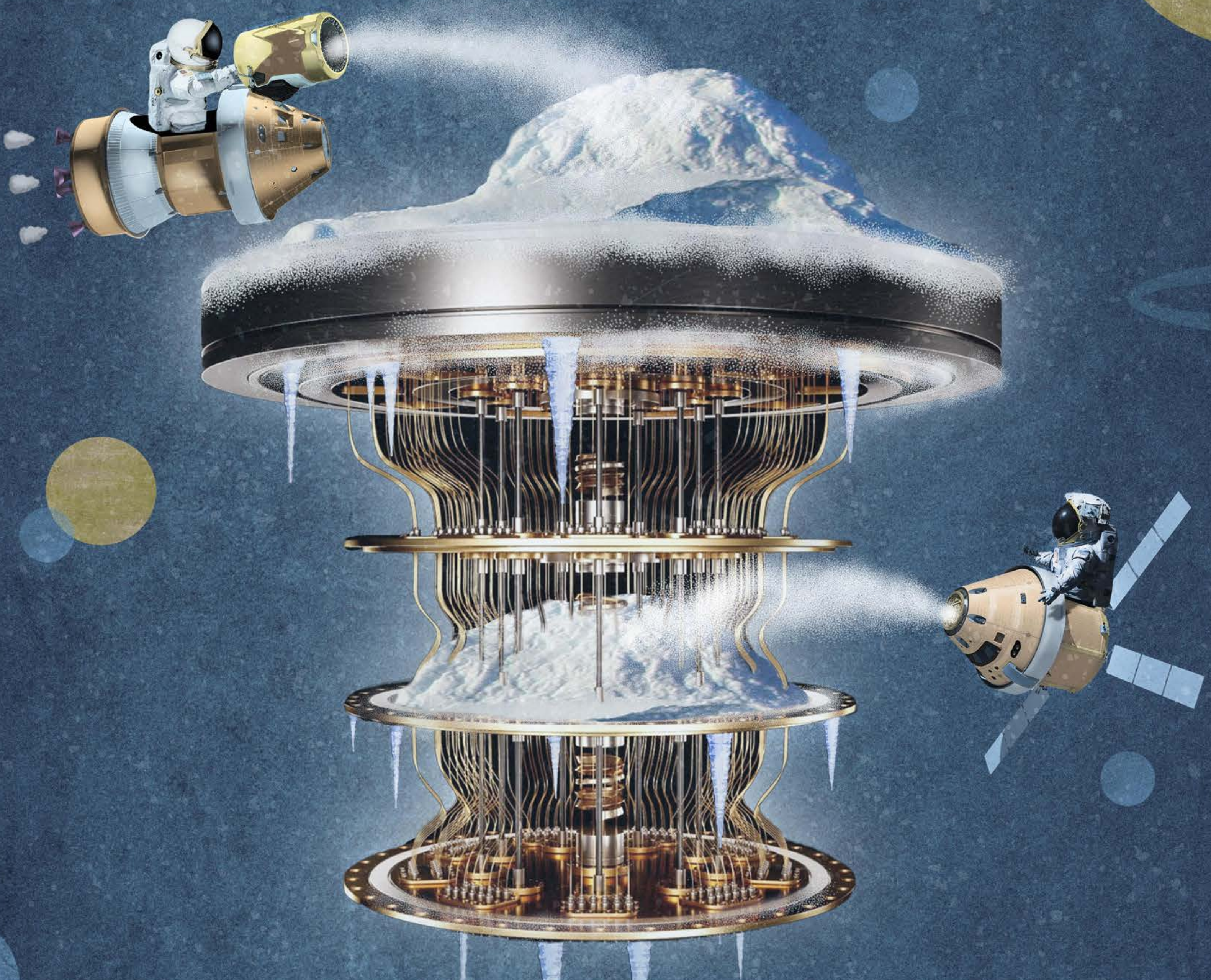
effzett

FORSCHUNGSZENTRUM JÜLICH'S MAGAZINE

1-22



Icy machines

It is colder in quantum computers than in space.
Electronic systems are now being developed for these extreme conditions.

LIKE THE BRAIN
Our thinking organ
as a model for computers

LIKE IN REAL LIFE
Large-scale experiment
simulates crowding in stations

LIKE A SKIN
New material
to improve wearables

↑

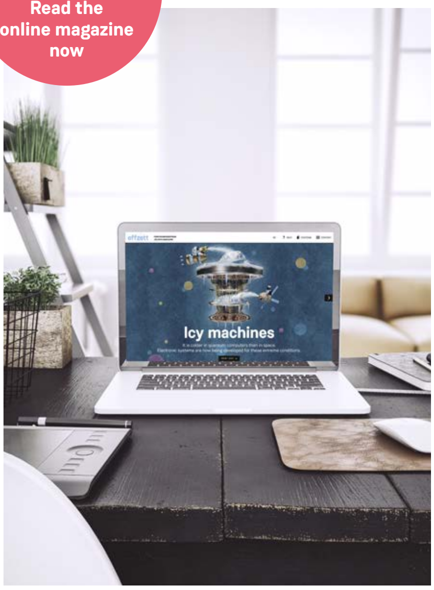
Green electricity and innovative agriculture

Something like this could be found more often on farmland in the future. It is not a shelter for livestock, but an agricultural/horticultural photovoltaic installation, allowing a twofold use of space: the roof made of solar modules generates electricity while crops grow underneath. The roof protects more sensitive plants from heat and hail. With additional technology, growth and water consumption can be controlled as well. “We are still in the test phase, but the initial lessons learned have been very positive,” says project leader Dr. Matthias Meier-Grüll from the Jülich Institute of Bio- and Geosciences (IBG-2). The plant is part of the structural change initiative BioökonomieREVIER.

More on crop production and photovoltaics (in German): go.fzj.de/agri-horti-pv

Can’t get any colder!

There’s even more!
Read the online magazine now



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It was an extreme winter. In 1929, a cold spell that lasted for weeks turned rivers and lakes in Europe into ice. In February, the thermometer in Wolnzach in Upper Bavaria dropped to minus 37.8 degrees Celsius – a cold record for Germany, according to the German Weather Service. The record low temperature on Earth, measured in 2013 by a NASA satellite on a plateau in East Antarctica, is significantly colder, namely minus 93 degrees Celsius. This is so icy that it makes human life practically impossible. Yet, it is still far from absolute zero in terms of temperature: this is minus 273.15 degrees Celsius or 0 degrees Kelvin. At this temperature, even the atoms themselves stop moving. The comfortable temperature for many qubits, the computing units of quantum computers, is just above absolute zero. For these extreme conditions, Jülich researchers are developing so-called cryo-electronic technology that controls the qubits. Our cover story tells why and how they do this.

Our other articles also show why special conditions often require special solutions: they deal with neuromorphic computers that compute much like our brains; pedestrian experiments that help make railway stations safer; and new materials for wearables – small networked computers that are tucked into clothing or worn on the body.

We hope you enjoy taking a look at our research
Your effzett editorial team

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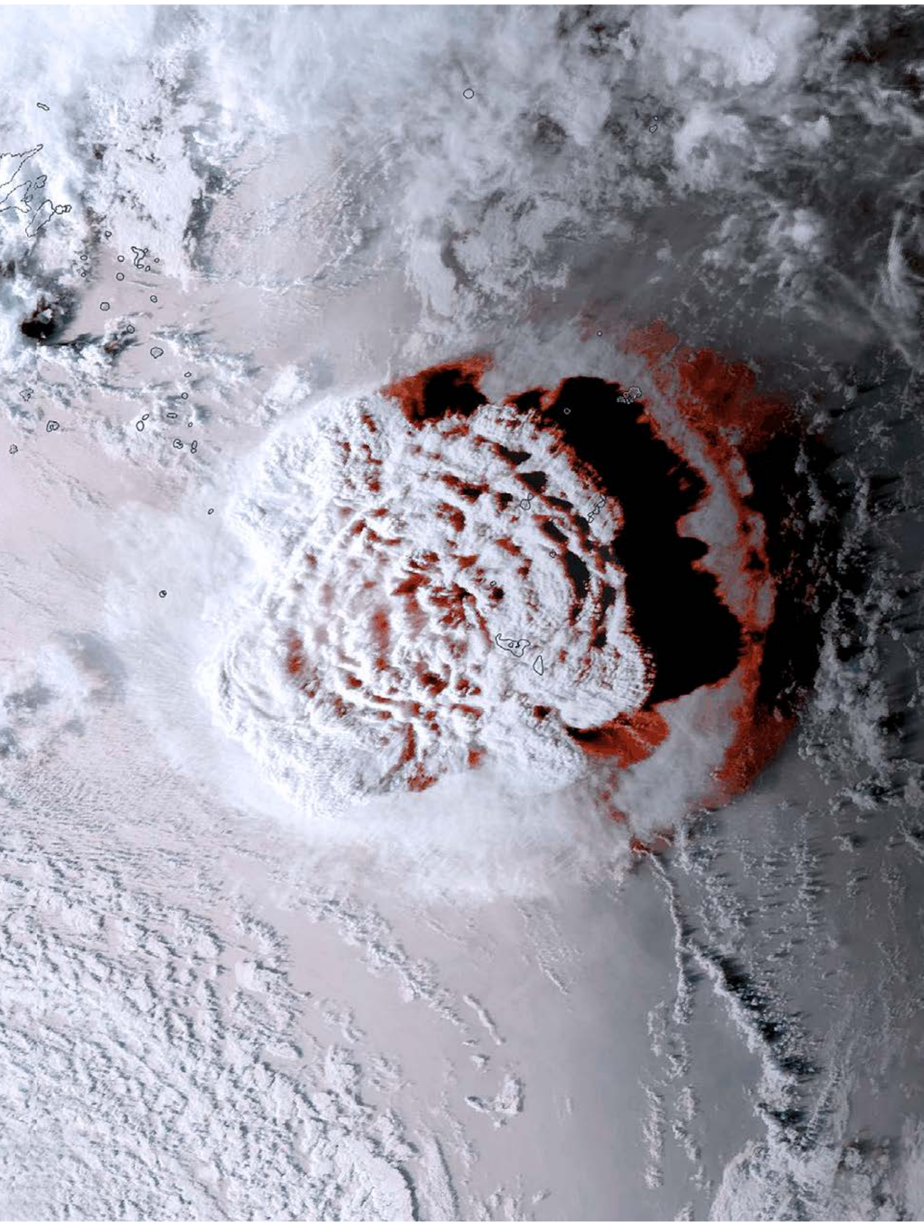


ATMOSPHERIC RESEARCH

Volcanic eruption making waves

On 15 January 2022, the underwater volcano Hunga Tonga-Hunga Ha'apai erupted in the South Pacific. It was the strongest explosive eruption in around 140 years, triggering a tsunami and causing severe damage in the island nation of Tonga. The outbreak also had an unexpected effect: in addition to the typical shock waves close to the ground, air oscillations were generated in higher layers of the atmosphere. The analysis of satellite data with the Jülich supercomputer JUWELS revealed this. These so-called gravity waves influence the climate and the weather. The data will now be used to test whether climate and weather models correctly describe the formation and propagation of such gravity waves.

