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Cooperation between RWTH Aachen University and Forschungszentrum Jülich has a long tradition. For many years, our institutions have been involved in a lively scientific exchange and we have jointly appointed a large number of professors. Together with our scientists, however, we have come to the conclusion that we could exploit our potential much more than we have ever done in the past by going beyond these selective collaborations and creating a joint strategic plan. Only by working together will we succeed as a university and a national research centre in making significant contributions to solving the most pressing challenges facing society.

This was our motivation in August 2007 when we set up JARA – the Jülich Aachen Research Alliance.

In JARA, we successfully work on exciting and perhaps most importantly pioneering fields of research. Examples include sustainable energy supply, information technology, computer simulation with supercomputers, brain research and particle physics.

In terms of the education and training of excellent young scientists, we try to meet the needs of our students and early-career scientists with specialized courses of study and tailor-made funding programmes. We thus also take account of the special requirements of cutting-edge research in a global environment.

Building on our scientific and technical infrastructures, we have created an environment that allows scientists to be both creative and successful. This is reflected in the growing number of joint publications and acquired third-party funds.

JARA has already opened up new ways of cooperating for RWTH Aachen University and Forschungszentrum Jülich. We will continue to steer and expand on this collective course in the future. In doing so, we are firmly convinced that this “JARA course” will function as a paradigm for other institutions and that it will help us to overcome institutional hurdles that still exist between universities and non-university research institutions.

In the pages that follow, we will show you exactly what we do in JARA and why we do it.

We hope it makes for interesting reading!

Prof. Dr.-Ing. Ernst Schmachtenberg, Rector of RWTH Aachen University, and Prof. Dr. Achim Bachem, Chairman of the Board of Directors of Forschungszentrum Jülich.
The Alliance establishes a world-class scientific environment attractive to the very best scientists. It strengthens the position of both partners in the global competition for research opportunities, funding and research equipment. This allows the Alliance to pursue research projects that neither of the partners could successfully tackle alone. In doing so, it provides scientific and technical answers to the key challenges facing society.

In line with its brief, JARA currently focuses on five areas of research:
- translational brain research (JARA-BRAIN)
- sustainable energy (JARA-ENERGY)
- information technologies of the future (JARA-FIT)
- simulation sciences with supercomputers (JARA-HPC)
- particle physics and antimatter (JARA-FAME)

RWTH Aachen University and Forschungszentrum Jülich thus selectively combine research fields in which they can effectively complement their individual expertise. In this integrated partnership model, strategies for science policy are identified and coordinated. Together, research objectives are defined and investments made. The joint appointment process for professors and academic staff is also important: in the future, JARA professors will simultaneously head an institute in Aachen and Jülich. These professors will have full rights and access to resources at both institutions. However, it is not just the JARA professorships that allow the Alliance to offer internationally respected scientists even better research opportunities than RWTH Aachen University or Forschungszentrum Jülich could do alone; JARA has also established joint junior professorships and young investigators groups. JARA has a staff of about 4,000 and a budget of around € 350 million. In 2009, the investment volume was almost € 40 million.

Since RWTH Aachen University and Forschungszentrum Jülich signed the JARA agreement on 6 August 2007 creating a strategic partnership, the Alliance has been continuously expanded. Today, cooperation within JARA is not just limited to research in the four core areas, but rather also includes jointly operated scientific and technical infrastructures and new approaches in funding for young scientists. In order to ensure JARA’s success in the long term, the scientists play an integral role in the development process.
The Alliance will see Forschungszentrum Jülich and RWTH Aachen University working even more closely together in the future, thereby expanding their respective strengths to include those of the other partner. This means that RWTH Aachen University will be more programme oriented than in the past and that the institutes of Forschungszentrum Jülich will benefit from greater flexibility and more scope for independent research.

The Partners

RWTH Aachen University ...  

... is one of the leading universities in Europe with its 260 institutes in nine faculties. Currently, approximately 33,000 students are registered at Aachen for over 100 different courses. This number includes more than 5,200 foreign students. Within the framework of the Excellence Initiative, a total of three clusters of excellence, a graduate school and the institutional strategy entitled “RWTH Aachen 2020: Meeting Global Challenges” were approved for RWTH Aachen University, thus boosting the university’s competitive edge internationally. JARA is a key component of this institutional strategy.

Forschungszentrum Jülich ...  

... pursues cutting-edge interdisciplinary research on solving the grand challenges facing society in the fields of health, energy & environment, and information technology. In combination with the two key competencies — physics and supercomputing — work at Jülich concentrates both on long-term, fundamental and multidisciplinary contributions to science and technology, as well as on specific technological applications. With a staff of about 4,400, Jülich — a member of the Helmholtz Association — is one of the largest research centres in Europe.
It is true that RWTH Aachen University and Forschungszentrum Jülich have been successfully working together on and off for a very long time. In doing so, however, it has become clear to all of us, and particularly to the scientists, that working on individual projects prevents us from even coming close to tapping into the huge potential offered by Aachen and Jülich.

