

# Annual Report 2014



# Facts and Figures



Forschungszentrum Jülich  
at a glance

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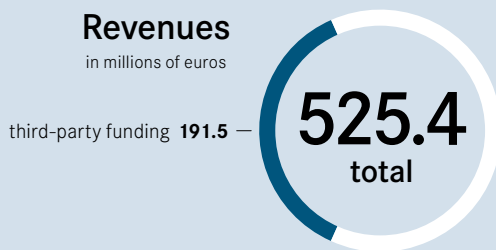
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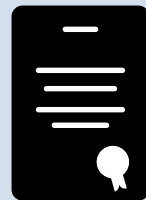


# Highlights 2014

Forschungszentrum Jülich addresses the pressing issues facing society in the fields of energy and the environment as well as information and the brain. As a member of the Helmholtz Association, it is one of the large interdisciplinary research centres in Europe.



**47**  
joint professorial  
appointments  
of the Jülich Aachen Research Alliance

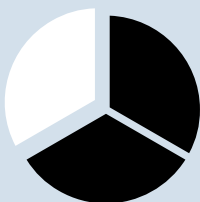


**84**  
new patent applications



**138**  
patents granted

**378**  
involvements  
in nationally funded projects



**1.33**  
funding turnover  
at Project Management Jülich  
in billions of euros



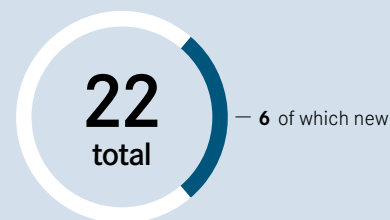
**1,614**  
publications  
in peer-reviewed journals



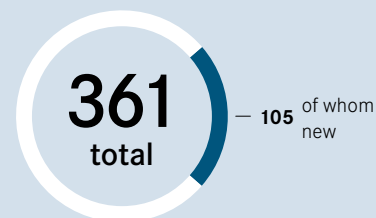




### Young investigators groups



### Trainees and interns



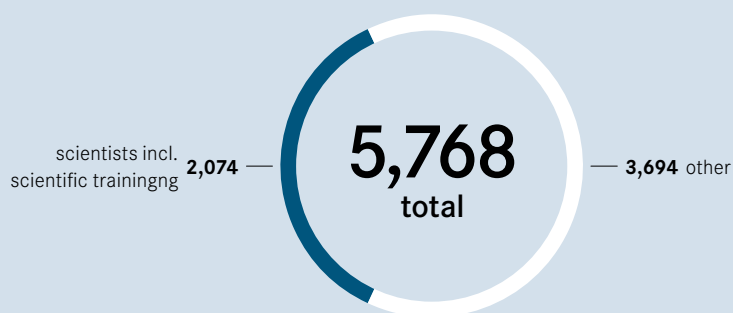
**907**  
visiting scientists



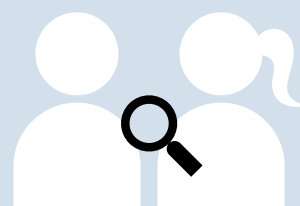
**2**  
ERC Starting Grants



### Employees



**3,830**  
school students at JuLab



## Board of Directors



**Professor Dr.-Ing. Harald Bolt**  
Member of the Board of Directors

**Professor Dr.-Ing. Wolfgang Marquardt**  
Chairman of the Board of Directors

**Professor Dr. Sebastian M. Schmidt**  
Member of the Board of Directors

**Karsten Beneke**  
Vice-Chairman of the Board of Directors

## Preface

*Dear Readers,*

By conducting research, we take on responsibility for the future because science does not only mean striving for outstanding results in scientific fields – we also meet the pressing challenges facing society, including energy supply, demographic developments, climate change, and medical technology. Our Annual Report demonstrates clearly in what areas our researchers are developing solutions.

Whenever scientific insights and results are translated into technologies, important consequences for society may ensue. This is why we constantly have to challenge ourselves: are we working on the right research topics, and is Forschungszentrum Jülich well positioned to do so? What do we want to achieve by 2025? Are we accomplishing insights and sustainable solutions which will have a positive impact on our society? In order to achieve these objectives, a strategy which is developed, supported, and implemented by all of us is crucial. This is the reason why we have initiated a Strategy Process, with broad participation by our employees.

But responsible research also means enabling actors outside of science to engage in research and innovation processes. As the largest employer in the region, Forschungszentrum Jülich has highly diverse areas of contact. In order to enter into a long-term and regular dialogue, we initiated Jülich's neighbourhood dialogue in early 2015. Commercial enterprises, schools, environmental associations, and many others are involved in it. In the future, wishes and expectations from both sides will be expressed in a moderated dialogue, and will lead to joint activities.

Forschungszentrum Jülich also faces up to its responsibilities on a national and international level, for example through coordinating large-scale research projects, as a major cooperation partner, or by supplying scientists from all over the world with research infrastructures.

All these activities are part of the great achievements that Forschungszentrum Jülich has been able to accomplish.

*W. Chawin*



# Chronology

1 April 2014

## Respiration and brain function

Scientists from Forschungszentrum Jülich and the University of Tennessee present results which it is hoped will help in understanding the role of breathing in human brain functions. Researchers had discovered that the activities of nerve cells in the whisker barrel cortex in the brains of mice are closely linked with their breathing.

14 April 2014

## Surprising atmosphere

In *Science*, Jülich researchers dispel the conventional belief that nitrous acid is a significant source of hydroxyl (OH) radicals, the “detergent” for the self-purification mechanism of the atmosphere. They base their findings on air measurements made with a zeppelin (see also “News on the OH Washing Cycle”, page 26).



17 April 2014

## Calculated for quantum computers

*Nature* publishes results of an experiment at Yale University which advances the development of quantum computers on the basis of superconductors. Jülich physicist Gianluigi Catelani supports the results through calculations which explain why the energy loss in elementary components of superconducting circuits can be suppressed. In the future, it is hoped that quantum computers will solve certain tasks much faster than conventional computers.

14 May 2014

## Naturally less friction

Cartilage is coated with a special polymer layer allowing joints to move virtually friction-free, even under high pressure. Using simulations on Jülich's supercomputers, scientists from Forschungszentrum Jülich and the University of Twente develop a process that technologically imitates biological lubrication and even improves it by using two different types of polymers. This type of lubrication is interesting for applications in the plungers of syringes, or for hinges or axle bearings, for example.

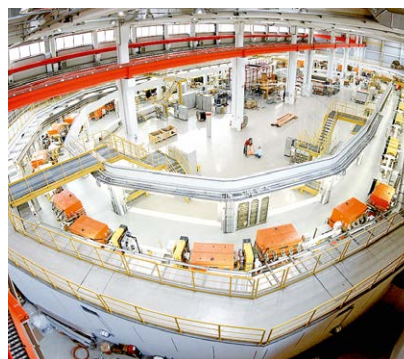
16 May 2014

## Flying on algal fuel

At Forschungszentrum Jülich, the Algae Science Centre is launched, in which algae are cultivated and three production systems for this biomass are compared. It is hoped that the algae will produce organic fuel for aircraft (see also Algae fuel, page 50).

23 May 2014

## Quarks in six packs



109 researchers, among them around 32 from Jülich, publish the result of an experiment at Jülich's particle accelerator COSY. It shows that quarks also come in six packs. This provides physicists with another piece of the jigsaw puzzle depicting the creation of the world (see also “News from the Building Blocks of the Universe”, page 18).

4 June 2014

## New CFCs detected

Jülich researcher Corinna Kloss, together with other researchers, reports on analysing air samples collected over the Australian island of Tasmania between 1978 and 2012. The scientists discover three chlorofluorocarbons (CFCs) – one of them a halocarbon – which until then had not been detected in the atmosphere. Since 2010, the use of CFCs has been prohibited because they damage the ozone layer.

10 June 2014

## Centre of excellence for battery research

German Federal Minister of Education and Research Johanna Wanka and North Rhine-Westphalian Science Minister Svenja Schulze launch Helmholtz Institute Münster. It pools the battery research competences of Forschungszentrum Jülich, RWTH Aachen University, and the University of Münster and is run as a branch office of Forschungszentrum Jülich (see also “Energy Storage for a Transformed Energy Sector”, page 87).

1 July 2014

## New Chairman of the Board of Directors



Prof. Wolfgang Marquardt takes office as Chairman of the Board of Directors of Forschungszentrum Jülich. At his inauguration, with 400 invited guests from science, politics, and industry, German Federal Minister of Education and Research Johanna Wanka says: “Prof. Marquardt, with his passion for research, will continue to drive progress forward.” Marquardt, a qualified process engineer, previously headed the German Council of Science and Humanities.

1 July 2014

## Sustainability Report presented

How do we work at Forschungszentrum Jülich and how are values put into practice? Where will Jülich source the energy required for its campus over the next few decades? And what happens to the waste produced? The Jülich Sustainability Report – the first of its kind within the Helmholtz Association – answers such questions and illustrates how Forschungszentrum Jülich can develop sustainably (see also “Researching Sustainably”, page 82).

2 July 2014

## Brain rewards social contact

Gossiping while shopping, playing cards at the pub, or taking a bike trip together: humans are social beings. The reason for this is that interaction with other people activates the reward system in the brain. Neuroscientists from Jülich, Cologne, and Aberdeen show this using a new method of magnetic resonance imaging (MRI) for testing subjects. Treatment for people with autism could benefit from the method and the insights obtained.

27 July 2014

## Wild genes withstand stress

In order to make use of the resilience with respect to aridity and stress of the wild tomato species *Solanum pennellii*, it has often been crossed with cultivated tomatoes. *Nature Genetics* publishes the results obtained by an international research team which help to understand the special characteristics of this wild tomato originating in the Andes. The team, which also includes Jülich scientists, analyses the genome of *Solanum pennellii*.

31 July 2014

## Research to solve algae problem

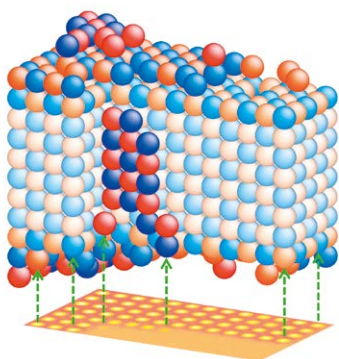


The results of a Jülich study are pointing the way towards effectively solving the algae problem in the Altmühlsee lake in Upper Bavaria within the next few years. A computer model developed in Jülich reveals the sources and quantities of the phosphates reaching the lake, which cause the excessive algal growth. According to these findings, agriculture in the catchment area of the lake is the source of approximately 60% of the phosphates in the water.

15 August 2014

## Solar cell made of liquid silicon

Jülich researchers in cooperation with Evonik develop a solar cell consisting of a very thin film made from a liquid silicon compound. Just like other cells of this type, it can in principle be produced very cheaply, but with an efficiency of 3.4% it is seven times more efficient.



21 September 2014

## Microscopy in a new dimension

Researchers from Jülich and Xi'an, China, present a new method in *Nature Materials* with which only a single electron micrograph is needed in order to spatially represent the atomic structure of crystals (see also "A New Dimension to Microscopy", page 12).

9 October 2014

## New chapter in neutron research



The foundation stone for the European Spallation Station (ESS) is laid in Lund, Sweden. It is among a new generation of neutron sources and makes do without nuclear fission. Forschungszentrum Jülich is involved in this large-scale European project and coordinates the German effort (see also "Jülich research for neutron source", page 55).

9 October 2014

## Flow behaviour of biopolymer fibres

Researchers from Jülich and Amsterdam find out why semiflexible biopolymers, which are neither completely flexible nor completely rigid, can flow in a solution when it is stirred vigorously. Usually, polymer fibres are entangled with each other like a pile of spaghetti. In flow, they re-form as hairpin-like structures which slide past each other almost without touching.

24 October 2014

## Platform for the Energiewende

With a total investment of € 22 million, the Energy Lab 2.0 is launched – an intelligent platform dedicated to researching the interaction of future energy systems components. Karlsruhe Institute of Technology, Forschungszentrum Jülich, and the German Aerospace Center are involved in the new research infrastructure.

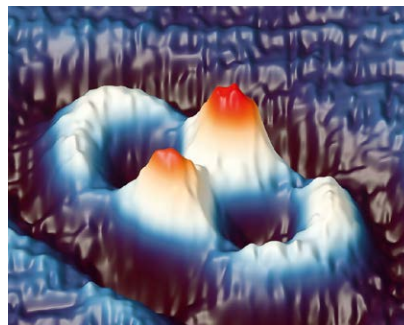
3 November 2014

## Silver lining for solar cells

Jülich researchers succeed in taking a closer look at light propagation in thin-film solar cells in which periodic nanostructures capture the sunlight particularly efficiently. The scientists make use of near-field optical microscopy and the quantum tunnelling effect of light in order to make the captured light visible from the outside. The new method may help to improve solar cells and optoelectronic components.

11 November 2014

## Influential magnetic pairs



Researchers from Göttingen and Jülich succeed in making visible electron waves which due to the Kondo effect develop around magnetic impurities in copper crystals. They discover that the impurities – pairs of magnetic iron atoms – influence the electrons over longer distances than previously thought. The results will help in better understanding the properties of materials which are interesting for future information technology.

18 November 2014

## Powered by greenhouse gas

In Dresden, a demonstration plant is launched by Sunfire. It produces liquid fuels such as diesel from water and carbon dioxide (CO<sub>2</sub>) and is operated on green electricity. The most important step in this power-to-liquid process is high-temperature steam electrolysis. Forschungszentrum Jülich is involved in its further development, in a collaborative project funded by the Federal Ministry of Education and Research.



20 November 2014

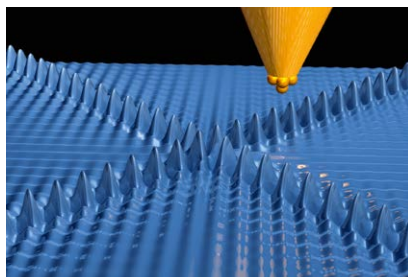
## Jülich end-of-year keynote lecture

Leibniz laureate and Jülich scientist Prof. Rainer Waser gives insights into his research to 350 guests from politics, science, and industry: together with his team, he aims to get to the bottom of electronic phenomena that could be used for novel information storage systems, logic devices, or energy conversion. The researchers work closely together with companies such as Intel and Samsung Electronics.

26 November 2014

## Huge nano-phenomenon

When the density of conduction electrons in a metal fluctuates periodically around a foreign atom, experts call the effect Friedel oscillations. Jülich researchers find out how these oscillations can be intensified in a thin iron film and concentrated in various directions. They produce variations in electron density that reach 50 nanometres, which is much further than usual. The phenomenon may be used in order to exchange or filter magnetic information.



26 November 2014

## Adhesive force of molecules measured



Every chemistry textbook explains the van der Waals forces, responsible for molecules attracting each other, even when bond-saturated. Jülich researchers report that they have measured how strongly these forces bind large molecules to a surface by making use of a scanning force microscope and a new measuring technique.

27 November 2014

## Simulated microscopic methods

Variations of a Jülich method by means of which scanning tunnelling microscopy results in more detailed images have been attracting attention in the scientific community for several years. The method involves attaching individual small molecules to the tip of the microscope. Researchers from Jülich and Prague present computer simulations which provide comprehensive insight into the physical fundamentals of the new imaging technique (see also "A New Dimension to Microscopy", page 12).

30 January 2015

## Simulated protein transporters

A research group coordinated by Jülich achieves a breakthrough in the understanding of glutamate transporters. These proteins play an important role for information transmission in the human central nervous system. With the aid of super-computer simulations, the researchers develop a structural model and confirm it in experiments.

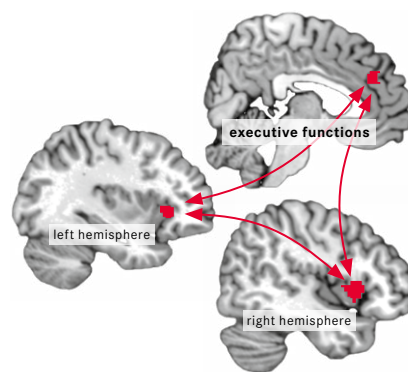
1 February 2015

## Special characteristics of language regions

According to scientists from Jülich and Leipzig, there is a unique molecular fingerprint which distinguishes language-related areas in the brain. The typical concentrations of the neurotransmitter receptors in the language areas differ significantly from those in other areas of the brain (see also "Molecular Code Shared by Language Regions in the Brain", page 34).

11 February 2015

## The biology of the psyche



Patients with different psychiatric disorders such as schizophrenia, depression, and anxiety or addictive disorders show surprisingly similar reductions in grey matter in three particular brain regions, a team including Jülich brain researcher Prof. Simon Eickhoff finds out. The scientists conduct a meta-analysis on 193 studies which used imaging techniques and consolidate the findings in an overall result.

20 February 2015

## Magnetic nano-vortices for IT

Scientists from Jülich, Dresden, and Strasbourg report that they have electrically read out the magnetic vortices in nanodiscs. They make use of characteristic microwaves which are emitted by two nanodiscs positioned on top of each other. These nanodiscs could be used to construct extremely small components for novel memory technology or wireless data transmission.

27 February 2015

## Better treatment through breaks

Overactive, synchronously firing neuron clusters occur in various neurological disorders such as Parkinson's disease and tinnitus. Jülich researchers present a new approach for improving treatment using desynchronizing stimulation techniques. Computer simulations revealed that the neurons' abnormal behaviour can apparently also be eliminated using stimulations which are technically too weak to have any effect – as long as there are breaks between the stimulations.

27 February 2015

## Life cycle assessment for large batteries

Stationary large-scale battery storage could stabilize the electricity grid quickly and precisely. According to a study conducted by scientists from Forschungszentrum Jülich and Younicos, they also have ecological advantages compared to hard-coal-fired power plants.

10 March 2015

## Suitable substrates for graphene



Due to its unusual electronic and mechanical properties, graphene – a special form of carbon – is being investigated intensively worldwide. On many substrate materials, these properties are lost, however. Jülich physicists, together with research partners, present a simple criterion with which scientists can easily look for suitable substrates for graphene.

11 March 2015

## Research for the Energiewende

The transformation of the German energy sector requires effective and affordable energy storage systems to make wind and solar power available throughout the year. At Forschungszentrum Jülich, Parliamentary State Secretary Thomas Rachel announces funding from the Federal Ministry of Education and Research totalling € 6.5 million for five new projects in which Jülich scientists research suitable storage materials.

27 March 2015

## How damaging protein filaments grow

A pathological hallmark of Parkinson's disease is the aggregation of tiny threads of endogenous protein in the brain. Researchers from Jülich and Düsseldorf show that these alpha-synuclein fibrils grow according to a stop-and-go pattern. For the first time, they use a specific microscopy technique to make direct and temporally resolved observations of how the fibrils form.

27 March 2015

## Supercomputer confirms world picture

The fact that the neutron is very slightly more massive than the proton is the reason why atomic nuclei have exactly those properties that make our world possible. A European team, among them researchers from Jülich, calculates this tiny mass difference by means of the Jülich supercomputer JUQUEEN. *Science* presents the results, which are viewed by many physicists as a milestone and confirmation of the theory of the strong interaction.





# Research

Page 11–42



# A New Dimension to Microscopy

Electron and scanning probe microscopes are among the most important tools of modern sciences. Not just one but several Jülich research teams succeeded in enhancing the possibilities of these widely used methods in 2014.

Imagine that somebody projects your shadow onto the wall and claims that he can tell you exactly what size your chest is. This is just how fantastic many of our colleagues found our results to be,” says Andreas Thust, smiling. He is part of the team who succeeded in doing this on the nanoscale. The researchers developed a method through which a single “snapshot” taken by an electron microscope suffices to reconstruct what is not visible at first sight: the three-dimensional atomic structure of the sample.

The sample, for example a nanometre-sized crystal, is irradiated with electrons from a transmission electron microscope (TEM). After the electron beam hits the atoms in the crystal, which are arranged in columns, an image sensor or fluorescent screen shows a two-dimensional image of the crystal structure. The atom columns are shown as individual dots. “But this image is not a simple two-dimensional projection of the sample, since electron microscopy follows the rules of quantum mechanics,” explains Thust’s colleague Chunlin Jia, who conducts research both here at Jülich and at Xi’an Jiaotong University in the Chinese province of Shaanxi. “On its way through the crystal lattice, the electron wave from the microscope functions as a highly sensitive detector for atoms and is influenced by each individual atom.” This influence is so small, however, that even among the members of the successful team, there was much debate on whether the minute differences between the dots on the electron micrographs were random or wheth-

er information on the third dimension – length and position of the atom column – could be determined from them.

Thust compares the starting position with the situation of archaeologists who know that there are tablets with writing in a little known language to be found in a certain region. One day, one of the team members discovers a badly weathered stone tablet and thinks he recognizes writing and can read a message. His colleagues are sceptical and think that the supposed writing may simply be random marks left by weathering. In the case of the German-Chinese team from Jülich’s Peter Grünberg Institute (PGI) and Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons (ERC) and Xi’an Jiaotong University, it was Jia who presented the image of a nanocrystal to his





Dr. Andreas Thust in front of one of the high-performance electron microscopes at Ernst Ruska-Centre.

colleagues – his version of the weathered stone tablet. The dots in the image showed minute variations in their intensity and shape. Was this actual information or were they random traces?

### One million simulated images

The scientists proceeded like archaeologists who produce one million different inscription tablets with known contents and artificially weather them so that they can no longer be distinguished from the original tablet. A computer program then automatically deciphers the artificial tablets, and the scientists determine how well it can read the damaged characters. Once the archaeologists know the percentage of how many characters and sentences the program has correctly identified, they also know how well it can distinguish real

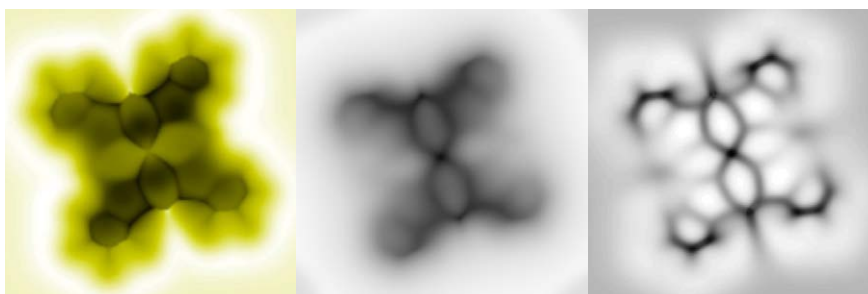
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## Electron microscopy

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Conventional optical microscopes cannot image atoms or devices on the nanoscale, such as the transistors in today's computers. Why? Because the wavelength of the light restricts the resolution of the microscopes. The resolution is an indication of how far apart dots may be from each other in order to still be visualized separately from each other. With the electron microscope (TEM), invented in the 1930s, the limitations of optical microscopy were overcome, since it uses electrons instead of light. The electron beam with its extremely short wavelength is guided by magnetic fields, lending them the function of the glass lenses in an optical microscope. Unlike scanning probe microscopy, electron microscopy also provides information on the inner structure of materials.

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dynamic scanning force  
microscopy

scanning tunnelling  
microscopy

inelastic scanning  
tunnelling spectroscopy

Three simulated images of  
the same organic molecule.  
The images differ in the  
simulated microscopic  
imaging technique.

## Scanning probe microscopy

Scanning probe microscopy includes a number of methods. The two most important ones are scanning tunnelling microscopy and atomic force microscopy (STM, AFM). Both were developed in the early 1980s.

Scanning tunnelling microscopy exploits the quantum mechanical tunnelling effect whereby electrons can “tunnel” through non-conductive barriers, including a vacuum, so that a current flows. In a scanning tunnelling microscope, a fine needle tip scans the surface of a sample at an extremely small distance. The tip is moved with a piezo crystal, which expands or contracts slightly if a voltage is applied. The current strength increases drastically the closer the tip is to the surface. Conversely, this means that if the current strength has a certain value, the tip remains at the same distance to the surface. Controlled in this way, the tip rises at each hump on the surface. A scanning tunnelling microscope thus “feels” information on the surface. Images are created from this information by an oscillograph or a computer which processes the electronic information for the human eye.

Scanning tunnelling microscopy is only suitable to examine samples which are electrically conductive. Atomic force microscopes are not limited in this way. In the simplest case, the probe tip is attached to a probe spring, the cantilever. The tip feels the tiny forces exerted by the atoms of the surface. As a consequence, the cantilever moves up or down. The displacement of the cantilever is measured by pointing a laser beam at it and registering the change of direction of its reflection. From this information, an image of the surface is obtained. Stefan Tautz’s working group uses a variation of the atomic force microscope where the probe tip is attached to a sort of tuning fork. When the probe tip approaches the surface, the frequency of the tuning fork changes. This frequency shift is the measure of the forces occurring at the surface.

information from the random background noise – and how well it is suited for deciphering the real, old tablet.

“We didn’t produce artificially weathered tablets, but simulated one million images of crystals,” says Thust, transferring the process to his own area of work. This served to study how well a computer program was able to correctly calculate the – known – three-dimensional structure of a crystal, and distinguish real information from random deviations. In this way, the researchers showed that information on the third dimension can be decrypted from the electron micrograph and thus unknown three-dimensional structures can be correctly recognized with high probability.

### Gentle on the sample

It had previously been possible to spatially map samples with electron microscopes, but dozens or even hundreds of images taken from different perspectives had been necessary. Requiring only a single image not only saves time: the new method is also suitable for radiation-sensitive samples, which are quickly destroyed by the microscope’s high-energy electron beams. The relatively short scanning duration may even make it possible to image fast chemical processes in the future. The gentle measuring technique also permits detection of not only heavy, but also light chemical elements, such as oxygen, which plays a major role in numerous technically important materials.

Thinking outside the box was also worth it for another research group in the field of electron microscopy: Lothar Houben from ER-C and PGI, together with two



scientists from the Weizmann Institute of Science in Israel, resurrected a technique that had been “forgotten” by the community, developed it further, and thus improved the examination of bacteria, cells, and other biological samples.

Such samples are usually shock-frozen to keep them intact for three-dimensional imaging. Their low contrast is a disadvantage. They can be dyed, but in many cases, this causes damage to their natural structure. For this reason, scientists mostly prefer the phase-contrast imaging method, which makes use of differences in the refractive index and the thickness of an object to produce a light/dark contrast. The better contrast that is thus achieved comes at a cost, however: the resolution capacity of the microscope and the image quality suffer.

#### More contrast through raster scanning

In principle, there is an alternative used to study semiconductors and other materials: scanning transmission electron microscopy (STEM). For this method, a very thin electron beam scans the sample, line by line. This means that the image contains no interfering scattered electrons from other points of the sample, which improves contrast.

Until the German-Israeli team published their results in 2014, the perception among scientists worldwide was that only phase contrast imaging produced satisfactory contrast for biological samples, and that no other electron microscopic method could – STEM included. “This perception set in at a very early stage. During the period that followed, it was simply assumed that biological samples that were not dyed do not scatter the electron beam sufficiently,” says Houben. The STEM method for the examination of biological samples was forgotten.

“But we recognized that there was no sufficient theoretical explanation and no sufficient practical verification for why phase contrast imaging should be the only way,” explains Houben. This finding did not let the researchers rest: they adapted the STEM method as used in materials research for use in measuring biological samples – for instance, they arranged the detectors differently. And lo and behold: used in this way, the “forgotten” method allows the spatial structure, particularly of thick organic samples, to be better imaged than the phase contrast method.

## We were fully aware of the brilliant discovery we had made at the time.

**Stefan Tautz** | Professor at the Peter Grünberg Institute

Just like the scientists from ER-C, Jülich researchers from Stefan Tautz’s team at PGI also became creative – and in the process discovered new possibilities for scanning tunnelling microscopy (STM). In 2008, they published images of organic molecules which caused a stir in the scientific community. They made the atomic structures within molecules visible for the first time. Prior to that point, STM had imaged a molecule of seven interconnected rings, for example, as simply a round spot. The Jülich images, on the other hand, showed the honeycombed inner structure formed by the rings.

The Jülich scientists’ trick to achieve this was to attach a minute hydrogen molecule to the tip of the microscope as a molecular sensor. It scanned structures with a much better resolution than a needle-shaped metal tip. “My colleague Ruslan Temirov and I were fully aware of the brilliant discovery we had made at the time. But what has become of it since then has really surprised and delighted us,” says Tautz.

Tautz and his colleagues tried to convince theoretical physicists to join them in trying to get to the bottom of the improved image phenomenon. They also soon came up with the idea that it might be a phenomenon which could also be applied to other types of scanning tunnelling and atomic force microscopy. According to Tautz, “The attached molecule provides the microscope tip with additional possibilities for “feeling” the characteristics of the sample, so to speak.”

Since then, this has been confirmed, and there are various scanning probe microscopy methods which make use of the little molecule attached to the tip. The Jülich researchers, together with theorists from the Academy of Sciences of the Czech Republic in



Prague, have since developed a computer model which explains the operating principle of the different new options for which a molecule is attached to the tip. “The formation of micrographs is easily understandable with this model, since the simulations match the experimentally obtained images,” says Tautz. “Only if you understand how the method works can you interpret the images correctly.”



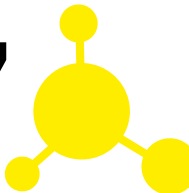
This word was created molecule by molecule with the tip of a scanning tunnelling microscope.

The Jülich physicist is particularly delighted about his team’s recent development of a further microscopic option. It makes it possible to measure electrical fields surrounding molecules on surfaces with a higher resolution and sensitivity than ever before. Such forces are often decisive for an electron’s behaviour on a surface. It is not a hydrogen or similarly small molecule that is attached to the tip of the microscope for this technique, but the flat and relatively large semiconductor molecule PTCDA, which consists of seven connected rings of carbon and oxygen atoms.

But the researchers headed by Tautz not only image surfaces or molecules with the scanning tunnelling microscope, improving resolution and image quality: they also use the microscopes to lift and move larger molecules such as PTCDA. If you watch PhD student Matthew Green doing so, you might think that he has immersed himself in the virtual world of a games console: completely focused, Green stands in a dimly lit room; only his arm is moving – downwards, upwards, and then sideways. On his hand, a shimmering silver sphere glitters. It reflects the light from two infrared cameras mounted on the wall and ceiling.



Matthew Green at the sample inlet of a scanning tunnelling microscope

47 

molecules were lifted one at a time by Green and moved elsewhere to create the word “Jülich”.

ed objects such as organic molecules. In contrast to atoms, they can kink, bend, or even develop spring forces when you tug at them,” Tautz explains.

#### Adhesive force of molecules measured

Using an atomic force microscope, the research team headed by Tautz was able for the first time to experimentally determine the van der Waals forces, which make molecules adhere to surfaces. These forces were discovered around 150 years ago, but their strength had not yet been precisely determined – at least not for molecules – although they are quite significant for the behaviour of biomolecules such as proteins.

But Green is not manoeuvring game figures around dangerous obstacles. Instead, he is controlling the tip of a microscope. When Green moves his hand five centimetres upwards to the right, the cameras register this and transmit the information to a computer. The computer ensures that the metal tip of the microscope also instantly moves upwards to the right, but only by a tenth of a millionth of a millimetre, the typical size of an atom. This way of controlling the microscope tip was developed by the Jülich scientists themselves.

Green uses the tip to grasp the semiconducting molecules off the surface of the sample and lift them. This is possible because a chemical bond forms between the metallic tip and the oxygen atoms of the molecule. It is important to know where to point the tip: if the molecule is grasped incorrectly, it will not budge and instead remains stuck to the surface. “You have to position the tip at the edge of this type of molecule and then slowly lift it upwards in an arc,” explains Green and then deposits the molecules somewhere else.

“With this method, we hope to find out how much control can be exercised over relatively complicat-

The ability to lift molecules off a surface and move them somewhere else in a controlled manner is crucial in order to join them to form molecular machines or minute devices. “It is just like in our visible world: grasping objects, positioning them, and joining them. This is the basis of all engineering skills,” says Tautz. But of course, there was a certain amount of gaming involved – all in the name of a good cause, of course – when Green created a single layer of exactly 47 molecules, which he lifted individually just to create the tiny word “JÜLICH” on a surface. And just like in archaeology, it takes sensitivity and patience.