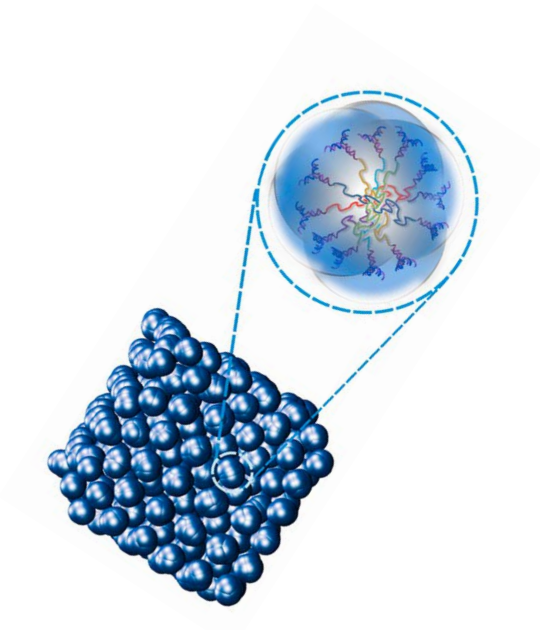
– JÜLICH SUPERCOMPUTING CENTRE –

MATERIALS RESEARCH

A new state of matter

Provided they attract each other, several matter particles can join to form a larger unit, a cluster. Under certain conditions, however, even repulsive particles could form clusters – or so rearchers theoretically predicted some 20 years ago. A team from Jülich, Vienna and Siegen has now made this condition a reality for the first time. Like crystalline solids, the cluster crystal has a regular, lattice-like structure in which particles have a fixed place. What makes this special: in the new crystal, these lattice places are occupied by clusters consisting of several purely repulsive particles.

– INSTITUTE OF BIOLOGICAL INFORMATION PROCESSING –



“Greenhouse gas neutrality by 2045 is possible, both technically and economically.”

PROF. DETLEF STOLTEN

An analysis by Jülich scientists shows how Germany can achieve a greenhouse gas-neutral energy supply.

More on this topic: go.fzj.de/greenhouse-gas-neutrality

INFORMATION TECHNOLOGY

Double quantum boost

Research into quantum technologies continues to be expanded. In the new QSolid project, coordinated by Forschungszentrum Jülich, a German quantum computer is being created. It is to be based on superconducting qubits that have a low error rate. The Federal Ministry of Education and Research and the industry are supporting the project with a total of €76.3 million.

The federal state of North Rhine-Westphalia is concentrating quantum technology research in the new network “EIN Quantum NRW” – EIN (German for “one”) standing for Education, Innovation and Networking. The network aims to bring together universities, non-university research institutions and the business community. Up to €20 million will be available for this purpose over the next five years. Jülich will be a strong driver of networking and cooperation.

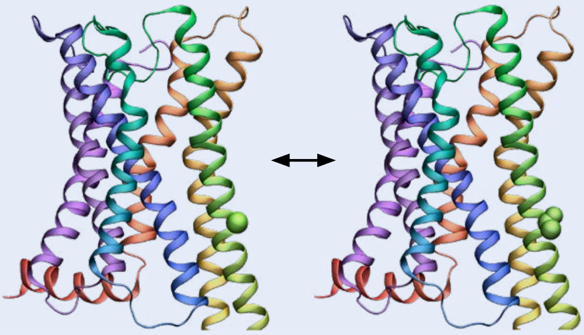
– PETER GRÜNBERG INSTITUTE/JÜLICH SUPERCOMPUTING CENTRE/CENTRAL INSTITUTE OF ENGINEERING, ELECTRONICS AND ANALYTICS, ELECTRONIC SYSTEMS –

BRAIN RESEARCH

Small variation with big consequences

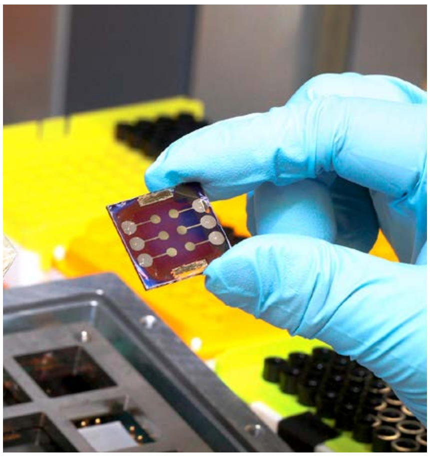
The hormone oxytocin influences our social behaviour and fosters trust and empathy. Released in the brain, it triggers a chain of reactions in nerve cells. Mutations in the receptor of this “cuddle hormone” have long been associated with autism. A study by researchers from Regensburg and Jülich is the first to show in detail how even a small genetic variation of the receptor changes the effect of the hormone at the molecular and cellular level. In the long term, their results could lead to new therapies to treat patients with this mutation.

– INSTITUTE FOR ADVANCED SIMULATION AND INSTITUTE OF NEUROSCIENCE AND MEDICINE –



Oxytocin receptor

A218T oxytocin receptor variant



1,450

operating hours

without any significant loss in performance – this is how long a perovskite solar cell, developed by Jülich scientists, lasted for the first time. Perovskites are a class of materials with a special crystal structure that can also consist of organic and inorganic materials. They are considered promising candidates for the solar modules of the future because production of such modules is easy, cost-effective and energy-saving. Their big disadvantage so far had been their very rapidly declining performance.

– HELMHOLTZ-INSTITUTE ERLANGEN-NÜRNBERG FOR RENEWABLE ENERGY –

NEUTRON RESEARCH

Controlling pipelines with neutrons

Blockages in oil pipelines can have devastating consequences for supply. It is all the more important to find them quickly. However, common methods, such as thermal imaging cameras or gamma rays, do not work for pipelines under water. A research team with Jülich participation has found a new approach: neutrons. They can be used to measure the hydrogen concentration even through the pipe walls. This reveals whether there is oil, gas or hydrates in the pipe, the latter often being responsible for blockages. In the future, a mobile detector with a small neutron source could travel back and forth along the pipeline to measure the concentration.

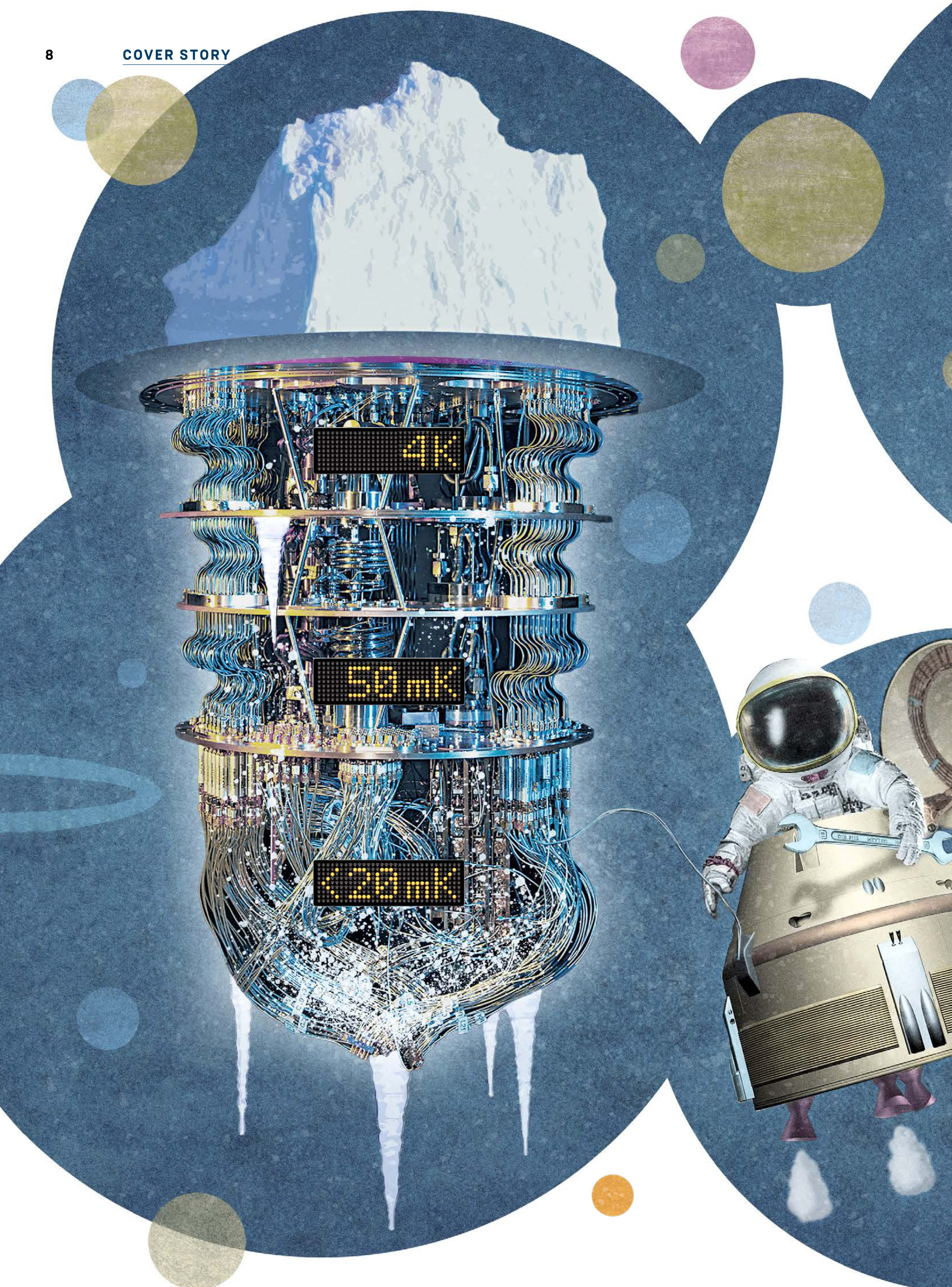
– JÜLICH CENTRE FOR NEUTRON SCIENCE –

FUSION RESEARCH

New energy record

Researchers from the European consortium EUROfusion have reached a milestone in the generation of fusion energy. In the JET test facility, they released 59 megajoules of energy, which is twice as many as the previous record set in 1997. Fusion reactors could cover part of the global energy demand in the future. Jülich researchers are also involved in EUROfusion.

