questions remain to be answered in relation to the laws governing this world. And there's a technical need for research in this area, as development is increasingly targeting the nano world, and things are being scaled down – just think of today’s computer chips. Nowadays they operate on the nano scale. To develop them further, we must advance deeper into this area.

IN BRIEF

A platform for quantum technology

The QSIT National Centre of Competence in Research brings together the Swiss laboratories of quantum technology and, in this way, seeks to research and develop new methods and components based on the laws of quantum mechanics. A total of 32 research groups work at QSIT with different experimental approaches but with a common goal: to drive quantum technology forwards. ETH Zurich and the University of Basel play a leading role here, with additional participation by the University of Geneva, the University of Lugano, the IBM Research Laboratory in Rüschlikon and EPF Lausanne. The programme was launched in 2011 and is financed with an annual budget of approximately CHF 4.5 million by the Swiss National Science Foundation.

Quantum leaps thanks to partnerships

ETH Zurich is already well-established in the field of quantum science. The time is ripe to expand quantum engineering into its own centre. ETH Zurich is currently taking a first step with the establishment of a professorship in this field. Partnerships with industry could provide additional momentum.

FINAL POINT

Image: ETH Zurich

Beaming people up as they do in Star Trek will presumably remain pure fantasy. Nevertheless, it is inspiring quantum physicists to create new technologies.

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