University of Stuttgart
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EUROPE IN FOCUS

FORSCHUNG LEBEN

THE MAGAZINE OF THE UNIVERSITY OF STUTTGART

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Dear Readers,

Photo: Uli Regenscheit

Euroscepticism, refugee debate, Brexit – probably no institution has been called more into question over the past few years as the European Union. At the same time, the dream of a united Europe is associated, like no other, with values such as freedom, humanism and tolerance.

This vision is exemplified by the European research environment, already today a guarantor for the unfettered exchange of people and knowledge, to which many researchers at the University of Stuttgart also contribute in accordance with the maxim "internationally involved and interconnected", one of the key strategic objectives anchored in our mission statement.

"Horizon 2020", the EU framework programme for research and innovation, is an important cornerstone in this context, in relation to which the University of Stuttgart is one of the most successful universities. In which subject areas is research being conducted at the University of Stuttgart in the context of EU projects? What positive developments are inspired by the multi-cultural environment and what are the challenges? And, can collaborative research really contribute to the concept of a united Europe?

All of these questions are addressed in the current issue of "FORSCHUNG LEBEN", our university magazine. In his guest article, no less a figure than EU Commissioner Günther Oettinger explains how to make the most of the European research environment. You'll also read how, together, European research institutes and companies are advancing laser-based technologies and what role Parma ham plays in this context. Join us in asking whether lobby groups actually represent the interests of the public. And, read up on the future of quantum technologies or a European balloon-based observatory in outer space.

"Cross-border research activities bring together the strengths of different cultures and locations, which is why internationalisation is one of the University of Stuttgart's strategic objectives".

Wolfram Ressel
Rector of the University of Stuttgart

Have an inspiring journey into the European research environment!

RESEARCH AND LIFE

FORSCHUNG LEBEN 10. 2018

... Heard in Passing

Information Offensive In Hanover

Once again the University of Stuttgart has nailed its colours to the mast at the "Research & Technology" exhibition, the main trade fair at the Hannover Messe, where, as co-exhibitors at the "Baden-Württemberg Communal Booth", which is organised by Baden-Württemberg International (bw-i), we presented examples from our major research projects to an international public. Showcasing state-of-the-art material-efficient construction and process technology, the exhibition booth, whose lightweight carbon-fibre-reinforced structure was continuously expanded by a KUKA robot as visitors looked on, was itself one of the highlights. On show within the booth were, among other things, a bio-inspired robotic model of a human leg moved by artificial muscles, the prototype for a quantum magnetometer and an autonomous self-propelled bicycle. Other visitors to the stand included Minister of Research Anja Karliczek, the Baden-Württemberg ministers Winfried Hermann (Transport) and Dr. Nicole Hoffmeister-Kraut (Economic Affairs) and other VIP guests.

Photo: University of Stuttgart

Lightweight Structure from Stuttgart at BUGA 2019 in Heilbronn

Two globally unique pavilions will be on display at the Bundesgartenschau (Federal German Horticultural Show - BUGA) 2019 in Heilbronn. They will be erected by two of the University of Stuttgart's institutes, the Institute for Computational Design (ICD, Professor Achim Menges) and the Institute of Building Structures and Structural Design (itke, Professor Jan Knippers). A special feature of these highly innovative lightweight structures, each of which spans 500 m^2, is that they

Images: BUGA

were planned and manufactured entirely by digital means. One of the pavilions is a bionic fibre structure, whose load-bearing frame is comprised entirely of fibre composite components, whose individual structures are made of glass and carbon fibres in a robotic production process, which makes it possible to adapt the geometry and fibre composition of each of the 60 individual components to the respective specific requirements.

The segments of the other pavilion, a bionic timber-frame structure, are initially engineered in the form of hollow coffers assembled from plates and beams in a robotic pre-production process. The wooden pavilion will be made up of 400 of these coffers and will overarch a 25-metre-wide exhibition space with ample room to spare.

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International Drop-In Centre

The University of Stuttgart's new Welcome Center is a service point that deals with the issues of international researchers. It can provide assistance in overcoming language or cultural barriers, dealing with the authorities, organising German courses for accompanying family members or finding day-care centres or schools.

Photo: Uli Regenscheit

Joint heads of the new Center are Maja Heidenreich and Raphaela Diel, who emphasise the fact that they "want to support international researchers before and upon their arrival, during their stay and later as alumni". In addition to providing help and advice in relation to administrative issues, both want to introduce international researchers to German life and culture as well as to life on campus and in Stuttgart. A whole raft of events are planned where people can meet and exchange ideas. For example, a tour of the Daimler production facility in Sindelfingen has already taken place. Addressing this target group in particular will help the University of Stuttgart to enhance its ability to cater for the international dimension, already a practical reality in the areas of study, teaching, and research.

Excellence I: Four Proposals

The University of Stuttgart delivered four weighty packages to the German Research Association (DFG) in time for the deadline on the 21st of February 2018: the proposals for the Cluster of Excellence for which the university is allowed to submit a tender proposal in the context of the strategy of excellence adopted by federal and state governments with a view to boosting cutting-edge research in Germany. Included in the package was the binding Letter of Intent to the effect that the university of Stuttgart will also be submitting a further proposal in December under the new "University of Excellence" funding programme. Thematically, the four cluster proposals highlight the University of Stuttgart expertise in key research areas all subsumed within a single programme under the motto "intelligent systems for a sustainable society".

Excellence II: International Conference Simulation Technology

In March this year, some 200 simulation experts from around the globe congregated at the University of Stuttgart to take part in the "2nd International Conference on Simulation Technology" (SimTech 2018). Attended by delegates of the highest calibre, the University of Stuttgart's Cluster of Excellence for Simulation Technology (SimTech) used the conference to create an international platform where recent advances in the field of simulation technology could be presented and current research projects discussed. The topics touched upon in the keynote speeches ranged from computational engineering to physical simulation to dealing with simulations in the political sphere.

Excellence III: 10-Year Milestone for the GSaME

The Graduate School of Excellence advanced Manufacturing Engineering (GSaME) presented an overview of the latest research findings in the field of intelligent production and manufacturing technologies at the 2018 annual conference in April under the heading "Integration, Agility, Efficiency – Key Factors in Sustainable Production". The GSaME summarised the overall situation following a decade of funding under the Excellence Initiative, presented its results in terms of research, and the promotion of early career researchers, and outlined its perspectives for the future.

Mobility and Production the Day After Tomorrow (überMORGEN)

About a year after relocating to the modern building complex and five years after its foundation, the ARENA2036 research factory presented its research results to date as well as its vision for the future at the two-day "überMORGEN" in February.

EU Commissioner Günther Oettinger was joined in a panel discussion by the Prime Minister of Baden-Württemberg Winfried Kretschmann, the

Photo: Max Kovalenko

Rector of the University of Stuttgart Professor Wolfram Ressel and Dr. Dieter Zetsche, Chairman of the Board at Daimler AG and others to explore the challenges facing the automotive industry of today, tomorrow and the day after tomorrow. Visitors were also given an insight into the four research areas: Production2036, Work2036, Mobility2036 and Digitalisation2036. On the second day, the research factory opened its doors to the general public.

Research at ARENA2036 is focused on lightweight construction and innovative production technologies and its researchers develop components based on fibre reinforced plastic. They also use metallic materials characterised by their low weight properties. Noise and thermal insulation as well as thermal, sensory and electrical wiring integrated within the materials result in further weight and cost savings.

Socio-Political Worldview

The University of Stuttgart's High-Performance Computing Center (HLRS) is home to one of Europe's most powerful super computers. Every day, researchers there investigate such things as the correct shape for a chassis to make it as energy-efficient as possible, how the climate is changing or how medical therapies could be optimised. Yet, until now, much of their findings have only been available to experts.

The HLRS founded a Public Advisory Board in April 2018 to enable more sectors of society to benefit from the use of simulations going forward. Its members are drawn from various industrial sectors such as nursing and care, architecture, education and journalism. Its current Chairman is Professor Ortwin Renn, Scientific Director at the Institute for Advanced Sustainability Studies in Potsdam. The committee's tasks are to point out potential areas in which computer simulations could make a socio-political contribution, to ensure that developments in the field are consistent with ethical values and social preferences, and to raise research questions for future research projects.

"Make the most of the European research environment"

Well educated, motivated young people are Europe's future. We must encourage and build upon their talents.

Europe must become even more innovative than it already is. An important prerequisite for this is to make the most of the European research environment, for example, by enabling researchers and highly-qualified personnel to work and carry out research throughout the EU. In his guest article for FORSCHUNG LEBEN, EU Commissioner Günther Oettinger explains what can be done in the political sphere to ensure that the public not only understands the merits of science and innovation, but also that it benefits the whole of society.

Science, along with innovation, shapes almost all areas of our lives. Science and innovation create new and improved products and services, leading to jobs and investment opportunities. The results of science provide also the foundations for evidence-based policy-making to tackle the big challenges such as health, climate change, sustainable energy, human migration, social integration, and last but not least the digital economy.

Because of that, science and innovation are central to the policy-portfolio of the European Union. That includes the direct support which the Union provides to scientists and innovators through the 8. multi-annual Framework Programme Horizon 2020 (2014-2020), as well as policies which create better conditions – a European Research Area – in which these scientists and innovators can excel. And it also includes the use of science to inform better regulation and policy making, whether provided by science-based agencies of the EU, standing committees and expert groups or by the High Level Group of Scientific Advisors to the College of European Commissioners.

Of course, there is more to be done. We need a far more innovative Europe in the future, at the front edge of global competition, where national strengths are optimised in a well-performing European Research Area, where knowledge and a highly skilled and educated workforce circulate freely, and where the outcomes of Science and Innovation are understood and trusted by informed citizens and benefit society as a whole.

Beyond Boundaries and Disciplines

Horizon 2020 has a budget of 80B€. It provides funding in areas of strategic economic or societal importance for the EU. The emphasis is on collaborative research, carried out by multi-national consortia comprised of universities, research organisations and private sector actors. Horizon 2020 continues to be the only large-scale programme under which universities in one Member State can have funded collaborations with industries in other Member States, across all boundaries, between countries, between disciplines and between basic and applied research. The FPs also provide specific measures to stimulate innovation in SMEs. Horizon 2020 has also proven that it is flexible and can respond to emergencies such as Ebola and Zika.

In the area of frontier research, Horizon 2020 promotes the excellence of EU science. Funding is provided to scientist-driven, bottom-up research across all areas of science, innovation and scholarship. The careers of countless EU scientists have benefitted from Marie Sklodowska Curie grants; and the European Research Council's grants to Principal Investigators are renowned for rewarding and producing excellent research. The impacts are clear to see: an abundance of highly-reputed publications and an increased participation of the world's most eminent scientists.

The interim evaluation of Horizon 2020 showed that Horizon 2020 is an attractive and well-performing programme. It has attracted so far more than 100.000 applications, a huge increase com-

Foto: Europäische Kommission/François Walschaerts

pared to the Seventh Framework Programme. It involves top level participants from the higher education, research and private sectors, from a wide range of disciplines and thematic fields, and from over 130 countries. Private sector participation has increased compared to FP7 and almost a quarter of the budget for industrial and enabling technologies goes to SME's, far exceeding the target. Horizon 2020 is also on track to be cost-efficient, achieving a very low administrative overhead and the large scale simplification of the rules for participation. It also has clear European added value, 83% of funded projects would not have gone ahead with EU funding. So, a lot of progress has been made, but a lot of progress is still to be made. The preparations for the next Framework Programme are in full swing and many stakeholders have presented their views on this. Let me pick out a few elements for you that I attach great importance to personally.

> Practicing an open research culture will be one of the central challenges facing the modern universities of tomorrow.
>
> **Günther H. Oettinger**
> European Commissioner for Budget and Human Resources

Involve Society

Firstly I acknowledge the importance of the human factor as was also emphasized in the German position paper on FP9: "The large number of well trained and motivated young people is one of Europe's strengths. These people design and represent Europe's future. We must make special efforts to foster their talent as young researchers who gain experience in different places throughout Europe or as young entrepreneurs who are changing the world by implementing their ideas. We must broaden our vision and consider the needs of citizens from the outset by developing adequate forms of public participation." The importance of involvement of citizens and their needs is also crucial. Performing Open Science, including the access to scientific articles and data to the wider scientific community and the general public, will be one of the key challenges to the modern universities of the future. Secondly, Europe must do better in innovation. Our competitors in the US and Asia lead the way in growing innovative companies and many of them are youngsters: less than 20 years of age. Names such as Tencent, Alibaba, Netflix, Paypal. In Europe, we have relatively few of these blockbuster companies. Europe has five times less venture capital than the US. FP9 will have to work on that. It will contain a European Innovation Council to help innovative companies with scaling up. We need public money for that, of course, but much more so private investments and venture capital.

Thirdly, in a recent report to the Commission the Italian economist Marianna Mazzucato has made a strong plea for mission-oriented research, these are systemic public policies that draw on frontier knowledge or "big science to meet big problems". Missions provide a solution to address the many challenges that people face in their daily lives. This requires

the active participation of all kind of stakeholders in society, who can contribute to a concrete solution so that the programme has maximum impact.

Finally, Horizon 2020 still suffers from underfunding, even if Research saw a steady rise in budget since the 80ies. This results in large-scale oversubscription, which constitutes an enormous waste of resources for applicants and good proposals for Europe. Redressing under-investment in R&I across most of the EU Member States, compared to the main global R&I players, notably China, is of crucial importance. However, the gap to the 3% of GDP benchmark will not be bridged by the EU R&I budget alone.

The University of Stuttgart is one of the most successful German universities in Horizon 2020. The University participates in 82 projects under Horizon 2020 and has received a EU financial contribution of more than €41 mln. up until now. In this issue you will find some excellent examples of research projects of the University of Stuttgart under Horizon 2020. I am very confident that the University of Stuttgart will continue and even reinforce their contribution to European research and society as a whole in the future!

Günther H. Oettinger,
European Commissioner for Budget
and Human Resources

Between 2005 and 2010 Günther H. Oettinger was the Prime Minister of Baden-Württemberg. He has been working for the European Commission since February 2010. Until October 2014, he was Vice-President of the European Commission in charge of Energy before becoming Commissioner for Digital Economy and Society from November 2014 to December 2016. He has been Commissioner for Budget and Human Resources since January 2017.

Tobias Blocher,
Projektingenieur

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Small impulse, major effect
The EU is a popular reference point for application-oriented research.

The University of Stuttgart is leading the field in terms of research into the use of laser technologies in industrial production processes, which is why the Institute of Laser Technologies (IFSW) is a popular partner in European projects. But, how does research work in a cross-border, inter-cultural context involving science and industry? And, what value is added?

Marwan Abdou Ahmed's background is just as international as his research projects. Born in Djibouti, he is a French citizen and works with researchers from Russia, Bulgaria, the Netherlands and Switzerland. He is currently Head of Laser Development and Laser Optics at the University of Stuttgart's Institute of Laser Technologies. "I've got a pretty good understanding of cultural diversity", says Ahmed, who holds a doctoral degree in Physics. That's a great advantage in his day-to-day work: international research collaboration is a particularly pronounced feature in his area of expertise. Collaboration partners include both government institutes and companies that wish to improve their production processes and are therefore interested in establishing close ties with university-based researchers. The University of Stuttgart is a popular partner in the field of laser technology. Over the past few decades, the IFSW has pioneered important research in this field.
One of Marwan Abdou Ahmed's projects is RAZipol (Ultrafast Lasers with Radial and Azimuthal Polarizations for High-efficiency Micro-machining Applications), the objective of which is to use disc lasers to make production processes even more efficient than is currently possible. One of the problems involved is that, currently, a laser beam can either operate extremely rapidly but with a lower level of precision – or very slowly but extremely precisely. "The challenge of this project", Ahmed explains, "is to combine these two objectives". Yet, entirely different parameters, such as the intensity and duration of the laser pulse, have a bearing on this. In contrast to the common laser pointer-type laser beams used in slide show presentations, industrial lasers do not use an uninterrupted beam; in a production setting they switch on and off in rapid succession whereby each individual pulse could last around a billionth of a second. In this way, very different tasks can be precisely executed depending on frequency and intensity. Lasers can be used to drill ultra-fine holes or to machine a surface to give it a structure that can only be seen through a microscope. "This kind of application process, is important for example in the field microelectronics" says Ahmed.

Fine Holes for Injection Nozzles

Smartphone and tablet manufacturers use laser techniques to machine tiny little components that are integrated within the devices: the same applies to the automotive industry. "It can be demonstrated", says Ahmed, "that Diesel injection nozzles made using ultra-fast lasers cause less air pollution that injectors made using conventional processes". Laser processes are also used in the production of spinnerets, which are used in the textile industry.
Also involved in the RAZIpol project, in addition to the IFSW, are the French Charles Fabry Research Institute, five medium-sized enterprises from different countries as well as Schweißtechnische Lehr- und Versuchsanstalt Mecklenburg-Vorpommern (SLV M-V) GmbH. The partner organisations submitted a joint funding application to the European Union, which they received and continue to receive. The collaborating institutions meet regularly to discuss progress in their work, whereby they proceed in accordance with rules and standards agreed upon during the project planning phase. To get funding from the European Union it is necessary, for example, to agree precisely who will be driving the research and in what direct and when the results are expected,

Laser technology is often about applied science: According to Abou Ahmed, Project Manager of the HIPERDIAS project, "our core focus is on practical utilisation in industry and that's also the starting point for all our planning ".

Photo: University of Stuttgart / Ulf Regenscheit

Whereby the various companies and research institutes share the work in an expedient manner. If, on the other hand, fundamental research is required in the field of laser physics then the researchers will be needed, whilst the partner companies focus applications in production processes.

Diamonds and Wristwatches

Marwan Abdou Ahmed knows how to manage European projects. He coordinated the RAZipol project and now heads up the follow-on HIPERDIAS (HIgh throughPut LasER processing of DIAmond and Silicon) project. The objective of this project is to develop highly efficient production processes involving disc lasers capable of machining three-dimensional structures in silicon, a crucial development for the semiconductor industry. Another focus involves processing diamonds used in industrial tools for machining hard materials. In addition, they need to be able to make ultra-precise incisions in very thin metal components, which is of interest, for example, to the wristwatch sector but also to medical device manufacturers. In addition to the University of Stuttgart, the ten collaboration partners involved in the HIPERDIAS project include the technology giant Bosch, the University of Limoges, Amplitude, a French laser manufacturer and other organisations from Germany, the United Kingdom, Ireland and Switzerland.

So, how did physicist Abdou Ahmed come to head up a Europewide science project? He laughs: "It was my idea – and the initiator usually takes on this job". Like other researchers, he also needs to apply for funding to get any project off the ground. One's success in doing so depends on multiple factors. First, of course, you need to have the idea and a good scientific reputation. It also doesn't hurt to have a network of contacts to find suitable collaborators. "I spent hours on the phone calling around research institutes and companies". People working in the field know one another from earlier projects or research conferences.

Laser technology is all about applied science. According to Abou Ahmed, "the focus is on practical utilisation in industry and that's also the starting point for all our planning ". He also asked around various companies to find out where research may be needed. In terms of funding, there are various institutes to choose from, such as the German Federal Ministry of Education and Research, the German Research Foundation (DFG) and the European Union. A prerequisite for EU funding is that the

project partners come from several countries. The EU is a popular choice for laser projects because, among other things, institutes such as the DFG are more apt to provide funding for basic research and they tend to regard laser beam sources as belonging within the scope of theoretical physics. "Therefore", Ahmed explains, "the chances of their funding more application-based laser-beam-source development projects such as the HIPERDIAS project were not so good".

Vital Third-Party Funding

Researchers often spend a large part of their working time submitting applications for third-party funding. Their success rate can vary widely, but is around 30 per cent across all funding bodies.

Even during the application phase, the international project partners have to get organised, with budget planning being the number one priority. "Each of the partners has to know exactly how much money they have available" says Ahmed. The research strategy can also be a bone of contention. "Companies like to focus on a specific aspect of the technology that is of particular relevance to themselves". The research perspective is usually more generalised and more focused on the fundamental science.

Cultural differences can also play a role in inter-European projects. As Ahmed explains: "the various partners sometimes interpret agreed aspects in different ways". For example, when it comes to when certain results are due. It can also happen that companies may attempt to block the publication of certain findings to avoid revealing too much to the competition. However, transparency is a prerequisite of all state-funded projects. According to Professor Thomas Graf, Director of the IFSW and Prorector for the Transfer of Knowledge and Technology at the University of Stuttgart: "all findings relating to fundamental science have to be published". His institute employs 50 staff members, some 80 per cent of whom rely on third-party funding and submit many applications to the EU. Whilst the German Federal Ministry of Education and Research also subsidises projects with an industrial focus, it does so to a lesser extent than used to be the case. "Germany recognised the importance of laser technology very early on", says Graf. The Federal Ministry of Education and Research lavished relevant projects with funding for more than two decades. "That gave us an enormous head start. But, at the same time, it was obvious that it couldn't continue like that forever".

For this reason, most applications tend to be submitted to the EU these days. Another project involving the IFSW and other European partners is the TresClean (High ThRoughput lasEr texturing of Self-CLEANing and antibacterial surfaces) project. One of the partners is ALPhANOV the French laser centre in Bordeaux. The University of Parma is also involved as is the Spanish-based Bosch Siemens Hausgeräte (BSH Home Appliances), Raylase from Germany and ECOR, an Italian manufacturer of filling plant. As Volkher Onuseit, who represents the IFSW within the project, explains: "the project is about creating antibacterial surfaces with the aid of laser technology". No surface is ever completely flat: structures, minute hollows, are always visible under the microscope; bacteria tend to colonise these spaces, which contaminates the surface. "It is possible to use ultra-short laser pulses to make the surface structure so smooth that bacteria can no longer find space to live on it", Onuseit explains. Nor can water or other liquids accumulate there.

No Need to Worry About Splashes

The benefits of this for filling plant manufacturers and the food industry are many. When sauce bottles are filled, for example, minute particles almost

always miss the opening and contaminate the machinery. If their surfaces are so smooth that neither food remains or bacteria can stick to them, then they don't have to cleaned as often, which means less production downtime and more efficiency.
Such surfaces are also of interest to dishwasher manufacturers. "Bacterial cultures can also flourish in the water tanks they contain", says Onuseit, but, if the surface has a certain structure then they cannot establish themselves. The goal of the project is to determine how best to create such structures with the aid of the laser. Researchers, such as Onuseit, are used to working in an international context. In terms of content, the engineer sees little difference between the research cultures in the various European countries. "Everyone concerned takes a professional approach to work and adhere to the same scientific standards".

Very Small Differences

However, the composition of the project teams can vary from country to country. Onuseit cites France as an example. "It's usual there to assign the relevant tasks to post-doctoral researchers". They collaborate with doctoral candidates on the German side, who tend to be older here and are allowed to work more independently than in France where doctoral studies follow a more regimented curriculum under close supervision.
One rapidly becomes familiar with such differences when working on international projects. Take Italy for example: "Those who earn a doctorate there often want a career in research", says Onuseit. Most students, who earn their doctorate in Germany, by contrast, tend to regard this phase as a stepping stone where they can gather experience and increase their chances of landing a good position in industry on the strength of the doctor title.

Heimo Fischer

Pencil, paper and arithmetic

Hans Peter Büchler is carrying out research into the basic principles of quantum information processing.

Hans Peter Büchler is Professor of Theoretical Physics and Head of the eponymous institute (ITP) at the University of Stuttgart. He was able to establish his research group, which researches many-particle quantum-mechanical systems, in 2016 thanks to funding from the European Research Council (ERC). The Swiss professor enjoys the challenges of understanding and explaining precisely how complex systems function.

Light passes through light without hindrance, which sounds so banal that one rarely gives it a second thought in daily life. Yet, this "non-aggression pact" between photons may present a real problem for potential future applications. How could ultra-fast computers use individual photons for computational purposes at some point in the future if they do not interact? Luckily, physicists have now found ways and means of overcoming this problem. It is possible to force photons to interact under laboratory conditions, by sending them into a suitable medium where they excite atoms. An interaction can then be induced based on the quantum nature of the photons in combination with the excited atoms, which the physicist can control in a targeted manner by choosing the appropriate framework conditions for the experiment. The whole process – as one would expect – is extremely complex and neither works perfectly under experimental conditions nor is it completely understood from a theoretical perspective.

First Order of Business: Reduce Complexity

Enter Hans Peter Büchler. The professor heads up the Institute of Theoretical Physics III at the University of Stuttgart, and – nomen est omen – is the very man for the theory. Together with his research group, he attempts to describe the processes involved in many-particle quantum-mechanical systems with as much precision as possible. "To answer the question of what is happening to the photons in such systems" says Büchler, explaining the challenge in more detail, "one has to solve the equations for an enormous number of quantum-mechanical particles, a task that cannot be achieved with precision". That's why he is looking into ways to reduce the inherent complexity whilst still being able to correctly describe the physics of many-particle systems – at least for a few special cases. "Sometimes it's even a challenge formulating the problem in tractable mathematical terms at all". Büchler uses analytical methods to recast the relevant equations in a form that eventually results in a solution. "Of course", says Büchler, "we also utilise numeric processes, i.e., we attempt to use the computer to approximate a solution. If we find ourselves struggling to make progress then we turn to specialists in the relevant numeric methods: getting to grips with programming code is never our own central research focus". This is why Büchler's research group frequently reverts, as it were, to pen and paper or the good old blackboard. He himself estimates that some 90 per cent of his "maths work" is of an analytical nature.