– INSTITUTE OF ENERGY AND CLIMATE RESEARCH –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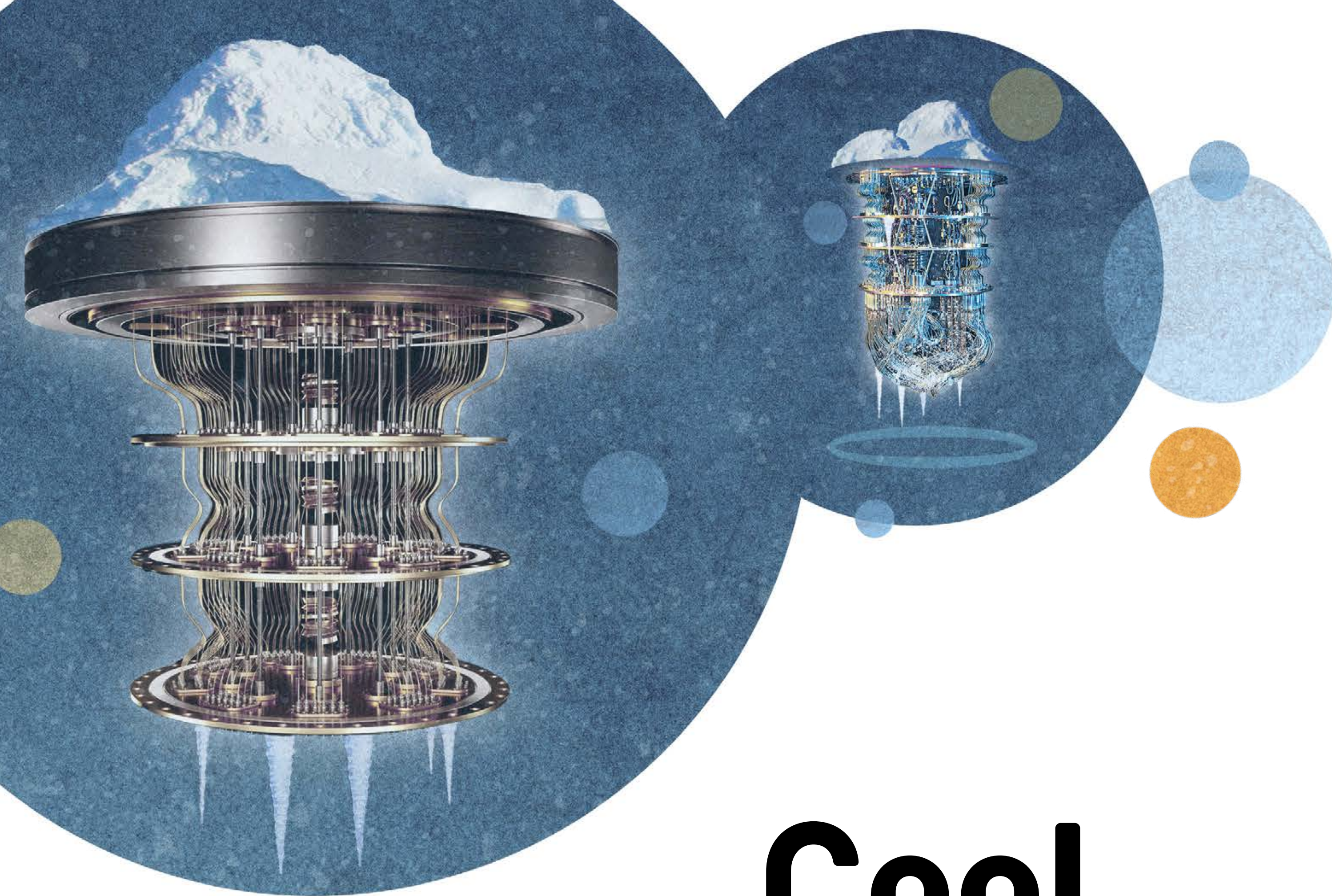


Cool calculators

Minus 273 degrees Celsius – colder than anywhere in the universe. Classical electronic systems are not designed for this extreme cold. However, this is supposed to change. Jülich researchers are working on microchips that function without interference in these frosty conditions. They are to control the computers of the future: quantum computers with millions of qubits that only work at such temperatures.

4 K = -269 °C; 50 mK = -273.1 °C; 20 mK = -273.13 °C

↑ René Otten is a doctoral researcher at the Institute for Quantum Information of the Jülich Aachen Research Alliance (JARA). He focuses on combining cryogenic electronics with quantum computers.

A shiny, red-gold structure hangs in a frame about 2.5 metres high, linking metal spirals and many curved metallic cables over four levels. The elaborate web in the laboratory of the 2nd Institute of Physics A at RWTH Aachen University is part of an experiment that could lead the way for the universal quantum computers of the future. Their computing power promises to outperform today's supercomputers like a racing car outperforms a tractor.

The shimmering construction is a cooling device in a class of its own: a cryostat. By mixing two different types of the noble gas helium, it can cool to a temperature close to absolute zero, that is, to almost minus 273.15 degrees Celsius, which is colder than ever measured in the universe. This is how extreme most qubits – the sensitive computing units of quantum computers – need it to be. Only then do they run stably and almost error-free. The many electrical cables are bent to prevent them from tearing from the extreme cold. Together with the cooling coils and the frame, they give the cryostat its typical appearance of a quirky chandelier. "Photographers love the motif – it has almost become the symbol of a quantum computer," says physicist René Otten from the JARA Institute for Quantum Information. This makes him smile, as "the quantum computer itself, the quantum processor, is only very small, sitting quite inconspicuously at the very bottom of the cryostat."

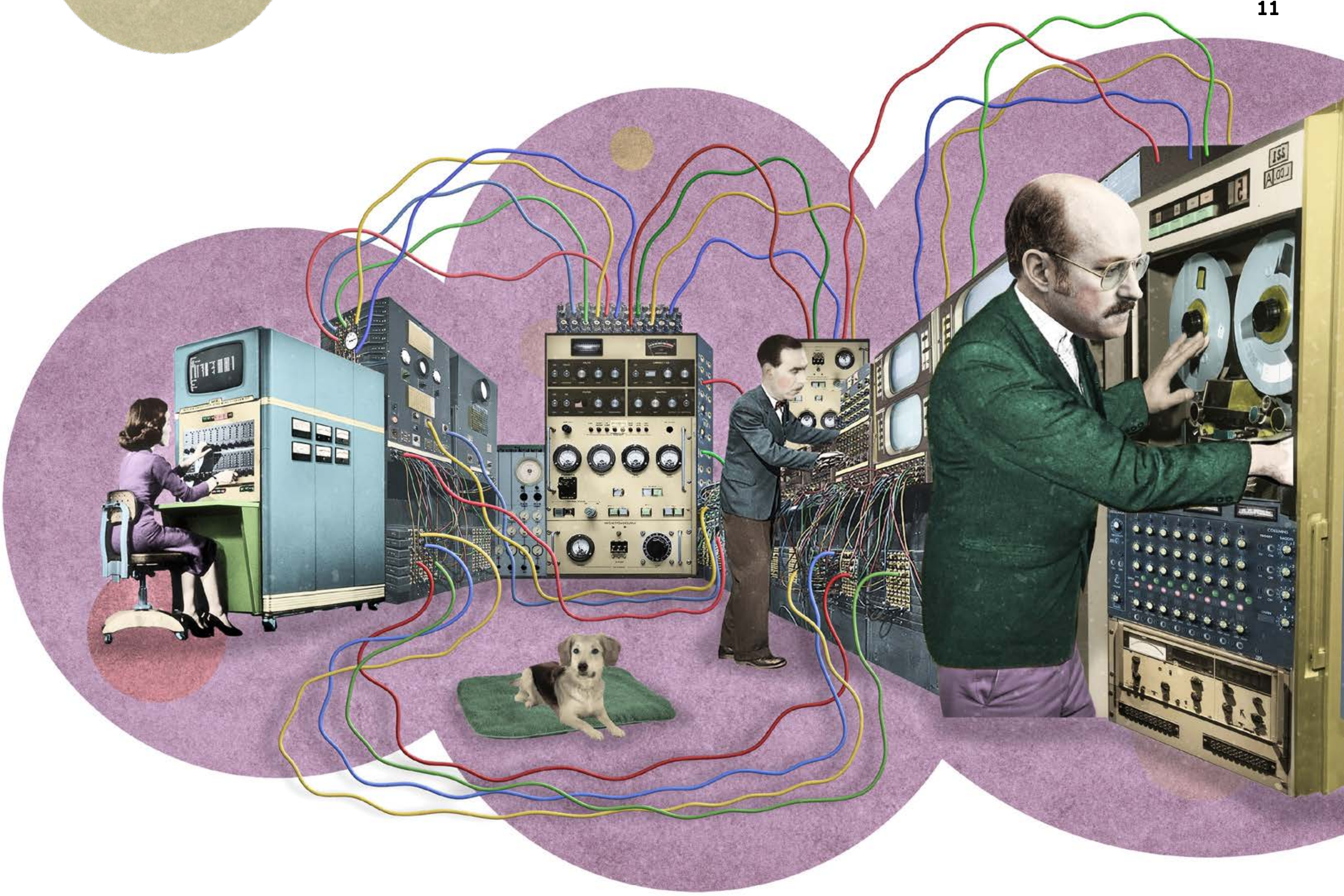
> **"It was completely unclear whether transistors, for example, would work at all near absolute zero."**
>
> DR. CARSTEN DEGENHARDT

TOO MANY CABLES

This quantum processor is controlled via the numerous wires. This, however, is precisely where a problem lies that complicates the path to future quantum computers involving millions of qubits: to control and read out the qubits, researchers use conventional electronics, which is not designed for temperatures below minus 40 degrees Celsius. For this reason, it is outside the cryostat. This means that the electronic devices generate signals at room temperature, which then run through the cryostat via the wires and finally arrive at the cryogenically cooled quantum processor.

