LICHTGEDANKEN 04

The Magazine of the Friedrich Schiller University Jena

ENGLISH

LASER PHYSICS

ULTRASHORT WORLD RECORD

Young physicist developed the most powerful ultrashort fibre laser

DIGITALIZATION

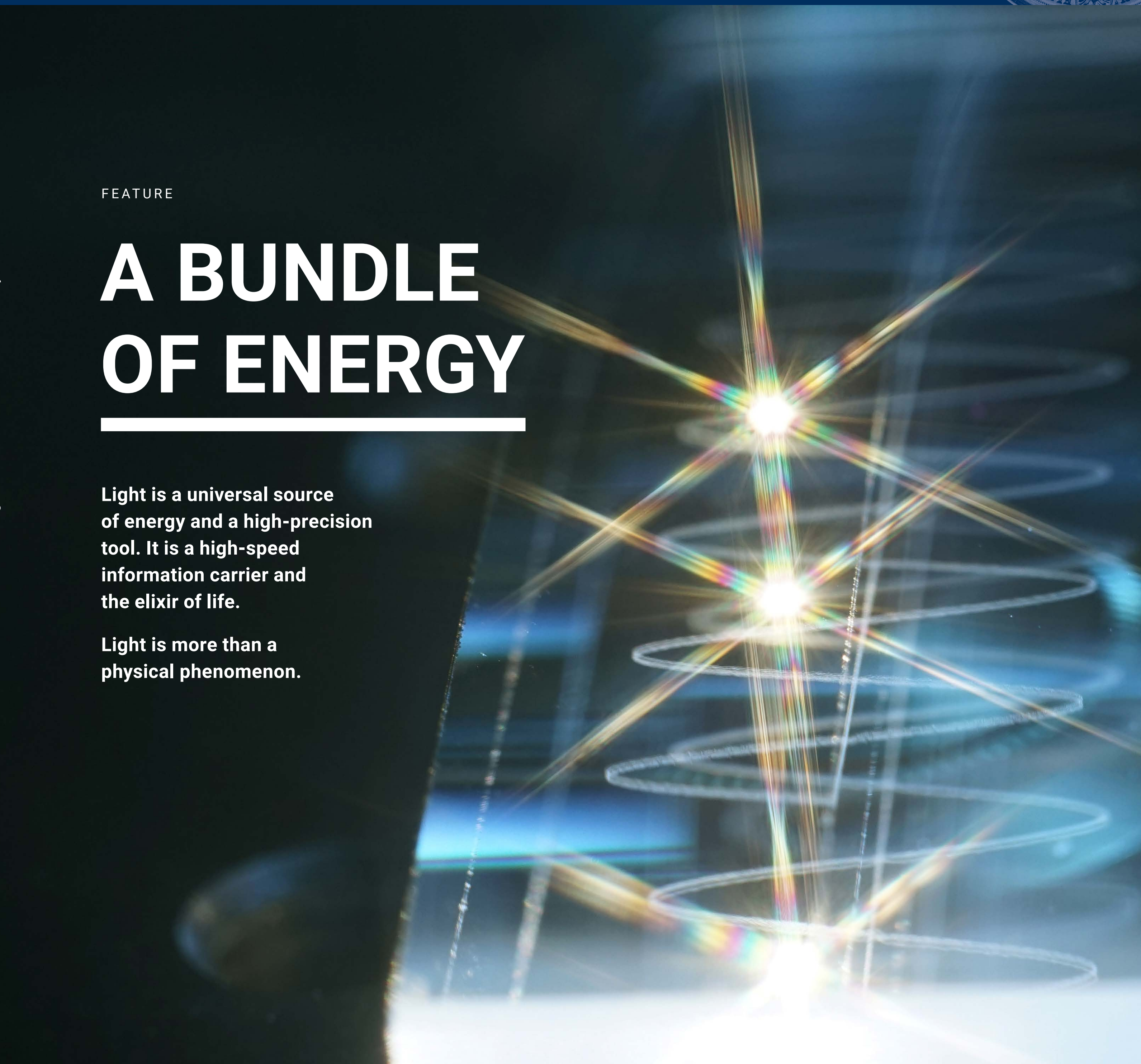
3D DATABASE FOR ANTIQUE CUNEIFORM SCRIPTS

Clay tablets from Mesopotamia available online

MICROSCOPY

AN INSIGHT INTO THE MICROCOSM

Photo gallery reveals research photos invisible to the naked eye



FEATURE

A BUNDLE OF ENERGY

Light is a universal source of energy and a high-precision tool. It is a high-speed information carrier and the elixir of life.

Light is more than a physical phenomenon.

FRIEDRICH-SCHILLER-UNIVERSITÄT JENA

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COOKBOOK **»SO IS(S)T DIE WELT«**

Thuringia is home to around 5,500 international students and approximately 900 students with an immigration background who have gone to school in Germany. Many of them frequent our canteens and like eating there. Who does not know the feeling, after having stayed abroad for a while, of being overcome with a particularly strong longing for their favorite dishes or for some of their mom's home cooking? A culinary homesickness of sorts is something that is not just experienced by international students, but also by those who might have grown up abroad or whose parents have international origins. This was reason enough for us at Studierendenwerk Thüringen to ask these students what they would like to have us serve them in our canteens.

We ended up cooking together. We invited students from twelve different culinary cultures to prepare authentic dishes from their homeland alongside our cooks in an intercultural setting. Things did not always go smoothly. Getting the correct consistency of Chinese sticky rice almost led us to sheer exasperation, as was the case with the difficult task of getting the shape of Pelmini right. However, we managed to master both these tasks through a successful intercultural exchange with the students.

We have been able to compile many more of these kinds of wonderful intercultural experiences in this cookbook.

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The University's motto and attitude to life

Prof. Dr Gerhard G. Paulus,
Chair of Non-Linear Optics and spokesperson for the »Light« steering committee at the Friedrich Schiller University Jena

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With its motto, Light, Life, Liberty, the Friedrich Schiller University has, in all modesty, made an ingenious choice. It does not just neatly describe our tradition; it also provides an outline and structure for our teaching and research professionals—at least, the kind of outline that might be visible from a great distance. Of course, you can find fault with anything. Subsuming our humanities departments under the term Liberty—well, alliteration almost certainly played a part here—and no one has yet checked to see whether the colleagues and members of staff who the University's management have placed under the profile line »Life« feel comfortable with this label.

Even the profile line »Light«, to which this edition of LICHT**GEDANKEN** is dedicated, requires a little creativity. Light only really describes the work of optics and photonics researchers in Jena in a very romanticized, almost Goethe-esque way. It requires even greater skill of abstraction and creativity to view the equally traditional and important quantum and gravitational fields theory as optics—especially as, as we will learn in this edition, it predicts eternal darkness—in several billions of years.

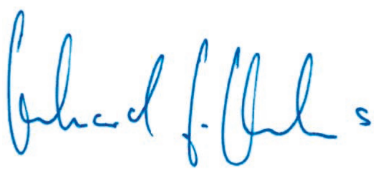
Until then, Jena will continue setting records when it comes to the most powerful lasers. Having said that, records tend to be sporting categories, and are, as a result, as (un)important as h-index and other impact factors. It is the knowledge that can be gained using these innovative lasers that is decisive; and this latest edition has something to say about that too.

One noticeable development at Friedrich Schiller University is the ever-stronger links that are developing between research within the profile lines Light and Life. Several articles prove this theory. The drawers are becoming worn. The recent appointment of Professor Eggeling from Oxford is an impressive example of this. Christian Eggeling has a Chair Professorship at the Faculty of Physics and Astronomy and is researching super-resolution microscopy; at Jena, this is something akin to the ventricle of Light. What is interesting, is that this research would be almost inconceivable without the contributions from chemistry and without the questions posed by life sciences.

When considered as »profile lines« alone, Light, Life, Liberty is too narrow a definition; and not just from a professional point of view. But Light, Life, Liberty is also a description of the attitude towards life at this university and, in the sense of enlightenment, freedom, tolerance and humanism, it is a challenge to us all.

With this in mind, I hope that you enjoy reading the LICHT**GEDANKEN**.

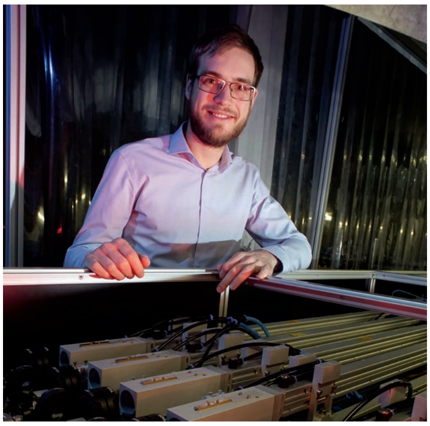
Yours

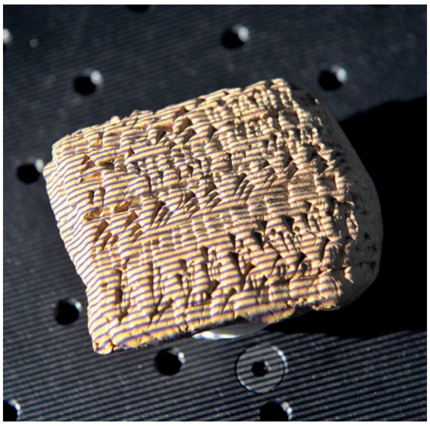


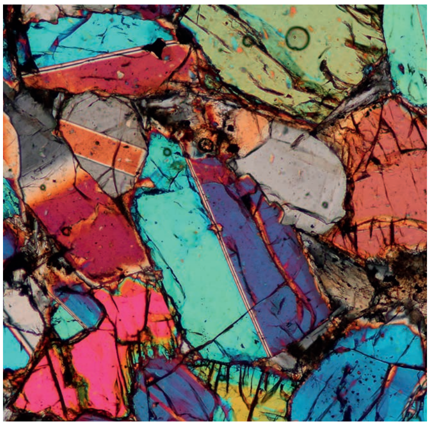
Jena, August 2018

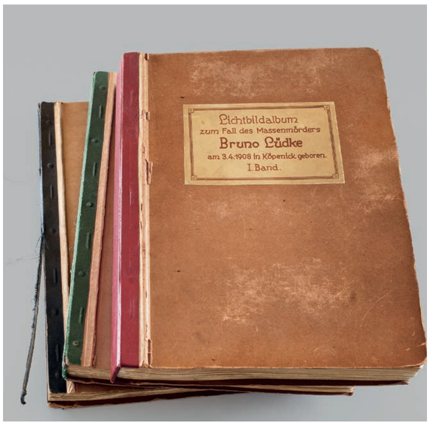
FEATURE

A BUNDLE OF ENERGY








Lichtbildalbum
zum Fall des Massenmörders
Bruno Lüdke
am 3.4.1908 in Köpenick geboren.
I. Band.

Insects—here an example of a »gladiator« Tyrannophasma gladiator—have to deal with a lot of dangers in nature. In many situations, the animals decide how to respond individually.

How individuality ensures survival

Ecologists investigate how living organisms manage to adapt to their environment and thus find their own ecological niche. The team working with Prof. Dr Holger Schielzeth is working in a new Collaborative Research Centre as an external partner

A grasshopper faces many different dangers. If a stork is trying to kill it, it is important to act with skill. It is not always the huge leap that saves its life. »When it comes to escaping, it makes sense to be flexible«, says Prof. Dr Holger Schielzeth.

Survival often depends on the element of surprise

The grasshopper jumps—sometimes far, sometimes not so far, sometimes to the right, sometimes to the left—and seeks cover. »Its survival is dependent on the element of surprise and each animal has its own strategy«, states the Jena professor of population ecology. A new Collaborative Research Centre/ Transregional Collaborative Research Centre, funded by the German Research Foundation with a total of around 8.5 million euros over the next four years, is investigating how living organisms manage to adapt to their environment and find their own ecological niche. The centre, which is called »Eine neue Synthese zur Individualisation für die Verhaltensforschung, Ökologie und Evolution: Nischenwahl, Nischenkonformität, Nischenkonstruktion« (A new synthesis regarding individualisation for behavioural science, ecology and evolution: niche choice, niche conformity, niche construction), is based in Bielefeld and Münster. Prof. Schielzeth is involved as an external partner and is responsible for two of the total of 19 projects. He is receiving around 350,000 euros for this role, which will be used for two additional doctoral positions. In one project, he is investigating how the question of how variability of behaviour can ensure survival. Schielzeth and his team are researching the flight behaviour of grasshoppers for this purpose. The researchers want to find out whether the behaviour of the animals is inherited and, if so, in what way. The strong statistical expertise of the Jena researchers is bearing fruit in another project. The synthesis project has the aim of creating a common platform for discussing the results of all subprojects so that these results can then be incorporated into meta-analyses. AB

Sustainable development needs research

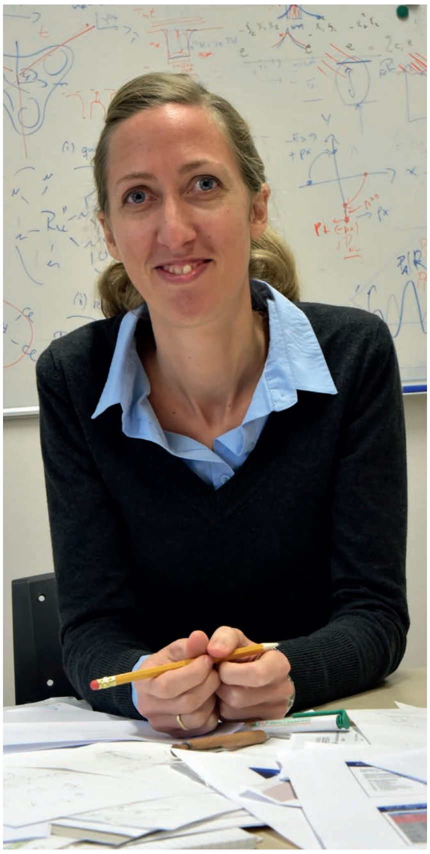
UNESCO is honouring the University of Jena with a Chair on Global Understanding for Sustainability

The new Chair, held by social geographer Prof. Dr Benno Werlen, will lead to the further integration of social sciences and the humanities into sustainability research over the next four years. Werlen has already made a start on this in recent years as the founder and director of the initiative »International Year of Global Understanding« (IYGU). »Thanks to the UNESCO Chair, Jena will continue to act as a key coordination unit for the numerous global initiatives that fall within the framework of the IYGU« says Benno Werlen. He believes that there is a great opportunity within the collaboration between research and society to establish sustainability as a primary criterion for political decision-making. As a holder of the chair, he wants to support and implement both research projects and educational campaigns in the respective regions. AB

Light meets matter

The European Research Council is funding the QUEM-CHEM project with 1.9 million euros. Dr Stefanie Gräfe, a professor of chemistry, receives an ERC grant as the first woman at the University of Jena

Anyone wanting to elucidate fundamental questions in science and to develop new theories as a result needs both perseverance and the necessary funds. The EU cannot provide time, but the European Research Council (ERC) has awarded one of its highest value awards—a Consolidator Grant—to Prof. Dr Stefanie Gräfe. After three male researchers, the Professor of Theoretical Chemistry is the first woman at the University of Jena to receive this rare research funding award. She intends to create eight positions for early-career researchers with the 1.9 million euros and thus to gain new insights in the field of non-linear optics. Over the next five years, her project QUEM-CHEM (time- and space-resolved ultrafast dynamics in molecular plasmon hybrid systems) has the aim of first coming up with theoretical foundations and new theories to then develop applications, for example for a highly sensitive sensor system. »Having received this grant, I now have a chance to carry out the project which I have been striving for a long time«, says the 38-year-old researcher, who aims at marrying electromagnetism with quantum mechanics.



Stefanie Gräfe is the first woman at the University of Jena to be awarded a Consolidator Grant from the EU.

What happens to metal when it is hit by a ray of light

When light meets matter, interactions occur. There is a further peculiarity in the case of metallic nanoparticles: the density of the charge carriers in the metal can oscillate after the exposure to light, causing physicists to talk about plasmonic quasiparticles. This causes light amplification. The smaller the nanoparticle, the greater the light amplification. In the new project QUEM-CHEM, Stefanie Gräfe and her team want to investigate fundamental questions at the nano level regarding what happens between metallic solids and molecules after the boundary surface is exposed to light. »There has not been any sound theory about it, yet«, says the expert—and this is precisely what she wants to change. Research within Gräfe's research group will begin with computer simulations. The aim is to calculate the plasmonic dynamics, in other words, the light-induced movement of the electrons in the metal. Furthermore, quantum chemistry methods will be used to calculate the molecular structure. These two different methods will then be combined.

This will make it possible to explain the chemical reaction mechanisms of light and the metal molecule system. The scientist wants to work together with colleagues involved in experimental work on this plasmon catalyst to be able to compare the theory being developed with practice. AB

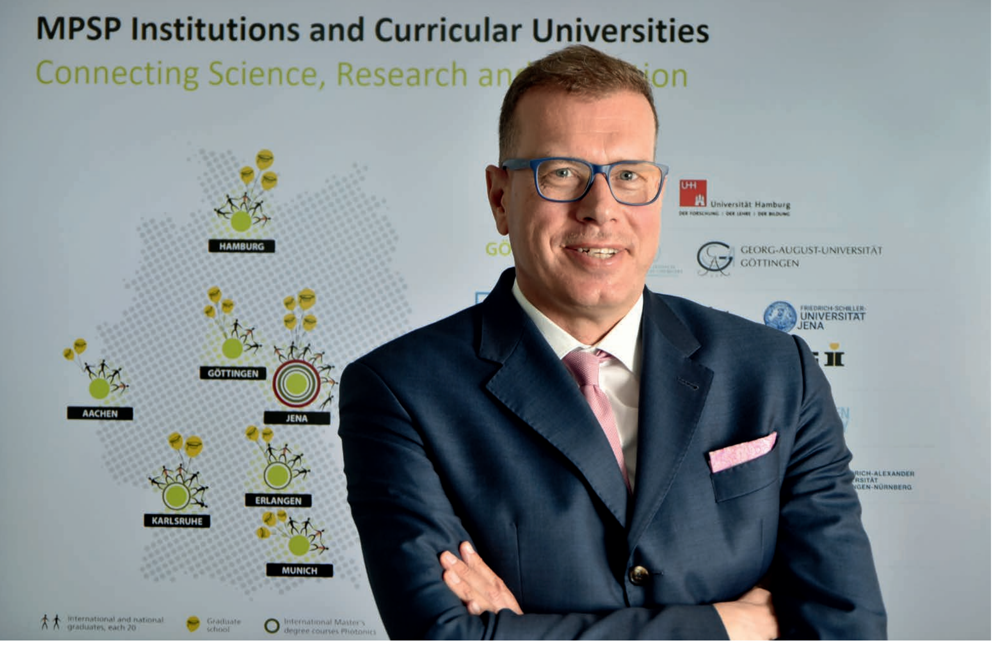
How trees cooperate

The University of Jena is participating in the international Research Training Group at the University of Halle-Wittenberg

At the University of Halle-Wittenberg, a new international Research Training Group is focusing on the interaction between trees and the consequences that this has for the ecosystem. This doctorate programme is going to be funded by the German Research Foundation (DFG) with 3.5 million euros for the next four and a half years. The group is being run in cooperation with the University of Chinese Academy of Sciences in Beijing. On the German side, the future doctoral candidates have chosen to work at the German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig.

Forests are the most important ecosystems in the world. They absorb carbon dioxide, produce oxygen, and regulate the climate. These benefits even improve when the variety of trees increases. The role of the interaction between individual trees, however, has been hardly investigated up to the present. This is the starting point of the new Research Training Group, which has the name »Tree Diversity Interactions: The Role of Tree-Tree Interactions in Local Neighbourhoods in Chinese Subtropical Forests« (TreeDì). The early career researchers want to investigate how trees exchange information and nutrients via their roots, and how they create a favourable microclimate for each other above ground. The doctoral projects are intended to shed light on the underlying processes and mechanisms behind this cooperation.

Funds for 18 doctoral positions have been provided for the first funding period. The half of them will be located on the German side, the other half in China. The doctoral candidates must spend at least half a year in each partner country. PR



Prof. Dr Andreas Tünnermann is the Chair of Applied Physics, Director of the Fraunhofer Institute for Applied Optics and Precision Engineering and has recently become spokesperson for the Max Planck School of Photonics. The MPSP was elected for a pilot phase together with two other schools.

Cooperation and competition

The Max Planck School of Photonics with its headquarters in Jena is part of an innovative new national network of excellence, the Max Planck Schools. They represent a new instrument for promoting excellence within Germany. It has been developed under the leadership of the Max Planck Society, together with non-university research institutions, universities and the Federal Ministry of Education and Research. In this interview, spokesperson Prof. Dr Andreas Tünnermann explains how it is possible to raise the promotion of early-career researchers up to the global level and to become competitive with elite American institutions.

INTERVIEW: AXEL BURCHARDT

Physics at Jena already profits from an excellent global network. Now a new network has been added with the Max Planck School of Photonics. What is so special about it?

Science lives from cooperation and competition. The Max Planck Society and other non-university institutions, such as the Fraunhofer-Gesellschaft, have stepped up to develop a unique network in the field of graduate education. The idea behind the Max Planck Schools is to link up locations across different regions within Germany. The development of a joint doctoral programme will be able to attract the best of the best early-career researchers. The focus here is not on the institutions; but rather on the individual people involved—the supervisors of the doctoral work. The School will be supported by winners of the Nobel Prize and Leibniz Prize—researchers with a global reputation, who are very active within the scientific community. Thus, outstanding scientists, who are responsible for about a third of all publications within a dedicated area in Germany, are involved in the Max Planck School of Photonics. When they work together, our scientists can have a greater scientific influence in the field of photonics than the previously leading elite institutions like Harvard and Caltech.

The new network is intended to compete with elite institutions like Harvard University and the Massachusetts Institute of Technology in the future. How can this vision become reality?

In addition to the scientific excellence of the supervising researchers, photonics research in Germany is currently distinguished by the tight network between academia and industry. This gives us the opportunity to address fundamental questions with our research; but also, to use innovations to get things moving and change the status quo. In addition, requirements for applicants and the application process itself are synchronised with the international system and admissions are sent in the early spring (March/April).

Who can apply in September 2018?

Bachelor students can apply from their fifth semester for the PhD programme with an integrated master programme, as it is international standard. Master students can apply directly for the doctoral programme. From our experience with the Abbe School of Photonics, we are expecting to receive around 1,000 applications from across the globe and be able to choose the cream of the crop.

How many places will be available for the first year?