What do you mean?

Take the issues we address in JARA – in order to provide effective and decisive solutions, we must achieve a new level of quality in terms of cooperation. Society today is faced with massive challenges. How can we supply energy in the future in a climate-smart, secure and economic manner? How can we safeguard the quality of life in an ageing population? Such questions can only be answered in the long term provided that we address them strategically and work on them together. As one of the leading universities of technology and one of the largest research centres in Europe, we are aware of our responsibility and our potential. Together, we want to and we will actively shape the future. In JARA, we can do this better and easier than ever before.

What form does this “new quality” that you talk about actually take?

Excellent research is conducted by excellent scientists. In JARA, we pursue a joint strategy for the appointment of professors and we selectively pool our resources in order to attract the brightest minds in the world. This strategy has borne fruit, as demonstrated for example by the successful appointment of heads of young investigators groups, attracting individuals from internationally respected institutions such as Massachusetts Institute of Technology and ETH Zürich to Jülich. Another outstanding example is Prof. Dr. David DiVincenzo – prize winner of an Alexander von Humboldt professorship worth €3.5 million and one of the most cited theoretical physicists in the world – who has come from the USA to us here in Germany. He is the first JARA professor to be appointed and will head an institute in Aachen and Jülich simultaneously. This JARA professorship is much better equipped than a normal position as professor at Aachen or director at Jülich. It would have been more difficult for RWTH Aachen University or Forschungszentrum Jülich to attract Dr. DiVincenzo had they been acting alone.

Will RWTH Aachen University and Forschungszentrum Jülich amalgamate in the future as the University of Karlsruhe and Forschungszentrum Karlsruhe have done?

This is not an issue for us at the moment. There is no doubt that the Karlsruhe Institute of Technology, formed in a merger between the university and the research centre, is very successful. However, from the outset, our intention was to cooperate solely in complementary areas in order to combine our expertise in a targeted manner. And we continue to be convinced that we have chosen the correct route for us given the prevailing circumstances.

If you have ruled out the idea of an amalgamation to form one legal entity, then how do you organize and manage the Alliance?

For us, it is extremely important to continue to follow the “bottom-up” approach with which JARA was created. The scientists are closely involved in the steering and management of JARA through elected directors who function as their representatives. The directors develop joint strategies together with the Board of Directors at Jülich and the Rector at Aachen in the JARA Board of Scientific Directors, which also deliberates on personnel and investment decisions. Fun-
damental decisions are made jointly by the Board of Directors and the Rector for both institutions and are considered binding.

The JARA regulations, which apply equally to RWTH Aachen University and Forschungszentrum Jülich, ensure adequate clarity when it comes to the various processes. For example, there are regulations governing joint appointments of professors, a joint patent exploitation agreement and a coordinated press strategy. As a matter of principle, we have tried to keep the administrative effort to a minimum.

*Can the JARA model be transferred to other research institutions?*

I believe that JARA can function as a paradigm for other universities and research centres, and that we can thereby play a role in ensuring that the research opportunities offered by Germany can be fully exploited.
Innovative and Interdisciplinary

JARA would be inconceivable without excellent and dedicated young scientists. However, some training programmes required by the Alliance are not yet in place. This includes a course for the simulation scientist who must harness the performance of the supercomputer in the best and most efficient manner.
In order to train such experts, the German Research School for Simulation Sciences (GRS) has been set up, jointly financed by RWTH Aachen University and Forschungszentrum Jülich. GRS offers a specially developed master’s course in simulation sciences, as well as numerous research opportunities for PhD students. It has been equipped with special state-of-the-art facilities in Aachen and on the Jülich campus. Through GRS, young scientists have access to computers and imaging systems that are among the best in the world.

By implementing strategies such as the creation of four new junior professorships, for example, JARA-BRAIN is striving to establish another new profession, namely that of the “clinician scientist”. The clinician scientist is a doctor who works in a hospital but still has enough time both to conduct research and to train as a specialist. JARA-FIT has also created two new positions for junior professors. The young professors will focus on issues that interface with the established research topics at RWTH Aachen University and Forschungszentrum Jülich. In addressing these issues, they will make use of laboratories in Aachen and Jülich and will have teams at both institutions. In addition to all of this, JARA also has joint mentoring programmes for women, as well as dual career concepts, which aim to find a suitable position for the partner of a professor who has been appointed.

One of the characteristic features of JARA is that its scientists research in a strongly interdisciplinary manner. Adequately qualified young scientists are difficult to find, which is why the Alliance is involved in existing graduate colleges and schools or sets up its own. JARA-BRAIN and the University of Pennsylvania in the USA, for example, run an international research training group in which PhD students of various disciplines conduct research into scientific issues related to the mental disorders of schizophrenia and autism, and complete a tailor-made educational course in so doing. JARA-FIT is involved in two graduate schools set up by the German Research Foundation (DFG) focusing on the technical application of interfaces made from biological materials. Both sections have submitted applications for funding for further graduate schools. JARA-HPC cooperates closely with the AICES graduate school, while JARA-ENERGY has been integrated into a Helmholtz graduate school.

