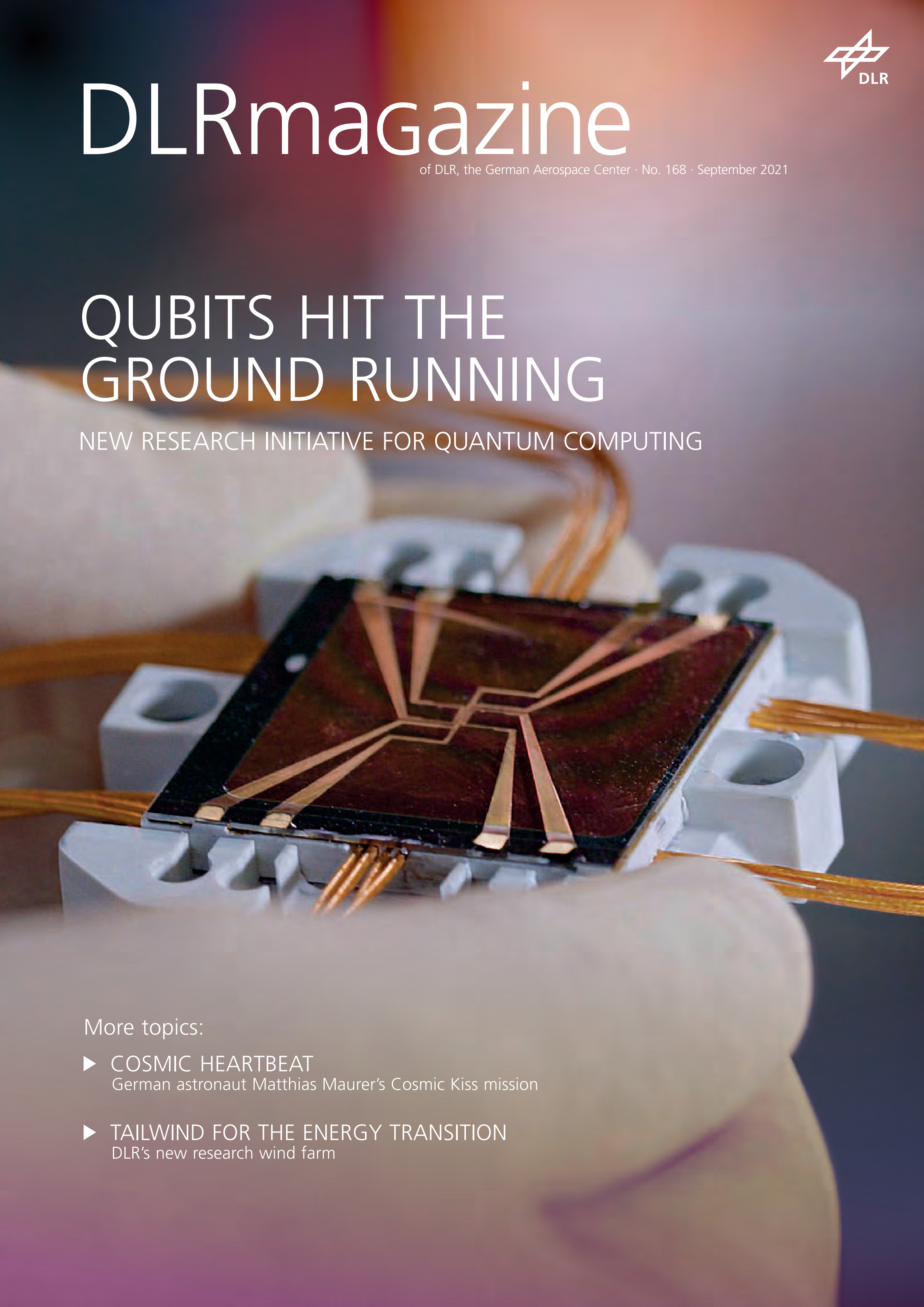

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QUBITS HIT THE GROUND RUNNING