During the pilot phase, 20 students will be accepted per year into the integrated master's programme and around 20 stu-

The Max Planck School of Photonics

The Max Planck School of Photonics combines **national and international graduate programmes across seven locations in Germany**. The aim is to transform **photonics research** into an interdisciplinary network that spans various locations and institutions.
In addition to the Friedrich Alexander University Erlangen, the Friedrich Schiller University Jena and the Karlsruhe Institute for Technology, where it is possible to attain a master's degree, partners of the Max Planck School of Photonics include RWTH Aachen University, the University of Göttingen, the University of Hamburg and Ludwig-Maximilians-University (LMU) Munich. The Fraunhofer Institute for Applied Optics and Precision Engineering IOF and for Laser Technology, the Max Planck Institute for Biophysical Chemistry, the Physics of Light and for Quantum Optics, the German Electron Synchrotron (DESY), the GSI Helmholtz Centre for Heavy Ion Research at Jena, and the Leibniz Institute of Photonic Technology are also involved.

dents into the doctoral programme each year sponsored by the state. We will also accept the same number of doctoral candidates via associated partners of the school. After the start-up phase, there will be around 40 master students and 100 to 120 doctoral candidates.

Will those who want to go to Jena for their master's first attend the Abbe School of Photonics or go directly to the Max Planck School?
The integrated master's programme is a key part of the new Max Planck School of Photonics. As part of the network, the universities in Karlsruhe, Erlangen and Jena, with their established and accredited master's programmes, will provide the opportunity to obtain an international master's in Photonics. The students apply at the Max Planck School of Photonics and, once accepted, can decide whether to study in Jena, Erlangen or Karlsruhe. There will be a reciprocal acknowledgement of assessed coursework and examinations within the partner universities. The programme will be supported by special lectures and general networking events organised by the Max Planck School of Photonics to facilitate networking within the school between students at the various locations and with the researchers at the participating universities.

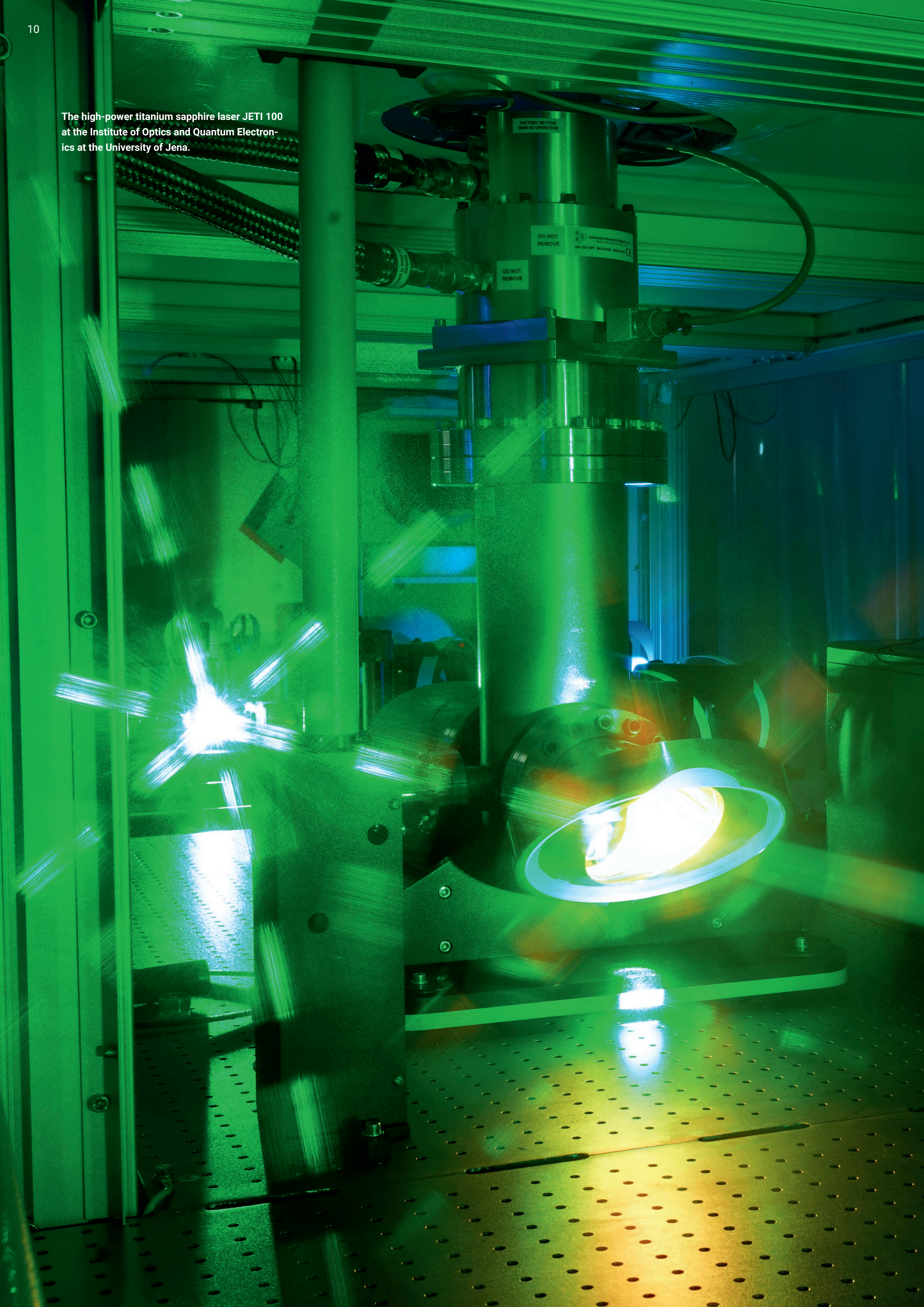
Which topics will be researched at the Max Planck School of Photonics?
The central question will focus on controlling light across all scales. It will be about developing methods and technologies to control light across many wavelength ranges, from the X-ray range to the millimetre range, with very high outputs across all timescales. The development of optics is another field to span the range from the atomic scale to dimensions in the region of several metres. With this, we will be supporting applications in the life sciences, in communications technology, in laser material processing and in fundamental research.

What will be the focus in Jena?
In Jena we will research questions of micro-optics and nano-optics. We will also work in the laser development sector.

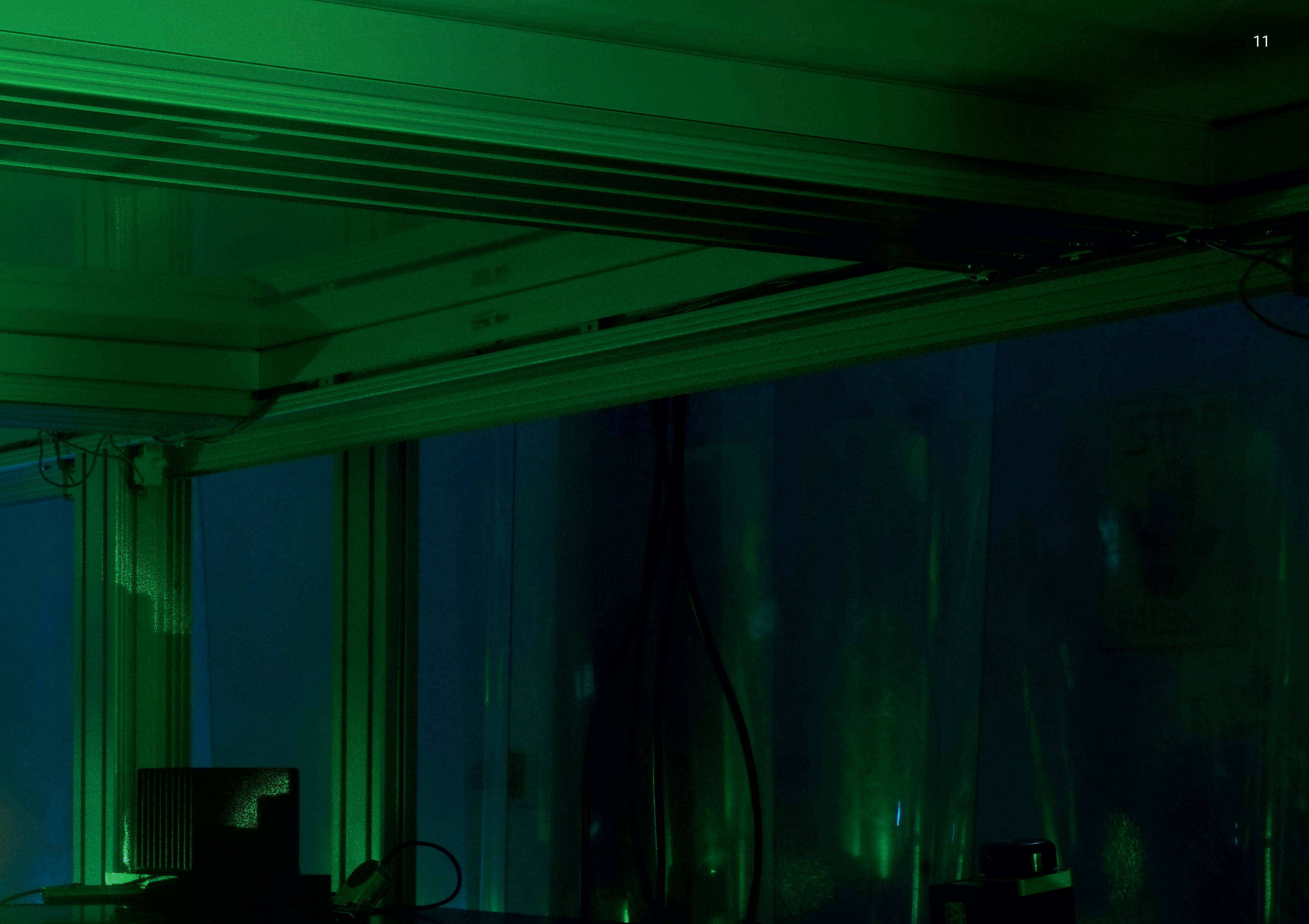
The Max Planck School of Photonics will receive 15 million euros of funding from the state for the pilot phase. What will this money be used for?
This money will actually be almost entirely used to pay for the personnel. During the master's phase, the students will receive highly remunerative scholarships and there will be full-time positions for the doctorate phase. The research itself will have to be funded by the supervising scientists.

Many institutions, which are competitors on the national level, are now in the same boat. What do you need to be aware of in collaborations such as this one where competitors become partners?
Referring to my initial thoughts: science lives from cooperation and competition. In fact it is always about the people involved. It is great when you know each other and are in friendly competition, whilst also working together to move forward with a shared research interest. That is the basis for cooperation in the Max Planck School of Photonics, which we hope to establish over the coming years. It is vital that the network, which already exists between individuals and institutions in the sector of photonics, becomes even closer. That is the way to generate added value for the researchers, which is then reflected in the research findings.

Which conclusions should be drawn in five years after completing the first funding phase?
We will have established the Max Planck School of Photonics, we will be receiving applications from the best students across the world, and we will be attracting the most qualified students to complete a doctorate in Germany. Thus, in terms of promoting early-career researchers, we will be in competition with the elite photonics institutions and will be able to provide our doctoral candidates with the most attractive education and research conditions in the world. ■



The high-power titanium sapphire laser JETI 100 at the Institute of Optics and Quantum Electronics at the University of Jena.



FEATURE

Light—a bundle of energy

Light illuminates the world, it is a tool and the elixir of life

Bundled and intensified light waves have become a key component of research and industry, medicine and communications. Laser beams and pulsed bundles of energy provide insights into fundamental processes at the subatomic level, assist in the diagnosis and treatment of illnesses, and serve as precision instruments in the production of industrial goods. Light waves also transport information from the depths of the universe and provide insight into its composition and development since the Big Bang. The light of the sun is, quite simply, the elixir of life on earth: from single-celled green algae to humans, life follows a 24-hour rhythm. Artificial light sources illuminate our cities, powerful microscopes provide detailed images of living cells, and optic data highways enable communication at the speed of light. »

Optics experiment during the basic internship for second-semester physics students. Yet, light is not only a subject of research for physicists. At the University of Jena, the profile line »Light« brings together researchers from five of the ten faculties.

Sources of enlightenment

Science sheds »light on the dark«. Researchers have »a light-bulb moment«. The list of light-based metaphors in science goes on and on, and even includes the title of this research magazine—after all, LICHT**GEDANKEN** stands for illuminating thoughts, enlightened spirit and knowledge. Light, however, is more than just symbolism. Light, in all of its many facets, is one of the focuses of research at the Friedrich Schiller University Jena that brings together physicists, materials scientists, chemists, biologists, medics and computer scientists, and is not just limited to physical phenomena.

BY UTE SCHÖNFELDER

Light is what we see: a small section from the spectrum of electromagnetic radiation for which the human body has developed two detectors—the eyes—over the course of evolution. In addition to high-energy radiation in the ultraviolet, X-ray and gamma ranges, and low-energy radiation, for example infrared waves, microwaves and radio waves, the range of visible light constitutes only a fraction of the electromagnetic radiation spectrum.

Electromagnetic radiation consists of waves. The character of light waves can be demonstrated using the double split experiment. When a ray of light is split into two by a screen, it does not just split into two new rays of light; instead it is split into several rays with different levels of brightness. This is due to the wave characteristics of light. The point at which the crest and trough of the wave of the two resulting rays cancel each other out remains dark. The point where the two wave crests intensify one another is light. The distance between the two neighbouring wave crests and troughs represents the wavelength, which is used to classify the electromagnetic radiation. The wavelength of visible light ranges between 380 nanometres (violet light) and 780 nanometres (red light).

Particles with zero mass but maximum speed

Why do humans perceive this very part of the huge spectrum of electromagnetic radiation? The answer is a simple one: this part is equivalent to the frequency range in which the sun emits the most intense electromagnetic radiation. But there is more to light than that which is described as classic waves. It was back in the 17th century when Isaac Newton stated that light is made up of tiny particles. Albert Einstein then explained the photoelectric effect at the beginning of the 20th century: the energy of light, just as that for other electromagnetic radiation, is quantized in tiny portions known as photons. Thus, light is both waves and particles. In contrast to other components of matter, for example as electrons and protons, light particles have zero mass. They travel at speeds of almost 300,000 kilometres per second in a vacuum—the maximum speed in the universe.

Light is energy, a tool and information

On average, the sun emits around 1,300 joules per second per square metre of the earth. Sunlight is the most reliable and greatest energy source that we have—utilizing it and storing it is one of the main challenges facing the growing population. Researchers at the Jena Centre for Energy and Environmental Chemistry work with environmentally friendly solar cells and batteries to make energy from sunlight available to applications (p. 16 of this edition). Light is also the foundation of life in general. Plants, algae, and some bacteria use sunlight for photosynthesis to convert carbon dioxide and water into energy-rich organic compounds, e.g. sugar. Life-essential oxygen is a by-product of this process. Living organisms—from single-celled green algae to humans—use the light of the sun to synchronize their internal clocks. Botanists from the Matthias Schleiden Institute at the University of Jena are working to decipher how this clock works.

Light has always been used as a tool. Nowadays, it is mainly lasers that are used in multiple fields as precision instruments. Physicists in Jena use specially pulsed laser light, which releases enormous amounts of energy in scarcely conceivable short flashes. Laser pulses lasting just a few attoseconds (one quintillionth of a second) can be used to reproduce and thus decode ultrafast chemical processes (p. 20).

The pulses that physicists use to light up air and thus display three-dimensional objects in free space are only fractionally longer, in the femtosecond range (p. 24). Laser beams are also being used to digitalize antique clay tablets to present the millennia-old cuneiform scripts from Mesopotamia to the public in a contemporary way (p. 26).

Light is information. Electromagnetic radiation from space that we detect on earth can provide information about distant stars and galaxies. Astrophysicists from the University's observatory look into the depths of the universe, and analyse starlight (p. 34) and stardust (p. 40).

Thus, light is not just illuminating the macrocosm. Light also provides insights into the microcosm: either living cells, nanoparticles, meteorite rock or polymer layer, a huge range of microscopic procedures are turning minute details into fascinating pictures, as demonstrated by the photo gallery in this edition (p. 30). ■

LIGHT IDEAS

In my discipline, light is the simplest, yet most concise metaphor for searching and acquiring knowledge.

Prof. Dr Stefan Matuschek,
literary scholar

Light is the origin of all being and what creates the space around us as we see it.

Prof. Dr Kalina Peneva,
chemist

Observing and measuring light is practically the only method we have to understand the stars.

Prof. Dr Ralph Neuhäuser,
astrophysicist

Light is the tool to investigate the properties of matter in the highest possible spatial and temporal resolution.

Prof. Dr Thomas Pertsch,
physicist

In terms of my research, light means the power of the active mind to use basic concepts and accurate inference to attain knowledge that can be universally imparted and justified—in contrast to the allegedly effortless, sudden insight from enlightenment or divine revelation.

Prof. Dr Andrea Esser,
philosopher

Light is essential to life, but it is also destructive. I use light to attract moths to be able to learn about their variety and diversity.

Dr Gunnar Brehm,
zoologist

Light can be far more than the information carrier for our sight. It reveals its inconceivably high power when we focus it on the smallest spacial and temporal scales.

Prof. Dr Malte Kaluza,
physicist

Light is the perfect key to understanding the modern physics. Light can be used to elucidate the dynamics and structures of matter on an atomic scale.

Prof. Dr Christian Spielmann,
physicist

Light is the prerequisite for knowledge and understanding: understanding something means viewing it in a certain light. Theology asks: what does it mean to see the world in the light of God and how do people who see the world in the light of God live?

Prof. Dr Miriam Rose,
theologian

Light is the prerequisite for the life of most organisms on our earth, especially for algae and higher plants. Both produce the oxygen that is vital for our life, remove the greenhouse gas carbon dioxide from our environment, and serve as a source of nutrition for us.

Prof. Dr Maria Mittag,
botanist

Sunlight to go

Materials scientists and chemists at the Center for Energy and Environmental Chemistry Jena (CEEC Jena) have been working on the development of organic solar cells and organic batteries for many years. A recently concluded research project has now seen them combine both components to facilitate a more efficient energy generation for small applications, and thus to open up whole new processing and application options for the developed solar batteries as a result.

BY JULIANE DÖLITZSCH

Sustainable energy use is one of the greatest challenges of our time. Scientists across the globe are searching for ways to utilise renewable energies and to create self-sufficient systems. Houses that generate their own electricity by way of photovoltaics and electric cars powered by a battery charged predominantly from wind, water and solar power are now commonplace. Materials scientists and chemists at Jena have been thinking on a smaller scale: they are focusing on small, mobile applications.

As far as Prof. Dr Ulrich S. Schubert and Dr Martin Hager are concerned, the key lies in flexible solar batteries, which combine the benefits of organic solar cells in terms of flexible solar fabric with organic batteries. The five-person Solar Batteries research group, which has been funded over the past two years as part of a research group from the Thüringer Aufbaubank with funds from the European Social Fund and the Free State of Thuringia, is searching for a suitable way to connect the two components and has already achieved some promising results. In addition to the CEEC Jena, the Leibniz Institute of Photonic Technology was also involved and provided production facilities for flexible solar fabric.

Chemical liaison: marrying solar cells and batteries

»We had the idea of creating an integrated system that incorporates both energy conversion and storage«, explains Martin Hager from CEEC Jena. »In order to achieve this objective, we married solar cells and batteries to develop a solar battery.« Benefits include the fact that cables are largely redundant and that the battery recharges in the sun even when it is currently in use. This guarantees a continuous power supply. »The battery stores the absorbed energy, which can then be used when there is no sun.«

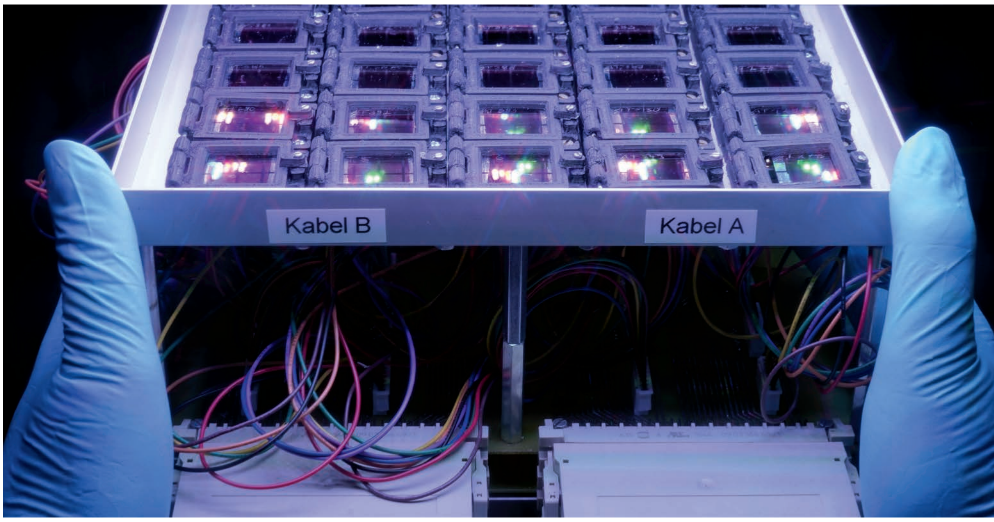
The researchers connected organic polymer solar cells or a solar fabric comprising silicon solar cells directly with an organic battery. The solar cells supply the electricity and are thus able to charge the polymer batteries. This ensures continuous charging when in the sun, as well as the discharge of the energy when there is no sun. »This combination is highly complex and lots of adaptive processes are required«, says Dr Hager. »It was very important for us to be able to adjust the voltages.« A solar cell generates a maximum of 0.7 volts, but a mobile phone requires 3.8 volts to charge, for example. »Thus, we had to interconnect several solar cells to produce sufficient voltage.«

The solar batteries are thin, lightweight and flexible—they are ideal for small, light applications that are regularly exposed to the sun and for which the low amounts of energy are sufficient. »The solar battery is ideal for safety clothing with reflectors, which light up independently. New sensory functions, such as connections to the smart watch, are also possible«, continues Prof. Schubert. »Furthermore, it is suitable

Image left: Sunlight is a virtually inexhaustible source of energy. Organic solar batteries represent one way to store this energy so it can be used in a sustainable manner.

Image top right: The polymers for the solar batteries are processed in an inert gas preparation plan (or »a glovebox«).

Image bottom right: The polymer solar cells are tested under LED lighting.



for anything that can be layered, such as packaging materials, billboard advertising and signs, which need to light up at night without cables.«

As the polymer batteries can be charged and discharged 1,000 times, they are tailored to product life cycles. One pre-requisite for wide-scale use is that the solar batteries must be easy to apply to the materials during production. Schubert and Hager are optimistic in this regard and some companies have already registered an interest. »The technology does not represent competition to classic silicon solar cells or lithium-ion batteries«, emphasises Schubert. »Rather, the solar batteries offer totally new, complementary options for processing and applications.«

And what might sound like fanciful gimmicks are in fact extremely sustainable: »Solar batteries are not just environmentally friendly in terms of their usage, but in terms of production too«, explains Martin Hager. »We use organic polymers and thus there are no non-organic materials in the batteries, which are critical or even toxic. Furthermore, the comparatively cost-effective manufacturing process for the polymer, recyclable plastics uses far less energy than that for conventional batteries.« In terms of future challenges, the task now is to optimise the capacities of the solar batteries and to find further applications.

