Quantum cosmos adventure

Jülich pioneers build computers that conform to the rules of this bizarre world

BRIGHT SPOT
Why Europe’s solar industry draws new hope

SMART ALECK
Why some birds are able to think in complex terms

MIRACLE WORK
Why nature can be a role model for power grids
This is what high-tech looks like! “This” refers to the seemingly innocuous, grey-white something protruding from the wall. The device, however, is a ripsnorter: it is one of the best high-precision milling machines in the world. Six axes ensure that it is able to work on materials from all directions and angles. This way, it can precisely form even the most complicated components, ranging in size from a few millimetres to two metres. A team led by Dr. Yannick Beßler from the Central Institute of Engineering, Electronics and Analytics (ZEA-1) uses it to manufacture complex components such as for the European Spallation Source’s neutron source, which is currently being built in Lund, Sweden.

Read our Jülich blog for more on the big milling machine: fzi.de/fraese (in German)
A comeback for Europe’s solar industry?

Photovoltaics expert Uwe Rau explains in an interview why new technologies offer hope.

24

So much for “birdbrain”!

Some birds show amazingly smart behaviour. A new look at the bird brain reveals structures that could explain this.

26

Cover Story

In superposition

Jülich experts are tracking down the secrets of the quantum cosmos, the basis for tomorrow’s computing machines.

8

Research

1939 prediction confirmed

Neutrinos provide Livia Ludhova with data on a special fusion process in the sun.

18

Research in times of corona

Mathematics, physics and supercomputers are helping to better understand and target the virus.

22

Well-supplied

Planning power grids optimally with the help of a new model inspired by networks from nature.

20

More hydrogen using ultra-thin layer

Atomic differences of the catalyst increase the production of the energy carrier.

19

Sections

Editorial

Publication details

What are you researching right now?

Knowing-it-all

Thumbs up

Research in a tweet
The pioneering age

70 years ago, the world witnessed a premiere: on 12 May 1941, Konrad Zuse presented the Z3 and, thus, a functioning digital computer. He was not the only pioneer of his time. There were Howard Hathaway Aiken, John Atanasoff and Thomas Harold Flowers, among others, who, during the 1940s, all developed or constructed early computers such as the Mark I or Colossus.

Today, bright minds have once again embarked on developing a new generation of calculating machines. They no longer deal with punch tapes, relays and electronic tubes, however, but with the bizarre world of quanta. At Jülich, a large number of experts have joined forces to reach new breakthroughs with the quantum computer. In our cover story, six of these Jülich pioneers talk about the challenges they have to overcome and why Forschungszentrum Jülich offers an ideal environment for this.

Uncharted waters are also to be sailed in other areas: read about what we can learn from nature in the construction of power grids, why the bird brain is more complex than previously assumed, and why new technologies could lead to a renaissance of European photovoltaics.

We hope you enjoy this issue,
Your effzett editorial team
They look like jewellery from a glassblower: synthetic cells, simulated and artistically depicted on the computer. They serve as a model system for biological cells that can assume a wide variety of shapes when they move around or take up nutrients. Researchers from Jülich and Zurich have used the model to investigate how physical forces bring about the natural diversity of cell shapes and cell movements – the Jülich researchers with simulations, the Zurich researchers in the laboratory. The findings will support the employment of synthetic cells as miniature factories or microrobots in the future.

Video in the web magazine: effzett.fz-juelich.de/en

A matter of shape

Oxygen is transported to the tissue throughout our body using red blood cells. These are filled with the protein haemoglobin, which binds and releases oxygen. Researchers from Australia, Sweden and Jülich have found in neutron scattering experiments that the shape of the blood cells influences the properties of haemoglobin, such as its mobility in the cell, which is important for the efficient exchange of oxygen.
NEWS IN BRIEF

1,170,000 tonnes

of biomass per year could potentially be processed into higher-value products in the Rhineland region. According to a study by Prognos AG, commissioned by the BioökonomieREVIER initiative, which itself is coordinated by Forschungszentrum Jülich, this conversion of organic waste, green waste and residues from the food industry could create an important advantage in terms of location for the region between Aachen and Cologne.

- RHINELAND INITIATIVE BIOÖKONOMIEREVIER/INSTITUTE FOR BIO- AND GEO SCIENCES -

LIFE SCIENCES

Nitrogen storage

An international team led by Jülich researchers has discovered that microalgae store vital nitrogen in the form of tiny crystals called guanine. They can draw on this reserve in “hard times”. At the same time, this special form of storage prevents a harmful nitrogen surplus in the organism. The nitrogen balance of the microalgae is essential, among other things, for the phytoplankton to be able to remove vast amounts of CO₂ from the atmosphere. These wee plants are responsible for at least half of the CO₂ that is absorbed worldwide through photosynthesis.

- INSTITUTE OF BIO- AND GEO SCIENCES -

Avoiding blackout – with data

On 8 January 2021, Central Europe was on the verge of a large-scale power blackout. Leonardo Rydin Gorjão from the Institute of Energy and Climate Research (IEK-STE) analyses data that are expected to help prevent such situations.

You have been involved in building a database of worldwide frequency measurements in power grids. What are its benefits?

Small frequency deviations occur in the power grid all the time. Thanks to our database, we can analyse these. This way, risks can be identified and control mechanisms improved in order to prevent excessive frequency interference and, thus, a blackout.

A first analysis of the data is available. What does it reveal?

Frequency interferences in the same grid at widely separated locations such as Istanbul, Karlsruhe and Lisbon influence each other. We have identified how quickly these disturbances subside. The analysis also shows that threatening fluctuations can occur especially in micro and island grids.

Why is it important that your data is publicly accessible?

In socially significant research areas in particular, it is important that all researchers can compare and review data. Open data also facilitates collaboration across disciplines and countries.

FRANK FRICK ASKED THE QUESTIONS.
Accelerating transfer

The winners of the Clusters4Future ideas competition are considered to be the new flagships of the national “High-Tech Strategy 2025”. Forschungszentrum Jülich is involved in two of the seven selected future clusters: one is all about hydrogen as an energy carrier, while the other cluster, called Neurosys, is all about biologically inspired chips for artificial intelligence. The regional networks are to ensure that innovations are incorporated more quickly into everyday life.

SAFETY RESEARCH

Reference for the nuclear detectives

The purpose of the International Atomic Energy Agency (IAEA) is to ensure that countries do not secretly divert nuclear material for nuclear weapons. The IAEA relies on the internationally active Network of Analytical Laboratories (NWAL) to examine samples taken by inspectors on-site at nuclear facilities. The Jülich Institute of Energy and Climate Research (IEK-6) has newly been added as a member of the network. Of the participating laboratories, it is the only one to supply uranium oxide reference particles, which are used to check the quality of NWAL analyses of wipe samples (pictured: Dr. Philip Kegler (left) and Dr. Stefan Neumeier).

PHYSICS

Effect with deceptive fingerprint

The Kondo effect influences the electrical resistance of metals at low temperatures. It is significant for novel data processing concepts, such as for those using quantum dots. According to current theory, a scanning tunnelling microscope (right: schematic representation) provides unequivocal evidence of this effect by producing a characteristic spectroscopic fingerprint. Now, however, Jülich researchers have been able to show that this “distinguishing characteristic” is possibly caused by another phenomenon. Their conclusion: many findings pertaining to the Kondo effect need to be re-examined.
More than 20 years ago, David DiVincenzo formulated five basic criteria that a quantum computer needs to fulfill.
A mysterious world hides deep inside matter – the quantum cosmos. It is governed by laws that are difficult to understand. The things lurking there can be connected through ghostly encounters from afar, both dead and alive at the same time.