Physicist from and with Passion

The 44-year-old has been fascinated by mathematics from an early age: "I always found it a doddle!" Büchler grew up in Wattwil, a scattered community in eastern Switzerland with a population of just a few thousand, 40 kilometres by car from St. Gallen and just 20 kilometres as the crow flies from Mount Säntis. By contrast, he was "appalled" by secondary-school physics, despite the fact that he was just as fascinated by it. "If you asked the teacher something that went beyond what was included in the curriculum, you'd be fobbed off and told that it was all way too complicated". Some would have been satisfied with this answer, but Büchler saw it as

“Sometimes it's even a challenge formulating the problem in tractable mathematical terms at all”.

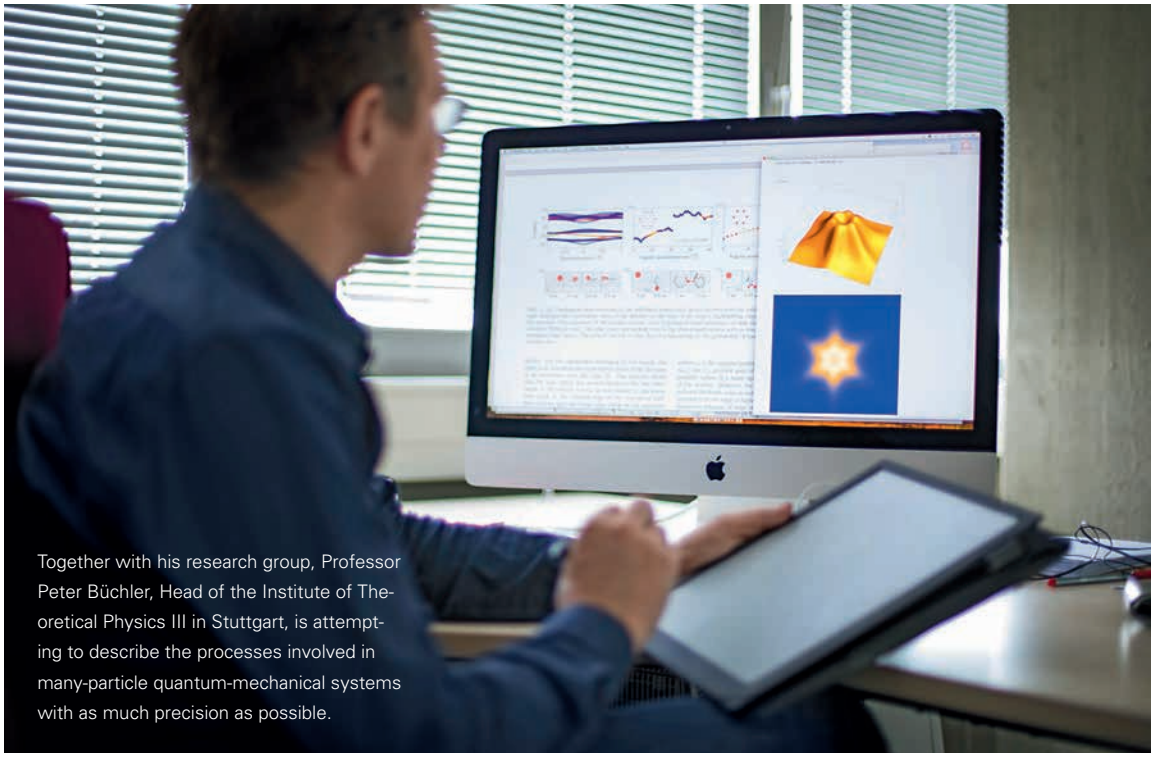
Peter Büchler

Photo: University of Stuttgart / Uli Regenscheit

a challenge “to get to grips with, say, the theory of relativity by myself”. After gaining his *Abitur* (university entrance qualification), he studied Physics at the ETH Zurich (Swiss Federal Institute of Technology). “At the start of the course there”, says Büchler, “mathematics and physics were closely interrelated, which played to my talents”. He also knew early on that he would gravitate towards theoretical physics: “In that field, one can get a real understanding of things from the bottom up”. He might have gone into string theory, “but during a lecture, a professor convinced me to go into theoretical physics instead, as the relevant equations are amenable to empirical verification at some point in the future”. The professor in question was Gianni Blatter, under whose supervision Büchler later completed his master's dissertation and doctoral thesis, both on topics relating to solid-state physics. In 2004, as post-doctoral researcher, he joined a research group headed up by theoretical physicist Peter Zoller, a professor at the University of Innsbruck. Three years later and just 13 years after beginning his studies, Büchler, now 33 years old, took up his W3-professorship at the Institute of Theoretical Physics III in Stuttgart.

Bright Minds are What Count

He had planned to stay for six years, but it’s already been over a decade. “As the old saying goes”, says Büchler with a wink, “you can take the man out of Switzerland, but you can't take Switzerland out of



Together with his research group, Professor Peter Büchler, Head of the Institute of Theoretical Physics III in Stuttgart, is attempting to describe the processes involved in many-particle quantum-mechanical systems with as much precision as possible.

Photo: Universität Stuttgart/Uli Regenscheit

the man. But, I was immediately made to feel very welcome and found the locals to be really open right from the start". He refers to Stuttgart as one big village – and means it in a positive way. And, it's not just the region himself that impresses him but, above all "the excellent, extremely productive collaboration" with the experimental physicists in Stuttgart. "They come up with new ideas and experimental set ups that are also extremely interesting for theorists like me". Following the untimely death of the former institute director, Professor Alejandro Muramatsu, Büchler officially took over the role last autumn.

In 2016 Büchler received funding from the EU in the form of a so-called ERC Consolidator Grant, a funding facility for up to two million euros. That's a lot of money for a theoretical group working in basic research, which has no need to invest in expensive experimental setups, getting by instead with a computer, paper, blackboard and pencil. So, Büchler only applied for the amount he actually needs, most of which is used to cover personnel costs. For, as is usually the case in theoretical research, it is not the equipment that plays the crucial role, but rather a competent team. The fact that Büchler is also rather frugal in this respect is only partially due to the innate thriftiness of the Swiss. The main reason is that the professor simply loves to get to grips with the mathematics himself rather than spending all his time on managerial tasks.

Michael Vogel

Visionary Researchers

The European Research Council (ERC) provides funding for cutting-edge and visionary research and targets excellent researchers at different stages of their careers. ERC grants have come to be seen as the hallmark of internationally competitive universities. A whole host of researchers at the University of Stuttgart have received the prestigious grant, which provides up to 2.5 million euro of funding.

Starting Grants

Professor Oliver Röhrle

Institute of Applied Mechanics
Project: Biomechanical Research for Better Leg Protheses
(2012 – 2017)

As a young researcher, Oliver Röhrle used the ERC Starting Grant to intensify work he was doing in the area of modelling movement sequences in patients, whose legs had been amputated above the knee. This area of research is situated at the interface between mechanics, physiology and medicine. “The ERC Starting Grant was a fantastic confirmation of my research activities. The funding also helped me to establish my biomechanical research group on an excellent long-term footing”.

Former ERC Prize Winners

Professor Clemens Bechinger

(now at the University of Konstanz)
Project: The Behaviour of Colloidal Particles
(2016 – 2021)

Professor Lapo Bogani

(now at the University of Oxford)
Project: Optical Quantum Control of Magnetic Molecules
(2014 – 2018)

Professor Albrecht Schmidt

(now at the Ludwig Maximilian University of Munich)
Project: The Digital Augmentation of Human Senses
(2016 – 2021)

Consolidator Grants

Professor Hans Peter Büchler

Institute of Theoretical Physics III
Project: Interactions Between Photons
(2016 – 2021)

Being able to control interactions between individual photons would be useful for many quantum-technological applications. Hans Peter Büchler carries out research into relevant methods. His starting point is the phenomenon of slow light by which the photons, by causing them to interact with atoms, are strongly influenced by the electronically excited state of the atoms. Once these Rydberg conditions have been achieved, the strong interaction between Rydberg atoms in turn result in an interaction between the photons.

Professor Johannes Kästner

Institute for Theoretical Chemistry
Project: Project: The Quantum-Mechanical Tunnel Effect
(2015 – 2020)

Johannes Kästner uses simulations to investigate the quantum-mechanical tunnel effect of atoms, which causes certain chemical reactions to happen more quickly at low temperatures and makes it possible for the reactions to take place in the ice-cold environment of outer space. “I've been fascinated by the tunnel effect for years” says the Viennese native, who conducts his research at the University of Stuttgart's Cluster of Excellence for Simulation Technology (SimTech). “Thanks to the EU grant, I am in a position to investigate this effect comprehensively. In addition, I've been able to significantly increase the size of my research group”.

Advanced Grants

Professor Peer Fischer

Institute of Physical Chemistry / Max Planck Institute for Intelligent Systems
Project: Project "Holographic acoustic assembly and manipulation"
(2018 – 2023)

Ultrasonic sound with a wavelength of just a few hundred micrometres that spreads through water is used successfully in medical imaging applications and can also be used to capture and manipulate microparticles. Peer Fischer and his team want to use sound waves to create structures, up to and including entire organoids, out of microparticles and cells in a far simpler and quicker manner than is possible with 3D printing.

Professor Harald Giessen

Institute of Physics IV
Project: Plasmonics at the Ultimate Limit
(2013 – 2018)

Thanks to metallic nanostructures, light can be focused to tiny dimensions – much smaller than the light's own wavelength – with the aid of nano-antennae. This has resulted in new effects in light-material interactions, for example, in the field of sensor technology. Harald Giessen is conducting research into the ultimate limits of such interactions to bridge the gap between basic and applied science as well as between the disciplines of Physics, Chemistry and Molecular Biology.

Professor Tilman Pfau

Institute of Physics V
Project: Interactions in Quantum Gasses
(2011 – 2016)

Quantum systems with long-reach interactions are enabling the creation of novel material states and quantum components, such as integrable and scalable single-photon sources and sensors. Tilman Pfau and his team are conducting research into novel quantum fluids as well as high-sensitive quantum sensors for microwaves and trace gases. They showed that atoms also react to each other so sensitively that they can sense one another over a distance of one micrometre, as a result of which they were able to demonstrate a single photon source at room temperature.

Professor Hans-Joachim Werner

Institute for Theoretical Chemistry
Project: Quantum-Mechanical Simulations of Molecules and Chemical Reactions
(2013 – 2018)

In the course of the project, Hans-Joachim Werner and his team have developed new methods and a broad range of computer programmes for calculating the electron structures of large molecules. Starting from the underlying laws of physics and natural constants, these can be used to predict the chemical and physical properties of molecules without reference to empirical data.

Professor Jörg Wrachtrup

Institute of Physics III
Projects: Quantum Technology with Electro-Spin
(2011 – 2016)
Imaging Electrical Fields of Single Molecular Charges with Quantum Sensors
(2017 – 2022)

Jörg Wrachtrup and his team used funding from the ERC Advanced Grant 2011 to investigate the potential for exploiting atomic defects in diamonds for quantum-technological purposes, whereby they succeeded in establishing new quantum sensor sensitivity records – even in ambient conditions. "With the second grant in 2017, I would like to use the new grant to show how it is possible to use quantum sensors to trace electrical fields with a hitherto unparalleled sensitivity and spatial resolution and to use this, for example, to track individual electrical charges. I am especially pleased about receiving an additional proof-of-concept grant, which will enable me to realise certain ideas as practical applications".

IQST – or Quantum Physics Shaping the Future

Enhanced performance for computers or increased data security, highly sensitive measuring methods for medical engineering or environmental analyses, novel materials for improved resource efficiency: quantum-based technologies are considered key in an increasingly complex world. With 27 participating institutes at the Universities of Stuttgart and Ulm and the Max Planck Institute for Solid State Research, the Baden-Württemberg Center for Integrated Quantum Science and Technology, IQST) is an international hub and linchpin. It is staffed by top researchers from the respective Physics faculties, who work hand-in-hand with researchers from other disciplines and collaborate directly with the industrial sector to tackle future challenges based on the principles of quantum physics. This interdisciplinary coupling of outstanding basic research with excellent applied research and partners in the industrial sector is designed to help with the transfer of a plethora of quantum-technological concepts into practical technical applications. To inspire the second quantum revolution is also the objective of the European Commission's flagship quantum research and technology initiative, which was initiated with significant input from IQST. It is one of the EU Commission's most ambitious long-term research and innovation initiatives. With a funding facility of 1 billion euro, the EU grant made available this year is designed to secure and consolidate Europe's leading role in quantum science.

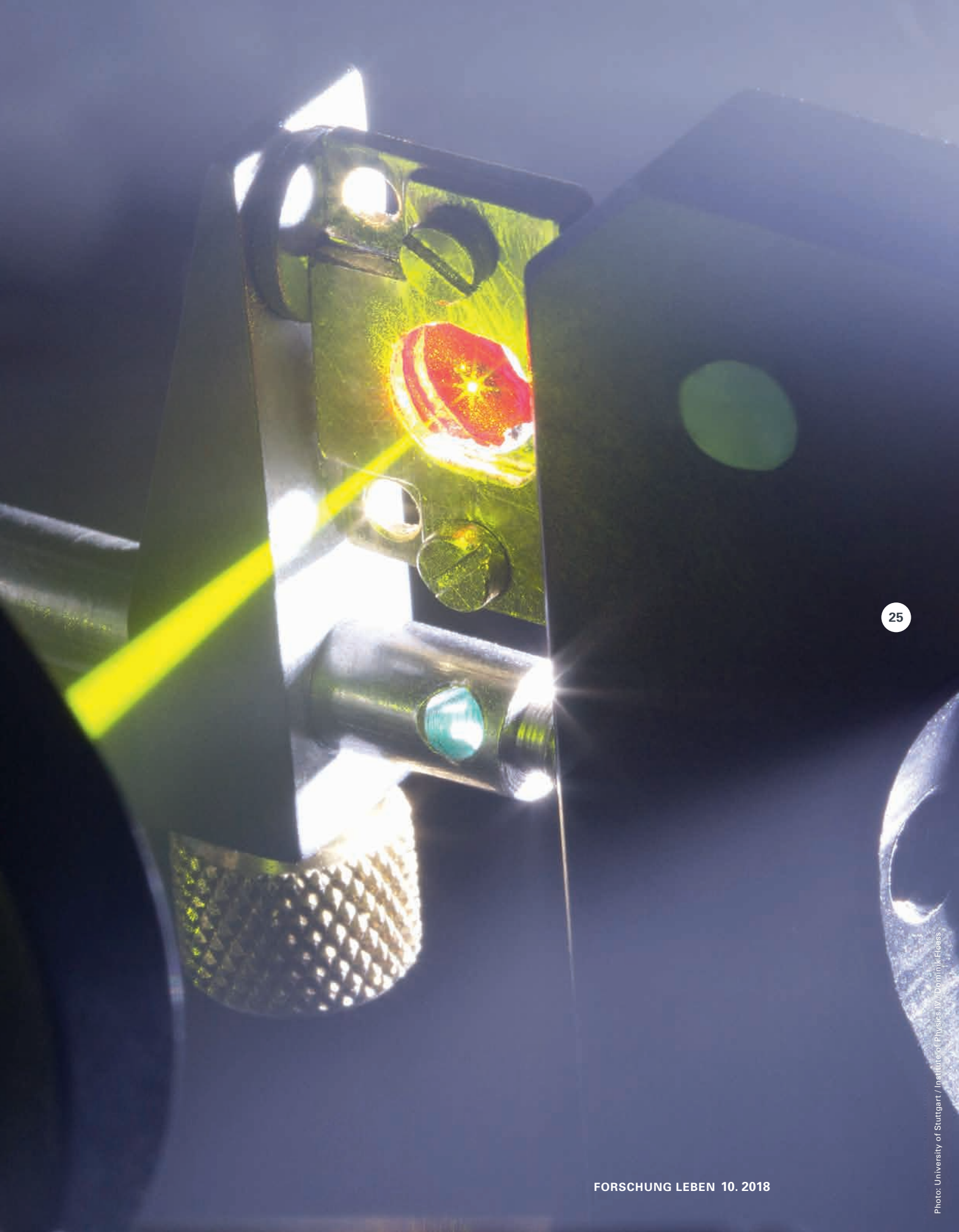
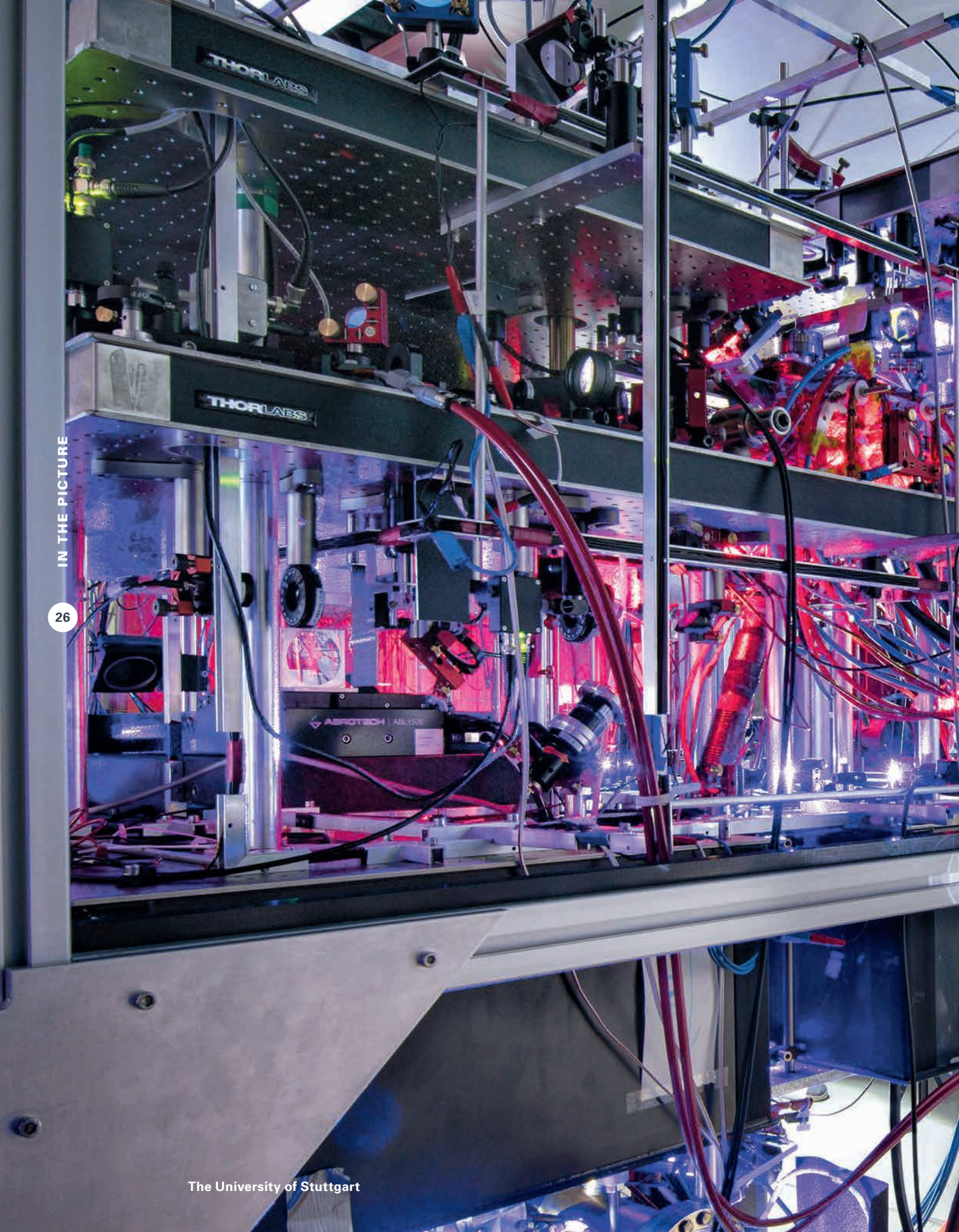


Photo: University of Stuttgart / Institute of Physics IV / Dominik Floess



The University of Stuttgart

Quantum physicists work hand-in-hand with other disciplines to control individual atoms, electrons and photons with which the functions of electronic components can be modelled, which is intended to further the development of digital technology. What's more, the natural building blocks of material make ideal sensors, as they react extremely sensitively to physical stimuli and are highly precise. At the laser lab', Professor Tilmann Pfau, Head of the Institute of Physics V at the University of Stuttgart and Director of the IQST, and his team are creating the foundations for miniaturised measuring devices. There, experimental trials are being carried out, as yet still at the macroscopic level, to find out how photons can be used to interact with and interrogate sensors.

Photo: University of Stuttgart Institute of Physics V / Wolfram Scheible

In their search for materials with hitherto unknown properties, an interdisciplinary research team from the Max Planck Institute for Solid State Research, the University of Stuttgart and the University of Tokyo under the auspices of Professor Hidenori Takagi recently succeeded in obtaining experimental proof of an unusual quantum state of material: they were able to confirm the theoretical prediction that not all materials transition into a solid state of aggregation just above absolute freezing. What they discovered is a substance that, whilst being solid, still evinces the properties of a fluid in a magnetic sense. That is so fundamentally new that relevant application scenarios for it still need to be developed.