"This works with 50 qubits, which is what quantum computers from IBM and Google use today, for example, or even with 100 qubits, but not for quantum computers in ten years' time or more, which are expected to have over a million qubits," says Dr. Carsten Degenhardt from the Jülich Central Institute for Engineering, Electronics and Analytics (ZEA-2), convinced. "In a few years, we could be in the same position with quantum computers as were the operators of conventional computing systems in the late 1950s." Back then, engineers were designing ever more complex circuits to increase the computing power of computers: solder joints and the wiring of the individual components to one another were increasing to such an extent that both the space required and the probability of connection errors rose enormously. The situation could turn out similarly with qubits: the more there are to be controlled, the more wires will be needed. This is not only a problem of space. The wires are prone to interference; the more wires, the more interference. Furthermore, the wires give off heat, which seeps into the cryostat – poison for the qubits, which need the cold.

In the 1950s, the tangle of cables was eliminated by the invention of the integrated circuit, the microchip: a semiconductor wafer on which the electronic components – transistors, resistors, capacitors – were mounted, along with their connections. Now, a microchip is again expected to fix this and make the electronic wires almost superfluous. The challenge this time: the chip has to work at temperatures of around minus 273 degrees Celsius and convert digital inputs into signals for the quantum computer just as reliably as at room temperature. However, such unexpectedly tolerant components are unpurchasable.



FROSTY NEW TERRITORY

Five years ago, therefore, the experts at ZEA-2 began working on their own chips. First, it was necessary to clarify the special requirements that a quantum processor presents to such a chip. For this purpose, the ZEA-2 team contacted the physicists led by Prof. Hendrik Bluhm at the JARA Institute for Quantum Information. Bluhm is working on a "Made in Germany" semiconductor quantum processor in the QUASAR project. Close cooperation developed between the JARA researchers, especially René Otten, and ZEA-2. "Together we determined, for example, the level and increments of the voltages that the chip is supposed to generate, plus the maximum electrical power acceptable for it to consume to achieve this without heating up the qubits too much. These are the basics for a circuit diagram," says Dr.-Ing. Patrick Vliex, who is responsible for designing the prototype at ZEA-2.

Up to this point, Vliex had largely moved along the familiar paths of room temperature electronics. With the next step, however, he entered unknown territory. In order to create the circuit diagram and convert it into concrete construction instructions for the microchip – that is, for the chip design – he needed precise information about the behaviour of the individual microelectronic components such as resistors and transistors. This information is available, albeit only down to minus 40 degrees Celsius. "It was completely unclear whether transistors, for example, would work at all near absolute zero, that is, at more than 230 degrees Celsius less. That's why we first carried out tests to that effect," says Carsten Degenhardt. Fortunately, the construction elements proved to be unexpectedly tolerant: they behaved differently at very low temperatures compared to room temperature, but still fulfilled their function. The scientists thus decided to continue working on the design of the chip and carry out simulations.

Simulations can be used, for example, to check the voltage signals that the designed chip produces on the basis of digital inputs. If something is amiss, the chip layout can be changed without incurring large costs before production starts. The ZEA-2 tested the new chip as well with the help of simulations. "We were aware, however, that these simulations reflect our cryochip to no

↑ Physicist Carsten Degenhardt and his team at Jülich develop integrated nanoelectronic and microelectronic systems: for quantum computers, among other things.

↑ Electrical engineer Patrick Vliex designed the prototype for the new cryochip.

more than a limited extent, as they only include the models and data available to a maximum of minus 40 degrees Celsius," says Vliex. Still, the results of these simulations were similar enough to those of the cryogenic test measurements for them to proceed. Besides, in designing the chip, Patrick Vliex was able to take into account some of the possible deviations in the behaviour of the components at around minus 273 degrees, for example by providing additional transistors that can be switched on if necessary.

QUBIT MEETS CHIP

After about a year of development, the Jülich electrical engineers finally commissioned a chip factory to produce a real chip from the finished design. Then came the waiting: "About half a year later, the chip factory delivered several copies of the prototype, and with that, everything was ready for our first joint test run with the Aachen researchers," Vliex says. In the meantime, the colleagues in Aachen had continued researching their semiconducting qubit. The qubit is generated in a semiconducting wafer consisting of several layers (see infobox). The wafer is mounted on a circuit board. René Otten also placed ZEA-2's low-temperature chip on this circuit board.

In March 2022, the time had come: René Otten closed the heat-insulating cover of the cryostat and started the experiment in the Aachen physics building. The following measurements, which lasted several days, showed that the signals from the chip in the cryostat were driving the qubit chip as desired. "That worked perfectly. The next step will be to check whether the chip also reads out signals as desired. In the long term, we want to establish a process with which we can design cryoelectronic chips in the same way as we already do room temperature microchips today. This would also include adapting the existing models for simulations," says Degenhardt. Together with partners from research and industry, this is already to be implemented in another quantum computer project: in the QSolid project launched in 2022.

The shiny, red-gold wire web for the electronic control system could therefore soon be largely dispensed with. The cryostat would then probably be less photogenic. On the other hand, the entry into a realm of technology that is expected to enable a million-qubit quantum computer in ten or twenty years will then be made.

FRANK FRICK

ⓘ More about quantum computing at Jülich (in German): go.fzj.de/quanten

An open race

One way to create qubits is with semiconductors. The team led by Prof. Hendrik Bluhm from the JARA Institute for Quantum Information uses two single electrons trapped in a tiny wafer in a kind of trap. They form the qubit. The wafer consists of five semiconducting layers that differ slightly in composition but mainly contain the elements gallium, arsenic and aluminium. The JARA scientists at Jülich's Helmholtz Nano Facility have applied a tiny grid-like structure made of metal to the top layer.

Due to the special layer structure, a plane exists in the wafer on which electrons move back and forth without being able to leave the plane. The scientists can restrict the remaining free space of the electrons in the plane by applying an electrical voltage to the metal grid. This is because the negative charge on the metal forms an insurmountable hurdle for the electrons, which are also negatively charged: the trap called the quantum dot has snapped shut.

The JARA researchers' semiconducting qubit wafers are particularly closely related to the chips used in today's microelectronics. As the industry has gained extensive experience with the production of microchips for decades, semiconductor qubits could be particularly suitable for future upscaling.

However, there are also other approaches to creating qubits. It is still open as to which technology will win the race in the end. At Jülich, scientists are also researching superconducting qubits. This approach is currently considered leading, with Google and IBM, for example, relying on it. Here, qubits are generated from currents that flow without resistance in superconducting circuits. It is still unclear whether computers with thousands of these qubits can be developed.

While functioning systems have already been developed for semiconductor and superconducting qubits, research into hybrid qubits is still in its infancy. The idea: a so-called topological insulator is applied to an ordinary superconductor. Jülich is researching this, and so is Microsoft. Topological insulators are a class of materials that, in simple terms, have the properties of an insulator on the inside and those of a conductor on the outside. This would make it possible, at least theoretically, to create a qubit that is less susceptible to interference than, say, semiconducting or superconducting qubits, which are very sensitive. Even the smallest disturbances can cause errors.

Candidates for hybrid qubits are Majorana particles, which are, however, difficult to generate, and so-called gatemons, in which a superconducting qubit is modified by a topological insulator.

JUNIQ machinery park

For all those who want to use quantum computers, an Eldorado is in the making at Jülich. The first systems are already available.

Quantum computers are considered the computers of the future. While there is still a long way to go, the first experimental systems, prototypes and commercial devices can already be used today. JUNIQ – short for "Jülich UNified Infrastructure for Quantum computing" – provides science and industry with access to various of these quantum machines. Some systems are located directly at Jülich, others are in partner facilities. The Jülich supercomputers are also part of this infrastructure through links with quantum systems. JUNIQ also supports users in the development of algorithms and applications for quantum computing.

Emulators

Emulators are programmes that run on ordinary computers and mimic quantum computers. In this way, for example, algorithms that will run on quantum computers in the future can already be tested today.

JUQCS – Jülich Universal Quantum Computer Simulator

Access: since January 2022

Location: Jülich

Number of qubits: 43 (simulated on Jülich's supercomputer JUWELS)

Feature: JUQCS runs on both laptops and supercomputers. Only supercomputers, however, can simulate more than 32 qubits. JUQCS holds the record with 48 qubits, simulated on K (Japan) and Sunway TaihuLight (China).

ATOS Quantum Learning Machine

Access: since January 2022

Location: Jülich

Number of qubits: 30 (simulated on Jülich's ATOS QLM-30)

Feature: The emulator runs on a special hardware infrastructure about the size of a simple business server with large storage capacity. In its maximum configuration, an ATOS-QLM can simulate up to 41 qubits.

Quantum annealers

Like other quantum computers, a quantum annealer uses quantum mechanics to perform calculations. Annealers, however, are not universally programmable. They are specialists in optimizing tasks and processes, for example to simplify supply chains or control traffic flows.

D-Wave Advantage System JUPSI

Access: since January 2022

Type: First Production System

Location: Jülich

Type of qubits: superconducting qubits

Number of qubits: max. 5,760

Feature: It is the first quantum computer in Europe with over 5,000 qubits. The Annealer is to be integrated into the Jülich supercomputer infrastructure in order to combine the systems' capabilities. (see page 16/17)

Quantum simulators

A quantum simulator is a kind of quantum computer "lite" – in other words, it is still a quantum system, but less flexible and only suitable for certain problems, such as when many particles interact with each other. Basically, it is about simulating another, usually more complex quantum system with a known, controllable quantum system. In the course of 2023, a quantum simulator with about 100 qubits is scheduled to start operation in Jülich.