Researchers at Jülich have set out to prise the secrets out of the quantum cosmos. One ambitious goal unites them all: they want to learn to control the smallest particles in order to construct a computing machine like the world has never seen before – a powerful quantum computer. This computer could help pharmacists and materials researchers in their search for new active ingredients and catalysts by simulating complex molecules. It could optimise logistics problems and production processes in factories in next to no time – faster than any high-performance computer.

So, the Jülich experts search for exotic materials, using them to design new types of circuits, which they then assemble into the first prototypes. They write singular algorithms and pit their computers against the fastest supercomputers in the world. Forschungszentrum Jülich offers them an optimal environment for their endeavour: modern laboratories and powerful equipment, plus partners from the industry and a local service infrastructure. However, regarding the success of the research site, it is the minds behind the research that will make the difference after all: a team of highly specialised experts who contribute their ideas, knowledge, experience, pioneering spirit and perseverance to achieve the common goal. We would like to introduce them here – who they are, what they have achieved so far and what visions they are pursuing.

In the beginning, there is the idea: information can be carried by the smallest particles such as atoms, electrons or photons. If several of these quantum bits, or qubits for short (see box), are coupled together, countless calculations can be carried out in parallel. On quantum computers, certain algorithms require only a tiny fraction of the time that they need on conventional computers. One of the first to draw up this concept was David DiVincenzo.

DAVID DIVINCENZO
The quantum whisperer

“In the early 1990s, I became interested in computing with quanta. The scene was still rather small at that time,” recalls Prof. David DiVincenzo. A breakthrough, however, came as early as 1994. Mathematicians were able to show for the first time that fast quantum algorithms can actually solve relevant problems. “So they approached us physicists and asked if the quantum processors needed to do this could actually be built.”

Two years later, DiVincenzo defined the basic concept behind all computers of this kind, capturing it in the five criteria named after him. The first criterion describes the basic requirement of any computer of this type: it calculates with qubits instead of bits. “Nowadays, these principles sound like trying to explain to a kindergartener how a computer works. But at the time, we had no precise idea of what a quantum computer could look like,” explains the physicist, who is considered one of the major pioneers in quantum computing. He spent a large part of his career in a research laboratory of IT giant IBM. In 2010, he became JARA Professor at Jülich’s Peter Grünberg Institute (PGI-2 and PGI-11) and RWTH Aachen University. “Here, I have the resources and freedom to pursue my own research interests,” says the physicist. “I also appreciate the environment: the diversity of topics and thought approaches.”

In Jülich, he devotes himself to error correction: The unstable nature of the quantum state frequently results in errors slipping into the calculations. The physicist aims to remedy this: “We are currently..."
pursuing the idea of dividing a qubit into three electrons sitting in a semiconductor cage,” DiVincenzo explains. If an error sneaked into one particle of the trio, it could then easily be checked with the other two.

From idea to implementation: quantum systems must first of all be found that can easily be controlled from the outside. They form the foundation – the smallest unit of a quantum computer. Stefan Tautz is one person who is looking for such materials.

Quantum bits

Otherwise known as qubits, these are the counterpart to classic computer bits: they can be, for example, atoms or ions floating in a row like a string of beads in an optical trap; or they can be superconducting loops through which circular currents flow; they can even be individual electrons trapped in cages made of semiconductor materials, so-called quantum dots. What is crucial is that all these systems can exist in two states that correspond to the binary values of a classical computer: zero or one. Plus, qubits all have the properties of waves, meaning that they can overlap themselves. This state is called “being in superposition”. As a result, they are also able to assume all states between zero and one. The challenge, however, is to protect the fragile quantum state from external interference factors. The superposition must persist long enough to use the qubits to make calculations.

Stefan Tautz is helping to set up the Helmholtz Quantum Center, where all aspects of quantum computing are to be researched.
Whether atom traps, superconductors, semiconductors, Majorana particles or completely different types of qubits: it is not yet decided which technology will perform best. Accordingly, a central technology laboratory, which is currently being set up at Jülich, is designed to be just as versatile: the Helmholtz Quantum Center (HQC). “It covers the whole development arc from the materials to the quantum computer and the algorithms that will run on it,” says Stefan Tautz, who represents the scientists at the HQC. “It will provide a rich ecosystem where all aspects of quantum computing will be explored.” Therefore, the HQC building will accommodate countless specialised labs while offering a strong infrastructure. Because of the fragile nature of qubits, the experiments need to be conducted only just above absolute zero. The premises must be insulated against interferences from magnetic fields, high-frequency fields and vibrations.

The molecule manipulator

Prof. Stefan Tautz can move individual molecules with his bare hands. He directs the tiny entities by swiping through the air. He detaches them from their cluster, shifts them, turns them sideways or arranges them on a surface as desired. Granted: the literal manoeuvring is done by a scanning probe microscope, whose fine probe tip manipulates the molecules. Infrared cameras record the hand movement in three-dimensional space and transmit it to the tip.

This technique of pushing molecules is not new in itself. Researchers at the Peter Grünberg Institute (PGI-3) are now harnessing it to search for new materials for future quantum computers, since individual molecules with the right electronic properties can be used as qubits. “With our microscopes, we can build targeted, customised structures very quickly, a kind of molecular 3D printing,” Tautz explains. “We then test them for their suitability as qubits.”

“Our excellent infrastructure, which we are expanding even further, such as in the Helmholtz Quantum Center (see box), helps us with all of this,” says Tautz. Much more important, however, are the people who come together here to work towards a common goal. “No one builds a quantum computer all by themselves,” says the researcher. “It takes countless experts with a variety of skills and academic backgrounds. Jülich offers the best conditions for this.”

**Bits and qubits**

- 1 qubit encodes a complex number, at least 16 bits.
- 2 qubits encode three complex numbers.
- 10 qubits are equivalent to 16 conventional kilobytes.
- 50 qubits mark the presumed quantum supremacy limit.
- 45 qubits are roughly equivalent to the memory size of the currently largest conventional supercomputer.

**STEFAN TAUTZ**

**The molecule manipulator**

Prof. Stefan Tautz can move individual molecules with his bare hands. He directs the tiny entities by swiping through the air. He detaches them from their cluster, shifts them, turns them sideways or arranges them on a surface as desired. Granted: the literal manoeuvring is done by a scanning probe microscope, whose fine probe tip manipulates the molecules. Infrared cameras record the hand movement in three-dimensional space and transmit it to the tip.

This technique of pushing molecules is not new in itself. Researchers at the Peter Grünberg Institute (PGI-3) are now harnessing it to search for new materials for future quantum computers, since individual molecules with the right electronic properties can be used as qubits. “With our microscopes, we can build targeted, customised structures very quickly, a kind of molecular 3D printing,” Tautz explains. “We then test them for their suitability as qubits.”

“Our excellent infrastructure, which we are expanding even further, such as in the Helmholtz Quantum Center (see box), helps us with all of this,” says Tautz. Much more important, however, are the people who come together here to work towards a common goal. “No one builds a quantum computer all by themselves,” says the researcher. “It takes countless experts with a variety of skills and academic backgrounds. Jülich offers the best conditions for this.”

**Helmholtz Quantum Center**

Whether atom traps, superconductors, semiconductors, Majorana particles or completely different types of qubits: it is not yet decided which technology will perform best. Accordingly, a central technology laboratory, which is currently being set up at Jülich, is designed to be just as versatile: the Helmholtz Quantum Center (HQC). “It covers the whole development arc from the materials to the quantum computer and the algorithms that will run on it,” says Stefan Tautz, who represents the scientists at the HQC. “It will provide a rich ecosystem where all aspects of quantum computing will be explored.” Therefore, the HQC building will accommodate countless specialised labs while offering a strong infrastructure. Because of the fragile nature of qubits, the experiments need to be conducted only just above absolute zero. The premises must be insulated against interferences from magnetic fields, high-frequency fields and vibrations.