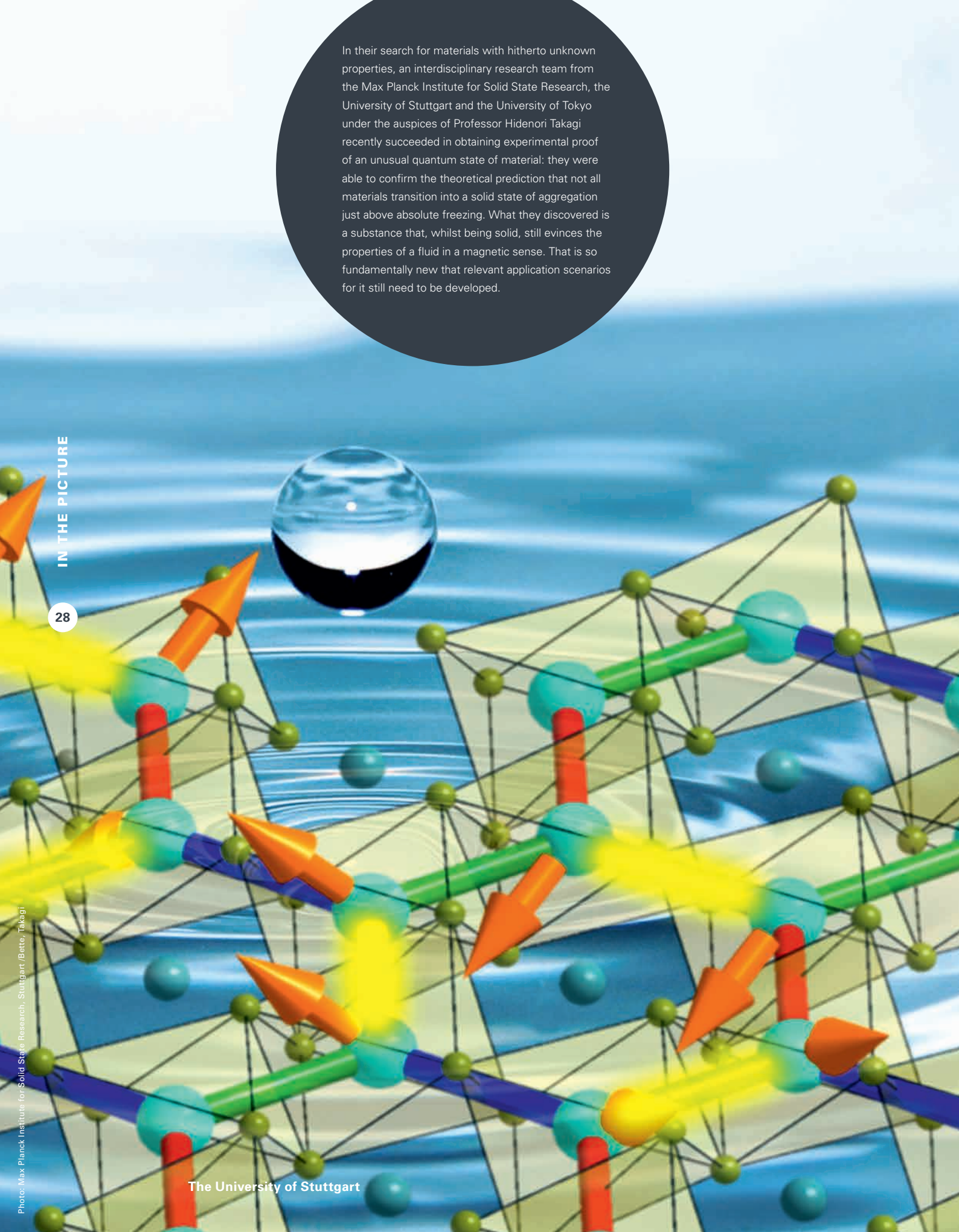
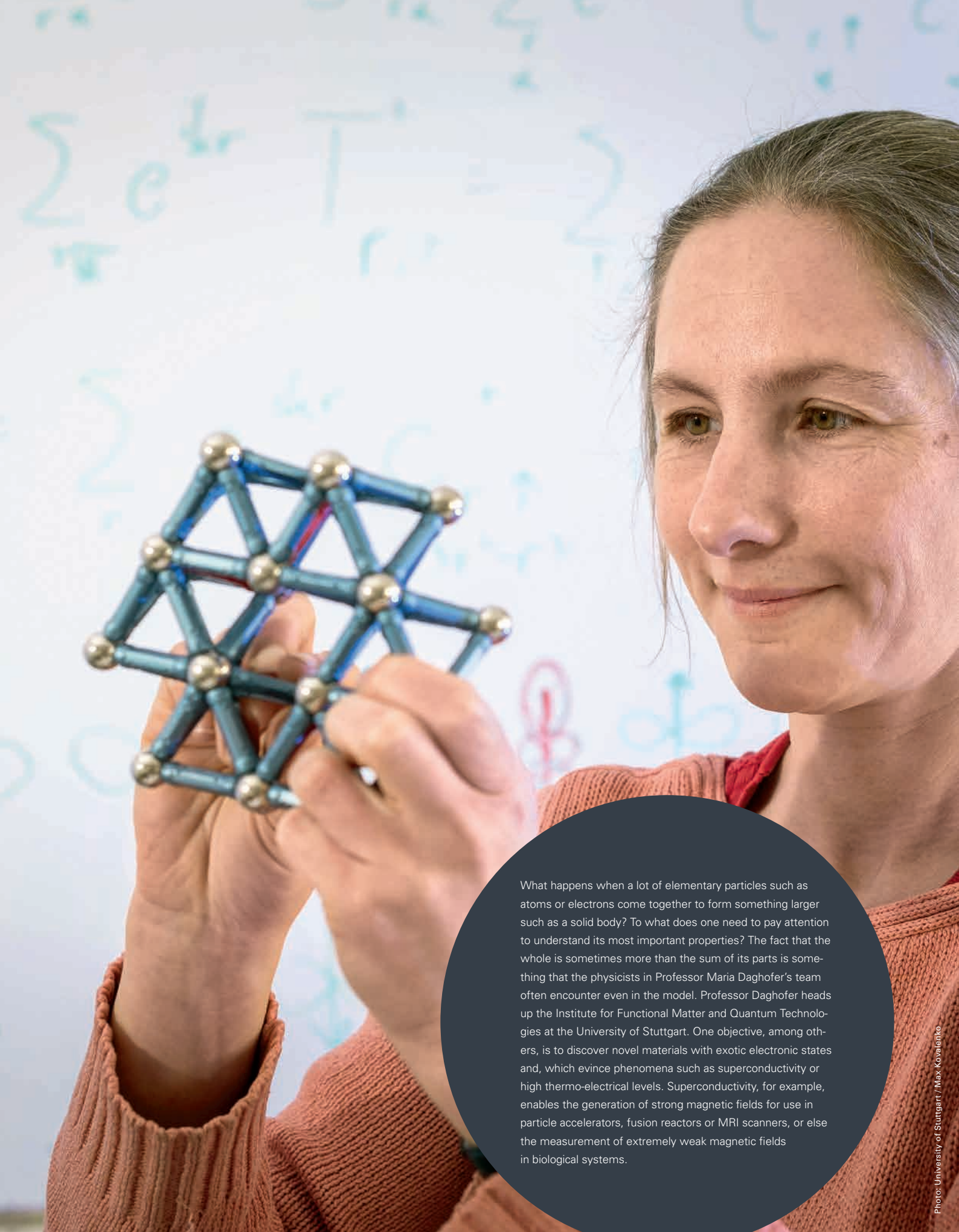
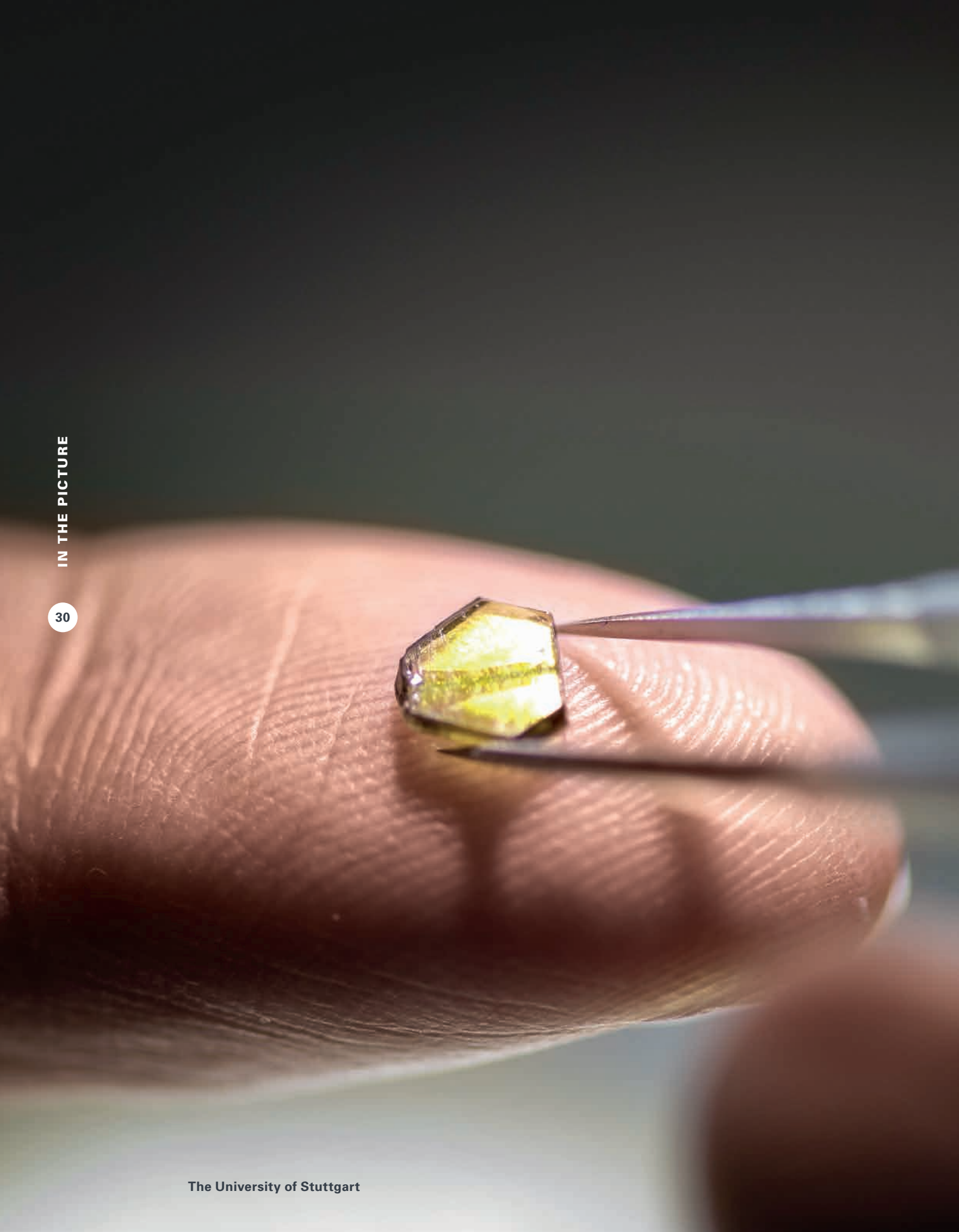


Photo: Max Planck Institute for Solid State Research, Stuttgart /Bette, Takagi



What happens when a lot of elementary particles such as atoms or electrons come together to form something larger such as a solid body? To what does one need to pay attention to understand its most important properties? The fact that the whole is sometimes more than the sum of its parts is something that the physicists in Professor Maria Daghofer's team often encounter even in the model. Professor Daghofer heads up the Institute for Functional Matter and Quantum Technologies at the University of Stuttgart. One objective, among others, is to discover novel materials with exotic electronic states and, which evince phenomena such as superconductivity or high thermo-electrical levels. Superconductivity, for example, enables the generation of strong magnetic fields for use in particle accelerators, fusion reactors or MRI scanners, or else the measurement of extremely weak magnetic fields in biological systems.

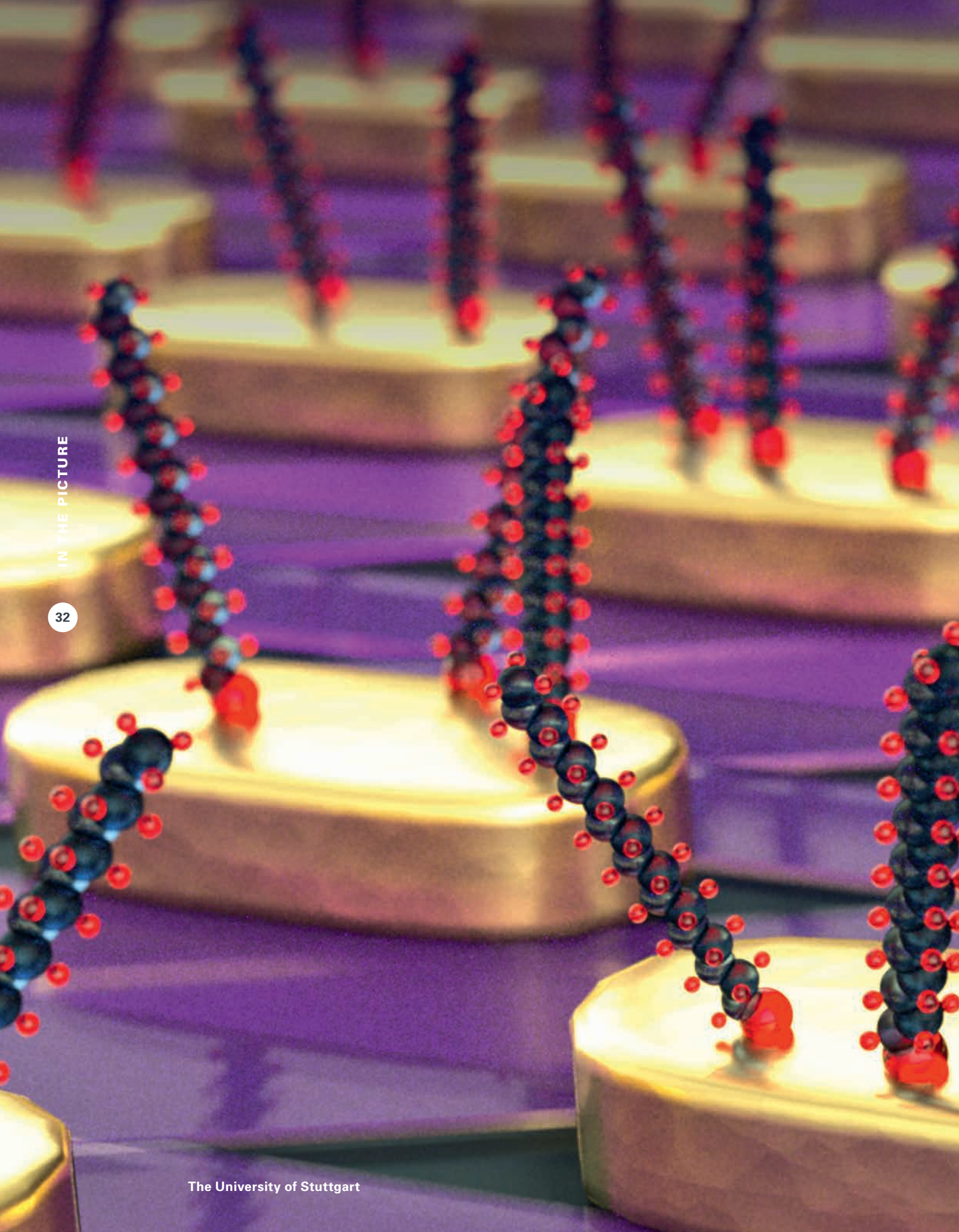
Photo: University of Stuttgart / Max Kovalenko



The University of Stuttgart

In future, quantum-physical principles will play a significant role in data processing and transmission as well as in sensor technology. To this end, Professor Jörg Wrachtrup, Director of the University of Stuttgart's Institute of Physics III, and Professor Fedor Jelezko, Director of the Institute of Quantum Optics at the Ulm University are exploiting the physical properties of diamonds: because they are so hard, they protect the atomic defects so well that quantum states can be prepared at room temperature. To manipulate ultra-pure diamonds at the atomic scale, nitrogen atoms are fired into the material, which then take the place of carbon molecules. This desirable "defect" has a magnetic component. Having been marked with a "magnetic bar code" in this way, minute diamond particles could be used to label medical agents in future, resulting in improved diagnostic systems.

Photo: University of Stuttgart / Max Kovalenko



The University of Stuttgart

A standard TV antenna receives signals transmitted with electromagnetic frequencies in the Megahertz range and converts them to electrical pulses in the power cable, whereby different orders of magnitude are coupled together via the antenna. The transmission wavelength is in the centimetre to metre range, whereas the size of an electrical cable is in the millimetre range. Professor Harald Giessen, Director of the Institute of Physics IV, and his collaborators at the Max Planck Institute for Solid State Research, succeeded in transferring this concept into the field of Nano-Optics. They are building metallic structures of around 100 nanometres that efficiently receive optical frequencies in the range of several hundred Terahertz, thus creating new possibilities for rapid data transmission as well as highly sensitive sensors. The image shows individual molecules on the nano-antennae that can be detected with exquisite precision with the aid of their own vibrations.

Photo: University of Stuttgart / Institute of Physics IV

The University of Stuttgart

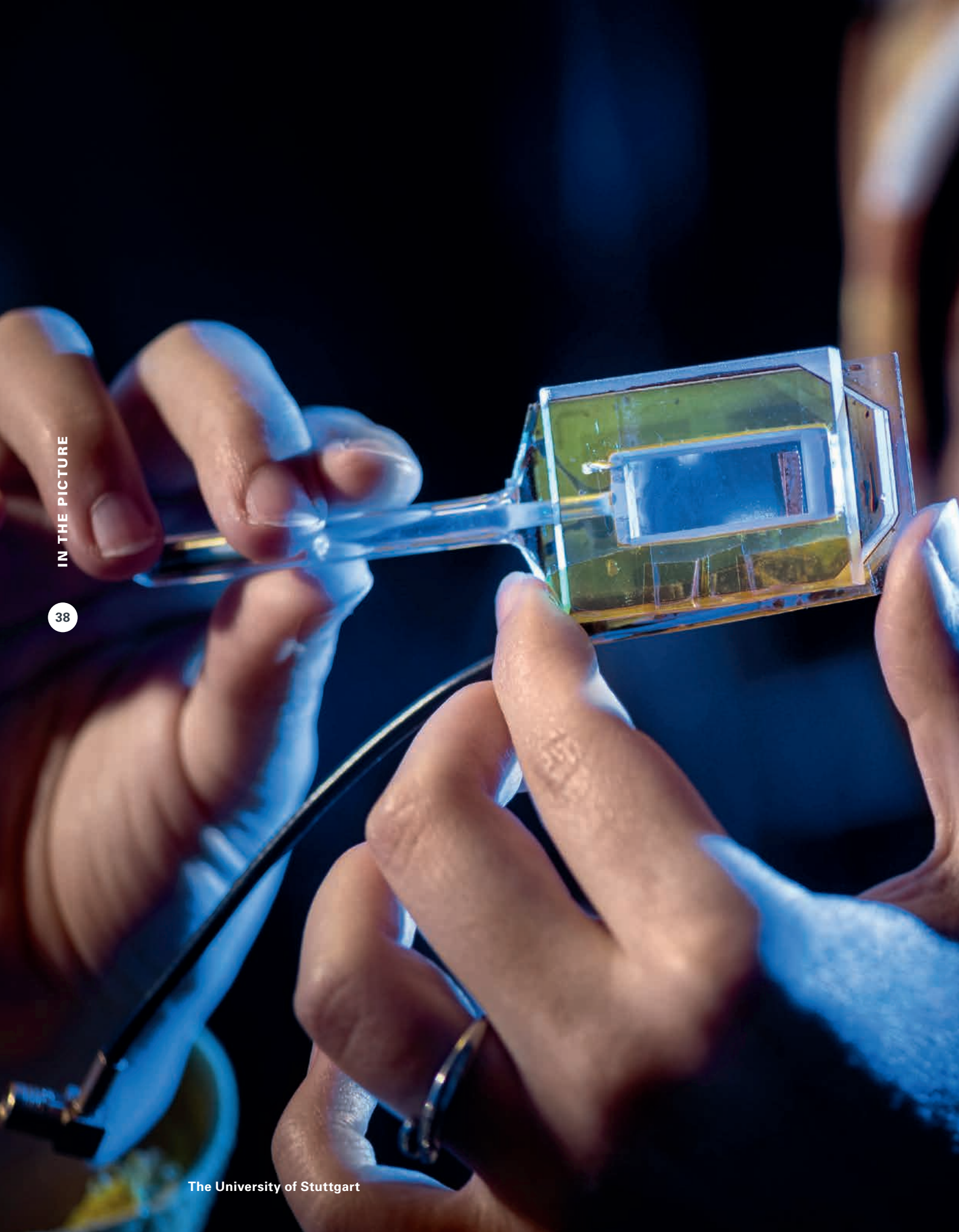
Cloud computing without the security risk– that could become possible through the combination of quantum computers and quantum-technological processes for data encryption. Yet, what sounds like a practical orientation, is actually absolutely fundamental research. That's what Professor Stefanie Barz, who heads up the "Integrated Quantum Optics" research group at the Institute for Functional Matter and Quantum Technologies is working on. The team generates individual photons and measures them with the objective of demonstrating applications from the field of quantum data, such as small quantum computers, quantum simulators and quantum networks. Bridging the gap between theoretical quantum physics and practical application requires a close collaboration with their colleagues in the engineering sciences.

Photo: University of Stuttgart / Max Kovalenko

The University of Stuttgart

Tracking quantum-mechanical process in the formation of molecules. Electrical and magnetic fields are used to trap ions, i.e., electrically charged atoms or molecules, are trapped in an ion trap. A new field of research has developed over the past few years, which involves bringing cold, trapped ions into contact with supercooled, neutral atomic gasses. Together with his colleagues in the IQST team, Professor Johannes Hecker-Denschlag, Director of the Institute of Quantum Materials at the Ulm University is studying the collisions and reactions that occur between the ions and the neutral atoms. Based on these experiments, they then draw conclusions about the interactions between the particles. The research results could contribute towards a means of forcing chemical processes to proceed in a very efficient and controlled manner.

Photo: University of Stuttgart / Max Kovalenko



The University of Stuttgart

Atmospheric vapours enclosed in glass cells are already being used as atomic clocks and magnetic field sensors. At the Institute of Physics V at the University of Stuttgart, in the context of IQST, laser stimulation is applied to combine them in highly excited "Rydberg states" in order to open up new fields of application. These range, for example, from microwave sensors to single photon sources to trace gas sensors.

Photo: University of Stuttgart / Max Kovalenko

Novel micro- and nanostructures often work by manipulating exquisitely sensitive quantum states. Even the most minimum contamination during the production of such structures can already impair the performance of the components. The clean rooms at the University of Stuttgart and the Max Planck Institute for Solid State Research satisfy the most stringent requirements in terms of air purity, humidity and temperature as well as EMF screening and protection from mechanical vibrations. The clean rooms' complementary equipment encompasses a plethora of devices for the epitaxial generation of ultra-pure thin layers and volume crystals and to structure them by means of electron and ion beams as well as for the characterisation of the finished components. The production of prototypes bridges the gap between the fundamental science and technological application of quantum-physical phenomena as a precursor to full industrial exploitation.

The University of Stuttgart

Photo: University of Stuttgart / Max Kovalenko

From virtual networks to the real world. The annual IQST Day is the forum at which the centre presents its current research projects: it promotes the exchange of scientific knowledge and provides important stimuli for the dialogue with the economic and political spheres. Distinguished quantum researchers from around the world present their most recent results from the highly innovative field of research in which they work and explore the potential ramifications of the EU Commission's flagship quantum science and technology initiative.

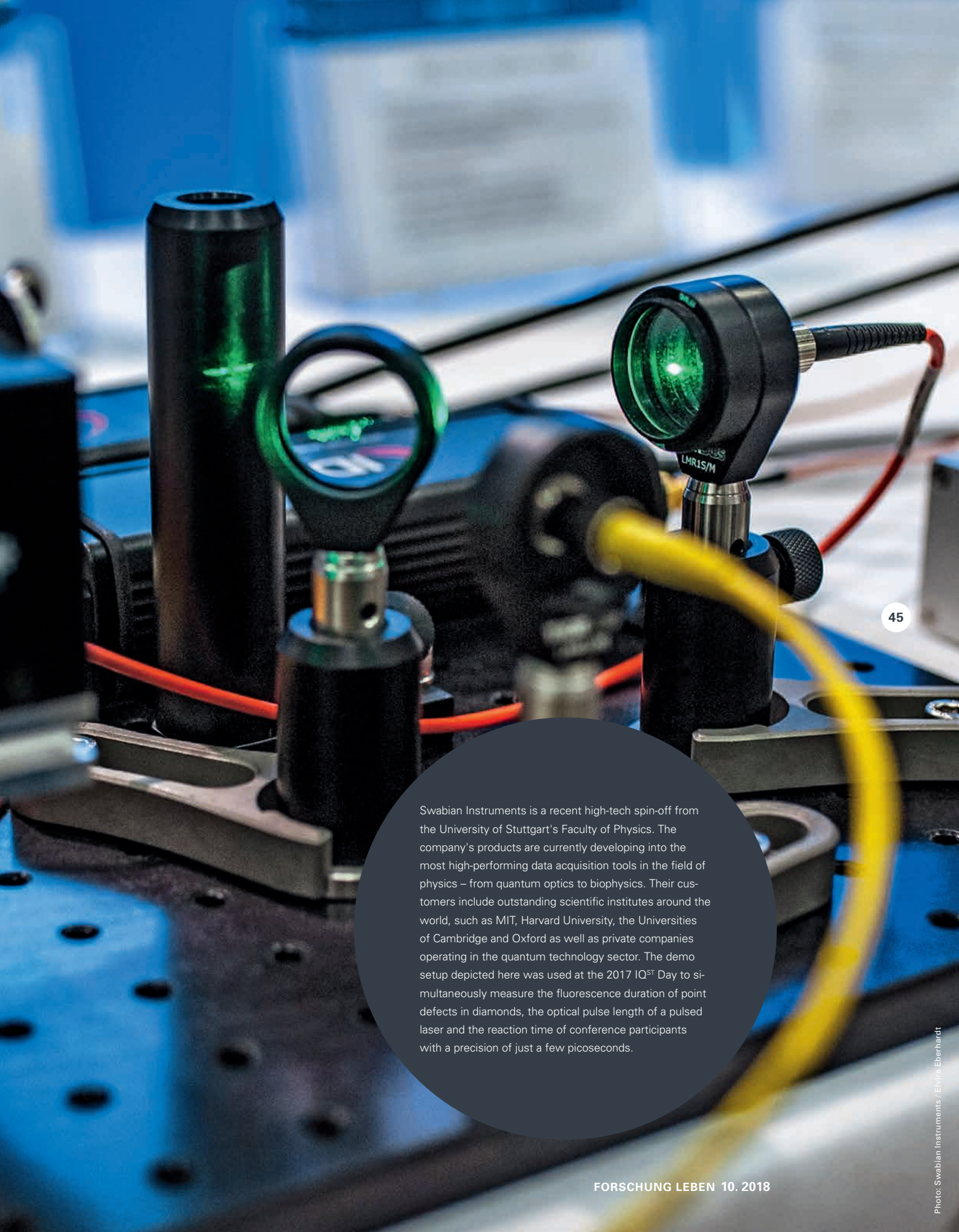
The University of Stuttgart

Photo: University of Stuttgart /IQST / Elvira Eberhardt

NVision Imaging Technologies is a spin-off from the Ulm University's Institutes of Theoretical Physics and Quantum Optics. Entrepreneurs, product developers and world-leading scientists are working together to take over the leading role in the development and commercialisation of novel image processing and sensor applications. The discovery of the unique quantum properties of isolated nitrogen vacancy defects (NV centres) in diamonds is being exploited. Because of the rigidity of the diamond lattice, the electron spin of individual NV centres can be initialised by laser, detected and manipulated with microwaves. NVision utilises these functions to significantly improve medical imaging and, for example, to optimise MRI.

The University of Stuttgart

Photo: Adobe Stock / Milles Studio



Swabian Instruments is a recent high-tech spin-off from the University of Stuttgart's Faculty of Physics. The company's products are currently developing into the most high-performing data acquisition tools in the field of physics – from quantum optics to biophysics. Their customers include outstanding scientific institutes around the world, such as MIT, Harvard University, the Universities of Cambridge and Oxford as well as private companies operating in the quantum technology sector. The demo setup depicted here was used at the 2017 IQST Day to simultaneously measure the fluorescence duration of point defects in diamonds, the optical pulse length of a pulsed laser and the reaction time of conference participants with a precision of just a few picoseconds.

Photo: Swabian Instruments / Elvira Eberhardt

Grammatical Combiners

Linguists are tracking down linguistic changes in bilingual people.

"Hey droog .. guess what's just gone down, dude?" This sentence from a WhatsApp message sent by an ethnic Russian teenager to one of his friends is just one brief example of how young people from ethnic backgrounds are interlacing idioms from their ancestral, or heritage, language with the dominant language of their "host" countries. For the first time ever, one research group now plans to take a comparative approach to investigate, whether and how, these people are permanently changing the grammatical structures of their languages. To do so, two linguists at the University of Stuttgart are studying the speech of young ethnic Russians in the USA.

A woman on a bike has been knocked down by a car. How exactly did it happen? What do the people involved do? The language testing being carried out at the University of Stuttgart's Institute of Linguistics is based on a series of photos, such as this one. The images are presented to a group of test subjects, who are then instructed to describe the scene to someone in the room, a friend via a messenger service on their smartphone, and a policeman whilst being questioned as a witness. All of the test subjects have one thing in common: all of them have Russian ancestors but grew up in the USA. In their "Grammatical Dynamics in a Language Contact Context – a Comparative Approach" project, Professor Sabine Zerbian and her doctoral student Yulia Zuban want to study how the members of this group speak Russian and English. The German Research Foundation (DFG) will be funding the project until 2021 because Zerbian is collaborating with five other institutes at different German universities. This project will deliver the first ever comparative results of whether and how bilinguals alter grammatical structures in a total of five languages.