# News from the Building Blocks of the Universe

In 2014, a team of scientists published the results of an experiment conducted at Jülich's particle accelerator COSY. It showed that quarks also come in six packs. This provides physicists with another piece of the jigsaw puzzle depicting the creation of the world. In future, COSY will serve as a development and testing device for a unique project which is designed to solve the riddle of why the universe even exists.



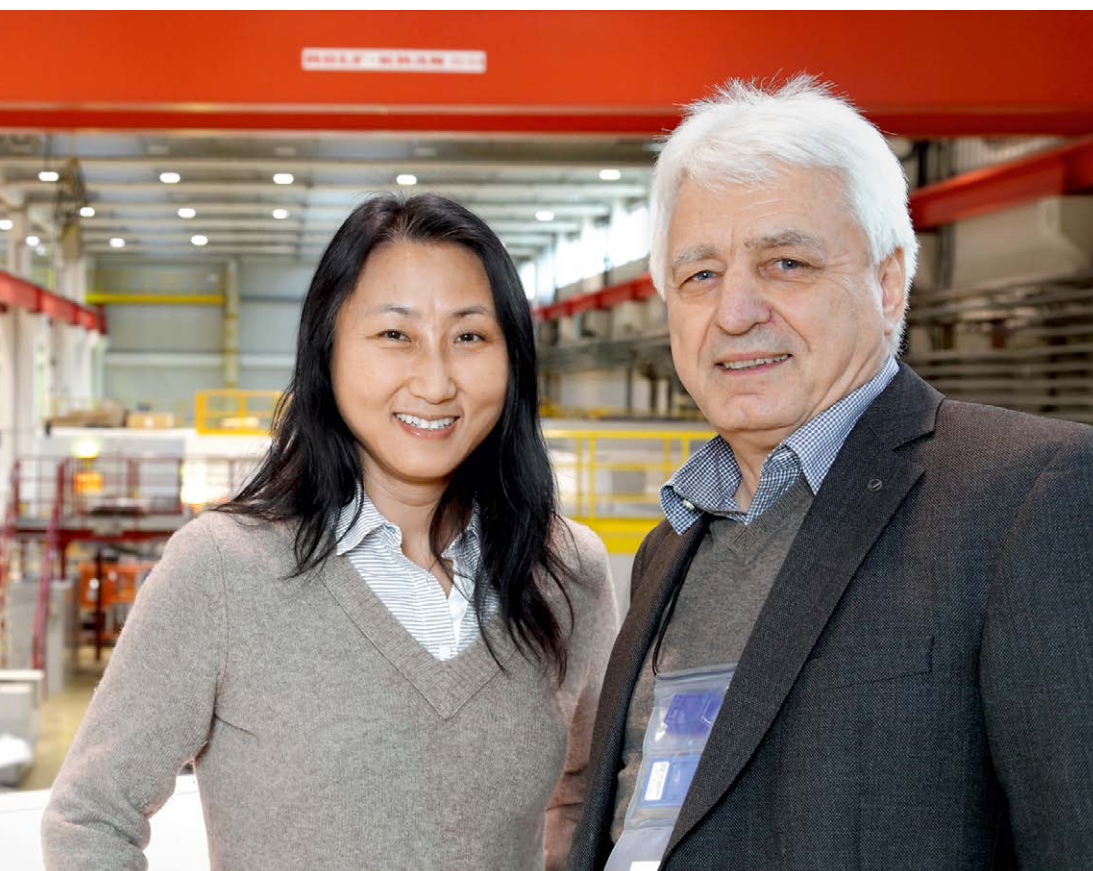
It is “a grotesquely modest name for one of humankind’s greatest achievements,” as Nobel laureate in physics Frank Wilczek once commented: the Standard Model – a theory with which physicists describe all the building blocks of matter and the forces at work between them. Quarks play a major role in this. They are elementary particles – that is, according to current knowledge, they cannot be broken down any further – but have never been observed as individual, free particles. Three of these quarks together make up protons and neutrons, which are the building blocks of atomic nuclei. Atomic nuclei in turn, together with their cloud of electrons, form the chemical elements of which all matter in our world is made.

Until recently, scientists had only ever been able to observe quarks in groups of three in a particle, or as a combination of one quark with one antiquark. In 2014, a team of more than 120 scientists from eight countries at the Jülich particle accelerator proved that a bound state of six quarks also exists. This had been indicated during another experiment in 2011. But this state only exists for the unimaginably short time of a hundred-sextillionth (0.000 000 000 000 000 000 000 01) of a second. This time span is so short that light only travels a distance equivalent to the diameter of a tiny atomic nucleus.

In order to understand why this discovery is so remarkable, it is important to know more about the physicists’ view of the world, i.e. the Standard Model. According to this model, quarks have an electric charge. In addition, the Standard Model assigns a colour charge to quarks to explain the forces – which are known as interactions – between them. There are three different types of colour charge: there is a red charge, a green charge, and a blue charge.

## White particles only – up to now

Up to now, physicists have only ever observed particles whose colour charges combined in line with conventional colour theory to create white. One example of this is baryons, which also include protons and neutrons: they are made up of three quarks each, whose colour charges of red, green, and blue combine to become colourless white. Another example is mesons, which are made up of quark-antiquark pairs. An antiquark has the same mass as its counterpart, the quark, but it possesses the opposite charge. Mesons are also colourless: anti-quarks occur in antired (cyan), antigreen (magenta), and antiblue (yellow). When combined with the corresponding quarks, white is the result (see figure on the right).



Prof. Mei Bai and Prof. Hans Ströher, directors at the Jülich Nuclear Physics Institute, want to solve one of the great mysteries of physics.

The Standard Model permits other colourless particles, with more than three quarks or more than a quark-antiquark pair. For decades, however, evidence for the existence of such “exotic” particles proved elusive – in spite of an intensive search. Jülich’s current research shows: “At least one of the exotic particles predicted by the Standard Model actually exists,” according to nuclear physicist Volker Hejny from Jülich’s Institute of Nuclear Physics (IKP). In other words, the scientists have confirmed another part of the picture they have painted of the world, of matter, and of the creation of both.

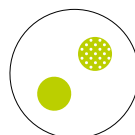
The quark six pack was produced artificially in the particle accelerator, which is used to make protons and other particles collide at almost the speed of light. “It is highly likely that this exotic bound state also occurs naturally in the universe, for example when stars are born, and that it plays a role in cosmic events,” explains Hejny.

He is one of the members of the WASA-at-COSY collaboration, the team of 120 scientists who made the discovery. The name stems from the use of the WASA detector, an enormously complex device with which the scientists were able to detect the decay products of the quark six pack – in other words what is left of

## Quark bound states

well-known and new particles

### Old acquaintances



#### Meson

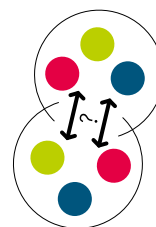
Lifetime:  
 $< 10^{-8}$  seconds



#### Baryon

Lifetime:  
from  $> 10^{30}$  years  
to  $< 10^{-10}$  seconds

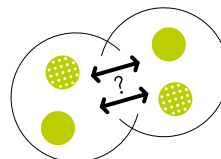
### New additions from Jülich



#### Dibaryon

Lifetime:  
 $< 10^{-23}$  seconds

### Recently discovered



#### Tetraquark

Lifetime:  
 $< 10^{-23}$  seconds



Quarks



Antiquarks



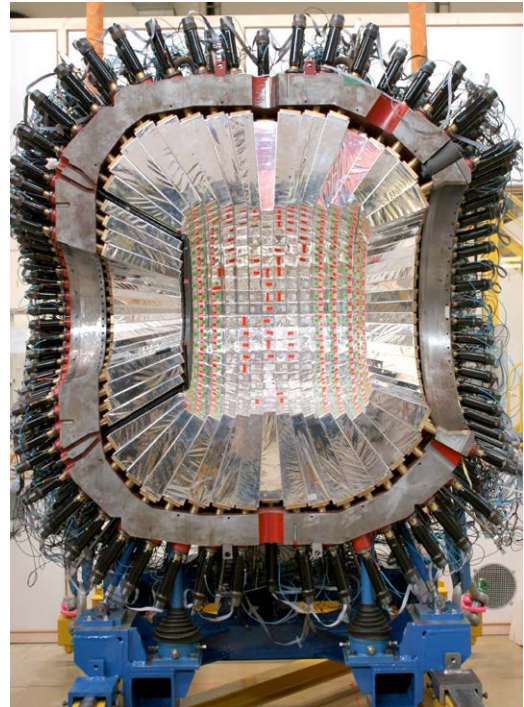
Type of interaction unclear

it after a hundred–sextillionth of a second. Due to its ultra–short period of existence, the six pack cannot be observed directly.

The WASA detector used to be at home in Uppsala, Sweden, before moving to Jülich about ten years ago. It consists of several subordinate detector systems, which register different decay products. “For each part, there was a specialized working group who developed and maintained it,” says Hejny. This also explains the large number of scientists involved in the collaboration. Around one quarter of the researchers involved are from Jülich.

Scientists from Forschungszentrum Jülich will continue to look for other exotic states in the future, in order to further develop the Standard Model and with it the understanding of the structure of the world. However, this research will no longer be conducted at Jülich’s COSY accelerator, but at the new international accelerator facility FAIR (Facility for Antiproton and Ion Research) in Darmstadt. As part of this billion-euro project, Forschungszentrum Jülich has taken on the construction of the HESR high-energy storage ring and is involved in developing the PANDA detector. The project will benefit greatly from the know-how that Jülich’s scientists have gained with COSY.

This will not mean the end of Jülich’s accelerator, however. Instead, the scientists will be using it to test detectors and other devices for FAIR, and to examine certain issues which will be crucial for the operation of the new accelerator complex. COSY will also be used to prepare a unique experiment, which concerns the question of why the universe exists at all. According to physicists, the Big Bang, 13.8 billion years ago, was a violent battle of annihilation: matter versus antimatter. For every particle of matter, a twin particle of antimatter was formed – with the same properties but a different charge. When the two collide, they



View into the WASA detector, used to detect the existence of the quark six pack.

annihilate each other, leaving nothing behind but pure energy. However, planets, moons, and solar systems were formed.

Our cosmos is made up of the leftovers, the matter that remained after the annihilation. But why was there any matter left? Was there an imbalance, a disrupted symmetry, at the very beginning of the universe?

#### **The universe in a proton**

In order to answer these questions, Jülich’s scientists are banking on a particle no bigger than around

## **At least one of the exotic particles predicted by the Standard Model really exists.**

Dr. Volker Hejny | Jülich Nuclear Physics Institute



two trillionths of a millimetre – the proton, a stable building block of atomic nuclei. To put it simply, accepted physical models say that what holds for the whole must also hold for the tiniest component. In other words, if excess matter is the reason why the world exists, then this asymmetry of the universe must also be reflected in the properties of the proton and other minute particles. Proof of such asymmetry in a proton would be a teeny tiny, but measurable, dipole moment, as this is an asymmetric charge distribution. In an electric dipole, the negatively and positively charged poles are spatially separated from each other. According to the Standard Model, a dipole moment of a proton or neutron should not exist – but it is believed that it does. In such a case, the physical theories would need to be adjusted and would then in all probability also explain how the universe came into being.

“The existence of a dipole in protons or neutrons could not be verified in the past – probably because measurements were not precise enough to make the tiny poles, which are located extremely close together, visible,” says Prof. Hans Ströher, director at IKP. “If the proton was as big as the Earth, what we want to measure would be separated by a distance no bigger than the thickness of a human hair.” Together with the other scientists at the FAME section of the Jülich Aachen Research Alliance (JARA), he developed a concept to make dipole measurements on elementary particles at least a thousand times more precise. “Finding an electric dipole moment would mean identifying a symmetry violation,” says Ströher. “If this violation is large enough, it would explain the excess matter in the universe.” And thus our existence.

The plan is based on the fact that protons possess a spin. In simple terms, this spin is a bit like a small bar magnet: if protons possess an electric dipole moment, its orientation will alter in an electric field.

To measure this, the JARA researchers want to first produce a proton beam in which they can force the spins of all protons to turn in the same direction. Or in scientific terminology: with COSY’s help, they want to produce a polarized proton beam. Then they will send the protons into a second ring, which would be unique in the world, where the electrostatic fields will keep the protons on track and – if a dipole moment exists – influence their spins. “Such an electrostatic storage ring does not yet exist anywhere in the world,” says Prof. Mei Bai, who joined IKP as a director last December. The opportunity to make this

# 120



scientists from eight countries were involved in proving the existence of the new particle.

ring a reality is what convinced her to come to Jülich from Brookhaven National Laboratory in New York. This new ring at Jülich, which can be completed in five years at the earliest, will have the length and shape of a 400 m track at an athletics stadium, according to current plans. In more than 30,000 repetitions of one 15-minute experiment, the researchers want to measure whether the direction of the spins is altered at all, and if so, by how much, during the circulation – in other words whether protons have an electric dipole moment.

Until this challenge can be tackled, the JARA scientists, together with researchers from ten countries, will perform the necessary preliminary experiments with COSY, as part of the large-scale project JEDI. Their aim here is twofold: they want to optimize the measuring technique, and to determine the upper limit of the value of this electric dipole moment for the first time ever.

There is thus a lot yet to be done with COSY, and the researchers are only at the beginning of a new journey, at the end of which they may find the answer to a 13.8-billion-year-old riddle.

# Measurements in the Clouds

For the atmospheric research team headed by Dr. Martina Krämer, 2014 was a special and exciting year: measurement campaigns lasting several weeks took them to the icy clouds over the Arctic, Europe, and the tropics in the Amazon area. The first analyses of the data collected already permit new insights into clouds as a climate factor.

**E**veryone has experienced at some time or other the chilling effect of clouds passing in front of the sun on a summer's day. The reason is that clouds do not allow all the radiation from the sun to reach the surface of the Earth. However, clouds also heat the lower layers of air by trapping heat radiation reflected by the Earth. On balance, the cooling effect outweighs the warming effect in the case of clouds composed of droplets of liquid water. But in cold layers of air, clouds may be composed of ice particles.

## It's complicated

Ice particles do not reflect radiation in the same manner as droplets, with the result that for an ice cloud the net effect can be different. Decisive factors are the number and size of ice particles in these clouds and whether they are densely packed or far apart from each other. What makes matters even more complicated are "mixed-phase clouds": they contain not only liquid droplets but also ice particles.

Numerous factors, such as temperature, pressure, buoyancy, humidity, and air pollution all influence conditions in the sky – this is one important reason why science so far has not been able to fully understand

the characteristics and processes responsible for the formation of clouds and ice clouds in particular. Computer models for climate simulations are also struggling to get to grips with this. However, clouds play an important role in climatic processes. The Intergovernmental Panel on Climate Change (IPCC) believes that on the whole clouds will mitigate the observed rise in temperature caused by increasing levels of greenhouse gases in the atmosphere. This





Close to the clouds – even in Jülich: Dr. Martina Krämer and her working group took part in three measurement campaigns in 2014

means that without clouds, the temperature would increase more steeply. The IPCC has even put a figure on this cooling effect of clouds, but concedes that the reliability of this figure is low, since the climate simulations on which it is based come to a range of different results. “Clouds are the largest source of uncertainty in the IPCC’s climate change predictions,” says Martina Krämer from the Institute of Energy and Climate Research – Stratosphere (IEK-7).

In order to make more accurate simulations possible, which can predict how global climate will change in the future, researchers worldwide require more accurate information. But what are the properties of ice and mixed-phase clouds around the world, and how are these characteristics, which have an impact on climate, linked to the conditions under which the clouds are formed?

In 2014, the researchers were especially active in acquiring the missing information in the form of measurement data. Among them was the team headed by Martina Krämer, who participated in three large-scale measurement campaigns: the Mid-Latitude (ML) Cirrus mission was the first. It led to the ice clouds – known as cirrus clouds – over the North Atlantic and Europe (Portugal, United Kingdom, Germany, and the Alpine region among others). Whether cirrus clouds have a warming or a cooling effect in these mid-latitudes, in particular, is not yet known. The second mission, entitled RACEPAC (Radiation-Aerosol-Cloud Experiment in the Arctic Circle), targeted clouds over the Arctic. Global climate change shows the most extreme effects here: the temperature rise is more severe than anywhere else in the world, and manifests itself in a drastic decrease of sea ice cover.

#### Measurement flights over the rain forest

Finally, the third campaign was concerned with the high-rising cloud towers over the Amazon rainforest. The acronym ACRIDICON-CHUVA stands for “Aerosol, Cloud, Precipitation, and Radiation Interactions and Dynamics of Convective Cloud Systems” and is the Portuguese word for “rain”. Rain and storm clouds in the tropics are especially complex and contain many aerosols which rise to high altitudes very quickly.

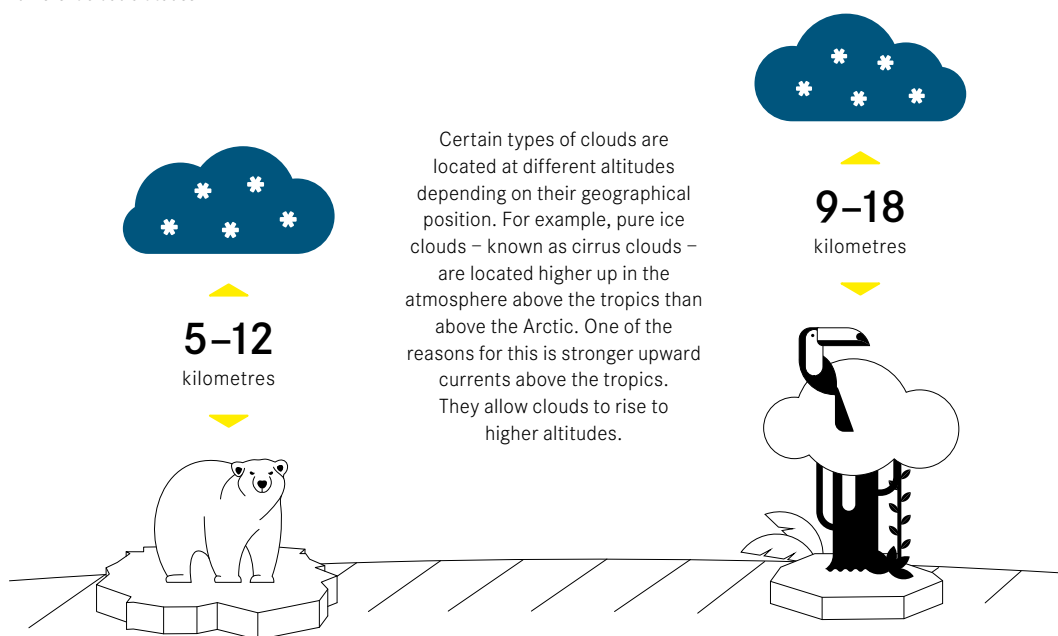
Planning the flight for the ML-Cirrus measurement campaign was exceptional: in order to target cirrus clouds over Europe with the research aircraft HALO, the researchers used a computer model which predicts such ice clouds. The model was developed at Jülich and the University of Mainz. “It worked surprisingly well. Predicting cirrus clouds over large areas is still extremely difficult,” says Krämer.

The flights into the mixed-phase clouds over northern Canada during the RACEPAC campaign were especially thrilling, although they took place at an altitude of only five kilometres at most. “There is no pressure compensation in the the cabin of the 70-year-old



## Tropics or Arctic

different cloud altitudes



Polar 6 aircraft,” says Dr. Anna Luebke, cloud researcher at Jülich, who was in charge of the measuring instruments on board. The plane also creaked and groaned whenever it flew through the clouds, since clouds in the Arctic contain large ice particles even at low altitudes.

During the third campaign, the researchers used HALO to fly from Manaus, Brazil, into the atmosphere at up to 15 kilometres altitude in 14 seven-hour measurement flights. In the bottom part of the cloud towers over the rainforest, they encountered liquid droplets. These transform into ice particles when they rise within the cloud. The topmost part of the cloud tower therefore consists of ice crystals. In between are mixed-phase sections, which are dangerous to aircraft: “Within seconds, the aircraft may be covered in beard-like ice structures because the droplets freeze the instant they touch the surface – these are flying conditions which you would normally avoid at all costs,” says Krämer.

### NIXE, FISH and HAI

On all campaigns in 2014, a measuring instrument – christened NIXE-CAPS (New Ice eXperiment – Cloud and Aerosol Particle Spectrometer) by Jülich scientists – was on board. It measures the number and size of cloud particles and determines whether they are liquid or frozen.

The Jülich cloud research team had already used the spectrometer in a cloud chamber – one of the first worldwide – as well as on two other measurement campaigns, and had been able to suggest improvement options to the manufacturer. But 2014 was the year during which the device had to prove its worth under a multitude of conditions. “Our preliminary analyses show that NIXE has provided us with great data sets on the composition of the clouds,” says Krämer.

Another of Jülich’s instruments is a proven expert on the high-altitude atmospheric layers in which ice clouds occur: FISH (Fast In Situ Stratospheric Hygrometer) is able to measure the total water content in these relatively dry atmospheric layers, as well as the ice water content in cirrus clouds. The device is not suitable for atmospheric layers with higher humidity, so it was only used on the ML-Cirrus campaign in 2014. Designed around twenty years ago by Jülich scientists, FISH has proven time and time again that it delivers particularly reliable data. In a current publication entitled “Two decades of water vapor measurements with the FISH fluorescence hygrometer: a review”, Jülich researchers have compiled the results of numerous intercomparisons with similar instruments. They show that the results obtained with the other instruments approached those of FISH, which had been calibrated and operated in the same way for two decades.

“During the ML-Cirrus project, our results were very similar to those from other devices and research groups, and to those from our HAI,” says Krämer, delighted. HAI is a new measuring instrument that was developed together with the Physikalisch-Technische Bundesanstalt, Germany’s National Metrology Institute, and adjusted specifically for use in the research aircraft HALO. It offers more functionalities than FISH, and is also suitable for the very common mixed-phase clouds. It enables researchers to determine the amount of water contained in clouds and whether this water is present in a gaseous, liquid, or solid state – and all this based on just one measuring principle. According to Krämer, “ML-Cirrus and ACRIDICON are among the first campaigns for which we used HAI, and we can already say that the instrument has proven itself.”

For researchers to make such statements, and to produce spectacular results only a few months after the campaigns, is rather unusual in a research field in which several years often pass before measurement data are evaluated. “This proves that it was worth the extraordinary effort of developing software tools prior to the campaigns to evaluate and to analyse data quality,” explains Krämer.

### Far-reaching consequences

Results were obtained for cirrus clouds in particular – i.e. clouds which contain ice particles only. Until recently, the scientific community had been sure that cirrus clouds almost always form when uniformly liquid droplets freeze into ice particles – a process known as homogeneous freezing. Heterogeneous freezing, in contrast, involves ice building up around solid particles such as mineral dust or soot. The measurement data from the ML-Cirrus campaign demonstrate that the established scientific doctrine may have to be reconsidered. “Cirrus clouds arise mainly from heterogeneous freezing,” claims Krämer. This finding could have far-reaching consequences, because it means that changes in land use or in the emission of particles by industrial plants could have an impact on the formation of cirrus clouds. In contrast, if cirrus clouds froze homogeneously, as previously believed, then changing particle emissions caused by human activities would be of no consequence to them.

There is also news on mixed-phase clouds. Even before the campaigns in 2014, it had become clear from Jülich’s measurements, among others, that this type

of cloud is more common than experts had previously thought. The new measurement campaigns were also concerned with measuring the differences in these clouds over various parts of the globe. “The ACRIDICON campaign showed that the mixed-phase clouds over rainforests vary micro-physically from those in mid-latitudes or over the Arctic,” says Krämer. What she means is that particles in tropical mixed-phase clouds are distributed differently from those further north, and have a different average size and composition.

Why? Due to the strong solar radiation, clouds close to the equator rise particularly fast. For this reason, droplets remain liquid at altitudes at which, in other parts of the world, they would long have turned into ice crystals. “At temperatures under  $-20\text{ }^{\circ}\text{C}$ , clouds are always completely icy over the Arctic and at mid-latitudes. In the tropics, however, we found clouds at  $-40\text{ }^{\circ}\text{C}$  with liquid droplets as well as ice crystals,” says Krämer.

The results of the three campaigns, ML-Cirrus, RACEPAC, and ACRIDICON, provide important pieces of the puzzle for future climate models. They help to further clarify how clouds, on average, globally and regionally influence the radiation and climate balance. This makes more reliable climate forecasts possible.



The research aircraft Polar 6 was used in the RACEPAC measurement campaign over northern Canada.

# News on the OH Washing Cycle

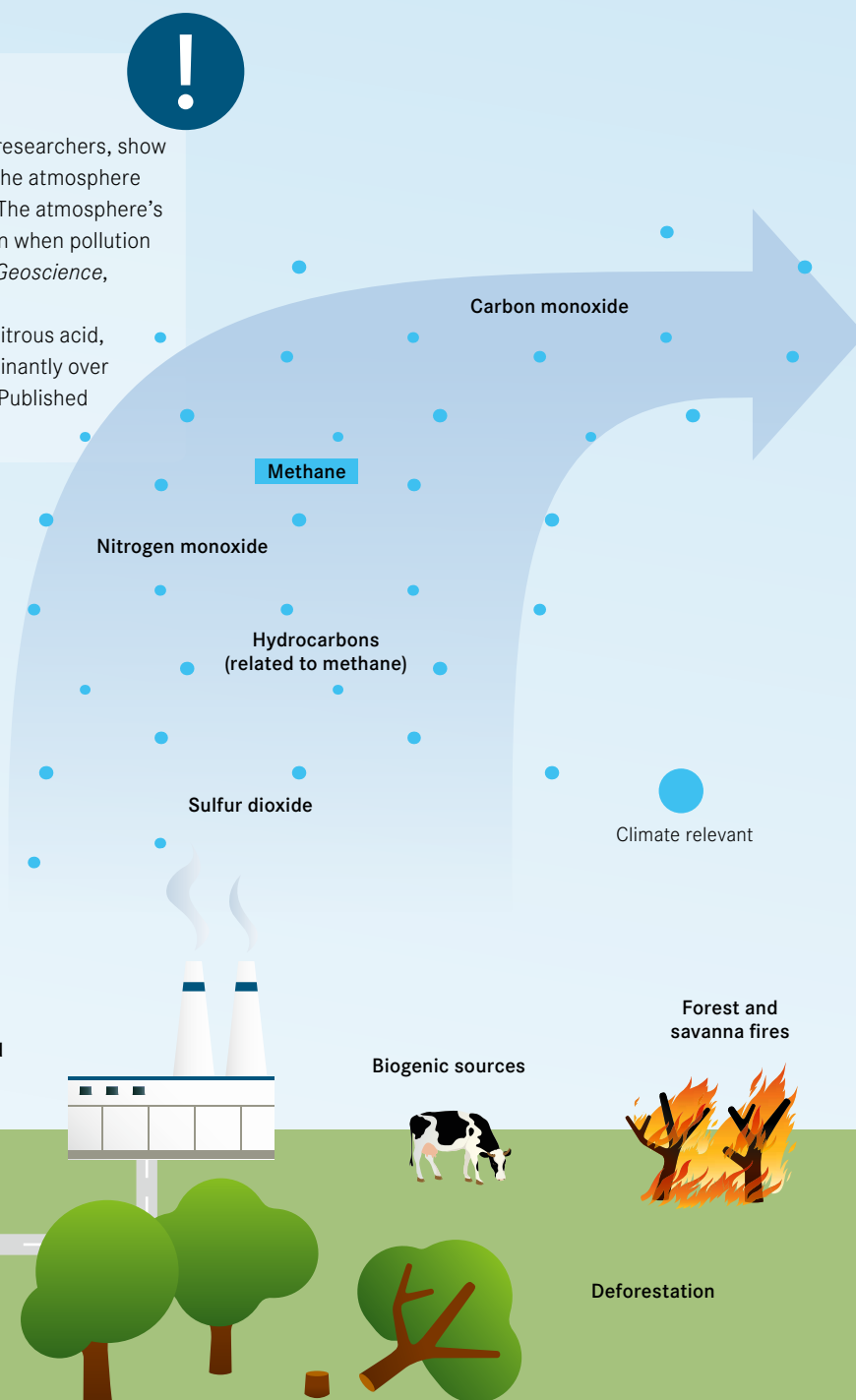
Every day is washing day in the sky. The “detergent”, hydroxyl (OH) radicals, in particular, permits the atmosphere to clean itself of many trace gases which adversely affect air quality or climate – or both. In 2014, Jülich scientists published important new insights into this washing cycle.

## The new findings

- Worldwide measurements, collated by Jülich researchers, show that there is more detergent (OH radicals) in the atmosphere than conventional computer models predict. The atmosphere's self-cleaning abilities function efficiently, even when pollution levels in the air are high. Published in *Nature Geoscience*, 13 June 2014.
- In contrast to what was previously believed, nitrous acid, which is formed from nitrogen oxides predominantly over conurbations, is not a source of OH radicals. Published in *Science*, 18 April 2014.

## Questions resulting from these findings

- Where does the additional detergent come from?
- What unknown processes occur during the washing cycle?
- How good is the atmosphere's ability to cleanse itself in reality?
- What happens when air pollution increases?





## The source of energy

The sun supplies the energy for the entire washing process

## The detergent

- is formed mainly from ozone, water vapour, and sunlight
- is only present in tiny concentrations: the average annual ratio of OH to air is 1:25 trillion
- reacts with almost all trace gases in the air
- is recycled to a large extent when trace gases are degraded

OH



## The measurement platforms

of the Institute of Energy and Climate Research:

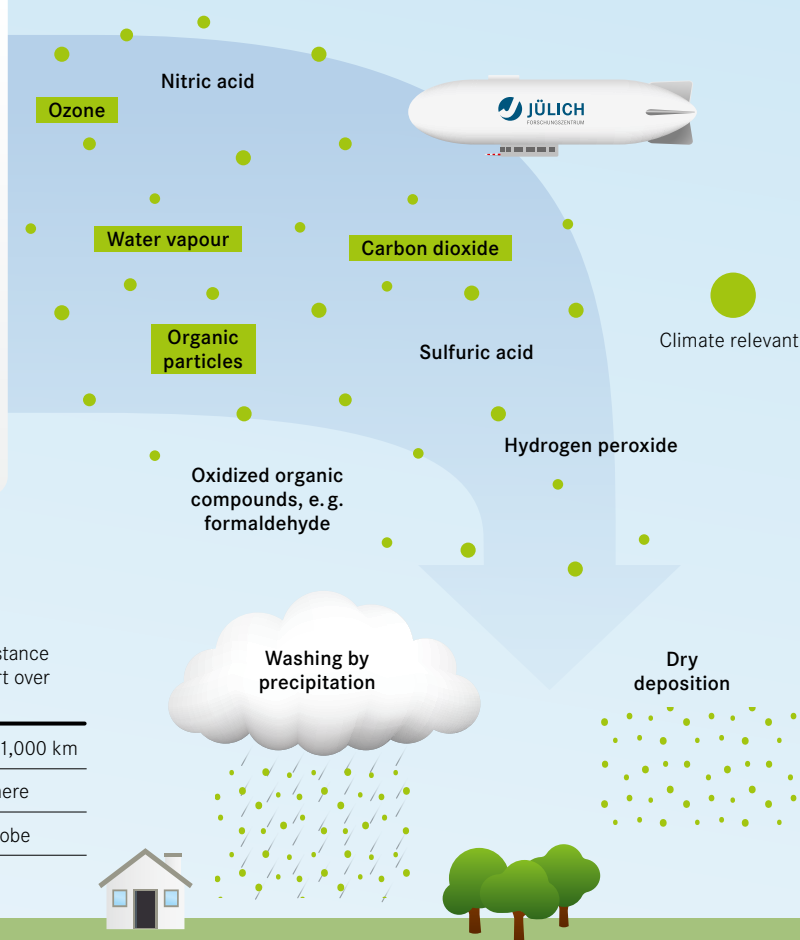
**Zeppelin NT** can take measurements and fly in the decisive atmospheric layer (up to 1,000 m)

**Saphir** a 300 m<sup>3</sup> atmospheric simulation chamber for verifying chemical models

**Saphir Plus** a plant chamber connected to Saphir that also considers the influence of plant emissions

## The washing process

OH radicals transform trace gases. In the process, substances are produced which are removed from the atmosphere by precipitation.