**Source (in German):** www.quantencomputer-info.de/quantencomputer/quantencomputer-einfach-erklärt
Once materials have been found to create the qubits, several qubits must be connected to form small, switchable units. In the classic computer, transistors made of semiconductor materials take over this task. New concepts are required for quantum computers, which is what Hendrik Bluhm is working on developing.

HENDRIK BLUHM

The electron shifter

“It is this pioneering work that excites me, this moon-landing character of the research,” says Prof. Hendrik Bluhm. “We are developing a technology with truly tangible benefits on a completely new basis, which knows no comparison in classical data processing.”

The physicist designs elementary components for a future quantum computer and investigates their properties. In order for quantum processors to be able to even exploit their advantage over classical high-performance computers, they must have a sufficient capacity of qubits. “For many of the planned applications, you need millions of qubits. There is still a long way to go before we get there,” explains Bluhm. It is therefore important to develop architectures that can be easily implemented on a large scale. To do this, he relies on so-called semiconductor spin qubits, which store information in the intrinsic angular momentum of individual electrons.

In Hendrik Bluhm’s view, these have important advantages: compared to superconducting systems, semiconductor qubits could be used to create much more powerful processors in the long term. To produce these, the standard processes from established semiconductor manufacturing can be deployed. “In addition, compared to superconducting qubits, they are less susceptible to external disturbances such as thermal radiation or the cosmic background radiation,” explains the JARA professor, who conducts research at Jülich’s Peter Grünberg Institute (PGI-11) and at RWTH Aachen University.

Several electrons are coupled together in order to calculate with semiconductor qubits, that is, their electron spins are entangled with each other. The tiny particles have to be brought close together for this. However, the more electrons that are to be connected, the more difficult this becomes, because then the distance also inevitably increases. Therefore, Hendrik Bluhm’s team is working on a way to move the entangled electrons back and forth across the chip as information carriers. With such an electron shuttle, it could be possible to connect a large number simultaneously (see QUASAR infobox).

Such alternative concepts would offer Europe the opportunity to catch up more easily with the market leaders. Jülich would play a key role in this: “Forschungszentrum Jülich has continuously expanded its competencies in quantum technology in recent years. The group of experts has become consistently larger and more diverse.”

QUASAR and QLSI

The principle of the electron shuttle is intended to be applied to the development of a German semiconductor quantum processor in the QUASAR project. The circuits that have already been successfully tested in the laboratory will be scaled up for this purpose with the ultimate outcome being a demonstrator with 25 coupled qubits. Individual electrons on a chip can be transported over longer distances in a controlled manner via an element referred to as a quantum bus. Other partners from academia and industry are also on board QUASAR. Semiconductor manufacturer Infineon, for example, will investigate how quantum chips can be realised with conventional silicon technology and manufactured on an industrial scale. Jülich is also involved in the European Quantum Flagship’s QLSI project, in which similar silicon-based quantum chips are being developed.

“For many of the planned applications, you need millions of qubits. There is still a long way to go before we get there.”

HENDRIK BLUHM

An overview of Jülich quantum research can be found online in our dossier, “Quantum Technology”: t1p.de/bcd9
something as well. And quantum computing is the ideal field for that.”

At Jülich, the researcher from the Peter Grünberg Institute (PGI-12) is working on combining individual quantum systems into circuits like those found on conventional computer chips. There, they consist of individual transistors that are interconnected in such a way that they can perform fundamental computing operations. For quantum computers, Frank Wilhelm-Mauch is focusing on qubits in superconducting contacts, which are similar to the technology used by Google or IBM. “They provide the starting point of our quantum chips,” he explains. “We are developing new devices on this basis and are looking at strategies to make existing hardware simpler, sturdier and smaller.”

Frank Wilhelm-Mauch fondly remembers his first computer, a Sinclair ZX-81. The British calculating machine was one of the first home computers to come onto the market 40 years ago – even before
the famous Commodore 64. “In terms of development, today’s quantum computers are not quite as far along as the ZX-81 was back then, but the feeling you get while programming is still comparable. It’s about getting the best out of limited hardware.”

Speaking of hardware, the theorist has in fact also been given the opportunity to build a unique prototype: the OpenSuperQ project aims to create a freely programmable quantum computer that is accessible to all researchers in Europe. Wilhelm-Mauch is coordinating the project (see infobox).

“We first need to reduce the probability of error in quantum computers and then increase the number of qubits.”

FRANK WILHELM-MAUCH
interviewed ttp.de/uubl

OpenSuperQ

The OpenSuperQ project aims to produce the first freely programmable European quantum computer that is superior to conventional high-performance computers. For this, at least 50 qubits would have to be entangled with each other. The construction of the computer, which is based on superconducting quantum circuits, is coordinated by Jülich researcher Frank Wilhelm-Mauch: ten partners from science and industry are working together in the OpenSuperQ project. The open-architecture computer will then be remotely available to experts around the world as part of the Jülich quantum infrastructure JUNIQ at the Jülich Supercomputing Centre. OpenSuperQ is part of the European Quantum Flagship. Jülich researchers are also involved in other flagship projects.

Only for certain algorithms can quantum computers exploit their parallel computing advantage. This can occur, for example, when large amounts of data need to be sifted through or the properties of molecules and materials need to be calculated. In order for the corresponding programmes to run smoothly on the computers that are still error-prone, the machines need mature firmware. This programme level, which mediates between the hardware and the applications running on it, is the domain of Tommaso Calarco.
In one process step in a quantum computer, entangled qubits are transferred from one defined state to another. The physicist and his team are developing methods to ensure that potential obstacles and errors are avoided along the way. This happens on a level between the actual quantum computers and the quantum algorithms running on them. “It’s the firmware for quantum computers, exactly between hardware and software,” explains Tommaso Calarco. Firmware performs basic tasks in a computer or other electronic devices. For example, it adapts the quantum computers in such a way that they are able to process new algorithms.

Tommaso Calarco is a man of many talents. He holds a bachelor’s degree in classical guitar, among other things. The fact that he gave preference to quantum physics should be seen as a stroke of luck for the entire European quantum research community: the physics professor is considered the initiator of the Quantum Manifesto that led to the EU’s billion-dollar flagship programme. In it, he holds the office of Chairman of the Quantum Community Network (QCN), which brings science and industry together (see infobox).

In his research, he looks for ways to improve the basic processes and thus the calculation accuracy in quantum computing – as well as for all types of qubits. “In the quantum world, we use the smallest particles such as atoms and electrons. However, we manipulate them with macroscopic tools. It would be like if I played guitar with boxing gloves,” explains Calarco. The necessary intuition is provided by a mathematical method called control theory. It plays an important role in aerospace, for example, but also in optimising production processes. “We have applied this theory to the field of quantum technologies in order to selectively influence quantum processes and get the best performance out of an existing system,” says the scientist from the Peter Grünberg Institute (PGI-8).

TOMMASO CALARCO
The chief networker

In the European Quantum Flagship’s Quantum Community Network (QCN), each member state has two representatives: one from research and one from industry. “The QCN is an important instrument for international networking – facilitating not only the coming together of theorists and experimental groups, but also of science and industry,” explains the QCN chair, Jülich researcher Tommaso Calarco. He also promotes regular exchange with industry through the Quantum Industry Consortium (QuIC), which was established on the initiative of the QCN and brings European companies together.