By teaching at RWTH Aachen University and offering students work placements, JARA scientists provide students with the opportunity to work on current research topics and study at state-of-the-art facilities. JARA is involved in international university courses and international exchange programmes. Last but not least, the Alliance also runs intensive courses – in the form of summer and winter schools – on specific areas of research.
The Jülich Aachen Research Alliance, which came into being in summer 2007, is still young. However, it has already become clear that the strategies and measures created within the partnership are taking effect.

The most important proof of scientific performance is furnished by publications: at the end of 2009, the number of publications co-authored by researchers from Aachen and Jülich had almost tripled compared to the number of such papers published before JARA was founded. Further proof that JARA has a positive impact can be seen in the number of professors teaching and researching at Aachen and Jülich: in 2006 – before JARA came into being – there were 11 such professors, who had been jointly appointed in line with a long tradition at RWTH Aachen University and Forschungszentrum Jülich. These professors usually headed an institute at either Jülich or Aachen. However, since the foundation of the Alliance, the number of professors jointly appointed has increased significantly, amounting to 28 in 2010. Today, the concept of

Young and Successful
What JARA has already achieved.

Prof. Dr. David P. DiVincenzo, internationally renowned physicist and Alexander von Humboldt Professor.
a JARA professorship has expanded this model and further intensified the links between RWTH Aachen University and Forschungszentrum Jülich.

Another important activity is the frequent organization of joint scientific conferences, such as the 1st International JARA-ENERGY Conference and the JARA-FIT Nanoelectronic Days. Such activities help JARA to make a name for itself in professional circles.

With its "seed funds", JARA supports projects in pioneering areas of research that are still in the initial start-up phase. This instrument has already proven to be effective: thanks to the initial funding, some of the projects were so successful that third parties – from Germany and abroad – stepped in and offered funding for further research activities. This facilitated the successful creation of Collaborative Research Centres and DFG research groups from the JARA seed fund projects.
JARA-BRAIN scientists investigate how neurons in various areas of the brain communicate with each other.
Every fifth European will suffer from a mental disorder at least once during their lifetime. Needless to say, this also has immense financial consequences for state health care systems and national economies. A projection to the year 2030 made by the World Health Organization (WHO) Global Burden of Disease confirms this. All of this makes neurological and mental disorders one of the central challenges facing society in the 21st century—a challenge that scientists are addressing in JARA-BRAIN. They are developing new strategies for diagnosing, treating and preventing such disorders.

"In order to overcome the clinical challenges, we need a better understanding of the structure and function of the brain in both healthy and ill individuals," says Prof. Dr. Karl Zilles from the Institute of Neuroscience and Medicine at Forschungszentrum Jülich, one of the two JARA-BRAIN directors. The scientists conduct research, for example, on the type of communication that occurs between the neurons and the synapses in different areas of the human "control centre". They are particularly interested in the cerebral cortex, which is important for many emotional and cognitive processes. According to Zilles: "A single institute alone would never be able to conduct the complex research work required."

JARA-BRAIN combines the strengths of Forschungszentrum Jülich—the development and application of advanced high-tech equipment and experience in interdisciplinary research—with the expertise of University Hospital Aachen, one of the leading and largest European university hospitals in the areas of psychiatry, neurology and neuropsychology. "In JARA-BRAIN, we cover the entire spectrum of expertise, from basic research right up to clinical applications," emphasizes JARA-BRAIN director Prof. Dr. Dr. Frank Schneider from the Department of Psychiatry, Psychotherapy and Psychosomatics at Aachen University Hospital. Findings from the research laboratory can therefore be applied almost immediately in the hospital in order to prevent and treat illnesses—and observations of patients can be fed back into basic scientific research without delay. According to Schneider, "this guarantees an effective transfer between research and practical application, which benefits the patient."

The JARA-BRAIN scientists, who come from about 25 departments and institutes of RWTH Aachen University and Forschungszentrum Jülich, are particularly interested in research on developmental disorders in children and adolescents as typical examples of illnesses occurring early in life, as well as schizophrenia, a disorder that appears in middle age. They also focus on neurodegenerative diseases which tend to occur in old age, such as Alzheimer’s, Parkinson’s and dementia.
You conducted research in the USA before you came to JARA-BRAIN. What convinced you to accept the appointment in Germany?

Two things were decisive: the unique interdisciplinary research environment at RWTH Aachen University and Forschungszentrum Jülich, and the model of the “clinician scientist” that has been implemented here. JARA-BRAIN gives me the opportunity to combine hospital and research work with each other in an ideal manner. As a young clinician scientist, I can thus continue my professional training in the form of residency, I can develop areas of clinical expertise – for example, specialist consultation – and I can conduct scientific research. And I
can do all of this in parallel. By working part-time at the hospital and part-time in research, both activities are closely intertwined.

How does your work at University Hospital Aachen profit from cooperation with Jülich?