»Solar batteries could also be used in the Internet of Things and in smart building façades. It could even be possible to create nappies that communicate when they are full via a sensor«, says Hager. »Although there are other ways to find that out«, he adds, grinning. As long as the sun shines in the sky, there are no limits to their possible uses. ■

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The internal clock

It is not just our willpower that determines whether we are awake or asleep. Our sleep-wake cycle is governed by an internal clock, which is entrained by the rhythmic change of daylight and darkness. Prof. Dr Maria Mittag is investigating the internal clock of tiny green algae. In this interview, the botanist talks about what single-celled organisms have in common with humans from the view of a chronobiologist, how the internal clock works under free-running conditions in constant darkness, and why this topic earns a Nobel Prize.

INTERVIEW: JULIANE DÖLITZSCH

For a long time you have been researching the internal clock of green algae—what are you currently working on?
We are investigating the properties and functions of cryptochromes. These are proteins that exist in many organisms and act either as receptors, which forward light information to the endogenous oscillator, or are themselves a part of the internal clock. In the case of the single-celled flagellate green alga *Chlamydomonas reinhardtii*, there is one plant-based and one animal-like cryptochrome, amongst others. Interestingly, the plant cryptochrome does not just transmit light information; it also appears to be part of the internal clock itself.

How did you come to these conclusions?
We know from previous experiments that *Chlamydomonas* cells that are placed in permanent darkness react to light pulses only during the subjective day and swim towards them, but not during the subjective night. This circadian rhythm is known as photoaccumulation. We recently reduced the expression of the plant cryptochrome from *Chlamydomonas* to around ten percent and discovered that the circadian behavior of the photoaccumulation in these green algae changed: the period extended to around 28 hours and the behavior became arrhythmic after a few days. This suggests that the plant cryptochrome plays a decisive role in controlling the internal clock of *Chlamydomonas* within the endogenous oscillator.

And humans also have cryptochromes?
Yes, animal-like cryptochromes have been identified as part of the endogenous oscillator for the circadian clock in mice and humans. Thus, they directly affect the sleep/wake cycle.

Do we need light for our internal clock?
The internal clock is synchronised using the light-dark cycle. If you expose the organism to permanent low light or permanent darkness, a human will, for example, experience a period of around 25 hours during one sleep-wake cycle. This means that, at some point, humans miss a day. Jürgen Aschoff discovered this already in the 1960s when he conducted experiments observing the sleep-wake cycle of people in bunkers over several days. Students often participated in such experiments. In parallel, they were often also studying for exams, but had to sleep at some point. Depending on the organism, the period may be slightly longer or shorter than 24 hours under constant conditions. Thus, an internal clock determines the daily routine for most organisms.

How great is the influence of light on the day-night rhythm?
In principle, every journey into a different time zone represents a manipulation of our internal clock. Once we have spent two to three days in the USA or Australia, we overcome the jet lag and adapt to the new light-dark cycle, as our internal clock resynchronizes. This applies to both humans and green algae.

Green algae know what time it is in Australia?
Of course. There were some people who were sceptical of the idea of an internal clock and they conducted experiments. Thus, colonies of bees were once flown to the USA because the researchers believed that they would simply continue with their rhythm once there. But, after a few days, they had been adapted to the new light-dark conditions and had synchronized their internal clock accordingly. It would also have been possible to simply keep them in Germany and expose them to a reversed dark-light cycle to test the same thing, as chronobiologist Colin Pittendrigh rightly noted. Algae have also been sent to outer space, as scientists believed that their rhythm may be dependent on the earth's gravitational pull. However, the rhythm of the photoaccumulation of *Chlamydomonas* continued in space, as Dieter Mergenhagen and his wife Elke demonstrated. This confirms that an internal clock continues to dictate things, even at microgravity.

In recent years, the Nobel Prize for Medicine or Physiology has been awarded to Jeffrey C. Hall, Michael Rosbash and Michael W. Young. The three Americans have been researching chronobiology since the 1980s. Why have they now been honoured with a Nobel Prize?
Almost every organism on earth is subject to light-dark cycles and their adaptation to these is associated with many bene-

Image left: Expert for micro algae and their internal clock: botanist Maria Mittag.

Image right: Culture bottles and petri dishes containing *Chlamydomonas reinhardtii*. The single-celled green algae have their own »alarm clock« for their day-night rhythm. Maria Mittag and her team of researchers have demonstrated this in a study (original publication under: https://doi.org/10.1104/pp.17.00349).

fits—and this is vital knowledge at a time when almost one quarter of working people performs shift work. If the internal clock is disturbed, it can cause harm. Affected people are not just tired; but also more susceptible to illness. Significant correlations between circadian rhythms and the health of the organism in question have been under debate recently. It was about time to acknowledge the scientists who characterized the first clock gene and who have made a decisive contribution to the understanding of the molecular mechanism of the internal clock.

What do these findings mean for medicine?
That the internal clock shouldn't be ignored in the treatment process: studies have shown that patients tolerate various medications better at certain times of the day, as the proteins, which contribute to the absorption of the medicines, their distribution and their breakdown, can be controlled by the internal clock. So-called chronotherapy has now been introduced to the treatment of certain cancers as a result; predominantly with the aim of reducing the side-effects of the medication.

Getting rid of daylight saving time has once again become a hot topic within the EU. What does changing the clocks mean for the organism?
Changing the clocks is basically the equivalent of a mini jet lag for the body. It destroys the activity profile of humans and has to be synchronized again. Lots of people are adversely affected by this; some people are more susceptible to depressive moods and the number of accidents increases. Others adapt well to the change and don't experience any problems.

What do you think about getting rid of daylight saving time?
Biologically speaking, it would make sense to keep the time the same, so that millions of people do not have to suffer a disturbance in their circadian rhythm. Having said that, using mobile phones or certain LED lights around midnight is just as disruptive as changing the clocks. The blue light that they emit is extremely efficient at shifting the phase of our internal clock so we are awake at night and tired during the day. ■

Chronobiology

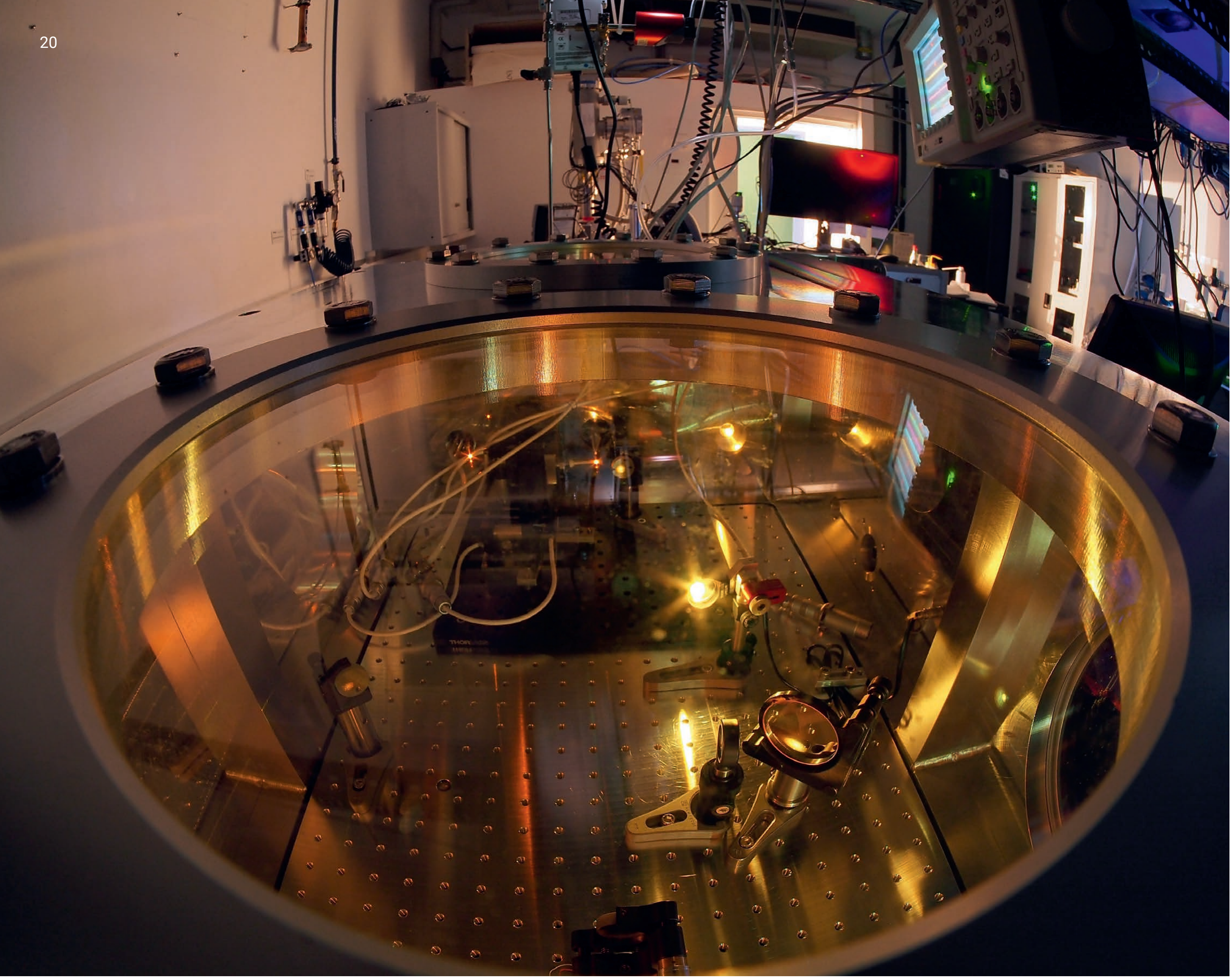
Chronobiology investigates **biological rhythms** like the internal daily clock; in other words, it seeks to describe and research the time structure of organisms. Organisms follow a precise, temporal structure in line with events or physiological processes that repeat periodically; humans and many other organisms have a **circadian rhythm**—a daily rhythm, which is around 24 hours long when they are exposed to free-running conditions. It is controlled by the **endogenous oscillator** or the internal clock. The fact that the leaf movements of some plants follow a circadian rhythm has been known since observations by academics in the 18th century—initially on the mimosa, which closed its leaves and reopened them during both, light-dark experiments and also when in constant darkness (subjective day and subjective night).

Algae and light

The behaviour of algae is controlled by light in a multitude of ways. They use **light as a source of information** to synchronize their internal clock, to control their movements and for their sexual cycle. Furthermore, they need **light as an energy source** for photosynthesis. This is a physiological process where higher plants, algae and some bacteria convert low-energy substances, such as carbon dioxide and water, into high-energy substances with the help of light—oxygen is released as a by-product during this process.

The significance of algae

Algae, including blue-green algae (cyanobacteria) are responsible for around half of the **photosynthetic activity** and thus contribute around 50 percent to the **CO_2 fixation** on Earth. Algae (phytoplankton) also stand at the start of the **food chain** in the sea and in freshwater: they are eaten by zooplankton, which in turn serves as food for crustaceans, which are then eaten by fish.



Chemical reactions in super-slow motion

Many chemical processes occur so quickly that, until now, we only had an approximate idea of what is going on. The available methods to analyse them are simply too slow to capture the decisive ultra-short moments. A team of physicists from Munich and Jena has now succeeded in combining two different spectroscopic techniques to visualize a key part of chemical processes, the ionization of atoms, to the degree of several quintillionth of a second (attosecond) and control it on the quadriollionth time scale (femtoseconds). This pump-probe spectroscopy produces snapshots, which can be put together to create a film in super-slow motion. The new technology is intended to help provide a better understanding of processes such as photosynthesis and to develop faster computer chips.

BY ANJA WAGNER

Green plants, algae and bacteria use light energy to convert carbon dioxide into high-energy biomolecules and oxygen. This process has been known as photosynthesis for over 200 years and has been the subject of extensive research: the starting materials, reaction and intermediate products have been clarified, as has the chronology of the chemical reactions.

However, little is known about the elementary processes, which take place in the molecules within the plant cells that are involved in the photosynthesis. »We know that during photosynthesis, and during numerous other photochemical reactions, atoms or molecules are ionized«, reports Junior Professor Dr Birgitta Bernhardt. »Yet it has not yet been possible to fully track the process of the ionization reactions.« The reason: these reactions, which see electrons being pulled out of atoms or molecules, can take place extremely quickly. They

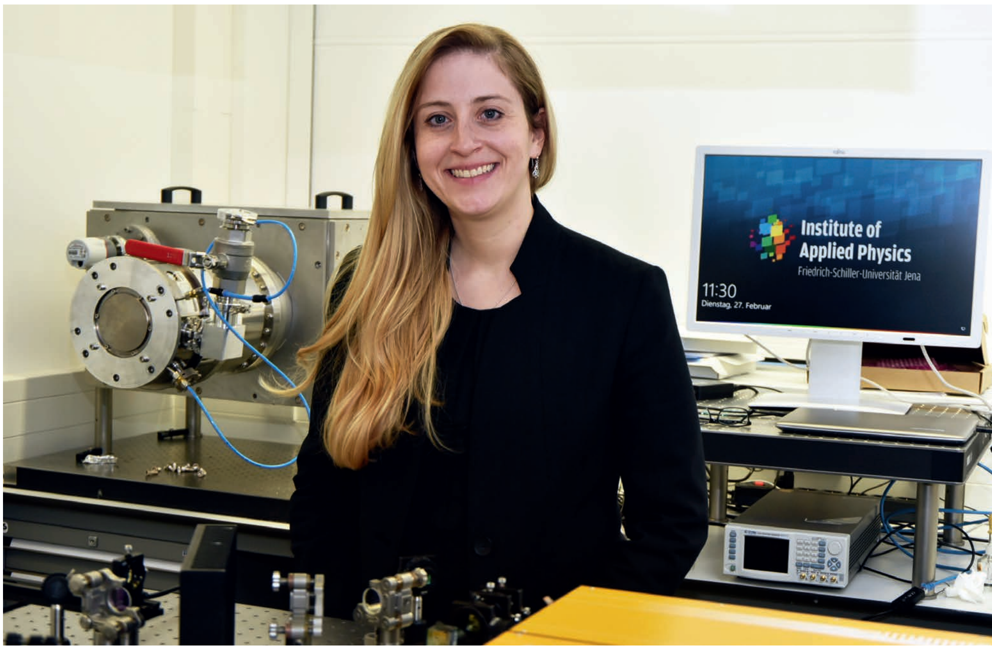


Image left shows one of the three vacuum chambers at the TU Munich, in which the isolated attosecond flashes of light are generated. Image right: Junior Professor Dr Birgitta Bernhardt in her Jena laboratory at the Institute of Applied Physics.

only last a few femto- or attoseconds (a quintillionth of a second). It is such an inconceivably short space of time that physicists often make this striking comparison: one attosecond is to a second what a second is to the age of the universe—and that is almost fourteen billion years old.

Molecule cinema: 300 femtoseconds are turned into 35 minutes

The team of scientists working with the 37-year-old physicist from the Institute of Applied Physics and colleagues from the Technical University of Munich has now succeeded in making it possible to watch ultrafast ionization processes in a level of detail that has previously been unheard of. As they write in the renowned specialist journal *Nature Communications*, the researchers use the so-called pump-probe spectroscopy and do so twice over. This method sees the sample—in this case the noble gas krypton—be stimulated by an ultra-short laser pulse to stimulate the ionization process. A second, time-delayed laser pulse detects the status of the process.

»In this way we can measure the change to the absorption and the ion formation in the noble gas in relation to the time delay of this second pulse«, explains Bernhardt. Repeating the measurement with different time delays results in lots of individual snapshots, which are put together to create one single video. The researchers have put together 70 of such snapshots by recording a video sequence of around 35 minutes, which covers a period of just 300 femtoseconds of the actual chemical process

By combining the two measuring techniques, the scientists can record more than just ultra-fast ionization processes: by varying the intensity of the second, interrogating laser pulse, the ionization dynamics can also be controlled and influenced. »This control represents a very strong instrument«, explains Bernhardt. »If we can simulate and even influence rapid ionization processes, we can learn a lot about light-controlled processes like photosynthesis—including about those first moments when this complex machinery bursts into action; things that there has been little understanding of to date.«

Controlling the ionization of silicon facilitates the production of better computer chips

The technology developed by Bernhardt and her colleagues is also of interest for the development of new, faster computer chips, for which the ionization of silicon plays a key role. If you cannot just prompt but also control the ionization state of silicon within such a short time window—as the first experiments with krypton suggest—then scientists will possibly be able to use this technique to develop innovative and even faster computer technologies. ■

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Ultrafast Quantum Control of Ionization Dynamics in Krypton. Nature Communications (2018), DOI: 10.1038/s41467-018-03122-1

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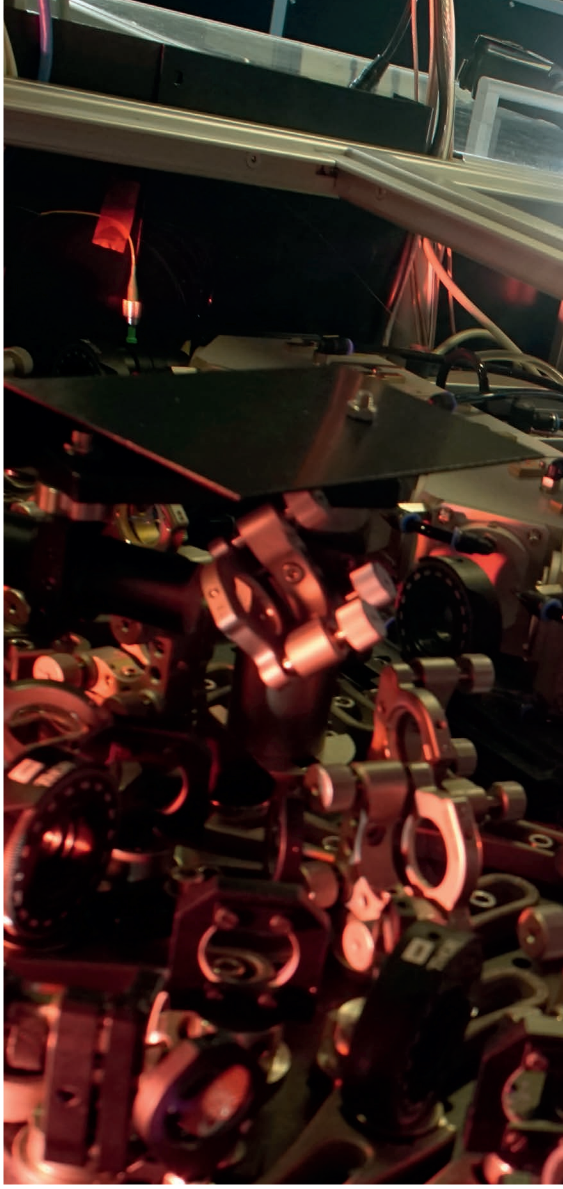

World record with short-pulse laser

Last year saw early-career physicist Michael Müller build the world's most powerful ultra-short-pulse fibre laser—and he proved this in February with the presentation of his research findings at the »Fibre Lasers XV: Technology and Systems« conference in the USA, where he came second in the Best Student Paper Awards. Who will be able to break his record? »At the moment, probably only me«, believes the doctoral candidate at the Institute of Applied Physics.

BY JULIANE DÖLITZSCH

Michael Müller is 27 years old, a doctoral candidate at the Institute of Applied Physics and currently the world-record-holder for the most powerful ultra-short-pulse fibre laser. The young physicist has been working on the development of short laser pulses for three years within Prof. Dr Jens Limpert's working group »Fibre and Waveguide Lasers«.
Müller does not see this as a reason to withdraw from the group: »There are plenty of research groups working on the development of high-performance lasers, but we are currently following the most successful concept for output scaling«, he explains.

Records are part of the day job in science

That is why he believes it is likely to be himself that breaks the world record: »Perhaps in one or two years, when my colleagues and I have developed the next laser system.« What does the record mean to him? The physicist, who was born in Heiligenstadt and completed his bachelor's and master's programme at the University of Jena, is laid back in this respect too: »In a fast-developing field like laser research, scientists are constantly eclipsing previous results. World records are quite common«, he smiles. In the experiment, the early-career researcher and his colleagues succeeded in overlaying individual laser beams by exploiting the wave properties of the light. Thus, he was able to generate light pulses with a duration of just 220 femtoseconds (10^{-15} seconds) with an average output of 1.9 kW and with the best-possible quality of the laser beam—a previously unheard-of combination.
He lengthened a classic fibre laser experiment to generate this level of light output in such short pulses and used several glass fibres to do so; 16 in total. This is because a single optical fibre is too small for so much energy; the non-linear effects either cause it to break or the pulse becomes too long. Thanks to the combination of 16 laser beams, however, it was possible to create »ultra-short pulses in a brilliant laser beam«.
»The technical process of avoiding non-linear and thermal disruption is far more difficult than the physics that lies behind it«, reports Müller, »the devil really lies in the detail.« The next limit: »Increasing the output further would mean that the laser beam could no longer be propagated in the air; experiments would have to take place in a vacuum.«
It may sound theoretical and far-removed from reality, but it is actually closer than you might think. Ultra-short laser pulses play a key role in the generation of coherent X-rays; in the microscopy of minute structures; and in the inspection of computer chips. The relevance of his findings surely played a part in the Jena doctoral candidate winning a Best Student Paper Award at the international optics and photonics exhibition »SPIE.Photonics West« in San Francisco last February. At the sub-conference »Fibre Lasers XV: Technology and Systems« he won second place with his research.

Showcases by the laser designers: who has the best?

Travelling to big conferences is not just part of the day job for the physicist; it is also one of the highlights of his work. That is why he packs his case once or twice a year and travels to a trade show—beginning with San Francisco in the USA, via Vienna and Munich, and as far as Nagoya in Japan. The entire thing is like a showcase event: »Everyone shows what they have. The big question is: who has the best laser?«
He still gets nervous making presentations in front of up to 100 scientists, but, like so much else, it is a case of getting used to it. Having the opportunity to present your own work is, at any rate, a requirement for winning a prize and for recognition within the world of sci-

ence. The atmosphere at a trade show is, generally, very special. »When so many scientists get together, thought-provoking impulses are everywhere; there are so many ingenious and, sometimes also simple, ideas. At times you wonder why you didn't come up with it yourself«, laughs Müller.

Together with his colleagues, the Thuringia-born physicist has already been speculating about the upcoming experiment. Unlike the last experiment, which saw them send laser pulses through 16 glass fibres with 16 individual glass cores, he can imagine that the next step would involve using just one glass rod with a larger number of fibre cores. »It would make the entire system smaller so it could be integrated in a more compact way.«

Müller's greatest desire is for a career in science—but he has a very relaxed view of the future. »Up to this point, a door has always opened that met my expectations and so I took the opportunity. I just hope it continues to be so exciting.« Before writing his dissertation on the ultra-short-pulse fibre laser, he wants to experiment further with it and »make the short pulse even shorter.« His aim is to generate an even greater output, and that is what drives him—be it at the conference in the USA or in his local laboratory in Jena. ■

World-record holder Michael Müller and his laser system, which consists of 16 amplifier modules, with a coherent beam combination. The 27-year-old is a doctoral candidate at the Institute of Applied Physics. The aim of his research is not, however, just to break records. He wants to develop powerful short-pulse lasers for use in microscopy or in the manufacturing of computer chips and in fundamental research.