Quantum Community Network

In one process step in a quantum computer, entangled qubits are transferred from one defined state to another. The physicist and his team are developing methods to ensure that potential obstacles and errors are avoided along the way. This happens on a level between the actual quantum computers and the quantum algorithms running on them. “It’s the firmware for quantum computers, exactly between hardware and software,” explains Tommaso Calarco. Firmware performs basic tasks in a computer or other electronic devices. For example, it adapts the quantum computers in such a way that they are able to process new algorithms.
Applications for quantum computers, the algorithms, can already be developed and tested now, even without ready-made quantum computers being available: these processes can be simulated on conventional high-performance computers. Kristel Michielsen knows how this works.

KRISTEL MICHEISEN
The arithmetic artist

In the pioneering days of quantum computing, her computing skills were in demand: Prof. Kristel Michielsen and her team from the Jülich Supercomputing Centre contributed to Google’s proof of the so-called quantum supremacy in 2019 with simulations on the Jülich supercomputer JUWELS. Quantum supremacy means the point in time at which a quantum computer is, for the first time, superior to a conventional computer in a particular task. Proving this was considered a great challenge.

Kristel Michielsen uses the Jülich high-performance computer JUWELS to test quantum algorithms, that is, programmes that will run on quantum computers in the future. JUWELS can perform 85 petaflops, which means 85 quadrillion computing operations per second. This computing power exceeds that of 300,000 modern PCs. “Strictly speaking, the quantum algorithms can also run on conventional computing machines. Only above a threshold value of about 50 qubits do bit-based computers reach their limits,” explains the researcher.

According to Michielsen, a major advantage of the simulations is that the simulated quantum bits all work a hundred per cent reliably – in contrast to the real circuits on real quantum processors. Comparing simulation and reality also allows for an assessment of a quantum computer’s computational quality.

However, supercomputers reach their limits when it comes to simulating a quantum computer like the ones that are already available today at companies such as IBM or Google. “In 2018, we simulated a process with 48 entangled qubits,” says the physicist. “That was the world record, which might be difficult to tie because with every qubit added on top of that, the memory required by the computer running the simulation doubles.”

ARNDT REUNING
Simulations of quantum computers on high-performance computers are an important component of the Jülich User Infrastructure for Quantum Computing, or JUNIQ for short. It is a kind of machine park for quantum computers that brings devices with different levels of technological maturity together in one place. A 5,000+ Qubit Advantage System, which is a quantum annealer from the Canadian company D-Wave Systems, will be operated at JUNIQ starting mid-year in 2021. By the end of 2022, a quantum simulator from Pasqal will be added, which will be deeply integrated into the JSC’s modular supercomputer architecture. In addition, starting in autumn of 2021, JUNIQ will also be offering remote access to the European quantum computer of the EU flagship project OpenSuperQ, which is operated at the HQC. By 2024, remote access to a digital-analogue quantum computer will be added, which is being developed in the DAQC project (see the Quantum Ticker). In addition, access to a variety of other systems is planned, including hybrid systems. There are also support, training and collaboration opportunities, and software tools, modelling concepts and algorithms as well as prototype applications are being developed. “Every user of this infrastructure will then have a whole range of systems at their disposal, from which they can choose what is best for them,” says Jülich physicist Kristel Michielsen, one of the initiators of JUNIQ.

DIGITAL AND ANALOGUE WORK HAND IN GLOVE

Jülich researchers are involved in the DAQC joint project. It aims to build and operate a digital-analogue quantum computer. Analogue quantum computers, in which the qubits interact continuously with each other, are less prone to error. However, they are not universally programmable. Their robustness is now to be combined with the flexible computing power of digital circuits.

YIN-YANG QUBITS GO PERFECTLY WELL TOGETHER

An international team involving Jülich researchers has succeeded in perfectly entangling two qubits. This entanglement is essential for the two information carriers to be able to interact with each other at all. In this, however, the qubits are typically always hindered by a parasitic interaction based on mutual repulsion. This leads to errors when calculating. The scientists have now coupled two complementary types of superconducting qubits: the two differed in the sign of what’s known as anharmonicity, through which the mutual repulsion could be avoided. As in the Far Eastern yin-yang symbol, the two opposing qualities balanced each other out. The researchers were able to show that the accuracy of the computing operation could be significantly improved for the tiny quantum circuit.

ION TRAPS AND SUPERCOMPUTERS CALCULATE TOGETHER

Forschungszentrum Jülich also contributes to the joint project IQuAn. It focuses on quantum computers that work with ions in traps. Their advantage: they retain their quantum state for a relatively long time. In the IQuAn project, novel architectures are being tested for such systems, which allow for up to 100 qubits to calculate together. A hybrid system is planned in which a quantum processor is connected to a high-performance computer.

PRECISE CONTROL IMPROVES QUBIT QUALITY

The GeQCoS project has set itself the goal of fundamentally improving quantum processors with superconducting qubits. The central component is to consist of only a few computing cells, but they will be more strongly interconnected than in previous models. Particular emphasis is placed on improving the quality of the qubits. Among other things, Jülich researchers are contributing methods for the precise control of qubits to GeQCoS.

A GYRATOR ENSURES QUANTUM BALANCE

Researchers from Jülich, Aachen, Basel and Delft have designed a quantum circuit with a built-in passive error correction. It is based on qubits in superconducting loops. Usually, errors here have to be corrected by active intervention: several unstable qubits have to be combined to form a logical qubit. This makes it possible to identify errors and eliminate them through corrective operations. In the novel circuit, a so-called gyrator renders this intervention redundant. The electrical component has two ports and couples current at one port to voltage at the other. It is implemented between two superconducting qubit loops and stabilises the stored information. This principle could greatly simplify the construction of a quantum computer with a large number of qubits in the future.
The Sun produces not only light and heat, but also neutrinos. With the help of these particles, researchers have, for the first time, demonstrated a special fusion process in the Sun.

Neutrinos originate from our Sun as one of the products of nuclear fusion. Unlike light, however, which takes several hundreds of thousands of years to travel through the hot and dense stellar matter, neutrinos penetrate to the outside without hindrance. As they interact only weakly with matter, these particles are almost impossible to detect. Physicists are trying to do so with the help of the Borexino experiment, which is being conducted near Rome in the world’s largest underground experimental laboratory. “More than ten years ago, we first detected neutrinos from inside the Sun,” says Ludhova. Borexino can reliably determine not only the quantity of neutrinos, but also their energy. “With its energy, each neutrino carries with it a fingerprint of the reaction from which it originated,” Ludhova explains.

In 2020, the researchers were able to identify neutrinos from the CNO process in the Sun using data obtained from Borexino since July 2016. There, this process plays a minor role, because the sun, being a so-called low-mass star, only derives about one per cent of its energy from this process, in contrast to high-mass stars. Nevertheless, the discovery is a great scientific success as it proves the existence of the CNO cycle: the journal Physics World lists it among the ten most important breakthroughs in physics in 2020.

The detection of the CNO process in the Sun can reveal even more about the interior of the Sun, such as the proportion of elements that are heavier than hydrogen and helium. Livia Ludhova is confident: “Through the analyses of the measurements, we will improve our understanding of the Sun and also of other stars.”
If water is split in an electrolysis system using electricity from renewable sources in a climate-neutral way, so-called “green hydrogen” is produced. It is considered an important component of energy transition because, among other things, wind or solar energy can be stored in it and released again when needed. However, producing hydrogen is expensive. This impedes its widespread use. Researchers from Jülich, Aachen, Stanford and Berkeley have discovered an effect by means of which the amount of hydrogen produced can be doubled in a model system – without increasing the required energy and costs. The effect is caused by a layer just 200 billionths of a millimetre thick.