NEW RESEARCH INITIATIVE FOR QUANTUM COMPUTING

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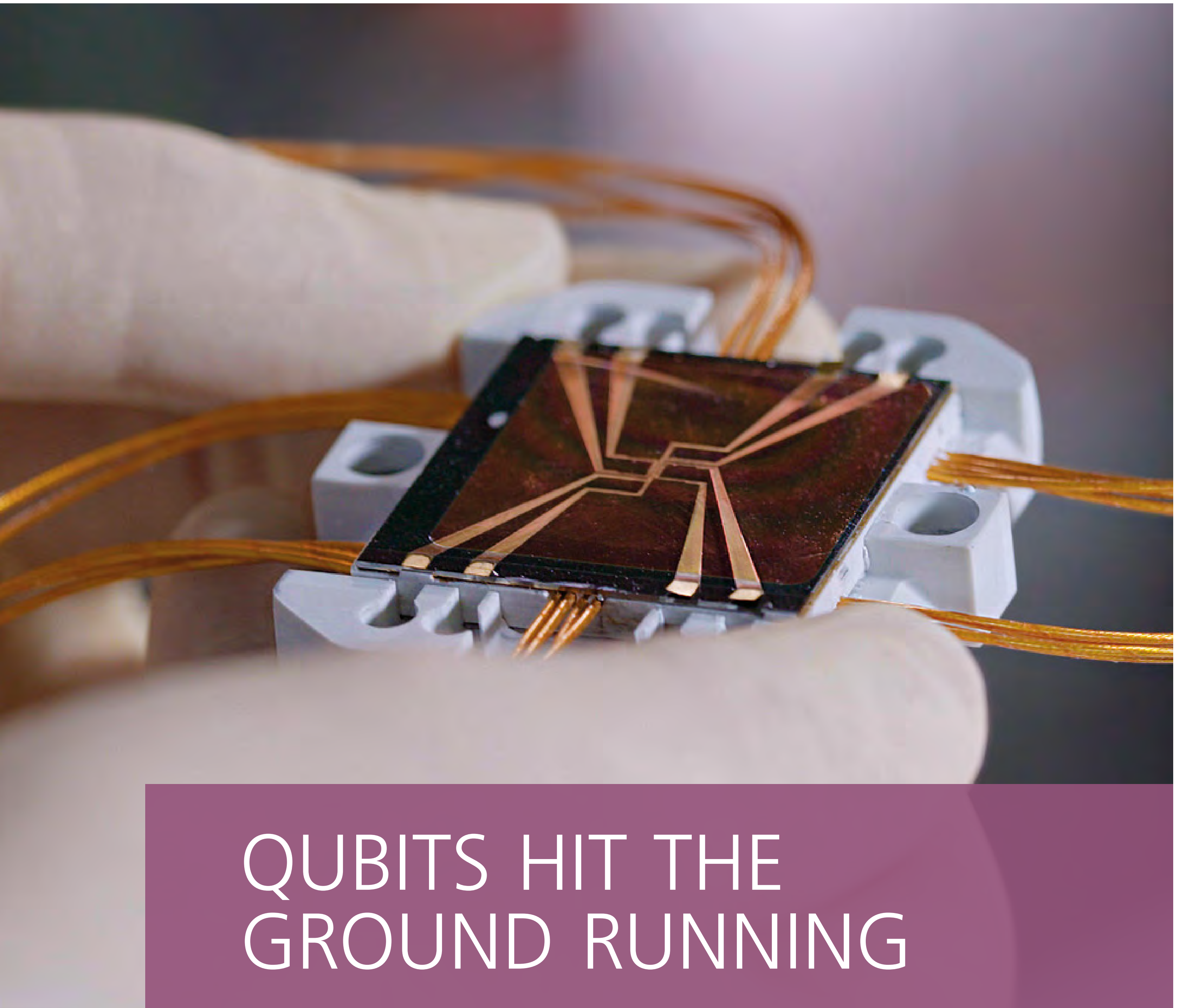

QUBITS HIT THE GROUND RUNNING

A new research initiative supports quantum computing 'made in Germany'

By Tim Suckau

Today's most cutting-edge high-performance computers still operate based on the ones and zeroes of conventional digital 'bits', but this might not be the case for much longer. DLR is leading an initiative to develop a prototype quantum computer in Germany based on quantum bits (qubits) that, in addition to being a revolutionary technological leap, will open up new opportunities for industry, science and society. This is the goal of a recent decision by the German Federal Government, which approved a total of two billion euros in funding to promote quantum technology in Germany. DLR will receive 740 million euros of this for the purpose of establishing the necessary scientific and industrial framework, together with partners from industry, start-ups and research groups, as part of the DLR Quantum Computing Initiative.