My area of scientific interest lies in neurodegenerative diseases. My working group and I, for example, explore the changes in the structures and functions of the brain brought about by Parkinson’s, Huntington’s and Alzheimer’s diseases. The early stages of these diseases, before the first symptoms emerge, are particularly interesting. To study these changes, we use imaging techniques such as magnetic resonance imaging (MRI). Here, we cooperate closely with the Jülich group headed by Prof. Dr. Jon Shah. We apply different techniques including innovative MRI methods, such as the measurement of sodium and water contents.

We are currently planning tests in particularly strong magnetic fields with high-field magnetic resonance imaging scanners.

Where do you see yourself going in terms of your career?

Obviously, I hope that I will be able to consolidate and expand my young working group. I also want to achieve my goal of transferring innovative methods, particularly those for the early diagnosis of neurodegenerative diseases, to the hospital. Beyond this, I hope that the dual concept of the “clinician scientist” continues to be viewed as a positive development and that it is implemented in practice.
The human hunger for electricity will continue to grow – ensuring that it can be met in an economic and simultaneously climate-smart manner is the focus of the work of JARA-ENERGY researchers.
The 2,200 employees working at almost 50 institutes within JARA-ENERGY are united by the objective of securing the energy supply and mobility in the future in an economic way and of protecting the environment and safeguarding the climate in doing so. "We work on a large number of the fields of action defined in the German Government’s Energy Concept," says Prof. Dr. Dirk Bosbach of Forschungszentrum Jülich, one of the two directors of JARA-ENERGY. The scientists are working on improving fossil power plant technology, while simultaneously investigating renewable energy sources as well as looking at nuclear and electrochemical energy technologies. “In the future, we will continue to satisfy our energy demand from a variety of sources. In other words, we will have an energy mix,” says Bosbach.

However, the researchers do not limit themselves to the areas of “energy carriers” and “energy conversion” — or to put it more directly, to the search for alternative ways of generating electricity in an even more climate-smart manner than is currently the case. They are also working on low-loss techniques for transporting and storing energy and on energy technologies for cars and other mobile applications. All in all, they focus on overarching interdisciplinary topics. One example involves investigating new materials, on which progress in energy technology often depends.

Another example is systems analysis, which looks at the availability of technological developments in energy systems and assesses the associated risks and opportunities, before classifying the findings in the context of society as a whole.
JARA-ENERGY pools the corresponding competencies of energy researchers at Aachen and Jülich. "We are trying to find economically efficient solutions in close cooperation with industry and we are sought-after consultants for associations and politicians," says Prof. Dr. Reinhard Madlener of RWTH Aachen University, JARA-ENERGY director. The researchers' expertise encompasses basic research as well as its application in end products, spanning the entire value chain.

JARA-ENERGY is younger than the other three JARA sections. Despite this, the fusion of energy researchers from Aachen and Jülich has already facilitated pioneering decisions. In Jülich, for example, a new sub-institute will be set up to conduct research on fundamental electrochemical principles for new or improved batteries. Its director will simultaneously be appointed professor at RWTH Aachen University. This will allow the two institutions to strategically expand an area of research that is extremely important for society as a whole and indeed for Germany as a beacon of research: high-performance batteries are considered key components for future electric cars. Batteries could also be used as storage systems in decentralized energy networks, for example, in order to counteract fluctuations in electricity production caused by wind and solar installations. "We will define even more priority topics in the future but we will also continue to structure our research in a broad-based manner. After all, no single mega-project is capable of solving all of the energy problems," emphasizes Bosbach.

One element of science management that JARA-ENERGY, and indeed the other JARA sections, has successfully implemented is financial support for pioneering projects that are still in the initial start-up phase. For example, in one of the projects funded through the "seed fund", scientists are investigating the potential associated with developing a turbine blade for temperatures above 1,400 °C using a certain combination of ceramic materials. Such a turbine blade would improve the efficiency of converting the fuel in gas power plants to electric current and si-
multaneously ensure that less carbon dioxide is released into the atmosphere. In order to test the feasibility of the materials concept, the interdisciplinary expertise of two Aachen institutions – the Chair for Textile Machinery and the Chair and Department of Mineral Engineering – and of the Jülich Institute of Energy and Climate Research are essential.

In another seed fund project, scientists aim to use quantum chemical methods to determine the characteristics of ceramic membranes that could be used to capture carbon dioxide in conventional power plants. While the Jülich scientists involved in the project have years of experience in characterizing the thermochemical and thermomechanical properties of materials, the Chair of Materials Chemistry at RWTH Aachen University boasts proven expertise in quantum chemical calculations. The scientific know-how at Aachen and Jülich, each complementing the other, is once again the driving force behind this research.
Exloring Elementary Building Blocks and Forces

It is one of the world’s greatest mysteries: where did the antimatter go that was present in the beginning of the universe? According to our present physical knowledge, equal quantities of antimatter and matter should have been created with the Big Bang. Researchers in the JARA-FAME section intend to bring to light the fate of the antimatter with the help of ingenious experiments.