THE SURFACE DOES THE TRICK

The layer referred to here is the surface of an electrode: during electrolysis, hydrogen is formed at the negatively charged electrode (cathode), while oxygen is formed at its positive counterpart (anode). Both processes can only co-occur, so that facilitating the formation of oxygen also increases hydrogen production.

Lanthanum nickelate (LaNiO₃) is an established catalyst that promotes this electrolytic formation of oxygen. In its crystal structure, nickel oxide and lanthanum oxide layers alternate. Normally, it is a coincidence which layer forms the surface of the anode. The German-American research team has developed a method with which they can determine whether a layer of lanthanum oxide or one of nickel oxide is on top.

“Surprisingly, this makes a huge difference,” says physicist Dr. Christoph Bäumer from the Peter Grünberg Institute (PGI-7), who was significantly involved in the research, both in Jülich and Aachen and in the USA. The researchers found that an anode with a nickel oxide surface produced twice as much oxygen in the same time as the other variant. The reason: during electrolysis, only this surface develops a disordered, catalytically very active layer that encourages the formation of oxygen.

“So far, our results only constitute basic research. However, they suggest that when developing better catalysts, one must also bear in mind for other materials that the uppermost atomic layer can be decisive for the electrochemical processes that take place under operating conditions,” says Bäumer.

Inside the electrolysis cell

Twice as much oxygen is produced at the anode with the nickel oxide surface (left) as at the lanthanum oxide variant (right). Likewise, because the processes are coupled, more hydrogen is formed at the cathode.
A total power blackout would cripple a country’s infrastructure in no time. For this reason, power grids are usually constructed in such a way that they can compensate for fluctuations and damage to individual lines. This is achieved by having several pathways leading from the source to the consumer. If necessary, the power can thus bypass single interruptions in the grid. This so-called mesh architecture is therefore much less susceptible to disruption than a tree structure, which branches out increasingly, but in which only one pathway connects source and consumer at a time. However, the mesh architecture requires more lines in a power grid and incurs higher costs.

Larger regions, such as entire countries, are usually supplied by means of mesh power grids. For smaller areas, such as individual municipalities, the more economical tree structures are more likely to be used. Both types are also used in other technical networks, including water supply or telecommunications. Franz Kaiser and Prof. Dirk Witthaut from the Institute of Energy and Climate Research (IEK-STE) are using models to investigate how power grids should best be structured.

When exchanging ideas with their colleague Dr. Henrik Ronellenfitsch (formerly of the Massachusetts Institute of Technology, now of Williams College in the USA), who does a lot of

**Nature as a model for power grids**

- **Tree structure**
- **Mesh structure**

- Gingko leaf
- Poplar leaf

**Well-supplied**

We expect power grids to reliably supply us with energy even when there are fluctuations and faults in the lines. Models of how to plan technical supply networks even better can be found in networks in nature. Based on these, Jülich researchers have developed a model with which they want to calculate optimal grids in the future.
The first mesh structure would form slowly when influences such as input fluctuations or the degree of the damage change slightly,” says Kaiser. However, that is not the case. From a mathematical point of view, even very small changes can lead to the model yielding a new ideal network in which there is suddenly a mesh where before there had been none – that is, a new pathway within the network.

The researchers want to transfer their theoretical findings on the development of networks to concrete technical systems such as the power grid, using their model to calculate how to design such systems efficiently. At what points, for example, are meshes in a regional power grid expedient in order to compensate for possible disruptions, and what costs are incurred as a result? “If we then estimate the cost range of power outages, we can also estimate the savings that are possible with a mesh network,” Kaiser adds.

“The work is a good example of how interdisciplinary cooperation can advance research and how results that, at first glance, seem very theoretical can help answer everyday questions – in this case, the question of the optimal structure of power grids and other supply networks,” Dirk Witthaut says happily.

Meshless supply networks (left) provide only one possible pathway from the source to the consumer. This type of network is technically simpler and cheaper to set up and maintain, but also more prone to failure than meshed ones: in a mesh network, failure of a connection can be compensated for by other paths. An example of meshless supply networks is the vascular system of the ginkgo. The leaf of the poplar, on the other hand, has several meshes (right). The Jülich researchers’ model can be used to construct the transition from tree-like to mesh-like structures. This helps in planning when and where it makes sense to incorporate meshes.

Analyses by other researchers had already shown that in nature, fluctuations and disturbances in the networks lead to the formation of meshes. Apparently, the mesh structure has proven successful in compensating for interruptions in the system – for example, if insects nibble a leaf, the plant can use other pathways in the existing supply network to bypass the damaged area.

This network behaviour can be modelled. “With our simulations, we see that, for example, a network that is exposed to more damage develops differently from one that is largely ‘trouble-free’,” Kaiser explains. The scientists can also reconstruct when and at which location the first mesh in the network is created when certain parameters change. The surprising result: the change is saltatory. “You might think that

Meshless supply networks (left) provide only one possible pathway from the source to the consumer. This type of network is technically simpler and cheaper to set up and maintain, but also more prone to failure than meshed ones: in a mesh network, failure of a connection can be compensated for by other paths. An example of meshless supply networks is the vascular system of the ginkgo. The leaf of the poplar, on the other hand, has several meshes (right). The Jülich researchers’ model can be used to construct the transition from tree-like to mesh-like structures. This helps in planning when and where it makes sense to incorporate meshes.

Analyses by other researchers had already shown that in nature, fluctuations and disturbances in the networks lead to the formation of meshes. Apparently, the mesh structure has proven successful in compensating for interruptions in the system – for example, if insects nibble a leaf, the plant can use other pathways in the existing supply network to bypass the damaged area.

With the new network model, Franz Kaiser wants to provide the foundations for building an efficient power grid.

Dirk Witthaut investigates and models energy systems with a particular focus on the stability and dynamics of networks.

NATURE PREFERS MESH

Analyses by other researchers had already shown that in nature, fluctuations and disturbances in the networks lead to the formation of meshes. Apparently, the mesh structure has proven successful in compensating for interruptions in the system – for example, if insects nibble a leaf, the plant can use other pathways in the existing supply network to bypass the damaged area.

This network behaviour can be modelled. “With our simulations, we see that, for example, a network that is exposed to more damage develops differently from one that is largely ‘trouble-free’,” Kaiser explains. The scientists can also reconstruct when and at which location the first mesh in the network is created when certain parameters change. The surprising result: the change is saltatory. “You might think that
Research in times of corona

More than a year after the start of the pandemic, the virus is still one step ahead of man. With mutations, SARS-CoV-2 has increased its pace, but science is hot on its heels. Mathematics, physics and supercomputers help to better understand the spread and properties of the virus in order to slow it down.

Participation matters!

As long as much of the population is not vaccinated, reducing contact remains the sharpest weapon in the fight against the pandemic. Calculations by the Jülich Supercomputing Centre and the Frankfurt Institute for Advanced Studies show how strongly the “participation rate” affects the occurrence of infection: a significant decline in new infections can only be achieved within a few weeks if contact restrictions are sufficiently strong and enough people adopt the rules. Based on the numbers in Germany in autumn 2020, the researchers assumed an R value of 1.5 and a 7-day incidence of 150 at the start of their simulations.

Scenario 1: One part of the population reduces physical contact by 75 per cent, while the other part does not change behaviour – in the first picture, 50 per cent join in, in the second 70 per cent and in the third 90 per cent. Only the last variant succeeds in significantly reducing the number of infections within weeks.