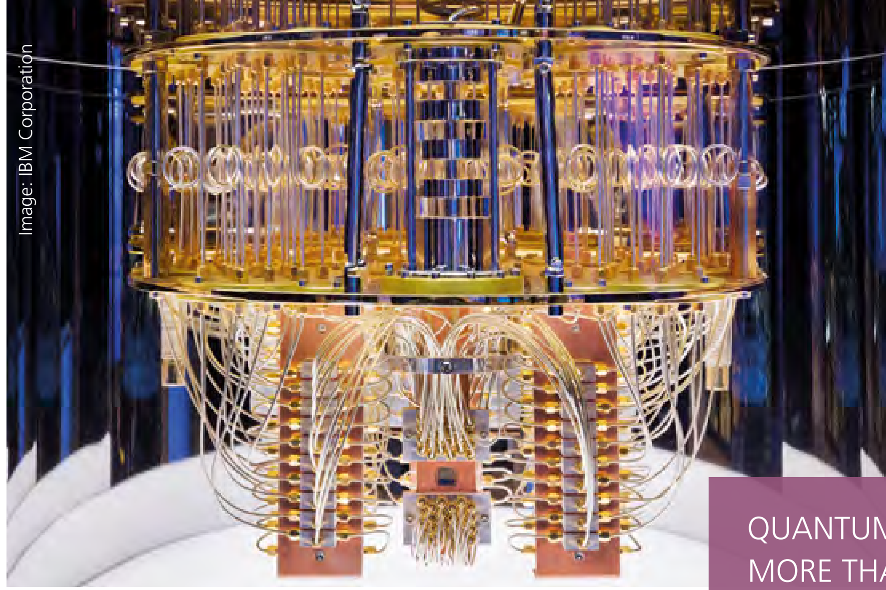

Image: IBM Corporation

The 27 qubits of the IBM Q System One are the heart of the quantum computer at the Fraunhofer Competence Center 'Quantum Computing Baden-Württemberg' in Ehningen near Stuttgart. DLR uses the quantum computer to simulate atomic processes in batteries in order to increase their performance and energy density.

QUANTUM COMPUTERS – MORE THAN 0s AND 1s

A quantum computer works differently from a normal computer. Its quantum bits, or qubits for short, obey the laws of quantum physics. This describes the phenomena taking place on the atomic scale. The bits of a conventional computer can have only two states – 0 and 1. Qubits, by contrast, can take on an infinite number of intermediate values. Quantum physics also enables novel algorithms that are not possible with conventional computers. Quantum computers are thus able to solve problems which traditional computers cannot. Quantum physical objects, such as electrons, atoms, ions or photons, serve as qubits. Quantum computers will enable entirely new, hitherto unimaginable information processing techniques for research, science and industry.

Quantum computing dates back to the 1980s. In 1982, the US-American physicist Richard P. Feynman proposed a theoretical concept for quantum computers, with the aim of making it possible to accurately simulate and study quantum physical phenomena. The first quantum algorithms were developed in the 1980s and the first laboratory quantum computers with a few qubits were built in the 1990s. Today, the international race for the development and construction of quantum computers is well under way. Major US corporations have already demonstrated experimental quantum computers, which are being used by research institutions such as the Fraunhofer Society and DLR.

The fast-paced world of qubits

The new quantum computers are expected to deliver unprecedented computing power, opening up new economic and social opportunities and increasing Germany's international competitiveness. Quantum computers offer advantages for data and information processing, interception-proof cryptography techniques, artificial intelligence, materials research, medicine, the energy and transport sectors, and satellite-based communications and navigation. German businesses and industry therefore have a strong interest in the development of these technologies, solutions and applications in Germany, as this would ensure that the usage and patent rights also remain in the country.