Feature: The quantum simulator at Jülich and another one are to be closely linked with two European supercomputers – one of them being Jülich's supercomputer JUWELS – in the EU project "High-Performance Computer and Quantum Simulator hybrid" (HPCQS). This hybrid system is expected to make it possible to harness the power of quantum computers for the first practical hybrid applications.

Quantum computers

They are, so to speak, the premium class, and hopes are that they will be able to solve complex tasks in the future at which today's supercomputers fail. Experts speak of "universally programmable quantum computers" – in other words, quantum computers that can perform any calculation that computers can perform.

OpenSuperQ

Access: expected by late 2022

Type: experimental quantum system

Location: Jülich

Type of qubits: superconducting qubits

Number of qubits: 6

Feature: The OpenSuperQ project is part of the EU's Quantum Flagship research initiative launched in 2018. The goal is a European quantum computer with 50 qubits.

QSolid

Access: expected by 2024

Type: experimental quantum system

Location: Aachen

Type of qubits: superconducting qubits

Number of qubits: 10

Feature: In the QSolid project, funded by the Federal Ministry of Education and Research, quantum demonstrators have been under development since the beginning of 2022. It aims at qubits with a low error rate and, by 2027, at reaching a number of 30 qubits.

DAQC

Access: expected by 2024

Type: experimental quantum system

Locations: Jülich and Munich

Type of qubits: superconducting qubits

Number of qubits: 54

Feature: A digital-analogue quantum computer (DAQC) is being built in the project that combines the advantages of an analogue quantum computer that is not very prone to errors with the flexibility of digital circuits. The DAQC is to be paired with supercomputers and take over the task of a computing accelerator there.

QUASAR

Access: expected by 2027

Status: new hardware concept

Location: Aachen or Jülich

Type of qubits: spin-based qubits (semiconductor qubits)

Number of qubits: 25 (until 2027)

Feature: In the QUASAR project, funded by the Federal Ministry of Education and Research, work on a semiconductor quantum processor "made in Germany" is ongoing. A system with 25 qubits is to be developed in an expected follow-up project.

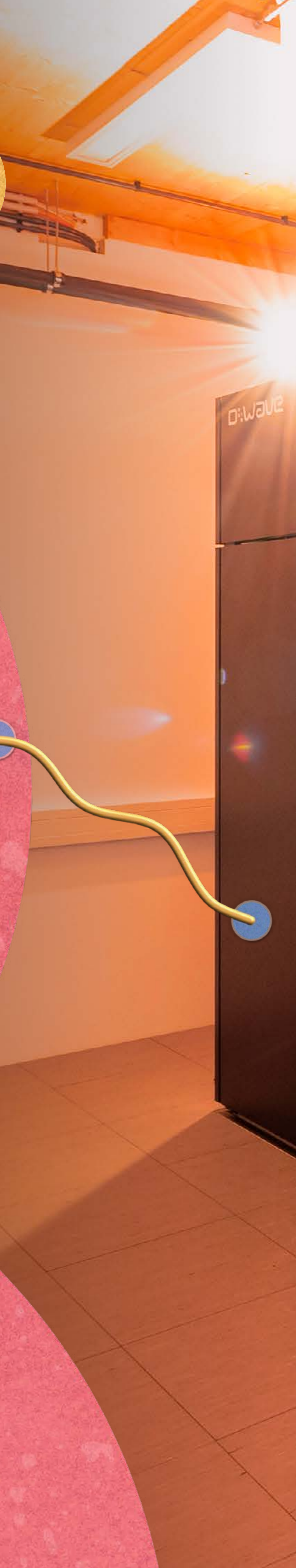
Europe's number one has over 5,000 qubits

This is what Europe's number one looks like. A quantum computer with more than 5,000 qubits has been running at Forschungszentrum Jülich since January 2022 – no other system in Europe offers so many computing units. The computer called "Advantage" was developed by the Canadian company D-Wave Systems. Only two similar computers exist, which have been running at D-Wave in Canada since 2020.

These systems are so-called quantum annealers. They are constructed differently from universal quantum computers – such as those being developed by IBM and Google, but also by Jülich researchers – and therefore cannot be universally programmed. Instead, they provide one specific computational process, which makes them specialists for challenging optimization problems, for example: efficient control of traffic flows or training of artificial neural networks for artificial intelligence applications. This capacity is also of great interest to industry. With the aid of D-Wave's quantum annealers, for example, a bank increased the return on an investment portfolio, a supermarket group improved its supply chains and an automobile manufacturer optimized workflows in the paint shop. Industry and science can access both "Advantage" and annealers in Canada via the Jülich user infrastructure JUNIQ, the range of quantum computers and supercomputers of which is constantly being expanded (see page 14).

The fact that "Advantage" is located at Jülich also opens up new insights and new opportunities for research. For starters, the annealer is to be closely integrated into the Jülich supercomputing infrastructure, while Jülich researchers can also put the system to the acid test, so to speak. After all, the technology is so new that it has not yet been completely clarified for which problems quantum annealing actually brings an advantage over classical computers. Jülich collaborations with the automotive industry and energy supply companies, for example, are expected to help find this out.

CHRISTIAN HOHLFELD



More on the quantum annealer at:
juelich-quantum.de/en


advantage
advantage

Skintight

The future belongs to wearables – small networked computers that are tucked into clothing or worn on the body. A new skin-like, synthetic material could advance the technology or even be used as artificial skin for robots.

One wipe along the jacket sleeve switches the living room light off; a tap of the hand on the coat collar places a phone call to the boss: what sounds like science fiction has long since arrived in science and also in the clothing industry. There is hardly a topic that captures people's imagination more than small networked computers, so-called wearables, which are worn on the body or integrated into clothing.

This wearable technology is already being used today, especially in sports: smartwatches and fitness bracelets measure pulse, heart rate and breathing rate. Smart shirts monitor sleep or help to perform movements correctly during yoga and Pilates. Such tops are equipped with sensors that detect body posture and muscle activity and indicate incorrect movements by applying light pressure to the respective area. There are now even fitness suits that train the muscles without you having to move yourself. Tiny electrodes are inserted into these to stimulate the muscles from the outside.

HIGH REQUIREMENTS

However, wearables are also taking over other areas: diabetic patients can use them to measure their blood sugar levels, data glasses project images directly onto the retina, and wearables in nappies track the sleep stages of babies. It is not just about technical challenges, such as the development of tiny sensors, but also about the conductive material. It must be robust and, at the same time, durable and stretchy – and of course comfortable to wear. "A second skin, so to speak," explains Dr. Baohu Wu. At the Jülich Centre for Neutron Science (JCNS) at the Heinz Maier-Leibnitz Zentrum (MLZ) in Garching, the physicist and instrument scientist is working on materials, including for wearables.

↑ Physicist and instrument scientist Baohu Wu studies matter with the help of neutrons.

1,600 per cent

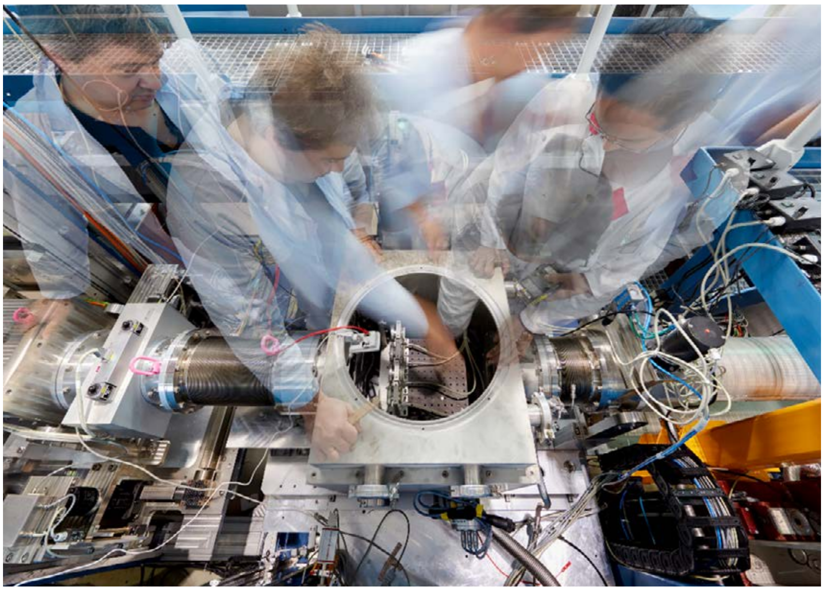
is the stretchability of the new elastomer. This means it can be stretched to its 16-fold size. For comparison: a balloon can be inflated to about 7 times its size.

Source: www.deutschlandfunk.de/kaum-zu-ueberdehnen-100.html (in German)

He draws his inspiration from nature: from biological materials that conduct ions – in this case, electrically charged macromolecules. To understand the details of the relationship between the structure of these materials and their properties, he relies on neutron and X-ray scattering methods. With the help of these methods, Wu, together with researchers from the Chinese Donghua University in Shanghai, has successfully developed a skin-like, synthetic material that meets all the requirements for materials for wearables. Smart clothing could also benefit. "Even artificial skin for robots is conceivable," explains Wu. Due to the special properties of the material, robots could feel their environment in greater detail and more sensitively than before – that is, they could become more human.

The material is a so-called elastomer: a plastic that can be easily stretched without tearing. "Far better than previous materials, our elastomer replicates both the elasticity of our skin and its ability to become more stable when reshaped. Our plastic even has skin-like self-healing powers, so that it can repair damage itself and restore functionality," Wu explains. Until now, it had barely been possible to produce these properties in a single material.

Wu and his colleagues had a trick: for their material, they combined two dynamic polymer networks that interact with each other and optimally complement each other in their properties. One polymer network dissolves chemical bonds



↑ The new material was studied using a neutron small-angle scattering facility at the Jülich branch of the Heinz Maier-Leibnitz Centre in Garching.

quickly, meaning that a material made of it can be stretched well, but it tears or wears out very quickly.