Antimatter is, broadly speaking, the mirror image of matter. Hydrogen is the simplest chemical element in the universe and consists of a positively charged proton and a negatively charged electron. In antihydrogen, in contrast, the building blocks have opposite charge. It is made up of a negatively charged antiproton and a positively charged antielectron, often referred to as a positron. Antihydrogen was first produced in 1995 in the particle accelerator at CERN in Switzerland – thanks to Prof. Walter Oelert’s team from Forschungszentrum Jülich.

If one of the fundamental principles of physics – namely symmetry – were always to apply, then there should be exactly as much matter as antimatter. However, our world consists only of matter. Does that mean that somewhere in the universe, there are areas that are composed solely of antimatter? The alpha magnetic spectrometer (AMS) on the International Space Station (ISS) will be looking for an answer to this question until at least 2020. The AMS could be used, for example, to detect anticarbon nuclei in space that could only originate from antimatter stars. The AMS can also identify simple antiparticles that form today, for example when particles of matter collide.

Researchers at RWTH Aachen University were involved in the construction of the AMS. The data supplied by the AMS are stored at the Jülich Supercomputing Centre (JSC). “In the JARA-FAME section, we bring together expertise from Aachen and Jülich for processing, analysing, and understanding AMS data,” says Prof. Achim Stahl. The physicist at RWTH Aachen University is one of the two directors of the FAME section – the acronym stands for “Forces and Matter Experiments.”
However, it is quite possible that all the antimatter created when the universe was born has been annihilated. This would mean that the symmetry principles have been violated even more than postulated by the Standard Model of particle physics. "An indication of this would be the presence of a permanent electric dipole moment in protons and other elementary particles," says Prof. Rudolf Maier from Forschungszentrum Jülich, the other JARA-FAME director. In other words, the centres of the negative and positive charges in the elementary particles do not coincide.

"The JEDI and AMS research projects are the pillars of JARA-FAME," says Maier, and his colleague Stahl adds, "In addition, the section, to which Jülich and Aachen contribute their perfectly complementary expertise, is characterized by the three cross-cutting tasks of theory, data processing, and detector development."

Prof. Dr. Rudolf Maier, Prof. Dr. Achim Stahl, directors JARA-FAME

In the JEDI project (Jülich Electric Dipole Moment Investigations), JARA-FAME scientists are aiming to find this dipole moment. They are preparing a complex experiment and extremely precise measurements (see interview with Prof. Jörg Pretz on the next page).

"The JEDI and AMS research projects are the pillars of JARA-FAME," says Maier, and his colleague Stahl adds, "In addition, the section, to which Jülich and Aachen contribute their perfectly complementary expertise, is characterized by the three cross-cutting tasks of theory, data processing, and detector development."
What’s the attraction of your research?

For a long time, I wanted to know what the smallest building blocks of things are. Of course, when you start thinking about this question, you’ll end up with protons and neutrons in the atomic nucleus and the fascinating question of what is inside them. Now, I can investigate one aspect of this question in an experiment that will measure one internal property of the proton very precisely. The added extra associated with this experiment is that it may also explain why the world consists of matter while the antimatter has disappeared.

In the JEDI project, you are planning to measure whether the positive and negative charges in the proton have different centres. How?

In principle, the experiment is very simple. The proton is exposed to an electric field. If in the proton, the centres of negative and positive charge do not coincide, then the proton’s quantum mechanical angular momentum, known as the spin, changes in this electrical field. However, measuring this effect is anything but easy, particularly because it’s so minuscule. After all, protons are only about a trillionth of a millimetre in size – and if dipoles exist inside them, the distance between the centres of charges is several orders of magnitude smaller.

Would it be possible to implement the JEDI project without the Jülich Aachen Research Alliance?
Here I can only speculate. In order to perform this kind of experiment, there’s no doubt that for the initial steps in the right direction, Jülich’s particle accelerator COSY offers the best conditions worldwide. It’s also clear that numerous technical problems must be solved, and this is where the expertise of RWTH Aachen University’s engineers is very helpful. In addition, my job wouldn’t exist without the cooperation between RWTH Aachen University and Forschungszentrum Jülich. I was appointed jointly by the two institutions. I teach at RWTH Aachen University, where changes in the German school system mean record numbers of students, and I conduct research for JEDI primarily at Jülich.

Where do you see your research in five years?

By then, we hope to have modified the COSY particle accelerator accordingly and to have made reliable measurements. However, it’s unlikely that they will be accurate enough to say anything about the matter-antimatter problem. But in five years’ time, we hope to have gathered enough experience to be able to construct a special accelerator ring in which we will be able to perform the final experiment.

Are you making good progress at the moment?

I have only been with JARA for a few months, but the JEDI project has already picked up pace. I’m very happy with the dynamics.
Developing the Information Technology of the Future

According to the iD2010 Action Programme by the Federal Government, information and communication technologies (ICTs) “play a key role in our progressively knowledge-oriented economy and, as such, they act as a catalyst for growth in many other sectors”. The report continues: “Roughly 40% of current macroeconomic growth stems from ICT use.”