This new technology is simply unbeatable in highly complex calculations. A quantum computer would be able to quickly solve problems that could take conventional high-performance computers years. The ability to precisely simulate highly complex quantum systems with a large number of interacting atoms, ions and electrons is particularly exciting. Such systems include the active ingredient molecules in medications or the quantum chemical processes occurring in battery electrodes or fuel cells. The aim would be to draw conclusions about macroscopic characteristics from the quantum mechanical processes taking place at the atomic scale. Among other things, it is hoped that this will accelerate the future development of new medications or high-tech materials. Quantum computers thus have enormous potential to facilitate innovations in many fields from fundamental research to industrial applications.

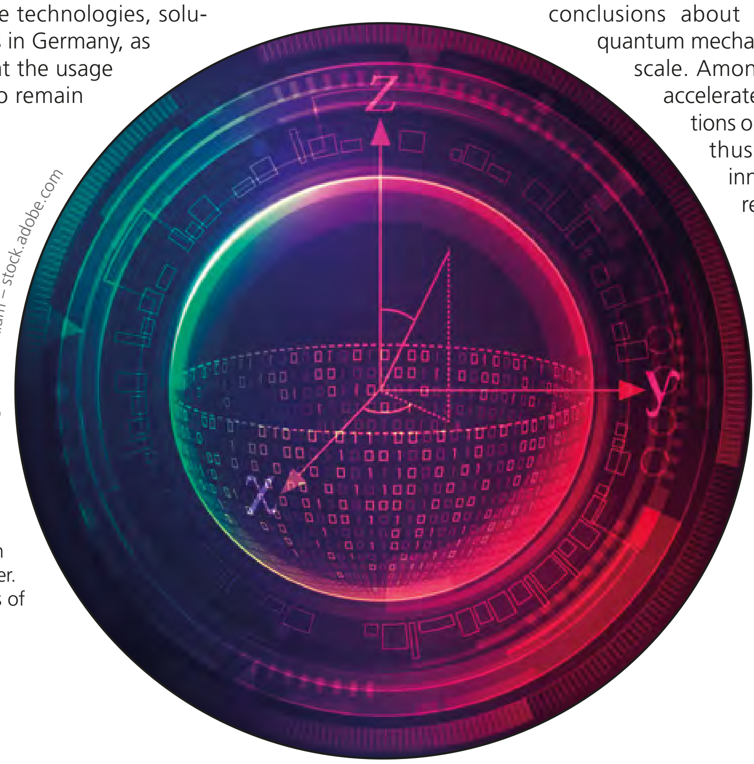

Image: Jackie Niam – stock.adobe.com

Qubits are the smallest computing and information unit of a quantum computer. They are based on the laws of quantum physics.

READY FOR A QUANTUM LEAP

Three questions for Anke Kaysser-Pyzalla, Chair of the DLR Executive Board

What potential does quantum computing offer industry, science and society?

: In modern society, we are exposed to a vast and heterogeneous flood of data. Its effective processing requires enormous computing power. Quantum computing will enable us to better adapt to this situation. This technology has the potential to revolutionise computing by significantly accelerating the solution of complex problems that are often impossible to address using conventional computers.

What is DLR's role?

: DLR will draw on its experience of managing large-scale projects by leading the Quantum Computing Initiative. This involves using the funds made available by the German Federal Ministry for Economic Affairs and Energy (BMWi) to finance projects conducted by industry, start-ups and research groups, and driving forward the ongoing development of quantum computers in a coordinated manner. This will involve the development of quantum hardware, software and, of course, the applications themselves. Only within the framework of such networking and with strategic coordination will we jointly achieve the goal of developing and testing the first German quantum computer prototypes.

What priorities will DLR set in order to establish the necessary economic and research environment?

: We are focusing on pursuing a range of technological approaches in order to be able to evaluate them and use them for the relevant applications. Only in this way is it possible to explore the advantages and disadvantages of different architectures for quantum computers. To this end, we will create the necessary ecosystem to facilitate cooperation between partners. Researchers, industry and start-ups can complement each other's skills by sharing their expertise. As a result, Germany will build up extensive knowledge in the field of quantum computing and achieve the greatest possible level of independence.