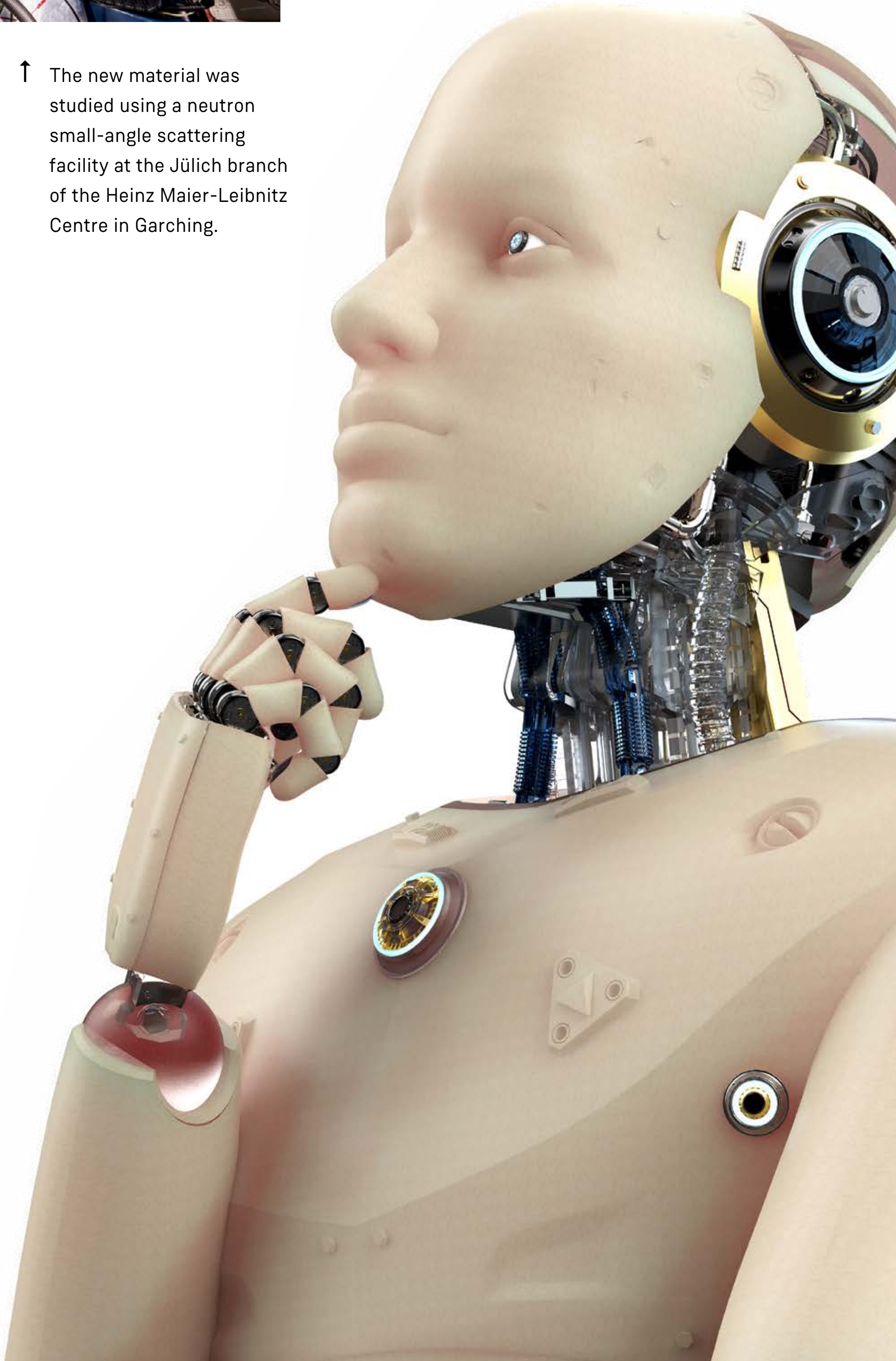
STRETCHY AND TEARPROOF

The chemical bonds in the other network, by contrast, remain stable. A material made of it does not tear, but would be rather stiff and hardly ductile. Thanks to the combination of the two, the new material can be stretched extremely well without tearing and then quickly slips back into its original shape. "Simply put: it fits like a second skin. According to our preliminary findings, it would be possible, for example, to wear portable devices such as electrocardiographs on the body like a second skin," says the Jülich researcher.

What's more, "The properties of our elastomer can increase the lifespan of wearables' materials, reduce replacement costs, decrease the degradation-related inefficiency of these materials and improve product safety," Wu concludes. By determining the interrelations between the structures and the sought-after properties, he made a decisive contribution, enabling his colleagues to develop the promising materials in a targeted manner.

Wu hopes that the new material will advance research. He firmly believes in the future of wearables: "They will continuously gain importance. Many other applications are conceivable if we succeed in developing even smaller and more powerful sensors and more durable devices that feel pleasant on the skin as well," the researcher elaborates, convinced.

KATJA LÜERS



Pioneers of a new computing era

The brain as a model: neuromorphic computers rely on an architecture that works in a similar way to the nerve cell network in our organ of thinking. John Paul Strachan and Emre Neftci have come to Jülich to make such computers ready for practical use.

Our brain is a masterpiece of evolution. In a gigantic network, 86 billion nerve cells are connected to each other via synapses and perform astonishing mental activities. John Paul Strachan and Emre Neftci both get excited when talking about the human brain and its incredible complexity, extraordinary capabilities and unprecedented efficiency. The two physicists aim to build computers that perform calculations based on the model of the brain, so-called neuromorphic computers.

Transferring the capabilities of the human brain to computers sounds tempting. "The neural networks in our brain process and store huge amounts of information. In contrast to computers, they spend very little energy doing this. They also keep flexibly adapting to new learning processes and experiences," Neftci describes. Technical systems with such capabilities would be ideal, for example to navigate cars autonomously through traffic or for computers to learn by themselves.

↑ Swiss-American Prof. **Emre Neftci** focuses on the software needed for neuromorphic chips. Most recently, he worked as an assistant professor at the University of California at Irvine. Before that, Neftci had completed his doctoral degree and did research in neuroinformatics at ETH Zurich.

Although the first neuromorphic model circuits already exist, they have not been widely used in real-world solutions. Strachan and Neftci intend to change that. To this end, the two came to Jülich from the US high-tech region of California in 2021. "Jülich has experts from different fields who we need for this kind of interdisciplinary research," says Neftci. He and Strachan complement the Jülich team of hardware and software engineers, semiconductor experts, basic scientists, theorists and neuroscientists.

However, building a computer that works in a similar way to our brain requires special components, a dedicated architecture and new algorithms. Unlike our brain, computers process and store data in different places. It takes time and consumes energy to send it back and forth between processor and memory. John Paul Strachan and his team are working on chips that process and store data simultaneously in one place. These so-called neuromorphic chips are modelled on the structure of neural networks in the brain and consist of highly interconnected artificial neurons and synapses.

At the same time, the researchers are developing new concepts for the architecture of neuromorphic computers, for which they are designing additional devices and suitable circuits. Computers of this kind are to use stored data to further develop their own capabilities. Like our brain, they build and optimize internal information highways. Simply put: they learn. In this way, computers are to solve tasks for which they were not initially programmed.

NEW AI CONCEPTS

“Neuromorphic technologies could also fundamentally change artificial intelligence, or AI for short,” says Emre Neftci. Previous AI concepts have used mathematical algorithms without regards for an efficient physical realization. This could change with neuromorphic computers, as these are designed similarly to their natural – very efficient – counterparts.

However, new hardware and new AI concepts also require suitable software and algorithms. This is where software expert Neftci and his team come in. “The algorithms used for conventional computing cannot simply be transferred to neuromorphic computing. Different principles and restrictions apply there,” he describes the challenge. In order to realize suitable programmes, he and his team work closely with other Jülich researchers, such as those working in brain research. “Their findings can help us to further develop software for machine learning,” says Neftci.

Strachan, too, hopes for significant impetus from interdisciplinary cooperation: “Neuroscientists could use our neuromorphic systems to test their models of neural circuits and to better understand the brain,” he explains. Their ideas and experience, in turn, will help him and his team to further improve the hardware systems. In the end, each discipline enriches the others, and together they approach their great goal: a neuromorphic computer.

JANOSCH DEEG/CHRISTIAN HOHLFELD

36

million euros

is being invested by the Federal Ministry of Education and Research in the development of hardware and algorithms for computers modelled on the brain. The ministry is funding the second phase of the interdisciplinary NEUROTEC project, in which John Paul Strachan and Emre Neftci are also involved. Coordinated by Forschungszentrum Jülich, NEUROTEC combines the expertise of Jülich, RWTH Aachen University and numerous regional companies. The partners want to help ensure that future computers for artificial intelligence will increasingly come from Germany and the EU.

↑ Born in Costa Rica, US-American Prof. **John Paul Strachan** worked in Silicon Valley at Hewlett Packard Laboratories, one of the pioneers in the field of neuromorphic computing. Strachan led a team there researching neuromorphic hardware. He holds more than 50 patents and completed his degree at two of the elite American universities, MIT and Stanford.

ⓘ Emre Neftci and John Paul Strachan detail their research in the digital lecture series, “Wissenschaft online”.

Lecture by Emre Neftci:

go.fzj.de/neftci-effzett22

Lecture by John Paul Strachan:

go.fzj.de/strachan-effzett22

A lighthouse for energy transition

Interview with Prof. Peter Wasserscheid, director of the new Institute for a Sustainable Hydrogen Economy (INW) since 1 November 2021.

The INW is to evolve into the innovative core of the "Helmholtz Cluster for a Sustainable and Infrastructure-Compatible Hydrogen Economy" (HC-H2), which was approved in 2021. The cluster is an important building block for turning the Rhineland region into a hydrogen model region with Europe-wide appeal in the course of structural change.

Mr Wasserscheid, you described yourself as an obstetrician when you took office. How's the young hopeful doing?

We're in the process of furnishing the children's room. A large research landscape will be created in the Brainergy Park near Jülich, around which companies are expected to settle. Office containers, laboratory buildings and a technical centre hall will be erected by the time the INW moves into its new building, so that research can start as soon as possible. Plus, we're looking for staff, both researchers and tradespeople. We also want to win municipalities, transport companies and other research institutions as partners.

What are the benefits of the research cluster?

Firstly, it creates new jobs. 100 will be generated here alone by the end of the year; by 2025, there are to be 500 at INW. But there's more to it than that: we want to build a beacon for energy transition, that is, enable a sustainable future with innovative hydrogen and energy technologies from the Rhineland region that are sold worldwide.