One World Leads to Another

"Language is subject to continuous change even among monolingual speakers", Zerbian explains. "But, we suspect that such language contract situations are subject to special dynamics. Language is all about communication. One wants to be understood and so one becomes creative. So, we're looking at the resulting linguistic peculiarities". Among the bilinguals, the team is focusing on so-called heritage speakers i.e., people who speak a language at home that is important in terms of their families' cultural heritage, but also use German or English as their dominant language because they grew up in Germany or the USA. "We look at grammatical developments in the speech of these speakers, both in the heritage and the dominant languages". The group plans to investigate Greek, Turkish and Russians spoken as heritage languages in Germany and the USA. This may reveal not only general language changes but also provide insights into how information about language is communicated or into the vocabularies and linguistic competencies of these groups. "Instead of seeing multilingualism as a barrier, we see it as an enriching language quality with its own particular dynamics", say Zerbian. The findings from the study could later be used, for example, to improve the performance of voice recognition programmes when, for instance, a speaker switches between languages.

For their heritage Russian with dominant English subproject, Zerbian and Zuban will record speech situations in connection with story boards with ethnic Russians in the USA. The 30 participants are all young adults between 16 and 18 years old or adults in their late 20s. The researchers will then look at how the spoken language differs from the standard written form and what happens when the volunteers converse informally with friends or formally with, for example, policemen.

The smartphone is the communication medium of choice among the younger generations. To investigate the impact of this development, an international research group headed by Professor Sabine Zerbian is looking into how this form of entertainment is affecting grammar as an example.

Photo: Adobe Stock/Daniel Ernst

Monolinguists as a Control Group

However, consultations with the other institutes will be necessary before the two researchers fly over to the USA, as everyone involved wants to agree a standard approach to recording and codifying the various speech situations. This will result in a shared database that everyone will later be able to access to work with and carry out research into all the recorded texts. This will enable, for example, comparisons to be drawn between heritage Greek in Germany and the USA and studies into whether the Greek spoken in Germany and USA changes is in the same way.

As a phonologist interested in spoken language, Zerbian plans to focus her studies on melody, rhythm and intonation. Previous studies have shown only that melodic intonation is subject to continuous change and that languages have mutual influence on one another. “We’ll be looking at sentence phrasing, word grouping and accent distribution to emphasise important aspects”. To be able to make sense of the results, the group will also be surveying the speech habits of monolinguals, such as Germans in Germany, Turks in Turkey and so on. “This will enable us to see how monolinguals manage the same tasks. We all know what the grammar guides prescribe, but encountering the “standard” language in actual speech is pretty rare”. The researcher cites the following example: in reciting the story board about the accident during a pilot project that has already been completed, some multilingual test subjects emphasised the word “her” in the sentence “he went over to her”. “That's unexpected”, Zerbian explains: in this context one would usually place the emphasis on “over to”. “Were we to come across multiple examples of the same thing, we could posit a grammatical cause”. Curiously, the research group also observed this intonation in the monolingual control group. “That just shows how important control groups are, as, in this case, we're dealing with a general linguistic change”.

Daniel Völpel

In the Name of the People?
Lobbying under the spotlight

In an ideal world, lobbyists would help ensure that the government placed issues on the political agenda that were of particular importance to the general populace. Researchers at the University of Stuttgart are collaborating with teams from the United Kingdom, the Netherlands and the USA to assess the extent to which lobbyists in the real world actually do represent citizens' interests.

Some of the underlying axioms of democracy are that the will of the people is expressed in elections, parliaments and laws. At the same time, a plethora of associations, clubs and initiatives make it their business to evangelise citizens' preferences and influence politicians accordingly. The barriers to forming such organisations are very low. According to Professor Patrick Bernhagen, current holder of the Political Systems and Political Sociology Professorship at the University of Stuttgart: "according to the old adage 'to look after yourself is to look after everyone' all demographic groups should be properly represented in such a system. However, the question is whether or not this is done fairly".
Findings from the political scientist's earlier studies raise doubts.

Advocate – For Whom?

According to the results of a survey conducted in 2012, supposedly strong and well-organised interest groups, such as the industrial sector, find it difficult to have their demands reflected in legislation, particularly at the EU level. Environmental and consumer groups, on the other hand, are often very successful. At the time of publication, this report was met with indignation, as the findings were in conflict with the commonly accepted negative view of lobbyism that continues to this day. This eventually led to the idea of gathering sound empirical evidence about the role played by lobbyists and checking whether their negative image is justified, which, in turn, resulted in the three-year research project "Agendas and Interest Groups" (AIG), which will continue to be funded by the European Open Research Area (ORA) till 2019.
The ORA is a collaboration between European funding bodies in which the German research community also participates. ORA projects usually involve universities from three to four European countries. Up to now, it has been possible to involve both US-American and Japanese researchers via the United Kingdom. In addition to the Stuttgart team, the AIG project involves research groups headed by Dr. Joost Berkhout (Amsterdam), Dr. Adam Chalmers (London), Professor Beth Leech (Rutgers, USA) and Dr. Amy McKay (Exeter, UK).
The focus of the AIG project has shifted in comparison with earlier projects: instead of continuing to ask who comes out on top, it looks at what the various actors are talking about. "What we want to know", says Bernhagen, "is whether lobby groups in the various countries actually represent the diversity of popular interests or if they simply involve themselves in spurious debates".

Social Issues, Renting, Security

In an attempt to answer this question, as Bernhagen explains, the researchers are banking on outcome impartiality and curiosity". First, 1000 people in each of the participating countries were asked to state what the most pressing issue is, from their respective perspectives, that politicians need to resolve. Whilst the responses have not yet been fully evaluated, they are - at least for Germany - hardly surprising at first glance: at the top of the list are socio-political issues such as old-age pensions, education and, as always, the refugee question.
At the same time, 100 lobbyists from various diverse groups are providing the researchers with informa-

tion about the issues they are currently working on. As expected, their responses are significantly more detailed, depend strongly on the structure of the given association and encompass a lot of highly partisan issues. But certain themes that are also of interest to the broader public, such as the digitalisation of the workplace and climate change, were also addressed. However, rendering the responses from the public and lobbyists comparable presents a challenge, to which end a coding scheme has been devised to categorise the responses under a limited number of topic headings. In this way, the researchers want to filter out the nine topics most often addressed by the various interest groups. The general populace will then be surveyed with reference to these "popular" topics in a second survey round. Sticking to the subject, how important is climate change to the general public and where do they see themselves between economy and ecology in the relevant context? "We'll probably get different responses from Daimler employees and members of the Green Party", Bernhagen supposes.

"Brexit" and Trump Dominate the Foreign Headlines

A cross-border comparison between the participating countries is made more difficult by the fact that current crises strongly affect perceptions of important topics. Such "irritations" are weighted very differently from one country to the next. As Bernhagen explains: "The so-called 'Brexit' movement is currently occupying people's minds in the United Kingdom and Donald Trump is the main subject of conversation in the USA. Other topics are relegated to the background as a result". However, the researchers' original concern that the survey would not reveal a sufficient degree of variance has not proved to be an issue: "a lot more topics were addressed". The study aspires to go beyond the obligatory lobbyist debate and has normative features.

"If we can estimate the extent of the discrepancy between the issues of interest to the lobby groups and the general public", says Bernhagen, "then we'll be able to draw conclusions about the extent to which organised interest groups really represent the hopes and fears of the populace, which, ultimately, reflects upon the state of our democracy". The comparative representativeness, and therefore quality, of lobbying between countries is recognisable from the data. In addition, the coding system reveals the extent to which specific legislative agendas, for example in relation to the coalition agreement, truly reflect the preferences of the general public.

Whilst the researchers have no plans to make concrete recommendations to politicians based on this baseline survey, it does have practical implications. Depending on the results, says Bernhagen with a wink, politicians could conclude that they don't have to take the bowing and scraping of lobbyists too seriously, "or, conversely, that they'll have to take lobbyists much more seriously in future".

Andrea Mayer-Grenu

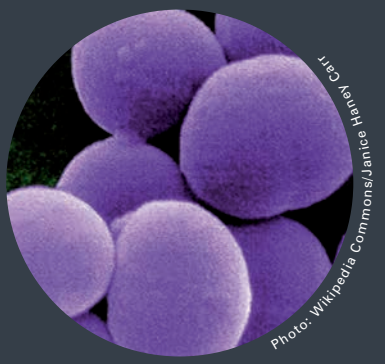


Photo: Wikipedia Commons/Janice Haney Carr

Micro Algae Ready for Outer Space

How will people feed themselves on long-haul missions to Mars or during the construction of a base on the surface of the moon? Algae could be the solution. The Institute of Space Systems (IRS) at the University of Stuttgart has recently provided Airbus Defence and Space with two photobiological reactor chambers designed to house Chlorella vulgaris, a species of micro algae, onboard the ISS by the end of 2018. This particular species of micro algae is particularly well suited to space travel because it grows rapidly and has very modest requirements in terms of space and water. It is rich in proteins and could meet up to 30 per cent of an astronaut's daily nutritional requirements. The Stuttgart-based researchers are also building a special device with which the astronauts will be able to feed and extract the micro algae. In addition, the researchers are responsible for developing and preparing the micro algae seed cultures as well as the relevant nutrient media and feeding units.

Standardised Batteries for Electric Vehicles

Forklift trucks, light vehicles, road sweepers and motorboats: it would be enormously beneficial if all electric vehicle types could be powered by a single standardised battery system. Researchers from the University of Stuttgart's Institute for Engineering Design and Industrial Design (IKTD) specialising in technical design are collaborating with partners from the research community, industry and standardisation institutes to realise this vision. The development of a standardised basic module based on state-of-the-art lithium-ion technology means that modular battery systems can now be assembled to suit any specific requirement, whereby the only standardised parts of the module are the interfaces, whereas the internal components are not specified. In addition, the researchers at the IKTD are working on designing ways to make the module easy to handle in line with ergonomic standards and to ensure that even laymen will be able to handle it safely. The objective is to design a battery that can be swapped either manually or automatically and that anyone could operate intuitively.

The Smartphone as a Microscope

To make a portable microscope – that was the task Professors Alois Herkommer and Carsten Reichert of the University of Stuttgart's Institute of Applied Optics (ITO) set themselves. Any commercially available smartphone can serve as a Microscope. Provided it is fitted with a specially designed attachment made from a repurposed smartphone lens used in conjunction with various clamping jigs, it will have a resolution in the region of three to four micrometres. Phase contrasts or holographic images can be taken with even more complex prototypes.

According to the professors, whilst competing products are available, most are designed for use with specific smartphone brands. In addition, they say, similar products are either extremely expensive or have a much poorer resolution. The model developed by Herkommer and Reichert sells for just €25 and can be used with various smartphone models.

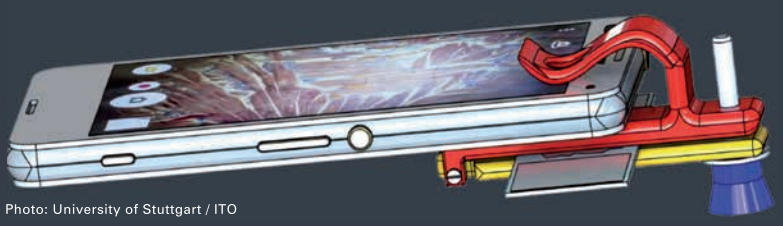


Photo: University of Stuttgart / ITO

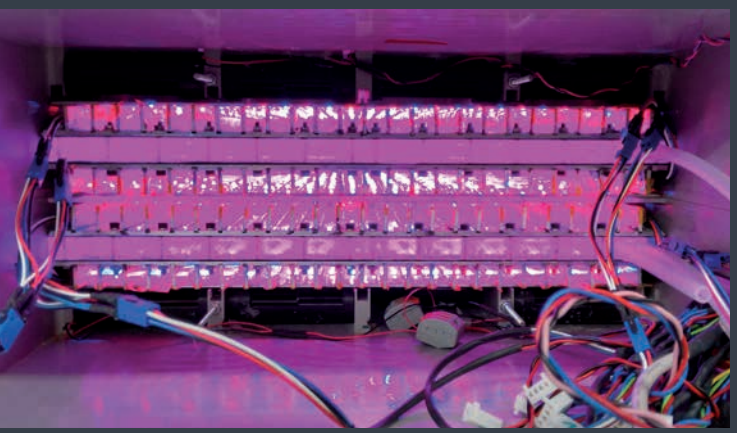


Photo: University of Stuttgart / IRS

Antibiotics against mult-iresistant? pathogens

Fewer and fewer antibiotics are available for use against multi-resistant pathogens, but there is hope: In a joint publication with researchers working under the supervision of Professor Friedrich Götz of the University of Tübingen, a research group headed by Professor Bernd Plietker of the University of Stuttgart's Institute of Organic Chemistry (IOC) described novel antibacterial structures that could make a significant contribution towards the battle against often lethal pathogens.

The researchers have demonstrated that non-natural derivatives from the polycyclic poly-prenylated Acylphloroglucinol class of natural compounds (PPAP) are powerful antibiotics against mult-iresistant pathogens. Whereas the currently available reserve antibiotics are often based on complex cyclic peptides and, among other things, work by inhibiting the cell-wall biosynthesis of bacteria, the PPAPs do not; nevertheless, their antibiotic activity is similar to that of the reserve antibiotics.

Novel Photovoltaic Generations

Photovoltaic modules are to become more efficient, environmentally friendly and of a higher quality. That is one of the research objectives of the University of Stuttgart, which is looking into a new manufacturing process for photovoltaic modules in collaboration with the energy supplier EnBW. The intention is to use laser technology in the manufacturing process to achieve a higher efficiency level. In addition, the new process will do without environmentally damaging substances and heavy metals such as lead and cadmium and also promises to be more cost effective.

Photo: University of Stuttgart/IPV

"With the new process, whose development we now want to complete together", Professor Dr. Wolfram Münch, Head of Research and Development at EnBW, explains, "solar cells could harvest more photovoltaic power than today but using the same surface area and without the use of any poisonous components whatsoever".

The joint research project should be completed by spring 2020. The German Federal Ministry for Economic Affairs and Energy is funding the research project and EnBW is also covering some of the costs.

Tomorrow's Cancer Experts
The EU is funding international networks of doctoral candidates

About 1.3 million people in the EU die of cancer each year, which accounts for around a quarter of all deaths. To counteract this, Professor Markus Morrison, Director of the Institute of Cell Biology and Immunology (IZI), initiated an international research and training programme for young cancer researchers. Since then it has become a model for two more doctoral student networks, each of which is receiving about four million euro of funding from the European Commission's Marie-Skłodowska-Curie Programme.

"The more we understand about the cellular processes within the tumour, for example about why it isn't reacting to treatment" says Markus Morrison, "the better our ability to intervene". His "Cellular Biology and Applied System Biology" research group is studying the complex intracellular signal paths that decide whether a cell dies or, as is the case in cancer, begins to multiply exponentially. That is not a task that a lone scientist in an ivory tower could solve, which is why the EU networks are reaching out to doctoral candidates even while they are still in training. As the biologist emphasises: "the idea behind it is that young researchers are brought into contact with researchers from other countries and learn to work in both academic, clinical and corporate environments". The objective is to expand the horizon beyond disciplinary and cultural boundaries to find new solutions in cancer research. Up to 15 doctoral candidates will receive funding for three years within the networks. Each of these doctoral student projects is run in conjunction with an academic institution, a hospital and a European and occasionally, a non-European company:
the members of the network spend some time in each of these, which is why they spend up to nine months travelling during their respective funding periods. "This isn't like it is in traditional research consortia where I would ask a given collaboration partner to take some measurement or other and have them send me the result", says Morrison.

Far from Home

International movement has also come about due to the fact that master's graduates were only able to apply to participate in projects outside of their home countries. One of the candidates was the bioinformatician, Nivetha Krishna Moorthy. "I was over the moon when I was selected", says the Indian, who holds a Master's in Biomedical Technology from the renowned Sorbonne in Paris, "after all, Marie-Curie doctoral programmes are extremely prestigious. So, she packed her bags and relocated to Stuttgart at the end of January 2018 where she began her doctoral studies within the GLIOTRAIN network at the Institute of Cell Biology and Immunology at exactly the same time as an Italian woman.
Launched in September 2017, this is the newest of the three networks: its 21 collaborating partners from eight countries are targeting glioblastomas, the most common and most lethal brain tumours. About 85 per cent of all sufferers fail to respond to treatment and succumb within two years. Morrison explains the dilemma: "it's a huge research challenge, but because brain tumours are relatively rare among the populace as a whole, it has been difficult to get funding in the past".

Passport for the Brain

Krishna Moorthy will be using computer simulations to design and experimentally test a brain penetrating variant of an active agent previously refined at the institute. The compound in question is a fusion antibody designed to initiate the programmed cell death of the cancer cells. To enable the substance to cross from the bloodstream into the brain, Moorthy will add a molecular tail that

The young researchers currently working at the University of Stuttgart's Institute of Cell Biology and Immunology as part of the MEL-PLEX network for skin cancer research hail from India, Italy, Croatia and Bangladesh.

Photo: University of Stuttgart / Max Kovalenko

will function as a kind of passport for the blood-brain barrier. Krishna Moorthy is learning how to produce bespoke human antibodies at YUMAB, a biotech company based in Braunschweig, Germany. Her second trip will take her to the Royal College of Surgeons in Dublin, Ireland, where she will be investigating the distribution of the active substance in the bodies of laboratory mice. "I don't think I'll ever get the chance to learn so much after I get my doctorate", says Krishna Moorthy, "but it's definitely possible with this doctoral student programme, which enables me to gather experience in the private and public sectors and to make loads of contacts so that I'll eventually be able to choose where I'd prefer to work".

Krishna Moorthy's supervisor, Morrison, knows the GLIOTRAIN coordinator at the Royal College of Surgeons from his own time in Dublin. Morrison, a native of Osnabrück, spent 13 years researching and teaching at the same department before accepting a professorship at the University of Stuttgart in 2016. The first doctoral student network, MEL-PLEX, which served as a model for the other two, was founded by Morrison in Dublin in 2014. The young researchers in the network are studying malignant melanoma, sometimes known as black skin cancer. This type of cancer is becoming more widespread, particularly among fair-skinned Europeans. Morrison has managed to recruit 17 partners from eleven countries into the network.

It was by no means a foregone conclusion that the EU would provide funding for the network, which will continue its work till November 2018: "competition is fierce within the life sciences", explains Morrison, who has been coordinating the skin cancer network since its inception, "and there are many exclusion criteria that could result in an application being turned down". Morrison is convinced that the other doctoral student networks have also received funding due to the fact that the concept has proved successful. More than 400 young researchers applied for a place in the MEL-PLEX programme when it was first launched, which may be due, in part, to the fact that the salary offered in the Marie-Curie programme is slightly higher than the usual remuneration for doctoral students in this country.

Forecasting Cancer

The initial objective of the MEL-PLEX network is to gain a better understanding of skin cancer, which spreads to other organs at a relatively early stage, where it forms lethal metastases. Until recently, pa-

tients first diagnosed in this advanced stage faced certain death. Whilst such patients do survive a bit longer today, thanks to new therapies, they are still a long way from being cured. That is why the scientists want to develop new therapeutic agents and to be able to use biomarkers to predict the likely course of a given case of cancer or whether the tumour will be amenable to treatment with a particular therapy. "We want to be in a position to immediately identify those patients, who will benefit from a given therapy", says Morrison. The remainder will be spared undergoing a course of treatment that would be ineffective in their cases, but would be associated with unpleasant side effects. "Because modern therapies are getting more and more expensive", Morrison continues, "the costs would otherwise cripple any health service".

One member of Morrison's research group, the Italian Cristiano Guttà, is focusing on such predictive models for malignant melanoma. His initial work within the MEL-PLEX network involved determining whether the formation of certain proteins that play a role in cellular quality control processes is increased or decreased within tumour tissue. "This so-called autophagy enables cells to digest any organelles and proteins that may be damaged or no longer required, and to recycle the molecules" Guttà explains. The process can even result in the complete self-consumption and, therefore, death of the cell in cases of severe damage.

"I populate mathematical models with data relating to the proteins and clinical pathology and with information about how the proteins are internetworked then test the predictive potential of the models" says the molecular biologist with a penchant for computer science. In this way he was able to confirm that the cancer progresses at a faster pace in patients in whose cells this autophagic mechanism is wound down in the early stage of the disease. Guttà gained the knowledge of statics needed to analyse the protein data when working with Oncomark, a Dublin-based company specialising in cancer biomarkers, where he spent two months.

"There's a huge transfer of knowledge"

Guttà is currently collaborating with pathologists at the University Hospital of Bern to quantify two other proteins involved in the autophagic sequence in tumour biopsies. "In this context, I get to see how the data I use is obtained – from the biopsy to data collection", says Guttà enthusiastically. "At the same time, my Swiss colleagues need someone to teach them about systems biology. There's a huge transfer of knowledge and expertise". Later, Guttà wants to investigate the protein profile of advanced skin tumours, as there is evidence to suggest that the cellular recycling programme actually fuels the cancer in this stage.

Apart from Guttà, a Croatian woman and a colleague from Bangladesh are collaborating in the skin cancer network at the Institute of Cell Biology and Immunology. "You meet the whole world sitting round the lunch table", enthuses Guttà, "this cultural melting pot is something I encounter throughout the science community". The doctoral students participating in one of the networks meet every six months, either to present their results or to take part in advanced training courses coordinated by Morrison. "Whenever we all meet up", says Josip Skoko, "it's as if we've known each other forever. You've got one research group here and another right across Europe in which you discuss your project and come up with new ideas".

Like Guttà, Skoko is also researching malignant melanoma. He is part of the TRAINERS network that is coordinated by one of Morrisons researcher friends in Galway, Ireland. Skoko, a Croatian, came to Stuttgart at the same time as Morrison. The doctoral students in the TRAINERS group, which was inaugurated in 2014 and will run until 2019, are in-

terested in general with the quality control processes of intracellular proteins, which can be impaired in various diseases. In neurodegenerative diseases such as Parkinson's or Alzheimer's, for example, misfolded proteins are no longer broken down and tend to clump together, causing nerve cells to die off. That is precisely the effect the scientists hope to achieve in tumours by blocking the breakdown of proteins, which will ultimately cause the cancerous cells to die.

Junk Overload Kills Cancer Cells

Substances that inhibit activity in the proteasome, the cell's protein dismantling centre, have already been approved. Skoko has discovered that cancer cells also die off when he treats them with the same agent. However, before they die, the cells send out signals that also mobilise the body's own immune system against the cancer. “Our hope is that a proteasome blocker will boost the efficacy of the existing immunotherapies or targeted therapies used to treat skin cancer, as an immune response can be delayed in the former and the tumour can rapidly develop resistance to targeted therapies”, says the biologist.

Yet, Skoko is not satisfied with that: he wants to further accelerate the programmed cell death triggered by the proteasome blocker as well as boosting the immune-system response by seeking out key proteins within the protein quality control process

Fluorescent probes manufactured by genetic engineering enable the real-time observation of cell-death decisions in cancer cells, which contributes to the efficacy of new therapeutic agents. This image shows two human cancer cells whose colour changes and morphological modifications are indicative of apoptotic cell death.

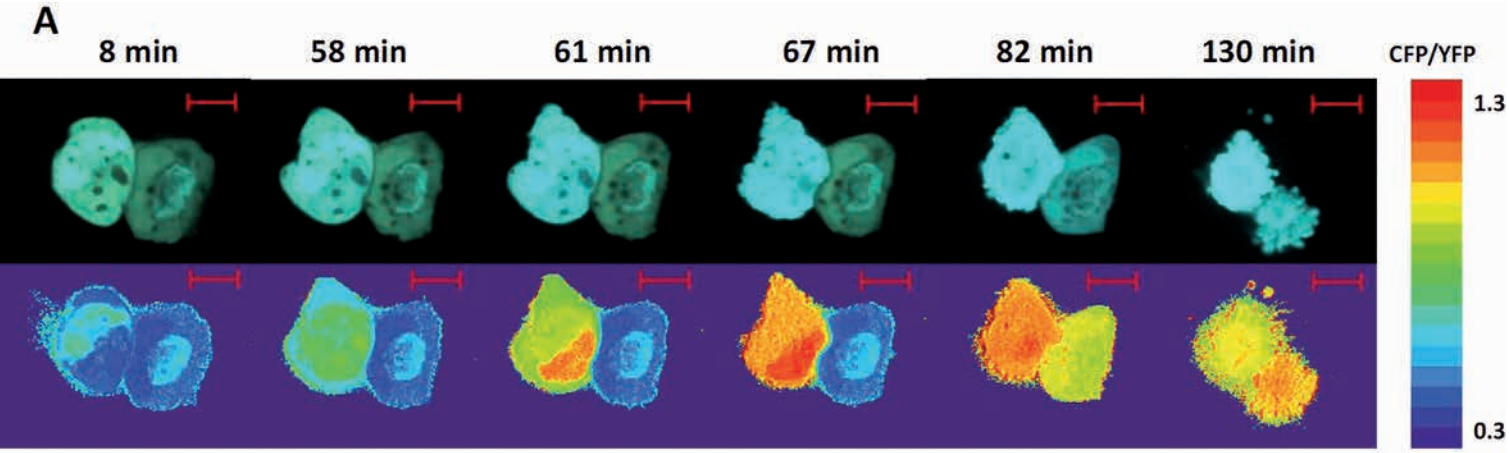


Photo: University of Stuttgart / IZI

and switching them on or off in a targeted manner. The extent to which the immune system's messenger substances, which the treated skin cancer cells then secrete, activate the immune system is still an open question. To this end, he initially plans to use biochips at one of the field offices of the diagnostics specialist, Randox, in Ireland, to detect all secreted immune system messenger substances. With the results in his pocket, he will then travel to the Catholic University of Leuven in Belgium to discuss his findings with experts in the subject of immune-system-induced cell death.