… and for Robert Axmann, Head of the Space Research and Technology Programme Strategy Department at DLR

Which quantum computing applications are DLR institutes and facilities researching today?

: In recent years, DLR has significantly expanded its expertise and infrastructure in the area of quantum computing. In addition to several newly founded institutes and facilities, this topic is also the subject of research for many of our well-established institutes (see info box for list of institutes), which are primarily concerned with the use of quantum computers to improve and accelerate modelling, simulation and optimisation. Our Institute for Software Technology, which has been researching algorithms and software for early quantum computers since 2015, is set to play a pioneering role, as is the Institute of Communications and Navigation. However, DLR's resources alone are not sufficient for the comprehensive implementation of quantum computing. This can now be achieved through a collaborative effort as part of the Initiative.

The DLR Quantum Computing Initiative is expected to run for four years. What are the main objectives during this period?

: The Initiative pools our resources and areas of expertise in order to develop various quantum computer prototypes and their components, including applications for scientific, industrial and security-related issues within the designated period. Market analysis by DLR has shown that hardware, software, applications and the necessary supply chains must all be considered.

How can interested companies, start-ups and research partners get involved?

: Based on its market survey, DLR will issue invitations to tender; potential partners can respond to these with their proposed projects. Our first task will be to evaluate the submitted proposals. We will then bring partners from industry and start-ups together with the research institutions in cases where their approaches and areas of focus complement one another. As a rule, the partners will be involved by the commissioning of research and development services, the purchasing of existing research results or joint research at innovation centres in return for a fee.

INSTITUTES AND FACILITIES INVOLVED IN QUANTUM RESEARCH

- DLR Institute of Quantum Technologies
- DLR Institute of Satellite Geodesy and Inertial Sensing
- DLR Institute for Software Technology
- DLR Institute of Engineering Thermodynamics
- DLR Space Operations and Astronaut Training
- DLR Institute of Materials Research
- DLR Institute of Communications and Navigation
- DLR Institute of Data Science
- DLR Institute of Optical Sensor Systems
- Galileo Competence Center
- Institute of AI Safety and Security

Quantum technologies at DLR

In the DLR Quantum Computing Initiative, research institutes, industry and start-ups will work together to develop quantum hardware, software and applications. DLR is contributing its wide-ranging expertise in quantum research, with almost a dozen institutes and facilities conducting research in the field of quantum technologies. The Institute of Quantum Technologies in Ulm and the Institute for Satellite Geodesy and Inertial Sensing in Hanover have recently been established. Among other things, they are working on the use of quantum sensors on board the International Space Station (ISS). At the Galileo Competence Center, research is being carried out on high-precision optical clocks for satellite-based navigation.

Until a German quantum computer is built, the DLR Quantum Computing Initiative will also implement hybrid systems. In this way, conventional high-performance computers can incorporate individual components of quantum computers in order to be able to use the enormous potential of quantum computing for research.

Tim Suckau is an editor in DLR's Communications department.

Quantum metrology enables time measurements of unprecedented accuracy – for much more precise navigation systems, among other things.

Quantum cryptography can be used to encode data in an interception-proof manner. Among other things, DLR is researching optical communication systems for small satellites, as here with PIXL-1.

Quantum technologies in space – but also for use on Earth. In the Bose-Einstein Condensate and Cold Atom Laboratory (BECCAL) project, DLR is working with NASA to investigate ultracold quantum gases such as Bose-Einstein condensates on Earth and in microgravity on the International Space Station (ISS).

More information –
DLR dossier: Quantum Computing

s.dlr.de/ZhEYH

Cover image

A chip can be the heart of a quantum computer. Atoms or ions can be separately trapped on it. These can serve as information carriers, so-called qubits or quantum bits. Quantum computers have the potential to solve problems that would push today's computers beyond their limits. Within the next four years, DLR, together with partners from industry, small and medium-sized enterprises, start-ups and science, will establish two consortia to create the framework for a German quantum computer as well as develop the corresponding software and identify quantum-specific applications.

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