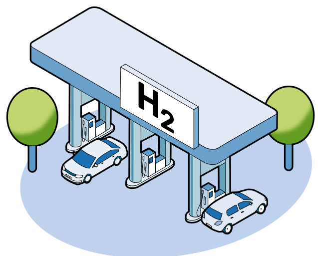
What technologies are we talking about specifically?

Technologies with which hydrogen can be transported and stored in large quantities and made available quickly, easily and cost-effectively. It's about supplying filling stations for bus fleets with green hydrogen, for example, or supplying a glassworks that, in the future, is to work with hydrogen technology instead of CO_2-emitting combustion technologies. With demonstrators, we want to show that our innovations can also function and be economical on an industrial scale.

When could the first demonstrators start?

By the end of 2022, we want to set up four demonstrators in the Rhineland region that will cover, straightaway, the entire spectrum of innovative hydrogen technologies. The provision of hydrogen for a stationary energy supply system and an application from the mobility sector will mark the starting point.

CHRISTIAN HOHLFELD ASKED THE QUESTIONS.



860

million euros

is provided by the federal government for the development of the HC-H2 from the funding for the structural change of the coal regions. North Rhine-Westphalia is also contributing state funds.

ABOUT

Chemist Peter Wasserscheid is the director of the Helmholtz Institute Erlangen-Nürnberg for Renewable Energy (HI ERN), a Jülich branch founded in 2013. He has also held the Chair of Chemical Engineering I (Reactional Engineering) at Friedrich-Alexander Universität Erlangen-Nürnberg since 2003. For his research, he was awarded the Leibniz Prize of the German Research Foundation (2006) and received two Advanced Investigator Grants from the European Research Council (2010, 2018).

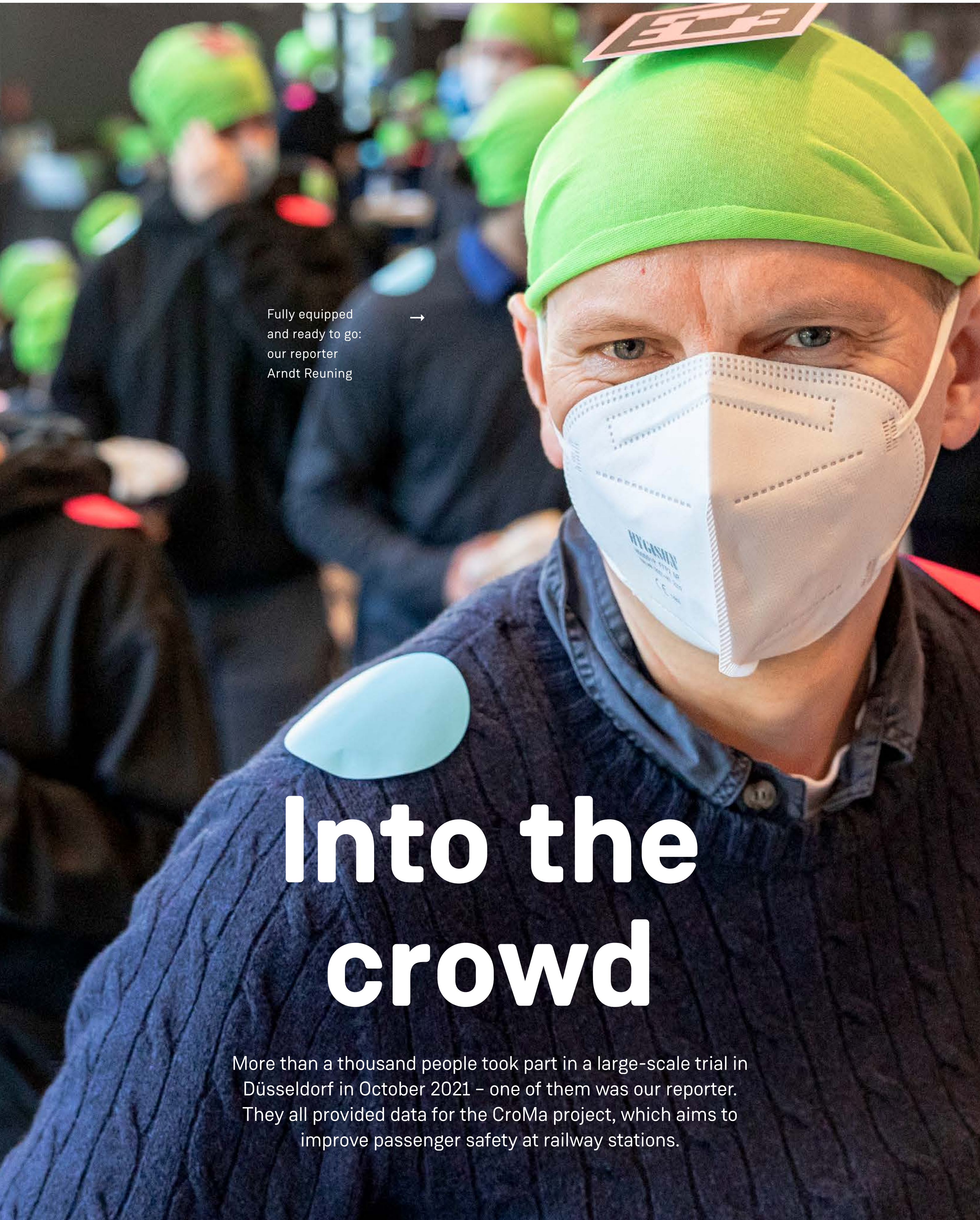
↑

What are you researching right now, Ms Rhoden?

Dr. Imke Rhoden, scientist at the Institute of Energy and Climate Research, System Analysis and Technology Evaluation (IEK-STE)

"I want certain materials from discarded refrigerators to be recycled rather than incinerated. Specifically: rigid foams used for insulation, which are used in the construction industry as well. The EU project CIRCULAR FOAM brings together experts from eight countries to investigate possibilities for a circular economy using waste for high-performance plastics. I analyze the economic conditions for this. The goal is a model that will enable regionally adapted development plans."

More about CIRCULAR FOAM in the Jülich Blogs: go.fzj.de/juelichblog-rhoden-en



Fully equipped and ready to go: our reporter Arndt Reuning →

Into the crowd

More than a thousand people took part in a large-scale trial in Düsseldorf in October 2021 – one of them was our reporter. They all provided data for the CroMa project, which aims to improve passenger safety at railway stations.

A sunny, cool autumn morning in Düsseldorf's Volksgarten park. It might be one of the last pleasant days this year. And me? I have nothing better to do than spend it in a windowless hall from the 1970s, huddling with a bunch of strangers. As a reporter for effzett magazine, I am taking part in the CroMa large-scale trial.

I do not yet know exactly what to expect. The project website says to expect large crowds, dense and pushy at times. I find close physical contact rather unpleasant, so I avoid crowds as much as I can. Especially in the pandemic. As a result, I have a queasy feeling in my stomach as I walk towards the Mitsubishi Electric Hall.

"Railway stations in Germany are not designed for the increasing passenger numbers we expect in the future. Extraordinary peaks could occur in special situations: at concerts, football matches or simply in bad weather. In the CroMa project, we want to develop concepts on how to change railway stations today so that they can cope with greater utilization. We are looking for ways to make the best use of the available space, increase passenger comfort and, most importantly, improve safety on the platform."

Armin Seyfried

1,200
volunteers
played train passengers for science for four days at the beginning of October. They waited, pushed and ran around, with and without luggage, to simulate typical situations at railway stations.

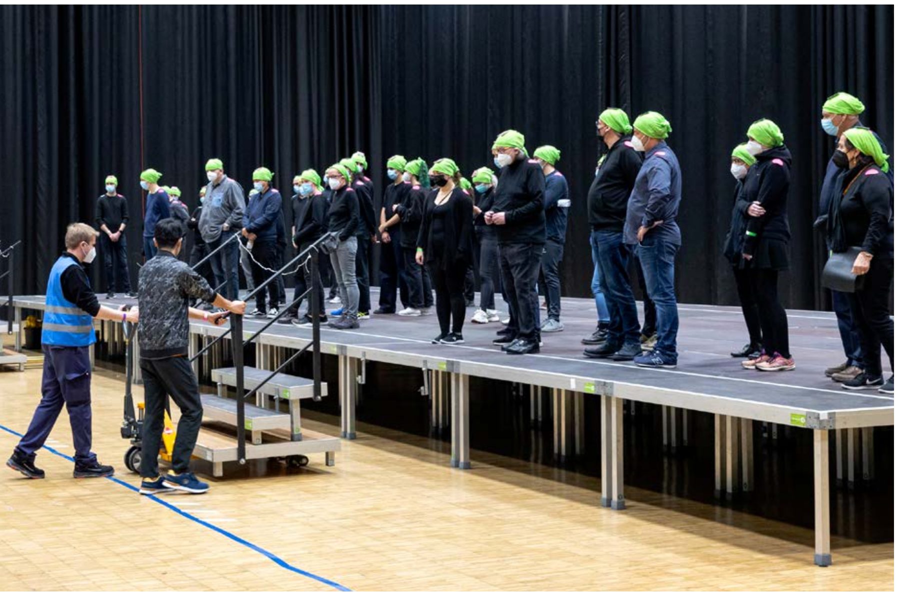
After a rapid test and wearing an FFP2 mask over my mouth and nose, I go to the entrance area of the hall. It is like an assembly line there: I receive a number, a light blue wristband and a laminated QR code. I complete a questionnaire and my measurements are taken: shoulder width, height, weight. A helper puts a green bandana on my head and sticks the QR code on top. Two big dots are glued onto the shoulders: sky blue on the right, piggy pink on the left.

Also a matter of security: a corona rapid test was compulsory for all. →

↑ **Dr. Maik Boltes**
- Mathematician and computer scientist
- Head of Pedestrian Dynamics – Empiricism at IAS-7

"We have collected huge data sets with the CroMa experiment. Cameras under the ceiling of the hall recorded the position and routes of the participants at each moment via the code on their heads. We link these movement profiles with other data. Special sensors measured heart rates and skin resistance in selected participants. This data tells us whether someone is under stress. We also used special suits to record the 3D movement of the participants: how do they use their bodies to make their way onto a train or through an entry gate, for example?"