## ... and examples of washing programmes

Trace gas	Degradation by OH radicals (%)	Atmospheric lifetime	Long-distance transport over lifetime
NO <sub>2</sub>	50	1–2 days	approx. 1,000 km
CO	90	2–3 months	hemisphere
CH <sub>4</sub>	90	8 years	entire globe

## The aim

Deciding on the right measures to improve air quality and climate

OH is directly or indirectly involved in hundreds of chemical processes, which occur simultaneously and are linked to each other. Only when researchers understand these correlations will they be able to predict the consequences of measures. Not everything that improves air quality is good for the climate. Example: organic particles. Reducing them improves the air quality, but simultaneously causes increased global warming because sunlight is not shielded as effectively.

# New Laser for Faster and More Efficient Computers

Light could transfer data between the components of a computer more rapidly and more energy-efficiently than electricity. Scientists from Forschungszentrum Jülich, together with international partners, have presented a semiconductor laser which can be applied directly onto a silicon chip. This represents an important step towards optoelectronic computers.

For decades, light has been used as an ideal medium for data transmission: there are optical fibre cables at the bottom of the oceans through which light signals speed. In this way, telephone conversations, documents, and videos find their way from continent to continent. Optical fibres – or more generally: optical waveguides – are also the arteries of data communication between cities and in computing centres. A single optical fibre with a single laser as a light source is capable of transferring more than 40 terabits (40 trillion bits) of data per second – nearly loss-free. That is the same as the content of 8,500 DVDs.

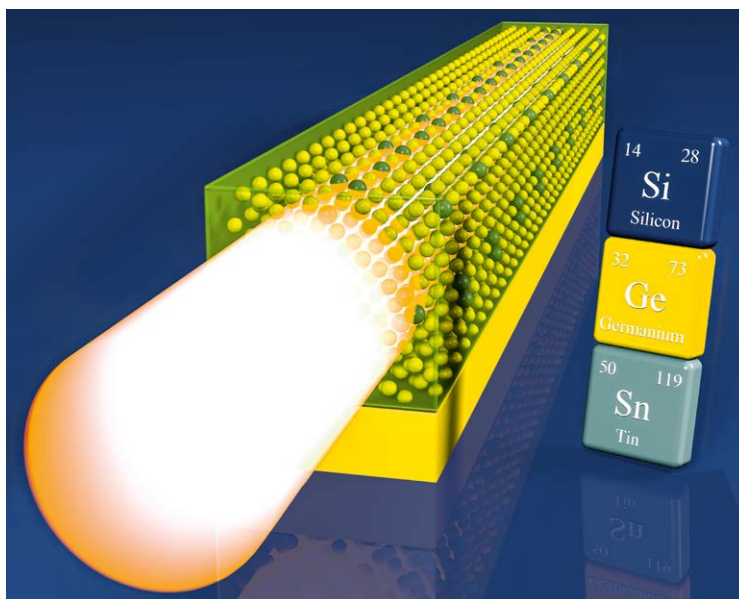
## Photons for electrons

With that in mind, it is quite surprising that computers still use electrons and copper wires to transfer data. Indeed, the data transfer between logic and memory chips or between the various processor cores of a chip is regarded as a bottleneck in current computer technology because the transfer capacity of copper connections is limited. “In addition, this type of signal transmission produces heat, which is harmful to all other components. This limits the possibilities of further developing larger and faster computers,” says Prof. Detlev Grützmacher, director at the Jülich Peter Grünberg Institute. Communication via light would therefore be rather convenient. It might even help to reduce the

energy consumption of computers: “In the conventional technology, the clock signal alone, in synchronizing the circuits, uses up to 30% of the energy – energy which can be saved through optical transmission,” explains Grützmacher.

In spite of intensive research efforts, the difficulty so far has been the lack of a light source, a laser, which can be easily integrated into the manufacturing process of

silicon chips. Semiconductor lasers, as used for data transfer in optical fibres, are not suitable for this purpose since their crystal characteristics are different from those of silicon. This means that they need to be produced separately and subsequently be glued onto the silicon component. These comparatively expensive lasers expand at a different rate than the silicon when heated, and this would quickly lead to defects.



Schematic structure of the germanium-tin laser, applied directly onto the silicon wafer (blue) by using an intermediate layer of pure germanium (yellow).



The successful Jülich researchers in the clean room pictured in front of the facility at which they manufactured parts of the new laser.

Scientists at the Jülich Peter Grünberg Institute, together with international partners, by and large solved this problem in 2014. In early 2015, they presented a semiconductor laser in the journal *Nature Photonics*: it consists of germanium and tin, elements which like silicon belong in main group IV of the periodic table and thus have similar properties. By means of a special technique, the new light source can be directly applied onto the silicon. The Jülich scientists developed this technique, which they called reactive gas source epitaxy, and filed a patent application for it. It can be used in commercially available facilities. It permits tin concentrations of 12–14 % to be incorporated within the crystal lattice of germanium without destroying its structure. Under normal circumstances, only 1 % tin is possible.

“The high tin content is decisive for the optical properties of the material,” explains Jülich PhD student Stephan Wirths.

These properties were measured at the Swiss Paul Scherrer Institute (PSI). “We were able to determine that the germanium-tin compound can amplify optical signals, as well as generate laser light,” says Dr. Hans Sigg from the PSI Laboratory for Micro- and Nanotechnology. So far, however, the material must be cooled down to minus 180 °C for the laser to function. To operate at room temperature, the tin content must be further increased. “With our international partners, we are on track towards overcoming this obstacle,” Detlev Grützmacher is convinced.

#### Handy sensor

The laser emits light at a wavelength of approximately 3 micrometres, that is in the near to middle infrared. The laser beam is not visible to the naked eye. For data transmission that is not significant, and in other regards, this wavelength region even offers new opportunities: radiation at this wavelength is especially strongly ab-

sorbed by greenhouse gases and biomolecules. By means of the new germanium-tin material, such substances could thus be detected – and very cheaply. The visions range from implantable chips for medical monitoring to portable sensors integrated into a smartphone to analyse substances in soil or air.

40 

terabits per second can be transferred through a single optical fibre with a single laser as a light source.



# Close Contact Within the Body

Cochlear implants enable around 30,000 people with impaired hearing in Germany alone to hear again, and retinal implants for the blind are being researched worldwide. The basis for these implants is a signal exchange between the brain and the electronics. Jülich scientists have found out how the contact between cells and electrodes can be improved, and thus the signal transfer.

**N**eurons transfer control signals within the body, and excitations caused by sensory stimuli. Amongst each other, the closest contact exists at the synapses – natural interfaces at which mostly chemical neurotransmitters transfer the signals from one cell to the next. Bioelectronic inter-

faces – or, to put it another way, artificial synapses – are being researched by Jülich scientists headed by Prof. Andreas Offenhausser, director at the Peter Grünberg Institute (PGI). “On one side of the interface there is biology, that is neurons,” explains Offenhausser. “On the other side is a tiny electrode. It is usually made of silicon,

gold, platinum, or other metals which are unproblematic for the cell.” The space in between the cell and the electrode is usually filled with an electroconductive liquid.

How well signals are transferred at such a bioelectronic interface depends on how close the cell is to the electrode. “A distance of as little as a ten thousandth of a millimetre prevents a signal from being measurable,” says Offenhausser.



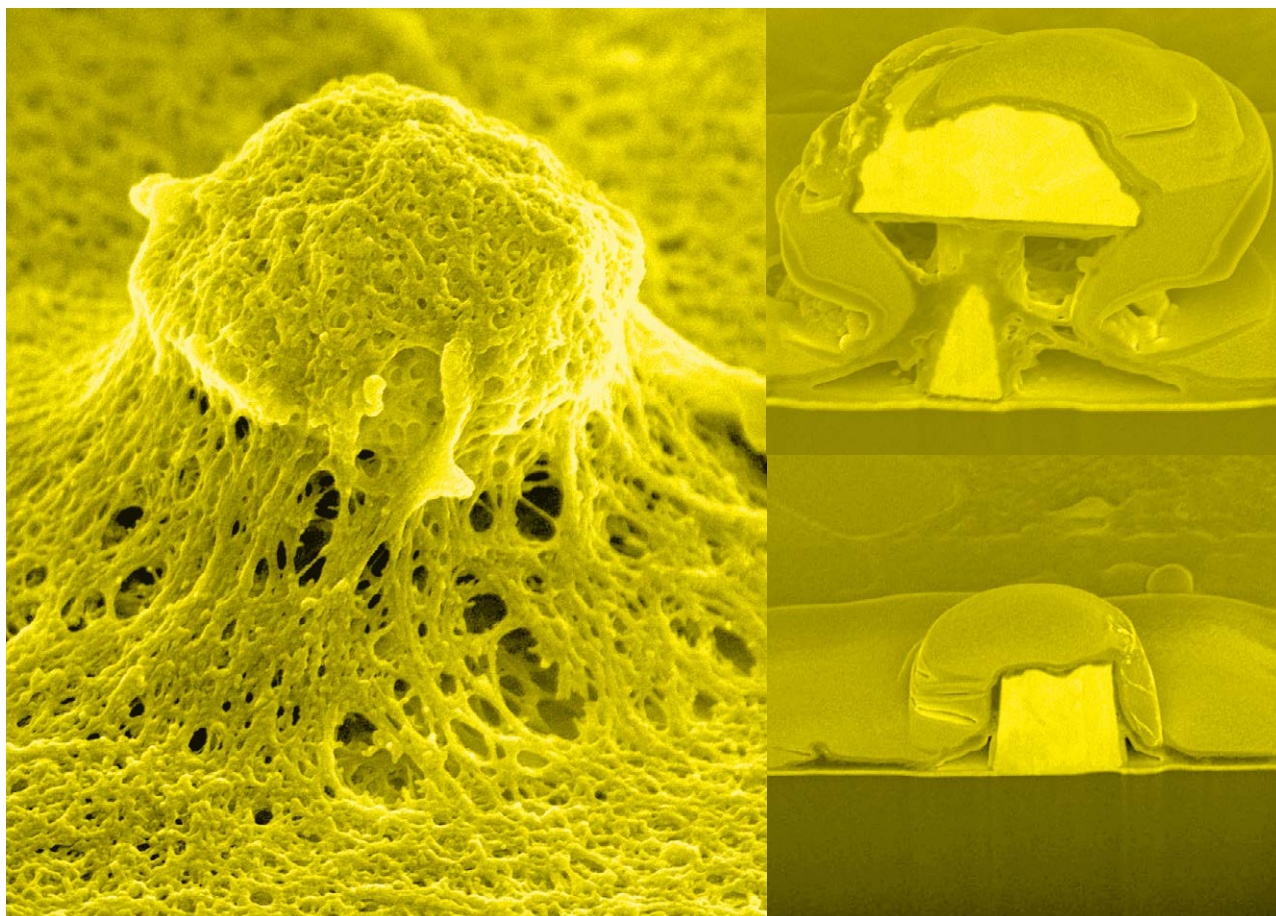
Prof. Andreas Offenhausser, bioelectronics expert at Jülich's Peter Grünberg Institute

## Nanoelectrodes as bait

To ensure that the cell is as close as possible to the electrode, the researchers use a trick. Most cells are capable of enveloping foreign bodies to subsequently incorporate them. Through this process, a cell ingests essential nutrients and neurotransmitters, but also, in some circumstances, harmful viruses or bacteria. This behaviour, called phagocytosis, is what the researchers take advantage of. Instead of flat electrodes, they design surfaces with the electrodes sticking out of them on the nanometre (millionths of a millimetre) scale. These three-dimensional electrodes appear to biological cells like a bait to be swallowed.

The design that is best for the bait, that is the nanoelectrode, in order to be most appealing to cells, was discovered in 2014 by the team headed by Offenhausser together with colleagues from Jülich's Theory





Under a scanning electron microscope, it becomes visible how the cell membrane wraps around the electrode.

of Soft-Matter Physics and Biophysics at the Institute of Complex Systems. According to their research, a simple cylindrical stalk is not ideal for the electrode. A mushroom-like shape with a long, thin stalk and a wide, umbrella-shaped cap is far superior.

#### Cleverly combined

The scientists reached this result by cleverly combining two methods: on the one hand, they studied the artificial interfaces by means of electron microscopy. By examining the cross-sections of the cells on the nanoelectrodes, they saw how close the cells were to the electrodes. On the other hand, they used a theoretical model of a cell membrane to predict its deformation. Their findings were published in the journal *ACS Nano*.

“In earlier tests, we experimented with other three-dimensional structures, but we chose the wrong dimensions and misjudged the cell,” says Offenhäusser. The cells were not able to envelop the nanoelectrodes if they were too small, or if the electrodes were located too close to each other on a surface. Researchers from all around the world had also manufactured three-dimensional nanoelectrodes with various shapes, but so far, no one had conducted a systematic study in which the experimental results with such electrodes were interlinked with the properties of cell membranes.

Near-perfect bioelectronic interfaces are important to improve retinal implants for the blind, and deep brain stimulation devices. Deep brain stimulation is a tech-

nique in which electrodes are implanted into Parkinson’s patients to alleviate the symptoms of the disease, such as strong trembling and motor disturbances. The Jülich insights may also prove helpful for the development of future neuroprostheses. A good connection between individual cells and electrodes may also be beneficial to sensor chips, with which for example the efficacy of drugs could be determined cheaply, rapidly, and without the need for animal experiments.

# Long-Distance Race to Alzheimer's Cure

It is a long and winding road: the way to a substance that in animal experiments helps alleviate the symptoms of Alzheimer's disease and that could become a drug involves many obstacles. A little molecule, developed at Jülich laboratories, has covered a good part of this way. An interview with its inventor, Prof. Dieter Willbold from the Institute of Complex Systems.

**In our ageing population, dementia disorders are becoming more and more frequent, and the world is waiting for an effective drug. How come your D3 substance, which works wonders for forgetfulness in mice, is not yet available on the market?**

Indeed, we were able to show years ago that mice exhibiting genetically determined dementia symptoms are protected from memory loss when given D3. D3 decreases the amount of dangerous  $\beta$ -amyloid molecule aggregates. It is particularly effective against small, soluble aggregates, the oligomers, which play a key role in the pathogenesis and progress of the disease. However, we were not able to spark any interest on the part of drug companies. This is not due to scientific concerns but because of things like patent protection: the patent application for D3 was filed in 2001, so the 15-year protective period is not valid for much longer. This, understandably, discourages companies from making big investments.

**What solution have you found?**

Firstly, we have further developed the substance: the new version eliminates  $\beta$ -amyloid oligomers even more efficiently. A patent was filed for this new active agent, so we have new patent protection. Secondly, we have decided to take matters into our own hands and to further develop the substance into a drug ourselves.

The Helmholtz Validation Fund gave us € 2 million to conduct a clinical phase 1 trial to show that our substance is well-tolerated by humans, and safe. Finally, we are thinking about founding our own spin-off company to further pursue the project. By the way, if we make any profit from it, we need to pay the money back to the Validation Fund. I very much approve of this idea, since other developments can then be funded.

**So you are going from researcher to company founder?**

Even if I do found a company, I will certainly remain a researcher. Operative management is a full-time job, it would have to be done by a managing director.

**Would it not be easier to approach industry again and to sell the licence for the new D3 active substance?**

The idea is less attractive to me, compared to founding a spin-off company. We have invested so much effort into this development, and the results are so promising, that I want our substance to have a real chance. That would not be guaranteed if it were licensed to a big drugs company. Even within one company, there are often substances competing with each other, and due to economic reasons some of them are not pursued further. I would like to avoid our substance simply disappearing into a drawer. We are now delegat-

ing the production of the active substance candidate and preclinical toxicology and safety tests to other companies. This is compulsory for a phase 1 clinical trial to begin next year.

**What else must be studied before that is possible?**

Particularly any potential side effects in animals, although we have not observed any in our tests. Our active substance is a D peptide, a short string of what are called D-enantiomer amino acids. They are a mirror image of L amino acids, which occur naturally in our own proteins. The advantages are that D amino acid molecules are very stable and our body breaks them down very slowly – if at all. They thus remain effective for a very long time. In addition, they are usually not recognized as foreign by our immune system, so they effectively fly under the radar of our body's alarm system. One theoretically conceivable disadvantage of this stability is that the active substance may be broken down poorly by the body.

**So it may accumulate?**

So far, we have found that the peptide is simply discharged unchanged with urine. But of course we have to be sure that it does not accumulate somewhere in the body where it is not supposed to. But there is another advantage of the peptide's stability: it easily survives the jour-



Prof. Dieter Willbold is testing a molecule of artificial amino acids as a potential active substance for Alzheimer's disease.

ney through the digestive and intestinal tracts, so it can be taken as a tablet instead of via injection.

**You seem very confident that your D peptide will make it all the way to the patient. Many other active substances which seemed promising at the beginning did not make it that far. How come you are so optimistic?**

Like many working groups, we tested the effectiveness of our substance in animal models, that is in mice which, due to a mutation, suffer from symptoms similar to Alzheimer's. Our advantage was that we tested D3 in several different Alzheimer's

mice strains, and the symptoms improved in each one. That encourages us. But whether or not it can help humans can only be determined in clinical trials, which will become possible after a successful clinical phase I.

**Alzheimer's dementia sometimes progresses quickly, and sometimes slowly and subtly. Would your substance, if it works at all, be effective for all forms of the disease?**

That is also a question that only trials with patients can answer. A drug would probably be more efficient the earlier during the course of the disease it is given to the pa-

tient. This is why we are also working on a process to diagnose Alzheimer's disease as early as possible. For this purpose, we link antibodies for  $\beta$ -amyloid molecules to fluorescent dyes. These fluorescent antibodies attach themselves to the soluble amyloid oligomers, which can then be detected and measured in bodily fluids with an elaborate microscopic imaging technique. If this diagnosing technique proves successful in practice we would have a new tool for an earlier and more reliable Alzheimer's detection. Early-stage Alzheimer's patients with the best prospects for success could then be selected in a targeted way to participate in clinical trials.

**What if it then only helps some of the patients?**

Even that would be a considerable step forward since, sadly, there is currently no causal treatment option. Seen optimistically, there will be several therapies and drugs in the end – just like for most other illnesses. It could also be that the term Alzheimer's actually disguises different forms of diseases. That is why it is good that currently many treatment strategies and active substance candidates are being developed, some of them very different from each other.

# Molecular Code Shared by Language Regions in the Brain

In the processes of speech and understanding language, different brain regions work together. JARA-BRAIN scientist Prof. Karl Zilles and a team from Jülich, Aachen, Leipzig, and Finland showed for the first time that there is a unique molecular code through which language-related areas in the brain recognize each other.

**F**orming words and sentences and understanding them is neuronal teamwork. Sounds must be received, concepts must be assigned, words must be comprehended in the context of sentences, and much more. It is not only adjacent brain regions that work together for this purpose, but also regions that are far apart. An example of this is the pSTG/STS area in Wernicke's region, which is

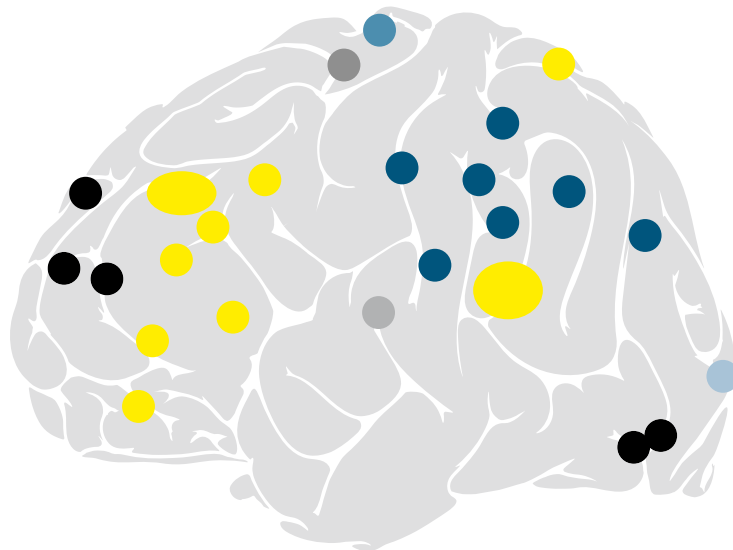
important for understanding language; it works together with the 45a area in Broca's region, which ensures smooth articulation. But how do these areas know which partners to work with? Neuroanatomist Karl Zilles and his colleagues recognized the molecular score through which individual notes combine into a "language symphony". "There is a molecular code shared by the language regions," says Karl Zilles.

"It is defined by the balance between the concentrations of the various transmitter receptors. Their typical balance in the language regions is clearly different from that in other regions which do not perform language-related tasks."

Receptors are protein building blocks which basically serve as docking stations in the brain for neurotransmitters such as GABA, glutamate, acetylcholine, norepinephrine, serotonin, and dopamine. These neurotransmitters are released quick as a flash between two neurons when an electric signal is received. They have to jump across a sort of trench – the synaptic cleft – between the cells. Upon arrival at the target cell, the transmitters dock into a certain receptor. For each of these neurotransmitters, there is one corresponding receptor – like the lock-and-key principle.

## Brain areas examined

The brain areas are located far from each other and still act as a team.



- Language-relevant brain regions
- Hearing ● Touch ● Sight
- Recognition of objects, working memory, emotions, spatial orientation
- Movement control
- Association of sight and touch to control actions





Prof. Karl Zilles and his team decoded the molecular basis of language processing.

### Biomarkers as smugglers

The molecular basis of language processing was previously unknown. Karl Zilles and his team succeeded in deciphering this code using a complex process to examine thousands of slices of the brains of deceased individuals. Even if it sounds simple, it involved precision work over weeks and months: first, the brains had to be prepared in a process involving several stages. With a microtome, they were then cut into thousands of slices 20 micrometres in thickness. This requires dexterity, patience, stamina, and, above all, concentration. After all, 20 micrometres is much thinner than the diameter of a human hair. Each individual slice was then mounted on a glass object slide for further scientific analysis.

In order to understand how language-related signals communicate in the brain, Karl Zilles and his colleagues analysed the distribution of 15 different receptors in language-related and language-unrelated brain areas. For this, the neuroscientists smuggled radioactively labelled molecules into the brain slices, which bonded with these receptors, but with only one type of receptor each. By exposing films that were placed on the slices, the receptors that had been invisible up to then were revealed – a bit like a secret code – and

scanned onto a computer. The higher the concentration of one receptor type in one place, the darker the film was in that particular area. “With the aid of quantitative receptor audiography, we obtained a very good spatial representation on the films of the distribution and concentration of the various receptor types,” says Karl Zilles. The intensity of the radioactivity was converted into real receptor concentration and imaged as different colour shades.

### Clusters of language areas identified

In order to recognize the similarities and differences in the number of signalling molecules in the functionally and structurally different human neural systems, areas with the same balance between 15 different receptor types (“molecular fingerprint”) had to be recognized as a cluster and functionally differentiated from other area groups. The aim of the research project was to identify the area cluster associated with language, and to isolate it clearly from clusters with other purposes through the statistical method of hierarchical cluster analysis. The result: “The molecular fingerprints of the language-related areas resembled each other, enabling them to form a cluster. This differs significantly from clusters in other brain regions, which process, for exam-

ple, sensory signals from the eyes, ears, or organs of touch,” explains Zilles. The analysis also showed that the language cluster in the left hemisphere encompasses more regions than that in the right. This corresponds on a molecular basis to clinical experience that the left hemisphere dominates speech and understanding language. The conclusion: all language-related areas of the cerebral cortex – which are sometimes far apart from each other – are united in a shared balance between various transmitter receptors. Each functional system within the cerebral cortex thus seems to be characterized by a typical molecular “chord” that links numerous areas with each other.

# Research for the transformation of the energy sector

It is hoped that renewable energy will cover around 80% of the electricity demand in Germany by 2050. In order to drive the “Energiewende”, the transformation of the German energy sector, various storage technologies are required, ranging from short-term storage of a few seconds to long-term storage for days, weeks, or even months.

**F**or days, the wind has been blowing over the northern German plain – but the rotors of the wind turbines are motionless. They had to be switched off because otherwise more electricity would have been produced than was needed. Whether it is a storm or a calm, or low solar radiation: electricity generated from renewables is by its very nature subject to strong fluctuations.

## Storage technologies in demand

The larger the share of wind and solar electricity becomes in Germany, the more important this effect will be for the electricity supply. According to the Federal Government's plans, by 2030 around half, and by 2050 around 80% of Germany's electricity demand is to be covered by renewable energy. This objective cannot be reached, however, without large, sta-

tionary storage. These units are required to take up surplus energy and later, when it is needed, to feed it back into the grid. “Storage technologies already play an important role in the energy system but that role is going to change distinctly due to the development of volatile renewable energy sources,” Prof. Rüdiger Eichel, head of the Institute of Energy and Climate Research – Fundamental Electrochemistry is convinced. Technologies are required which, depending on their application, range from high-performance storage systems for short-term operation to large-scale seasonal storage.

When it comes to energy storage for some days, pumped-storage and compressed-air power plants are today's state of the art. They employ mechanical energy storage systems. The Jülich scientists are taking a different approach: they are

banking on chemical energy storage in the form of hydrogen. “The electrolysis of hydrogen and subsequent conversion back into electrical energy with fuel cells lends itself to the purpose of seasonal energy storage. With this technology, energy can be stored on a large scale over several months,” explains Eichel. Once the energy-loaded hydrogen molecules have been produced, they can be stored without loss of energy – for example in the natural gas grid or in salt domes. Another decisive advantage is hydrogen's high energy density: a gas storage system can store far more energy than a compressed-air system of the same volume.

## Hydrogen energy storage

Hydrogen is well worth considering for energy storage because it is very easy to produce from electrical energy: if the wind produces more energy than needed, this surplus electricity can be used to split water into hydrogen and oxygen. “The problem with chemical energy storage systems is, however, that considerable losses occur during production,” explains Eichel. This makes the process uncompetitive.

The poor efficiency stems from the electrolysis stage, the process during which electricity is used to break a chemical bond. There are various techniques available for water electrolysis, which are either



Banking on chemical energy storage systems: Rüdiger Eichel, head of the Institute of Energy and Climate Research – Fundamentals of Electrochemistry (IEK-9).



Wind parks: wind today, a lull tomorrow, and gales the day after that – electricity generation from wind energy is subject to strong fluctuations.

already in use or are still in the development phase and can be used commercially only on a small scale. According to Eichel, “High-temperature electrolysis with solid oxide fuel cells for conversion back into electrical energy is still at the basic research stage, but it offers the highest efficiency of all electrolysis technologies.”

Solid oxide fuel cells (SOFCs) are therefore the focus of a Jülich project funded by the German Federal Ministry of Education and Research, which studies SOFC degradation and its causes and countermeasures. As part of the project, the lifetime of this type of fuel cell is to be increased to as much as ten years. “We first want to understand the ageing phenomena in such solid-oxide fuel cells,” explains Eichel. The influence of temperatures and pressure, for example, is being examined. Afterwards, the project partners want to develop countermeasures. In addition to IEK-9, who coordinate the project, the other partners are the subinstitutes Materials Synthesis and Processing as well as Microstructure and Properties of Materials, and the Fraunhofer Institute for Ceramic Technologies and Systems, the German Aerospace Center, KIT, the University of Oldenburg, and Clausthal University of Technology. “The three-year project thus pools the entire know-how from German SOFC research groups and industrial partners,” says Eichel.

### XXL batteries for the environment

When it comes to high-performance short-term storage solutions, the use of large-scale battery storage – XXL batteries, so to speak – is growing in importance. Currently, mostly thermal power plants such as hard-coal-fired power plants undertake this task. It can thus happen that during storms wind turbines are down-regulated while old power plants with high carbon dioxide emissions continue to be used. Large-scale battery storage based on renewable energy could in future stabilize the grid rapidly and precisely by compensating imbalances between electricity generation and demand within a few seconds. According to a study by Jülich scientists from the Institute of Energy and Climate Research – Systems Analysis and Technology Evaluation and the Berlin battery storage experts Yunicos, this form of storage also has ecological advantages in grid stabilization compared to hard-coal-fired power plants: coal-fired power plants contribute up to 90 times as much as battery parks to the greenhouse effect. In addition, their toxic effect on the ecosystem is 50 times as high, and their carcinogenic effect is up to 90 times as high. The data for the study were supplied by a large-scale battery storage system in Schwerin: here, Yunicos built Europe’s first commercial large-scale battery storage system in the form of a 5 megawatt lithium-ion facility. “The new

study is the first to incorporate ecological aspects and thus permits a multi-layered assessment of stationary large-scale battery storage systems and modern hard-coal-fired power plants,” concludes Prof. Jürgen-Friedrich Hake, head of IEK-STE. “Such systems analyses are of enormous significance. Scientific and technological developments are now much more strongly coupled with social, economic, political, and legal aspects – so as not to leave society out,” explains Eichel. This much is clear: the transformation of the energy sector can only be successful if politicians, scientists, and the public work together hand in hand.



times higher: the contribution of coal-fired power plants to the greenhouse effect, compared to battery parks.

# Energy to Go

The development of the lithium-ion battery is a success story. But for the future, rechargeable energy storage units for mobile applications are in demand which will not only be more powerful and durable, but also more resource-efficient.

It is currently unbeatable: the lithium-ion battery is the standard in all mobile devices. In 2014, far more than 5 billion of these batteries were sold – for smartphones, notebooks, cameras, and electric cars. Concerning further development, scientists think that the conventional lithium-ion battery will reach its performance limit in a few years. For example, they expect the range of electric cars with lithium-ion batteries never to achieve the same range as cars with fuel tanks. Smartphones are also becoming more and more energy-hungry and demand new solutions. Jülich researchers are pursuing two paths in battery research: on the one hand, they are trying to optimize lithium-ion technology. On the other hand, they are also looking for new approaches that do not require the sought-after alkali metal.

## Safe solid-state batteries

Scientists from the Institute of Energy and Climate Research (IEK-1) presented a promising approach for a new, particularly safe generation of lithium-ion batteries in 2014. Models commercially available contain liquid, sometimes toxic, or even flammable electrolytes. The electrolyte is the medium within the battery which internally transports the ions between the two electrodes. The Jülich researchers have now replaced the liquid electrolyte with a ceramic solid. Replacing the liquid with a solid alleviates problems such as leaking, burning, and toxicity and also permits a high energy density. This is the most important value in comparing various battery systems, and describes how much energy per mass or volume can be stored in a battery. The higher the energy density,

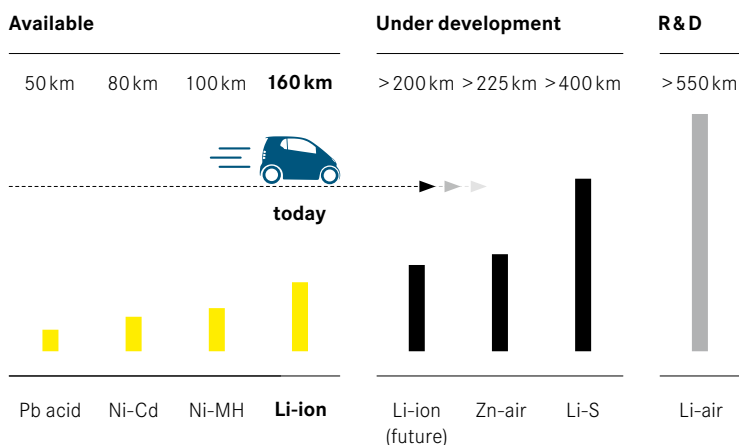
the smaller and lighter the battery for the same capacity. “On a laboratory scale, this solid-state battery is already working very well,” says Dr. Sven Uhlenbruck.