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Drawing with luminous air

Measuring objects in 3D no longer poses any technical problems—but presenting them in three dimensions remains an issue. You generally need to wear special glasses or have to accept viewing a two-dimensional image on a flat surface. Jena physicists have now developed a method to present 3D objects in thin air using laser beams.

BY SEBASTIAN HOLLSTEIN

Staff at an architecture firm are standing together, discussing a project. A three-dimensional illustration of the planned building shines in the centre of them. »Why not move the entrance ten metres to the left and the lift to the east wing—then there would be more space for a larger terrace«, one architect says to another. The person addressed moves his hands through the air like a conductor, causing the virtual walls of the model to move and come together in a different position. Admittedly, this scene has not yet happened. Architects continue to work with drawings on large sheets of paper, look at two-dimensional diagrams on a screen or create designs using models that require a lot of time and energy to produce. Yet, what may currently seem like science fiction, may actually be an everyday tool for many occupations in just a few years' time.

At least, if things go as Prof. Dr Stefan Nolte from the Institute of Applied Physics thinks they might. Together with his colleagues Dr Robert Kammel and Dr Roland Ackermann, he is working with the »Ultrafast Optics« working group to develop a new technology to present three-dimensional objects in thin air. This is all part of the project consortium »3Dsensation«. »In this alliance, we want to work together with partners from various scientific fields to develop technologies, which will improve the interaction between humans and machines, and will thus have a positive effect on people's lives and work«, says Stefan Nolte, explaining the vision behind »3Dsensation«. One of the basic premises of this is being able to present three-dimensional objects in actual 3D.

»There are currently several ways of capturing objects in 3D and generating coordinates for their three-dimensional representation. Medics now utilise the corresponding imaging processes on a daily basis«, explains Robert Kammel. »Yet, until now, it has not been possible to adequately present this information in 3D. Often, we have to make do with a two-dimensional image on a flat screen, or the images have to be generated with the help of displays and can only be viewed using special glasses.«

An invisible laser ionizes the air—mirrors move light points quickly

As part of the project »DiRLas—Untersuchungen zur Visualisierung von 3D-Objekten im freien Raum mittels Laser« (DiRLas—investigations into the visualisation of 3D objects in free space using lasers), Nolte, Kammel and Ackermann have now developed a very promising method. It involves the use of a femtosecond laser; in other words, a laser, which emits very short laser pulses. The light emitted is in the infrared range and is thus invisible to the human eye. The scientists use a lens to focus the laser beam on a specific point

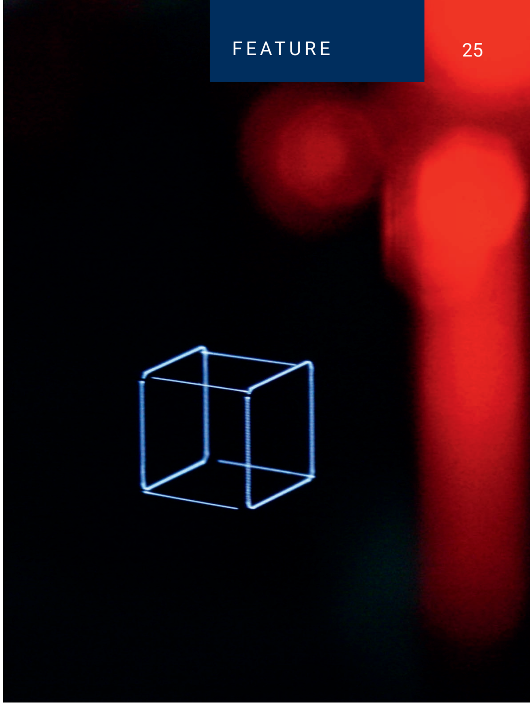

Image left: The three-dimensional presentation of complex objects in free space remains a vision of the future; but the technical foundations are already in place.

Image right: The method, which physicists at the Institute of Applied Physics and colleagues from the Fraunhofer Institute for Applied Optics and Precision Engineering are working on, already works very well for small objects, such as this cube with an edge length of around half a centimetre. The Jena-based research projects are being funded by the state.

in the air. The intensity is so great that it ionizes the air molecules and thus disrupts them. Electrons and ions separate resulting in a plasma. But, as soon as the electrons return and recombine, they emit visible light. Scanner technology—i.e. moving mirrors—can then be used to move this light point. If you do this at high speed, the result is three-dimensional structures appearing in the air. Computer data defines how these structures look. »To put it simply, we light up the air so we can then draw with it«, says Roland Ackermann.
In addition to air, the Jena scientists have also experimented with various other gases to find out whether they can produce brighter lines. The noble gas argon would be better suited. »But air has a big advantage over the rest: you don't need to create a special environment for it«, says Kammel.
The physicists have spent the last three years preparing the foundations for the new method. Now the challenge is to develop the technology so it is ready for use. The 3D images that have been produced up to this point are very small. The cube made up of illuminated lines has an edge length of just five millimetres, for example. This is something the researchers want to change with the recently commenced follow-up project »EiM3D—eigen-haptische Manipulation ausgedehnter 3D-Strukturen im Raum« (EiM3D—separate haptic manipulation of extended 3D structures in free space). They want to use an adaptive mirror with a reformable surface—developed by the Fraunhofer Institute for Applied Optics and Precision Engineering—for this purpose; it will help to deflect the light points downwards at extreme speed. To date, lenses have had to be moved mechanically, which limits the size of the structures that can be displayed and thwarts the picture generation.

3D images to be moved freely in the air using gestures

Furthermore, the researchers will spend the next months focusing on an additional function, which goes beyond pure image reproduction: »Together with the Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute in Berlin, we are currently developing a control that will allow us to move the 3D images using gestures«, explains Roland Ackermann. »A camera system records hand movements, forwards this information to the computer, which then uses it to alter the 3D structure. The result is an interactive imaging system.« Thus, it is possible to move the cube with great sensitivity by moving your hand towards it, without touching the image. Applications, like in an architecture firm, could become the reality.

»It will take us at least another five to ten years to get to the point where compact systems offering this technology are found in offices or used in practice«, estimates Robert Kammel. »In order to reach this point, we need to make the system far more efficient and lower the requirements on the laser, for example.« But, we are already at a point where this is far from »fiction«. ■

Further Information:
www.3d-sensation.de
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Laser beam meets antique clay tablets

They were a common means of communication in ancient Mesopotamia: clay tablets upon which people engraved their texts in cuneiform script over 5,000 years ago. Everyday correspondence, as well as scientific and literary texts, have thus been retained to this day. The Hilprecht Collection at the University of Jena encompasses over 3,000 pieces of text alone. These precious relics have been digitalized using laser technology over recent years and will soon be accessible to the public online.

BY STEPHAN LAUDIEN

They are relics of a bygone era—the cuneiform script tablets from Mesopotamia. Relics that are as much a part of the heritage of humankind as the pyramids of Giza or the Mayan temples. The German-American scholar Volrath Hilprecht (1859-1925) put together an important collection of these cuneiform script tablets as well as other artefacts. This collection is now known as the Hilprecht Collection of Near Eastern Antiquities and is one of the most valuable collections at Jena University. The Hilprecht Collection is the second-largest of its kind in Germany; exceeded only by the collection in the Vorderasiatisches Museum in Berlin. The collection is also of great importance worldwide: many of the objects can now only be found in collections in Baghdad, London, Paris, Philadelphia and Yale.

At home in the Jena Hilprecht Collection—freely accessible across the globe

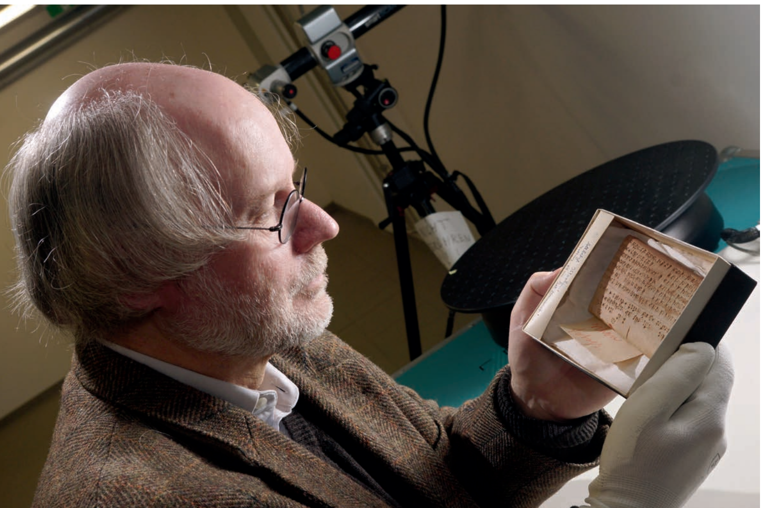
»We don't want to hide the collection; instead we want to make it digitally accessible to everyone«, says Prof. Dr Manfred Krebernik. The holder of the Chair of Ancient Near Eastern Studies is like the master of the Hilprecht Collection, which encompasses around 3,300 exhibits. Some of the exhibits are already accessible via the »CDLI« (Cuneiform Digital Library Initiative) online portal. This website is a joint project between the University of California, Los Angeles, the University of Oxford and the Max Planck Institute for the History of Science in Berlin. Originally, the plan was to only record the oldest cuneiform script texts from the 4th/3rd century BC; these pieces from the Hilprecht Collection were scanned using conventional methods prior to 1999/2000.

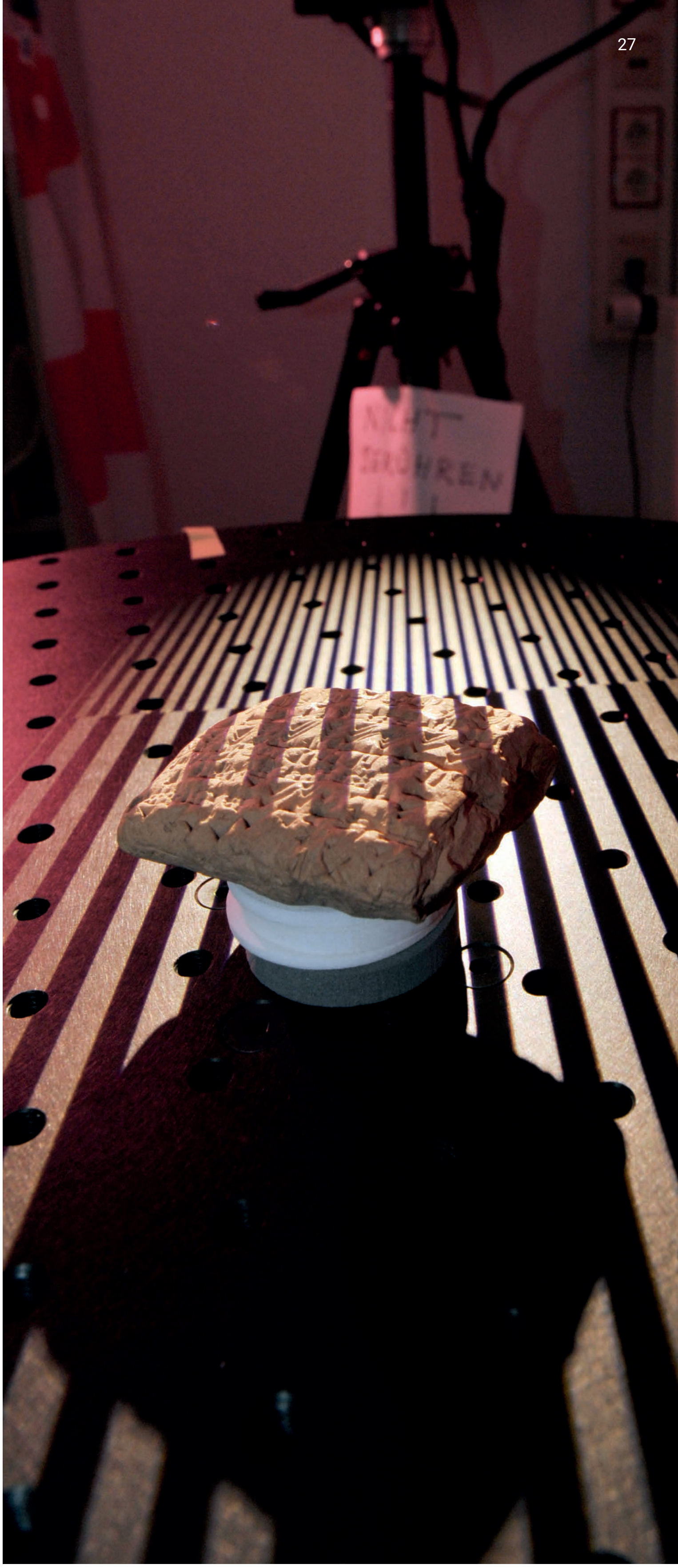
In 2009, together with the Max Planck Institute for the History of Science (MPI) in Berlin, work began on digitalizing the entire collection using 3D scanning technology. The extensive project was sparked during a research visit by Prof. Krebernik to the MPI. »It was Peter Damerow's idea«, says Manfred Krebernik. The science historian, who died in 2011, was extremely interested in the cuneiform script texts. The Hilprecht Collection is quite special compared with other collections: it contains a multitude of scientific and literary texts; including several precursors to the Gligamesh Epic and the oldest known map of a city in the world. This map of Nippur from the late second century BC is one of the most valuable exhibits within the collection. »The city of Nippur was one of the most important settlements in Mesopotamia prior to Babylon«, says Prof. Krebernik. Nippur was the special seat of worship for the highest Sumerian god Enlil; there must also have been many important scribal schools, as the vast majority of Sumerian literary works that have survived are from Nippur. The content of the clay tablets found there suggest that they were used to study the cuneiform script and ancient traditions.

In 1889, a team at the University of Pennsylvania—which Hermann Hilprecht belonged to as a philologist—began excavating. Numerous findings ended up in the Imperial Museum in Istanbul, now the Archaelogical Museum (Istanbul Arkeoloji Müzesi). Hilprecht, who was a friend of the family of the museum founder Osman Hamdi Bey, procured numerous pieces or was given them as gifts. He bequeathed his collection to the University of Jena in 1925. The collection was extended with pieces that botanist Heinrich Carl Haussknecht brought back from his research trips and that the Orientalist Arthur Ungnad procured. In addition to the cuneiform script tablets, which make up the largest part of the collection, it includes small archaeological findings from the Ancient Orient (e.g. terracotta, needles, styluses and other instruments), so-called magic bowls with incantations in the Aramaic language and Ottoman wall tiles.

The artefacts are recorded using a special 3D scanner. Two laser beams simultaneously scan the surface to capture multiple recordings. The researchers use a computer programme

Prof. Dr Manfred Krebernik is studying one of over 3,000 cuneiform script tablets from the Jena Hilprecht Collection.





A 3,700-year-old cuneiform script tablet is scanned. The clay tablet contains a mathematical table and originates from the city of Nippur in modern Iraq.

to put together the individual images to create a 3D view. It is a laborious process. There were technical issues with the first items; they contained gaps that were too large, for example. As Prof. Krebernik explains, the ever-improving programme has been able to close gaps like these.

The artefacts come in varying conditions: there are large items and others made up of numerous fragments. Manfred Krebernik says that the state of preservation of the clay tablets also varies. Hollow spaces within or crystals increase the risk of breakage—gloves must be worn to handle the tablets.

For researchers and the inquisitive public—extensive meta data accompanies the digital reproductions

The scanners and software are provided by the MPI. The technology provides high-resolution digital reproductions, which are up to five gigabytes in size. The original files are compressed for their online use so they load quicker. But it is also possible to download the originals.

A separate online database, linked with CDLI, has been created for the Jena collection. In addition to the 3D scans, it also contains older photographs, as well as numerous meta data, such as inventory numbers, dimensions, datings, item descriptions, discovery sites, transcriptions and secondary literature. Compiling the data records is a time-consuming process. It must also be ensured that the scanned files and meta data are correct and up-to-date. Sometimes during processing, it becomes clear that two or more fragments fit together. If they were originally recorded and scanned separately, they must now be scanned again and given a new data record and cross-reference. According to Manfred Krebernik, a total of around 3,000 items are to be recorded digitally. The majority of the work has already been completed—around 2,500 items have been scanned already—yet considerable effort is still required for meta files and the programming of the online database. The project is scheduled to finish at the end of 2019. The treasures of the Hilprecht Collection will then be available online for the world of research and inquisitive members of the public. The critical edition of the texts will, however, take a little longer; three volumes from the series entitled »Texte und Materialien der Hilprecht Collection« (Texts and Materials from the Hilprecht Collection) are currently in preparation or in print. ■

Further Information:
https://hilprecht.mpiwg-berlin.mpg.de
http://sammlungen.uni-jena.de
https://cdli.ucla.edu/

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Jena's journey to a City of Light

The development of microscopy opened the door to the microcosm. Scientists from almost all disciplines now use a multitude of microscopic methods. The key foundations for these were laid in Jena. Carl Zeiß, Ernst Abbe, and Otto Schott have been considered the pioneers of microscopy to the present day.

BY SEBASTIAN HOLLSTEIN

The successful cooperation between science and industry is not just shaping the global reputation of the City of Light Jena in the 21st century; it is also the basis upon which this reputation was founded. Two names played a vital role in optics research and industry in Jena: Carl Zeiß and Ernst Abbe. The former was born in Weimar in 1816 and opened his own workshop for fine mechanics and optics on 17 November 1846, following his training with a court mechanic Friedrich Körner in Jena and his attendance of some lectures at the local university. Having been encouraged by Jena's botanist Matthias Schleiden, he soon added microscopes to his range of services. Schleiden was the first to prove that plant components are made up of cells; he co-founded cellular biology and thus underlined the need to develop better microscopes for science. Zeiß' instruments were soon in great demand, even beyond the borders of the Grand Duchy of Saxe-Weimar-Eisenach. The business relations saw both the company and the demand for the devices grow. Zeiß no longer wanted to find the correct combination of lenses for a microscope optic through testing, he wanted to use calculations. A 24-year-old physicist helped him to turn this idea into a reality. His name was Ernst Abbe.

Revolutionizing the manufacture of microscopes leads to optical research

Born in Eisenach, Thuringia, Abbe studied physics, astronomy, and philosophy at University of Jena where he also received his doctorate. From 1863 onwards, Abbe taught as a private teacher. He became a professor in 1870. Four years before accepting the professorial position, Zeiß and Abbe decided to collaborate. Within a few years, the tandem recorded their first success: they made the manufacturing process more effective through a specialized division of labour. The scientist Abbe then developed test methods and measuring equipment to simplify the calculation within the optics. Continuous research eventually led to the theory of image formation in the microscope, which Abbe and Zeiß jointly put into practice. Thus, the researcher and businessman revolutionized the manufacturing of microscopes, justified the global reputation of their company—Abbe became a business partner—, and established optics research at the University of Jena. Glass manufacturer Otto Schott also played his part in the success. The chemist was born in the Ruhr area and was a doctoral candidate at the University of Jena. In 1884, he opened a glass technology laboratory in Jena, which developed, and later produced modern, high-quality optical lenses for the Carl Zeiss company.

With their work, the three pioneers did not just lay the foundation for the optics research having been developed in Jena since the end of the 19th century. The new possibilities created within the world of microscopy also opened up new worlds to other disciplines, for example, biology, as Schleiden had suggested.

The instruments from the Zeiss company were also valued by the natural scientists Charles Darwin and Ernst Haeckel. Furthermore, the collaboration also forged the way for many other new innovations. August Köhler and Henry Siedentopf, for instance, who both worked at the Zeiss company and were professors at the University of Jena, developed the fluorescent microscope. This was the foundation for new findings and methods in the field of biochemistry and medical diagnostics. ■

Ernst Abbe memorial in Jena, featuring the formula for the resolution limit of an optical microscope.

»We want to be able to visualize it!«

Biophysicist Prof. Dr Christian Eggeling is dedicated to super-resolution fluorescence microscopy. He uses it to observe proteins and other molecules interacting within living cells. He owes many fascinating insights to this technology—as well as an invitation to the 2014 Nobel Prize in Stockholm.

INTERVIEW: UTE SCHÖNFELDER

Mr Eggeling, why is microscopy so important to science?
Humans are visual creatures. We want to see something; we like to have a picture of something in our minds. It is only then that we believe it. And this is, of course, also true of research. You can use the most precise measuring methods to obtain detailed information and attain knowledge—but we can only really convince other people of something when we can create a visual representation of the findings.

What can researchers discover with the fluorescent microscopes of today?
Proteins and other molecules in living cells, for example. Until a few years ago, this wasn't possible. Now we can for example watch live as human immune cells identify and attack cancer cells. Above all, we can directly observe the molecular defence mechanisms and processes, by mapping the participating proteins and their structures.

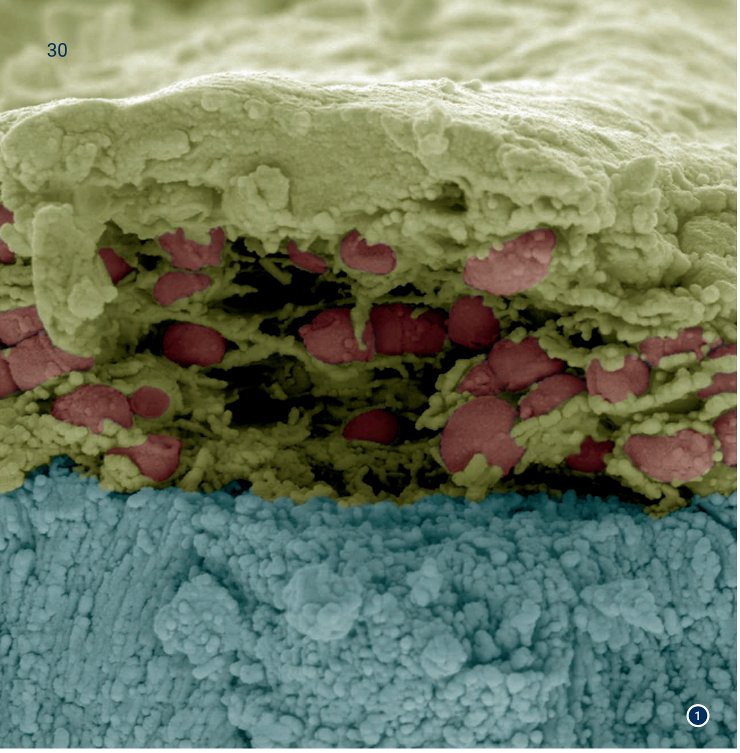
What made these advancements possible?
The lenses for fluorescence microscopy have continued to improve over recent years, as have the lasers and the technology as a whole. But it was not physics but chemistry that gave us the decisive leap we needed to super-resolution microscopy: thanks to the new fluorescence dyes. Stefan Hell initiated these advancements with his ideas that the resolution limit of an optical microscope, as postulated by Ernst Abbe, could be transcended through the use of suitable fluorescence markers. This has now been established as standard practice.