In the past, Moore’s Law reigned, whereby the number of transistors on a microchip roughly doubled almost every two years at no additional cost. Yet the very person who devised the law in 1965 – Gordon Moore, co-founder of Intel – was already convinced in 2007 that in ten to fifteen years at the most, the performance of today’s computers will plateau at a point determined by the speed of light and the atomic structure of matter. The scientists involved in JARA-FIT (Fundamentals of Future Information Technology) hope to push this limit for conventional silicon technology even farther into the future by designing new chip architectures and increasing the mobility of charge carriers. “We also pursue other concepts based on alternative technologies in an attempt to create more powerful energy-efficient hardware,” says Prof. Dr. Detlev Grützmacher of Forschungszentrum Jülich, one of the two directors of JARA-FIT. The scientists are thus developing new materials and blueprints for nanocircuits, non-volatile memories, and spintronics. They are also investigating how biomolecules and quantum effects can be used for information processing.

“Industry is not interested in pursuing long-term alternatives to the established technologies. Options such as quantum computing are still too far away to meet the real technical requirements of a
product,” says Prof. Dr. Markus Morgenstern of RWTH Aachen University. The JARA-FIT director continues: “One of the unique things about us is that we pursue this basic research, while also participating in projects aiming to meet the current needs of industry.”

A certain number of qualified scientists working in the same area is a prerequisite for certain research projects and also in order to acquire funding. “We have achieved this critical mass – to use a term from physics – through the Alliance,” says Morgenstern. Grützmacher continues: “The issues in information technology are very complex and interdisciplinary. To secure a leading position internationally in this research area, you need enormous resources.” This is where JARA-FIT has the upper hand: around 350 physicists, chemists, electrical engineers, mechanical engineers and biologists from approximately 20 institutes and departments at RWTH Aachen University and Forschungszentrum Jülich work together. These researchers have long played a leading international role, as was confirmed not least when the Nobel Prize for Physics went to Professor Peter Grünberg in 2007.

Scanning tunnelling micrograph of graphene – a very promising material for the computer technology of the future.
“Real Added Value”

Interview with Prof. Dr. Christoph Stampfer, JARA-FIT
What’s your research all about?

We are developing components for the information technology of the future, the function of which is based on selective manipulation of individual electrons. These components comprise carbon materials, such as graphene, measuring only a few nanometres – in other words millionths of a millimetre. What drives us in our research is taking quantum mechanics with its theoretical roots in the 20th century and putting it to use in engineering in the 21st century. The historical parallels are there, for example, with electrodynamics. It emerged in the 19th century but was first applied in the 20th century – we need only think of the electric motor, the television or mobile phones.

What advantages does JARA have for you?

We need the strong technology infrastructure of Forschungszentrum Jülich and use a clean room there in order to fabricate our single-electron devices. The labour-intensive measurements on the chips are then conducted in Aachen, as they are ideal for introducing undergraduates and postgraduates to this area of research. The two PhD students and four undergraduates on my team currently work two to four days per week at Jülich and one to three days at Aachen. Without access to Forschungszentrum Jülich, my research would simply be impossible, just as it would if I could not work at Aachen: JARA brings me real added value.

You are originally from Italy, you studied in Austria and Scotland, and you conducted research at ETH Zürich, which has an excellent international reputation. What impression did you develop of JARA during your first year here?

I was surprised how quickly I could start working here. Everyone assisted and supported me and made everything easy for me. The bureaucracy has also been kept to a minimum. The scientific work and the opportunities open to me here are very similar to those at ETH Zürich. I have always enjoyed working together with other scientists and this played a key part in my decision to come to JARA. Needless to say, I required some time to make scientific contacts at both locations but a number of collaborations are now up and running.

Prof. Christoph Stampfer, JARA-FIT junior professor
Simulations have become the third pillar of research alongside theory and experiment, providing us with insights that had long remained concealed for physical, technical or financial reasons.
Almost all areas of science benefit from them, including medicine, information technology, materials science and engineering, as well as environmental and energy research. For example, JARA researchers have used simulations to improve blood pumps that assist the hearts of critically ill patients, and they have created a “virtual brain” to help brain researchers explore the relationships of the real brain in more detail and improve their understanding of how the human brain works. Other scientists have calculated unusual magnetic and electronic properties of materials and thus gained information that helped them to construct novel electronic devices and data storage systems. Last but not least, JARA researchers have developed computer simulations that can be used to predict how human activities and measures will impact on the species richness in meadows and pastures in the Eifel National Park. These simulations can be integrated into decision support systems for agricultural management.