## Deliberately introducing defects

The DESIREE project, launched in 2014 and funded by the German Federal Ministry of Education and Research (BMBF), is also concerned with improving lithium-ion technology. Project leader Dr. Désirée van Holt and her team at IEK-9 are concentrating on the development of cathode materials for high-performance lithium-ion batteries, which it is hoped will replace present lithium-ion batteries in laptops, phones, and electric cars: “Everywhere where a lot of power is required in little space or with little weight, such systems are in demand,” says van Holt. Cathodes and anodes are important starting points for optimizing the energy and power density, since the lithium ions are inserted into and removed from them. In simple terms: the more electrode material is present, the more energy can be stored in it.

## Operating range of electric cars

What batteries are available on the market, and which are at the research stage? An overview.



DESIREE's focus is on high-voltage spinels, which are crystalline materials, known as doped lithium-manganese oxides. These spinels naturally contain defects, “holes”, which permit the ions to move through the lattice-like structure. By intentionally removing atoms from the lattice and thus creating further holes, the scientists can increase the number of lithium ions conducted. If there are too many, however, the lattice structure is destroyed. High-voltage spinels are





The future of the car is electric – but which battery type will win the race in the long term is not yet certain.

known for reaching high performances: voltages of up to 5 volts are possible. This high voltage ensures that the lithium ions move from the anode to the cathode very quickly. “The faster this transport happens, the faster the battery can be charged and electricity withdrawn from it. We want to further increase the conductivity of lithium-manganese cathodes so we can achieve even higher performance,” explains van Holt.

#### **Anode made of pure lithium**

A further possibility to readily increase the energy density of a lithium-ion battery by 50% is utilizing pure lithium for the anode. Currently, graphite is used, since the use of lithium brings some challenges with it, such as the formation of porous lithium at the anode. This build-up may cause short circuits or break through protective layers and thus destroy the battery. Developing countermeasures requires scientists to understand these processes in detail. “With electron spin resonance spectroscopy, we have found a new method with which we can observe in real time how the porous lithium is formed at the anode,

and some of it removed again,” explains Dr. Josef Granwehr from IEK-9, who helped develop the experimental set-up.

In 2014, IEK-9 also received considerable funding from BMBF for the further development of novel, post-lithium battery concepts. As part of AlSiBat, the scientists are researching metal-air systems, particularly aluminium- and silicon-air batteries. Theoretically, their energy densities promise to be close to that of petrol. Even if these cannot be practically achieved for the time being, AlSiBat project leader Dr. Hans Kungl, who researches metal-air systems, is convinced: “Energy densities five times higher than those of lithium-ion batteries are realistic.”

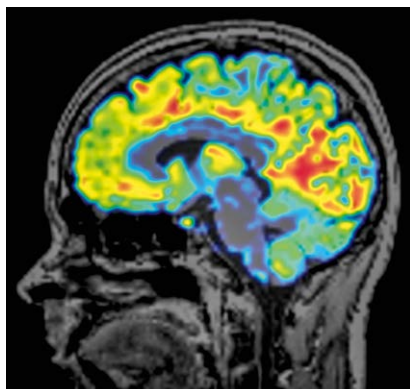
For their implementation, the scientists are banking on new electrolytes, such as low-melting salts, known as ionic liquids. The electrochemical reactions severely limiting the charge-discharge cycle of metal-air batteries are still mostly unclear: an iron-air battery, for example, can currently only be charged up to twenty times – for market maturity, 1,000 cycles are necessary.

Apart from the energy density, the availability of resources is also in favour of metal-air systems, and thus for AlSiBat, since whether or not there are enough lithium resources to cover the global energy market on the long term is uncertain. The metals aluminium, silicon, iron, zinc, and magnesium, on the other hand, are virtually unlimited, and can be much more easily processed. “We are just at the beginning of a potential success story of metal-air batteries. Currently, their efficiencies are much too low. It is our task to accomplish the necessary technical improvements,” says Kungl. Several decades will probably pass before market maturity. But Kungl remains optimistic: After all, the efficiencies of solar cells were also ridiculed in the 1990s. Today, transforming the energy sector is not conceivable without efficient solar technology.

# Projects at a Glance

## Brain research

### Risk factor or protective mechanism?



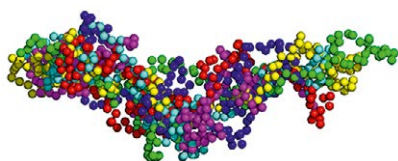
Fear of heights, of crossing large open spaces, or even panic attacks without apparent reason – these anxiety disorders are experienced by many people. Together with depression, they are the most common mental disorders in Germany. A team of researchers headed by Prof. Andreas Bauer from Jülich's Institute of Neuroscience and Medicine in cooperation with scientists from the universities of Münster and Würzburg has found out that this may be due to special proteins in the brain, known as adenosine A1 receptors. These receptors contribute to transferring signals which regulate wakefulness and tiredness, among other things.

In a pilot study with 28 healthy participants, the distribution of the molecule was examined by positron emission

tomography. The study showed that a gene variant which had previously been identified as a risk factor for anxiety disorders goes hand in hand with high concentrations of adenosine A1 receptors in certain brain regions. Since the test subjects had a genetic predisposition for anxiety disorders, but did not show any relevant symptoms, the researchers believe that the increased receptor concentration may be a compensation mechanism to counter the anxiety symptoms. It may also prove useful for diagnosing a predisposition to anxiety disorders. If the results are confirmed, they may also present a starting point for new medical treatment of anxiety disorders.

## Structural biochemistry

### Insights into the world of proteins



When it comes down to what proteins can do, it is all about the shape. Depending on their structure, proteins function as enzymes, antibodies, or muscle fibres, and carry out countless other tasks. In addition, many proteins change their shape during their work. Jülich researchers achieved new insights into this complex world in 2014.

A team from the Institute of Complex Systems, together with colleagues from the Institut de Biologie Structurale (IBS) in Grenoble, developed a new method, based on solid-state NMR spectroscopy, which can make short-lived protein states visible. They were able to show that the protein ubiquitin, which is responsible

for labelling faulty proteins to be broken down, can jump between two shapes. The method may prove useful to find previously unidentified points of attack for new drugs, for example.

Masters of metamorphosis can also be found: intrinsically disordered proteins are capable of very flexibly taking on new shapes again and again. That is also the reason why, until now, they had been difficult for scientists to grasp when trying to determine their structure and dynamics. Researchers at the Jülich Centre of Neutron Science have now managed to pull off this feat. They bombarded such a protein – the myelin basic protein (MBP), which envelops neurons in the brain – with neutrons and concluded from the neutron scattering that, in contrast to previous assumptions, MBP in a solution is only movable at its ends, while it has a relatively compact and rigid core region.

Neutron scattering experiments by Jülich and Munich researchers in collaboration with Leicester University also solved the mystery of what the decisive structure of the enzyme cytochrome peroxidase looks like, reports the journal *Science*. As part of the body's metabolism, the protein decomposes the toxic hydrogen peroxide. In this process, an iron atom in the enzyme plays a central role: it binds and transfers oxygen. The researchers got to the bottom of an intermediate state, which the enzyme takes on during this process, by flash freezing the molecules to minus 173 degrees, thus stabilizing the intermediate state.

## Brain research

## Sleepless in science



What happens in the human brain when someone is forced to stay awake for an unusually long time, and how long does recovery from sleep deprivation take? Jülich neuroscientists in cooperation with the German Aerospace Center (DLR) studied the consequences of extreme environmental conditions on humans and possible countermeasures at the DLR research laboratory :envihab. Using positron emission tomography, a team headed by Dr. David Elmenhorst and Prof. Andreas Bauer from the Institute of Neuroscience and Medicine analysed changes in the brain chemistry of people who stayed awake for long periods – up to 58 hours. Such long sleep deprivation leads to the metabolic product adenosine accumulating in the brain. When it attaches to neurons via the relevant receptor, the body takes it as a signal to go to sleep. If test subjects are prevented from going to sleep, however, the number of adenosine receptors increases: more adenosine can accumulate, while simultaneously the attention of the subject decreases. This may be caused by the higher number of receptors. However, after a relatively short period of 14 hours of sleep, the number of

adenosine receptors is normalized. Attention also returns to normal. Test subjects performed as well after the sleep phase as before the experiment. The insights are medically interesting because there are indications that chronic lack of sleep leads to changes in the brain similar to those of patients with dementia disorders.

## Materials research

## Platinum – cheap octahedron pack

Fuel cells require the expensive platinum to generate energy by combining hydrogen with oxygen to form water. The noble metal serves as a catalyst. Nanocrystals containing, for example, nickel or cobalt in addition to platinum are much cheaper than those containing pure platinum. Such particles, which are octahedron-shaped – they look like two pyramids, joined at their bases – had been developed as early as 2013 by scientists from the Peter Grünberg Institute and colleagues from TU Berlin. They require only a tenth of the amount of platinum usually necessary. Researchers from Jülich and Berlin together with colleagues from Tsinghua University in China were able to monitor how the useful shape of the binary nanocrystals came about by means of ultra-high-resolution electron microscopy as described in the journal *Science*. Firstly, a cross-shaped base frame with six points is formed, made up almost exclusively of platinum atoms. After this, nickel and cobalt atoms attach themselves to it until the depressions are filled in. As soon as an octahedron with smooth surfaces has formed, the growth stops. These new insights will help in developing more efficient and durable catalysts for fuel cells.

## Nanoelectronics

## Data transport on the nanoscale

Smaller, faster, more efficient – these are the requirements for the computer processors and data storage of the future. Spintronics represents a promising strategy. The aim is to process and store information based on the electron spin, instead of the electric charge, which is currently used for this purpose. Spin is a quantum-mechanical property of particles which can be imagined as a minute magnet. As early as 2011, scientists from the Peter Grünberg Institute together with colleagues from the University of Hamburg first described a skyrmion lattice – a magnetic vortex structure – at a surface. In 2014, they were able to deliberately modify this structure. They placed individual, honeycomb-shaped carbon compounds, e.g. tiny graphene “islands”, on an iron-iridium thin film. Hybrid compounds of the metal and the organic molecule are formed, and they drastically change the magnetic properties of the surface. The skyrmion lattice couples these “molecular magnets” with each other, so that they can be individually switched while the magnetic moment and the field intensity can be influenced. Since the magnetic coupling reaches quite far, the researchers expect that the new material combination may allow information to be transferred on the nanoscale.



## Nanoelectronics

### More mobile than assumed

Metallic nanoparticles are mobile in fluids, but generally immobile in solids, especially in non-conductive materials – that is the scientific consensus to date. But Jülich physicists, together with US researchers, got this rigid world view moving. With the aid of an in situ transmission electron microscope, they examined the interior of resistive memory cells – switching devices

for the future of nanoelectronics. Their result: they do move. Clusters of metal atoms such as silver or even platinum can move around in materials like silicon oxide if under the influence of a strong electric field and in the process build bridges between the two opposite electrodes of the switching device. This changes its electrical resistance: the non-conductive material becomes a conductor – a phenomenon which can be used for storing information.

This is what makes the insight interesting for developments in nanoelectronics: resistive switching elements are seen as very promising since they require little energy and are able to switch between dif-

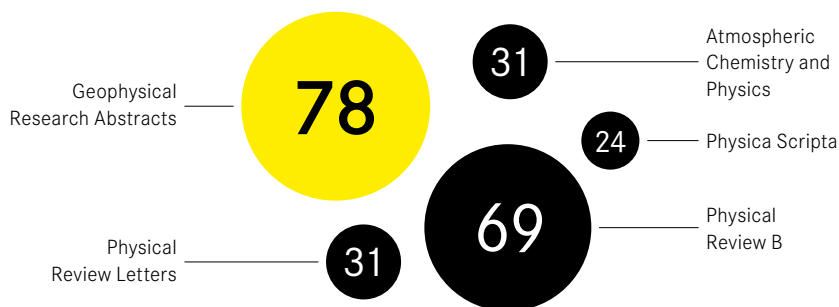
ferent states very quickly. Simultaneously, they combine logic and memory, similarly to neurons. Researchers hope that they could become the basis for circuits capable of learning using nature as a model. Observation of these mobile atoms has for the first time explained how the different states of resistive cells, which were already known, come about – an insight which may help to influence these processes in a targeted way.

## Publications

New scientific insights are only actually beneficial to the world in general if they are made accessible to other scientists – that is, by publishing them in a scientific journal. Only then can others verify the new knowledge, correct and amend it if necessary, and finally use it. It is therefore no coincidence that publications are considered to be an important benchmark for scientific achievements. Of particular importance are publications in journals which are often used and cited by colleagues, above all the renowned scientific journals *Nature* and *Science*. In 2014, a total of five articles written by Jülich researchers made it into the research journal *Nature*, and three into *Science*. The total number of Jülich publications has also risen once more.

### Journals in which Jülich researchers publish most frequently

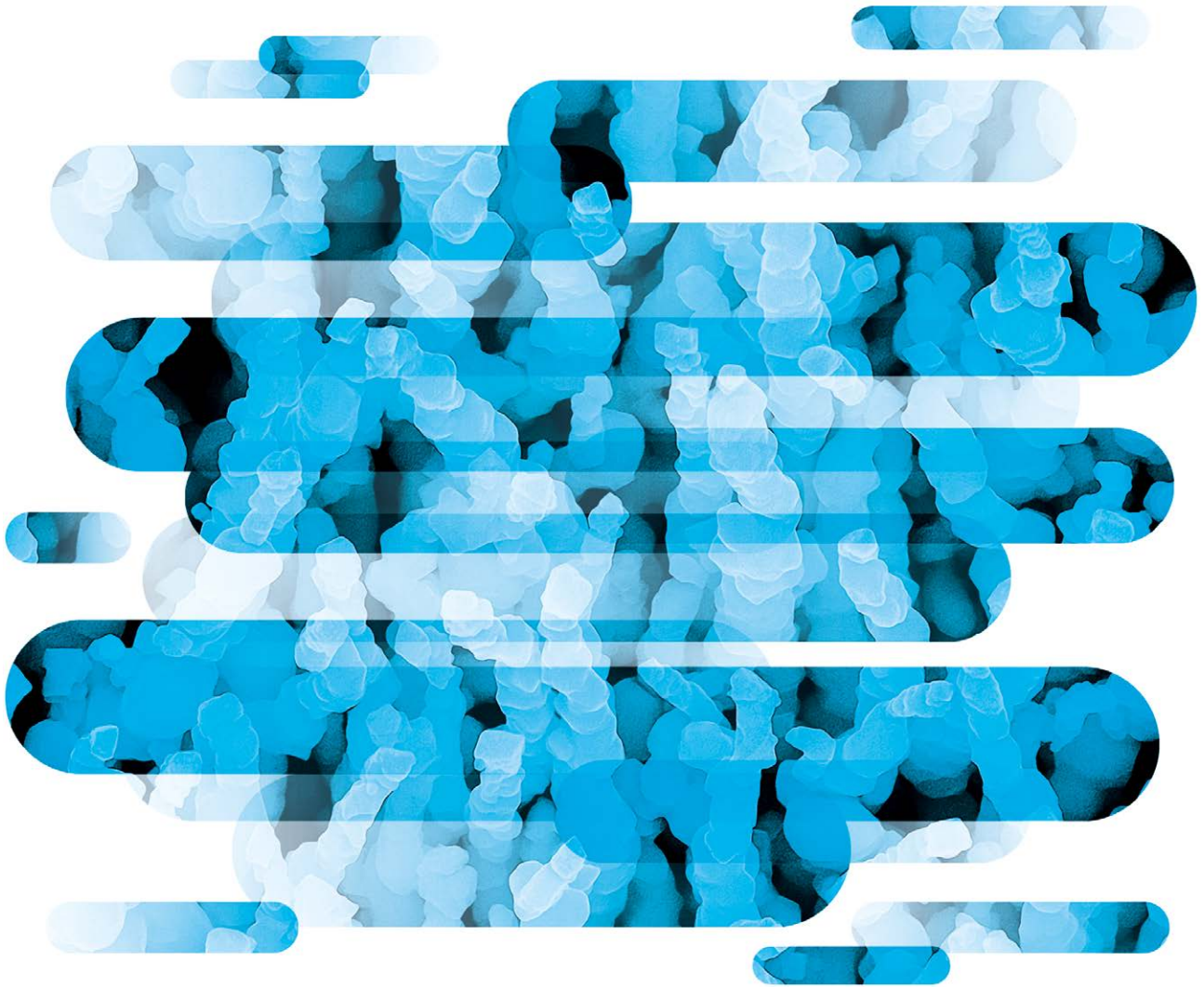
2014



### Jülich publications

Year	Total	Journals	of which with researchers from other institutions	Books, other publications	PhD theses, habilitations
2010	1,834	1,048	770   73.50 %	686	100
2011	2,115	1,363	1,013   74.30 %	651	101
2012	2,233	1,452	1,100   75.80 %	688	93
2013	2,414	1,485	1,175   79.10 %	825	104
2014	2,449	1,614	1,337   82.84 %	713	122





# Cooperation

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# Regional Solutions for Global Change

Large-scale research projects and expensive infrastructures are hardly realizable for individual institutions. For this reason, Forschungszentrum Jülich cooperates nationally and internationally with institutions from science and industry. TERENO is one example of many partners achieving great results.

**B**irds are singing and the sun penetrates the green canopy of leaves at the edge of a large clearing in the northern Eifel. Through the middle of the cleared area, the Wüstebach river meanders in its bed. With every step, dry spruce twigs crack under our shoes. Until two years ago, spruces grew right down to the river bank. After clearing them, it has become lighter, and young herbs and deciduous trees are already covering the open area. We walk deeper into the forest, until suddenly a metal fence as tall as a man blocks our path, with a scaffold-like mast which towers over the treetops. "This is our measuring tower," explains Dr. Heye Bogen, researcher at Jülich's Institute of Bio- and Geosciences (IBG). "We were able to build it within the scope of the large-scale project TERENO." TERENO is short for TERrestrial ENVIRONMENTAL Observatories and is, first and foremost, one thing: an assemblage of devices for collecting environmental data from the air and the ground.

## Observing Earth

The tower is packed full of instruments. The researchers record greenhouse gases such as carbon dioxide and nitrous oxide, which are exchanged between forest and atmosphere. "Forests protect our climate: they can store gases under certain circumstances, and therefore lower their concentration in the atmosphere," explains Heye Bogen. Other institutions, such as the universities of Trier, Cologne, Bonn, and Aachen, have also attached devices to the measuring

tower – ranging from rain scanners to bat detectors. "This was an important concern for TERENO: we specifically wanted to collaborate with other institutions," says Prof. Harry Vereecken from Forschungszentrum Jülich, who coordinates the project.

TERENO is a network of four observatories dedicated to Earth observation reaching from the north-eastern German plain down to the Bavarian Alps. "Even if the initiative came from Jülich, TERENO is not a local project from an individual institution," emphasizes Harry Vereecken, who also heads the Agrosphere sub-institute at Jülich. Six Helmholtz centres are involved



Distributing and installing rain collectors in a mixed beech forest



## The extensive infrastructure we built is available to all environmental researchers.

**Prof. Harry Vereecken** | Director at the Agrosphere subinstitute

Back in the spruce forest, the next instruments appear a few steps behind the measuring tower. At first glance, they look quite unremarkable: large circular steel rings with a diameter of one metre are sticking out of the ground. But underneath them are concealed real data collection centres: “Each of these approximately 1.5-metre-high metal cylinders – called lysimeters – is filled with soil and equipped with numerous sensors,” explains Dr. Thomas Pütz from IBG, who is responsible for these instruments within the TERENO project. The entire facility works fully automatically and via radio controls transmits data on evaporation, precipitation, temperature, carbon dioxide content, and many other parameters. “What’s exciting is that together with our partners in the TERENO project, we can, to some extent, simulate climate change with the aid of the lysimeters,” Pütz reports.

### Simulated Climate Change

“With 126 lysimeters in all the observatories, we have established the largest network of this kind worldwide: SoilCan,” he adds. The various locations have opened up completely new possibilities to the researchers: “We moved the filled lysimeters from one TERENO study location to another,” says Pütz. Not at random, but with a pattern: lysimeters from the climate-sensitive cold and wet Alps were brought to the rainy, but warmer lower Rhine embayment with its

with the large-scale project, which was launched by the Helmholtz Association in 2008 and which is planned to run for around 15 years. It unites hydrologists, soil researchers, biologists, climatologists, and socio-economists. Together, they are studying what local consequences result from global climate change – for the soil, water, vegetation, and ultimately the human habitat. “The extensive infrastructure is available to all environmental research. It makes it possible to collect quantities of data not obtainable before. For a single university or research institution, such equipment would simply be too expensive,” Harry Vereecken explains the benefits.

15 

years is how long the research project will run for at least.



Atlantic climate. Soil cores from the Eifel on the other hand were taken to the Central German lowland and its continental climate. “This region has seen more dry periods and wetter, warmer winters during the past few years. We moved each of the soils to the climate which, due to climate change, is predicted for the future in their region of origin. This helps us gain an impression of how soils may react to future changes in climate,” explains Pütz.

### Back to mixed deciduous forest

“What is special about TERENO is that all observatories have nearly identical technical equipment,” emphasizes Vereecken. This makes the results easily comparable. “You should know that terrestrial environmental research in Germany used to be very fragmented. Even within one discipline, there were many individual measuring approaches,” he says looking back. One big challenge of the project was therefore to unite the different disciplines. TERENO brought everyone to one table: together, they determined which parameters and issues to examine, what measuring techniques and instruments would be required, and how to ensure that the exchange and comparison of data would function.



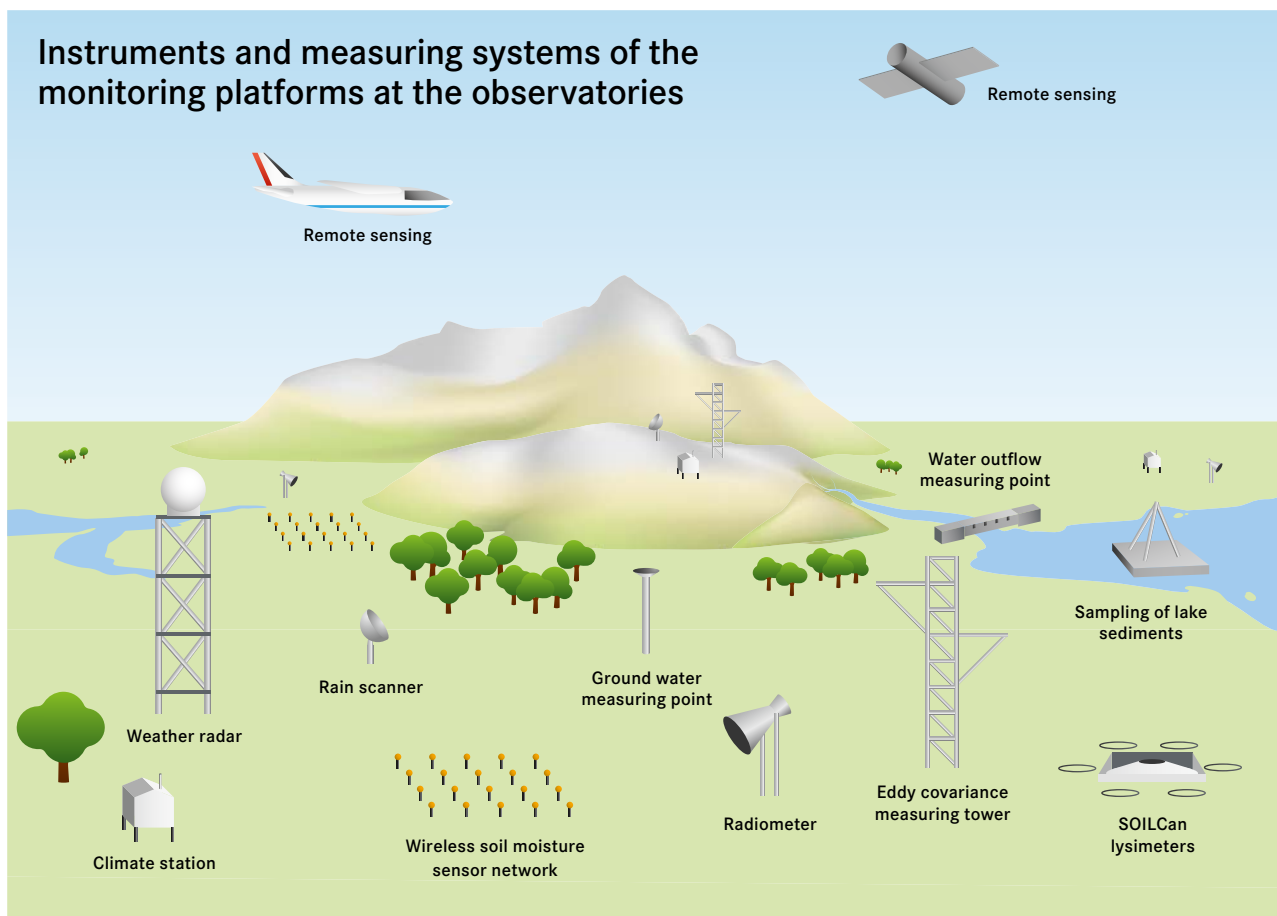
Selhausen  
climate station

The example of Wüstebach in the Eifel National Park clearly demonstrates the advantages of the cooperation. Eight hectares of spruce forest were cleared here in 2013 by the Eifel National Park. But the clearing is only intended as an intermediate stage. The first delicate rowan and beech seedlings are already unfurling their green leaves. In 30 years, a river-side forest with native birch, beech, and alder trees will grow here, and develop uninfluenced by humans or forestry. “Together with the universities in Bonn and Trier, we are monitoring this transformation from an artificial spruce forest to a near-natural mixed deciduous forest,” Thomas Pütz explains. The researchers want to find out what consequences clearing has on the soil, on biodiversity, water quality, and the exchange processes with the atmosphere. “Due to the deforestation, the soil is subjected to larger temperature fluctuations and more pronounced dehydration – but this is actually beneficial for colonization by microorganisms, who like it a bit warmer,” Pütz explains. “This may mean a change in nutrient decomposition in the soil.” But first results show that so far there has been no greater emission of nitrogen and carbon from the soil.

The scientists are also able to observe this through a wide-branching network of sensors in the soil, which continuously collects data on soil moisture and temperature. Just like little waymarks, numerous poles stick up from the ground. “They are indeed markers, but not for hikers. At these spots, probes are buried in the ground,” says Heye Bogena. They are inserted into the ground at five, 20, and 50 centimetres depth and via radio they transmit their measurement data to a receiving station at Forschungszentrum Jülich, almost in real time. “This sensor network, named SoilNet, was developed at Jülich within the scope of TERENO,” says Bogena. Around 900 measurement sensors are buried around the Wüstebach river alone, and there are others at the Rollesbroich site in the Eifel. SoilNet is also in use in the other observatories.

But cooperations within TERENO are not limited to activities on the ground. With the aid of research aircraft and space satellites, the researchers are collecting important information from the air and from space. In early 2015, a new satellite mission was started by NASA. The SMAP satellite (“Soil Moisture Active Passive”) gathers soil moisture data worldwide, from an altitude of around 670 kilometres. Soil moisture is an important climate variable for global and regional climate models. As part of TERENO, Jülich researchers are checking how accurate the calculations of





soil moisture from the satellite data are. For this purpose, they compare the results with their soil measurements from the TERENO observatory Eifel/lower Rhine embayment. Thus, if there are deviations, NASA can correct its calculation algorithms.

### Exemplary

Right from the start, the idea behind TERENO was to not simply concentrate on the individual processes of the compartments: “We also focus on the interaction between soil, plants, and atmosphere,” explains Vereecken. An ambitious approach like that can only succeed if all involved disciplines cooperate – nationally as well as internationally. For the European research infrastructure ICOS (Integrated Carbon Observation System) for example, an infrastructure designed for measuring greenhouse gases, TERENO is one of the most important cooperation partners gathering measurement data for Germany on greenhouse gases and carbon balances. TERENO is also active in the worldwide network LTER (Long-Term Ecological Research). “Cooperation and coordination are crucial. This is why we are even happier when cooperation partners from

Germany and abroad commend TERENO as exemplary,” Harry Vereecken is delighted to say.

The close cooperation that Jülich researchers have with the neighbouring universities at Bonn, Aachen, and Cologne is also exemplary: together, they form a collaborative research centre of the German Research Foundation (DFG). In late 2014, the DFG extended Transregio 32 by another four years. As part of the project, the scientists study, for example, how carbon dioxide and water vapour are exchanged between soil and atmosphere, depending on the landscape profile. For this purpose, the researchers use the infrastructure in the TERENO observatory Eifel/lower Rhine embayment, jointly developing models for flood predictions and weather forecasts.

But not only universities, water authorities, and agriculture profit from TERENO: the German weather service (Deutscher Wetterdienst) also uses the data from the TERENO weather radar, which is located near Jülich on the 290 m high Sophienhöhe hill. With it, Jülich researchers can locate precipitation within a radius of 100 km with a precision of 200 m, as well as

distinguish between rain, hail, and snow. These data help in predicting flood events, which the neighbouring water authorities at the numerous reservoirs in the Eifel region can then prepare for.

Everyone involved is so convinced of the value of the TERENO project that even today there is no formal cooperation agreement. “Of course, it started out as an interest group,” Vereecken remembers: the large-scale project received a lot of money – € 3.4 million through the first three years, and more than € 20 million altogether. “To receive that much money for basic research is a huge gain for everyone, since big industrial companies don’t invest in soil research,” Vereecken continues.

incidental results,” explains Vereecken. The researchers are particularly happy about extreme weather situations, such as the dry spell in spring 2011. “Nothing like that had happened for 100 years. It is during such extreme events that we learn the most because then we can see the concrete consequences in the soil and the biosphere,” adds Heye Bogena. TERENO is a success story which promises an interesting future. This also became apparent in the first international conference on TERENO, hosted in Bonn by Forschungszentrum Jülich in October 2014. “We built up something from nothing – and it has led to widespread international visibility,” Vereecken summarizes. “That is to the credit of everyone involved and their joint planning and excellent scientific contributions.”

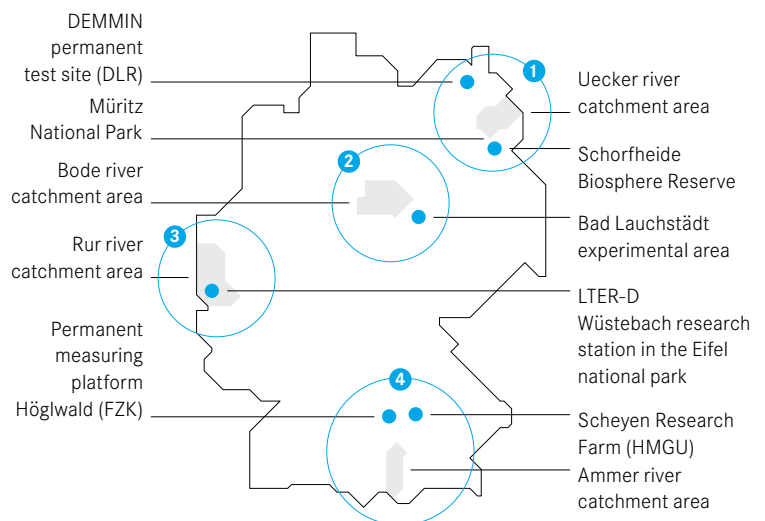
### Extreme weather conditions welcome

“But it is still too early for results because climatic processes fluctuate a lot. For that, we need long-term measurements. Only with those can we distinguish long-term trends from short-term variations and co-



Weather radar station on the Sophienhöhe hill near Jülich

## TERENO observatories



**1 Observatory north-eastern German plain**  
Coordination: GFZ

**2 Observatory Harz/central German plain**  
Coordination: UFZ

**3 Observatory Eifel/lower Rhine embayment**  
Coordination: FZJ

**4 Observatory Bavarian Alps/Alpine foothills**  
Coordination: KIT/HMGU

# Cooperations at a Glance



ORPHEUS –  
increasing fire  
safety in under-  
ground traffic  
arteries

▼  
€ 15  
million

## Fusion research

With the EUROfusion consortium, which encompasses 29 national fusion research centres from 26 countries, European research into fusion restructured itself in 2014: the resources of Europe's national fusion research centres are to be more efficiently concentrated on the common goal – the first fusion power plant. Around half of the € 857 billion five-year budget (2014–2018) is financed by the EU. Around € 15 million of that is earmarked for Forschungszentrum Jülich.