Scenario 2: Among the participating part of the population, physical contact is reduced by 50 per cent. Even at a rate of 90 per cent, the spread of infection is barely contained.
Computing power against SARS-CoV-2

Vaccination is going well. What is still missing, however, is an effective cure. In an international joint project with 18 institutions from seven European countries (Exscalate4CoronaVirus), Jülich researchers are hunting for molecules that block central proteins of the coronavirus and, thus, its replication.

They are using the computing power of Europe’s largest supercomputer centres for this, including the Jülich Supercomputing Centre: within weeks, they had checked the effect of millions of molecules. In the process, the researchers have found a way to more accurately predict which molecules inhibit the main 3CL protease of SARS-CoV-2 in the computer model.

The 3CL protease is an enzyme that enables the virus to replicate.

The team has taken into account the extremely flexible 3D structure of the active enzyme centre, which is crucial for its function. They calculated the numerous formations that the centre can adopt and what possible inhibitors would have to look like in order to block it.

Prof. Giulia Rossetti from the Institute of Neuroscience and Medicine (INM-9/IAS-5) and the Jülich Supercomputing Centre (JSC) says: “We have thus succeeded in identifying two new 3CL protease inhibitors. The method can also be applied to other proteins that have similarly flexible properties.”

3 questions for ...

... Prof. Jörg Labahn and Dr. Aurel Radulescu. Both work at Jülich branch offices: Jörg Labahn, from the Centre for Structural Systems Biology, uses Germany’s most intense X-ray sources at the DESY research centre in Hamburg to decipher structures of central proteins in the virus. Aurel Radulescu, a staff member at the Jülich Centre for Neutron Science in Garching, uses the neutron scattering instruments at Heinz Maier-Leibnitz Zentrum to investigate nanoparticles that coat the novel messenger RNA vaccines.

What exactly are you researching?

Jörg Labahn: We are investigating three proteins: the spike protein, which the virus uses to enter the cell; another that is essential for replication; and a third one called NSP6, about which we still don’t know much, though.

Aurel Radulescu: Without a nanoparticle coating, the messenger RNA of the vaccine would be destroyed directly by the body’s own enzymes – even before it can be taken up by cells and its information be read. We want to know how to improve the packaging.

What questions do the X-ray and neutron sources answer?

Jörg Labahn: With the help of X-ray structural analysis, we throw light on how the spike protein attaches to the cell. We also use it to study the structure of other corona proteins to find out how to block them and thus prevent the virus from replicating.

Aurel Radulescu: Neutron scattering characterises the internal organisation of nanoparticles. With this knowledge, we can assess whether a nanoparticle is suitable for introducing messenger RNA vaccines or other therapeutic agents into the cell.

What are the next goals?

Jörg Labahn: Of substances which have already been approved for therapeutic applications, we want to identify those that inhibit the functions of the viral target proteins. In the case of the membrane protein NSP6, it is also important to find out whether it is suitable as a target for medications.

Aurel Radulescu: Our results show that nanoparticles made of a combination of lipids and polymers significantly improve the transfer of messenger RNA into the cell. This can help to advance the further development of customised therapeutics and RNA vaccines.

RNA vaccines

Instead of a virus, these vaccines contain the building instructions for part of the virus in the form of messenger RNA. This causes the cells to produce the spike protein, which is then recognised by the body as “foreign” and attacked by the immune system.
A comeback for Europe’s solar industry?

In 2012, eight of the world’s ten largest photovoltaic companies were from Germany. Today, there is no German solar cell producer among the top 30. The competition from China in particular has prevailed in the price war. There is now hope for a renaissance in Europe, however. Photovoltaics expert Prof. Uwe Rau explains the background in an interview.

Prof. Rau, what is it that raises hope for a renaissance in European photovoltaic production?
We are on the verge of transitioning to a new level of technology. Some compare this to the transition from 4G to 5G in mobile communications. New types of solar cells are expected to come onto the market soon, such as silicon heterojunction solar cells – SHJ solar cells for short (see infobox) – or a variant of them, the IBC-SHJ. They offer a higher degree of efficiency as an advantage. Plus, Europe is ahead of the game here. An IBC-SHJ solar cell developed in the EU project NEXTBASE, which our institute coordinated, achieves an efficiency of up to 25.4 per cent. This is almost 3 per cent more than commercially available PERC cells, which convert sunlight into electricity with an efficiency of around 22.5 per cent. Moreover, we developed an industrially producible SHJ solar cell at Forschungszentrum Jülich that reaches 24.5 per cent.

How can some 3 per cent efficiency make a big difference?
With solar cells, it’s all about how much electricity they generate per surface area. In Germany in particular, the space needed for the modules is limited and very expensive. In addition to that, highly efficient cells can significantly reduce the cost of the electricity generated.

Are there any concrete plans to use the new technologies?
The partners in the NEXTBASE project have also developed manufacturing processes for the new solar cell that are suitable for industrial mass production. One of the industrial partners in NEXTBASE, Swiss company Meyer Burger, has announced they will start producing SHJ solar cells and modules “Made in Europe” this year at their German sites in Freiberg and the Thalheim district of Bitterfeld-Wolfen. The company is also already developing the production technology for IBC-SHJ cells. Another, even more efficient technology is also waiting in the wings: the tandem solar cell. Here, a second cell – made of perovskite, for example – is stacked on top of the silicon cell. The company Oxford PV is currently building a corresponding production line in Brandenburg, which is scheduled to start full operation in early 2023. The production technology for manufacturing the tandem solar cell and the underlying silicon cell also comes from Meyer Burger.

Can the new modules from Europe keep up in terms of price?
The costs of industrial production of the new modules will probably be in a range similar to the production costs of today’s commercially available PERC modules, which are mainly manufactured in Asia. So Europe could get back into manufacturing here. This would also make sense from an economic-political perspective.

Why’s that?
If we have production lines on a relevant scale again, research in Europe can increasingly drive further developments in this field. What’s more, an independent European value chain would minimise dependencies and risks.

Does it matter whether electricity in Germany, for example, is generated by modules from China or from Europe?
As a matter of fact, China currently dominates the world market with low-cost modules. The electricity generated by these modules is of course the same as that of a module from Europe. For the energy transition, however, solar power systems with a total output of several gigawatts will have to be installed every year in Germany alone. Therefore, the technology is of major importance and involves huge investments. Production in Europe would ensure that alternatives are always available on the world market. For example, the corona pandemic has also affected the supply chains of the solar industry: deliveries have been delayed and have become more expensive. Political or economic conflicts could lead to bottlenecks as well.

The interview was conducted by Frank Frick
Uwe Rau is Director of the Institute of Energy and Climate Research, active in the Photovoltaics section, and professor at RWTH Aachen University. He has been researching solar cells for over 25 years.

Types of solar cells

**PERC**
“Passivated Emitter and Rear Cells” are the current standard for solar cells made of crystalline silicon. A special layer on the back of the module reflects mainly red light, which remained unused in earlier modules. The light can thus generate electricity in a second run and improves efficiency.

**SHJ**
In the silicon heterojunction solar cell, a monocrystalline silicon wafer is coated by ultra-thin layers of disordered silicon atoms. On the surfaces of the wafer, these layers inhibit the rapid reunification of negative and positive charge carriers, which were separated by the solar energy.

**IBC-SHJ**
Whereas the current generated in silicon cells, including SHJ, is normally dissipated through electrical contacts on the front and back, the IBC-SHJ cell’s conductive paths are all on the back. As a result, the front is less shaded and the entire surface can be used to absorb sunlight.

**Silicon perovskite tandem cell**
While silicon captures light mainly in the red and infrared range, perovskite materials are mainly receptive to blue and green light. With a cell tandem of silicon and perovskite, the entire solar spectrum is thus used, which increases the efficiency (world record at present: 29.5 per cent).
So much for “birdbrain”!