“Many simulations, however, require massive computing power,” says Prof. Dr. Wolfgang Schröder. The head of the Institute of Aerodynamics at RWTH Aachen University continues: “The need for computing power will never reach a limit.” Aircraft turbines are a good example: some of the components in these turbines — such as the combustion chamber — can already be simulated quite well today using computers, “but even the most powerful computers in the world today still cannot develop and optimally design an entire aircraft engine,” says Schröder, who is also one of the directors of JARA-HPC. HPC here stands for high-performance computing.

Scientific progress requires more than just faster and more powerful computers. “Physical modelling must be simultaneously improved,” says Schröder. He uses a comparison to explain why this is so: “After all, what good would it do to develop a racing car capable of reaching speeds of 320 km per hour if it can only be equipped with tyres capable of withstanding speeds of 260 km per hour?”
And it has indeed become clear in the last few years that application software in computer-assisted research areas is trailing far behind the hardware developments for supercomputers. The JARA-HPC experts want to change this. "We combine specialized research with the methods required for massively parallel computing on supercomputers," says Prof. Dr. Dr. Thomas Lippert. The second JARA-HPC director and head of the Jülich Supercomputing Centre (JSC) continues: "For this purpose, we have created a new and unique organizational structure."

Part of this structure includes simulation laboratories (SimLabs), which are currently being set up. These comprise teams with specialized knowledge who, on the one hand, are familiar with the latest research questions of simulation users and who speak the same language, and on the other hand, who know how to operate and efficiently use a supercomputer. Each SimLab will be headed by an expert in the corresponding field – for example, "Highly Scalable Fluids & Solids Engineering" will be headed by an engineer, while a theoretical chemist or physicist will be responsible for "Ab Initio Methods in Chemistry and Physics" and a neuroscientist will head the "Neuroscience" SimLab. "Eight to ten people will make up one SimLab," says Lippert. The SimLabs will develop and refine codes and software for the corresponding specialized simulation applications.

Scientists look at a computer simulation of a blood pump which can support the heart of seriously ill patients.
JARA-HPC also has another new organizational form in addition to the SimLabs: cross-sectional groups. These teams comprise mathematicians and computer scientists whose methodological know-how benefits all users of high-performance computers and supercomputers. The cross-sectional group for "Parallel Efficiency", for example, develops algorithms and tools to analyse and improve the performance of parallel programs. SimLabs and cross-sectional groups work very closely together. "This means that we are optimally equipped to deal with issues in interdisciplinary research and to provide solutions using supercomputers in relatively short periods of time," says Schröder.

The fact that JARA-HPC is reprioritizing to concentrate on simulations that require supercomputers clearly shows how the Alliance functions as a whole. As Lippert puts it: "JARA is not a rigid institution. It is a process that continuously creates new things and through which we constantly improve."
Excellent research requires excellent scientists and an outstanding scientific infrastructure. Researchers must have access to state-of-the-art equipment in order to fabricate and analyse materials and devices. They require powerful computers to run theoretical calculations and to evaluate experimental results. They need the support and assistance of specialized workshops and technological departments to improve existing research instruments and develop new ones. They must be able to access databases and scientific publications to learn about the work of competing scientists. By forming an alliance, RWTH Aachen University and Forschungszentrum Jülich have increased their potential to expand and consolidate their scientific infrastructure.

A prime example is the Ernst Ruska Centre (ER-C): together, Forschungszentrum Jülich and RWTH Aachen University operate a centre of excellence for ultrahigh-resolution electron microscopy and spectroscopy of the highest international level. The scientific instruments used for imaging in ER-C provide us with insights into the atomic world that are indispensable for developing new combinations of materials and components for nanoelectronics and energy technologies. After all, the interplay of single atoms determines the properties of materials and components. This makes ER-C particularly important for researchers in JARA-FIT and JARA-ENERGY.

ER-C is also the first national user centre for ultrahigh-resolution electron microscopy open to scientists in research and industry that allows them to use the most powerful electron microscopes of our time in their work. In terms of user operation, ER-C offers top of the range electro-optical instruments and set-ups for sample preparation and preliminary tests on electron microscopic speci-
men, as well as comprehensive assistance in analysing measurement data. Specialized expert knowledge and experience are essential to generate usable results with ultrahigh-resolution electron microscopes.

Under the umbrella of JARA, RWTH Aachen University and Forschungszentrum Jülich also operate a Centre of Excellence in Joining Technologies. Joining technology is a key technology which exerts decisive influence on the development and production of almost all technical products. It comprises processes such as welding, soldering, bonding and mechanical joining. It is used, for example, to fabricate devices for research or to permanently join materials for energy technology. The collaborative use of personnel and equipment has led to the emergence of an expertise in joining technology that is unique in Europe.

Researchers in JARA-FIT will benefit to a large extent from the Helmholtz Nano-electronic Facility (HNF). This state-of-the-art clean room centre, which is currently being built by the Helmholtz Association, is due to be completed on the campus of Forschungszentrum Jülich by 2013. The industry-standard range of instruments alone will cost €15 million and will include facilities for illumination, cleaning, ion-beam processing, and the testing of wafers – the base plates in electronic devices – as well as an epitaxy and nanofabrication cluster that will be used to fabricate and analyse tiny structures on man-made crystals. HNF thus provides JARA scientists with an excellent basis to develop the computer technologies of tomorrow.