Future Perspectives

And, what will he do after his doctoral studies? "Well, we'll see", says Skoko, considering his options, "I might take up a post-doctoral post in a country I've never been to before. The most important thing", he adds, "is that, through the network, I get to hear about vacancies and new research projects before they've even become public knowledge". "Creating networks is also important for us as a research hub" says institute director Morrison. On the one hand, the doctoral students contribute new knowledge to the institute and, on the other, they function as ambassadors for the University of Stuttgart. "When our collaboration partners see that the doctoral students we send them are trained to the highest levels" he adds, "then their willingness to collaborate with us on other projects is significantly increased". As such, the doctoral student networks are beneficial to both sides.

Helmine Braitmaier

Not Just Hot Air

ICARUS combines protection from air-pollutant-related health risks with climate protection.

Public debate tends to revolve around two recurring topics: how to bring about a significant reduction in air pollutants, such as particulate matter and how to achieve internationally ratified climate protection targets to prevent the continued progress of global warming. To date, these two questions have been viewed separately. Researchers at the University of Stuttgart now want to help resolve these issues by developing a holistic concept for the City of Stuttgart aimed at air pollution control and minimising greenhouse gas emissions.

How could something be beneficial to the climate but damaging to the city's air? That seems like a paradox at first glance, but Professor Rainer Friedrich cites a simple example: replacing natural gas with wood-fired heating is CO_2-neutral, because wood is a renewable resource. “However”, as the Director of the Department of Technology Assessment and Environment at the University of Stuttgart’s Institute of Energy Economics and the Rational Use of Energy (IER) explains, “the health problems caused by the pollutants emitted by wood-fire heating plant far outweigh the benefits of the CO_2 reduction”. Until now, people have viewed climate protection and air pollution control as two separate challenges for which different departments within the relevant authorities are responsible. However, this approach is inappropriate, because the respective countermeasures have reciprocal effects, which is why the IER is participating in the ICARUS (Integrated Climate Forcing and Air Pollution Reduction in Urban Systems) project. In the course of the research project, which is scheduled to run until 2020 and has a project budget of 6.5 million euro, and is part of the “Horizon 2020” EU programme, institutes from various countries will be striving , on behalf

Photo: University of Stuttgart / Uli Regenscheit

of Stuttgart and eight other European cities, to find ways to maintain air purity and keep the cities climate neutral.

Short-term Measures, Long-term Vision

The University of Stuttgart plays an important role within the project. “We're initially developing and testing the methodology for Stuttgart before it’s implemented in the other cities”, explains Friedrich. In addition to the IER and the City of Stuttgart, other participants include Professor Günter Scheffknecht and his team from the Institute of Combustion and Power Plant Technology (IFK) as well as the Institute of Road and Transportation Science (ISV)’s Chair for Transport Planning and Traffic Engineering under the aegis of Professor Markus Friedrich. The ISV's traffic planning models can be used, for example, to calculate the effect of a city-wide congestion charge. The IFK is analysing air pollutants and associating them with their respective sources to discover what is responsible for which elements of the high concentrations of air pollutants. “For example, this has revealed that almost a quarter of the air-borne particulates in Stuttgart originate in wood-fired heating systems”, says Friedrich. “We have two objectives”, the physicist explains: “First, we want to identify particularly effective short- and medium-term measures”. To this end, the research-

Data collection by bike: the researchers took to the streets on their bikes to measure the particulate exposure at various points around the city

Photo: Universität Stuttgart/IER

ers have compiled lists of proposals, which they are currently discussing. The subject selected measures to a holistic assessment in terms of their respective advantages and disadvantages, such as associated health risks, costs, convenience and time savings or losses as well as climate protection. The respective research groups will then develop strategies for each of the model cities based on the most efficient measures. “However”, Friedrich continues, “these measures will only have a limited positive impact in terms of air pollution control and climate protection They won't help us to achieve the drastic improvements we wish to see. So, the second objective we've set ourselves is to develop a vision of how these cities could develop over the longer term, such that they really do become climate neutral and restrict air pollution to a bare minimum – and do so without negatively impacting the wellbeing and welfare of the resident populations”.

Going Off-Road

Friedrich cites an example from Stuttgart to emphasise the fact that the ICARUS project goes far beyond debates around statutory thresholds: The maximum exceeded threshold for PM10, a slightly coarser particulate, is around 50 micrograms per cubic metre of air on no more than 35 days per year. However, the lighter particulates are significantly more damaging. Significant chronic health risks are due more to long-term exposure than short-term peaks. Despite the fact that the threshold values for the lighter particulates are not being exceeded, the current air pollution level is damaging to health. “Therefore, whilst complying with threshold limits is necessary, it is far more important to minimise health risks from air pollutants”. The ICARUS study is set to deliver even more accurate results by taking account of the values measured at places where people tend to spend much of their time, rather than just those recorded at monitoring stations along the main roads. Above all, this applies to indoor spaces: “We want to determine which specific pollutants people are exposed to in their homes. This will enable us to consider health-protection measures that have nothing to do with the outside air”.

Based on the respective results, the intention is to develop a vision for a “green” Stuttgart by 2050. The most important areas to redesign will be traffic and heating systems, which are the main sources of the city’s current environmental issues. In the researcher’s opinion, the likely tendency will be to migrate both to electrically-powered systems – heating with heat pumps in combination with local and district heating networks in addition to solar heating systems. Transportation will be based on driverless vehicles, probably with electric motors, perhaps also with fuel cells in which the necessary hydrogen will be produced using power from renewable sources. These visions are based on contemporary science informed by projected future trends, “whereby”, says Friedrich, “we're well aware that our visions will not be realised in their current forms. However, they are necessary to point the way for developments in energy and traffic systems, And will be continuously updated to reflect new findings”. The City of Stuttgart and the other model cities have committed to discuss the results of the ICARUS project at the political level “so that our objective of bringing about a holistic improvement of air pollution control and climate protection won't remain just a vision”.

Daniel Völpel

Revolutionary Advance in Sensitivity
Drastic Improvement in Material Analytics through Quantum Technologies

Under the coordination of the University of Stuttgart, researchers are working on a technology, which will open up entirely new possibilities for nuclear magnetic resonance spectroscopy. Thanks to the quantum properties of certain impurities in diamonds, the sensitivity of the method can be increased by a factor of 1000. Pharmaceutical companies, laboratories, doctor's practices and, not least of all, personalised medicine will all benefit from this development.

The fields in which any technology finds application is determined by the price. If it costs a six- or seven-figure sum to procure it then it will remain a niche technology however well it performs. However, if the same technology were cheaper by a factor of 100 and the cost were to sink even lower to just a few hundred euro within a decade then that would amount to a revolutionary development: suddenly the technology in question would be available to anyone. This is precisely the sort of revolutionary development Professor Jens Anders, Director of the Institute of Smart Sensors (IIS) at the University of Stuttgart, has in mind when he talks about nuclear magnetic resonance spectroscopy. The electrical engineer is the coordinator of the EU's "Nanospin" research project, which is due to start imminently and will involve interdisciplinary teams from five European countries. The project participants have set themselves the goal of enhancing the sensitivity of nuclear magnetic resonance spectroscopy by a factor of 1000. "This will enable the development of systems that are either far more powerful than their predecessors or much smaller and cheaper than contemporary devices" Anders points out. To understand how this works, one needs to follow his train of thought from the extremely large – today's devices – to the extremely small, i.e., quantum effects. Ordinarily, the only contact most people have with nuclear magnetic resonance is when they're sent to the hospital for an MRI scan. Being "put in the tube" for a diagnostic scan involves lying in a device with a diameter of around two metres that generates images of one's tissues and organs. In some cases, patients are injected with a contrast substance. Apart from its use in medical practice, nuclear magnetic resonance is also used in the field of analytics, in which context the technology is used to probe materials and active agents with extreme accuracy, so accurately in fact that individual molecules can be identified with ease. This method is referred to as nuclear magnetic resonance spectroscopy and it is this application that Project "Nanospin" is all about.

Devices Big Enough to Occupy Entire Hangars

"It uses one of the quantum mechanical properties of atomic nuclei – their so-called nuclear spin", Anders explains. Each atomic nucleus behaves like a miniature magnet. A state of resonant excitation can be induced in these nuclear spins by exposing a material sample to a strong magnetic field and radiating energy into it via an alternating electromagnetic field after which they can be "read out" via a coil. Based on the resulting data, scientists can then draw conclusions about the structure and dynamics as well as the concentration of the molecules in questions. It is a powerful analytical tool – with large, powerful devices. "The most sensitive ones occupy entire hangars and achieve magnetic field strengths of 28 Tesla" explains Anders. That's about 3000 times stronger than a fridge magnet. Such powerful magnetic fields require correspondingly large currents in refrigerated magnetic coils. Whilst such gigantic machines are only found in a few specialised laboratories around the world, systems operating at around seven Tesla are relatively common, for example, in research in-

Professor Jens Anders (left) is Director of the Institute of Smart Sensors (IIS) at the University of Stuttgart and Coordinator of "Nanospin", an EU research project that units interdisciplinary teams from five European countries.

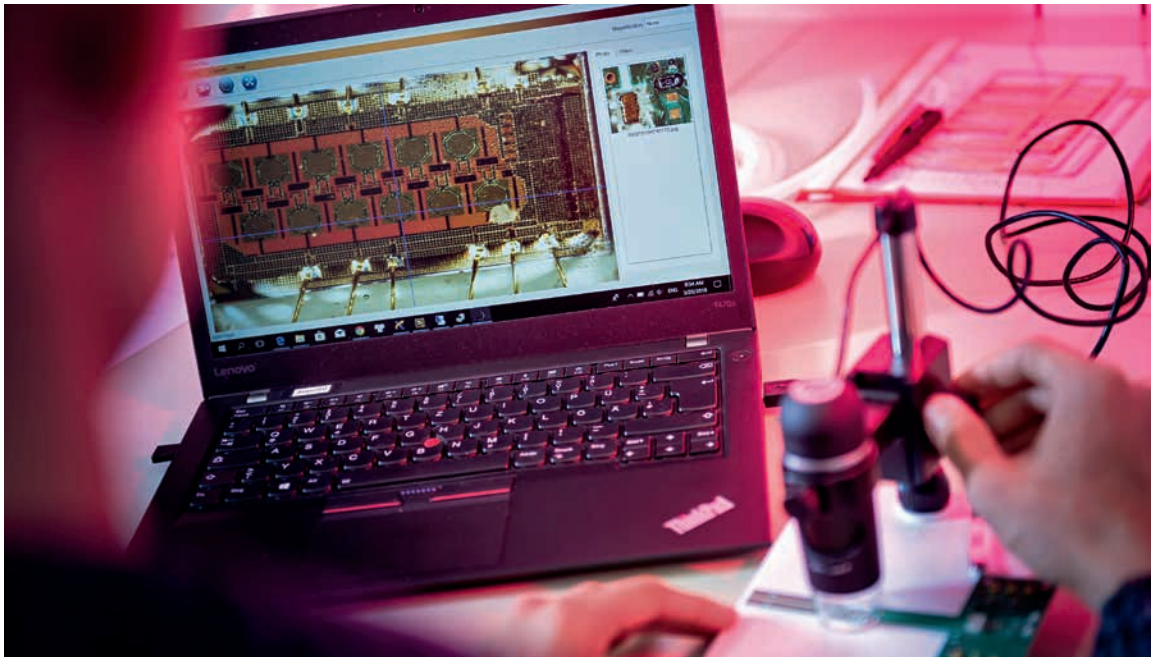
Photo: University of Stuttgart / Max Kovalenko

stitutes and pharmaceutical enterprises. "The main drawback of this technology", says Anders, "is its low sensitivity. Determining the composition of the molecules in a given sample, for example, takes the entire night". High turnover measurements of the type commonly used in pharmacological research are, therefore, often not cost-effective. Such measurements involve, for instance, the systematic evaluation of the efficacy of as many variants of pharmaceutical substances as possible. "Using nuclear magnetic resonance spectroscopy for this task is only possible if other methods have already been used to reduce the number of potential variants to the bare minimum", says Anders. "Only then will their number be small enough to subject them to time-consuming NMR-spectroscopic analyses". If, on the other hand, it proved possible to increase their sensitivity by a factor of 1000, then the time needed to complete the analyses would be dramatically reduced: what used to take all night could then be completed in just a few minutes.

Outwitting Nature

Unfortunately, it is hardly possible to increase the sensitivity of the process, as currently implemented, as the construction of magnets with even higher field strengths is subject to technical limitations. "Which is why we're taking a completely different approach in our project", says Anders. The scientists exploit a quantum mechanical effect based on F-centres in artificial diamonds, the so-called dynamic nuclear polarisation effect. F-centres are deliberately created impurities, produced, for example, by inserting nitrogen atoms, which absorb specific light wavelengths thus giving the inherently colourless diamond a specific hue. Ultimately, this makes it possible to align more atomic nuclei in the sample under analysis than would ordinarily have been possible. The more aligned atomic nuclei, the higher the sensitivity of the NMR-spectroscopic measurements, indeed by the factor of 1000 cited by Anders. An interdisciplinary team of researchers from five European countries are collaborating in the "Nanospin" project to achieve this ambitious-sounding goal. The groups headed by Professors Fedor Jelezko and Martin Plenio from Ulm University include proven experts in the study of the dynamic nuclear polarisation effect. In the course of the project, the Ulm-based researchers will work to advance the current understanding of the underlying physical principles to move the subject "from the realm of theoretical physics to the application laboratory" as

Nuclear magnetic resonance spectroscopes that are more sensitive by a factor of 1000 – that would enable the production of devices that were either much more powerful or much smaller and cheaper.



University of Stuttgart / Max Kovalenko

Anders puts it. Also onboard is NVision Imaging Technologies, a spin-off company co-managed by Jelezko and Plenio, which will contribute to the industrial implementation of the nuclear magnetic resonance spectroscopy research results. Jens Anders' Stuttgart-based group will in turn be responsible for the sensor-related implementation. In addition, with the Belgian University of Hasselt and the Czech Academy of Sciences two institutes are involved in the project that will focus on the materials-science perspectives. They have many years of experience with imperfections in diamonds and create them in a targeted manner. The Wigner Research Centre for Physics will complement this materials-science expertise with a theoretical component: physicists at the institute are using simulations to investigate the properties of the diamonds. And finally, the Wageningen University & Research augments the "Nanospin" project team with experts in nuclear magnetic resonance. "Within their respective disciplines", says Anders, "all project participants are among the world's leading experts and, through the University of Stuttgart, for the first time, the engineering side is represented in a research project of this kind, which focuses on so-called hyperpolarised nuclear magnetic resonance spectroscopy. That's a unique configuration made possible through intra-European collaboration". Project "Nanospin" is part of a European network known as "QuantERA", in which 32 organisations from 26 countries have banded together to advance research in the field of quantum technology.

Miniaturisation or Sensitivity Increase

The "Nanospin" project partners have set themselves three objectives, which they want to achieve within the three-year project period. First, they want to prove that by exploiting imperfections in

diamonds, NMR spectroscopic measurements are possible even at the level of single molecules. That would deliver new insights in the field of molecular biology. Second, the researchers want to implement hyperpolarisation technology on chips to enable the production of portable devices. This would limit the magnetic field strength to around one Tesla but this would be compensated for by the one-thousand-fold increase in sensitivity. “Our vision for the medium term”, explains Anders, “is to enable the production of affordable NMR spectrometers that would sell for less than 10,000 euro, which would make them economically viable for, for example, blood analysis in GP surgeries”. Within a decade, the electronic engineer hopes, chip-based devices could become so miniaturised and simplified that they could be acquired for just a few hundred euro. “That would be of interest in the field of personalised medicine. For example, patients could screen their own blood for specific disease markers in the same way that diabetics currently measure their own blood sugar levels”. The third objective involves high-end NMR spectrometers that currently occupy entire hangars. The researchers want to develop an add-on system for these with which existing operational devices can be retrofitted to shorten the mensuration times for typical experiments by far more than a thousandfold. Achieving any one of these objectives would be an enormous step forward by itself.

Michael Vogel

Living Chemical Factory
Using reprogrammed bacteria to conserve crude oil reserves

Paints, varnishes or cleaning products: most contemporary chemical products are made from crude oil and natural gas. Researchers in the EU, including some at the University of Stuttgart, want to change this situation by coaxing the soil bacteria Pseudomonas putida to produce commodity chemicals from sugar. To achieve this, they are using tools from the field of synthetic biology.

Humans have already been using microorganisms for thousands of years to make beer, wine, sourdough and cheese. One of the first industrial mass-production applications began in 1916 with the fermentation of starch or sugar by bacteria from the Clostridium acetobutylicum genus to produce the solvents Acetone and Butanol. The biochemist and later President of Israel, Chaim Weizmann, had previously isolated the bacteria and optimised the biotechnological process. However, following the Second World War, the burgeoning petrochemical industry made it more cost-effective to synthesise chemicals from crude oil rather than have bacteria do the work. Now, faced with rapidly depleting crude oil reserves, interest in bacterial factories is once again increasing. Professor Ralf Takors, Director of the Institute of Biochemical Engineering (IBVT) at the University of Stuttgart, is less interested in Acetone and more, among other things, in microbiologically produced Butanols and their gaseous descendants, Butene and Butadiene. Initially, Butanol was primarily needed for the production of artificial rubber. Today, it is widely used as a solvent in the paints and varnishes industry and as an additive in cleaning products. It also serves as a precursor material for the aromatic substances used in perfume and is under discussion as a potential biofuel component. The Butanol derivatives are used, for example, as intermediates for plastics and tyre rubber. Thus far, they have been produced exclusively by chemical means.

Photo: University of Stuttgart / IER

Mission statement of the EU's Empower-Putida project: the project focuses on the exploitation of the microorganism Pseudomonas putida for industrial applications. The objective is to use synthetic-biological methods to modify the strain such that it will be able to produce a wide range of basic and fine chemicals.

Like Weizmann over a century ago, Takors and his team also use sugar as a basis for the microbial fermentation process, but use other bacterial species, which have tended to be rather neglected by bioengineers. Floating in the murky culture fluid in a three-litre glass fermenter at the Institute of Biochemical Engineering are bacteria of the genus Pseudomonas putida, or more precisely of the KT2440 strain, which are being pumped in a circular motion via an extensive system of hoses. In another 200-litre bioreactor, Takors' researchers are testing the biotechnical mass production of biobutanol and its derivatives.

"Omnivores" with Great Potential

"This strain has several benefits", says the bioprocesses engineer, "it can tolerate both the accumulation of organic solvents, such as Butanol, and oxidative stress, which can occur during the cultivation process in gigantic biore-

Photo: Adobe Stock / abcmedia

actors". Takors' laboratory "pets" originated in the soil where they live on plant roots, feeding on almost anything they can find. They can even decompose toxic substances or evacuate them from the cell thanks to inbuilt "export pumps", which is why they are often found on polluted sites. In addition, they also produce the cellular reducing agents NADH and NADPH. They serve – for enzymes, for example – as cofactors that counteract oxidative stress. On the other hand, bioengineers can exploit this surplus reducing agent to transform sugar into significantly more chemically reduced products than has hitherto been possible from a bioengineering perspective. It is this natural robustness that will potentially enable Pseudomonas putida to become the new stars of bioengineering.

Until recently, bioengineers were usually thwarted by the low tolerance levels of their chosen bacterial strains to organic solvents. Even Weizmann only achieved a meagre harvest with his bacteria. "In high concentrations", Takors explains, "the bacterial strains that have been used to date consume a lot of sugar and energy just to deal with these harsh conditions, which reduces their efficiency". However, high production yields are necessary to keep the production costs down, as the existing oil-based products already sell for ridiculously low prices of less than one euro per kilogramme. Because, unlike Weizmann's bacteria, Pseudomonas putida does not naturally produce biobutanol and its derivatives, it has to be "empowered" to do so by means of synthetic biology. Researchers are currently collaborating in the Eu project "EmPowerPutida" to develop ways of genetically reprogramming the metabolism of Pseudomonas putida such that it will produce these products in addition to a particular herbicide. "We want to use this example to demonstrate that it functions successfully, which will increase the strain's acceptance for industrial applications", says Takors. He is collaborating in the project together with his colleague Bernhard Hauer, Director of the Institute of Biochemistry and Technical Biochemistry (IBTB), and other partners from Germany, the United Kingdom, the Netherlands, Portugal, Switzerland and Spain.

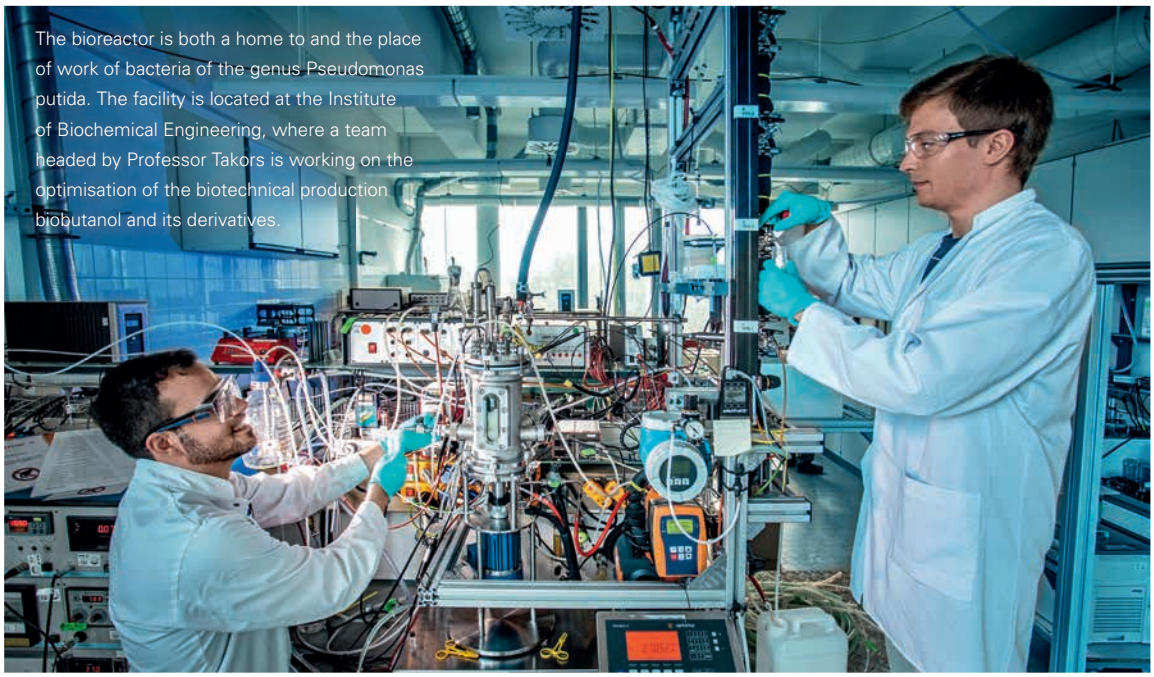
Conversion to Bacterial Factories

"The biggest challenge was to coax the omnivorous Pseudomonas putida into not consuming the products it makes itself", says Takors. To this end, the partners first reduced the bacterium's genome to the basic functions it needs to survive. Bernhard Hauer's

team then equipped the bacterium with the genetic material needed to create novel metabolic pathways that culminate in the desired product. “We also hypothesise based on enzymes from other bacteria, look at their structure and refine the enzymes with the aid of computer-based and evolutionary-learning methods such that they will, for example, accept other substrates”, Hauer explains.

To further increase yields, the partners ensure that the bacterial cell opens all available channels for the absorption of sugar and primarily uses it for subsequent production activities rather than to fuel its own growth. Takors’ research group designed novel, patentable regulatory circuits and gene switches intended to ensure that the bacteria continue to produce the desired products even under adverse conditions. As Takors explains: “the bacteria mustn't shut down their metabolic processes when conditions for growth are poor, but should instead maximise production”. The EU is providing over 5 million euro of funding for the four-year project via its Horizon 2020 framework programme. By the end of the project next year, the researchers want to further optimise both the production strains and the production process in large fermenters to achieve even greater yields. “All we could have done ourselves would have been to develop the enzymes” says biochemist Hauer. “The nice thing about the EU project is that, with the aid of the other partners, we were able to assemble everything to produce a viable, functioning bacterial strain”. This was one of just three projects submitted in response to the original call for applications in relation to Synthetic Biology that received funding, of which two involved Pseudomonas putida. As Takors emphasises: “this demonstrates the importance of these bacteria”.

Helmine Braitmaier



The bioreactor is both a home to and the place of work of bacteria of the genus Pseudomonas putida. The facility is located at the Institute of Biochemical Engineering, where a team headed by Professor Takors is working on the optimisation of the biotechnical production biobutanol and its derivatives.

Photo: University of Stuttgart / Uli Regenscheit

Lightweight Aircraft Construction Made Easy

The production of fibre composite components is set to get faster

Photo: University of Stuttgart / IFB

A Euro-Japanese research consortium wants to eliminate existing weaknesses in fibre composite materials that are already widely used throughout the aviation industry. The intention is to enable aircraft manufacturers to meet rising demands in air travel whilst building more energy-efficient aircraft. The University of Stuttgart's Institute of Aircraft Design (IFB) is also onboard.