Maik Boltes



↑ Station 1: The participants spread out on the improvised platform.

I close in on the first station. So far, I have managed well to keep my distance from the other 80 or so participants in my group. The task now is to enter an improvised platform via a few steps and wait there for an imaginary train. I had imagined it would have been worse. There is enough space for me at all times. We repeat the whole procedure several times, each time with slight variations: sometimes the groups that arrive at the platform at the same time are larger, sometimes the train takes longer to arrive.

← Station 2: In the first round, the participants wait patiently at the entrance gates.

← Station 3: Like in a train during rush hour, the participants stand close together in a simulated wagon.

At the second station, we are to go through one of three entrance gates. Things are pretty civilized. We arrange ourselves in three queues well before the actual barrier. The second time, we are supposed to imagine that we are in a hurry. Some participants actually start to cut in front and push ahead. A small crowd is developing at the gates. Some participants seem to be losing themselves in their role. But is it possible at all to model the true behaviour of people in such an experiment?

"Many use the stairs to get to the platform and then stop around the staircases. Even if there is enough space, it is often not used to its full potential. This may be due to obstacles on the platform, for example. In this case, it might help to decongest the platform structurally or to direct people purposefully away from the crowded areas. To do that, however, we first need to know how people behave in different situations on the platform."

Anna Sieben

↑ **Prof. Dr. Armin Seyfried**
- Project coordinator CroMa
- Physicist and security researcher
- Head of Jülich's Civil Safety Research institute IAS-7 and Professor of Computer Simulation for Fire Protection and Pedestrian Traffic at the University of Wuppertal

"In some situations, the participants behaved more ruthlessly than expected, for example at the entrance gates. This triggered a quite realistic dynamic. This is the precise advantage of the experiment over field studies: we can set the boundary conditions and observe people's reactions to them."

Armin Seyfried

Things get really tight at the third station: an improvised railway compartment is set up there. We are to hop on and off in ever-changing variations: with a backpack, a rolling suitcase, a pram. A staff member gives instructions: "The train is approaching. The train is coming to a halt. The doors are opening." Over and over again. I wonder what the bustle might look like for the camera above our heads. Could our movements of getting in and out perhaps even be described purely with physical formulae?

"As a psychologist, I am surprised at how much physics lies behind these phenomena. In pedestrian research, we can often simply think of people as spheres: when things get tight, they have to get past each other somehow – strictly according to the rules of physics. However, there are also phenomena where you have to look at individual behaviour: how much force does someone use to push their way to the front? How do others perceive that? Social norms also influence this. Physics and psychology have to join forces so that you get a realistic description of the situation."

Anna Sieben

One thing goes on throughout the day: completing questionnaires. Did I feel constricted? Did I push my way to the front by using my body? Was there enough space on the platform? At the very end, after the experiments, there is one last form. It is about the pandemic situation: have I been feeling safe? Have I been thinking about corona a lot today?

↑ **Dr. Anna Sieben**
- Psychologist and social scientist
- Head of Pedestrian Dynamics – Social Psychology at IAS-7 and a Social Theory and Social Psychology research associate at Ruhr University Bochum

Later, on the way home at the city railway stop, my mind keeps repeating: "The train is approaching. The train is coming to a halt. The doors are opening." This time, however, unlike the experiment, I really have to squeeze past other passengers extremely tightly as the train approaches. I sigh. Maybe the CroMa project will indeed help to change that soon.

ARNDT REUNING

It was a challenge to conduct such an experiment with over 1,200 people in a time of pandemic. We had to postpone it several times. That was very exhausting. We were in constant discussion with the health office and the crisis management group at Forschungszentrum Jülich. Our safety and hygiene concept with masks and rapid tests helped participants feel safe.

Maik Boltes

↑ Completing questionnaires again and again: this way, impressions and emotions could be sampled.

More pictures and more information about the project (video): effzett.fz-juelich.de/en/1-22/into-the-crowd

Safe and functional

CroMa stands for "Crowd Management in Transport Infrastructures". The project aims to optimize railway stations through comprehensive studies on the behaviour of pedestrians in large crowds. Especially at peak times, stations should remain functional and safe for passengers. The project team will develop recommendations to this end, for example how pedestrian flows can be controlled through targeted information or alterations to the platform. The project involves Bergische Universität Wuppertal as its coordinator, Forschungszentrum Jülich, Ruhr University Bochum and, among others, transport companies, event organizers, rescue services, the fire brigade and the federal police. The Federal Ministry of Education and Research is funding the project with a total of €3.4 million over four years.

Photograph of San Francisco Bay in visible light …

… and in short-wave infrared

Seeing through at low cost

Seeing through fog, rain and haze; precisely distinguishing colourless liquids – a new infrared detector makes for low-cost camera chips that can do so.

Fog lies over the bay. As is so often the case in San Francisco, dense wafts envelop the city's landmark, the Golden Gate Bridge. SWIR, short-wave infrared, makes it possible to penetrate them. Cameras with SWIR photochips can see through fog, rain and haze. They usually deliver razor-sharp images in grey scale. Such cameras are ideal for autonomous cars or in aviation, for example, where a clear view is indispensable.

However, very high manufacturing costs often prevent their use in everyday life. An inexpensive alternative, developed by Dr. Dan Buca's group at the Peter Grünberg Institute (PGI-9) together with colleagues from the Leibniz Institute for High Performance Microelectronics in Frankfurt (Oder) and the University of Milan, could change this. At the heart of it is a germanium-tin semiconductor from Jülich. Its elements are well compatible with silicon, the standard material for chips. As a result, the new detector can be manufactured using established technology and can be integrated on existing chips. Very low-priced camera chips could be constructed for use in today's smartphones and cameras.

The detector can also be switched between two ranges of infrared radiation, the near infrared (NIR) and the "short-wave" infrared (SWIR). This helps, for example, to precisely distinguish liquids that look colourless to the human eye but absorb NIR and SWIR radiation to different degrees. The partners now want to further develop their research detector to better demonstrate its potential applications.

CHRISTIAN HOHLFELD

KNOWING-IT-ALL

SUPERCONDUCTORS

Superconductors are metals and compounds in which current can flow without electrical resistance. For this, they need extreme cold or extreme pressure.

FOUR NOBEL PRICES IN PHYSICS

1913
Discovery of the effect

1972
Theory

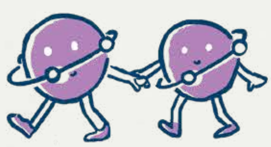
1987
Superconductivity in ceramic materials

2003
New theory

WHAT MAKES SUPERCONDUCTORS

SALTATIONAL

The transition from conductive to superconductive is sudden. In the case of lead, for example, this happens at a transition temperature of exactly minus 265,95 degrees Celsius.



TOGETHERNESS

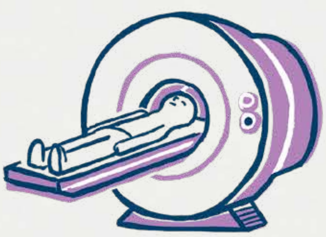
In superconductivity, electrons move without resistance. How exactly is not always clear. One explanation: the electrons form pairs. This changes their quantum properties.

DETACHED

Superconductors displace externally applied magnetic fields from their interior. This is why a magnet placed over a superconductor can hover.

APPLICATIONS

Superconductors measure small magnetic fields and generate large ones, for example in particle accelerators, fusion reactors and magnetic resonance scanners. They are also used in quantum computers, for energy storage and power lines.



WHAT ARE JÜLICH RESEARCHERS DOING?

They focus on suitable materials, create qubits in superconducting circuits and use superconductors for fusion devices and measurements on the heart.

THUMBS UP

YOUTUBE CHANNEL:
KLIMA WANDEL DICH (CHANGE, CLIMATE)

Time for the climate solution

They are already bestselling authors: now the creators of the two blockbusters “Kleine Gase – Große Wirkung: Der Klimawandel” (Small Gases – Big Impact: Climate Change) and “Machste dreckig – machste sauber: Die Klimalösung” (You Made it Dirty, Now Make it Clean: The Climate Solution) launched a new project. On their German YouTube channel, they get to the bottom of climate change myths in videos they shoot themselves. The two economics students approach questions such as whether tofu jeopardizes the rainforest or whether wind turbines shred birds.

– WWW.YOUTUBE.COM/CHANNEL/UCNBM61BXBAKTNSXTGGJVOTG (IN GERMAN) –

“TERRA X” EXPLANATORY VIDEOS

ZDF media library offers download

Whether climate change, viral diseases or spectacular natural phenomena – the German public-service television broadcaster ZDF’s documentary series “Terra X” uses vivid images to explain scientific principles and connections. Excerpts of the elaborate productions are now available for download from ZDF’s media library. This is a treasure trove for scientists and teachers, for example, who can use the clips freely for lectures or lessons thanks to the Creative Commons licence.

– WWW.ZDF.DE/DOKUMENTATION/TERRA-X/TERRA-X-CREATIVE-COMMONS-CC-100.HTML (IN GERMAN) –

OPEN DAY AT JÜLICH

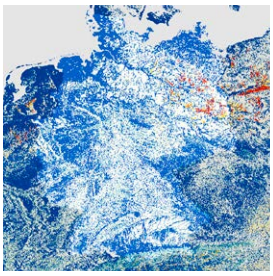
Experience science up close

Due to the pandemic, the Jülich campus has been rather sparsely attended in recent months. That is set to change this summer: we expect up to 20,000 visitors at our “Open Day” on 21 August 2022. We invite you to explore the campus and experience science live under the motto of “Shaping Change”. Look forward to easy-to-understand presentations and many hands-on activities. In short: a programme for young and old that excites curiosity. Make a note in your calendar now!

– WWW.TAGDERNEUGIER.DE/EN –

RESEARCH IN A TWEET

Everything fine?
The #WaterMonitor shows the water supply of plants in Germany on a daily basis.



With the interactive online tool …

… farmers and hobby gardeners, for example, can check how much water is available to the plants at their location. A search function allows quick and easy orientation throughout Germany. Forecasts up to nine days in advance are calculated on a daily basis with a resolution of 600 m. They are based on simulations with the hydrology model ParFlow of the Institute of Bio- and Geosciences (IBG-3). **wasser-monitor.de (in German)**

JÜLICH
Forschungszentrum
Shaping Change