What was the resolution limit?
At the end of the 19th century, Abbe stated that two points that were less than 200 nanometres apart were not discernible by a conventional optical microscope. This is due to the wave properties and the convergence of the light used for the observation, and the resulting diffraction. Molecules and cell components smaller than this can, therefore, not be represented with a normal optical microscope.

But they can with super-resolution fluorescence microscopy?
Yes, the protein structures that we are interested in are significantly smaller than 100 nanometres. In order to make these visible, we use laser beams to switch the fluorescence of dyes, used to mark the molecules under study, on and off. This reduces the effective fluorescent scope of observation to scales of less than 200 nanometres and thus improves the resolution accordingly. This was a real breakthrough, and Hell received the 2014 Nobel Prize for Chemistry as a result.

And you played a part too!
Yes, luckily (*laughs*)! I was part of Hell's working group in Göttingen between 2003 and 2012, and worked with him and other researchers to develop the methodology and brought it into usage. When he heard about the Nobel Prize, he invited me to attend the ceremony in Stockholm with him. And, when he received the medal from the Swedish king, I was a little proud myself! It was a very touching moment. ■

Prof. Dr Christian Eggeling wants to apply the so-called super-resolution STED microscopy (Stimulated Emission Depletion) to new areas, for example for the direct diagnosis of illnesses in patients. During his time in the laboratory of Stefan Hell, who later won the Nobel Prize, in Göttingen, he was involved in the development of the super-resolution procedure. Eggeling has contributed a photograph taken using STED microscopy to the photo gallery on the following pages (No. 10 on p. 31).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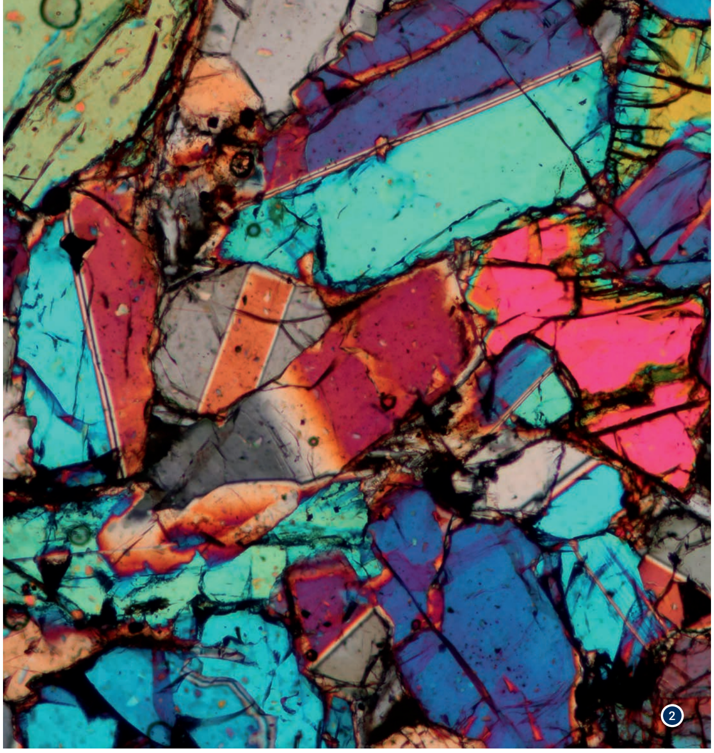
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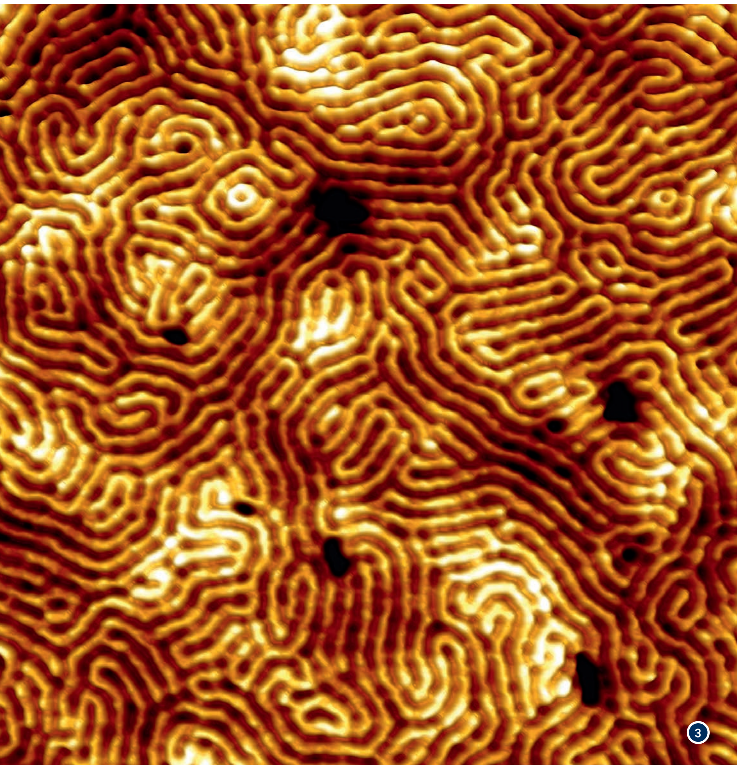
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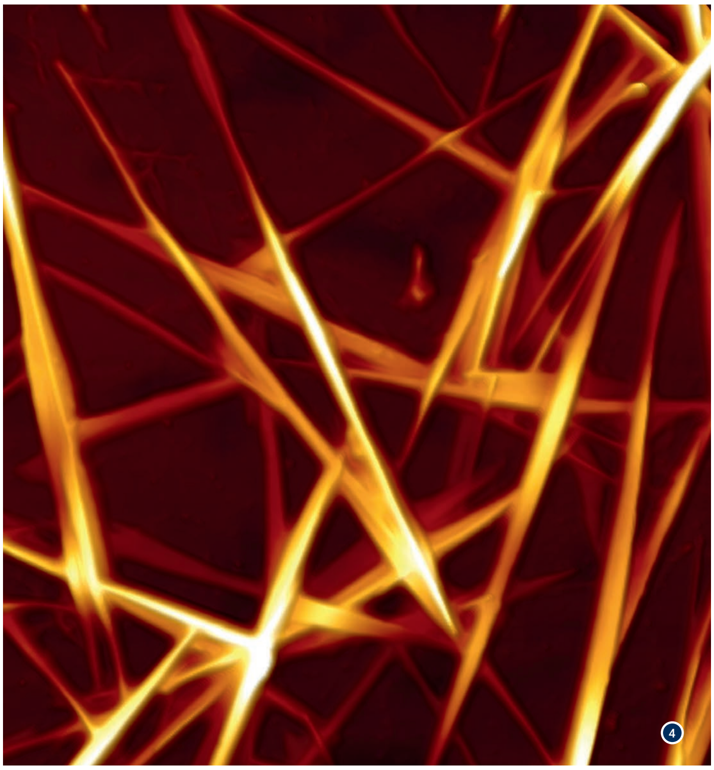
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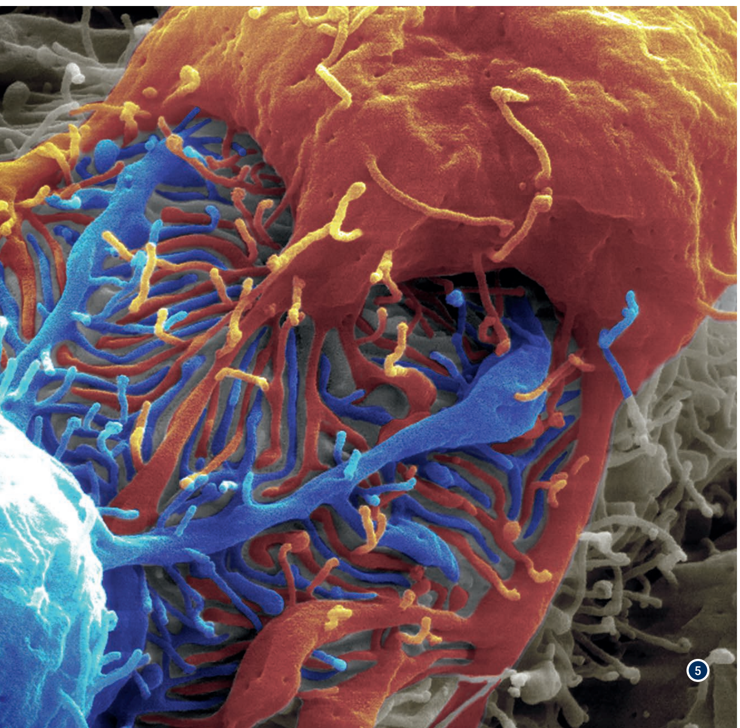
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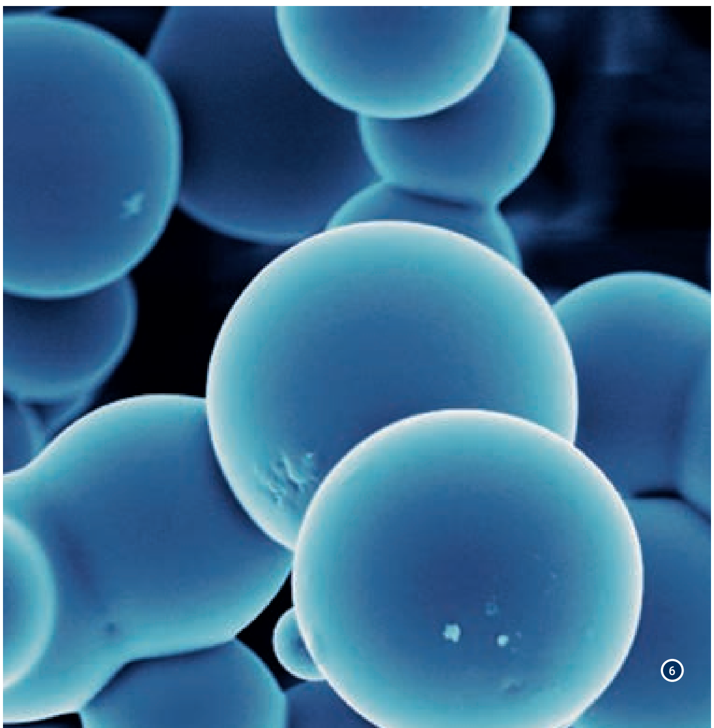
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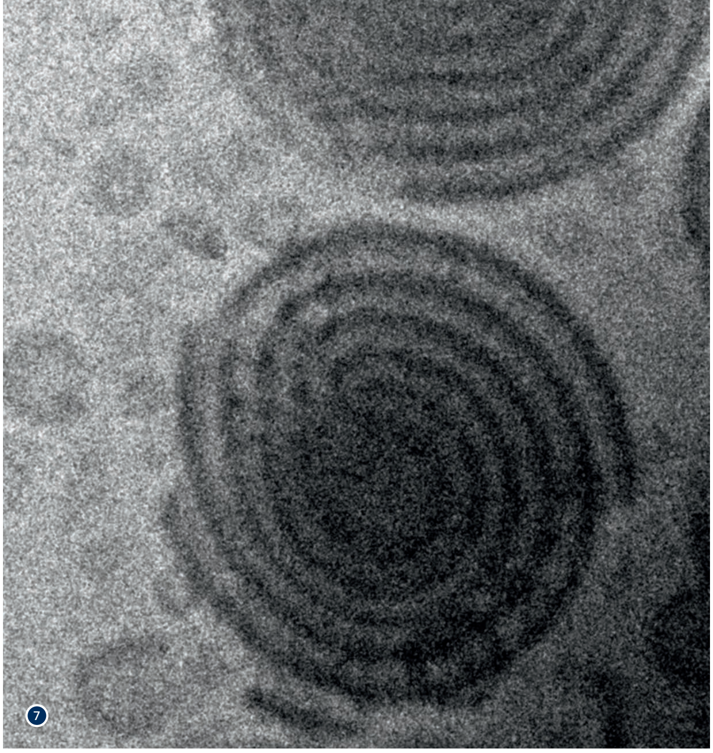
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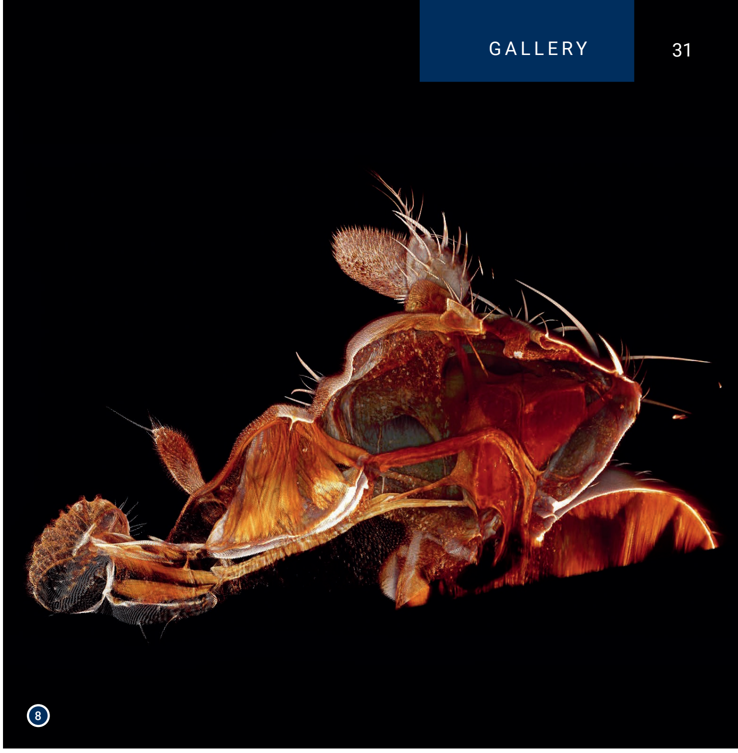
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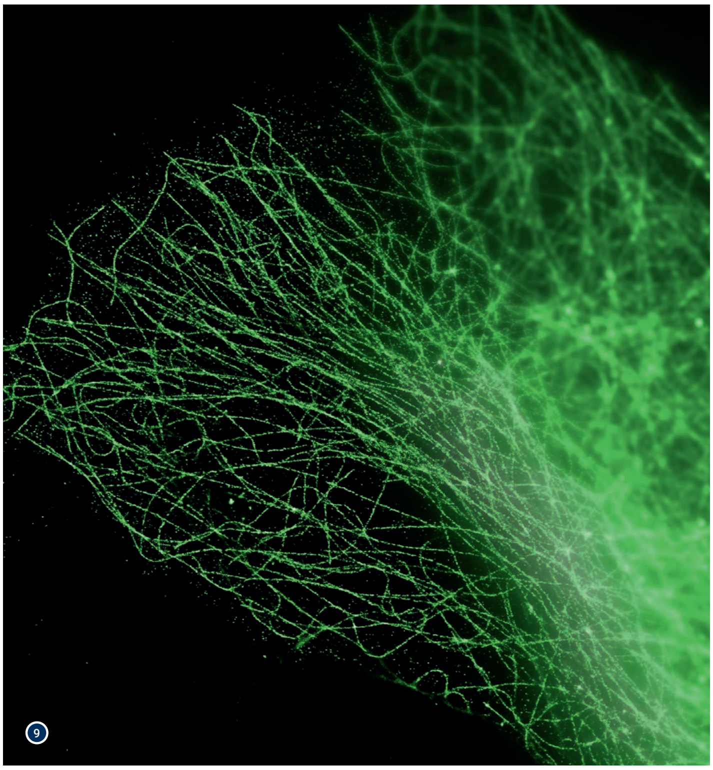
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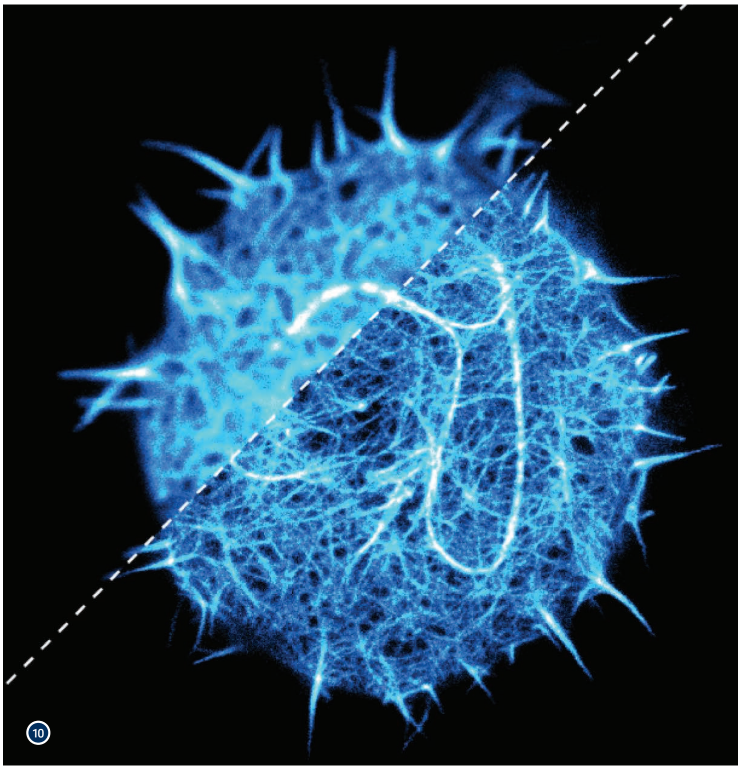
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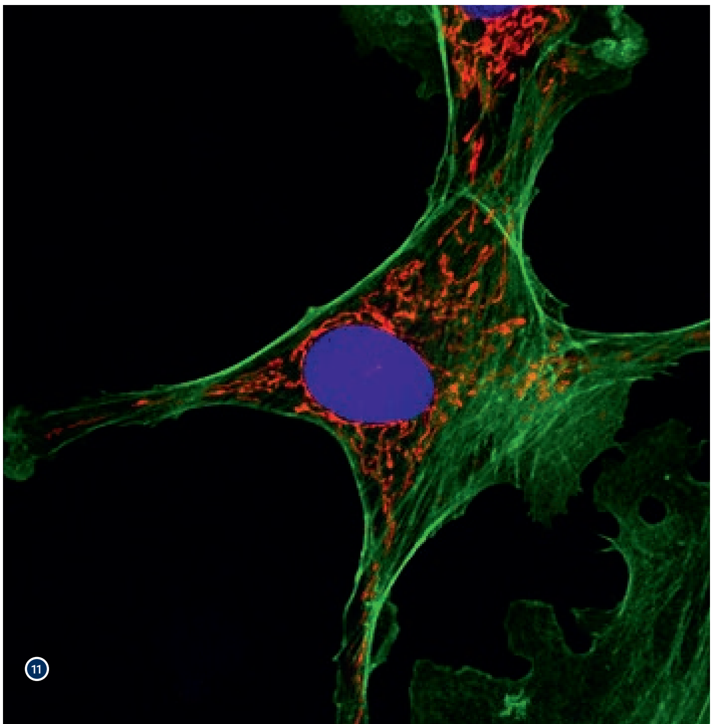
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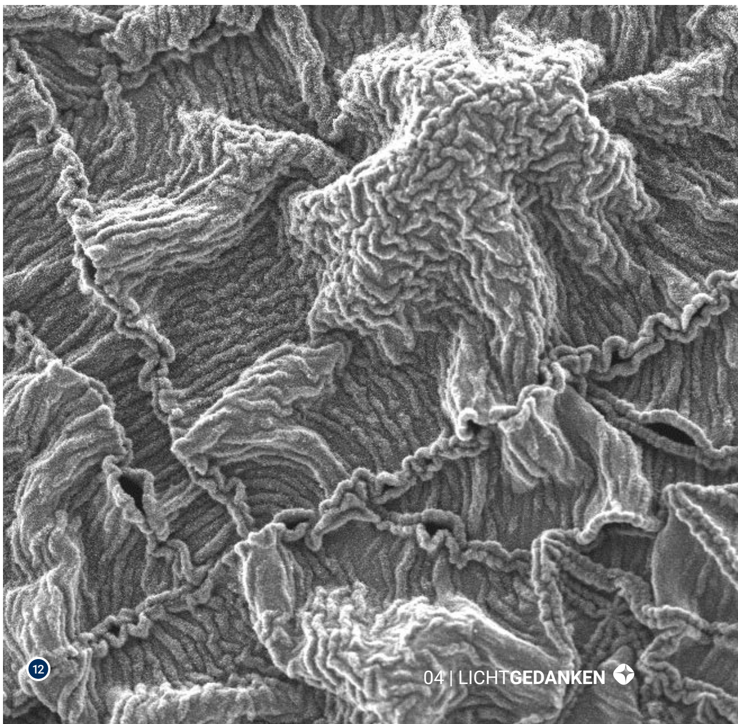
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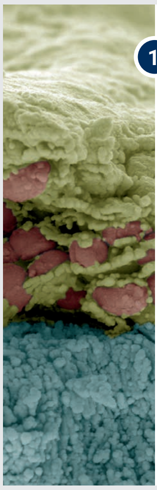
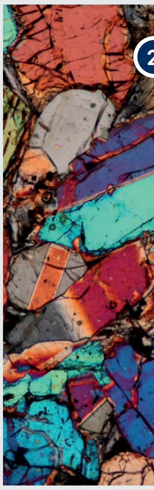
An insight into the microcosm

Physicists and materials scientists, geologists and biologists, pharmacists and medics all use microscopes to view and investigate minute structures. Nowadays, classic optical microscopy, as developed by Ernst Abbe and Carl Zeiß, only plays an ancillary role. High-resolution fluorescent microscopic procedures now provide insights into living cells and materials, or electron microscopes offer detailed images of living or lifeless micro worlds. On the following pages, the LICHT**GEDANKEN** picture gallery shows what the naked eye cannot see.