Looking at the newest version of the Airbus A350, one would not necessarily associate the passenger plane with the word “lightweight”. Yet, in a certain sense, that's just what it is. 52 per cent of its airframe – fuselage, wings, steering gear and landing gear – is made of carbon fibre reinforced composites. Just less than half is made of metals, which are two to five times heavier. Boeing cites similar figures for the lightweight structural components in its most recent 787 model as those quoted by its European competitor for the A350. “Lighter aircraft mean lower kerosene consumption”, says Dr. Stefan Carosella, summarising the aviation industry’s interest in fibre reinforced composites. And, in addition to propulsion and aerodynamics, the weight of any passenger or freight aircraft is one of the crucial parameters for more efficient machines. As group leader at the University of Stuttgart's Institute of Aircraft Design, Carosella is focusing his research on carbon fibre reinforced composite technology. “Whilst carbon fibre reinforced composites are already well established in the field of aircraft construction, they do have their problems”, he says. The difficulties to which the aerospace engineer is referring emerge in the production process: It takes too long! This is because, for fibre composites to achieve the necessary level of rigidity, they have to dry. This is done at high temperatures and under pressure in an autoclave, a kind of pressure cooker. “In the aircraft construc-

tion industry, these autoclaves are kilns the size of a house capable of housing fuselage structures of up to ten metres in length and six metres in diameter", Carosella explains. “The curing process takes days under ten times atmospheric pressure and at 180° Centigrade”. After all, the gigantic autoclave first needs to be heated and then cooled again.

Collaboration with Japan

In its current form, it is virtually impossible to expedite this process making it a production bottleneck. Manufacturers are currently managing to complete just 25 to 30 aircraft per month. However, they would need to double their performance to meet the predicted demand. The EFFICOMP (Efficient Composite Parts Manufacturing) research project, in which Carosella is also involved at the institute, is also intended to help them achieve this goal. The objective of the project, which began in April 2016 and will run for three years, is to develop a more efficient process for the production of fibre composite components. The four project partners have around 1.7 million euro of EU funding available for this purpose. In addition, the Europeans are collaborating with four Japanese partners – an EU strategy designed to ensure that the European research partners operate at an international level in important fields. Whilst the Japanese sub-consortium receives funding from Japanese sources, there is a joint project plan and the two sub-consortia share their research

"Out-of-Autoclave-Prepregs" are carbon fibre mats soaked in a resin. They are left to cure in a mould with an integrated heating system rather than in an autoclave.

Photo: University of Stuttgart / IFB

findings. The Japanese are conducting research into new lightning protection concepts for aircraft with integrated fibre composites. Lightning strikes are actually dissipated via the aircraft's metallic outer shell, which functions as a Faraday cage, just as in a car. However, fibre composites are poor conductors of electricity, which means that copper wire cages need to be integrated, which has a negative impact on weight. The Japanese researchers are working on a lightning protection concept that has less impact on weight. On the European side in turn, research is being conducted at the Delft University of Technology into better ways of joining cured fibre composite components, whereby the methods currently approved by the aviation authorities involve the use of adhesives and rivets. Airbus, which is responsible for overall project coordination, is looking into ways to reshape thick fibre composite components, for example, by pressing them into shape, whereby, in this context, "thick" starts at just ten millimetres. And, the German Aerospace Center is evaluating all new processes developed in the course of the project from an economic perspective.

Curing in a Heated Tub

Within the EFFICOMP project, Carosella's institute is developing a production process that does away with the autoclave. "We're using so-called Out-of-Autoclave-Prepregs for this", the engineer explains. These are carbon fibre mats soaked in a resin. "Prepregs are already used in aircraft construction because they facilitate the highest level of structural stability due to the prolated arrangement of the fibres". They are cured in a mould within the autoclave. Carosella and his team get by without the autoclave. They had already developed a process for the fabrication of fibre composites for the automotive industry in an earlier research project, which they are now applying to aircraft. It works at low temperatures and under normal atmospheric pressure conditions. To achieve this, the scientists place the Out-of-Autoclave-Prepregs in a plastic mould with an integrated heating system. "This means we don't need to raise the heat to such an intense level and, because the mould is thin and has a low mass, it can be heated and cooled much faster". This reduces waiting times and, therefore, the processing time. So, the concept has already been proven: now it's all about adapting the process to function in an actual industrial setting, which will inevitably involve a certain amount of automation. As currently practiced to some extent in aircraft construction, the Prepreg structures are also fabricated by robots in the Stuttgart process. "Our objective", says Carosella, "is to build a small demonstration plant capable of producing fibre composite components with surface areas of three to four metres. We're already better than the autoclave by a factor of five". That would mean two and a half instead of twelve hours processing time.

Michael Vogel

Targeted Manipulation: Airflow Across the Wing

Future aircraft generations should fly in a more environmentally friendly manner

Among the components whose modification could reduce noise, fuel consumption and exhaust emissions within the aviation industry is the engine. However, in conjunction with existing aircraft wings, the more efficient engines of tomorrow will also result in certain negative consequences. To find a solution, the University of Stuttgart's Institute of Aerodynamics and Gasdynamics (IAG) is collaborating with an international research team in the INAFLOWT project, which is part of the EU's CleanSky 2 research programme.

Aircraft manufacturers are predicting an increase in air traffic of over four per cent over the coming two decades. By itself, this increase will make it necessary for aircraft to consume less fuel and to make less noise. The Advisory Council for Aeronautics Research in Europe (ACARE), an advisory body to the EU, has issued a number of ambitious recommendations for the European aviation industry in connection with this. The goal is to achieve a reduction in CO2, nitrogen oxide and noise emissions by 2020 of 50, 80 and 50 per cent respectively compared with the best technology available in 2000, and to achieve even further reductions of 75, 90 and 65 per cent respectively by 2050.

One starting point for improvements in these areas are the propulsion units, which give the aircraft the necessary thrust. To do so, they suck in huge volumes of air and blow it back out, which causes an enormous din, particular upon take off. Propulsion units with an extremely high bypass ratio are considered particularly promising in terms of reducing this noise. In engines of this type, a large part of the air entering the propulsion unit flows around the outside of the combustion chamber whilst only the smaller proportion flows through it, which increases the efficiency of the engine.

Actuators Provide for Lift

Nevertheless, these so-called Ultra-High-Bypass-Ratio (UHBR) propulsion units, which are still in the research stage, have much larger diameters. "This perturbs the aerodynamic profile of the wings under which they are attached", explains Dr. Thorsten Lutz, Group Leader of Aircraft Dynamics at the University of Stuttgart's Institute of Aerodynamics and Gasdynamics. The UHBR impair the dynamic flow of air across the wing, which can result in flow separation, which, as Lutz explains,

Air flows around the wind and propulsion unit in the model. In propulsion units with an extremely high bypass ratio, a large part of the air entering the propulsion unit flows around the outside of the combustion chamber whilst only the smaller proportion flows through it, which increases the efficiency of the engine and reduces noise.

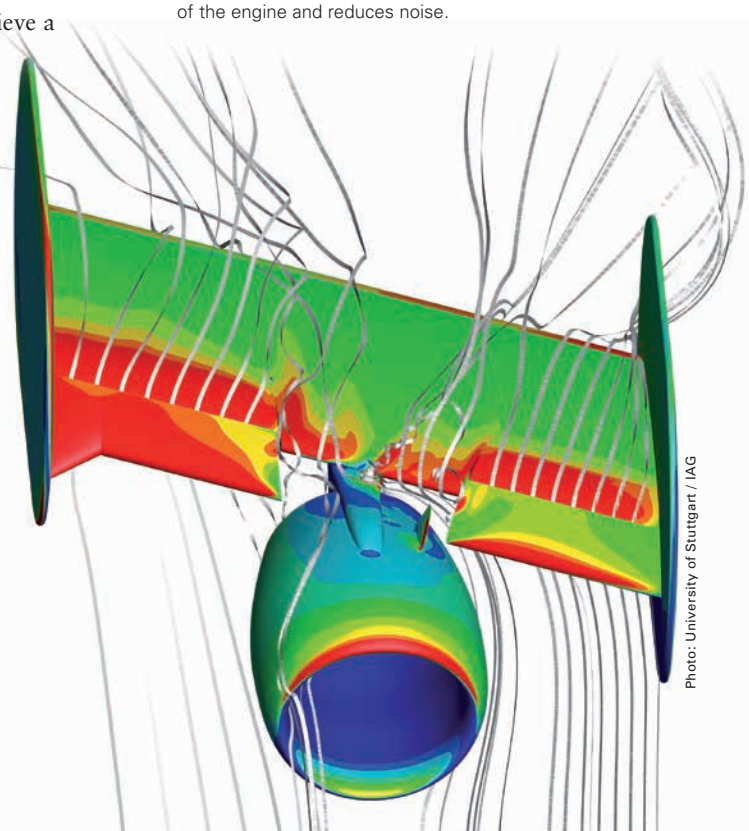


Photo: University of Stuttgart / IAG

Photo: Adobe Stock/ Airbus / A. Doumenjou

results in “a reduction in the potentially achievable lift”. So-called actuators, integrated within the wings, could remedy this situation. Actuators are engine components that convert electrical signals, such as commands from a control computer, into mechanical motion, or which convert other physical properties, such as pressure or temperature. How they would have to be dimensioned is what the Stuttgart-based institute is researching in collaboration with four other partners from Israel, The Czech Republic and Russia in the context of the EU's INAFLOWT project.

Modified Flow Field

“Actuators, such as these, can blow out or suck up air via small openings on the leading edge of the wing”, Lutz explains. This modifies the flow filed and, therefore, as it were, counteract the flow separation caused by the UHBR propulsion units. “To work out the correct dimensions and control the timing of these actuators”, Lutz continues, “one has to understand the air flows, which become very complicated due to the blowing and sucking, and are also extremely difficult to calculate numerically”.
The task assignments within the project team are as follows: the two Israeli partners will develop the actuators and build a small model to be tested in their own wind tunnel; the Czech researchers will simulate the current flows inside the actuators with a view to enhancing their geometry, and Lutz and his team are responsible for simulating the reciprocal effects in the air flows around the wings and propulsion units in the absence of the actuators. “We have access to supercomputers at the University of Stuttgart's High-Performance Computing Center (HLRS), which will be absolutely necessary if we're to perform the calculations for this complicated model at all”, says Lutz. And, finally, the Russian partners will test the results on a larger model in one of the biggest wind tunnels in the world. The project results should be available by the end of 2020.

Michael Vogel

By Hot Air Balloon to the Stratosphere

Cosmologists are working on more flexible and cost-effective telescope platforms

The European Stratospheric Balloon Observatory Design Study (ESBO DS) – to date, only a handful of scientists in Stuttgart, Tübingen, Munich, Spain and Sweden have set their sights on establishing a European balloon-based observatory as a long-term objective. But, the international team drawn from the fields of Spaceflight, Astronomy, Astrophysics and Extra-terrestrial Physics is set to grow to around 20 experts in the near future.

"Untethered from the Earth, the great balloon is floating completely weightlessly in the sky" – For researcher Philipp Maier, dreams based loosely on David Bowie's "Major Tom" are successively coming true. More flexible, lighter, more cost-effective, with room for larger telescopes: that's the motto of the engineer from the University of Stuttgart's Institute of Space Systems (IRS). Maier is the ESBO DS project coordinator. The three-year interdisciplinary project, which is funded under the EU's Horizon 2020 Agenda, is aimed at augmenting the field of Astronomy research environment with images of stars observed from an altitude of 30 to 40 kilometres above the Earth, taken from a helium-filled lighter-than-air balloon with a diameter of between 50 and 70 metres. The University of Stuttgart, which is acting as project consortium coordinator, will be playing a leading role in the effort. The Stuttgart-based researchers are responsible for building the telescope for the visible light spectrum, whilst the University of Tübingen will supply the main scientific instrument for observations of primarily variable stars in the ultraviolet range. The Swedish Space Corporation (SSC), according to Project Coordinator Maier, "one of the most experienced organisations in the world for sounding rocket and stratospheric balloons", will build the balloon gondola, which will serve as an instrument platform.

Clean High-Altitude Flight

The higher into the atmosphere the flight goes, the fewer atmospheric, and therefore, obstructive particles will obscure the telescope's view. Beyond a majority of the Earth's obstructive atmosphere, at altitudes of between 12 and 14 kilometres, at which the airborne telescope SOFIA orbits, for example, there is a largely unobstructed view of planets in other solar systems. "This enables research into whether or not our solar system is anything special", says Maier: "We can determine whether planets and also atmospheres in other solar systems may support life".

However, as NASA's Hubble mission shows, the cost of such high-altitude flights also increase astronomically. It was almost a billion euro over budget because another space shuttle had to be launched to rectify a polishing flaw in the telescope's main mirror. In terms of interstellar research, the ESBO DS project is far more modest, both in terms of cost and the entry-level size of the telescope. The latter will have a diameter of 50 centimetres in the prototype. As Maier explains: "the cost of a major balloon mission with a balloon diameter of 70 metres are typically between 15 to 20 million euro".

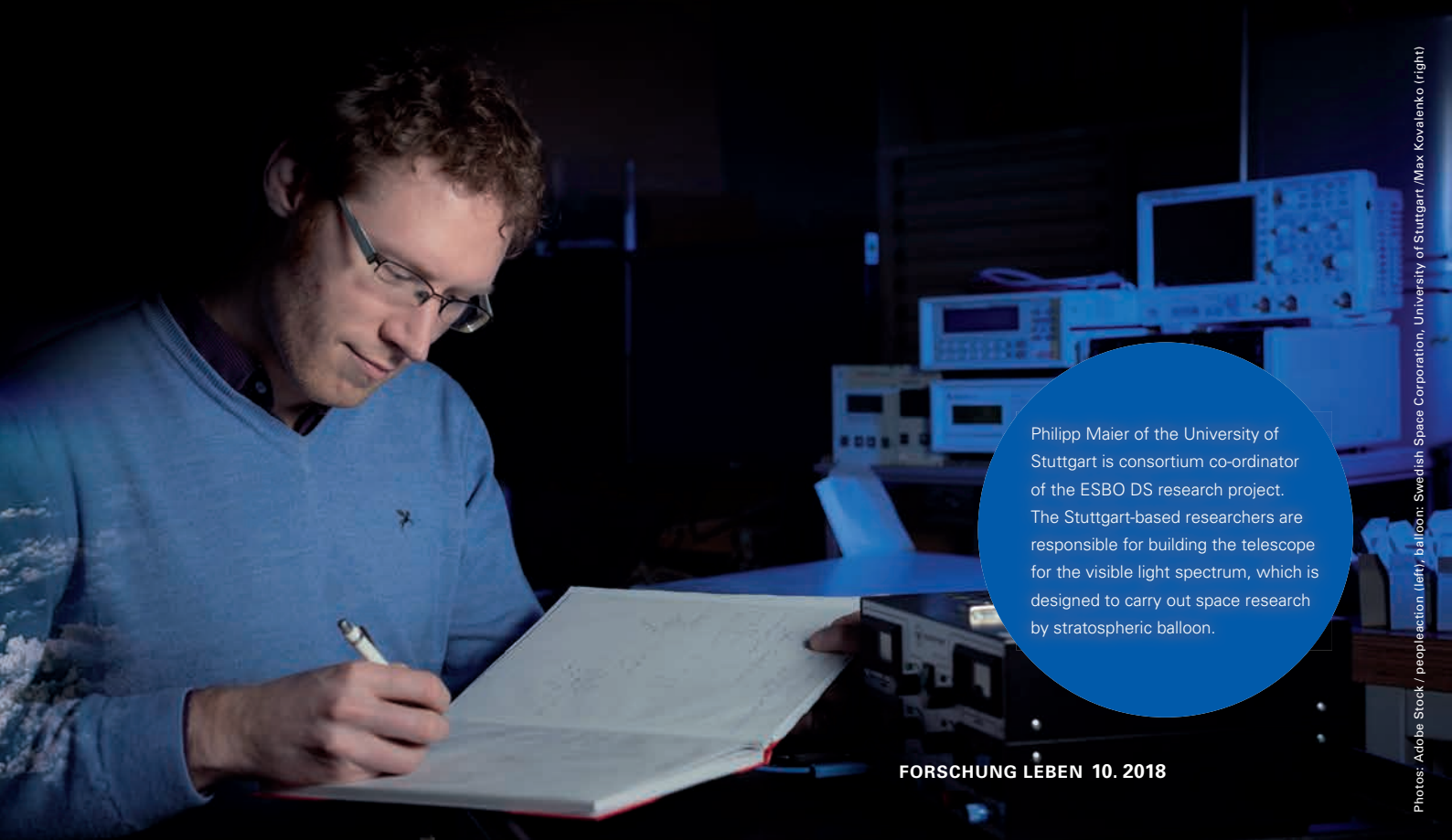
The project he is coordinating will be addressing two problems simultaneously: Earthbound observatories are limited by the atmosphere, whilst satellite-borne missions at altitudes up to the second Lagrangian Point (L2 Point), such as the Herschel observatory, are limited by cost. Balloons, on the other hand, can be launched multiple times: the liquid helium required for cooling can be replenished and repairs can be made between flights. For each mission carried out under the ESBO DS project and its precursor project, ORISON, in which the IRS was also involved, different instruments are carried aloft depending on the respective research objectives, which makes the balloon flights affordable for a larger research community. The only lim-

itation is that visibility is a bit restricted, even at an altitude of 30 kilometres, Which is why Maier sees balloon-based research as supplementary to, rather than a replacement for, satellite-based space research.

Balloon-based Observatories with Potential

The objectives of the EU project are ambitious: In the longer-term, the ESBO team plan to launch a long-wavelength-infrared telescope with a diameter of five metres. "The size just needs to be increased for a better spatial resolution" as Maier explains. The ESBO DS (prototype) will eventually result in the ESBO, at which time the findings from research carried out in the ultraviolet to near-infrared ranges during both the ORISON and ESBO DS projects will inform the construction of a long-wavelength-infrared telescope. As such, the ESBO would become a long-term research facility for many institutes and research facilities. As Maier summarises: "We want to create an organisation that operates various balloon-based telescopes and provides observation timeslots and transportation opportunities for scientific research". The project encompasses a range of topics from innovative optics to lightweight construction, which could be of interdisciplinary interest to many different institutes. That gives the project participants cause for optimism regarding the future of the ESBO. The next generation of long-wavelength-infrared observatories should become available within a period of around 15 years, based on the findings from the prototype project.

Susanne Roeder



Philipp Maier of the University of Stuttgart is consortium co-ordinator of the ESBO DS research project. The Stuttgart-based researchers are responsible for building the telescope for the visible light spectrum, which is designed to carry out space research by stratospheric balloon.

Photos: Adobe Stock / peopleaction (left), balloon: Swedish Space Corporation, University of Stuttgart /Max Kovalenko (right)

Do You Drive?
BRAVE identifies the challenges facing automated vehicles

How will we be driving in 2030? This question is currently making waves among politicians and the general public. In addition to the engine type, the question pertains to digitisation of transport in particular. At the European level, the BRAVE research project focuses on what drivers can expect from increasingly automated vehicles.

Seven countries, eleven partners, one goal - to bridge the gap between what the driver requires from an automated vehicle and what is actually on offer. In addition to five European countries, California and Australia are also involved to ensure a larger-scale transfer of knowledge. The German partners are the University of Stuttgart's Fraunhofer Institute of Human Factors and Technology Management (IAT), the Fraunhofer Institute for Industrial Engineering (IAO) and the University of Erlangen-Nuremberg's Social Sciences Institute (IfeS).
"BRAVE" stands for "BRidging Gaps for the Adoption of Automated VEhicles". The project won EU approval due to its objectives, which, according to the two IAT researchers Nicole Fritz and Sven Bischoff are to: "reveal niggles, weak points and improvement potential in relation to driverless vehicles and specifically from a user perspective". To this end, the IfeS will oversee a large-scale survey involving hundreds of citizens from the seven participating countries. "We want to explore the desiderata of the survey subjects and, as far as possible, to implement

Researchers are surveyed to reveal niggles, weak points and improvement potential from a user perspective Their findings and proposed solutions will then be demonstrate in a number of prototypes.

Photo: University of Stuttgart / Uli Regenscheit

Nicole Fritz and Sven Bischoff of the University of Stuttgart's IAT are currently developing innovative concepts for car interiors and cockpits.

Photo: University of Stuttgart / Uli Regenscheit

them in prototypes", Fritz explains. The ultimate objective is to arrive at a holistic view that recognises the technical challenges whilst taking account of end-user concerns.

From Driver to "Drivenger"

Fritz, Bischoff and a colleague from the Fraunhofer Institute are responsible for designing and developing innovative interior and cockpit concepts. The overriding question for the Stuttgart-based researchers is how people will interact with automated vehicles. What are the requirements of drivers who are increasingly becoming "drivengers", i.e., a cross between driver and passenger? How will automated vehicles interact with so-called VRU's (vulnerable roads users, i.e., pedestrians or cyclists)?

To ensure that drivengers react appropriately, the cockpit of the future must be intuitive and the relevant driver tasks easily learnable and applicable to many situations. Contemporary technologies could lead to a situation in which drivers gradually get out of the habit of braking because the vehicle takes on the task itself. But, what would happen if the system failed to recognise an obstacle? "Then I might brake too slowly", says Fritz. So, in a further step, it will be necessary to discover what the driver has detected and what not, for, if he or she is not completely focused on the task in hand, then the vehicle would have to warn him of her in good time. The phase in which problems of this kind and others are identified is currently underway and will be followed by another phase in which those issues will be identified, which can be addressed in the context of the project. By May 2020, when the EU project is due to finish, Fritz and Bischoff hope to be able to present some initial approaches to potential solutions, which will support the rapid and safe introduction of automated vehicle such that customers and other road users will see them as a positive thing.

Susanne Roeder

Highly Recommended
Analysis points politicians in the right direction for CO_2-neutral energy systems.

How must the European Union arrange its energy policy to ensure that it will no longer be necessary to generate electrical power from coal, oil or gas by 2050? An international research group, in which seven researchers from the University of Stuttgart's Institute of Energy Economics and the Rational Use of Energy (IER) are also participating, wants to address this question.

To find out what the EU needs to mandate to achieve a carbon-neutral energy system, researchers from eleven European institutes are compiling an integrated analysis based on multiple criteria in the course of the REEEM (Role of technologies in an Energy-Efficient Economy – Model based analysis of policy measures and transformation pathways to a sustainable energy system) project. This analysis of all relevant factors is intended to show how technologies, such as wind and hydraulic power generation, could be deployed synergistically for the purpose of decarbonisation and to identify the economic ramifications of different combinations of these technologies. In addition, the researchers will also be considering other aspects, such as air pollution control and social acceptance. As Dr. Ulrich Fahl, Head of the Energy Industry and Sociological Analysis Department at the IER, explains: "this integrated approach demonstrates that we are not simply focusing on the economy or technology, but are also looking at such things as social acceptance issues, which will give us a broader understanding of the potential ramifications".
The analysis will ultimately result in concrete recommendations about courses of action we already need to be initiating today to achieve the specified targets in 30 years' time and which potential developments can remain undecided for the time being. The objective of the EU's Strategic Plan for Energy Technology (SET-Plan) is to reduce greenhouse gas emissions by 80 to 95 per cent by 2050. "Specifically", says Fahl, "the project is about the detailed planning for the European emissions trading scheme, among other things". The current relevant regulations will remain valid until 2020. One of the questions the researchers are investigating is how it needs to be modified to be more effective going forward. But, the question list also encompasses such aspects as more effective support measures for building insulation that promise to be more successful than the current German Energy Saving Ordinance (EnEV). The question of how these measures and the technological developments match will remain at the forefront of the research teams thinking.
Initially, the researchers will investigate the opportunities for action open to the EU: what things could be aligned throughout Europe? Which framework conditions could be specified? The crux of the matter, in this context, is coordination between the various member states. In a second step, the group will consider how a "coalition of the willing" could promote European unification. And, in the third step, the researchers will look at the extent to which national, protectionist outlooks affect specific parties. Based on the results, they then plan to determine whether their energy policy recommendations would need to differ depending on which of the trends comes to dominate.

Computers Have a Lot to Do

The IER plays a central role in four of the five work packages that together make up the EU project, which has been granted four million euro of funding. For example, the Stuttgart-based engineering managers and economists will be investigating the ramifications of innovations in the energy sector. They are creating an energy-system-integration model to show how individual developments in the

Photo: University of Stuttgart / Daniela Leitner

construction, transport, power supply and industrial sectors could be integrated. Another research group is analysing the impact of the European energy system on health, air pollution control, climate protection and environmental conservation. To do so, the researchers are using various mathematical models and databases that they developed in earlier projects and are now refining. "We're modelling every member state separately", Fahl explains, "including Switzerland and Norway". That takes time, and, the more refined the results need to be, the more complex the task becomes.

The fourth research group is focusing on the extent to which the behaviour of individual actors may impact the development of the future European energy system. "Even within Germany people behave differently in the southern, northern and eastern regions", Fahl points out: "and things are even more interesting when you compare Scandinavia, the British Isles and Eastern and Southern Europe where the differences are more pronounced". In this context, the researchers always consider a range of variant consumer behaviours: some are inclined to passively accept whatever politicians prescribe, whilst others tend to actively invest in new technologies such as solar power and battery storage. The researchers are using survey data gathered by their project partners in London. According to Fahl: "This study enables us to see beyond national borders and to make relevant comparisons". What would happen if one were to implement something akin to the German Renewable Energies Act in other cultural settings? Would differences emerge and, if so, what would they be?