The Jülich researchers will focus on plasma-wall interactions and materials research. They will make use of Jülich's test facilities and be involved in the large-scale experiments JET, Wendelstein 7-X and ITER.

▼  
€ 11.5  
million

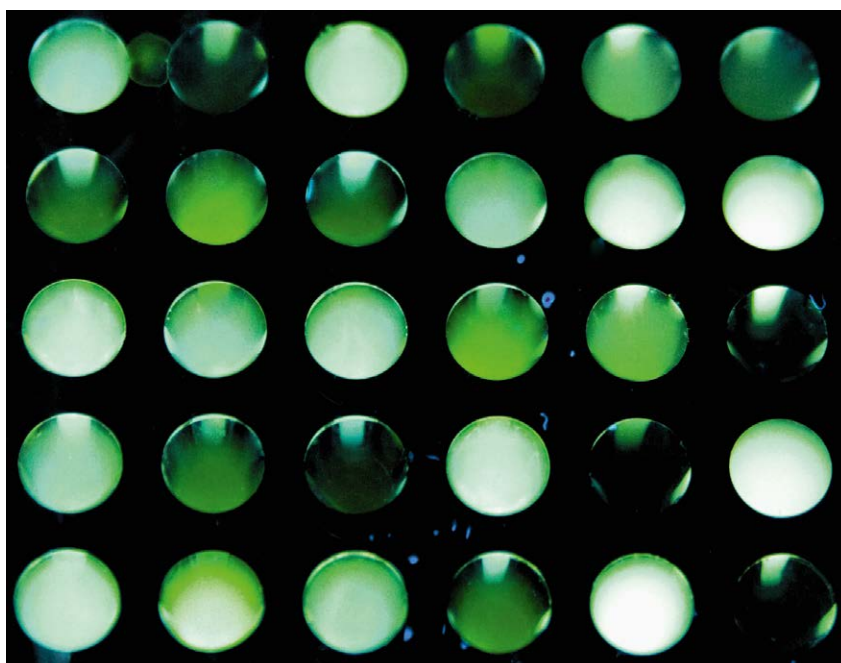
## Soil – plants – atmosphere

In November 2014, the third phase of the collaborative research centre Transregio 32 (TR 32) entitled "Patterns in Soil-Vegetation-Atmosphere Systems: Monitoring, Modelling and Data Assimilation" was approved. Here, new methods for examining the exchange of energy and substances – especially water and carbon – between soil surface, vegetation, and the atmosphere will be developed. This includes the development of dynamic models which are hoped to better predict these flows. TR 32 strengthens the regional cooperation between Forschungszentrum Jülich and the universities of Aachen, Bonn, and Cologne. This third phase of the project will be supported with € 11,549,800 by the German Research Foundation (DFG) from 2015 to 2018. Of that sum, 24.5% is dedicated to the work of Jülich's Institute of Bio- and Geosciences.

▼  
€ 2.6  
million

## Biotech tools

For the Helmholtz network "Molecular Interaction Engineering" (MIE), scientists from Forschungszentrum Jülich, the Karlsruhe Institute of Technology (KIT), and Helmholtz-Zentrum Geesthacht have been working on novel technologies for bioproduction since November 2014. This includes biotechnological tools which are created as "printable biology" in thin films on technical surfaces, in analogy to printed circuits in electronics. Possible fields of application are the pharmaceutical industry and food technology as well as molecular biology and medical diagnostics. BMBF will finance the project with € 2.6 million over five years.



Microtitre plate reaction vessels with *Escherichia coli* bacteria cultures, which contain various fluorescence proteins.

▼  
€ 1.1  
million

## Civil security

In February 2015, the ORPHEUS project on optimizing smoke management and evacuation strategies in underground train stations was launched. Together with university and industry partners, scientists from the Jülich Supercomputing Centre (JSC) are researching how fire safety can be improved in complex multi-storey underground stations. BMBF has pledged € 3.2 million, of which € 1.1 million is reserved for work at JSC.

▼  
€ 1.36  
million

## Optogenetics

In the collaborative project “New optical sensors and photoregulators for light-mediated control and analysis of molecular systems” (OptoSyS), new optogenetic approaches will be developed to control and observe biological processes in living cells and organisms. These methods make it possible, for example, to switch certain segments of the genome on and off, simply with coloured light. Researchers from Heinrich Heine University Düsseldorf (the lead partner), RWTH Aachen University, and Forschungszentrum Jülich are working on developing these methods for biotechnological production processes. BMBF is supporting the project with almost € 3.3 million, of which € 1.36 million is earmarked for Forschungszentrum Jülich.

▼  
€ 8  
million

## Algae fuel

At Jülich’s Algae Science Centre, researchers from the Institute of Bio- and Geosciences are working together with a dozen industry partners and research institutions to compare existing technologies for kerosene production from algae and to examine their feasibility. This is linked with the interest from the aviation industry in making aviation more climate-friendly and sustainable. Two Federal Ministries are supporting this financially:

The AUFWIND project examines the entire value-adding chain, from biomass to kerosene production. At Jülich, three algae farming systems are compared with each other in order to determine which plant is most efficient in converting CO<sub>2</sub>, light, and nutrients into biomass. In 2014, the Federal Ministry of Food and Agriculture increased the funding provided by the Agency for Renewable Resources from € 5.75 million to more than € 6 million. This makes the total budget almost € 8 million. The project duration was extended from two and a half years to three years, which means that it will run until August 2016. The OptimAL project is concerned with testing different algal strains to ascertain the highest-yielding algae for biokerosene production. Since 1 February 2014, the Federal Ministry of Education and Research has been supporting this work with € 1.4 million over three years.


## DFG-funded projects

coordinated, 2014









Projects	Number
<b>Total</b>	<b>43</b>
of which research training groups	4
of which DFG research priorities	7
of which collaborative research centres	28



## National Cooperations

Forschungszentrum Jülich coordinator 

current projects 2014 with funding in excess of € 2 million during the relevant project duration (in euros)

	Acronym	Project title	Funded by	Contract volume Jülich
	–	Construction of a petaflop computer	MIWF	44,200,000
	<b>PetaGCS</b>	Acquiring and operating supercomputers for GCS as a contribution to the national supply concept for Tier 0/1 as part of a European HPC ecosystem	BMBF	42,423,000
	<b>HESR</b>	High-Energy Storage Ring of the future international Facility for Antiproton and Ion Research (FAIR)	BMBF	38,220,000
	<b>DPPN</b>	German Plant Phenotyping Network	BMBF	18,342,495
	<b>BioSC</b>	Bioeconomy Science Center	MIWF	17,872,137
	–	Further development of a petaflop computer	MIWF	16,000,000
	<b>ITER</b>	Development and testing of prototype components for ITER at Forschungszentrum Jülich	BMBF	11,659,446
	<b>IAGOS-D</b>	In-Service Aircraft for a Global Observing System, main phase	BMBF	7,250,534
	–	Characterization of the local microstructure and spatially resolved composition of structural and functional materials for novel energy conversion and storage systems	BMBF	6,506,553
	<b>GRS</b>	German Research School for Simulation Science	HGF	6,200,000
	<b>ESS</b>	Contributions of the Helmholtz Association centres to the ESS Redesign Phase	BMBF	6,000,372
	<b>MeMo</b>	High-temperature electrochemical energy storage systems based on metal-metal oxides for centralized and decentralized stationary applications	BMBF	4,421,590
	<b>AUFWIND</b>	Algae production and conversion into aviation fuel: economic efficiency, sustainability, and demonstration	BMEL	3,070,952
	<b>VITI</b>	Virtual Institute for Topological Insulators	HGF	2,900,000
	<b>SABLE</b>	Multi-scale and multi-modal 3D imaging of high-performance electrochemical components	BMBF	2,900,000
	<b>MIE</b>	Molecular Interacting Engineering	BMBF	2,588,276
	<b>MEET Hi-END</b>	Materials and components for high-energy-density batteries	BMBF	2,516,692
	<b>HITEC</b>	Helmholtz Interdisciplinary Doctoral Training in Energy and Climate Research	HGF	2,400,000
	<b>CROP,SENSe</b>	Competence Networks in Agri-Food Research; subproject: Complex Sensors for Crop Research, Breeding, and Inventory Control (PhenoCrops)	MIWF, BMBF	2,252,739
	<b>IAGOS-D</b>	In-Service Aircraft for a Global Observing System, pilot phase	BMBF	2,224,595
	<b>METPORE II</b>	Nanostructured Ceramic and Metal-Supported Membranes for Gas Separation in Fossil-Fuelled Power Plants	BMW	2,029,906
	<b>MetAPU</b>	Metal-based SOFC light-weight stacks for on-board power supply in commercial vehicles	BMW	1,997,269
	<b>LIST</b>	Extensive light trapping in silicon-based thin-film solar cell technology subproject: optical functional layers and transparent contacts	BMU	1,956,628
	<b>AttendPredict</b>	How the human brain predicts the future: neuronal and neurochemical correlates of attention-based expectations in healthy brains and after strokes	BMBF	1,954,627

In 2014, Jülich was involved in 378 nationally funded projects, including 127 with several partners. Of these alliances, 18 were coordinated by Forschungszentrum Jülich.

# International cooperations

## Cooperations within the European Union

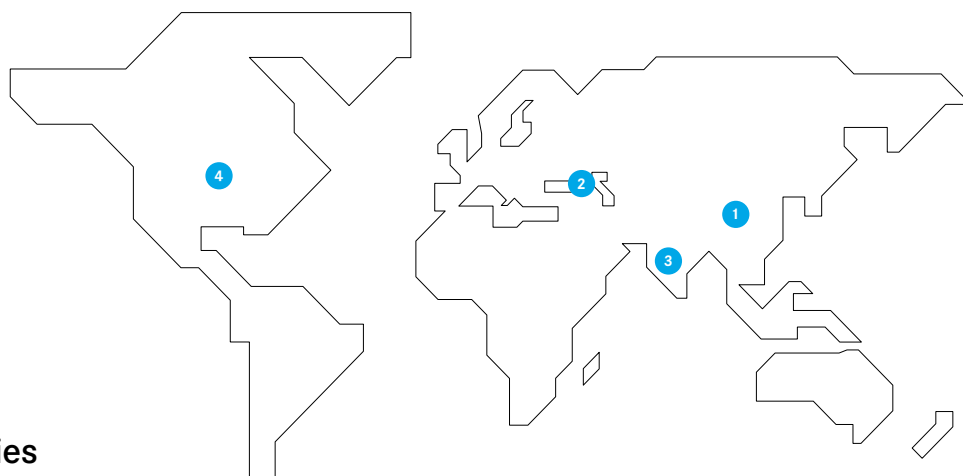
EU-funded projects involving Jülich in 2014,  
with funding in excess of € 1 million (in euros)

	Acronym	Project title	Contract volume Jülich
	<b>EURO-fusion</b>	European Consortium for the Development of Fusion Energy	<b>6,800,000</b>
	<b>HBP</b>	Human Brain Project	<b>3,618,200</b>
<b>C</b>	<b>ESMI</b>	European Soft Matter Infrastructure	<b>2,774,539</b>
<b>C</b>	<b>FAST-TRACK</b>	Accelerated Development and Prototyping of Nano-technology-based High-Efficiency Thin-Film Silicon Solar Modules	<b>2,178,251</b>
<b>C</b>	<b>IMAGINE</b>	Imaging Magnetism in Nanostructures using Electron Holography	<b>1,984,340</b>
<b>C</b>	<b>EPPN</b>	European Plant Phenotyping Network	<b>1,615,852</b>
<b>C</b>	<b>POLPBAR</b>	Production of Polarized Antiprotons	<b>1,509,900</b>
	<b>PEGASOS</b>	Pan-European Gas-Aerosols-Climate Interaction Study	<b>1,329,993</b>
	<b>PRACE-3IP</b>	Third Implementation Project Phase	<b>1,284,042</b>
<b>C</b>	<b>DEEP-ER</b>	Dynamical Exascale Entry Platform – Extended Reach	<b>1,247,449</b>
<b>C</b>	<b>GREEN-CC</b>	Graded Membranes for Energy Efficient New Generation Carbon Capture and Storage Process	<b>1,178,580</b>
<b>C</b>	<b>DEEP</b>	Dynamical Exascale Entry Platform	<b>1,108,495</b>
<b>C</b>	<b>PRACE-2IP</b>	Second Implementation Phase of the European High-Performance Computing Service	<b>1,037,155</b>
<b>C</b>	<b>MAO-ROBOTS</b>	Methylaluminoxane (MAO) Activators in the Molecular Polyolefin Factory	<b>1,001,862</b>

Involvement in EU programmes within the Seventh Framework  
Programme (in euros)

EU programme	Number of approved projects	Coordi- nated by Jülich	Jülich share of funding
<b>Health</b>	7	1	<b>2,190,000</b>
<b>Food</b>	16	–	<b>3,085,000</b>
<b>ICT</b>	16	3	<b>9,715,000</b>
<b>NMP</b>	16	3	<b>9,022,000</b>
<b>Energy</b>	15	2	<b>6,750,000</b>
<b>Environment</b>	10	2	<b>4,892,000</b>
<b>Space</b>	4	–	<b>1,420,000</b>
<b>ERC</b>	3	2	<b>4,077,000</b>
<b>People</b>	15	4	<b>4,957,000</b>
<b>Infrastructure</b>	31	7	<b>24,527,555</b>
<b>ERA-NET</b>	17	6	<b>4,530,000</b>
<b>Joint Techn. Initiatives</b>	11	4	<b>3,393,000</b>
<b>EURATOM</b>	14	1	<b>4,000,000</b>
<b>COST</b>	2	–	<b>360,000</b>
<b>EU-Russia</b>	1	1	<b>315,500</b>
<b>Science in Society</b>	1	–	<b>325,000</b>
<b>Research for the Benefit of SME</b>	1	–	<b>280,000</b>
<b>Regions of Knowledge</b>	1	–	<b>72,000</b>
<b>Transport</b>	1	–	<b>62,000</b>
<b>FRP7 gesamt</b>	<b>182</b>	<b>36</b>	<b>83,973,005</b>

**C** Forschungszentrum Jülich coordinator



## International Activities

(selection)

Place	Project title	Time
<b>1 China</b>	<p><b>Expanding cooperations with Chinese partners</b></p> <p>Forschungszentrum Jülich and Shanghai Institute of Microsystem and Information Technology (SIMIT) cooperate in expanding their research in the field of quantum materials. Prof. Sebastian M. Schmidt, member of the Board of Directors, and Prof. Detlev Grützmacher, director at the Peter Grünberg Institute – Semiconductor Nanoelectronics, signed an agreement providing for the establishment of a second joint laboratory during a visit to China. – Together with the Institute of Semiconductors at the Chinese Academy of Sciences (ISCAS) in Beijing, they signed a memorandum of understanding on the joint expansion of semiconductor research.</p> <p>Prof. Wolfgang Marquardt, together with a Jülich delegation, visited strategically important cooperation partners in China. During the visit, a memorandum of understanding was signed on setting up a Joint International Lab for atmospheric physics, and in Shanghai, a cooperation agreement with Fudan University was signed for the field of nanoelectronics.</p> <p>Xi'an Jiaotong University awarded Prof. Sebastian M. Schmidt, member of the Board of Directors of Forschungszentrum Jülich, an honorary professorship during a workshop with scientists from the Ernst Ruska-Centre (ER-C). Together with Prof. Andreas Offenhäusser of the Peter Grünberg Institute, he visited SIMIT in Shanghai. At the Institute of Automation of CAS in Beijing, closer cooperation in the field of neurosciences was agreed upon.</p>	<p><b>April 2014</b></p> <p><b>August 2014</b></p> <p><b>March 2015</b></p>
<b>2 Georgia</b>	<p><b>Long-standing cooperation continued</b></p> <p>During a ceremony marking the tenth anniversary of the scientific exchange between Georgia and Jülich, Prof. Sebastian M. Schmidt and the Georgian Minister of Education and Science Tamar Sanikidze agreed upon further strengthening their collaboration. The agreement provides for a bilateral exchange programme for bachelor's and master's students, as well as a cotutelle programme, a bi-national doctoral procedure.</p>	<b>July 2014</b>
<b>3 India</b>	<p><b>India Office in New Delhi</b></p> <p>The newly established India Office of Forschungszentrum Jülich in New Delhi was opened at a ceremony attended by the EU ambassador to India. The new representations of the University of Cologne and the European Commission's EURAXESS Links initiative have also come together under one roof with Jülich's office in the Indian capital. Together, the three institutions aim to consolidate contacts with decision-makers and cooperation partners in politics, research, and science. In collaboration with several German universities, workshops on materials structure and properties, imaging techniques, and cognitive neurology were held.</p>	<b>November 2014</b>
<b>4 USA</b>	<p><b>Energy workshop at Oak Ridge National Laboratory</b></p> <p>Prof. Wolfgang Marquardt, Chairman of the Board of Directors of Forschungszentrum Jülich, visited four close cooperation partners in Oak Ridge, Berkeley, San Jose, and Stanford, USA. At Oak Ridge National Laboratory (ORNL), he signed an agreement on continuing research collaboration and opened a workshop on the high-temperature and energy materials project. Since 2013, the project has been funded with € 600,000 annually by BMBF, and it is set to run for three years.</p>	<b>October 2014</b>

# International Research

## Energy research

### Membranes reduce energy demand



Ceramic membranes which can separate gases from each other promise a variety of benefits. After a focus was put on the separation of CO<sub>2</sub> from power plant flue gases in the Mem-Brain Project, concluded in 2014, the perspective was broadened for the EU project Green-CC, which was launched in autumn 2013. Fourteen European and Australian partners from science and industry are further developing membranes which supply oxygen for the oxyfuel process. The aim is to drastically cut energy requirements in industrial processes, for example in the steel, glass, or cement industry. The project has a total volume of € 8.275 million, of which € 5.463 million is EU funding. Of the total, € 1.3 million is earmarked for Forschungszentrum Jülich, with the Institute of Energy and Climate Research coordinating the project.

## Plant research

### Sustainable nutrient cycle

Using plant waste sensibly – that is what the German-Brazilian PURESBio collaboration project, which started in January 2015, is all about. Organic residues from arable farming and biogas production are to improve yields on nutrient-poor soils. On the German side, the Leibniz Centre for Agricultural Landscape Research (ZALF) is involved in addition to Forschungszentrum Jülich, while on the Brazilian side, the Ministry of Agriculture, Livestock, and Food Supply (EMBRAPA) as well as three further research institutions are participating. Over three years, the German Federal Ministry of Education and Research (BMBF) will fund the project with € 850,000, of which € 485,000 is intended for Jülich's Institute of Bio- and Geosciences.

## Brain research

### Network for Alzheimer's diagnostic agent

As part of a cooperation with the Piramal company, the Institute of Neuroscience and Medicine functioned as a testing centre for the clinical trials to license a new Alzheimer's diagnostic agent. Eighteen other international imaging centres were also involved in testing the active substance <sup>18</sup>F florbetaben. With this substance, the density of amyloid accumulations in patients' brains – indicative of Alzheimer's disease – can be determined. In a phase 2 study, the safety of the substance was tested, and in a phase 3 study its usefulness was examined clinically. After successful conclusion of the trials, the European Medicines Agency (EMA) licensed the diagnostic agent in 2014.

## Brain research

### Seeing and understanding the world

How does the visual system in our brains explore the visible world? And how does it then reconstruct it from the perceptions? That is what Jülich scientists, headed by Prof. Sonja Grün from the Institute of Neuroscience and Medicine, are studying together with a group headed by Ichiro Fujita from Osaka University. The project "Neural mechanism of active vision studied by combining large-scale sampling of neural activity and advanced computational analysis" is running from October 2013 to September 2016 and continues the German-Japanese cooperation which was initiated in earlier joint research projects.

## Supercomputing

### Storing and managing the data flood

Whenever researchers collect and produce large volumes of data, it is vital that storage, access, provision, archiving, and retrieval are secured. As part of the EU-DAT2020 EU project, a European data infrastructure is being constructed for this purpose, which will accommodate the requirements of various users from a multitude of disciplines. This Collaborative Data Infrastructure (CDI) is to serve as a trusted network within which many institutions, among them the Jülich Supercomputing Centre, will work together. For the project, in which 33 partners are collaborating, € 18 million is available for three years, starting from March 2015.



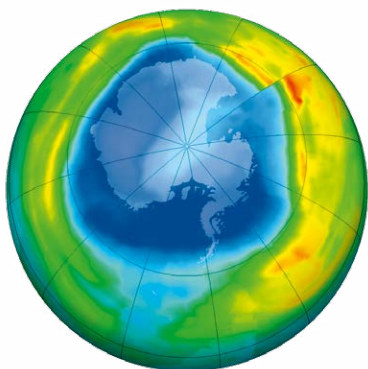


And this is what it will look like: the ESS site in Lund, Sweden, where the neutron source is being built.

#### Climate research

## Ozone layer and climate change

Ever since the ozone hole was first detected in 1985, the World Meteorological Organization (WMO) together with the United Nations Environment Programme (UNEP) has reported every four years on changes in the state of the ozone layer. Current analyses show that the ozone layer in the mid-latitudes and over the Arctic will have recovered by the mid-21<sup>st</sup> century. It is expected that the Antarctic hole in the ozone layer will disappear some decades afterwards. Jülich climate researchers contributed insights on how the ozone layer and global warming interact to the report published in 2014, which was created in collaboration between 300 scientists from all around the world.



#### Neutron research

## Jülich research for neutron source

When the foundation stone for the European Spallation Source ESS was laid in Lund, Sweden, in October 2014, it was an important day for Jülich as well, since the German contribution to the design update study was coordinated here. Four of the already accepted instrument suggestions for what is expected to be the most powerful neutron source in the world originated in Germany, two of them in the Jülich Centre for Neutron Science (JCNS). Three further suggestions from JCNS are in the process of being evaluated. In addition, Jülich researchers together with project partners received around € 4 million from the EU Framework Programme Horizon 2020 for the SoNDe project: within four years, a detector is to be developed in collaboration with Laboratoire Léon-Brillouin in France, ESS in Sweden, Lund University, Sweden, as well as the Norwegian company Integrated Detector Electronics – a detector which will take snapshots of biological and chemical processes possible at the ESS.

#### Structural biochemistry

## Testing Parkinson vaccine

As part of the SYMPATH EU project, the safety of two potential vaccines for Parkinson's disease and another neurodegenerative disease are being tested in a phase 1 trial. It is hoped that the vaccines will remove clumps of proteins which damage neurons. Scientists of the Jülich Institute of Complex Systems developed a highly sensitive test which detects the aggregates. In total, eight institutions from Austria, France, and Germany are involved in the study. The project, which started in 2014, is coordinated by the Austrian company AFFiRiS and the EU is providing funding totalling € 6 million for SYMPATH.



#### Supercomputing

## Simulating the brain with computers

In order for the Human Brain Project (HBP) to achieve its goal of simulating the human brain on the level of individual neurons, vast computing power and storage capacity is required. On top of that, the brain simulations are to be visualized and interactive control of them made possible. To this end, experts from the Jülich Supercomputing Centre (JSC) are coordinating the construction of a high-performance computing (HPC) platform as part of the European large-scale project in which more than 100 research institutions from over 20 countries are involved. Several manufacturers are competing in developing suitable computer technology and they will install test systems at JSC in 2016.

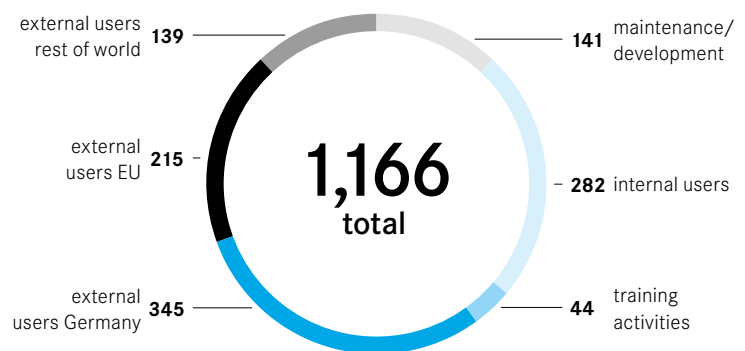
# Excellent Platforms

## Jülich Centre for Neutron Science (JCNS)

JCNS operates neutron research instruments at leading international neutron sources. JCNS is also responsible for the construction and operation of the Jülich instruments at the Heinz Maier-Leibnitz research neutron source (FRM II) in Garching near Munich. These instruments are also available to external scientists. In addition, JCNS operates instruments at Institut Laue-Langevin in Grenoble, France, at the Spallation Neutron Source in Oak Ridge, USA, and at the CARR research reactor near Beijing. Fifteen unique measuring instruments at these four leading international centres for research with neutrons in Germany, France, the USA, and China have been installed or retrofitted within a period of just eight years.

### Beam time allocated

in days, rounded, 2014



### Use of the JCNS neutron instruments by external researchers

2014

Instrument	Applications	days
<b>BIODIFF<sup>1)</sup></b>	Diffraction for large unit cell	76
<b>DNS</b>	Time-of-flight spectrometer with diffuse neutron scattering	47
<b>HEIDI<sup>2)</sup></b>	Single Crystal Diffractometer on Hot Source	60
<b>J-NSE</b>	Jülich neutron spin-echo spectrometer	60
<b>KWS-1</b>	Small-angle neutron scattering facility 1	57
<b>KWS-2</b>	Small-angle neutron scattering facility 2	65
<b>KWS-3</b>	Small-angle neutron scattering facility 3	45
<b>MARIA</b>	Magnetic reflectometer	52
<b>PANDA</b>	Cold neutron triple-axis spectrometer	70
<b>POLI<sup>2)</sup></b>	Polarized Hot Neutron Diffractometer	22
<b>SPHERES</b>	Backscattering spectrometer with high energy resolution	69
<b>ILL</b>	Institute Laue-Langevin, Grenoble	51
<b>SNS</b>	Spallation Neutron Source, Oak Ridge	29

1) in cooperation with TU Munich, 2) operated by RWTH Aachen University

# Helmholtz Nanoelectronic Facility (HNF)

The Helmholtz Nanoelectronic Facility at Forschungszentrum Jülich is the Helmholtz Association's central technology platform for nanoelectronics. HNF's objective is researching, manufacturing, and characterizing nano- and atomic structures for information technology. The nanoelectronic laboratory offers universities, research institutions, and industry free access to know-how and resources for fabricating structures, devices, and circuits – from the atomic scale to complex systems. The focus of work at HNF is resource-conserving “green information technology”.

## HNF in numbers

as of 31 December 2014

Granting of operating licence	<b>4 April 2014</b>
User numbers internal external	<b>220 32</b>
Usage days	<b>220</b>
Maintenance days	<b>33</b>
Hook-up (set-up and connection of the machines)	<b>90 days</b>
Total usage time of all machines	<b>20,477 hours</b>
External visitors	<b>1,680</b>

## Usage hours

2014

Facilities	Time [h/a]
Vapour deposition facility	<b>452</b>
Dektak 150 profilometer	<b>390</b>
Imprints	<b>160</b>
Wafer dicing saw	<b>479</b>
Mask Aligner	<b>812</b>
Nanoimprint Lithography	<b>97</b>
Vistec electron beam lithograph	<b>4,353</b>
Reactive ion etching facilities	<b>1,499</b>
Scanning electron microscopes	<b>3,280</b>
Focused ion beam	<b>1,224</b>
Oxidation furnaces	<b>242</b>
Wafer cleaner SSEC	<b>144</b>
Characterization	<b>717</b>
Wet benches	<b>6,628</b>

# Ernst Ruska-Centre (ER-C)

Forschungszentrum Jülich and RWTH Aachen University jointly operate ER-C as a centre for atomic-resolution electron microscopy and spectroscopy at the highest international level. It is simultaneously the first national user centre for ultra-high-resolution electron microscopy.

The joint undertaking, which is named after the inventor of the electron microscope, offers scientists a unique insight into the world of atoms and develops new methods for materials research on the Jülich campus. ER-C celebrated its tenth anniversary in January 2014.

Around 50% of the measurement time on the five Titan microscopes (CREWLEY, HOLO, PICO, STEM, and TEM) at ER-C is made available to universities, research institutions, and industry. This time is allocated by a panel of experts nominated by the German Research Foundation (DFG).

## Allocated measuring time

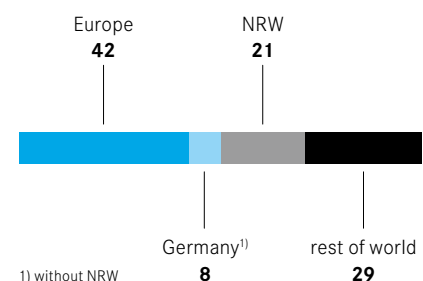
at electron microscopic instruments of ER-C<sup>1)</sup> in days

1) five of which are Titan microscopes

	2009	2010	2011	2012	2013	<b>2014</b>
Forschungszentrum Jülich	244	298	297	420	480	<b>455</b>
RWTH Aachen University	164	138	161	138	156	<b>190</b>
External users	284	294	266	463	412	<b>471</b>
Servicing and maintenance	132	132	178	150	220	<b>373</b>
<b>Total</b>	<b>824</b>	<b>862</b>	<b>902</b>	<b>1,171</b>	<b>1,268</b>	<b>1,489</b>

## Users

according to region, percentage, 2014



# Jülich Supercomputing Centre (JSC)

The Jülich Supercomputing Centre provides scientists and engineers working at Forschungszentrum Jülich, universities, and research institutions in Germany and throughout Europe, as well as the commercial sector with access to computing capacity on the most powerful class of supercomputers, enabling them to solve highly complex problems using simulation calculations. The John von Neumann Institute for

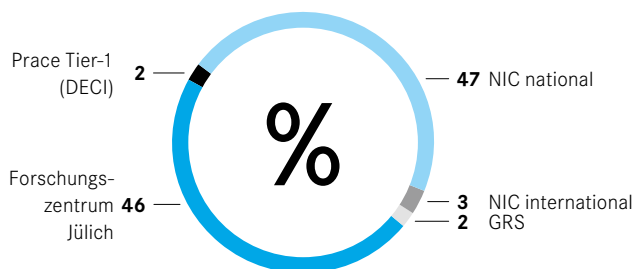
Computing is responsible for the scientific evaluation of projects.

As the fastest computer in Germany, the Jülich supercomputer JUQUEEN ranked eighth in the November 2014 TOP500 list of the fastest computers in the world, which is updated every six months. Forschungszentrum Jülich operates JUQUEEN as part of the Supercomputing research programme for, amongst oth-

ers, the Helmholtz Association. Approximately 70% of the computer are part of the national Gauss Centre for Supercomputing (GCS), which means that this part of the computation time is allocated to national and European projects through a well-established peer-review process. The remaining 30% of computing time is reserved for scientists at Forschungszentrum Jülich and the Jülich Aachen Research Alliance (JARA).