The bird brain was previously considered unstructured. A method developed at Jülich has now proven otherwise, which could explain the smart behaviour of some types of birds. According to the journal Science, the finding is one of the ten most important breakthroughs of 2020.

Skilled craftsmen: straight-billed crows build tools which they use to fish for tasty tidbits in rotten tree trunks.
An answer has now been found by a team led by Prof. Katrin Amunts and Prof. Markus Axer from the Institute of Neuroscience and Medicine (INM-1) in collaboration with researchers from the universities of Düsseldorf, Aachen and Bochum: they were the first to discover structures in the bird brain that resemble the cerebral cortex of mammals. As in the neocortex, the birds’ nerve cells form horizontal layers and vertical columns. The team published their findings in the journal Science – and these findings ended up as one of the magazine’s top ten most important findings in 2020.

MAKING BRAIN STRUCTURE VISIBLE

The Jülich researchers used a special type of light microscopy to make larger areas of the bird brain visible (see infobox): “We brought together the techniques of polarized light microscopy with the efficient data analysis of supercomputing. The result is the so-called ‘3D Polarized Light Imaging,’ or 3D-PLI for short,” explains Axer, who heads a research group on the method at Forschungszentrum Jülich. The images taken with 3D-PLI show how brain regions are connected via nerve fibres, making their position, course and orientation visible – that is, the paths along which signals are transmitted. Axer sums their research up: “Our results suggest that bird and primate brains, despite all their obvious differences, show strong similarities when observed in high-resolution detail – which also suggests similar thinking abilities.”

It beats its European relatives by a beak: the straight-billed crow of the Pacific island of New Caledonia. This crow builds tools from branches and twigs to reach its favourite food – larvae and maggots in rotten wood. Even more amazing: it makes the tool not only to get at the food, but also to fish for even better tool-building materials. Science sees the use of tools that do not directly serve to obtain food as a typical characteristic of intelligence. No wonder, then, that behavioural scientists consider the straight-billed crow to be one of the most intelligent birds. However, fellow species are also considered cunning and astute: corvids, for example, deceive their competitors by hiding and stealing food; grey parrots have a talent for mimicking human speech; and magpies recognise their own reflection – all amazingly intelligent feats.

But how do our feathered friends succeed in thinking in such a complex way? After all, their brain is no larger than a walnut at most, and researchers have previously searched in vain for a structured cerebral cortex like that of mammals. A part of the cerebral cortex referred to as the neocortex is, in a sense, the control centre of human intelligence. This unique structure is responsible for our ability to dream, speak or think in complex ways.

“Our results suggest that bird and primate brains show strong similarities when observed in high-resolution detail.”

MARKUS AXER

Grey parrots have a strong gift for speaking and help their fellow parrots without immediate reciprocation.

Markus Axer uses the 3D-PLI method to make nerve networks in the brain visible.
Axer has been working on polarized light microscopy imaging in Jülich since 2006. The physicist established the 3D-PLI method at Forschungszentrum Jülich and continually advanced it. He had previously adopted it from his older brother Hubertus, who is a specialist in neurology and anatomy. “The method has become somewhat of a family affair,” says Axer. Back then, however, his big brother had lacked the means to improve the technology.

The researchers have now already used the method to analyse three complete pigeon brains at a resolution of 1.3 thousandths of a millimetre. In each case, 250 wafer-thin sections were scanned at high resolution and reconstructed three-dimensionally. In the near future, these will be the basis of the first bird brain atlases, which Axer and his team want to make available to the community via the Human Brain Project’s EBRAINS brain research. Prof. Katrin Amunts, director of the participating institutes in Jülich and Düsseldorf, also shares their enthusiasm: “3D-PLI contributes significantly to a deeper understanding of the brain’s connectivity structure. The method also makes it possible to detect similarities and differences in the structure of neuronal networks across species.”

Axer assumes that the method will shine the “right polarization light” onto other brain regions. One thing is certain: “For the bird brain, it has definitely been a breakthrough.”

**What is 3D-PLI?**

The famous German neuroanatomist and brain mapper Korbinian Brodmann (1868–1918) already observed that light refracts differently in brain tissue than in other body tissue. Science speaks of birefringence. This is caused by the myelin sheath, which covers many nerve fibres like an insulation. Researchers measure this birefringence using a special light microscopy technique: polarized light microscopy. A microscope of this kind has special filters that only allow certain light to pass through, called polarized light.

“We measure how this polarized light changes when we shine it through brain tissue. With the help of supercomputers and efficient data analysis, we calculate the paths of the nerve fibres,” explains Axer. With this “3D Polarized Light Imaging” method, 3D-PLI for short, the researchers are able to visualise the orientation, position and course of nerve fibres for the entire brain.

The method fills a gap that other methods overlook: they either provide a very detailed view of the brain using tissue samples that show individual cells and their connections, which is time-consuming, or, as with MRI images, they make whole brain regions visible quickly, but in low resolution.

“The method has become somewhat of a family affair,” says Axer. Back then, however, his big brother had lacked the means to improve the technology.

The researchers have now already used the method to analyse three complete pigeon brains at a resolution of 1.3 thousandths of a millimetre. In each case, 250 wafer-thin sections were scanned at high resolution and reconstructed three-dimensionally. In the near future, these will be the basis of the first bird brain atlases, which Axer and his team want to make available to the community via the Human Brain Project’s EBRAINS brain research. Prof. Katrin Amunts, director of the participating institutes in Jülich and Düsseldorf, also shares their enthusiasm: “3D-PLI contributes significantly to a deeper understanding of the brain’s connectivity structure. The method also makes it possible to detect similarities and differences in the structure of neuronal networks across species.”

Axer assumes that the method will shine the “right polarization light” onto other brain regions. One thing is certain: “For the bird brain, it has definitely been a breakthrough.”

**What is 3D-PLI?**

The famous German neuroanatomist and brain mapper Korbinian Brodmann (1868–1918) already observed that light refracts differently in brain tissue than in other body tissue. Science speaks of birefringence. This is caused by the myelin sheath, which covers many nerve fibres like an insulation. Researchers measure this birefringence using a special light microscopy technique: polarized light microscopy. A microscope of this kind has special filters that only allow certain light to pass through, called polarized light.

“We measure how this polarized light changes when we shine it through brain tissue. With the help of supercomputers and efficient data analysis, we calculate the paths of the nerve fibres,” explains Axer. With this “3D Polarized Light Imaging” method, 3D-PLI for short, the researchers are able to visualise the orientation, position and course of nerve fibres for the entire brain.

The method fills a gap that other methods overlook: they either provide a very detailed view of the brain using tissue samples that show individual cells and their connections, which is time-consuming, or, as with MRI images, they make whole brain regions visible quickly, but in low resolution.

“The method has become somewhat of a family affair,” says Axer. Back then, however, his big brother had lacked the means to improve the technology.

The researchers have now already used the method to analyse three complete pigeon brains at a resolution of 1.3 thousandths of a millimetre. In each case, 250 wafer-thin sections were scanned at high resolution and reconstructed three-dimensionally. In the near future, these will be the basis of the first bird brain atlases, which Axer and his team want to make available to the community via the Human Brain Project’s EBRAINS brain research. Prof. Katrin Amunts, director of the participating institutes in Jülich and Düsseldorf, also shares their enthusiasm: “3D-PLI contributes significantly to a deeper understanding of the brain’s connectivity structure. The method also makes it possible to detect similarities and differences in the structure of neuronal networks across species.”

Axer assumes that the method will shine the “right polarization light” onto other brain regions. One thing is certain: “For the bird brain, it has definitely been a breakthrough.”