Fahl emphasises the fact that, to ensure that the REEEM strategy is actually implemented in reality, "this is no ivory-tower-type exercise". That's why the research group regularly organises workshops to discuss their interim findings with decision-makers from the political sphere, the industrial sector and non-governmental organisations, whereby the different perspectives are important and the data valuable: participants from the industrial sector, for example, provide data pertaining to current developments in battery storage technology and its potential for further refinement, which then informs further studies. As Fahl explains: "the objective is to come up with a set of robust policy recommendations for the future that will be taken seriously in terms of technological developments and their realistic implementation potential".

Daniel Völpel

Smart Ideas to be Imitated

Cutting-edge concepts for intelligent urban districts don't recognise state borders

How can the metropolises of tomorrow be made smart and worth living in? Since 2015, the collaborators in the EU's "Triangulum" project have been searching for ways not only to make cities more intelligent, but also to transfer the emerging knowledge to other cities and communities throughout Europe. Some important steps have already been accomplished.

There are many German translations of the English "smart", including terms that mean "intelligent" or "clever", yet none seems entirely to hit the nail on the head because the term long ago acquired connotations in colloquial German that go far beyond such a narrow interpretation as "intelligent". Today, the word "smart" implies clever solutions, integrated systems but also sustainability and inventiveness. It's no wonder then that the subject of "Smart Cities" is an important field of modern research, as most contemporary cities still have a long way ahead of them to become smart.

Pioneering concepts for intelligent urban districts are currently being devised in the "Triangulum" project, which is funded by the EU. And, not just in theory, but rather with the clear objective of implementing the fully developed, practicable and transferable solution in practice, initially in the three so-called "Lighthouse Cities", Manchester in England, Eindhoven in the Netherlands and Stavanger in Norway, and later in the three "Follower Cities", Sabadell in Spain, Prague - the capital of the Czech Republic and in Leipzig, Germany. The project is scheduled to continue until 2020: among its core objectives is the development of innovative, energy-saving technologies that will also dramatically lower carbon-dioxide emissions. Also planned are smart forms of mobility and a modern data infrastructure, but also citizen involvement in all creative and decision-making processes.

The University of Stuttgart is participating as a partner in the "Triangulum" project through the Institute of Human Factors and Technology Management (IAT). The Fraunhofer Institute for Industrial Engineering (IAO) in Stuttgart is the project coordinator, supported by the Steinbeis-Europa-Zentrum (SEZ), also based in Stuttgart. The core of the Smart City project is a transferable Smart City Framework and an IT architecture that will ensure that the various technologies in each city are internetworked and coordinated.

Systematic Citizen Involvement

In Leipzig, the project is primarily focused on districts in the city's west end. The objective: to modernise a district shaped by industry. To approach the

Impressions: Pioneering concepts for sustainable energy supplies, mobility and information technology, developed in the course of the EU project "Triangulum", are initially being implemented in the three cities, Eindhoven (the Netherlands), Manchester (England) and Stavanger (Norway).

Photos: http://triangulum-project.eu/index.php/press-releases/images/

topic of "Smart Cities", a comprehensive citizens' involvement scheme was launched in the Saxony metropolis in the context of Project Triangulum, which, among other things, focused on sustainable mobility, intelligent living and an active urban society. In parallel to this, representatives from the higher administration and city council level discussed these topics in so-called future forums, before concrete solutions were discussed in "future labs". The results of all of these initiatives were then compiled in the Smart-City Strategy Paper for Leipzig West, which was submitted to the EU in January 2018.
The visions set out for the district, which was originally dominated by a cotton mill, were informed by valuable insights from the Dutch "Strijp-S" project, which, under the auspices of Project Triangulum, centred on the transformation of an old industrial site in Eindhoven owned by Philips.

Solutions Replicated

One of the IAT's tasks, among others, was to work out how the solutions developed for the "Lighthouse Cities" could be replicated in the "Follower Cities". To this end, as IAT staff member Sonja Stöffler reports, the participants set up the "Follower City Training Mission" in 2017, a series of workshops designed around the knowledge requirements of the "Follower Cities". In the next step, cities, such as Leipzig, must find ways to fund and implement suitable solutions. According to Sonja Stöffler, one of the most important findings from the "Triangulum" project is that "it is very important to create an understanding of processes and organisational structures at the specific location". To implement smart solutions, she says, a close collaboration with all stakeholders is extremely important. This is why, throughout the further course of the project, the Stuttgart-based researchers will provide ongoing close support for the participating cities as they implement the ideas that have been developed.

Jens Eber

Cracks from the Computer
Researchers develop risk prognoses for fracking

The "FracRisk" research project team has spent three years researching the risks associated with fracking. Computer models are now available, which provide more insights into the risks involved in the process.

In many places throughout the world, natural gas reserves are found in so-called unconventional reservoirs, which means that the natural gas is locked away in shale and coal seams in deep rock strata and is, therefore, not amenable to conventional extraction methods, i.e., via boreholes. Instead, a technical process referred to as hydraulic fracturing or, as it has come to be known around the globe, "fracking" is used, which has polarised opinion in terms of its cost-benefit profile. There have also been anti-fracking protests in Germany, the participants in which fear irreversible environmental damage. On the other hand, organisations, such as the German Federal Association of Oil, Gas and Geothermal Energy, assure the public that fracking could "make a decisive contribution to meeting Germany's natural gas requirements" for decades to come. On its website, by contrast, the German Federal Environmental Agency states that fracking is "controversial", primarily because of the risk it poses to groundwater reserves. However, Professor Holger Class will not be pronouncing judgement on fracking per se: "that's not our role as researchers", says the Deputy Director of the Department of Hydromechanics and Hydro-System Modelling at the University of Stuttgart's Institute for Modelling Hydraulic and Environmental Systems (IWS). according to the scientific consensus, he goes on, fracking is associated with risk, inevitably so given the nature of underground conditions. The task now is to specify these risks: "We're working on computer models that could serve as tools in the decision-making process", says Class. The "we" to whom he refers are the researchers working as a consortium in the FracRisk project, which is funded by the EU. The project is coordinated by the University of Edinburgh and the Stuttgart group is responsible for the "Modelling" work package. The project title "FracRisk" is a more manageable abbreviation of "Furthering the Knowledge for Reducing the Environmental Footprint of Shale Gas Development". Thus, it is about furthering and expanding our knowledge about the risks involved in extracting natural gas trapped in shale seams deep underground, so-called shale gas.

Sparse Reliable Data for Europe

To date, there is not much reliable data available, at least for Central Europe, about the effective forces and processes that take place underground during the technical procedure. "The Americans have a lot of experience with fracking", Class confirms, "whereas we have very little valid data". However, data from America cannot simply be transferred, as different geological formations have developed on the European continent. Moreover, the shale seams containing the trapped methane are much deeper underground. Nevertheless, researchers from the USA are contributing to the FracRisk project with their experiences of the extraction method. The lack of European data is due to the difficulty in obtaining any sort of reliable data from several thousand metres underground.

In principle and in practice, fracking involves a drilling team drilling down to the stratum in which the gas is trapped, which is far below the groundwater level and overburden. Once there, the borehole pans to the horizontal and progresses more or less parallel with the surface. Next, the fracking specialists pump the fracking fluid, a mixture of water, quartz sand or ceramic spheres and highly diluted, sometimes poisonous, chemicals into this layer under high pressures of up to 1000 bar for up to two hours. This mixture, which ExxonMobil describes as a "slightly

Photo: Exxon Mobil

The fracking fluid bursts and cracks the shale layer to enable the extraction of the methane trapped inside it.

water-polluting mix, breaks up the rock and causes it to fracture - hence the name “frack”. In this way, the methane can be released and extracted. At the end of the process, the fluid is pumped back out and disposed of.

Simulation Models for Risk Forecasting

For example, gas or water can theoretically enter the groundwater if the cracks opened up in the process extend through to the porous overburden or if there are any fault zones, i.e., natural flow paths, in the rock, for example, along upthrows or fissures. Then it would be possible, in the worst-case scenario, for the gas and fracking fluid to penetrate through to the higher groundwater layers. Whilst Christopher McDermott, Project Coordinator at the University of Edinburgh, considers this risk to be vanishingly small, particularly as specialist fracking firms put a great deal of effort into monitoring their boreholes, the potential impact on fresh drinking water reserves is too important an issue to be left unaddressed. That is why Project FracRisk has been studying the risks in precise detail for the past three years. So far, predictions about the actual geological conditions in gas fields have barely been possible. Fracking companies had to sink a series of test boreholes and analyse the drill cores in addition to reconnoitring the environment using seismic measurements. One result of the FracRisk project is that, in future, simulation models can contribute towards calculating the specific risks in potential gas fields with a high degree of probability. This is essentially based on models developed by Professor Class and his team at the IWS during the project period. It all sounds much simpler than it really is, because countless calculations on high-performance computers are required to verify such models.

Jens Eber

Simulating Actual Facts
Simulation Models for Emergencies

At the heart of a research consortium, the University of Stuttgart's High-Performance Computing Center (HLRS) is working on simulation models that could, for example, contribute towards a better understanding of the spread of a dangerous disease or to predict the behaviour of refugee flows.

Somewhere in the world there is a breakout of some lethal viral disease that is spreading rapidly, threatening to become a pandemic. Health authorities around the globe need to take immediate action to contain the disease. But, which airports will they have to shut down? And, where can specially-trained aid workers best be deployed?
Of course, such decisions already have to be taken today. However, they are usually based on empirical data and a large portion of gut instinct, as the dissemination path of any given virus cannot be accurately predicted. The Center of Excellence for Global Systems Science (CoeGSS) in which the University of Stuttgart's High-Performance Computing Center plays a major role, is collaborating in a number of international projects that could pave the way to more reliable simulations of complex scenarios. However, Dr. Bastian Koller, Managing Director of the HLRS and Technical Project Coordinator for the CoeGSS, makes a placating hand gesture at this point. It will probably take quite some time before it actually becomes possible to accurately simulate the spread of a pandemic or the path of potential refugee flows in the wake of a war with a high degree of probability.

Data Quality is the Decisive Factor

Researchers from the international consortium, in which twelve partners from the German, Spanish, Italian, Swedish and Polish industrial and research sectors are involved, will primarily be working on other questions until the end of the project period in September 2018. The challenge, in this context, is not so much the necessary computing performance - after all, there is a super computer at the HLRS that can currently execute 7.4 billion calculation steps per second. In fact, the main thing the researchers are asking themselves is how best to deploy this power in the most expedient and effective manner. Koller explains the approach: “we're trying to use data from various sources to incorporate it into the simulation model. These include both official statistics and social media”.
In this context, the researchers first had to clarify what data they could utilise at all and which companies would, at least in an emergency situation, release their data temporarily. Apart from this, not all data proved to be equally suitable or reliable. According to Koller: “It is relatively clear that, in the case of Twitter, for example, some 20 to 30 per cent of all accounts are in fact held by so-called bots. These can easily skew the results”. Following the start of the project in October 2015, the CoeGSS researchers’ task, therefore, was to obtain an appraisal for the quality of the data and to identify parameters for a simulation, which are, of course, different for every problem.

A Question of Perspective

In addition to the Stuttgart-based IT specialists, the interdisciplinary team also includes social scientists, whose task was to model the scenarios, i.e., essentially to determine which data and parameters would be necessary to enable the computation of a given scenario. Also involved was Dialogik, a non-profit institute for communication
and cooperation research in Stuttgart, which was founded by Professor Ortwin Renn, the former Scientific Director of the University of Stuttgart’s Research Center for Interdisciplinary Risk and Innovation Studies (ZIRIUS), whose task was to

Dr. Bastian Koller is the Managing Director of the University of Stuttgart's High-Performance Computing Center (HLRS) as well as Technical Project Coordinator of the Center of Excellence for Global Systems Science (CoeGSS) in which the HLRS plays a major role. Researchers at the CoeGSS are working on paving the way to more reliable simulations of complex scenarios.

Photo: University of Stuttgart / Max Kovalenko

mediate between the various research groups. “The challenge was to unite the different approaches prevalent in the various disciplines such as IT and the social sciences”. Yet, all of the participants soon realised that simply gathering vast amounts of data and feeding them into some arbitrary computational model on the super computer would not be an effective approach. “Problems cannot be solved through computational power alone”, as Koller emphasises. On the contrary, in the worst-case scenario, the computer's performance will be offset. Koller provides an example: “We can always model a five-wheeled car, but, of course, that would make no sense”. Thus, deliberations always turn on the question of ramifications: “our models should reflect reality, which is why the quality of the data and the model are absolutely crucial”.

Just One Among Many Criteria

To find out what data a given computational model requires, and what properties it needs to have, the CoeGSS researchers concentrated on three simple scenarios that had already been relatively well researched, to model them into the simulation. For example, under the heading “Green Growth”, they studied the factors that motivate people to buy electric cars. If it were to prove possible to use the simulation to identify the city in which a major increase in electric cars could be expected then this would allow one to draw inferences about the necessary infrastructure, Koller explains.

In Koller's opinion, modelling actual developments on the basis of good-quality data, thereby determining which of the data and parameters are crucial, is the correct way to refine the models. The fact that the European Commission provided 4.5 million euro of funding for the project highlights the depth of interest there is in simulations of this kind. Thus, as Koller reports, government authorities have already indicated their interest in simulations of the behaviour of refugee flows, which will be developed in a follow-up project. It will still take a few years until such simulations will be used in practice, and even then they will not form the only basis for decision-making but rather they will be considered as just one among several decision influencers for the resulting measures. “We'll never achieve a hundred-per-cent probability, but we're working on achieving as high a probability as possible”, says Koller. As such, the value of simulations will increase, but, even in the long-term, the calculated results will remain just one basis for human decision making.

Jens Eber

Better Than its Reputation
CO_2 as a safe and flexible source for electrical power generation

As a greenhouse gas, carbon dioxide (CO_2) has a poor image. Yet, when subject to high pressure, it can absorb an enormous quantity of heat in a very small space, which is why researchers from the University of Stuttgart's Institute of Nuclear Technology and Energy Systems (IKE) want to use it, rather than water, for more compact heat dissipation systems. These could be retrofitted, for example, to nuclear power stations to protect against a core meltdown, or to core-powered power stations to enable a more flexible ramp up and shut down.

Fukushima, 11th of March 2011: a severe earthquake and subsequent tsunami lead to core meltdowns in three nuclear power station reactors. Whilst the fast shutdown trip system does work, which shuts down the nuclear fission reaction, the cooling systems shut down because the power supply is cut and the emergency power supplies are submerged in the flood waters, a "beyond-design-basis event" occurs. The reason was that, even after the reactors are shut down, cooling is still necessary because the existing short-lived fission products continue to decay radioactively for several days, which generates so-called decay heat.

"We could easily retrofit a nuclear power station with a heat dissipation system that would simultaneously use the decay heat to generate electricity, and which would also be very small" says Jörg Starflinger, Director of the IKE. Because systems of this kind generally generate more power than they require for their own operation, they could be used during power outages for such things as recharging emergency power supply batteries. This may have been enough to prevent the reactor catastrophe at Fukushima. Engineers at the IKE are currently collaborating with other partners in the EU project "sCO_2-HeRo" (Supercritical CO_2 Heat Removal System) to assess the feasibility of this type of retrofittable back-up system for nuclear reactors.

CO_2 Instead of Steam

The emergency cooling system developed by the team works in a similar way to the usual steam circuit that drives a turbine to generate electrical power in nuclear and coal-fired power stations – only it uses CO_2.

The CO_2 is strongly compressed and heated up in the heat exchanger by steam from the reactor, which reaches temperatures in excess of 200 °C. This further increases the CO_2 pressure and sets a turbine in rotation, which drives the compressor and a power

Professor Jörg Starflinger and his team have been working on the development of a heat exchanger in the SCARLETT research facility at the IKE. A living-room-sized part of the CO_2 circuit has been set up there.

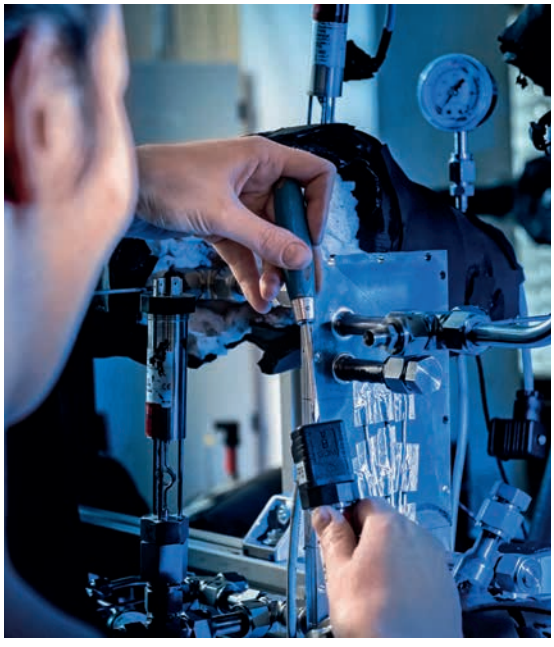


Photo: University of Stuttgart / Max Kovalenko

Photo: Adobe Stock / Thorsten Schier

generator. The CO_2 then decompresses back to its starting pressure and cools down. The residual heat is dissipated via a second heat exchanger, the condenser, into the ambient air and the CO_2 is pumped back into the compressor to begin a new cycle. The system starts automatically whenever the power cuts out, whereby a valve opens that had previously been held closed by electromagnets, which allows hot steam to flow from the reactor to the heat exchanger through which the CO_2 is flowing.

Smaller Than a Lorry Container

"The biggest challenge", Starflinger explains, "is the lack of space in a nuclear power station". Therefore, to retrofit one with a heat dissipation system, it would have to be as small as possible. To achieve this, the scientists employ a trick: they use the CO_2 above its critical temperature of 31 °C and its critical pressure of 74 bar, which is still around three times lower than that reached in the water-steam circuit. In the supercritical state, there is no longer any difference between the gaseous and liquid forms. Close to the critical point, this supercritical CO_2 has the density of a liquid and the toughness of a gas.
What is special about this is that it stores a vast amount of heat in a small space, without heating up strongly, thus its impact on the materials is minimal. Because, in addition, working pressure and the pressure gradient to the turbine are lower, more compact heat exchangers, compressors and turbines can be used than with a water-steam circuit – yet with a similar degree of efficiency. "The system could potentially be accommodated in a lorry container, whereas a water-steam circuit would require an entire hall", says Starflinger happily. In the SCARLETT research facility at the IKE, his team has been working on the development of a heat exchanger consisting of parallel plates through which steam and supercritical CO_2 flow alternatively in a sandwich-like configuration. A living-room-sized part of the CO_2 circuit has been set up there.

Small-Scale Demonstration System

"Compared with water, I only need one sixth of the heat-exchange surface area to absorb the same amount of heat", says the reactor safety specialist. The question is, how small can the heat-exchange channels become, without building up too much pressure, which would then be missing at the turbine end? That would, in turn, mean less electrical output. In the meantime, the partners have sent the individual components, which they each developed

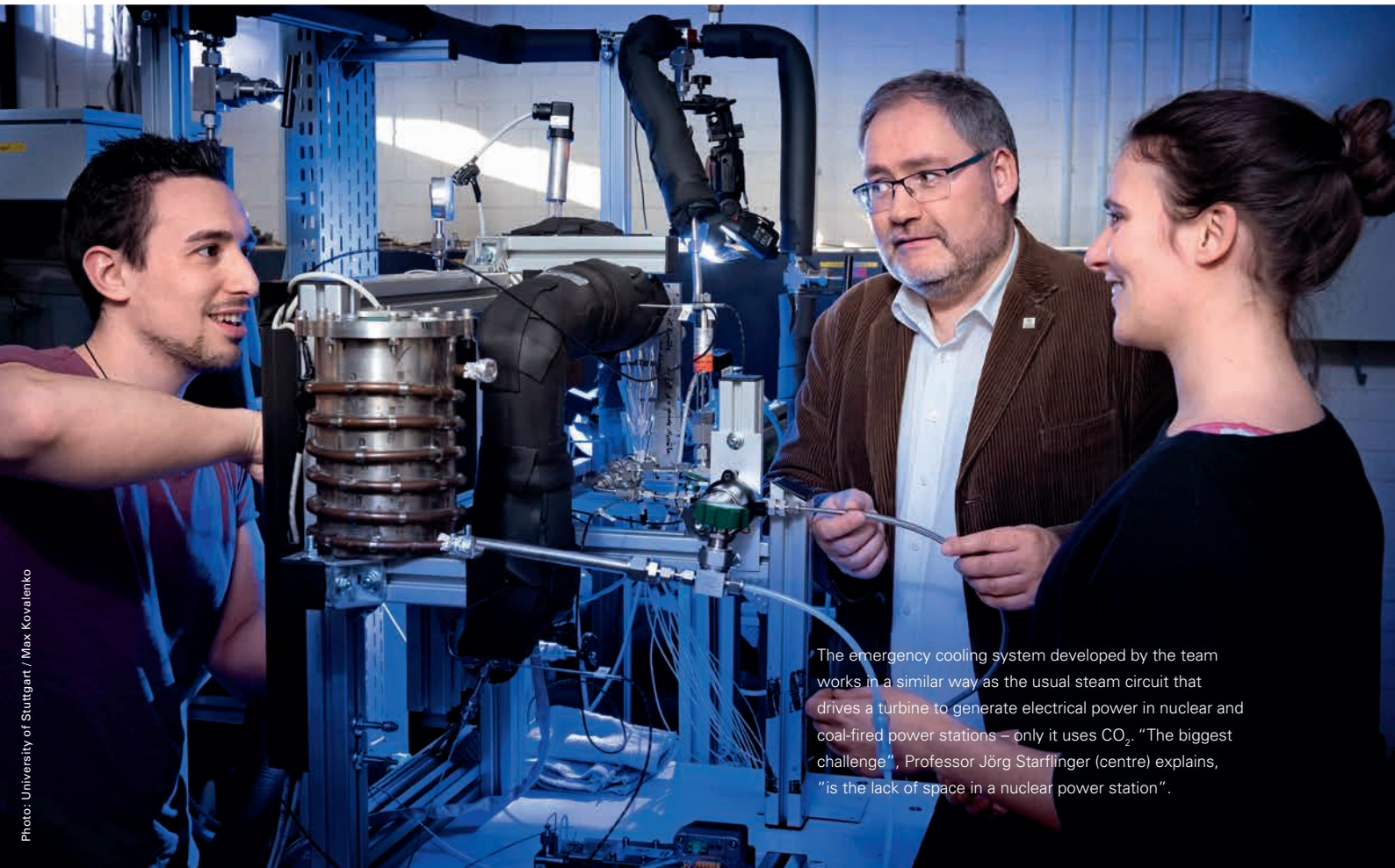
independently, to the simulation centre in Essen, where they have assembled them to build a small-scale demonstration system, where the developers can simulate various faults to test whether the system could function as an emergency back-up system.

Independent of the Heat Source

However, the supercritical CO_2 circuit is not restricted to nuclear power stations. In the EU project "sCO_2-Flex", which was launched at the beginning of this year, ten European partners, including the IKE, want to replace the water-steam circuits used for power generation in coal-fuelled power stations. Because the CO_2 system is more compact, the coal-fuelled power station could be powered up and down in just a few minutes thus producing more or less electricity depending on the demand. Conventional coal-fuelled power stations can take up to half an hour to reach their maximum performance. "In future, these systems will have to be able to react better to fluctuating feed-in from solar and wind-power systems", Starflinger explains, going on to say that, the hope is that they could also be built more cost-effectively, as less material is required.

Not a 1:1 Transfer

Although, says Starflinger, the CO_2 circuit will be the same, in principle, as for a nuclear power station, it is still not possible to transfer the system on a 1 for 1 basis. All components need to be redesigned and adapted to the much higher temperatures of up to 600 °C, which result from the combustion of



The emergency cooling system developed by the team works in a similar way as the usual steam circuit that drives a turbine to generate electrical power in nuclear and coal-fired power stations – only it uses CO_2. "The biggest challenge", Professor Jörg Starflinger (centre) explains, "is the lack of space in a nuclear power station".

Photo: University of Stuttgart / Max Kovalenko

coal, as well as to the greater increase in pressure that the absorbed heat will cause within the system. Two doctoral students at the IKE are currently researching the condensation of supercritical CO_2 in the test system with a view to developing a condenser in collaboration with a corporate partner at a later date. “We're primarily interested in how the velocity and orientation of the flow direction affects the thermal transfer and pressure loss close to the critical point” Starflinger explains. The question as to who would even need these systems whenever they are finally ready for market, given the agreed national energy transition policy, elicits nothing but a tired smile from Starflinger. “If not Germany then some other country”, the engineer counters. France, Finland and the United Kingdom, for example, are already planning new nuclear power stations. Altogether, he says, the idea of exploiting supercritical CO_2 for power generation is completely independent of the heat source. “One could also consider generating electricity wherever excess heat is produced throughout industry”, Starflinger adds, “for example in the cement and paper industries, or even in solar or bio-mass-fuelled power stations”. So, the greenhouse gas, CO_2, can also have its uses!

Helmine Braitmaier

“Simulation Technology” – a Cluster of Worldwide Excellence

To a large extent, scientific progress depends on new inspiration and committed work from young up-and-coming scientists. To provide appropriate support for this, the Cluster of Excellence for Simulation Technology (SimTech) has been offering an interdisciplinary bachelor degree in Simulation Technology since 2010. This provides up to 30 students per academic year with both a broad basic education and specialist training in the field of simulation technology. The excellence degree programme gives the students an insight into the relationship between the various disciplines. It addresses all subject areas that have a bearing on simulation technology including mathematics, engineering, IT and the natural sciences.