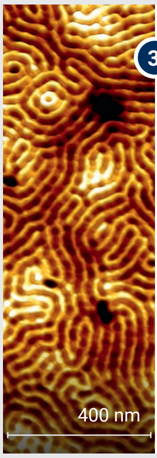
1 Plaque

The coloured scanning electron microscopic image shows a biofilm of bacterial plaque with 10,000x magnification. The image shows the cross-section of the biofilm (red bacteria in a yellow matrix) on the surface of a tooth (grey). The biofilm is approx. 10 micrometres (0.01 millimetres) thick. Taken by Dr Sandor Nietzsche/Center for Electron Microscopy at the Jena University Hospital



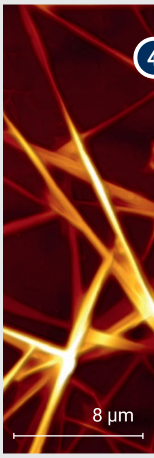
2 Meteorite

The image shows a thin section of the Nakhla meteorite under the polarizing microscope. This Mars meteorite fell from the sky in Egypt in 1911 and consists of magmatic rock that is around 1.3 billion years old. It is assumed that Nakhla was thrown into space as the result of an asteroid hitting Mars, and that it was »caught« by Earth over 100 years ago. The width of the section shown is approx. one millimetre. Taken by Prof. Dr Falko Langenhorst/Chair of Analytical Mineralogy of Micro- and Nanostructures



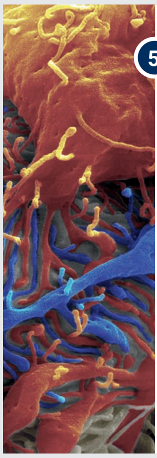
3 Block copolymer

The scanning force microscopic image shows the structure of a lamellar nano-structured diblock copolymer consisting of polystyrene and polydimethilsiloxane. The aim is to use these nano-structured polymer surfaces to control the adsorption of proteins on materials surfaces to lend them new characteristics, e.g. sensor technology. The width of the section shown is 1.5 micrometres (0.0015 millimetres). Taken by Xiaoyuan Zhang/Chair of Materials Science



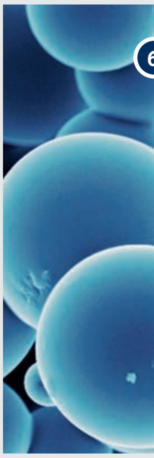
4 Fibre network

This scanning force microscopic image shows the structure of a protein network from denatured fibrinogen and fibronectin. Nanofibres have lots potential applications in materials science and medical technology; including in the creation of artificial organs and tissue. The width of the section shown is 25 micrometres (0.025 millimetres). Taken by Christian Helbing/Chair of Materials Science



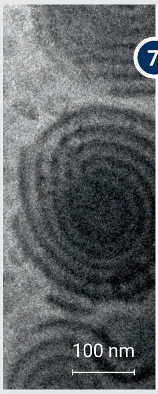
5 Kidney cells

The coloured scanning electron microscopic image shows cells of the glomerulus (podocytes) of a mouse kidney with 10,000x magnification. The cells (orange and blue) are closely interdigitated by so-called foot processes. The kidney's filtration barriers are located in the gaps between the processes. The cell bodies are around 6 micrometres (0.006 millimetres) in size. Taken by Dr Sandor Nietzsche/Center for Electron Microscopy at the Jena University Hospital



6 Hydrogel beads

The picture shows a coloured scanning electron microscopy image of a three-dimensional compound of hydrogel particles. The spheres have a diameter of around 10 micrometres (0.01 millimetres) and consist of polyoxazolines. Hydrogels can absorb and store large quantities of water in their internal polymer structure. Besides that their structure provides tissue-like mechanical properties. Taken by Steffi Stumpf/Jena Centre for Soft Matter

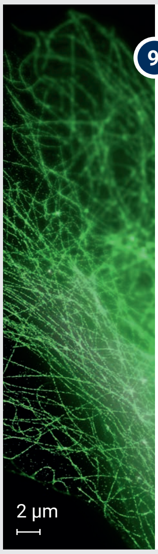


7 Nanoparticles

The cryo-electron microscopy image shows snail-like coils of micelles of block copolymers in an aqueous solution, which have been formed by self-organisation. The diameter of the micelles is around 200 nanometres (0.2 micrometres or 0.0002 millimetres). Taken by Dr Stephanie Höppener/Jena Centre for Soft Matter

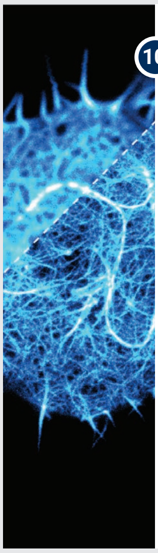
8 Head of a fly

This image, which was taken using a light-sheet microscope, offers an insight into the throat area of a fruit fly (Drosophila melanogaster). The sample is hit from the side with a »light wedge« which is around one thousandth of a millimetre in size and can be moved around. The head is half a millimetre in size. Taken by Ulrich Leischner/Department of Microscopy, Leibniz Institute of Photonic Technology



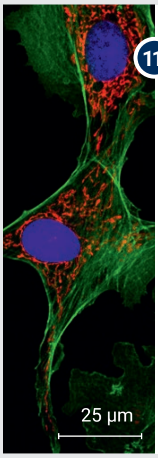
9 Cytoskeleton

The fluorescent microscopic image shows so-called microtubules. They are protein filaments from the cytoskeleton of cells, which contribute to their stability. The image compares two microscopic methods. The right half of the image shows an image of the cell taken with a conventional wide-field fluorescent microscope; whilst the left half of the image shows the result of high-resolution localisation microscopy dSTORM (direct Stochastic Optical Reconstruction Microscopy). The width of the section shown is approx. 40 micrometres (0.04 millimetres). Taken by Patrick Then/Department of Microscopy, Leibniz Institute of Photonic Technology



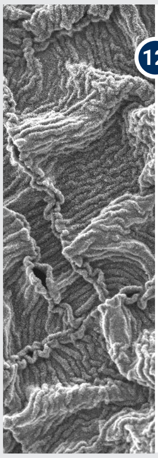
10 High-resolution immune cells

High-resolution image of fluorescently marked actin filaments (structural proteins, blue) in white blood cells (T-lymphocytes) in suspension. The image shows a 3D reconstruction of scanned image stacks. Top left: images with a confocal laser scanning microscope; bottom right: images from a high-resolution STED microscope (Stimulated Emission Depletion). The lymphocyte has a diameter of around 10 micrometres (0.01 millimetres). Taken by Marco Fritzsche/Mathias Clausen, AG Christian Eggeling/ Institute of Applied Optics



11 Endothelial cell

The fluorescent microscopic image shows an endothelial cell, which lines the inside of blood vessels and which has been labelled with different fluorescence dyes. The fluorescent dyes are chosen to highlight individual cell components by specific colours. On this image, the nucleus is blue, the membranes green and the cytosol red. The cell has a diameter of around 50 micrometres (0.05 millimetres). Taken by Martin Reifarth/Jena Centre for Soft Matter



12 Catalyst layer

The scanning electron microscopy image shows a catalyst layer made of activated nickel acetate. A layer of nickel acetate is heated up using microwave radiation until the thick »carpets« made of small metal nanoparticles are formed. They can be used to synthesize carbon nanotubes, for example. The picture section has a width of around 50 micrometres (0.05 millimetres). Taken by Almut Schwenke/Jena Centre for Soft Matter

Night shift under a starry sky

The University's Observatory is situated in a section of forest near Großschwabhausen, shielded from the night lights of Jena City of Light. Exoplanets, young star clusters, double stars and gigantic black holes are all observed here on almost every clear night. Astrophysicists Markus Mugrauer and Susanne Hoffmann gave our reporter a look behind the scenes and the chance to admire the sky through the reflector telescope. Find out what she discovered in this article.

BY UTE SCHÖNFELDER

It is a warm spring evening, shortly after Easter. It is around seven o'clock at night and the sun still glistens on the horizon, as I travel due west from Jena. I pass Remderoda and, after around ten kilometres, arrive in Großschwabhausen. The small villages are quiet and secluded on a slight hill; the sky seems closer than it does in the valley basin of Jena. A rural idyll, fresh air, peace and quiet.

I check the directions provided on the Observatory's website to remind myself: there should be a track leading off from the main road towards the Observatory. Despite this, my sat nav just shows a green space. Feeling slightly uneasy, I turn left and follow a track that is barely three metres in width, directly into the forest, lined on each side by a dense forest of tall trees. After around three hundred metres: relief. Between the treetops, with the sun setting in the distance, I discover the dome of the round, yellow-painted building, which stands in a small clearing.

The astrophysicists begin their work in the »blue hour«

A precisely cut hedge directs you to the entrance. Dr Markus Mugrauer welcomes me into the building. He will spend the night watching the sky together with his colleague Dr Susanne Hoffmann. For the astrophysicists, their working day begins at dusk, in the »blue hour«. »Depending on the weather, we can observe the sky from here for around 120 nights each year«, says Mugrauer. He is planning on making the most of the predicted period of good weather over the next three days. It is Friday evening, I say, a weekend in the service of science. There is no better way to spend a clear night, responds Mugrauer with emphasis and a smile, before beginning to enthuse about the conditions for observing the night sky in Chile, where he lives from time to time and has spent the past weeks. »No clouds, no mist, from sunrise to sunset. We only get that for a handful of nights per year here.« That is why it is so important to make the most of them.

This passion for the stars, combined with the various technologies used to observe them, can be felt in almost every sentence Mugrauer utters. He began watching the stars back in primary school; back then in the public observatory in his home town of Munich. That was 32 years ago—»not long ago in the cosmic dimensions.«

While his colleague prepares the observations in the control room, Markus Mugrauer takes me inside the dome—the centrepiece of the Observatory—in which the 90-centimetre reflector telescope stands: five metres tall and weighing 13 tonnes. Mugrauer presses a button to move the dome into position, and then the roof opens immediately afterwards, with a loud rumbling. There is now hardly any light coming from outside; evening birdsong is the only thing to penetrate the air.

Mugrauer climbs an aluminium ladder and removes the large metal cover, which encloses the tube of the telescope to protect it from dust and insects. »We operate three telescopes on one mounting«, he explains. Two smaller telescopes sit next to the large 90-centimetre reflector: a reflector telescope with a 25-centimetre diameter—a so-called Cassegrain telescope—and a refracting telescope with a 20-centimetre diameter.

The University telescope can even be controlled from Hawaii

The University Observatory has been operating in Großschwabhausen for 56 years now, and the telescope and its mirror are still in their original condition following the »first light« in 1962. »Only the drive motors have been replaced«, explains Mugrauer. Back in the 1960s, researchers controlled the telescope using a control desk measuring just under two metres in width and located in the dome. Nowadays, it is controlled from the heated control room, located on the floor below. »Or from Hawaii«, jokes Mugrauer. In theory, the University telescope could be controlled from anywhere on earth.

However, in this moment, we go down the stairs with the help of torchlight. The control room is the only lit part of the Observatory; light in any other part of the building would interfere with the observations. There is coffee. Mugrauer takes his seat, several computers hum, four monitors sit side-by-side.

Susanne Hoffmann has already started several calibration measurements. But for now, the screens are just displaying lots of controls and coordinates and making dull white noise. »We start by taking various comparative images«, explains the astrophysicist. Thus, the homogeneous grey surface of the sky is captured at dusk so the various sensitivities of the CCD detectors used can be corrected. The recorded dark images also register the individual signals of the light-sensitive CCD detectors, which need to be taken into account when processing the data.

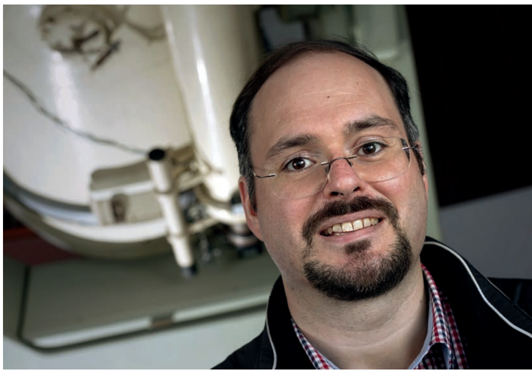
At the same time, Mugrauer calibrates the échelle spectrograph. The telescope is currently being operated in Nasmyth

mode: additional reflectors in the beam path direct the light collected by the main reflector out of the tube of the telescope and focus it on a fibre optic, which is connected with the spectrograph. The light is segmented into its spectrum colours there and the spectra of the stars are recorded.

The sunset sparks activity in the control room

I am reminded of an aeroplane cockpit, in which all of the instruments need to be checked prior to take-off—the atmosphere in the silent, now almost totally dark clearing in the forest has an almost hectic edge to it. Mugrauer keeps returning his attention to the screen, which is reporting the status of the sun. But what I consider to be »total darkness« is not sufficient for the astrophysicists. More test recordings are made with the telescope and the signal strength checked for the various colour ranges. Then, finally, the sun lies twelve degrees below the horizon; we have reached »nautical darkness« and the first observation can begin.

This observation concerns the spectroscopic investigation of a double star with an unpronounceable name, comprising three letters and a six-digit number. Markus Mugrauer lets me enter the coordinates of the target object into the computer and, two mouse clicks later, the telescope and dome above our heads rattle and rumble in movement and can surely be heard throughout the dark forest. After a few seconds it is once again quiet, and the first stars appear on the monitor.
One look at the map in the observation handbook and Mugrauer has quickly identified our target object amongst the bright dots, which now fill the display window. It is several dozen light years away, in the centre of the Camelopardalis constellation. Camelopardalis? Susanne Hoffmann shows me a picture of the huge Giraffe, which can be seen over the northern sky throughout the year. I decide that I really need to refresh my knowledge of the constellations. And it continues: after a short test recording, our double star is aligned with the glass fibre entry to the spectrograph; Mugrauer moves the star using arrow keys so it sits within a crosshair on his monitor. Another click and the recording of the first spectrum begins.
During the measurement, we can see the star flickering and sparkling in his crosshair. But wait, weren't we talk-



Dr Markus Mugrauer runs the University Observatory in Großschwabhausen.

Top image: The 90-centimetre reflector telescope is five metres tall, weighs 13 tonnes and has been in operation since 1962.

The large emission nebula »M42«, approx. 1,400 light years away from the earth, in the Orion constellation. This image is a colour-composition image, which was taken with the Schmidt telescopic camera on the 90-centimetre reflector telescope at the University Observatory using three filters (B, V, R). The Orion nebula is a place where stars are formed and is just a few million years old. The nebula is lit up by massive stars, which have already formed in its centre. Many new stars will be formed from the large masses of gas here over the next million years.

Final movements before the observation begins. Dr Markus Mugrauer checks the small Cassegrain telescope, which is located next to the large 90-centimetre reflector. The refracting telescope can be seen in the bottom right.

ing about a double star? »It is actually at least two stars, which are circling around each other«, confirms Mugrauer, »but they are so close together that, from the Earth, it just looks like one star.« The objective of the current observation is to precisely measure the orbital parameters of the two celestial bodies. How quickly, how eccentrically, how frequently they revolve around one another—all of this can be calculated from the spectral data. Over the course of the night, Susanne Hoffmann and Markus Mugrauer will focus on around a dozen other objects of this kind.

Observers work together in pairs for themselves and for their colleagues

The observers follow a precise procedure: all of the latest research projects are summarised in the observation handbook—a thick document file. »We work in service mode«, says Susanne Hoffmann. This means that each observation night, the team on site records images and spectra for all of the on-going projects. »As the observers take turns, everyone plays their part in recording data for themselves and their colleagues.« There are currently around ten members of staff and students working as observers, and there are always two people in the Observatory each night.

YETI is one of the most extensive projects currently running. It is being conducted by the Jena astrophysicists in collaboration with partners from around the world. YETI stands for »Young Exoplanet Transit Initiative« and focuses on the search for young planets in young, open star clusters. The stars that come into consideration are continuously observed for a period of several weeks and their brightness is measured precisely. If a planet is orbiting a star, it can eclipse it from our perspective on the Earth, which in turn reduces the brightness level of the star. Thousands of planets have been found using this transit method, although predominantly with old stars. However, the Jena astrophysicists together with their partner in YETI are looking for young planets. In this case, young means less than 10 million years old. They make it possible to check the validity of the current models of planet formation and evolution.

As we talk, several double stars are spectroscoped. Then—a good two hours after we started—the conditions have been met to set the telescope up on a totally different object. OJ287 is located in the sky above Großschwabhausen. Markus Mugrauer takes an overview image. It features a dozen light spots of various brightness and size. Our object is one of the hardest to see. OJ287—a quasar—a quasi-stellar object—is not a star. »It is the brightly shining nucleus of a galaxy with one of the largest black holes that we have come across.«

With 18 billion solar masses, it is over 4,000 times as massive as the enormous black hole in the centre of our Milky

Dr Susanne Hoffmann and Dr Markus Mugrauer control the instruments, the telescope and the dome of the Observatory from the control room. Astrophysicists from the University of Jena observe the night sky some 120 nights a year.

Way. A gigantic accretion disc—an orbiting disc, which transports huge amounts of matter around its central body—surrounds this colossus. And, as if that weren't spectacular enough, this huge black hole is orbited by a second black hole. This second black hole is also enormous, measuring around 150 million solar masses. »The fascinating thing about this constellation is that it allows us to pretty much test the validity of Albert Einstein's general theory of relativity.« Markus Mugrauer is in his element. »GTR« he says, referring to the general theory of relativity. »Whenever the smaller of the two black holes passes through the accretion disc of the larger, it causes enormous outbursts of luminosity, which can be observed from earth and which precisely correspond to the predictions calculated using GTR.«

Light from the quasar would also be visible from the »end of the universe«

Even without Einstein and his general theory of relativity, I am impressed: OJ287 is located around 3.5 billion light years away from us. The light of this minute light spot, which I can see on the small monitor, has been travelling here for 3.5 billion years. These dimensions of time and distance are unfathomable. As are the mighty forces, which control it all. »The object is so bright that you could place it at the end of the universe, and we would still be able to see it here with our telescope«, Mugrauer is convinced.

But enough philosophizing; now it is time to measure. We take more brightness measurements for OJ287. These will later be used, together with the data from other international partners, to produce light curves. »This allows us to practically keep OJ287 in view at all times.« The last great outburst of luminosity took place in 2015. The next observable outburst is expected in 2022. If this happens—and Markus Mugrauer has no doubt it will—he and his colleagues will be able to watch it live from Großschwabhausen; if you ignore the 3.5-billion-year time delay, of course. The two black holes will also soon collide, precisely as the predictions from GTR suggest. »In just another 10,000 years, we will be able to measure a gigantic gravitational wave signal«, promises Mugrauer. Seriously. Until then, the researchers at Jena will continue to fill the astronomical databases with their observations. Despite the repetitive routines, the night-time observations lose none of their fascination for Markus Mugrauer. »Each individual star that we look at could be the host star of a planetary system, similar to ours.« He is still and will always be fascinated by looking at and discovering new objects.

These words are revolving around my head as I drive back towards Jena, one hour before midnight. Maybe on one of these planets out there, there is even a life form which is using refined instruments to capture the light of the stars to create an image of the world. Observing our sun from afar; a medium-sized star in an advanced age, and, in doing so, discovering that this star is surrounded by a planetary system. Seeing the clusters of stars and double stars and analysing the black holes. In that moment, after looking into space, it doesn't seem that unlikely at all. ■

The University Observatory online:
www.astro.uni-jena.de/index.php/gsh-home

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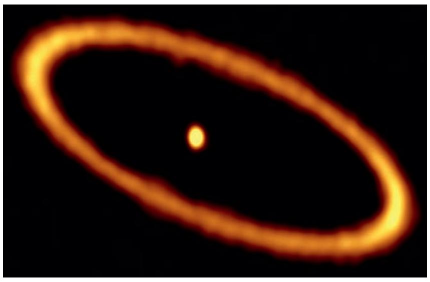
Radio antennas from the »Atacama Large Millimeter/submillimeter Array« (ALMA) in Chile, directed towards the Milky Way. ALMA recorded the asymmetrical debris disk around Fomalhaut (image below).

Imbalance in the ring of debris

Numerous stars are surrounded by ring-like debris disks: pieces of rock, debris and fine dust orbit the stars, and the stars' gravity keeps the rings in line like giant hula hoops. Astrophysicists are analysing the light from the pebbles disks, which can reveal a lot about the stars themselves and their planets, even if the latter have not yet been seen.



Asymmetrical debris disk around the Fomalhaut star
©ALMA (ESO/NAOJ/NRAO); M. MacGregor

BY UTE SCHÖNFELDER

It is the outpost of our solar system: around six billion kilometres away, the Kuiper belt—a collection of thousands of frozen dwarf planets, pieces of rock and ice—orbits the sun. These particles are constantly colliding with one another, shattering and disappearing in huge clouds of dust—the Kuiper belt fully lives up to its name as a dust or debris disk. In addition to the Kuiper belt, our solar system also boasts a further example of a cosmic rubbish dump—namely the asteroid belt between Earth and Mars. Researchers have discovered debris disks around approximately one in four stars; and far more are presumed to exist. Dr Torsten Löhne from the Institute of Astrophysics explains why these objects are of scientific interest. »Debris disks are a vital part of planetary systems. But, unlike distant planets, they are fairly easy to observe from Earth.« And this is despite the fact that the individual objects are generally far smaller than planets. The physicist uses a comparison to explain the reason behind this: »Place a kilogramme of flour, packaged in a bag, in the centre of a football stadium.« From the edge of the pitch, you can see the flour but it would be barely visible to spectators at the back of the stadium. »If you distribute the same amount of flour, but as a cloud of dust, it can fill the whole stadium.« If this dust is then illuminated, it can be seen far further away than the packaged flour. »The exact same principle applies to planets and debris disks. While the planet focuses a large mass in a small space; a debris disk distributes this mass across a far larger space.«

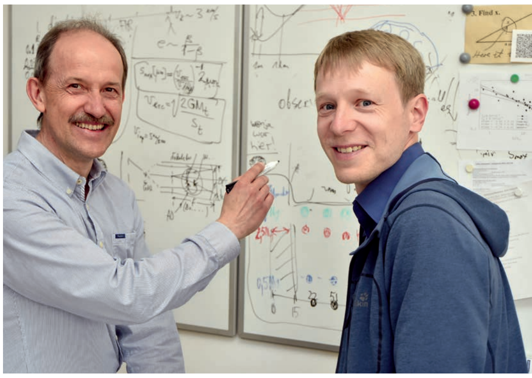
By observing debris disks, Dr Löhne and his colleagues are acquiring information about the planetary systems that host them. The shape, size and dynamics of the dust rings allow the scientists to draw conclusions about the, as yet, undiscovered planets. Furthermore, debris disks provide information about their own development processes. The astrophysicists have recently been investigating asymmetrical debris disks. One such example can be found orbiting the star »Fomalhaut«—the brightest star in Piscis Austrinus. This star is around 25 light years away and has around twice the mass of our sun. It has an impressive dust belt, as infrared images taken by the »Atacama Large Millimeter/submillimeter Array« (ALMA) in Chile have shown. When you look closely, you notice: the ring is not radially symmetrical to the star; in fact, the star lies slightly outside the centre of the ring.

In their study, Torsten Löhne and his colleagues in Jena, together with researchers from the University of Kiel, have been analysing the causes behind this imbalance using computer simulation.

»One explanation for the asymmetrical debris disk is the presence of a planet between the star and dust belt, which is distorting the ring due to its gravitational field«, says astrophysicist Prof. Dr Alexander Krivov, head of the team in which Torsten Löhne works. »There are, however, other effects that could lead to the formation of this shape«, continues Krivov. Whilst the formative influence of planets is already well-researched, there hasn't yet been sufficient research into non-gravitational effects; in other words, the effects that are not owed to the gravitational fields of larger objects.
And it is precisely these influences that Löhne and Krivov are looking into. They have modelled debris disks with varying degrees of warping and calculated their development over a period of several hundreds of millions of years. »By doing this, we have been able to identify a range of factors that can be used to explain the manifestation of the asymmetry«, summarizes Torsten Löhne. And: the non-gravitational effects actually play a significant role. Constant collisions produce smaller fragments and dust, which is heated by the star and blown away by its radiation pressure; this in turn alters the trajectory of the dust and causes an asymmetrical halo to form around the star. Depending on the wavelength range used to observe it; the asymmetry will be more or less obvious.
»Our collision analyses have also shown that the fragments are not evenly distributed within the ring«, continues Dr Löhne. Thus, you can find larger dust particles on the ring side that is closer to the star than on the distant side. This in turn influences the prevailing temperature, which is also reflected in the appearance of debris disks, especially in the infrared range.