## JUROPA – Relative numbers according to users

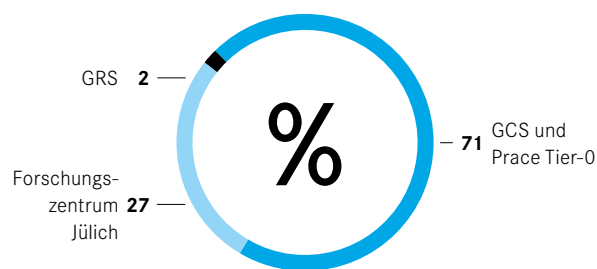
2014



Based on the GCS computing time periods Nov. 2013–Oct. 2014 and May 2014–April 2015

## JUQUEEN – Relative numbers according to users

2014



Based on the GCS computing time periods Nov. 2013–Oct. 2014 and May 2014–April 2015

## Overbooking factor

2014

Supercomputers	Factor
JUQUEEN	2
JUROPA	3

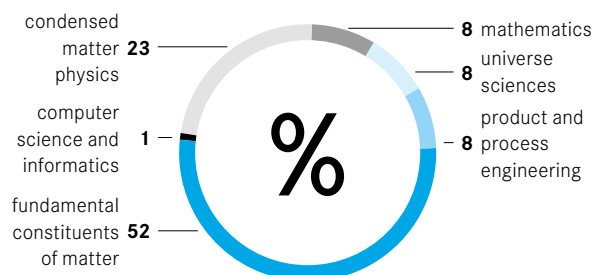
## User statistics

in millions of computing core hours (core-h), 2014

Supercomputers	Core-h
JUQUEEN	3,200
JUROPA	185

## JUQUEEN – Research fields of ongoing European projects

PRACE Tier-0, 2014



Based on the PRACE computing time periods Sept. 2013–Aug. 2014 and Mar. 2014–Feb. 2015. In 2014, as part of the Partnership for Advanced Computing in Europe (PRACE Tier-0), eleven European projects were computed on JUQUEEN. Most of the computing time – 52% – was allocated to projects in the field of fundamental constituents of matter, followed by condensed matter physics with 23%.



JÜLICH AACHEN RESEARCH ALLIANCE

# JARA Expanding

The close collaboration between RWTH Aachen University and Forschungszentrum Jülich, manifested in the Jülich Aachen Research Alliance (JARA for short) since 2007, bore further fruit in 2014: a new section was founded and the establishment of specialized JARA institutes in Aachen and Jülich was resolved.

**W**ith JARA-SOFT, a new section was created which will focus on researching soft matter. With this newly-founded organ, the number of sections has risen from three at the beginning of the research alliance to six. JARA-SOFT represents an institutionalization of the pre-existing close cooperation between Jülich and RWTH,

whose competences in the field are thus effectively complemented. Included in this is the Leibniz Institute for Interactive Materials (DWI), which is affiliated to RWTH Aachen University. Similar to the way that stone, bronze, and iron characterized pre-historic ages as the prevailing materials, soft matter – including plastics – plays an outstanding role in the modern era. JARA-SOFT is all about understanding and systematically influencing the characteristics of soft matter. The goal of the new section is to pool competences in this research field, to lay out the joint work for the long term, and also to increase international visibility of this branch of research.

## New projects and institutes

New research initiatives have also been established in the existing JARA sections: in 2014, JARA-ENERGY saw the launch of six Seed Fund projects with a total funding volume of approximately € 1 million. In these projects, scientists from both institutions work together in research projects, contributing to setting the long-term strategic orientation of the section. Among others, the projects Power-2-Fuel, Competence Center for Self-Reliant Power Generation from Volatile Renewable Energy Sources, and Technology-Based Energy Systems Analysis were approved. In the JARA-HPC section, five Seed Fund projects have been funded with a total of € 750,000 for Jülich and Aachen since 2014.



Prof. Ernst Schmachtenberg, Rector of RWTH Aachen University (right), and Prof. Wolfgang Marquardt, Chairman of the Board of Directors of Forschungszentrum Jülich (left), signing the framework agreement on establishing joint institutes.

The entry into force of the new law regulating universities in North Rhine-Westphalia was the prerequisite for the framework agreement on establishing JARA institutes signed on 1 October 2014. These institutes will concentrate on certain topics within the JARA cooperation, and will be headed collegially by three to five JARA professors, who will bring part of their resources from Aachen and Jülich and additionally receive funding from the Excellence Initiative. Initially, two institutes will each be established in the sections JARA-BRAIN and JARA-FIT:

- In **JARA-BRAIN**, the institutes “Brain structure-function relationship: Decoding the human brain at systemic levels”, investigating the neuronal basis of healthy and pathologically changed behaviour, and also “Molecular neuroscience and neuroimaging” will be formed.
- The **JARA-FIT** section will see the establishment of the “Green IT” institute, at which new architecture concepts and reliability analyses for nanoelectronic circuits will be developed, and the “Quantum Information” institute, whose work will focus on concepts for quantum computing. Headed by Prof. Hendrik Bluhm and Prof. David DiVincenzo, the collaborative research centre “Scalability of Quantum Information Processing” was applied for in 2014. Further JARA institutes in other sections are to follow.

## JARA in figures

Budget	in millions of euros
Total	500
Amount invested	60
Funds from the Excellence Initiative <sup>1)</sup>	13.6
<small>1) for the period 2012–2017</small>	
Professorial appointments	since 2006
Joint Professorial Appointments <sup>2)</sup>	47
<small>2) as of 31 December 2014</small>	
Publications	2014
Publications by JARA members	1,917 <sup>3)</sup>
Joint publications	919
<small>3) peer-reviewed publications</small>	

# JARA at a Glance

JARA, the cooperation between RWTH Aachen University and Forschungszentrum Jülich, looked back on seven years of successful joint research in 2014. In late 2014, a further research field was added to the already established sections: JARA-SOFT. This means that JARA now comprises the following sections:

1

Translational brain medicine

## JARA-BRAIN

JARA-BRAIN was instrumental in the successful application for the BMBF-funded research network on psychiatric disorders. As part of the APIC (Antipsychotic-induced structural and functional changes) network, and coordinated by JARA-BRAIN director Prof. Frank Schneider, JARA scientists together with colleagues from the universities of Cologne and Düsseldorf are investigating the long-term effects of medication on the brain structure.

2

Sustainable energy research

## JARA-ENERGY

JARA-ENERGY in October 2014 invited representatives from politics, research, and industry to Berlin to attend the JARA-FORUM on future prospects for the transformation of the energy system. Former Minister for the Environment Prof. Klaus Töpfer emphasized that JARA, as a “hybrid” of university and non-university research, contributes significantly to the successful transformation of the energy sector.

3

Forces and matter experiments

## JARA-FAME

JARA-FAME, as part of the AMS project, explores cosmic radiation by means of a particle detector installed at the International Space Station ISS. One of the objectives is verifying the existence of dark matter. In September 2014, Nobel laureate Prof. Samuel C. C. Ting presented the latest results of the measurement of high-energy electrons and positrons. Headed by Prof. Stefan Schael, scientists from the JARA-FAME and JARA-HPC sections are involved in this endeavour.

4

Fundamentals of future information technology

## JARA-FIT

JARA-FIT has included the new research training group “Quantum mechanic many-body approaches in condensed matter” since 2014. Headed by Prof. Volker Meiden, insights into the interactions of complex systems are to be gained over the next four and a half years, which may allow conclusions to be drawn on opportunities for applying such materials in nanoelectronics.

5

High-performance computing

## JARA-HPC

JARA-HPC has developed a visualization (VisNEST) with which the connection between brain structure and brain function can be visualized and experienced three dimensionally. Simulation results from research projects such as the EU’s Human Brain Project or the Helmholtz portfolio topic Supercomputing and Modelling for the Human Brain are the basis for this.

6

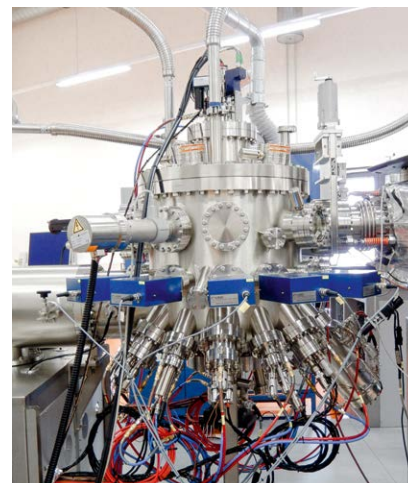
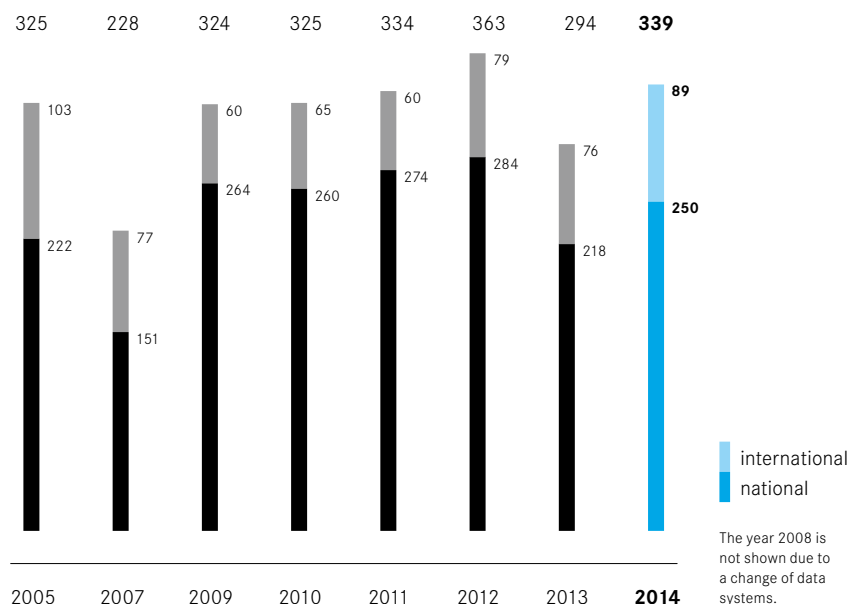
Soft matter science

## JARA-SOFT

JARA-SOFT was launched in December 2014 and is the latest addition to the JARA sections. With it, the JARA portfolio has been expanded to include soft matter research. The term comprises polymers as well as colloidal and amphiphilic (fat-soluble and water-soluble) structures and emulsions which are significant, for example, in the plastics industry or in biotechnology. The JARA scientists are researching the properties of soft matter in order to develop possible new applications.

# Collaborations with Industry

## Number of industrial collaborations



The molecular beam epitaxy system is part of the Nanocluster, an ultrahigh vacuum facility developed and built by Omicron®, operated jointly by the Peter Grünberg Institute and RWTH Aachen University.

## Important industrial collaborations

2014

Industrial Partners	Project
MTU Aero Engines GmbH	Lifetime modelling of aircraft engine blades
Ansaldo Energia	Next-generation thermal barrier coatings
DSM Advanced Surfaces	Effects of MAXRAY coatings on photovoltaic technologies
Dataport	Continuation and further development of nutrient modelling
Omicron Nanotechnology	Cooperation for HNF cluster tool
Kawasaki Heavy Industries	Activity plan of hydrogen recombination for the application on hydrogen-carrying vessels
Siemens AG	Run-time analysis of parallel applications for industrial software development
Plansee	Oxidation behaviour of chromium-plated materials
Bayer CropScience AG	Multi-dimensional coupled modelling of root growth, and water and nutrient uptake by roots with water flow and transport of matter in soil
Sulzer Metco	Investigation of the spitting phenomenon in PS-PVD
MAN Diesel & Turbo	Investigation of alloys in power plant prechambers
Grünenthal GmbH	Combination of molecular modelling and experiments to understand the structure-activity relationships of opioid analgesics on a molecular level for the development of new analgesics with optimized pharmacological profile
Piramal	Clinical trials to test the new drug Neuraceq

# Research for Practical Applications

Some of Jülich's research results find their way directly into our everyday life. Two current examples illustrate this.

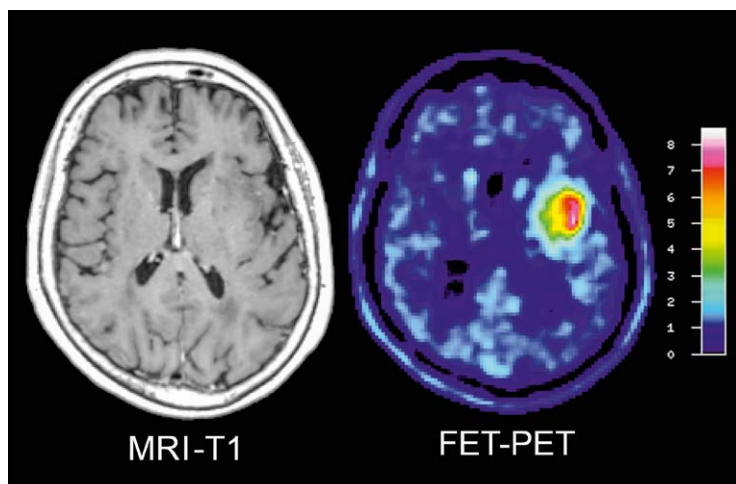
## Diagnosing brain tumours more efficiently

Brain tumours can be better demarcated from the surrounding tissue by means of positron emission tomography (PET) and a radioactively labelled amino acid developed in Jülich, than by conventional methods. This was shown in numerous studies conducted over many years by Jülich researchers in cooperation with neighbouring university hospitals. In 2014, this amino acid, called  $^{18}\text{F}$ -fluoroethyl tyrosine (FET), was officially approved for everyday use in clinics in Switzerland.

In Germany, approval is still pending. The Jülich neuroscientists are, however, involved in further national multi-centre studies which will help to further assess the FET-PET method and to achieve the

approval of the amino acid. "This would mean that FET-PET would not only benefit patient groups in clinical trials but that it could be used in everyday procedures in German hospitals," says Prof. Karl-Josef Langen of the Jülich Institute of Neuroscience and Medicine. He is delighted that Switzerland, as the first country to give approval, has made a start in drawing practical consequences from the positive results of the research which goes back to the year 1994, when a Jülich PhD student first created the radiopharmaceutical FET. So far, in Jülich alone, it has been used to examine approximately 3,000 patients, and for the whole of Germany, around 12,000 patient data sets are available.

Although patients with malignant brain tumours of grades II, III, and IV have very slim chances of recovery, their lifetime can be extended by means of neurosurgical procedures, chemo-, and radiotherapy. According to nuclear medicine specialist Langen, "it is obvious: for a less damaging and simultaneously effective operation or radiotherapy, the brain tumour and later tumour recurrences must be very well distinguishable from unspecific changes in tissue." This is where FET-PET offers distinct advantages compared to the conventionally used magnetic resonance imaging (MRI): PET images – unlike anatomical MRI images – visualize the biochemical processes, which in tumours are distinctly different from those in healthy tissue. With the FET-PET method, position and dimensions of a tumour can be detected with 90% certainty.



A brain tumour is more easily recognized and demarcated with the FET-PET method (yellow-red area in the image on the right) than via MRI.

### Practical advantages

FET also has advantages over other radiopharmaceuticals, particularly in the following two points: by means of a process optimized in Jülich, it can be produced in large quantities. But more importantly, FET has a longer half-life than other labelled amino acids. It can thus withstand longer transportation periods, and this means that one production location can service clinics and surgeries in a larger area.



# Robust Fuel Cells for Trucks

Developing more stable and cheaper fuel cells which can supply trucks with power – that is the aim of Jülich scientists, who together with TU Wien and two Austrian companies have been working at the Christian Doppler Laboratory at Forschungszentrum Jülich, inaugurated in early 2015.

## Energy-consuming breaks

Long-distance truck drivers also use their trucks as sleeping cabins and living space. They make themselves as comfortable as possible in their breaks, not wanting to do without air conditioning and communications technology. The electricity required for this is supplied by an additional little combustion engine. Each truck driver in the US thus consumes diesel worth US\$ 5,000–US\$ 9,000 every year. The efficiency of this type of electricity generation is only around 10%.

The best alternative would be integrating a novel fuel-cell generator. These devices theoretically reach efficiencies of more than 35%, which would decrease diesel consumption by 75%. The automobile supplier AVL List has been testing various types of fuel cells for such generators since 2002. The company from Graz con-

siders a metal-supported high-temperature solid oxide fuel cell to be especially promising: they can generally be produced more cheaply than the conventional full ceramic equivalent, and are less vulnerable to shocks and vibrations.

## Collaboration with enterprises

The Austrian company Plansee SE, together with Forschungszentrum Jülich, is developing such cells, which do not need expensive platinum catalysts. In order to research basic issues of the new cell type, the partners initiated the setting up of the Christian Doppler Laboratory at Jülich, also involving TU Wien in the project. The Austrian Christian Doppler Research Association promotes the cooperation between excellent application-oriented research and business through these laboratories. One half of the Jülich laboratory is funded by the Austrian Federal Ministry of Science, Research and Economy, and the other half by AVL List and Plansee.

The performance of the new, metal-supported cells currently still drops significantly after a few hundred operating hours – too quickly for practical application in truck cabins. “One main reason is that the ceramic functional layers of the metal-supported cells have to be produced differently from those of conventional cells so the metal substrate is not damaged,” says Dr. Martin Bram, head of the Jülich Christian Doppler Laboratory. “There is great potential for improvement in the microstructure of the electrodes and the layer adhesion at interfaces. Additionally, long-term operation can cause atoms at the interfaces to be exchanged, and this changes the characteristics of the cell.” The researchers want to understand these mechanisms in detail and to develop measures to prevent the premature drop in performance. If successful, the novel generator could considerably decrease the undesirable byproducts of stationary trucks, such as noise, soot, and climate-damaging exhaust gases.



Dr. Daniel Röhrens is among the scientists who conduct research into metal-supported fuel cells at the Christian Doppler Laboratory.



Cassette with metal-supported high-temperature fuel cell and gas distribution structure (centre).

# Patents and Licences

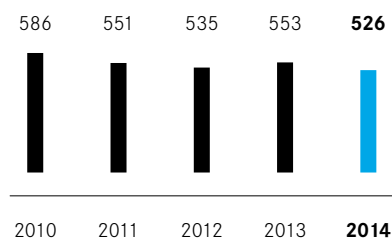
Jülich research focuses on basic topics and creates innovations which benefit both industry and society and which lead to protective rights and licensing agreements. Protective rights include inventions for which patent applications have been filed (patent applications) as well as patents granted.

## Patent portfolio

as of 31 December 2014

### Patent families

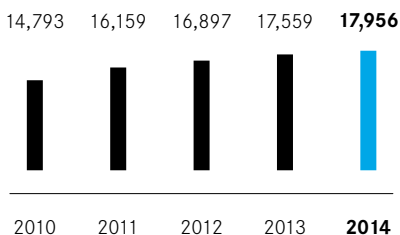
2010–2014



The patent portfolio is described by the number of patent families and the total number of protective rights (patent family: one or several patents in Germany or abroad which refer to one patentable technology).

### Protective Rights

total number, 2010–2014

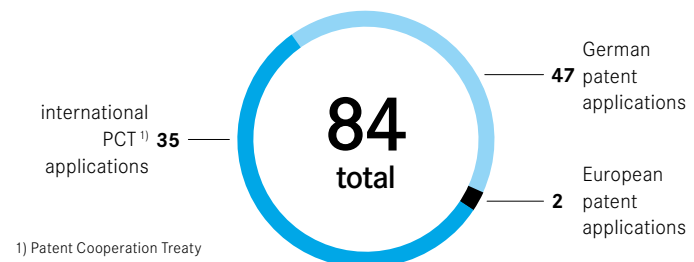


The total number includes European and international patent applications according to the Patent Cooperation Treaty, which each comprise several individual protective rights.

## Current patent activities

### New patent applications

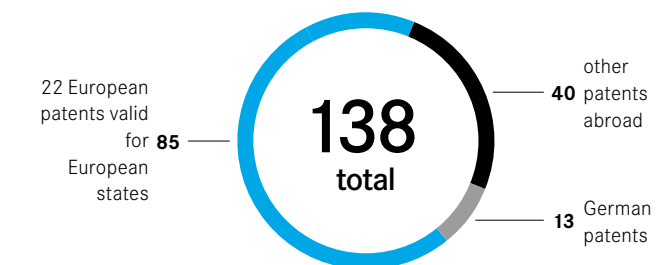
2014



1) Patent Cooperation Treaty

### Patents granted

2014



## Licences

### Number of licences

Total 78			
of which new	share SMEs	total share abroad	share USA
5	61	21	8

Revenues from licensing and know-how agreements: **€ 783,000**.



# People

Page 65 – 80

# High Expectations, Smart Decisions

What we perceive depends not only on what is actually there around us, but also on our expectations. But what happens in our brains when we expect certain events, but not others? And how does the brain take in the unexpected? This is what psychologist and neuroscientist Dr. Simone Vossel wants to find out.

**T**he brain constantly has to decide what elements of its surroundings it takes in, that is which of the many things out there will actually make it into the conscious mind. And I want to know how that happens,” the 35-year-young scientist summarizes her field of work. Simone Vossel herself had many smart decisions to make before she could take over the leadership of her own working group at Forschungszentrum Jülich in the spring of 2014. Choosing to study psychology was the beginning. “I had thought about studying physics, back when I was at school,” she says. In the end, she found human behaviour more interesting. “But right from the start, the natural sciences side of things was also very interesting to me. And it is particularly the interdisciplinarity of brain research – spanning everything from mathematics to medical sciences – that I find tremendously exciting. We still know so little about how the brain works. Only in cooperation between various disciplines can we advance.” Looking back on her studies, Simone Vossel finds especially the in-depth examination of various statistical methods useful.

## The blind side

After completing her studies at Mainz University, she decided upon a PhD position at Forschungszentrum Jülich. “It seemed quite a remote area to me, but the topic and the research environment were simply too interesting.” Simone Vossel had already investigated the topic of “neglect” in her doctoral thesis. This is what neurologists and neuropsychologists call the

phenomenon according to which some patients after experiencing brain damage, such as a stroke, simply blank out one side of the world. From a purely physiological standpoint, they can see everything that is for example lying on a table or that is shown on a screen. However, one side seems so unimportant to the brain that it does not allow it to enter the conscious mind, instead noticing only whatever happens on the other side. In some affected people, the problem wears off after a while, but in others it does not. Simone Vossel examined whether these patients can be helped, with medication for example, or with appropriate hints on the neglected side of the world. “It is not as if these people cannot ever learn to use the neglected side. But reorienting attention is often a very slow process,” explains Vossel.

With her doctorate under her belt, another decision was due. “I wanted to learn new techniques, particular imaging methods with which the information flow in the brain can be followed,” the psychologist explains. The best place for this was London, the new PhD decided, and thus for two and a half years she worked at the Wellcome Trust Centre for Neuroimaging of University College London.







Dr. Simone Vossel has been a BMBF group leader at the Institute of Neuroscience and Medicine since early 2014.

1.9 

million euros is how much will be made available to the project by the German federal government over the course of five years.

processes,” explains Vossel. “On the other hand, we are hopeful that in the future we can improve therapies for attention impairments such as neglect after stroke.” The research projects with patients are made possible through close collaboration with the Department of Neurology of Cologne University.

#### Learning to lead

But it is not only science which harbours challenges: “It is certainly something else, leading my own working group, mentoring PhD students, and continuously motivating the whole team,” says Simone Vossel. “That was something I first had to learn, too.” She feels well supported by the additional training courses which Forschungszentrum Jülich offers especially to early-career scientists in executive positions.

And what comes after the five years of BMBF funding? Simone Vossel’s expectations are clear: she wants an executive position in science. “Thinking about the high proportion of women studying psychology, it is definitely conspicuous how few professorships in this field are filled by women,” she notes. But backing down is not an option. Simone Vossel has the hard-to-attain aim clearly in mind: “Of course, I am aiming for a professorship. By leading a BMBF Young Investigators Group, my chances have undoubtedly risen.”

What drew the ambitious young scientist from the British metropolis back to this “remote area” was a call for proposals from the Federal Ministry of Education and Research (BMBF). Particularly young women scientists in the neurosciences were to be given the opportunity to build up their own working group and thus to gain international renown at a German research institution: female executives are still significantly under-represented in this research area. Simone Vossel decided that this was exactly right for her and applied for the coveted funding. “Well, and then I actually got it,” she says laconically. Her research project was one of five chosen from around 90 applications. So back to western Germany it was. Vossel still retained fond memories of Jülich’s great conditions for brain research.

Since 1 March 2014, she has been heading a working group with two PhD students and one postdoc at Jülich. With BMBF funding of € 1.9 million over five years, she is looking into the question of how the brain directs its attention to certain things, and what processes in the brain influence its expectations. “On the one hand, it is the basic question of understanding what neuronal events underlie such learning

“You do have to be flexible in your private life,” Simone Vossel admits. Until a short while ago, she led a long-distance relationship, since her partner lived in London. “But now he has found a job in Cologne,” she says, pleased. She sees reconciling a family with an executive position as challenging but doable: “If you want to achieve a great deal, you need high expectations.”

# Promoting Young Talent

Kindling young people's interest in science, supporting them during training and studies, and offering them excellent conditions for their first job, their career in science, and taking on their first executive tasks – these are the goals of Jülich's strategic concept for promoting young talent, *juelich\_horizons*.





The 2014 Girls' Day attracted 94 girls to Forschungszentrum Jülich. Here, they had the opportunity to learn about occupations and study programmes in IT, skilled trades, science, and technology, in which women are still under-represented.

## 1 juelich\_impulse

Giving children and young people the opportunity to develop their natural curiosity, promoting their understanding of natural sciences, further supporting this during their school years, and offering them guidance for their careers – that is the purpose of Jülich's JuLab schools laboratory, an entire laboratory complex with committed scientific and educational experts. 3,830 school students came here to perform experiments in 2014. Especially girls were successfully targeted: the majority of visitors to the schools laboratory – 2,023 of the school students – were girls. The range of topics covered everything from creative tinkering for primary school students to introduction to brain research as well as ambitious projects like building a cyclotron for school and teaching purposes.

### Research live

Needless to say, JuLab is not a replacement for school lessons, but as a place of learning outside the school, it complements them in many ways – not least with the sort of equipment not usually available at schools. Students, as part of their excursion to Forschungszentrum Jülich,

also have the opportunity to experience a place where internationally recognized research is carried out daily. In addition, JuLab supports school teachers with training sessions for continuing professional development. In 2014, 64 teachers made use of this offer. A pilot project with a vocational college in Züllich trains teachers to answer children's questions on natural science topics. Close cooperations with schools in the region, such as the "Schule entdeckt Forschung" project, which aims to support science at school, attracted 440 students from four schools in the Düren district during the 2014/2015 school year.

### Holiday explorers

A special service for children of employees at Forschungszentrum Jülich are holiday activities. A survey from the Equal Opportunities Bureau (BfC) revealed that many parents at Forschungszentrum Jülich were in need of childcare especially for their six- to eight-year-olds during the school holidays. BfC together with JuLab thus organized the "explorer weeks for energy detectives" for children starting school classes 1 to 3 in 2014. The boys

and girls lucky enough to get one of the very popular places created "light balls" with soldering irons, went on excursions, and planted eight apple trees "so that they can make oxygen" – or alternatively, "so that we can eat the apples".



The nearby daycare centre, especially the groups for children under three (U3), is expanding.





## 2 juelich\_tracks

Forschungszentrum Jülich and its training programme not only satisfies its own need for qualified personnel, but also combats the shortage of skilled employees in the region. “For many years, the excellent cooperation between all of the partners in our twin-track vocational training programme has made it possible to provide high-quality vocational training with a practical focus,” says Ulrich Ivens, head of vocational training. A considerable number of Jülich’s trainees simultaneously undertake university studies. On 1 September 2014, 105 new trainees started in 16 different occupations, laying the foundation for their careers. Three of these occupations – technical system planner, sewage engineering technician, and water supply engineering technician – were offered for the first time at Forschungszentrum Jülich. Due to the situation on the job market, it had become necessary to train new personnel in these occupations.

### Vocational training without borders

Forschungszentrum Jülich also puts out feelers internationally to attract new trainees: in 2014, two young people from other European countries started their training at Jülich. But teaching intercultural competence is just as important for German trainees, since Forschungszentrum Jülich is characterized by an international workforce, which is reflected in our vocational training. This includes the collaboration with the German School in Thessaloniki, Greece, which was initiated in 2014, and cooperations with vocational training institutions in the Seville region in Spain.

### Project team television tower

Realistic and practical training which provides qualifications for an exacting career and is fun at the same time – how this aspiration can be realized was shown



Trainees presenting their project work: a model of the Düsseldorf television tower.

More information on vocational training at Forschungszentrum Jülich is available at:

[www.fz-juelich.de/gp/DE/Leistungen/ZentraleBerufsausbildung/\\_node.html](http://www.fz-juelich.de/gp/DE/Leistungen/ZentraleBerufsausbildung/_node.html)

[www.facebook.com/fzjuelich.ausbildung](https://www.facebook.com/fzjuelich.ausbildung)



by a group of trainees who, as part of an interdisciplinary project, copied the Düsseldorf television tower on a scale of 1:96. The project team comprised four industrial mechanics and four electronics technicians for industrial engineering. Former trainees, who had passed their examination six months early, also joined in. Planning, organizing, and coordinating the tasks between the different interfaces presented a special challenge for the trainees and promoted collaboration across the various disciplines. The detail of the faithful copy speaks for itself. Even the digital clock, which characterizes the tower, was reproduced.



In 2014, 72 young people successfully completed their vocational training at Forschungszentrum Jülich, 15 of them with the best grade achievable, "sehr gut", 35 with the second-best, "gut". Twenty-one trainees completed their training faster than usual because of their outstanding performance. They are among the almost 4,600 skilled workers who got off to a good start to their careers by training at Forschungszentrum Jülich over the past 52 years.

## Vocational training places

new trainees 2014

Occupations		of which including a dual study programme
Laboratory technicians	26	7
Electricians	11	–
Metalworkers	10	1
Technical product designers <sup>1)</sup>	–	–
Administrative occupations	15	3
Mathematical-technical software developers	27	27
Other	16	–
<b>Total</b>	<b>105</b>	<b>38</b>

1) no new trainees in 2014

## Dual study programmes

incorporated into traineeships, 2014

	Total duration in years	Years to IHK examination	Semesters to bachelor's degree	Period between IHK examination and bachelor's degree
Bachelor of Science in Scientific Programming + mathematical-technical software developer (MATSE), IHK	3	3	6	approx. 2 months
Bachelor of Science + chemical laboratory technician, IHK	4	3	8	6 months –1 year
Bachelor of Engineering in physics engineering + physics laboratory technician, IHK	4.5	3.5	9	approx. 1 year
Bachelor of Mechanical Engineering + industrial mechanic, IHK	4	2.5	6	approx. 1.5 years
Bachelor of Electrical Engineering + electronics technician for industrial engineering, IHK	4	2.5	6	approx. 1.5 years
Bachelor of Arts Business Administration + office communications specialist, IHK	3.5 <sup>1)</sup>	3	7	approx. 6 months
Bachelor of Applied Sciences, after IHK examination for biology laboratory technician	2 <sup>2)</sup>	2 years parallel to employment, after completion of vocational training		
Bachelor of Applied Sciences, after IHK examination for chemistry laboratory technician	2 <sup>2)</sup>	2 years parallel to employment, after completion of vocational training		

1) parallel to employment, 2) including traineeships



Federal Research Minister Prof. Johanna Wanka (fourth from the left) and the President of the Helmholtz Association Prof. Jürgen Mlynek (right) presented the prizes at the annual general assembly of the Helmholtz Association in Berlin.

### 3 juelich\_chances

Forschungszentrum Jülich is a career stepping stone for undergraduates and PhD students. The fact that they make good use of the opportunities offered here is reflected in the various kinds of success that Jülich's young researchers achieved in 2014 – whether it is the fierce competition for the best doctoral theses or the entertaining public demonstration of their research.

#### Science on stage

The HITEC Graduate School, a joint project by RWTH Aachen University, Forschungszentrum Jülich, and other universities, offers well-founded interdisciplinary know-how on scientific, technical, and social dimensions of energy to around 160 PhD students. But that is not the only thing taught there: an emphasis is also put on presenting scientific content in innovative formats and entertaining ways. At the first HITEC Science Slam, in March 2014, early-career scientist Yulia Arini-

cheva from the Institute of Energy and Climate Research won the day. Among the ten-minute contributions, during which the “slammers” presented their research area in an easily understandable and diverting manner, her short lecture on how she cooks stones in the laboratory – i.e. her work in nuclear waste management – was the most popular among the audience at the crowded Kulturbahnhof Jülich.