Since 2013, graduates have had the option of continuing their studies in the master's course during which they can specialise in certain areas of application. The research-based Master of Science course provides students with an outstanding basis for subsequent doctoral studies, for example, at the Simulation Technology (GS SimTech) graduate school.

Whether taken in the course of a bachelor's or master's degree, time abroad is always an enriching experience, both personally and professionally, which is why students are given the opportunity to spend a semester abroad, either studying or completing their final assignment. Agreements are in place with a plethora of foreign universities on the basis of which studies conducted outside of the country can be recognised in Germany – and we make full use of these agreements.

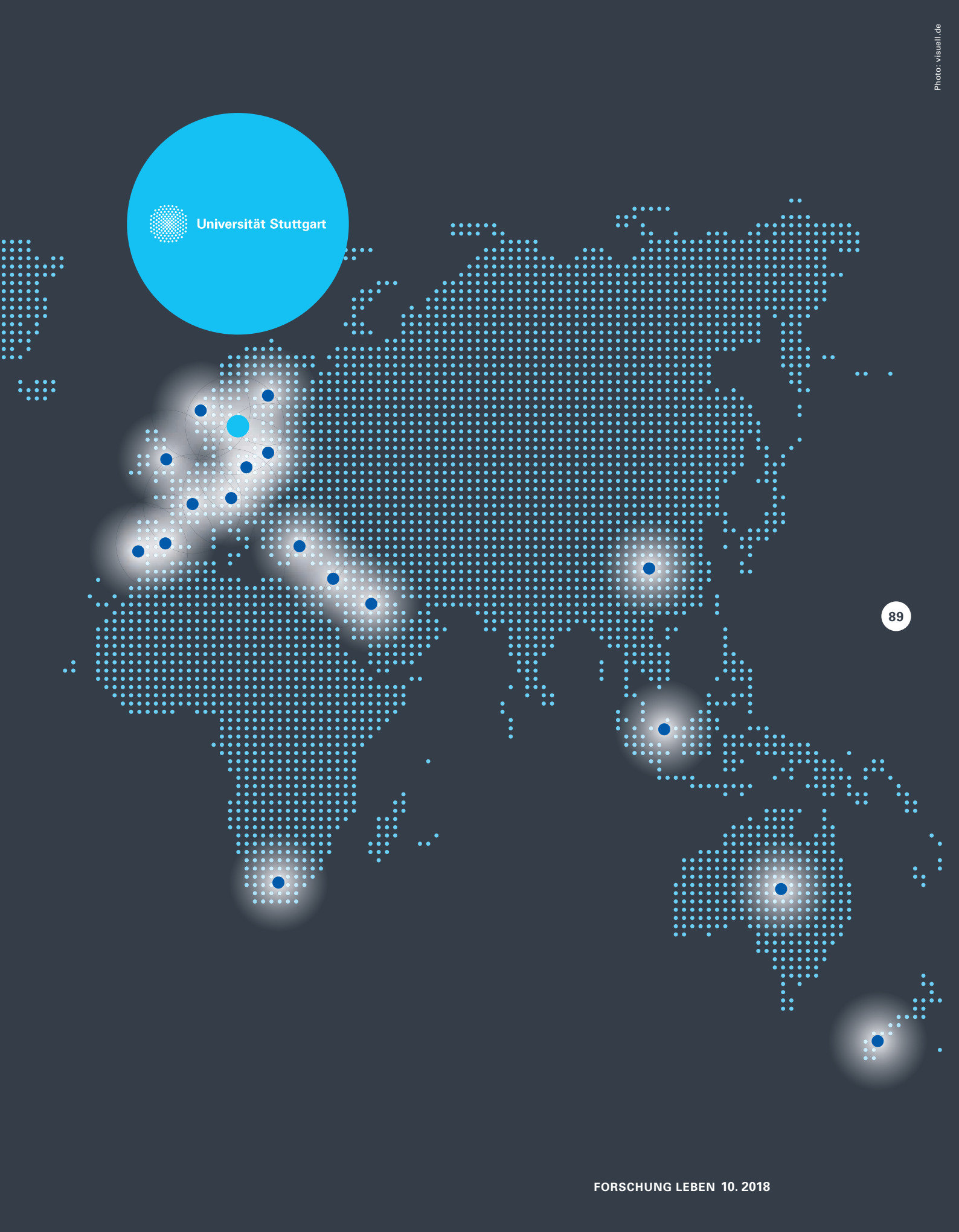


Photo: visuell.de

The Aesthetics of Resource Efficiency
... or: how to build beautiful sustainable structures with less material

Five years ago, Daria Kovaleva made the trip from Russia to Baden-Württemberg to experience the particularly successful collaboration between architects and civil engineers in Stuttgart. Her first major project immediately became a showcase for this collaboration. Together with her colleagues at the Institute of Lightweight Structures and Conceptual Design (ILEK), she planned the Rosenstein Pavilion, which was intended to demonstrate how interdisciplinary research can sweep away the design limits of previous architectural and construction styles.

Using resources efficiently is one of the prerequisites for sustainability in the construction sector. This is particularly relevant to the work of architects and engineers, as a building's ecological footprint is already defined in the design phase. That's why, when it comes to the development of material-saving architectural solutions, the experts are taking inspiration from nature and are studying, for example, cases where biological organisms apply various construction principles to fulfil their vital functions using minimum resources. One of the ways in which biological tissues react to the demands of the external environment is by only using material where it is functionally necessary.

A pavilion built for a special exhibition of construction bionics at the natural history museum in Rosenstein Palace, Stuttgart, shows how such insights can be applied to architecture and construction. The pavilion was designed and planned by Daria Kovaleva, a research associate at the ILEK and one of many researchers at the collaborative research centre "Transregio (TRR) 141: design and construction principles in biology and architecture. Analysis, simulation and implementation". Since 2014, architects, construction engineers, mechanical engineers and structural engineers from the University of Stuttgart have been collaborating at the TRR 141 with biologists and physicists from the University of Freiburg as well as geoscientist and evolutionary biologists from the University of Tübingen. Their common goal is to analyse the operating principles of biological systems and replicate them in architecture and construction. To this end, the researchers are studying such things as the skeletal structure of sea anemones and the mechanism by which the crane flower (Strelitzia reginae) opens.

Fusion of Form, Structure and Material

The Rosenstein Pavilion was modelled on natural tissues that serve a load-transference function. As Kovaleva explains: "human bones dynamically adapt their structure over the course of life to meet the external demands placed on them". Bodies build more bone mass in areas of the body that are subject to higher load stresses and save material and weight in those areas where the bones have less to support. The young architect's objective was to apply these construction principles to her experimental structure and to use fewer resources by distributing materials differentially to meet the specific load requirements at each point. Just as in nature, the 31-year-old explains, one should not consider an object's structure and material separately in this context, but rather one has to view them as a single entity. Because architects and construction engineers traditionally work closely together at the IKEK, the pavilion was developed in the context of an integrated planning process, in which the team took a holistic approach to the architectural, structural and production engineering requirements at the very early design stage.

For planning purposes, Kovaleva also referred to studies relating to functionally graded structures, which the ILEK team and its director Professor Werner Sobek have been carrying out since the 1990s. The work in question involves modifying the inter-

nal structures of structural elements, to utilise less material, whilst leaving their external geometry unchanged. In the case of so-called gradient concrete, for example, different concrete mixtures are poured at different points of a building to meet the specific local structural requirements.

Light Work through Internal Finesse

With her contribution, Kovaleva is now introducing this concept to the broader public. "For the first time ever", she says, "we want to implement the principal of functional grading at the architectural scale. We decided to opt for an open porosity to make it visible to the observer. Just as in biological, direction-dependent structures, the density and orientation of the porosity correspond to the magnitude and direction of the area of tension". This resulted in the creation of a "scientific-artistic vision" of how resource-saving construction could work in the future.

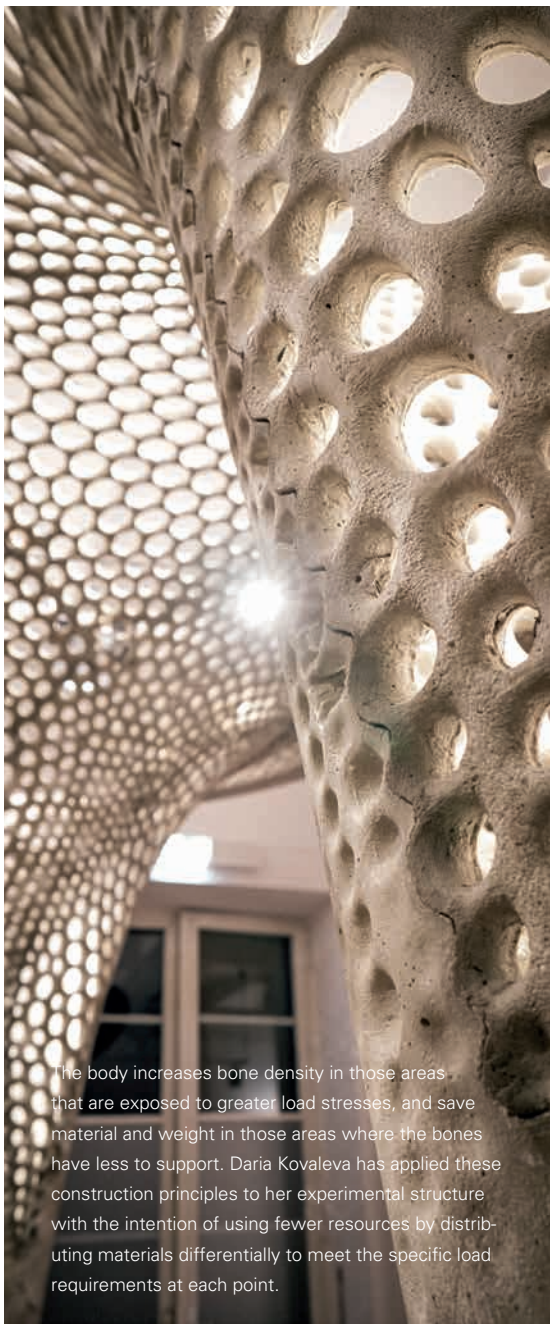
Photo: University of Stuttgart / Uli Regenscheit

The team worked on the Rosenstein Pavilion for one and a half years. Also involved were researchers from the Institute for Control Engineering of Machine Tools and Manufacturing Units (ISW) and Institute of Textile Technology and Process Engineering Denkendorf (ITFT). To fabricate the 69 individual construction elements, the geometry of each individual segment was produced on the computer, then exported as a negative form (mould) so that the formwork could then be milled on a CNC machine. The forms were lined with carbon fibres to reinforce the concrete and then poured out. Once the concrete hardened, the experts removed the formwork, which was reused to cast other segments. Finally, the structure was assembled on a frame and fastened into place before an external metal cable then ensured that the structure took on its intended geometry.

By this means, Kovaleva achieved a 40 per cent material saving compared with a continuous concrete shell with a comparable load rating. At 3.5 metres high and with a surface area of almost six by six metres, the shell is only three centimetres thick and weighs just 1.7 tonnes. Daria Kovaleva designed her structure to fit exactly into the space allocated for the pavilion, the former breakfast room in Rosenstein Palace with its columns and pilasters. The structure rests on four extremely delicate-looking supports that precisely fit within the pattern of the marble floor and – via an ascending funnel form – terminate under the coffered ceiling. The original room is visible through the pores, which accentuates the aesthetic effect and the impression of unity of form, structure and material.

Interdisciplinarity is The Future of Construction

The ILEK's particular approach and that of other institutes at the University of Stuttgart was what drew



The body increases bone density in those areas that are exposed to greater load stresses, and save material and weight in those areas where the bones have less to support. Daria Kovaleva has applied these construction principles to her experimental structure with the intention of using fewer resources by distributing materials differentially to meet the specific load requirements at each point.

Photo: University of Stuttgart/ILEK

Kovaleva to Germany five years ago. Having gained her master's degree in Russia, she worked with various firms as an architect and was also employed as a site manager for the renovation of an historic residential block. At the same time, she began designing experimental architecture and installations to explore the form-giving and spatial delineation potential of materials, such as textiles and plaster, in which context, she drew inspiration from the works of Werner Sobek and his predecessor, the visionary architect and Pritzker-Prize-winner Frei Otto. Otto was already drawing upon nature for inspiration and aspired to minimise material wastage back in the 1960s – principles still espoused by TRR 141 today.

Kovaleva joined the Moscow offices of the Werner Sobek Group in 2012, which is where she first encountered the Stuttgart school, which emphasises a close collaboration between construction engineers and architects. A year later, she relocated to Stuttgart, the capital of Baden-Württemberg, to underpin her practical experience, garnered in the Werner Sobek office, with the research being carried out at the ILEK. “Germany”, she says, explaining her motivation, “is extremely forward looking with a thriving culture of fundamental research”.

To concentrate on research, she then transferred to the institute, where she is currently working on her doctoral thesis. Her work is focused on gaining “a better understanding of the structural aspects of architectural design” and consolidating her knowledge of construction engineering. The architect feels she is in the right place to do this: “The Stuttgart school of architecture is very specific to Germany and Europe”. That’s another reason why she wants to develop the theoretical basis for her work here. “The structural demands are one of the most important aspects of the design process”, she says: “Only a close collaboration between architects and the engineers results in projects, that are planned on an

integrated basis right from the start and which generate new theoretical insights. Material-saving and energy-efficient construction – that's what Stuttgart stands for".

Plans for the second funding period for TRR 141 are currently being prepared. The first already provided some ten million euro of support for the German research community. Daria Kovaleva and her project colleagues now want to do more analysis at the material level to develop novel CO_2-neutral, more creative ways of building using fewer materials. Given the burgeoning global population, simply continuing the traditional approach to construction is not an option. "We need to find a way to better exploit the properties of construction materials", says Kovaleva, "and of producing holistic structures by taking account of these during the design process". In precisely the manner, in fact, that she succeeded in doing with the Rosenstein Pavilion.

Daniel Völpel

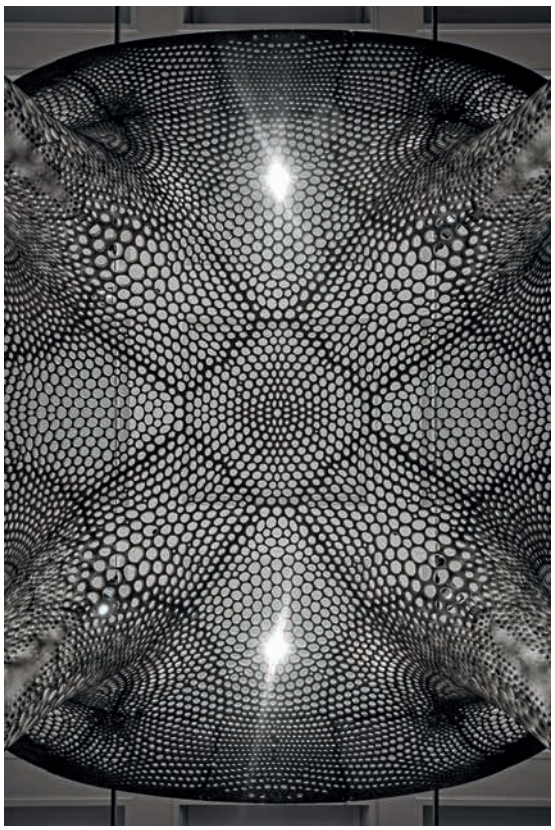


Photo: University of Stuttgart/ILEK

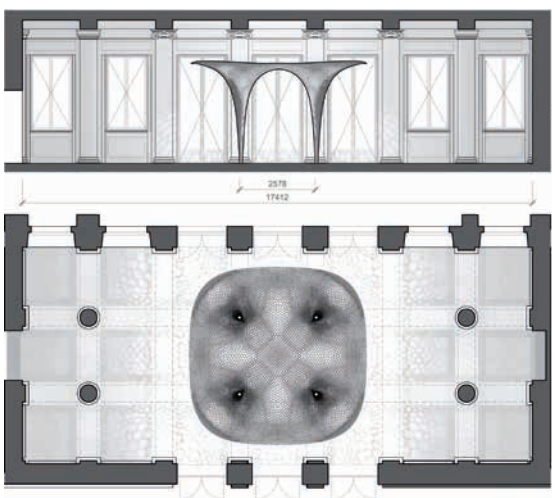


Figure: University of Stuttgart/ILEK

Inspired by nature: Architects and building engineers are taking inspiration from the skeleton of a sea anemone to design the "roof" of the pavilion.

“The best from two university environments” Mixed language and teaching cultures have prepared Hanna Petri very well for her EU career.

Completing a bilingual course of studies in the Social Sciences in Stuttgart and Bordeaux have earned Hanna Petri a place with the European Commission in Brussels. The wide-ranging study programme and cultural interchange laid the foundations for her career in the field of collaborative development.

Petri found her study period both challenging and exciting. After completing her Abitur (university entrance qualification) and spending a year as a voluntary aid worker in Bolivia, she relocated to Bordeaux to begin her first semester in the ”Filière intègrée franco-allemande” – or FIFA – degree course. From then on, she regularly moved between the capital of Baden-Württemberg (Stuttgart) and the university town in south-west France. She found the continual relocations quite stressful, especially in the beginning: “By the time I was getting to grips with being back in Germany”, she remembers, “I’d have to head back to Bordeaux. I did find it difficult to get used to the university and the way they do things in France”. Yet, as time passed, her appreciation of the fact that the dual course structure was giving her an insight into different scientific approaches in addition to the French language and culture increased: “The two completely different ways of thinking and learning have made a lasting impression on me”. Whereas the content taught at the institute in Bordeaux, which is part of the Grandes Écoles, a network of elite schools in France, was extremely wide ranging, the young student learned a lot about methodical approaches to empirical social research. “For me, the thematic variety on the one hand and the methodical training on the other combine the best from two university environments”, says Petri.

Like a Personalised Degree Course

For 20 years, the Social Sciences degree programme has been a successful collaboration between the University of Stuttgart and the Institutes of Political Studies in Bordeaux, incorporating an advanced French language course and the opportunity to participate in the Voltaire Student Exchange Programme. The young Petri, a native of Hessen, was extremely well-positioned to benefit from this and also saw this diversity as her personal chance: “I didn't want to consolidate my French language skills in a dedicated language course”, the 29-year-old explains: “instead, I wanted to do so in combination with another discipline entirely”. As such, the FIFA programme was tailormade for her as, in addition to politics and economics, it also covers law and the French “culture générale”, including languages and history.

Following the bachelor-level education, the master's programme offered a wide range of opportunities to specialise. Here, Petri, whose passion for Latin America was first awakened by a Chilean girl who lived next door, set the course of her future career. “From an early age”, she says, “I could imagine myself working in the field of collaborative development. That's why I chose the very specific “Risk Management in the Southern Hemisphere” master's degree”, in the course of which she focused on the features of party-affiliated German foundations as actors in the field of collaborative development.

Interest-led in the Best Sense

With a German and French degree as well as a Dual-Graduate's Certificate in her pocket, she was able to rapidly establish her professional career. “Just being bilingual was a great advantage when it came to landing a job in the proximate EU environment. But, my master's degree was certainly also instrumental in preparing me for a career in collaborative development”, Petri explains with conviction. Following a traineeship with the Eu-

"The two completely different ways of thinking and learning coupled with thematic variety on the one hand and methodical training on the other have made a lasting impression on me", says Hanna Petri with reference to her degree studies in Bordeaux and Stuttgart.

Photo: University of Stuttgart / Uwe Noelke

ropean Commission, she worked for the German Corporation for International Cooperation GmbH (GIZ) and the Directorate-General for Development and International Cooperation (DGCID) in Brussels. The Director General of the European Commission is responsible for the administration of the European Union's foreign aid programme and ensures the provision of European aid around the globe. In this context, she worked as a project manager, providing support for environmental and climate-related projects funded by the EU, which included editing project reports and reviewing general development-policy agreements relating to the EU-funded projects. She also had editorial responsibility for the "Green Development News" newsletter. As such, her work not only involved an exciting scope in terms of content, but was also very diverse in terms of its international dimension. "My colleagues came from all over Europe and had very different backgrounds in terms of their careers. Our team included everything from legal practitioners and political scientists to biologists and cultural scholars". It was multicultural, diverse and extremely demanding, as Petri now had to switch back and forth between three different foreign languages in her daily activities. "The dynamic atmosphere is good fun", says Petri, "but one could definitely also sense an air of competition, as there are a lot of highly-qualified people working in Brussels".

Profession and Passion United

Yet, she did remain true to her passion and is currently working in the GIZ's EU Liaison Office, where she is involved in climate and environmental protection in Latin America In which role she advises her overseas-based colleagues on such things as the sequence of events relating to EU co-funding procedures, explaining the relevant processes and contract formats and responding to questions of any sort relating to the EU. In terms of where she may end up in the future, Petri is open to anything. The past has also shown her that many things can come about by pure coincidence. "I can well imagine returning to Latin America, either as a GIZ employee or as part of an EU delegation", says Petri, "but there's no pressure right now, so I'll just see what happens".

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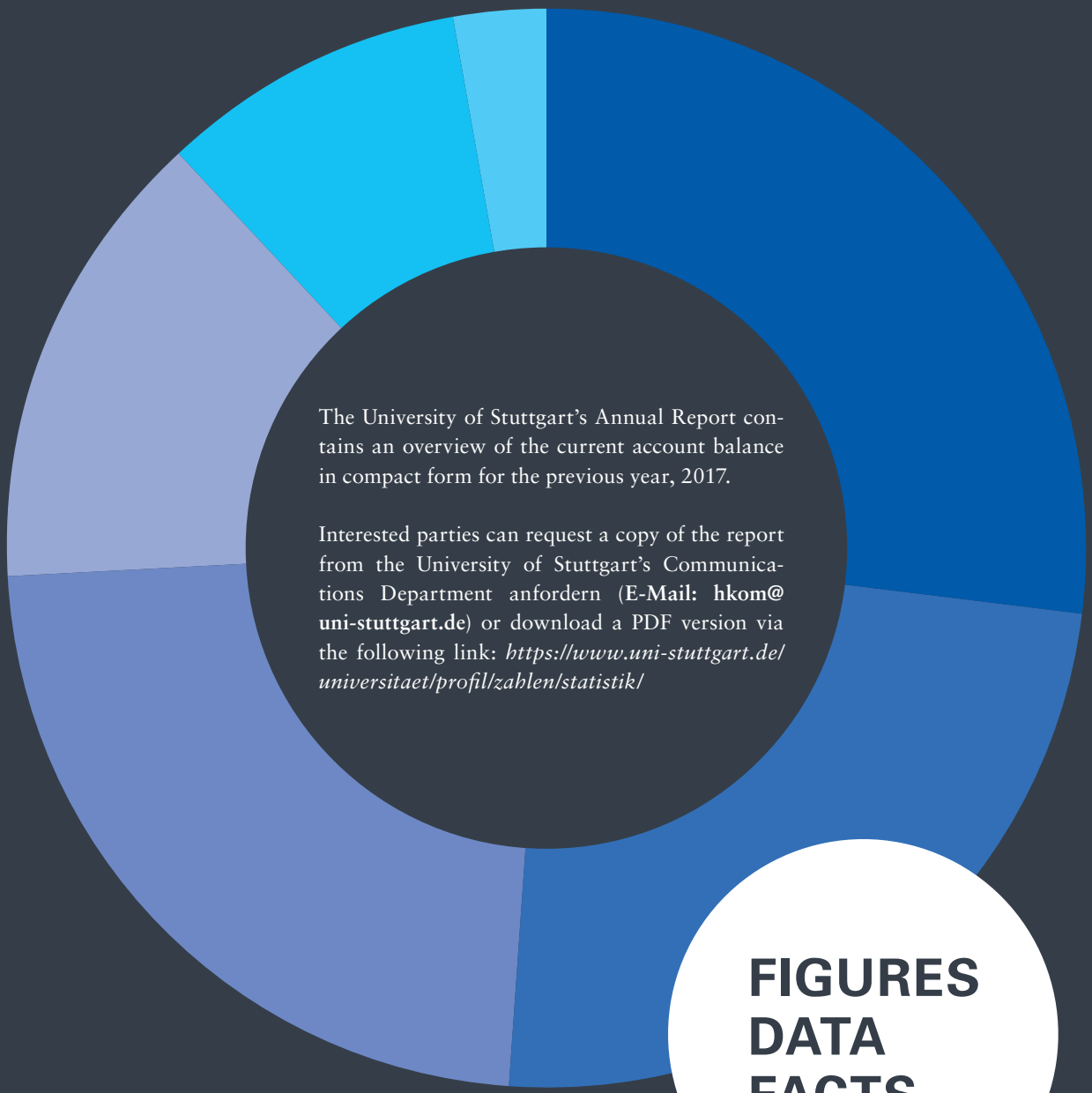

The University of Stuttgart's Annual Report contains an overview of the current account balance in compact form for the previous year, 2017.

Interested parties can request a copy of the report from the University of Stuttgart's Communications Department anfordern (**E-Mail: hkom@uni-stuttgart.de**) or download a PDF version via the following link: *https://www.uni-stuttgart.de/universitaet/profil/zahlen/statistik/*

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2017

„Ich sorge für Verteidigungstechnik, auf die Verlass ist."

Tanja Müller, Qualitätsingenieurin, ist verantwortlich für die Erfüllung der Qualitätsanforderungen für Luftverteidigungssysteme bei Diehl Defence in Deutschland.

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