Debris disks aiding the search for new planets

The researchers have concluded that these new findings will make it possible to provide more precise interpretations of the observation data concerning debris disks in the future—including, and in particular, with regard to the discovery of unknown planets. »It is only by having a precise understanding of the correlations between dust belts and planetary systems that we can predict where we should be searching for planets and which properties these planets would likely have«, clarifies Krivov. The researchers now want to put their findings to the test and, in doing so, bring some clarity to one or two areas of science that are still obscured by metaphorical dust. ■



Astrophysicists Alexander Krivov (left) and Torsten Löhne are calculating collisions in debris disks.

Publication: Collisions and drag in debris discs with eccentric parent belts, DOI: 10.1051/0004-6361/201630297
Further Information: www.astro.uni-jena.de/index.php/theory.html

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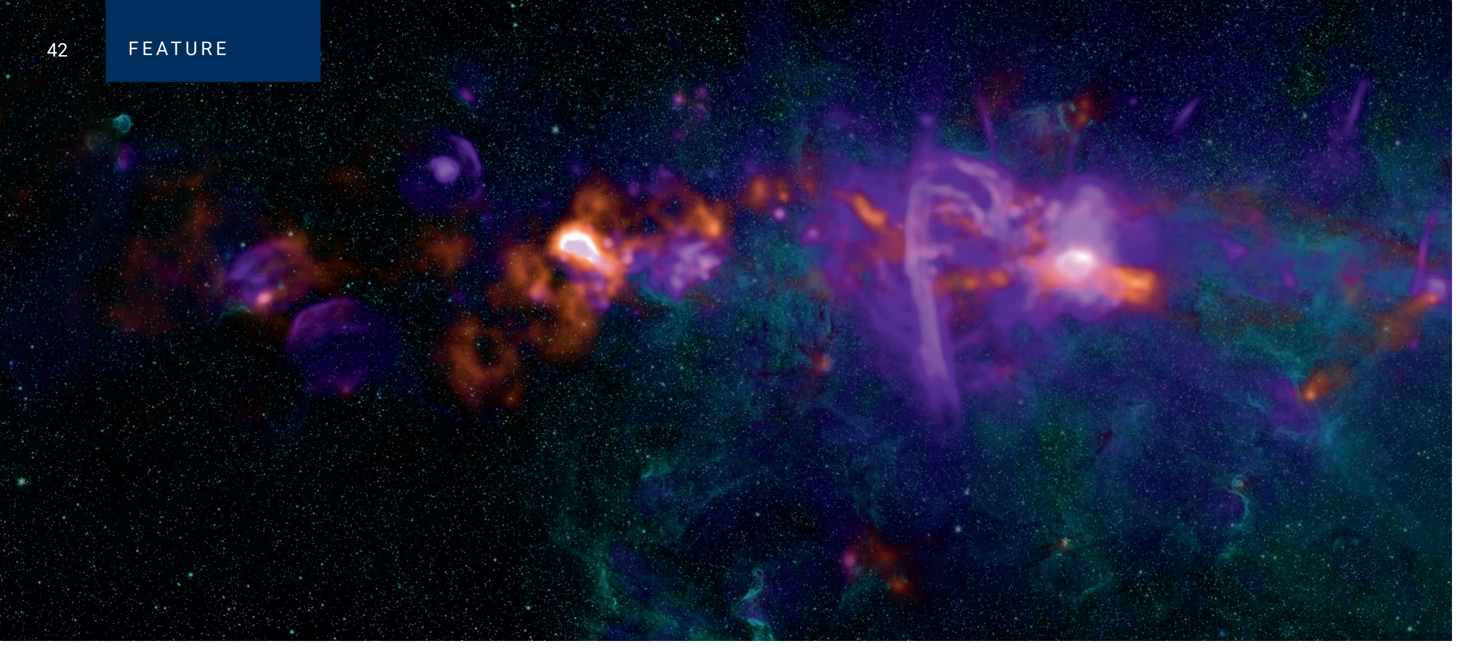


Someday it is going to be perfectly dark

In addition to space, time and matter, the Big Bang, which occurred some 13.8 billion years ago, created electromagnetic radiation and, in doing so, created visible light. This light could not be seen for the first 300,000 years, however. In this interview, physicists Holger Gies and Martin Ammon explain why the universe was initially opaque; what happens to light when it is absorbed by a black hole; and when the light will once again go out in the universe.

INTERVIEW: UTE SCHÖNFELDER

Was everything dark before the Big Bang?
Ammon: No-one knows what existed before the Big Bang and even if there was a »before«. According to the latest cosmological models, the Big Bang created the universe, the laws of nature and time. Prior to the Big Bang, neither time nor space existed. Since the Big Bang, the universe has been expanding to its current size in line with Einstein's general theory of relativity.

Gies: Nowadays we assume, however, that Einstein's theory alone cannot fully describe the process of the Big Bang. It represents the beginning of the universe as a so-called singularity: matter and space-time were focused in an infinitesimal point; the density of particles and radiation was infinitely large. Quantum physical effects are required to describe this constellation. At present we, along with physicists across the globe, are working to combine Einstein's theory of relativity with quantum theory. A unified theory—that of quantum gravitation—would allow us to pose reasonable questions about the »before« and to seek answers.

So, to put it another way: did the Big Bang ignite the light in the current universe?
Ammon: Yes, the natural forces that we know today, including the electromagnetic force and thus light, emerged just a blink after the Big Bang. Despite this, the universe remained opaque for a while. There were light particles up to around 300,000 years after the Big Bang, but the light was not able to expand freely.

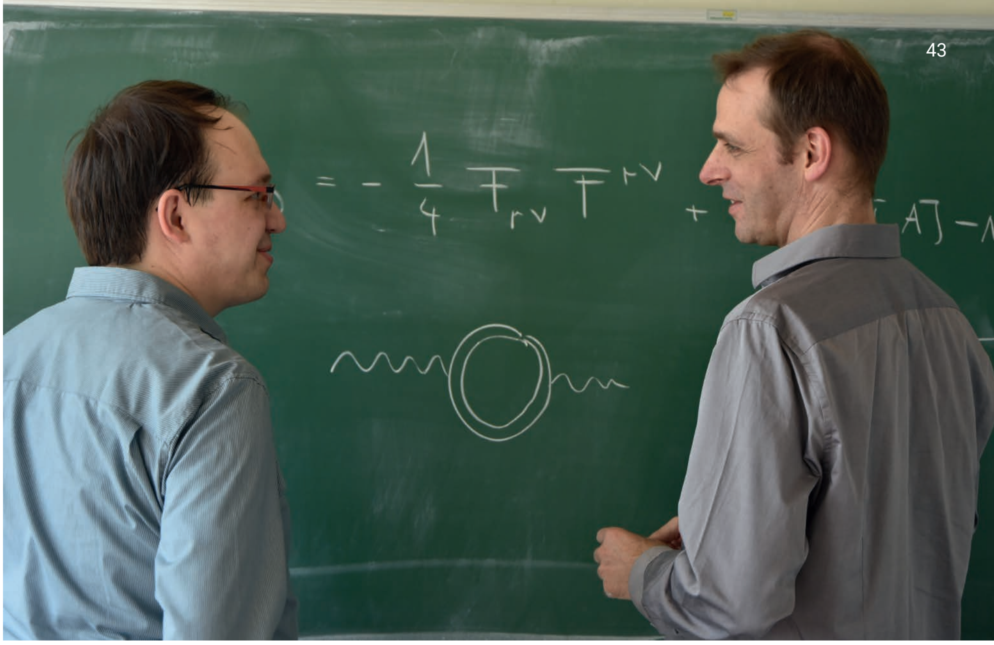
Why not?
Gies: Think of it as a glass of milk that you cannot see through. During this early phase, the matter lay in very hot plasma, in which the atomic nuclei and electrons were separate from one another. It was only later on, after around 300,000 years, that the atomic nuclei and free electrons came together to form the atoms and the light particles were no longer absorbed. It was only then that the universe became transparent.

Ammon: And this does not just apply to the range of visible light; it also applies to all electromagnetic waves. The oldest sign of electromagnetic radiation that we have been able to receive—essentially the oldest light in the world—is microwave radiation from the cosmic background. This comes from precisely this period, when the young universe was around 300,000 years old.

Amongst other things, your research grapples with celestial bodies, which could be described as the natural enemies of light: the black holes. Why do black holes absorb light?
Ammon: A black hole is a massive, highly compact object, which deforms the surrounding space-time to such a degree that, according to Einstein's theory of relativity, neither matter nor light can leave the object. Black holes are created at the end of the life cycle

Image left: The centre of the Milky Way. It is the location of the central black hole »Sagittarius A*«, which weighs around four million solar masses. © NRAO/AUI/NSF

Image right: In order to explain what happens to light and matter in a black hole, Junior Prof. Dr Martin Ammon (left) and Prof. Dr Holger Gies are attempting to combine Einstein's general theory of relativity with quantum theory.



of massive stars, which implode due to their own gravitational force. If light particles reach the sphere of influence—the so-called event horizon—of a black hole, they are diverted along curved space and swallowed; just as water disappears down a drain in a vortex. When light has traversed the event horizon—in other words, has practically fallen into the black hole—it can no longer leave.

What happens to the light in the black hole?
Gies: We can only speculate based on our knowledge of mathematics and Einstein's theory of relativity: just as with the Big Bang, a singularity exists inside a black hole in which all matter appears to fall. These point-like singularities are, however, incompatible with quantum mechanics. That is why we are looking for a complete theory of quantum gravity, which can explain the resolution of such singularities. For, in contrast to what Einstein's theory purports, we now know that black holes also emit radiation.

So, a black hole is not actually black?
Ammon: Exactly. To put it simply, black holes are not black; they are more a grey colour. In a ground-breaking work, physicist Stephen Hawking, who recently passed away, showed that black holes emit light and material particles through a quantum effect—Hawking radiation. Having said that, even in the case of large black holes, the radiation is in the nanokelvin range and its existence can, therefore, not currently be proven using the technology we have today.

How can black holes be observed?
Gies: When we look into the universe, we see the light emitted by the celestial bodies. Because black holes don't emit anything that we have yet been able to measure, we cannot see them directly. But we can see their effects; for example, how other stars move around black holes. Or we can see gas clouds and other forms of matter, which fall into black holes and, in doing so, produce gigantic X-ray flashes.

Can black holes capture infinite amounts of matter and light?
Ammon: The theory does not predict a maximum mass for black holes. In reality, we see black holes with masses ranging from a few to several million solar masses. The black hole in the centre of our galaxy is around four million solar masses in weight, for example.

Will black holes eventually swallow all light?
Gies: No, that won't happen. But at some point, our universe will become completely dark. But this won't be due to the growing number of black holes; rather because the universe is expanding at an ever-increasing rate. The number of stars and galaxies, whose light has yet to find us, will decline over the long term. Thus, it will be the expansion of the universe that will eventually switch off the light.

When will this happen?
Ammon: We can't answer that yet. The accelerating expansion of the universe is attributed to dark energy, which makes up around 70 percent of the energy of the universe. By way of comparison: conventional matter and light only make up around four percent of the energy content of the universe. Despite extensive research, we still know almost nothing about dark energy and dark matter. In order to be able to precisely predict the expansion of the universe, we must first come to understand dark energy. ■

HISTORY

The fascination with evil

Berlin coachman Bruno Lüdke was known as the »worst serial killer in criminal history« until the 1990s. Journalists created true crime stories based on artefacts from the National Socialist CID; the feature film »Nachts, wenn der Teufel kam« brought international attention to the case. A historian, a cultural scientist and a graphic designer have now reinvestigated the topic for a case study. The result is a multi-faceted visual history about racist conceptions of man and violence. How and why did the »fake news« about the alleged serial killer arise in the Third Reich and continue in the media democracy? The interdisciplinary study on constructing the abnormal pleads for greater visuality in scientific depictions.

BY STEPHAN LAUDIEN

Evil has had a morbid hold over the public since time immemorial. Whether it be fictional serial killers like Hannibal Lecter in the box-office hit »Silence of the Lambs« or reports about real perpetrators like Jeffrey Dahmer or Andrei Tschikatilo: »sex and crime« are a great way to sell tickets.

During the early years of the Federal Republic, readers and cinema-goers were captivated by the demonic figure of serial killer Bruno Lüdke. Founder of »Spiegel«, Rudolf Augstein, wrote about Lüdke in a series of articles about the head of Germany's Criminal Police Arthur Nebe; meanwhile, journalist and bestselling author Will Berthold laid a trail for the general public with 15 »factual reports« about Lüdke. And a young actor by the name of Mario Adorf shone as Lüdke in 1957 in the award-winning film »Nachts, wenn der Teufel kam« by Robert Siodmak.

The real Bruno Lüdke has been relegated to the background in all the frenzy. The coachman and labourer Bruno Lüdke was born near Berlin in 1908. In 1940, he was forcibly sterilised following the ruling of a Hereditary Health Court; the diagnosis stated »hereditary mental retardation«. Lüdke was arrested three years later as part of a murder investigation. During suggestive interrogations, he took the blame for 53 murders, mainly of women, which had been committed across the Reich since 1924. Bruno Lüdke was secretly murdered in the Viennese Institute of Criminological Medicine in mid-April, 1944.

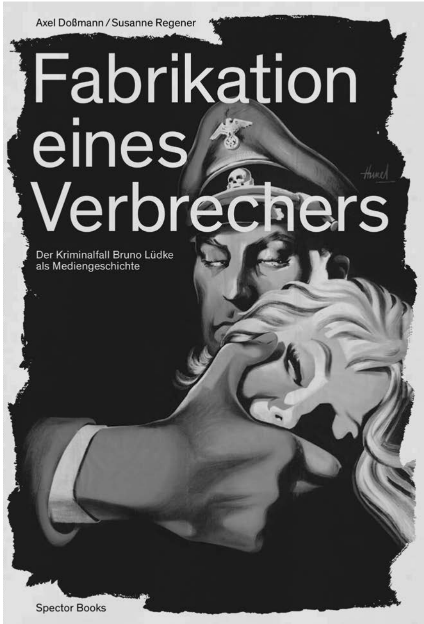
How did Bruno Lüdke become »the devil in human form«? What interests were the police and judicial system in

Image left: The Police Museum in Berlin contained numerous artefacts relating to the case of the supposed serial killer Bruno Lüdke.

the Third Reich following? And why did the horror story of the »monster« Lüdke hit a nerve with the public in the Federal Republic?
Dr Axel Doßmann and Prof. Dr Susanne Regener have been following up on these and related questions. »Fabrikation eines Verbrechers. Der Fall Bruno Lüdke als Mediengeschichte« (Fabrication of a criminal. The case of Bruno Lüdke as a media history) is the title of their recently published book. In the book, the historian from the University of Jena and cultural scientist from the University of Siegen discuss criminality, violence and racist conceptions of man in the 20th century and do so in a way that is as thrilling as a detective story. The findings of their research are given a further level of reflection thanks to the special book design by Markus Dreßen: the readers are directly shown several evocative sources: crime scene photos, interrogation records, a bust of Lüdke from 1944, secret documents, film posters and magazine articles from the 1950s.

Bruno Lüdke was a victim of the Nazis, not a serial killer

Susanne Regener first came across Bruno Lüdke in the 1990s. She visited the Police Historical Collection in Berlin as part of her post-doctoral thesis and examined the social and cultural significance of »mug shots« and exhibited artefacts like a hand cast of Bruno Lüdke. The criminal case of Bruno Lüdke clearly shows the fabrication of conceptions of man and presentations of evil. Evidence suggests that high-ranking Nazis from the Reich Security Main Office (Reichssicherheitshauptamt) wanted to use the Lüdke case as a pretext for introducing a new social-racist law against so-called Gemeinschaftsfremde (socially undesirables). »This law would have made it legal to prosecute and murder all maladjusted Germans«, says Axel Doßmann. As a mentally ill serial killer, Bruno Lüdke would have provided the required foil for this law.
Regener and Doßmann also show their doubt concerning previous theses about the murder of Lüdke. It is highly probable that Bruno Lüdke died as a result of an experiment with poisoned munition. The aim of this »Secret Reich matter« was to test assassination attempts for high-ranking politicians. »It is beyond doubt that Bruno Lüdke was a victim of the Nazis and not a serial killer«, confirms Axel Doßmann. »But it is not just the Nazis, but also the German Federal press and judicial system that share responsibility for the myth surrounding the serial killer: sixty years ago, on 17 April 1958, Hamburg Higher Regional Court legally sanctioned the fake news of the serial killer.« In the mid-1990s, Dutch criminologist Jan A. Blaauw proved in his meticulously detailed work that it is highly unlikely that Lüdke could have committed a single one of the crimes attributed to him. The book by Doßmann and Regener now elucidates this criminal case within the historical and media context and, in doing so, allows parallels to be drawn with the present day. For it is all too easy for the mentally ill and other outsiders to find themselves caught in the wheels of criminal proceedings and the justice system. ■



»Fake news« from the post-war period: Jena historian Dr Axel Doßmann and Siegen cultural scientist Prof. Dr Susanne Regener have reassessed the criminal case of Bruno Lüdke and the subsequent mediatization of evil: the alleged serial killer was a victim of the Nazi criminal investigation department and the media democracy of the 1950s. Here you can see the cover of their joint publication.

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Nitrogen oxide is a risk over short periods, too

There is a long-standing evidence that high levels of nitrogen oxides in the atmosphere are harmful to health, particularly to the circulatory system. In a recent study, scientists of the Jena University Hospital have proven that a rapid rise of nitrogen oxide in the surrounding air within 24 hours increases the short-term risk of a heart attack. Such dynamic changes in concentrations of air pollutants are not covered by current European statutory limits.

BY UTA VON DER GÖNNA

In its latest report on air quality, the European Environment Agency lists the years of life that air pollution costs the population, among other things. According to the list, in 2016 Europeans lost the equivalent of over 800,000 years of life as a result of the levels of nitrogen oxide in the air—based on a conservative estimate.

The main sources of nitrogen oxide in the European Union are combustion engines in motor vehicles, in particular diesel cars, and in heating systems. The gas has been shown to irritate and damage the respiratory organs and increases the risk of a heart attack. The limit values of 200 micrograms per cubic metre of air as a maximum hourly value and 40 micrograms as an annual average, which apply across Europe, are monitored using a dense network of measuring points as a result.

In a study published by the »European Journal of Preventive Cardiology«, doctors and medical statisticians from Jena have now proven that a rapid increase in nitrogen oxide levels in the air can also have an impact on health. The researchers considered all patients who were treated for an acute heart attack at Jena University Hospital between 2003 and 2010. The only data included in the analysis were that relating to those patients who lived within ten kilometres of the hospital and for whom it was possible to fully reconstruct what happened when the complaints had begun.

The data from these patients, who numbered just under 700, was then compared with the recorded emissions data for nitrogen oxide (NO_X/NO_2),

Image left: Combustion engines, especially those in diesel cars, can significantly increase the levels of nitrogen oxide in the air over the short-term.

BACKGROUND

Nitrogen oxide (NO_x) is predominantly released through the burning of fossil fuels, such as coal or oil, but in lower quantities also through electric discharges in the atmosphere during storms. When combined with ultraviolet sunlight, nitrogen oxide contributes to the formation of ozone (summer smog), particularly in congested inner cities. Nitrogen oxide also functions as a greenhouse gas and is responsible for the formation of »acid rain«. Nitrogen oxide irritates and damages the respiratory organs and can, as the latest study from Jena proves, also significantly increase the risk of a heart attack.

ozone (O_3) and fine dust (PM_{10}) taken by the Thuringian Regional Office for the Environment and Geology, which collects these parameters for air pollution in Jena. The researchers looked in great detail to see whether the concentrations of the key air pollutants changed to an unusually high degree within the 24 hours prior to the first heart attack symptoms.

Even Jena's clean air is affected by temporarily dangerous smog

The researchers knowingly opted for a clean city as their study location. In the eight-year period considered, the applicable European limit values for all measured air pollution parameters were adhered to in Jena, with the exception of just a few days. At the start of the study, the doctors expected the risk for heart attack to correlate with the changes in air quality. »We were really surprised by how direct the correlation is; it is almost linear«, says Dr Florian Rakers, senior author of the study. The Jena scientist and doctor is focusing his research on the effect of environmental influences on the emergence of illnesses.

Acute risk of heart attack doubles when nitrogen oxide increases

Prof. Dr Matthias Schwab, senior consultant at the Neurology Clinic and co-author of the study, explains: »The acute risk of heart attack in our study doubled in cases where the concentration of nitrogen oxide increased by 20 micrograms per cubic metre within one day«. »Rapid increases in the concentration of nitrogen oxide occur around 30 times per year, even in a supposedly clean city such as Jena. This is likely to be due to an exceptionally high volume of traffic or meteorological factors, which favour the development of smog«, continues Dr Rakers.

The results were less clear-cut for fine dust and ozone. »It was not possible to draw a correlation between a rapid increase in both of these air pollutants and the acute risk of heart attack. Nevertheless, high concentrations of fine dust and ozone are particularly harmful for patients with lung diseases«, emphasised Prof. Dr P. Christian Schulze, Director of the Clinic for Internal Medicine I and the co-author of the study.

With their study, the Jena scientists are expanding upon the available knowledge about the harmfulness of nitrogen oxide. Dr Florian Rakers: »Evidently, the risk of a heart attack does not just increase when people are exposed to high levels of nitrogen oxide in the ambient air for short or long periods but also when the level of nitrogen oxide rises quickly.« As a result, nitrogen oxide can be harmful even in comparatively clean air. According to the authors of the study, the clinical relevance of the findings means that there is an urgent need for a larger-scale research also in other geographical regions, so that the EU limit values can be expanded to include dynamic components where required. ■

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Rapid increases in nitrogen oxides are associated with acute myocardial infarction: A case-crossover study. Eur J Prev Cardiol (2018), DOI: 10.1177/2047487318755804

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NEUROBIOLOGY

Commissario Prefrontale investigates

What do Leonardo da Vinci's Mona Lisa, Charles Darwin's theory of evolution and a plane have in common? They all represent an expression and the result of creativity. Jena neuroscientist Konrad Lehmann has been researching and writing about how the human brain produces creative flashes of inspiration—with the active support of a fictitious figure. The result is an entertaining journey into the depths of our nervous system.

BY SEBASTIAN HOLLSTEIN

Whether you are an artist or a scientist, a tradesperson or a manager—everyone needs creativity. Whether it is to create artistic forms of expression, to answer scientific questions or to solve everyday problems. But where does this »superpower«, which has facilitated cultural advancements in the history of mankind, come from?