**What is 3D-PLI?**

The famous German neuroanatomist and brain mapper Korbinian Brodmann (1868–1918) already observed that light refracts differently in brain tissue than in other body tissue. Science speaks of birefringence. This is caused by the myelin sheath, which covers many nerve fibres like an insulation. Researchers measure this birefringence using a special light microscopy technique: polarized light microscopy. A microscope of this kind has special filters that only allow certain light to pass through, called polarized light.

“We measure how this polarized light changes when we shine it through brain tissue. With the help of supercomputers and efficient data analysis, we calculate the paths of the nerve fibres,” explains Axer. With this “3D Polarized Light Imaging” method, 3D-PLI for short, the researchers are able to visualise the orientation, position and course of nerve fibres for the entire brain.

The method fills a gap that other methods overlook: they either provide a very detailed view of the brain using tissue samples that show individual cells and their connections, which is time-consuming, or, as with MRI images, they make whole brain regions visible quickly, but in low resolution.

“This method has become somewhat of a family affair,” says Axer. Back then, however, his big brother had lacked the means to improve the technology.

The researchers have now already used the method to analyse three complete pigeon brains at a resolution of 1.3 thousandths of a millimetre. In each case, 250 wafer-thin sections were scanned at high resolution and reconstructed three-dimensionally. In the near future, these will be the basis of the first bird brain atlases, which Axer and his team want to make available to the community via the Human Brain Project’s EBRAINS brain research. Prof. Katrin Amunts, director of the participating institutes in Jülich and Düsseldorf, also shares their enthusiasm: “3D-PLI contributes significantly to a deeper understanding of the brain’s connectivity structure. The method also makes it possible to detect similarities and differences in the structure of neuronal networks across species.”

Axer assumes that the method will shine the “right polarization light” onto other brain regions. One thing is certain: “For the bird brain, it has definitely been a breakthrough.”

**What is 3D-PLI?**

The famous German neuroanatomist and brain mapper Korbinian Brodmann (1868–1918) already observed that light refracts differently in brain tissue than in other body tissue. Science speaks of birefringence. This is caused by the myelin sheath, which covers many nerve fibres like an insulation. Researchers measure this birefringence using a special light microscopy technique: polarized light microscopy. A microscope of this kind has special filters that only allow certain light to pass through, called polarized light.

“We measure how this polarized light changes when we shine it through brain tissue. With the help of supercomputers and efficient data analysis, we calculate the paths of the nerve fibres,” explains Axer. With this “3D Polarized Light Imaging” method, 3D-PLI for short, the researchers are able to visualise the orientation, position and course of nerve fibres for the entire brain.

The method fills a gap that other methods overlook: they either provide a very detailed view of the brain using tissue samples that show individual cells and their connections, which is time-consuming, or, as with MRI images, they make whole brain regions visible quickly, but in low resolution.

“This method has become somewhat of a family affair,” says Axer. Back then, however, his big brother had lacked the means to improve the technology.

The researchers have now already used the method to analyse three complete pigeon brains at a resolution of 1.3 thousandths of a millimetre. In each case, 250 wafer-thin sections were scanned at high resolution and reconstructed three-dimensionally. In the near future, these will be the basis of the first bird brain atlases, which Axer and his team want to make available to the community via the Human Brain Project’s EBRAINS brain research. Prof. Katrin Amunts, director of the participating institutes in Jülich and Düsseldorf, also shares their enthusiasm: “3D-PLI contributes significantly to a deeper understanding of the brain’s connectivity structure. The method also makes it possible to detect similarities and differences in the structure of neuronal networks across species.”

Axer assumes that the method will shine the “right polarization light” onto other brain regions. One thing is certain: “For the bird brain, it has definitely been a breakthrough.”
"We are interested in phages. These viruses look a bit like tiny lunar modules. In reality, however, they are not bluish violet and measure only about 50 to 200 nanometres. Phages are masters at manipulating their hosts: bacteria. They specifically change the metabolism of the bacteria so that they can multiply optimally in them. We would like to copy the tricks they use and apply them in industrial processes – for example, in order to have bacteria produce active medical ingredients or fine chemicals.”
Semiconductors are solids. Their electrical conductivity lies between that of insulators and that of electrical conductors such as copper—but it can be changed in a targeted way.

**HEAT-FRIENDLY**
Semiconductors do not conduct electricity at temperatures close to the absolute zero of -273.15 degrees Celsius. If the temperature rises, their conductivity increases—unlike with metals.

**MIGRATION-FRIENDLY**
In contrast to metals, not only negatively charged electrons migrate in semiconductors. The electrons leave behind positive voids, so-called holes, which also move.

**TRANSFORMATION-FRIENDLY**
The properties such as the conductivity of a semiconductor can be specifically influenced by heat and light, but also by incorporating foreign atoms (doping).

**VARIABLE TYPES**
Semiconductors can be made either from one element (particularly from silicon), from a combination of different substances, such as gallium arsenide, and from organic, that is, carbonaceous materials.

**IN USE EVERYWHERE**
Semiconductors paved the way for the triumph of microelectronics. They are in computer chips, smartphones, television sets, cars, solar cells and lasers. They are also interesting for quantum computers.

**WHAT IS JÜLICH DOING?**
Researchers are dealing with fundamental questions of semiconductor physics, with materials and technologies. They are developing devices and components for nanoelectronics, laser technology, photovoltaics and quantum computing.
Anniversary Year

200 years: Hermann von Helmholtz

He devoted himself to optics and acoustics, researched questions of geology, meteorology and thermodynamics: Hermann von Helmholtz (1821–1894) is considered one of the last polymaths. His drive to get to the bottom of the phenomena of our world is still a model for many researchers today. It is not without reason that the Helmholtz Association, to which Forschungszentrum Jülich also belongs, named itself after this exceptional natural scientist. This year, its namesake celebrates a special anniversary: on 31 August, the scientist would have turned 200.

Congratulations!

- HELMHOLTZ200.DE - (German website)

Experimenting at Home

Taking off like a rocket

“What happens when the polar ice caps melt?”, or “Let’s build a rocket engine”: with a wide variety of offers, the 30 Helmholtz school labs show how children and young people can get a taste of research and understand the scientific connections by means of doing their own experiments. The experiments are presented in videos, comics and brochures so that everyone can turn their home into a research laboratory – not only in times of a pandemic.

- HELMHOLTZ.DE/FORSCHUNG/AKTUELLES/EXPERIMENTE-FUER-ZUHAUSE - (German website)

Virtual Tours

Visit museums from your sofa

Corona has severely restricted public life – even museums are affected. Some institutions, however, have opened their doors virtually and invite visitors to take an interactive tour. For example, culture and technology enthusiasts can explore the Deutsches Museum in Munich from home, marvelling at permanent exhibit highlights such as the telescope of the Bavarian optician Fraunhofer or the table on which the atomic age began with the first nuclear fission in 1938.

- VIRTUALTOUR.DEUTSCHES-MUSEUM.DE -
Next phase: the PRI-002 Alzheimer’s drug candidate (#Alzheimer-Wirkstoffkandidat), developed at Jülich, can now demonstrate its therapeutic effect in Alzheimer’s patients.

What’s called the Phase II clinical trial, involving Alzheimer’s patients and scheduled to start in 2022, aims to show that PRI-002 has a positive effect on memory and cognition. Results are expected by 2026 at the latest. The drug candidate developed by Prof. Dieter Willbold (photo) and his team has already demonstrated safety and tolerability in daily use over a four-week period. The Federal Agency for Disruptive Innovation, SPRIND, supports the project.

[link]