This electron micrograph shows how the position of oxygen ions in a material changes when information is written to the material.
State Secretary, you were there when JARA was set up in 2007. Back then you said the following: “JARA shows that a completely new type of cooperation is possible between universities and non-university research institutions. The rest of Germany should learn from this. Such a move does not just benefit research, but also the education of scientists.” Have your expectations been fulfilled?

My personal impression is that the JARA activities have intensified considerably this year in particular. Of course, during the early phases after the official announcement, the necessary organizational prerequisites first had to be created. Today, solid structures are in place, the mandatory coordination bodies have been established, and a series of W3-grade and junior professors have been appointed. A few weeks ago, Dr. David DiVincenzo, an Alexander von Humboldt award winner, was appointed as the first JARA professor. Five areas of cooperation have been defined – research, education, facilities, innovation and services – whereby the content of the work concentrates on the four JARA sections: BRAIN, ENERGY, FIT and HPC. The latter section in particular, namely high-performance computing, has seen the creation of a new model for training young experts in the simulation sciences in the form of the German Research School for Simulation Science.

What makes this cooperation between a university and a large research institution so special in your opinion?

The new element is a strategic one: previous collaborations tended to focus on individual activities and were mainly driven by researchers working together. JARA, in contrast, creates a joint structure for planning and making decisions. This new cooperation has a much broader base and is designed to last in the long term. It also aims to take up other pioneering and promising fields in the future. However, it also necessitates intensive coordination between all of those involved in the various sections, as the universities are free to choose their research topics, while the centres in the Helmholtz Association have organized their research into six research areas within the framework of programme-oriented funding with a corresponding number of research programmes.

Should more universities cooperate with large research facilities?

Such strategic alliances between universities and non-university research institutions will be part of the future in Germany. JARA is one way of linking two science segments that were more or less strictly separated in the past and thereby building a bridge between universities and research establishments. Such cooperation guarantees that synergies are exploited on a broad basis and that the new generation of scientists have access – more so than in the past – to an optimal research infrastructure. For the German Federal Ministry of Education and Research, this is incredibly important in terms of research policy as it represents a decisive step towards securing Germany’s reputation as a beacon of science and research.

In addition to the JARA cooperation and the model of the Karlsruhe Institute of Technology, the Helmholtz Institutes are another method of establishing closer cooperation structures between a university and a non-university research institution. These Institutes were set up last year in Mainz, Jena and Saarbrücken.

Why are large collaboration efforts such as those in JARA so rare?

The answer can be found in the basic structure of this model. First of all, professional relationships are established between the institutes of a large research centre and a university through collaborative work on research projects. Then, the scientists involved agree to consolidate and further intensify cooperation. This is a classic bottom-up model. Forschungszentrum Jülich and RWTH Aachen University have successfully cooperated for many years in certain disciplines – for example, in neuroscience or on the de-
development of new information technologies. In short, the optimal prerequisites were already in place in the region here, and this is also exactly what makes it difficult to repeat the success of JARA in other regions.

How can politics sustain and simplify further collaborations in the future?

Collaborations such as JARA testify to the success of the Excellence Initiative launched by the German federal government. From BMBF’s point of view, this initiative has met the expectations placed on it: it sets the pace in the German research community and provides motivation for our universities to strategically consolidate their research potential with an eye to the future. It has encouraged the players in the research scene to network even more closely and, in doing so, they have improved the innovation capacity of our nation. And finally, it has increased the international visibility of our universities and research institutions, and has thus improved our hand in the international competition – not just in terms of attracting the best minds. Last year, we concluded an excellence agreement (Exzellenzvereinbarung II) with the federal states, which regulates the provision of additional funds for graduate schools, clusters of excellence and institutional strategies for the expansion of top-class university research between 2011 and 2017. The German federal government will provide 75% of these funds, while 25% will come from the respective federal state. It is important not to forget that JARA itself is a model that originated from the Aachen institutional strategy, which was granted funding within the scope of the first Excellence Initiative.

What is so special about the role that is played by research in our society? Tax payers are not always aware of what happens to their money.

Knowledge and innovation are the factors that decide whether we can deal with the challenges of the future. Just think of the megatopics of mobility, renewable energies or research on age-related diseases like dementia or Alzheimer’s. And if this really is the case, then we must put the knowledge and know-how that we have acquired with large amounts of money to even better use in society than we have done so in the past. It is no longer enough to simply publish research findings in high-impact journals or with respected publishers. We have to think about how we can provide society and politics with better access to research findings today. We have a responsibility to transfer the results – a responsibility that we are still only beginning to address. We need the great good of scientific neutrality with all of its insights in order to solve the key challenges of the future.

State Secretary, where do you see JARA 10 years from now?

From a research and university policy point of view, I would like to see JARA establish itself as such a successful model that it will go on to be used as a blueprint for other collaborations.