#### Successful Jülich PhD students

Three early-career scientists from Forschungszentrum Jülich, among them two women scientists, were awarded the 2014 Helmholtz PhD Prize at the annual general assembly of the Helmholtz Association. Half of the six winners thus came from Jülich. In total, 17 candidates from Helmholtz centres had been nominated for achievements related to their doctoral degrees. Each of the awardees receives prize money worth € 5,000 for their further research as well as € 2,000

per month for a research stay abroad for a maximum of six months. Jülich's winners:

- **Dr. Heidi Ursula Heinrichs** from the Institute of Energy and Climate Research analysed in her PhD project the long-term impact of electromobility on the German energy system in the European context. She is the prize winner in the Helmholtz research field of Energy.
- **Dr. Anja Klotzsche** from the Institute of Bio- and Geosciences received the prize for the research field of Earth and Environment. In her doctoral thesis, she presented an improved method for the characterization of groundwater aquifers in the soil – an important contribution towards less aggressive and more sustainable use of soils and water.
- **Dr. Torsten Sehl** from the Institute of Bio- and Geosciences took home the prize for the research field of Key Technologies. In his doctoral thesis, he

developed a novel method for producing special amino alcohols in a faster, cheaper, and more environmentally friendly manner than previously possible. These substances are important for sectors such as the pharmaceutical industry.



Prof. Harald Bolt (right) congratulates Yulia Arinicheva (2<sup>nd</sup> from the right), who won the HITEC Science Slam.

## Outstanding young scientists honoured

At the PhD students event JuDocs 2014 – Karriere made in Jülich, Armel Ulrich Kemloh Wagoum and Benjamin Stadtmüller were awarded the Excellence Prize of Forschungszentrum Jülich, which is endowed with € 5,000 for each winner.

- For his doctoral thesis, **Dr. Armel Ulrich Kemloh Wagoum** worked at the Jülich Supercomputing Centre on generating computer simulations of human navigation behaviour in pedestrian flows. He also worked on very complex empirical behavioural studies.
- **Dr. Benjamin Stadtmüller** (formerly Peter Grünberg Institute) focused in his doctoral thesis on investigating the fundamental principles of physical processes and materials as they appear in organic electronic components. Such elements can already be found in applications such as photovoltaics and LEDs.

The fact that the Excellence Prize honours excellent early-career scientists with its highly competitive selection procedure is reflected whenever previous prize winners receive further important accolades during their later careers, as did Dr. John Kettler, who had won the Excellence Prize in 2011: he now works at RWTH Aachen University and in early 2015 was appointed to “Junges Kolleg” of the North Rhine-Westphalian Academy of Sciences, Humanities and the Arts. Admission to “Junges Kolleg” is one of the most important accolades for young scientists in North Rhine-Westphalia.



The seven-person JuBräu team of students and PhD students at Jülich's Biotechnology Institute won first prize at the fifth international beer brewing competition of Hamburg University of Technology with their beer creation “Mojito”.

## Summer schools, laboratory and compact courses

selection, 2014

Name	Participants		International participants	
	Total	of whom women	Total	of whom women
<b>45<sup>th</sup> IFF Spring School</b>	<b>281</b>	65	<b>147</b>	34
<b>JCNS Laboratory Course Neutron Scattering 2014</b>	<b>55</b>	29	<b>18</b>	14
<b>Hadron Physics Summer School 2014</b>	<b>44</b>	13	<b>10</b>	–
<b>JSC visiting students' programme</b>	<b>11</b>	2	<b>6</b>	2
<b>CECAM tutorial: Atomistic Monte Carlo Simulations of Biomolecular Systems</b>	<b>27</b>	6	<b>21</b>	6
<b>Joint European Summer School on Fuel Cell, Electrolyser, and Battery Technologies JESS 2014</b>	<b>47</b>	12	<b>40</b>	12
<b>Atmospheric Chemistry and Dynamics Summer School</b>	<b>36</b>	17	<b>21</b>	14



## Doctoral Qualifications with Partner Universities

2014

Lead institution	Graduate school/research training group	Partner organizations	Further information
<b>Aachen</b>	BioNoCo – Biocatalysis	RWTH Aachen University, Forschungszentrum Jülich, Heinrich Heine University Düsseldorf	<a href="http://www.bionoco.rwth-aachen.de">www.bionoco.rwth-aachen.de</a>
<b>Aachen</b>	Selectivity in Chemo- and Biocatalysis (SeleCa)	RWTH Aachen University, Forschungszentrum Jülich, Osaka University Japan	<a href="http://www.seleca.rwth-aachen.de">www.seleca.rwth-aachen.de</a>
<b>Aachen</b>	Biointerface – detection and control of interface-induced biomolecular and cellular functions (discontinued in 2014)	RWTH Aachen University, Forschungszentrum Jülich, Université de Liège, Maastricht University, DFG	<a href="http://www.biointerface.rwth-aachen.de">www.biointerface.rwth-aachen.de</a>
<b>Aachen</b>	International research training group: brain-behaviour relationship of emotion and social cognition in schizophrenia and autism	RWTH Aachen University, Forschungszentrum Jülich, University of Pennsylvania (USA), DFG	<a href="http://www.irtg1328.rwth-aachen.de">www.irtg1328.rwth-aachen.de</a>
<b>Aachen</b>	AICES Aachen Institute for Advanced Study in Computational Engineering Science	RWTH Aachen University, Forschungszentrum Jülich	<a href="http://www.rwth-aachen.de/go/id/xve">www.rwth-aachen.de/go/id/xve</a>
<b>Aachen</b>	Resistively Switching Chalcogenides for Future Electronics: Structures, Kinetics, and Component Scaling “Nanoswitches”	RWTH Aachen University, Forschungszentrum Jülich (JARA)	<a href="http://www.sfb917.rwth-aachen.de">www.sfb917.rwth-aachen.de</a>
<b>Aachen</b>	Functional Microgels and Microgel Systems	RWTH Aachen University, Forschungszentrum Jülich (JARA)	<a href="http://www.jara.org/de/research/jara-soft/nachrichten/details/2015/funktionelle-mikrogele-und-mikrogelsysteme/">www.jara.org/de/research/jara-soft/nachrichten/details/2015/funktionelle-mikrogele-und-mikrogelsysteme/</a>
<b>Bonn</b>	Research training group: Bionics – Interactions across Boundaries to the Environment	University of Bonn, RWTH Aachen University, Forschungszentrum Jülich, DFG	<a href="http://www.bionik.uni-bonn.de/bionik-graduate">www.bionik.uni-bonn.de/bionik-graduate</a>
<b>Düsseldorf</b>	Interdisciplinary Graduate School for Brain Research and Translational Neuroscience (iBrain)	Heinrich Heine University Düsseldorf, Forschungszentrum Jülich, Leibniz Research Institute for Environmental Medicine	<a href="http://www.ibrain-duesseldorf.de">www.ibrain-duesseldorf.de</a>
<b>Düsseldorf</b>	Communication and System Relevance in Liver Damage and Regeneration	Heinrich Heine University Düsseldorf, Max Planck Institute of Molecular Physiology, Forschungszentrum Jülich	<a href="http://www.klinikum-duesseldorf.de/index.php?id=93900&amp;no_cache=1">www.klinikum-duesseldorf.de/index.php?id=93900&amp;no_cache=1</a>
<b>Düsseldorf</b>	International Graduate School for Plant Science (iGrad-Plant)	Heinrich Heine University Düsseldorf, Michigan State University, East Lansing (USA), Forschungszentrum Jülich, DFG	<a href="http://www.igrad-plant.hhu.de">www.igrad-plant.hhu.de</a>
<b>Düsseldorf and Jülich</b>	Heinrich Heine International Graduate School of Protein Science and Technology (iGRASPseed)	Heinrich Heine University Düsseldorf, Forschungszentrum Jülich	<a href="http://igrasp.lwdb.de/welcome">igrasp.lwdb.de/welcome</a>
<b>Jülich</b>	Helmholtz Interdisciplinary Doctoral Training in Energy and Climate Research (HITEC)	Forschungszentrum Jülich, RWTH Aachen University, Ruhr-Universität Bochum, University of Cologne, Heinrich Heine University Düsseldorf, University of Wuppertal	<a href="http://www.hitec-graduate-school.de">www.hitec-graduate-school.de</a>
<b>Jülich</b>	International Helmholtz Research School of Biophysics and Soft Matter	Forschungszentrum Jülich, Heinrich Heine University Düsseldorf, University of Cologne, caesar Bonn	<a href="http://www.ihrs-biosoft.de">www.ihrs-biosoft.de</a>
<b>Jülich and Aachen (JARA)</b>	German Research School for Simulation Sciences	Forschungszentrum Jülich, RWTH Aachen University, Helmholtz Association, MIWFT, BMBF	<a href="http://www.grs-sim.de">www.grs-sim.de</a>
<b>Jülich and Aachen (JARA)</b>	Quantum-mechanic many-body approaches in condensed matter	RWTH Aachen University, Forschungszentrum Jülich (JARA)	<a href="http://www.jara.org/de/research/jara-fit/nachrichten/details/2014/graduertenkolleg-quantenmechanische-vielteilchenmethoden">www.jara.org/de/research/jara-fit/nachrichten/details/2014/graduertenkolleg-quantenmechanische-vielteilchenmethoden</a>
<b>Aachen, Bonn, Jülich, Cologne</b>	Geoverbund ABC/J doctoral programme: Centre for High-Performance Scientific Computing in Terrestrial Systems (HPSC TerrSys)	Forschungszentrum Jülich, RWTH Aachen University, University of Cologne, University of Bonn	<a href="http://icg4geo.icg.kfa-juelich.de/willkommen">icg4geo.icg.kfa-juelich.de/willkommen</a>
<b>Bonn</b>	Patterns in Soil-Vegetation-Atmosphere-Systems: Monitoring, Modelling and Data Assimilation (TR 32) (IRTG, Graduate School)	RWTH Aachen University, University of Bonn, University of Cologne, Forschungszentrum Jülich, DFG	<a href="http://tr32new.uni-koeln.de/index.php/irtg/graduate-school">tr32new.uni-koeln.de/index.php/irtg/graduate-school</a>
<b>Cologne</b>	Cellular and sub-cellular analysis of neural networks	University of Cologne, Forschungszentrum Jülich, MPI for Metabolism Research	<a href="http://rtg-nca.uni-koeln.de">rtg-nca.uni-koeln.de</a>
<b>Cologne and Bonn</b>	Bonn-Cologne Graduate School of Physics and Astronomy	University of Bonn, University of Cologne, Forschungszentrum Jülich, DFG	<a href="http://www.gradschool.physics.uni-bonn.de">www.gradschool.physics.uni-bonn.de</a>



## 4 juelich\_heads

The international Helmholtz Association PostDoc programme offers a career kick-start. Young scientists who have completed an outstanding doctoral degree during the past twelve months are supported. Successful applicants receive funding of € 300,000 each, spread over three years. This year, 19 young scientists were successful at the final stage, among them all four applicants from Forschungszentrum Jülich:

- **Dr. Anja Klotzsche** from the Institute of Bio- and Geosciences, who was also awarded the 2014 Helmholtz PhD Prize, wants to demonstrate in her work precisely what influence climate-relevant peat bog and permafrost soils have on the emission of the greenhouse gas carbon dioxide.
- The Polish physicist **Dr. Ewa Mlynczak** from the Peter Grünberg Institute is researching the relation between the fundamental electronic structure and the electric conductivity of novel magnetic thin-film systems. Her work is of great interest for developing the energy-efficient nano-scale storage media of the future.
- **Dr. Julen Ibanez-Azpiroz**, who came to the Peter Grünberg Institute from



Funded by EU Starting Grants: Dr. Jan Marienhagen (left) develops biosensors for the detection of biotechnologically interesting molecules in bacterial cells. Dr. Pitter Huesgen (right) investigates a particular metabolic process in stressed plants.

Spain, is working on improving a model from physical theory. The objective of his project is to expand on this model by adding the influence which electron spin fluctuations have on materials properties.

- **Dr. Derya Baran** conducts research in the field of organic photovoltaics – i.e. solar cells made from plastics which can be produced cheaply and applied like foil. In her work, the young scientist, who has a Turkish background, aims to improve techniques for quality control.

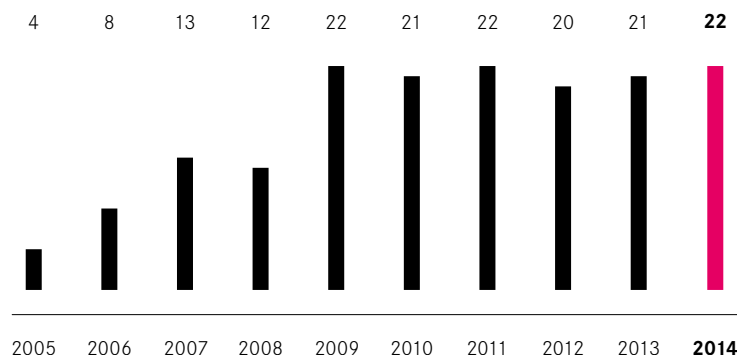
With this support programme, the Helmholtz Association wants to help young scientists to establish themselves in their research area and to effectively expand their scientific expertise.

### EU Starting Grants for Jülich

Not one, but two young Jülich scientists successfully applied for the internationally coveted Starting Grants from the European Research Council (ERC). This means that they will receive funding of around € 3.3 million over five years from the European Union's Horizon 2020 programme.

## Young investigators groups at Jülich

the figures comprise young investigators groups funded by the Helmholtz Association, Forschungszentrum Jülich, and third parties, 2005–2014



### New young investigators groups

In 2014, six new young investigators groups started their work at Forschungszentrum Jülich. Their leaders, who can build up their own team, are Dietrich Kohlheyer (Institute of Bio- and Geosciences), Simone Vossel (Institute of Neuroscience and Medicine), Carolin Schmitz-Antoniak (Peter Grünberg Institute), Dirk Witthaut (Institute of Energy and Climate Research), Moritz Helias (Institute of Neurosciences and Medicine), and Alexander Graf (Institute of Bio- and Geosciences).

# Personnel

If you want the best, you need to have something to offer. An excellent infrastructure and the opportunity to realize your own ideas – those are great incentives for qualified young talents and executive employees to come to Jülich. But an outstanding working environment requires even more: a pleasant working climate, the reconciliation of work and family life, equal opportunities, and flexible working hours are examples. In 2014, Forschungszentrum Jülich has again taken important steps in this area. This is also indicated by Jülich's first-ever placing on FOCUS Spezial's list of best employers 2015.

Exemplary activities:

- In order to improve women's chances in science, self-imposed quotas were presented to the Supervisory Board of Forschungszentrum Jülich. The Board of Directors had previously determined that by 2017, every third new position should be filled with a woman. For the highest salary grade W3/C4, the quota must increase by almost 7 percentage points to 11 % by the target date of 31 December 2017.
- Support programmes from the Helmholtz Association (HGF) help to attract top talents: if a woman is newly appointed to a W2 or W3 position, HGF provides € 150,000 (W2) to € 200,000 (W3) over five years. In addition, a recruitment initiative from HGF supports joint appointments with universities with up to € 600,000 per year.
- In order for new employees to feel at home right from the start, the onboarding process has also been improved. The guidelines for executives and mentors of new colleagues were revised, and an online welcome guide developed. To ensure that good intentions are not all that comes of this, late 2014 saw



Jülich's solid vocational training provides qualified professionals for its own needs as well as a good foundation for its trainees' successful careers.

the introduction of repeated surveys among new employees.

- Human Resource Development offers a varied qualification programme for PhD students as well as employees in executive positions. The mentoring programmes for women, implemented with RWTH Aachen University as TANDEMplus as well as with the Helmholtz Association as Taking the Lead, were continued.
- The pilot project Ad Hoc Teleworking, introduced on 1 March 2014, was evaluated simultaneously. In the first ten months, 439 employees made use of the opportunity to work from home on up to ten days a year.

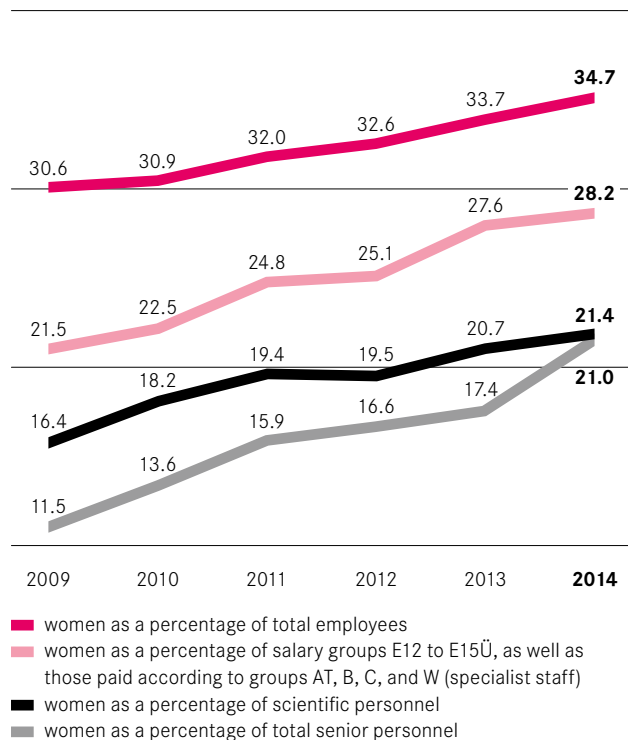
The activities in Personnel Marketing ensure that all of that is also visible to the outside. As such, Jülich was present at 25 recruiting fairs and events in 2014. Especially activities to attract women scientists and executives were expanded, such

as participation in the women&work congress in Bonn, the Women in Physics Conference in Heidelberg, the WoMenPower conference in Hannover, and the Ladies' Night in Aachen. In addition, visitor group tours followed by workshops on career opportunities and working conditions at Forschungszentrum Jülich were organized for women studying science, technology, engineering and mathematics (STEM) subjects at North Rhine-Westphalian universities.

International personnel marketing was also increased, for example by participation in a recruitment event at MIT Boston. Forschungszentrum Jülich is increasingly active on social media channels relevant to personnel marketing: the career portal [http://www.fz-juelich.de/portal/DE/Karriere/\\_node.html](http://www.fz-juelich.de/portal/DE/Karriere/_node.html) was optimized in 2014.

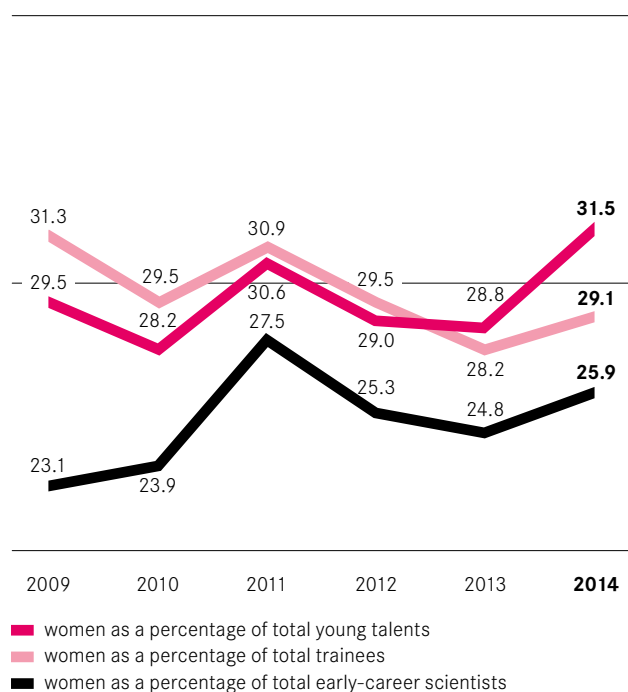
## Proportion of women employees at Forschungszentrum Jülich

percentage, 2009 – 2014



## Proportion of young women

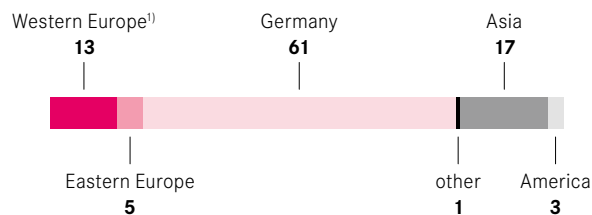
percentage, 2009 – 2014



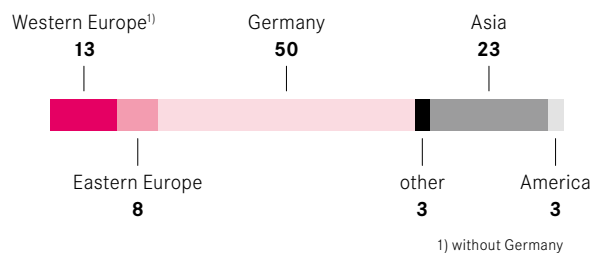
## Visiting Scientists

percentage, 2013 – 2014

2013: 995 in total from 39 countries



2014: 907 in total from 65 countries



## Overview personnel

as of 31 December 2014

Area	Number of employees <sup>1)</sup>
Scientists and technical personnel	3,753
of which scientists incl. university students	2,074
• of which PhD students	540
• of which scholarship holders	24
• of which undergraduates/postgraduates	152
• of which joint appointments with universities <sup>2)</sup>	111
• of which W3 professors	51
• of which W2 professors	49
• of which W1 professors	11
of which technical personnel	1,679
Project Management Organizations	937
Administration	717
Trainees and students on placement	361
<b>Total</b>	<b>5,768</b>

1) only employees with a contract paid by Jülich,  
2) excl. members of the Board of Directors

# Accolades

2014

Name	Accolade
<b>Prof. Katrin Amunts</b> Institute of Neuroscience and Medicine	Voted Key Player in the 10 New Breakthrough Technologies 2014 by MIT Technology Review
<b>Prof. Steven Beale</b> Institute of Energy and Climate Research	Dedicated Service Award of the American Society of Mechanical Engineers
<b>Dr. Stephan Binder, Dr. Georg Schaumann, Peter Kallien, Dr. Thomas Schwarz</b> Institute of Bio- and Geosciences	PEP Awards in the category Early-Phase Spin-off Projects
<b>Dr. Stephan Binder and Dr. Georg Schaumann</b> Institute of Bio- and Geosciences	Technology Review's TR 35 "Innovators under 35" award
<b>Dr. Anna Dovern</b> Institute of Neuroscience and Medicine	Dissertation Prize 2012 from from the Faculty of Medicine at the University of Cologne.
<b>Prof. Dirk Feldmeyer</b> Institute of Neuroscience and Medicine	Member of the Wellcome Trust Peer Review College
<b>Prof. Janina Fels</b> Institute of Neuroscience and Medicine	Admittance to "Junges Kolleg" of the North Rhine-Westphalian Academy of Sciences, Humanities and the Arts
<b>Jennifer Groß</b> Institute of Energy and Climate Research <b>Maya Kletzin, Marina Weingartz</b> both Jülich Supercomputing Centre	Medal of honour of Aachen University of Applied Sciences
<b>Alexander Grünberger</b> Institute of Bio- and Geosciences	Klaus Goerttler Award and BioSC Competence Award for his doctoral thesis
<b>Dr. Johann Haidenbauer</b> Institute for Advanced Simulation <b>Dr. Rolf Stassen</b> Nuclear Physics Institute	Encouraging Prize of the Russian Joint Institute for Nuclear Research
<b>Dr. Heidi Ursula Heinrichs</b> Institute of Energy and Climate Research	Helmholtz PhD Prize 2014
<b>Prof Hans Herzog</b> Institute of Neuroscience and Medicine	Nuclear Medicine Prize from Schattauer Publishers
<b>Dr. Anja Klotzsche</b> Institute of Bio- and Geosciences	Helmholtz PhD Prize 2014 and Geoverbund ABC/J Young Academic Award (3 <sup>rd</sup> place)
<b>Dr. Andreas Küberl</b> Institute of Bio- and Geosciences	Josef Deutscher Award for "Excellence in Content and Presentation" at the 1 <sup>st</sup> International Conference on Post-Translational Modifications in Bacteria, Sept. 2014, Göttingen
<b>Dr. Wolfgang Kurtz</b> Institute of Bio- and Geosciences	Geoverbund ABC/J Young Academic Award (2 <sup>nd</sup> place)
<b>Dr. Ute Linz</b> Institute of Complex Systems	Appointment to the Scientific Advisory Board of the International Particle Accelerator Conference
<b>Gia Vinh Luong</b> Peter Grünberg Institute	"Best Paper Award" at the international Ultimate Integration on Silicon (ULIS) conference
<b>Prof. Rudolf Maier</b> Nuclear Physics Institute	Honorary doctorate from the Russian Joint Institute for Nuclear Research
<b>Prof. Wolfgang Marquardt</b> Chairman of the Board of Directors	Member of the Leopoldina German National Academy of Sciences
<b>Prof. Ulf-G. Meißner</b> Nuclear Physics Institute	President's International Fellowship for Distinguished Scientists of the Chinese Academy of Sciences (CAS)
<b>Dr. Thomas Mühleisen</b> Institute of Neuroscience and Medicine	Elliot Gershon Paper of the Year Award



Name	Accolade
<b>Dr. Sascha Nehr</b> Institute of Energy and Climate Research	Dissertation Prize 2013 of the Association of Friends of the University of Wuppertal
<b>PD Dr. Irene Neuner</b> Institute of Neuroscience and Medicine	2014 award for the investigation of psychiatric disorders in the category clinical practice of the German Association for Psychiatry, Psychotherapy and Psychosomatics (DGPPN)
<b>Dr. Marisol Ripoll</b> Institute of Complex Systems	Named as Germany's representative on the Management Committee of COST Flowing Matter Action.
<b>Prof. Sebastian M. Schmidt</b> Member of the Board of Directors	Honorary doctorate from the Georgian Technical University Honorary professorship of Xi'an Jiaotong University
<b>Jun.-Prof. Gunnar Schröder and Dennis Della Corte</b> Institute of Complex Systems	2 <sup>nd</sup> place in the international CASP competition for computational structural biology
<b>Prof. Otto W. B. Schult</b> Nuclear Physics Institute	Honorary doctorate from the Georgian Technical University
<b>Dr. Torsten Sehl</b> Institute of Bio- and Geosciences	Helmholtz PhD prize 2014 and BioSC Competence Award
<b>Prof. Lorenz Singheiser</b> Institute of Energy and Climate Research	Heyn commemorative medal from the German Society for Materials Science
<b>Dr. Benjamin Stadtmüller</b> formerly Peter Grünberg Institute <b>Dr. Armel Ulrich Kemloh Wagoum</b> Jülich Supercomputing Centre	Excellence Prize of Forschungszentrum Jülich
<b>Prof. Detlef Stolten</b> Institute of Energy and Climate Research	Sir William Grove Award from the International Association of Hydrogen Energy, member of the Editorial Board of the Journal of Energy Storage
<b>Prof. Detlev Stöver</b> formerly Institute of Energy and Climate Research	Skaupy Prize 2014 from Gesamtausschuss Pulvermetallurgie
<b>Prof. Hans Ströher</b> Nuclear Physics Institute	Honorary doctorate from the Georgian Technical University
<b>Prof. Jan van der Kruk</b> Institute of Bio- and Geosciences	Harold Mooney Award of the Near Surface Geophysics Section (NSGS) of the Society of Exploration Geophysicists
<b>Prof. Harry Vereeken</b> Institute of Bio- and Geosciences	American Geophysical Union Fellow 2015
<b>Prof. Christian Wandrey</b> Institute of Bio- and Geosciences	PEP Award in the category Professors as spin-off promoters and Biocat Award 2014
<b>Prof. Rainer Waser</b> Peter Grünberg Institute	Tsungming-Tu Prize of the National Science Council of Taiwan
<b>Anna Westhoff</b> Jülich Supercomputing Centre	"PARS-Nachwuchspreis der PARS-GI/ITG-Fachgruppe" at the 11 <sup>th</sup> Workshop on Parallel Algorithms and Systems and Algorithms in Lübeck
<b>Prof. Martin Winter</b> Helmholtz-Institut Münster	IBA Award for Technology of the International Battery Association, Inclusion in the list of Highly Cited Researchers 2014 by Thomson Reuters (host of the Web of Science database)
<b>Prof. Gerd Wolf</b> formerly Nuclear Physics Institute, jointly with <b>Prof. Chevalier Paul Vandenplas, Prof. Marnix van der Wiel</b>	Minerva Prize of Jülich's Museum Association
<b>Prof. Karl Zilles</b> Institute of Neuroscience and Medicine	Election as president of the Organization for Human Brain Mapping, OHBM Glass Brain Award

# Appointments

## Joint professorial appointments with universities

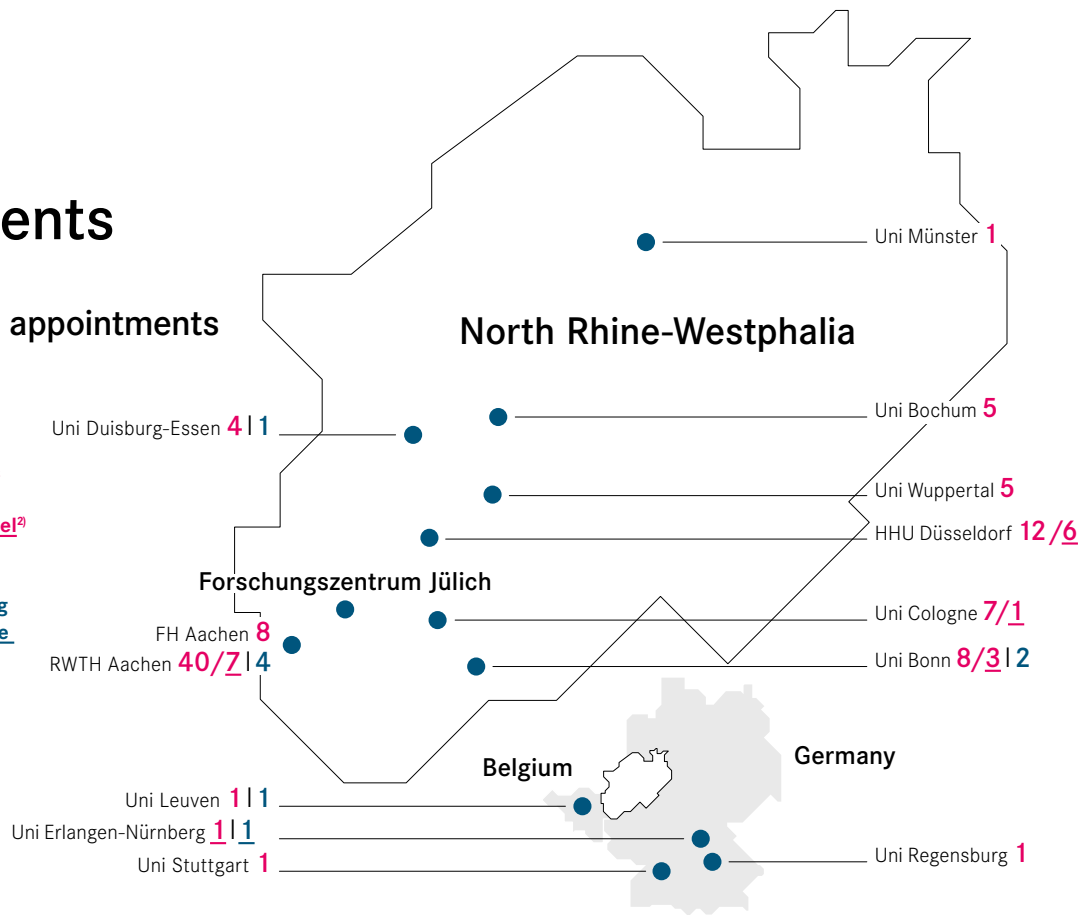
as of 31 December 2014

**Total number of professors appointed according to the Jülich model<sup>1)</sup>/reverse model<sup>2)</sup>**

**Number of new professors appointed in 2014 according to the Jülich model<sup>1)</sup>/reverse model<sup>2)</sup>**

1) Jülich model: Scientists are appointed professor in a joint procedure with one of the partner universities and are simultaneously seconded by the university to work at Forschungszentrum Jülich.

2) Reverse Jülich model: Professors whose primary employment is at their university also work at Jülich (secondary employment).



## Professorial appointments

- **Prof. Christoph Buchal** of the Peter Grünberg Institute was appointed Wilhelm-und-Else-Heraeus Senior Professor.
- **Prof. Dr. Simon Eickhoff** of the Institute of Neuroscience and Medicine was appointed visiting professor at the Chinese Academy of Sciences.
- **Dr. Klaus Günther** of the Institute of Bio- and Geosciences was appointed adjunct professor of food chemistry by the University of Bonn.
- **Prof. Sonja Grün** of the Institute of Neuroscience and Medicine was appointed visiting professor at Osaka University, Japan.
- **PD Dr. Stefan Heim** was appointed adjunct professor by RWTH Aachen University.
- **PD Dr. Bert Heinrichs** was appointed W2 professor of ethics and applied ethics in a joint appointment procedure by the University of Bonn and Forschungszentrum Jülich.
- **Dr. Michael Faley** of the Peter Grünberg Institute was appointed adjunct professor at the Institute for Theory of Statistical Physics at RWTH Aachen University.
- **Dr. Dietrich Kohlheyer** of the Institute of Bio- and Geosciences was appointed junior professor by RWTH Aachen University.
- **PD Dr. Silke Lux** of the Institute of Neuroscience and Medicine was appointed adjunct professor at Bielefeld University.
- **Dr. Michael Ohl** of the branch office of the Jülich Centre for Neutron Science in Oak Ridge was appointed adjunct professor by the University of Tennessee.
- **Dr. Dörte Rother** of the Institute of Bio- and Geosciences was appointed junior professor by RWTH Aachen University.
- **Dr. Dr. Giulia Rossetti** of the Institute for Advanced Simulation was appointed junior professor by RWTH Aachen University.
- **Prof. Dr. Andrea Schnepf** of the Institute of Bio- and Geosciences was appointed W2 professor by the University of Bonn.
- **Prof. Kalman Szabo** of the Jülich Supercomputing Centre was appointed professor by the University of Wuppertal.
- **Dr. Vicky Temperton** of the Institute of Bio- and Geosciences was appointed professor by Leuphana University Lüneburg.



# Campus

Page 81–96



# Researching Sustainably

Researching and developing solutions which will enable future generations to lead a good life – Jülich attaches the utmost importance to this. But Jülich scientists are also concerned with conducting their research in a sustainable and resource-conserving manner.



In 2014, Forschungszentrum Jülich was the first member of the Helmholtz Association to present a sustainability report.

**B**ut what does sustainability actually mean? A good example is presented by the 120 employees at Plant Sciences: when they meet up, the topic is usually their research – for example, the question of how to cultivate sugar beets or barley in a way that permits drugs or washing powder to be produced from them efficiently. But in 2014, they were also concerned with a different question in their seminars: how much electricity, district heat, drinking and cooling water does our research require? Initiator Prof. Ulrich Schurr says: “I wanted to show my colleagues how their behaviour influences the consumption of water and energy.” He has been concerned with the issue since he came to Jülich in 2001 as head of Plant Sciences. But only since 2011, when around 900 meters that can be read remotely were installed in all buildings, has he been able to actually access his division’s consumption data. Before, only data for the whole of Forschungszentrum Jülich were collected.

## Conservation suggestions developed

For the plant scientists, the numbers are rather encouraging: in 2014, their building’s energy consumption was around 70 % lower than ten years earlier. At that time, the building’s energy consumption was measured separately as a temporary measure before the building was renovated with respect to energy specifications. However, the 120 plant researchers in their four buildings still use 20 times as much drinking water and as much as 470 times more electricity per year than an average four-person household. When this was brought to the researchers’ attention, they

developed 15 suggestions for saving energy which were examined by experts and some of them were then implemented.

The sophisticated meters found their way into the Sustainability Report, entitled “Networking, Researching, Thinking Ahead”, which Forschungszentrum Jülich presented on 1 July 2014. Previously, only two non-university research establishments had drawn up sustainability reports following the relevant test guidelines. “With the report, which is certified according to the Global Reporting Initiative (GRI) guidelines, we have laid the foundation for regularly comparing and examining our activities with regard to sustainability,” says Dr. Peter Burauel, head of Sustainable Campus.







Peter Burauel, head of Sustainable Campus, mobilizing for sustainability

He is convinced that sustainable development is not possible without involving the employees and appreciating their work. As in Schurr's group on a small scale, numerous suggestions were made on how to conserve energy, it is hoped this will work on the large scale: for all issues concerning research, work, and life at Forschungszentrum Jülich. In response, Burauel and his colleague Dr. Ellen Kammula created the Sustainable Campus Arena discussion platform on Jülich's intranet. Here, employees have the opportunity to comment on topics like energy efficiency or the Urban Development Master Plan 2050. With it, Jülich hopes to create the conditions for successful research and a high standard of life, according to the Sustainability Report. The plan includes the concept of concentrating the institutes in a green zone at the

# 70

percent less energy was used by Jülich plant researchers in their main building in 2014 as compared to 2004.

centre of the campus, while facilities for energy and drinking water supply will be placed in locations in the forest. In the middle of the campus, a car-free boulevard will be created. The most important means of transport would be bicycles.

### The importance of exercise

"Exercise and health will be an important aspect of the Urban Development Master Plan – helping our employees to improve their health," says Burauel. This was also the topic of the talks and discussions at Sustainable Campus' one-day workshop entitled "Brain, Food, Move" where 150 participants discussed how brain activity is connected with nutrition and exercise as well as with obesity. Another event organized by Sustainable Campus as part of the Jülich Colloquia was all about electromobility. In the end, this also contributed to the introduction of electric vehicles into the fleet of Jülich company cars in December 2014.



Speakers and organizers during the Brain, Food, Move workshop

# Work at Other Locations

Forschungszentrum Jülich provides researchers with access to unique instruments and facilities – on the Jülich campus as well as at other locations in Germany and abroad. Institutes run jointly with universities and joint promotion of young talents are added on top.

**F**orschungszentrum Jülich is represented at other locations as follows:

- In **Aachen** through the **German Research School for Simulation Sciences (GRS)** and the **Jülich Aachen Research Alliance JARA** (for more on JARA, see p. 59). GRS GmbH is an independent subsidiary of Forschungszentrum Jülich. As a joint institution of Forschungszentrum Jülich and RWTH Aachen University, each of which has equal shares, GRS offers programmes in computer science and engineering for master's students and PhD students;
- At the **research reactor in Garching near Munich**, where the Heinz Maier-Leibnitz Zentrum is run by the **Jülich Centre for Neutron Science (JCNS)**<sup>1)</sup>, Technische Universität München, and Helmholtz-Zentrum Geesthacht.
- At the Spallation Neutron Source SNS at **Oak Ridge National Laboratory (ORNL), USA**, where JCNS operates the only non-American measuring instrument.

1) JCNS is one of the institutes of Forschungszentrum Jülich. It operates neutron scattering instruments at the leading national and international neutron sources FRM II, ILL, and SNS as part of a joint strategy.

- At the high-flux reactor at **Institut Laue-Langevin (ILL) in Grenoble, France**. Forschungszentrum Jülich is a joint shareholder of ILL along with the French Alternative Energies and Atomic Energy Commission (CEA), the French National Center for Scientific Research (CNRS), and the Science and Technology Facilities Council (STFC) in the UK. Jülich has a share of 33%. This guarantees the participation of the entire German neutron research community in the operation of ILL.
- Jülich coordinates Germany's contribution to the design update phase of the planned **European Spallation Source (ESS)**, which is being constructed in **Lund, Sweden**. The aim is to establish a German branch office at ESS.
- The activities of the **Peter Grünberg Institute** in the area of synchrotron radiation in **Dortmund, Berlin, Trieste (Italy)**, and **Argonne (USA)** are coordinated by the Jülich Synchrotron Radiation Laboratory (JSRL).
- **Project Management Jülich** – as a largely independent organization at Forschungszentrum Jülich GmbH – has branch offices in **Jülich, Berlin, Rostock**, and **Bonn** (see p. 85).
- In **Düsseldorf**, Technology Transfer runs the branch office of the **biotechnology cluster BIO.NRW**, funded by the Ministry of Innovation, Science and Research of the State of North Rhine-Westphalia (MIWF). BIO.NRW initiates cooperation between research institutions, companies, investors, and policy makers at regional, national, and international levels.
- The activities of Forschungszentrum Jülich in **India** are coordinated by an office in **New Delhi** (see p. 53).
- As a member of the **Helmholtz Association (HGF)**, Forschungszentrum Jülich is also represented internationally by its offices. The HGF has international offices in **Brussels, Moscow, and Beijing**.
- The **Helmholtz Institute Erlangen-Nürnberg (HI ERN)** is set up as a branch office of Forschungszentrum Jülich and is operated in close cooperation with Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) and Helmholtz-Zentrum Berlin (HZB). It focuses on research into renewable energy.
- The **Helmholtz Institute for Ionics in Energy Storage** was established in **Münster** in June 2014 as a branch office of Forschungszentrum Jülich (see p. 87). The institute will pool the expertise of Forschungszentrum Jülich, RWTH Aachen University, and the University of Münster in battery research.

# Project management

Forschungszentrum Jülich is active not only in its own research, but also in the area of research management: Project Management Jülich (PtJ) and Project Management Organization Energy, Technology, Sustainability (ETN) implement research and innovation funding programmes on behalf of the public authorities.

In 2014, the go-ahead was given for a new funding period in the Investments in Growth and Employment programme, financed from the European Regional Development Fund (ERDF). With the money from ERDF, the EU supports North Rhine-Westphalian projects, boosting research, technological development and innovation, as well as increasing the competitiveness of small and medium-sized enterprises. Other objects of funding

are efforts at reducing CO<sub>2</sub> emissions as well as sustainable urban development. For this purpose, the state of North Rhine-Westphalia has developed the 2014–2020 “Investment in Growth and Employment” operational programme for the European Regional Development Fund (OP ERDF NRW). The two Jülich project

management organizations, ETN and PtJ, were jointly commissioned by the state government as lead market agency LeitmarktAgentur.NRW to hold competitions for all those interested in applying for funds from the programme’s various funding priorities, referred to as the lead market initiative. The target groups comprise particularly companies, universities and research institutions. Among the tasks of LeitmarktAgentur, which is based in Jülich, are conception and implementation of the competitions, advisory services for the applicants, approval of the applications, assistance for the funded projects, and finally disbursement of funding to the recipients. LeitmarktAgentur.NRW can thus supply a complete service package to the state government and everyone interested in funding. Five of the eight competitions were started by March 2015.

For three of these eight lead markets, ETN is heading project management (energy and environmental economy, health, mobility and logistics). The remaining five are handled by PtJ.



Celebrating Project Management Jülich’s 40<sup>th</sup> anniversary: Dr. Christian Stienen, head of Project Management Jülich, Thomas Rachel, Member of the German Bundestag and Parliamentary State Secretary to the Federal Minister, Heinrich Stommel, mayor of Jülich, and Karsten Beneke, Vice-Chairman of the Board of Directors of Forschungszentrum Jülich (from left to right).

## The eight lead markets

Subject area	Launch of the lead market competition
Media and creative industries	21 October 2014
Energy and environmental economy	17 November 2014
New materials	20 January 2015
Health	20 February 2015
Mechanical and plant engineering/production technology	16 March 2015
Mobility and logistics	13 April 2015
Life sciences	May 2015
Information and communication economy	June 2015

## Project Management Organization Energy, Technology, Sustainability (ETN)

In addition to building up new funding structures for LeitmarktAgentur.NRW, ETN expanded its basis by acquiring new tasks and topics. For example, a major contract from the Ministry for Climate Protection, Environment, Agriculture, Conservation and Consumer Protection of the State of North Rhine-Westphalia was acquired: namely, the funding competitions on climate protection, one of the priorities of EFRE 2014–2020. The breadth of activities was expanded strategically by taking on the topics of civil engagement and animal welfare.

Data project management ETN	2014
Coordinated projects	<b>more than 800</b>
Newly approved projects	<b>100</b>
Total budget	<b>≈ € 420 million</b>
of which funding	<b>≈ € 325 million</b>
Employees <sup>1)</sup>	<b>75</b>
New members of staff	<b>5</b>

<sup>1)</sup> number includes one trainee

## Project Management Jülich (PtJ)

In 2014, Project Management Jülich celebrated its 40<sup>th</sup> anniversary. With its expertise in research and innovation management, PtJ has supported clients on the federal and state level in implementing their funding policy targets since October 1974, as well as the European Commission for many years. Together with clients, partners, and representatives from Forschungszentrum Jülich, the anniversary was celebrated on 30 September 2014 with an official ceremony at its main offices at Forschungszentrum Jülich. Among the guests were the mayor of the town of Jülich and Parliamentary State Secretary to the Federal Minister of Education and Research (BMBF) Thomas Rachel, Member of the German Bundestag. In his welcome address, he emphasized the important role that PtJ plays for the implementation of research and innovation policy through project management.

The beginning, 40 years ago, saw project management for energy research (PLE) being commissioned by the Federal Government to implement the first energy re-

Data project management PtJ 2014

Managed funding	<b>€ 1.33 billion</b>
Newly approved projects	<b>4,644</b>
Projects in progress	<b>16,774</b>
Employees <sup>1)</sup>	<b>868</b>
New members of staff	<b>48</b>

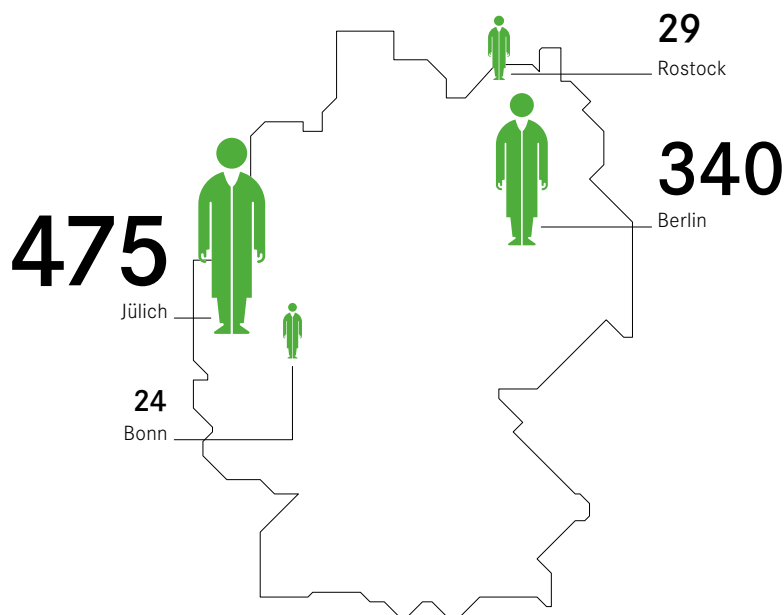
<sup>1)</sup> number includes five trainees

search programme, as well as the coordination office for nuclear solid state research (KNF). The project management organizations were pioneers in project funding at Jülich. With 20 employees, they supported almost 200 projects in 1974, and managed around € 60 million in funding.

Today, PtJ manages well over € 1 billion in funding every year and is one of the largest high-turnover project management organizations in Germany. Strategies concerning research and innovation policy are increasingly in demand, oriented towards the needs and demands of society, but also considering knowledge and technology transfer. Project Management Jülich is therefore expanding its range of services to encompass offers in the field of policy advice and innovation support. In 2014, PtJ succeeded in acquiring a commission from the Federal Environment Agency (UBA) for a study identifying and analysing factors hindering the transformation of the German economy to a green economy. Green economy is the guiding principle for economic development aiming to combine ecology with economy. The objective is an economy which satisfies the demand for goods and services while at the same time decreasing resource consumption and emissions. The study is being realized in collaboration with the Institute for Applied Ecology in Freiburg. In addition, PtJ was involved in the conception and further development of various funding programmes in 2014, such as the BMBF funding programmes for materials research and sustainable development.

## Number of employees at PtJ

distribution at the different locations, 2014





# Helmholtz institute: Energy Storage for a Transformed Energy Sector

How can electricity be stored long-term, in great quantities and taking up as little space as possible? The new Helmholtz Institute Münster (HI MS) will answer these questions. It will unite Jülich's competences in battery research with those of Münster University and RWTH Aachen University. It is run as a branch office of Forschungszentrum Jülich.

"The aim of the transformation of the German energy sector is creating a safe, affordable, and sustainable energy supply. To achieve this, we need progress in energy storage," Federal Research Minister Johanna Wanka said in June 2014. She continued: "I am therefore delighted that by founding the Helmholtz Institute Münster we can boost research into electrochemical storage solutions."

Starting in early 2015, € 5.5 million per year will be available to HI MS for this research. Of that, 90% will be financed by the German Federal Government and 10%

by the Federal State of North Rhine-Westphalia. North Rhine-Westphalia will invest another € 11 million as initial funding: € 6 million of this will be made available for a new building in Münster, which will be built at a location very close to the existing MEET institute (Münster Electrochemical Energy Technology) by 2018. The other € 5 million will be used for new laboratory equipment.

The focus of HI MS's research will be the electrolyte, a central component of batteries which makes the effective current flow between negative and positive terminal possible at all. The characteristics of the electrolyte decisively determine important features such as performance, safety, and lifetime of a battery.

The basis of the work is a concept that had been deemed "scientifically excellent" by an international panel of experts. It carries on the long-standing research traditions in Münster, Jülich, and Aachen.

It also ensures that the scientists contribute their individual expertise to interdisciplinary research topics. "By pooling expertise and resources from three institutions, we can more easily acquire third-party funding, that is, project-specific financial support from companies and the public sector," emphasizes Dr. Hinrich-Wilhelm Meyer, scientific coordinator at HI MS.

The institute will continue to have three locations: Münster, Jülich, and Aachen. It is planned that a total of 35 scientists will conduct research for the institute, most of them in the new building in Münster. In May 2015, 16 scientists were already working at HI MS. Work must start immediately: "By 2017, we need to prove to an expert panel that our concept is successful and that we are making scientific progress," says Meyer.



Federal Minister of Education and Research Prof. Johanna Wanka (right), North Rhine-Westphalian Science Minister Svenja Schulze (left), and the President of the Helmholtz Association Prof. Jürgen Mlynek (middle) were among the prominent guests at the launch of HI MS.

# Finances

Investments in science and research secure our future. Public funding makes it possible for Jülich to conduct the independent preliminary research that is essential to ensure sustainable development. In addition to this, Forschungszentrum Jülich also generates income from licences with its industrially oriented research.

## Balance sheet

in millions of euros, 2014

Assets	2014	2013
<b>A. Fixed assets</b>	<b>533.2</b>	<b>526.4</b>
I. Intangible assets	2.9	3.2
II. Tangible assets	530.1	523.0
III. Financial assets	0.2	0.2
<b>B. Current assets</b>	<b>625.1</b>	<b>939.0</b>
I. Inventories	35.1	38.2
II. Accounts receivable and other assets	26.0	20.8
III. Government equity to balance the books	551.7	862.2
IV. Cash on hand and on deposit with Deutsche Bundesbank, deposits with credit institutions, cheques	12.3	17.8
<b>C. Accruals and deferrals</b>	<b>9.8</b>	<b>18.7</b>
<b>Total assets</b>	<b>1,168.1</b>	<b>1,484.1</b>
Liabilities	2014	2013
<b>A. Equity capital</b>	<b>0.5</b>	<b>0.5</b>
<b>B. Special items for subsidies</b>	<b>587.4</b>	<b>591.5</b>
I. for fixed assets	532.7	525.8
II. for current assets	54.7	65.7
<b>C. Provisions</b>	<b>516.0</b>	<b>831.0</b>
I. Decommissioning and disposal of nuclear installations	432.4	491.7
II. Pensions and miscellaneous	66.5	61.9
III. Provisions for taxation	17.1	277.4
<b>D. Accounts payable</b>	<b>63.0</b>	<b>59.7</b>
<b>E. Accruals and deferrals</b>	<b>1.2</b>	<b>1.4</b>
<b>Total liabilities</b>	<b>1,168.1</b>	<b>1,484.1</b>

## Profit and loss account

in thousands of euros, 2014

	2014	2013
<b>Income from subsidies</b>	<b>169,359</b>	<b>562,612</b>
Other subsidies	78,807	465,171
from federal government	66,837	417,279
from state government	11,970	47,892
Third-party project funding	90,552	97,441
from federal government	50,426	44,574
from state government	4,741	14,997
from DFG	4,340	6,444
from others	15,002	12,609
from EU	16,043	18,817
<b>Revenues and other income</b>	<b>641,417</b>	<b>181,558</b>
Revenues from research, development, and use of research facilities	8,165	11,556
Revenues from licensing and know-how agreements	783	1,001
Revenues from project management organizations	80,952	75,688
Revenues from infrastructure services and the sale of materials	8,881	9,551
Revenues from the disposal of fixed assets	292	610
Increase or reduction in the inventory of work in progress and services (of which EU € -5,171,000; prev. year € 641,000)	-3,115	-2,352
Other own work capitalized	921	793
Other operating income	278,470	21,456
Other interest and similar income	266,068	63,255
<b>Allocations to special items for subsidies</b>	<b>-58,169</b>	<b>-66,220</b>
<b>Transferred subsidies</b>	<b>-46,998</b>	<b>-44,235</b>
<b>Income from subsidies, revenues and other Revenues and other income</b>	<b>705,609</b>	<b>633,715</b>
<b>Personnel costs</b>	<b>313,053</b>	<b>291,159</b>
<b>Operating costs</b>	<b>57,414</b>	<b>54,815</b>
Material costs	31,561	28,056
Costs for energy and water	20,218	19,692
Costs for external research and development	5,635	7,067
<b>Other costs</b>	<b>331,439</b>	<b>273,562</b>
<b>Other interest and similar costs</b>	<b>1,767</b>	<b>11,694</b>
<b>Taxes on income and earnings</b>	<b>1,936</b>	<b>2,485</b>
<b>Non-recurring expenses</b>	<b>0</b>	<b>0</b>
<b>Depreciation on fixed assets</b>	<b>0</b>	<b>0</b>
Depreciation on fixed assets	61,295	58,990
Income from liquidation of special items for subsidies	-61,295	-58,990
<b>Total expenditure</b>	<b>705,609</b>	<b>633,715</b>
<b>Result of normal business activity/Annual result</b>	<b>0</b>	<b>0</b>

## Revenues

in thousands of euros, 2014

Area	Structure of Matter	Earth and Environment	Energy	Key technologies	Total Research fields	Other revenues	Total
EU funding	621	184	2,795	6,470	10,070	802	10,872
National project funding (excl. DFG)	1,723	2,139	19,984	25,617	49,463	20,707	70,170
incl. transferred subsidies	51	5	1,109	2,639	3,804	20,203	24,007
DFG funding	49	1,068	1,027	2,272	4,416	0	4,416
<b>Subtotal project funding</b>	<b>2,393</b>	<b>3,391</b>	<b>23,806</b>	<b>34,359</b>	<b>63,949</b>	<b>21,509</b>	<b>85,458</b>
Contracts, abroad	83	177	1,062	286	1,608	392	2,000
Contracts, Germany	3,091	1,081	2,927	2,753	9,852	13,212	23,064
Project management organizations						80,952	80,952
<b>Subtotal third-party funds</b>	<b>5,567</b>	<b>4,649</b>	<b>27,795</b>	<b>37,398</b>	<b>75,409</b>	<b>116,065</b>	<b>191,474</b>
Institutional funding							333,882
incl. dismantling projects							69,597
<b>Total</b>							<b>525,356</b>

## National project funding

excluding DFG, in thousands of euros, 2014

<b>Total</b>	<b>70,170</b>
from federal government	50,427
from state government	4,741
from other (national) sources	15,002
<b>of which:</b>	
Transferred subsidies	24,007
National project funding excl. DFG adjusted for transferred subsidies	46,163

### Information

Third-party funding is classified according to the funding body or client. In addition to the revenues obtained as subsidies from the EU or from commissions as listed in the profit and loss statement, assessments of incomplete services are also accounted for. The composition of national project funding is listed in the above table "National project funding excluding DFG". DFG funding consists of subsidies and the reimbursement of personnel costs financed by DFG.

The break-down into individual research areas is effected in accordance with accounting valuation methods with the purpose of transfer to the profit and loss statement.

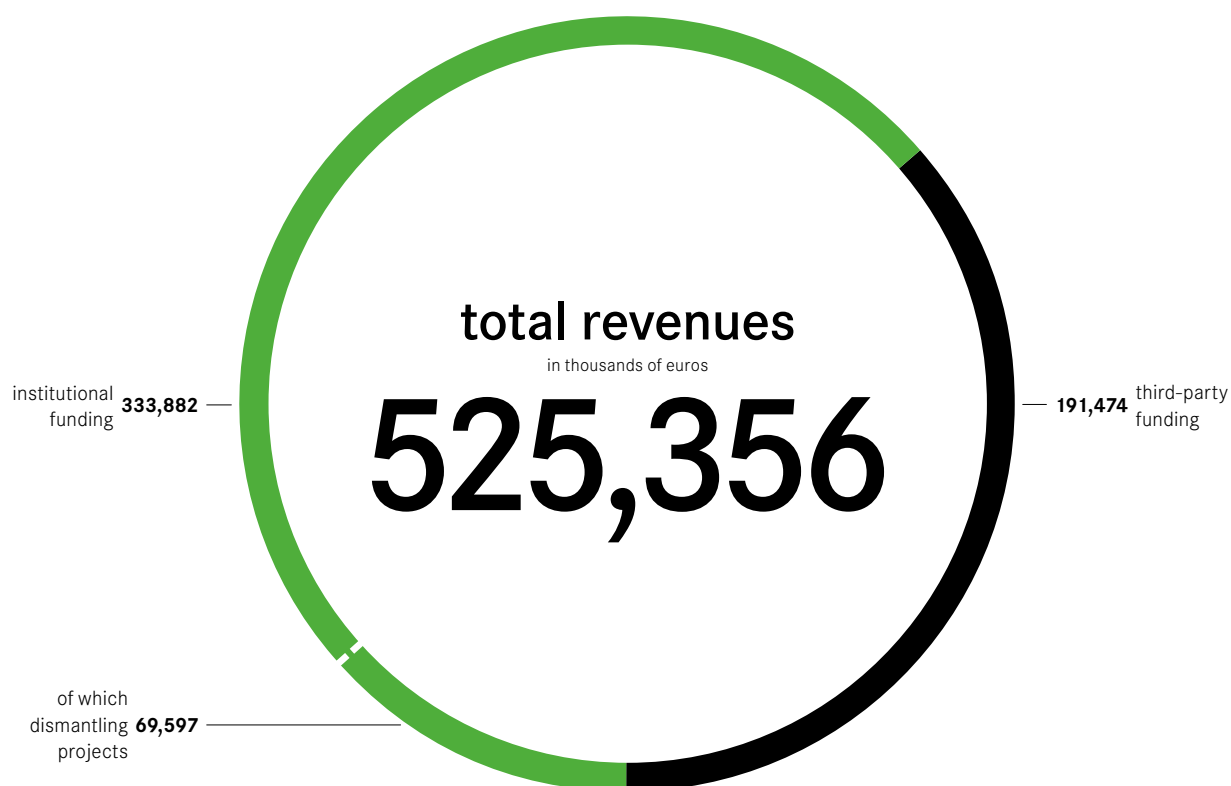


### Revenues 2014

In 2014, Forschungszentrum Jülich's third-party funding totalled € 191.5 million, remaining at the same level as the previous year. Most of this third-party income resulted from research and development activities for industry, the

acquisition of funding from Germany and abroad, plus project management on behalf of the Federal Republic of Germany and the federal state of North Rhine-Westphalia. In 2014, Forschungszentrum Jülich also received subsidies from the federal

and state governments (including changes in provisions) amounting to € 333.9 million to cover expenses (i.e. for day-to-day operation) and to finance fixed assets (i.e. for investments). These include € 69.6 million for dismantling projects.



# Bodies and Committees

Forschungszentrum Jülich was established on 11 December 1956 by the federal state of North Rhine-Westphalia. On 5 December 1967, it was converted into a GmbH (limited company) with the Federal Republic of Germany and the state of North Rhine-Westphalia assuming the role of shareholders. The task of the company is

- to pursue scientific and technical research and development at the interface between mankind, the environment, and technology,
- to undertake or participate in further national and international tasks in the field of basic and application-oriented research, especially precautionary research,
- to cooperate with science and industry in these fields of research and to communicate know-how to society as part of technology transfer.

## Bodies

The Partners' Meeting is the principal decision-making body of Forschungszentrum Jülich GmbH.

The Supervisory Board as a body supervises the lawfulness, expedience, and economic efficiency of the management board. It makes decisions on important research-related and financial issues of the company.

The Board of Directors conducts Forschungszentrum Jülich's business pursuant to the Articles of Association. It reports to the Supervisory Board.

## Councils

The Scientific and Technical Council (WTR) and the Scientific Advisory Council (WB) are committees of Forschungszentrum Jülich. WTR advises the Partners' Meeting, the Supervisory Board, and the management board on all issues associated with the strategic orientation of Forschungszentrum Jülich and on all scientific and technical issues of general importance.

The Scientific Advisory Council advises Forschungszentrum Jülich on all scientific and technical issues of general importance. This includes Jülich's strategy and the planning of research and development activities, promoting the optimal use of research facilities, and issues related to collaborations with universities and other research institutions.

The Scientific Advisory Council comprises members who are not employees of Forschungszentrum Jülich. The chairman of the Scientific Advisory Council is a member of the Supervisory Board.

## Partners' Meeting

The Partners' Meeting is chaired by the German federal government, represented by the Federal Ministry of Education and Research.

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## Supervisory Board

**MinDir Dr. Karl Eugen Huthmacher**  
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Federal Ministry of Education and Research

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Vice-Chairman  
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<sup>1)</sup> in accordance with Articles of Association

# Organization Chart

## Partners' Meeting

Partners: Federal Republic of Germany, represented by the Federal Ministry of Education and Research; North Rhine-Westphalia, represented by the Ministry of Innovation, Science and Research

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Prof. D. Willbold, Dr. A. Wischnewski (acting)

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Prof. U.-G. Meißner

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Prof. R. Waser

## IT Services

F. Bläsen



as of July 2015

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**Board of Directors**

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## Visitor Service

We organize guided tours of Forschungszentrum Jülich for interested groups. Please contact our Visitor Service for more information.

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As of July 2015



Since August 2010, Forschungszentrum Jülich has been certified as part of the "audit berufundfamilie" initiative. Jülich has thus committed itself to continuously defining and implementing measures for improving the reconciliation of work and family life.



Jülich's Annual Report 2014 won the Award of Excellence for layout in the 6<sup>th</sup> International Corporate Media Award competition.



## SEM Images

Scanning electron microscopy offers fascinating insights into the structure of crystals as well as metallic and ceramic materials. Scientists at the Institute of Energy and Climate Research – Materials Synthesis and Processing investigate and develop materials, parts, and components for highly efficient future energy conversion and storage systems.



Cover

### Offretite

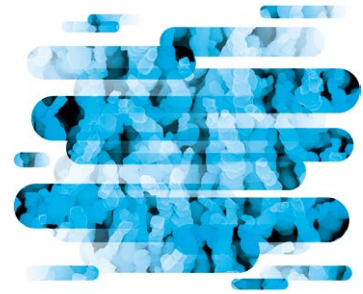
Offretite is a rare hexagonal mineral from the silicates and germanates class. Structurally, it is part of the zeolite family. Offretite develops small crystals of up to 3 millimetres length.



Page 11 | Research

### Clinochlore

Clinochlore is a common mineral from the silicates and germanates class. It develops mostly tabular to flaky or radiating crystals, but also massive aggregates.



Page 43 | Cooperations

### LSCF

Lanthanum strontium cobalt ferrite, a ceramic material of the ferrites group, is used as a material in fuel cells. It is manufactured by means of magnetron sputtering, a method for producing metallic layers.



Page 65 | People

### Nickel titanium powder

Powderized alloy with strong shape-retaining and superelastic properties, used in metal injection moulding to manufacture shape-memory parts.



Page 81 | Campus

### SrZrO<sub>3</sub>-ceramic powder

Ceramic layers, in the form of thermal barrier coatings, protect power plant gas turbines at high temperatures. The ceramic powder is produced by spray drying.