Biologist Dr Konrad Lehmann has dedicated his book »Das schöpferische Gehirn« (The Creative Brain) to this question, in an exceptionally creative manner. The author takes the reader on a seven-day investigation together with Commissario Prefrontale to find the »secrets of the brainwave«. »I wanted to combine the neurobiological knowledge that I have acquired from my work with my life-long fascination for the wealth of cultural creations«, says the author, explaining the motivation behind his new work.

»For me, creativity is one of the finest human capabilities. Thus, I was really excited to learn that psychologists and, increasingly neuroscientists, have been

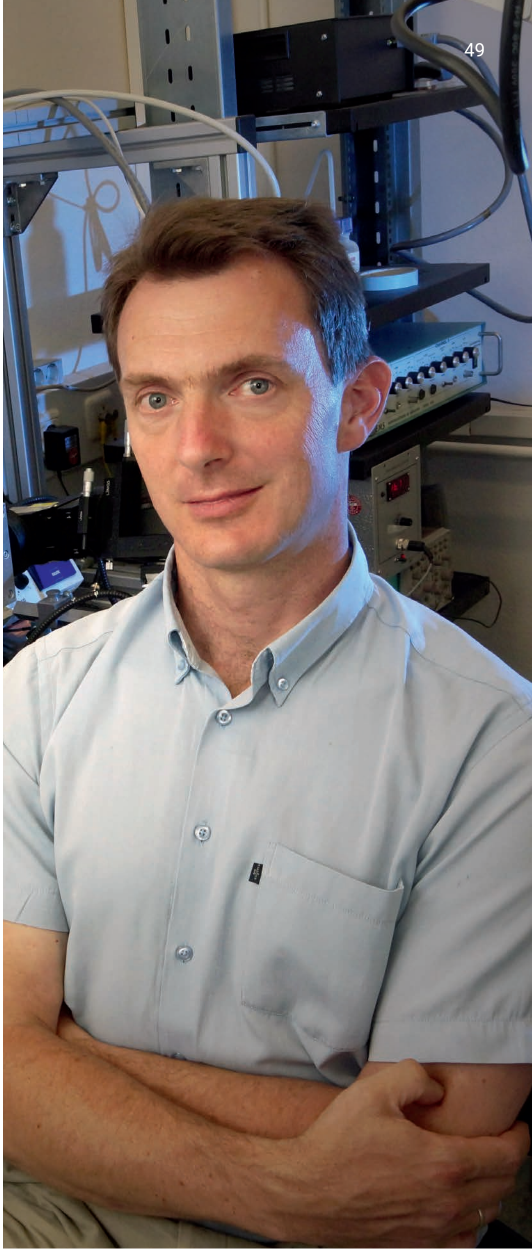
Image left: The creativity network within the human brain is always at work when the mind is taking a break from abstract thought.

conducting detailed research into how creativity arises in the brain in recent years. I really enjoyed working my way through these findings and editing them in a scientific manner, whilst also creating what I hope to be an entertaining and easy-to-understand book. Intrinsic motivation—as you discover in Chapter 3—is a pre-requisite for creativity.«

The background story and the informal tone of the book make the scientific facts and results of the latest research easier to access. The experienced neuroscientist invites you to search for clues in the nervous system, and thus leads you deeper and deeper into the matter. Along the way, he ponders why creative insights often occur suddenly and unexpectedly.

Creativity doesn't come from nothing—good ideas take time

Even when an idea appears to come from nothing, it is owed to an elaborate process. Back in the 1920s, the English psychologist Graham Wallas divided it up into five phases, which Lehmann draws upon: the starting point is the preparation through learning and collating information. Then there is a phase in which nothing appears to happen. But the brain works during this incubation period. A feeling that one is close to solving the problem arises in the person in question—and then the brainwave hits. After careful analysis, one concludes that a good result has been found.
The incubation phase is of particular interest to neurologists, as it is responsible for the element of surprise associated with a brainwave. After all, a moment of creativity often occurs when we are not in »thinking mode«.
And it is precisely this that may be the reason for the creative inspiration, as Lehmann vividly describes. Brain researcher Marcus Raichle was the first to conduct in-depth studies into areas of the brain that are active when people do nothing. »There is a limited number of regions that always fall silent when attention is required«, explains Konrad Lehmann. »This implies that these parts of the brain are always active when no attention is required.« It is precisely this network of areas of the brain, which are responsible for introspection and »a stable, continuous self«, that provide freedom for creativity.
Konrad Lehmann uses metaphorical excursions into our head to describe the various processes, which guarantee our inventiveness. He also looks at questions of talent and genetic predispositions and provides answers. And, along the way, he provides a colourful combination of cultural history and modern neurology. ■



Neuroscientist Dr Konrad Lehmann.

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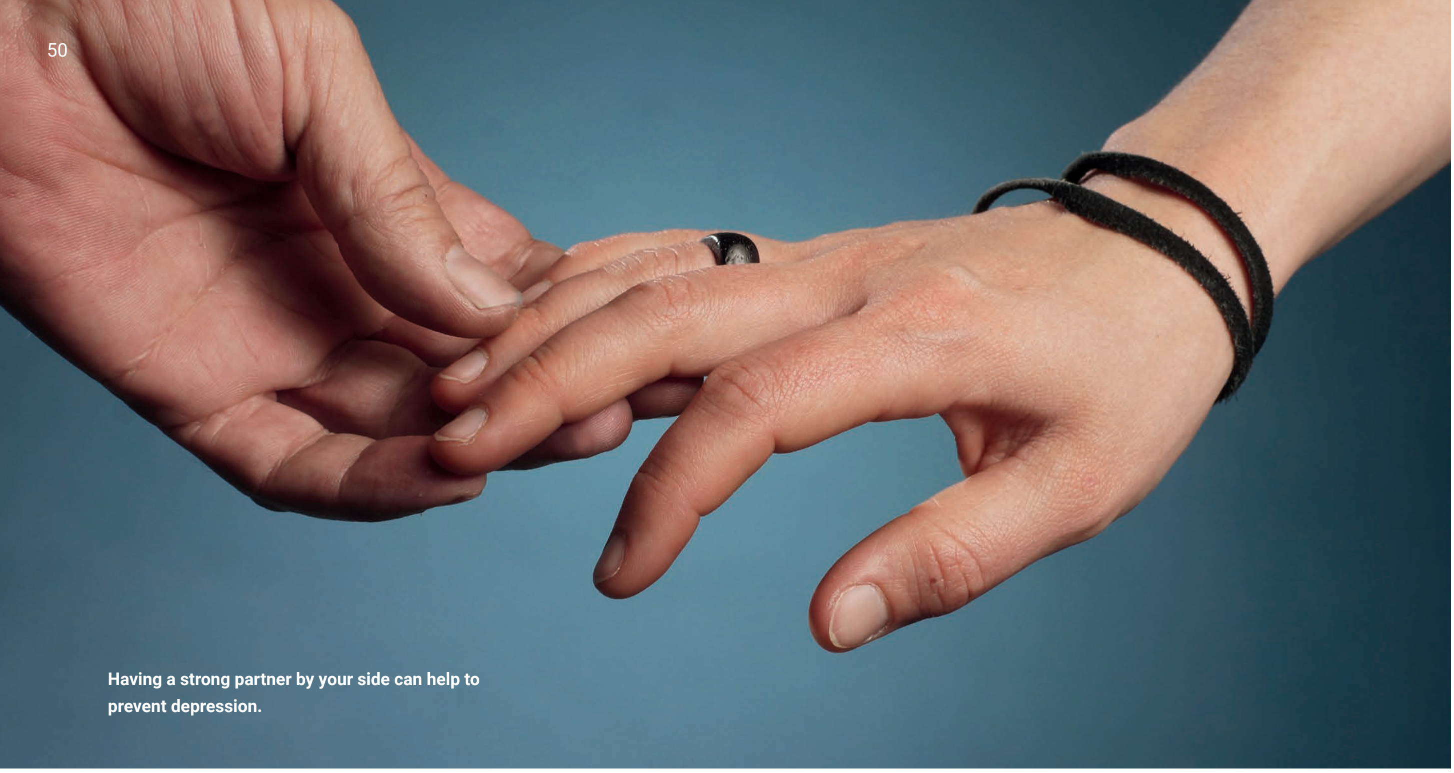


Having a strong partner by your side can help to prevent depression.

Partners can reduce the risk of depression

Scientists from several German universities have been researching couple relationships and their dynamics as part of a long-term study. They have recently found that, often, it is not crisis situations that lead to separations. The German Research Foundation (DFG) has now extended funding into the study.

BY SEBASTIAN HOLLSTEIN

How do couples get together? How do they structure their relationship? Why do some stay together and some not? For the past ten years, researchers from various German universities have been investigating the dynamics of partnerships and families within the Federal Republic of Germany as part of the 14-year longitudinal study »Panel Analysis of Intimate Relationships and Family Dynamics« (Pairfam). They have been surveying 12,000 people each year, as well as their partners, parents and children. Now the DFG has extended financing for the project and promised funding of around 7.6 million euros for the next two years—1.6 million euros of this funding will go to the University of Jena.

»We are thrilled that the DFG will continue to finance this excellent research enterprise, which does not just provide the researchers working on the project, but also many colleagues in Germany and abroad with valuable data and information«, says Prof. Dr Franz J. Neyer, who has been working on Pairfam since 2014, along with colleagues from Bremen, Chemnitz, Cologne and Munich. Together with his colleague Dr Christine Finn and some Jena early-career researchers, he has obtained some fascinating findings over the past two years as part of Pairfam.

»Together with Canadian partners, we have managed to further reveal the correlation between feelings of self-esteem and depression within a couple relationship«, explains Neyer. »Thus, a low sense of self-esteem often increases a person's propensity to depression; but a partner with a greater sense of self-esteem can have a positive effect on them and can counteract the higher risk of suffering from depression.«

Disagreements between partners are often a reason for separation

A further result from the findings provides answers to one of the most common questions regarding relationships: Why do some pairs stay together for life and others split? »Without a longitudinal study like Pairfam it would be very hard to elucidate this problem«, explains Christine Finn. »It is the only way that we can observe the development of a relationship, from the beginning to the end—and to do so from the perspective of both partners.«

This is precisely what they have done and, in doing so, have ascertained that the perception of the needs of the individuals within a relationship is decisive for the journey along a common path. Couples who agree with one another, develop in sync and »gradually move together in harmony«. As a result, it is not generally dramatic crisis situations that are responsible for separations; but rather personal characteristics, which are set from the start.

As far as the data from the surveys over the coming years is concerned, the Jena psychologists hope to reach further illuminating conclusions—not least as, with the continued financing by the DFG, it will now be possible to also survey millennials. This generation offers completely new perspectives; for example, concerning the impact that the internet has on relationships. ■

Why people abroad learn German

Economist Prof. Dr Silke Übelmesser is investigating motives of people abroad to learn the German language in a project funded by the German Research Foundation (DFG). She is particularly interested in finding out to what extent the language learning is motivated by potential migration.

BY STEPHAN LAUDIEN

The German language is becoming increasingly popular abroad. But why are German language courses—a language that is generally considered to be difficult to learn—top-sellers in many countries? Is there a link between language learning and migration? Prof. Dr Silke Übelmesser and her team from the University of Jena are studying these questions as part of a project funded by the German Research Foundation (DFG).

The research project »Investition in Sprachkenntnisse und Migrationsentscheidungen« (Language-Skill Investments and Migration Decisions) started in February this year. The two-year project will be conducted with partners including the Ifo Center of Excellence for Migration and Integration Research (CEMIR) in Munich, which is led by Prof. Dr Panu Poutvaara, and selected Goethe Institutes. The DFG is providing funding of almost 160,000 euros.

Do people learn German with the intention of migrating?

As Silke Übelmesser, who holds the Chair of Public Finance, explains, the new research is building on the previous project »Spracherwerb und Migration« (Language learning and migration). This research project began in 2015 and was also funded by the DFG.

The previous research was based on the Goethe Institute's yearbooks from 1965 to 2014. Initially, the data was collated and analysed on an aggregated level to see if there are correlations between language learning and migration. The new project will build those results by looking at the individual level.

Silke Übelmesser explains: »We want to ask course participants about their concrete motives behind learning the language.« The reasons can be very diverse: occupational benefits, making personal connections with Germans, an interest in the German culture and language, and also the intention of moving to Germany.

Course participants at ten to twelve Goethe Institutes will be surveyed; with two thirds of the Goethe Institutes lying in Europe and one third outside of Europe. The selection criteria include the distance of the language from the German language and the geographical distance. Thus, far-lying countries like India and Japan are included as well as close neighbouring countries like the Netherlands and Poland. The participants are being surveyed based on paper and pen questionnaires.

Silke Übelmesser hopes that the answers will make it easier to categorise and interpret the previous findings. It is, for example unclear how important the intended migration is as a possible reason, and what the concrete temporal correlation is. In other words: »Do language students want to increase their chances in the case of migration by learning German, or are they learning German because they actually want to migrate?« The answers from the language students promise to be exciting.■

Prof. Dr Silke Übelmesser is investigating the correlation between language learning and migration.

As part of a new project, Dr Thomas Schneider is synthesizing and characterizing nanoparticles—here he presents solutions with nanospheres made of gold (left) and silver.

Tiny and useful—and harmless?

Nutritional scientists at Jena want to trace nanoparticles in foodstuffs. The aim of the project, which is funded by the EU and the state of Thuringia, is to be able to properly assess the risk potential of nanomaterials in foodstuffs.

BY UTE SCHÖNFELDER

To paraphrase a German saying: you eat with your eyes. That is why food manufacturers often pull off a range of tricks to make their products as visibly appealing as possible for consumers. Silicon or titanium dioxide are, for example, used to ensure that ketchup flows smoothly out of the bottle, that colourful chocolate buttons shine appealingly and that instant cappuccino powder doesn't clump together in the packaging. These substances form fine powders, which lend the foodstuffs their desired properties. The problem: the powders are so fine that—depending on the manufacturer—they always contain a certain amount of minute nanoparticles.
Nanoparticles measure only a few nanometres in size and are thus smaller than most molecules that our body deals with. »If nanoparticles end up in the human digestive system through our diet, they can, due to their tiny size, pass through the intestinal wall and spread practically all over the body«, says Dr Thomas Schneider from the Institute of Nutritional Sciences at the University of Jena. »Despite this, no one can currently say with any certainty whether these particles are harmful or what health risks they actually pose.« According to the nutritional toxicologist, the study has been extremely inconsistent to date. This is largely due to the inadequate test methods and the lack of opportunity to show that there are nanoparticles in the body and to characterize them.

Analysis platform to detect potentially harmful nanomaterials in foodstuffs

In order to change this situation, Thomas Schneider and his colleague Prof. Dr Michael Glei have grouped together with a partner from the industry, Analytik Jena AG, to launch a research project. The new joint project »Analyse von synthetischen Nanopartikeln in Lebensmitteln mittels Einzelpartikel-ICP-MS« (Analysis of synthetic nanoparticles in foodstuffs using single particle-ICP-MS) is being funded for two and a half years by the state of Thuringia using funds from the European Regional Development Fund to a sum of 615,000 euros. Around 285,000 euros of this funding will go to the University of Jena.
The aim of the project is to develop an analysis platform to detect potentially harmful nanomaterials in foodstuffs. The researchers want to utilise the highly sensitive process of inductively coupled plasma mass spectrometry (ICP-MS) for this purpose. »This analysis procedure can be used to detect even the smallest traces of metals, such as titanium, gold or magnesium«, explains Dr Schneider. In order to utilize the method for the analysis of nanoparticles in foodstuffs, the researchers must first develop a special sample supply system and some data analysis software.
»In addition to this, we also want to gauge the toxicological properties of the nanoparticles«, states Prof. Glei. The particles are tested on cell cultures in his laboratory. This test shows whether and to what degree they affect the growth of the cells and whether they lead to damage, for example with regard to DNA. Bowel cell cultures are used to model the natural barrier of the human digestive tract. ■

Prevention through strong personalities

Following on from its successful implementation in schools in Thuringia, psychologists from the University of Jena are now extending their addiction prevention programme for young people across Germany. Project partner Techniker Krankenkasse is supporting »IPSY« with around 750,000 euros over a four-year period.

BY SEBASTIAN HOLLSTEIN

Drugs are harmful to the body and the psyche. Not to mention they are addictive. Many are only available from illegal sources. Relaying these facts is an important part of addiction prevention amongst pupils at schools.

But the educational programmes often barely touch upon a decisive aspect: the actual cause for taking the drugs. Young people often become addicts because they hope to improve their social status amongst friends with drugs or use them to try and deal with problems typical of their phase of life.

This is precisely where the programme »IPSY—information and psychosocial competence«, which has been developed and evaluated at the University of Jena as part of a research programme, comes in. By implementing the project in the classroom setting, teachers can boost the personality of their pupils and thus make them less susceptible to alcohol and the rest. Following a successful regional project in collaboration with the Techniker Krankenkasse (TK) in Thuringia to circulate the programme across schools in Thuringia, the Jena psychologists are now working to establish IPSY in schools across Germany. The TK has been sponsoring the project since March and is providing around 750,000 euros over a four-year period.

Prevention is more than just education —learning to say »no«

»IPSY is one of the few evidence-based prevention programmes whose effect has been proven in long-term scientific studies«, says Thomas Holm, Head of Health Promotion in Living Environments at the TK. »Now that we have received numerous positive responses from the model region of Thuringia, we are even more pleased with the apparently successful correlation between research and practical prevention.«

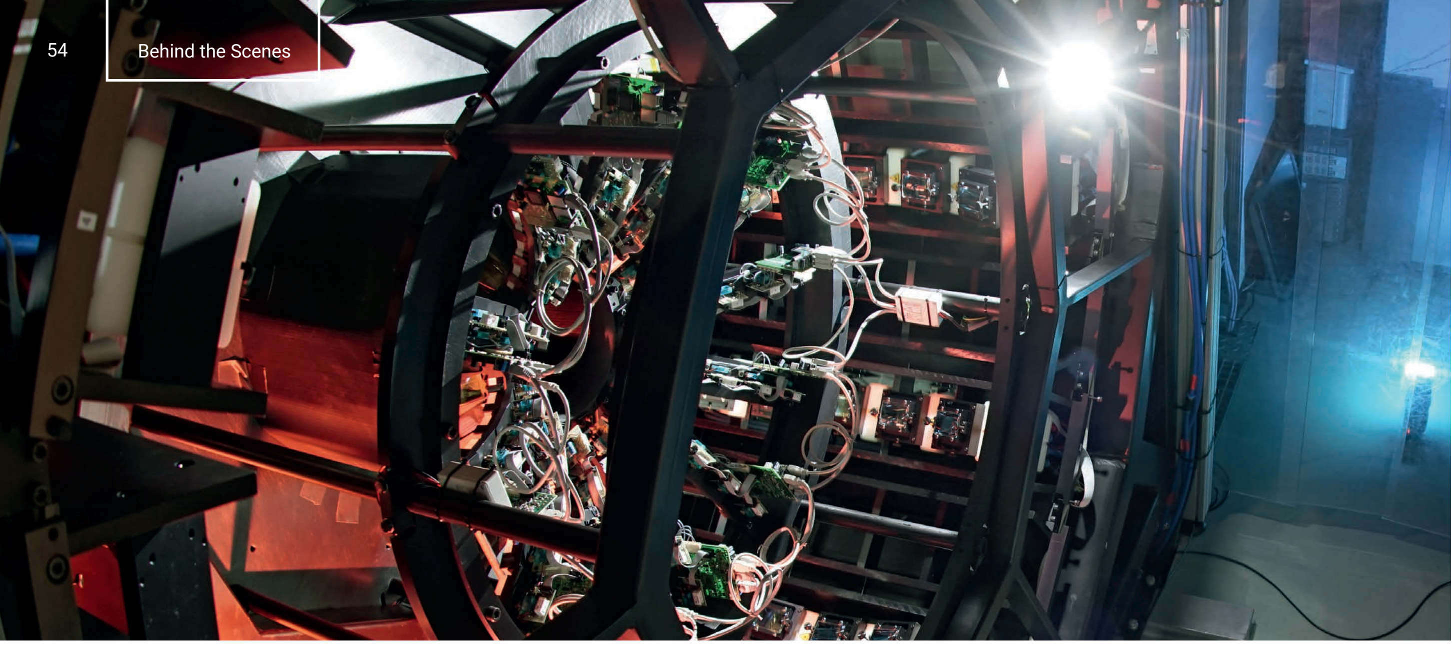
»Addiction prevention is often reduced to providing information about the different kinds of drugs and the associated health risks«, says Prof. Dr Karina Weichold. »But a programme like this can do a lot more. Teachers can give their pupils the tools that they need to simply say no to drugs and thus to go through life with a more stable personality.« According to Weichold, pupils should be happy and satisfied, should be able to navigate life successfully and should also learn that drugs will not help them along this path.

Long-term study proves success—drug consumption considerably lower

The school environment has a huge influence on children and youngsters. »That is why it was important for us that the teachers or social workers carried out the training themselves and thus influenced the personal development of their pupils«, says the scientist. The teachers work based on resources; in other words, they have to identify the strengths of their pupils and help them to consolidate these strengths.

The success of this approach has not just been proven through feedback from the schools, but also through a long-term study. »Research shows that pupils who have taken part in the IPSY programme resort considerably less to alcohol, cigarettes and illegal drugs.« Karina Weichold believes that the success of the project is owed to the intense scientific development of the training and the good preparation of the teachers through training courses. ■

»IPSY« project manager Prof. Dr Karina Weichold.



The final amplifier stage of the high-performance laser POLARIS.

Half-speed ahead

POLARIS is one of the most powerful laser systems there is. Jena researchers have already made several world records with POLARIS. Yet the laser only rarely reaches peak performance during normal operation. How come?

BY UTE SCHÖNFELDER

It is a good two years since Prof. Dr Malte Kaluza and his team announced their last world record: with the POLARIS laser, researchers from the Institute of Optics and Quantum Electronics and from the Helmholtz Institute Jena have achieved the highest peak load energy for a fully diode-pumped short-pulse laser system. POLARIS generated over 50 joules of pulse energy—in principle, each of these pulses could be compressed to 100 femtoseconds to thus provide an output of over 100 terawatts—equivalent to global electricity consumption many times over.

Even though this places POLARIS in the league of huge lasers—in the petawatt class—in its routine operation it rarely does full justice to its name (POLARIS stands for Petawatt Optical Laser Amplifier for Radiation Intensive experimentS). This is because, physicists generally just »shoot« with pulses containing 15 to 17 joules; i. e. around 170 terawatts, rather than the maximum achievable laser energy. Why?

It is largely to do with the complexity of the laser, explains Kaluza: »POLARIS, like other laser systems, isn't a device that you simply switch on and then use automatically in the same way each time.« It is actually an enormous technical challenge to keep the output of the laser at a consistent quality for a long enough period of time so it can be used for reproducible scientific measurements. »And, at the end of the day, that is our main interest.« POLARIS is a scientific tool and peak performance is not an end in itself.

Hundreds of optical components need to be calibrated and maintained

Around 170 diode stacks, hundreds of mirrors and seven amplifying crystals or glasses must be carefully aligned to guarantee a defined beam profile and reproducible laser quality. The beam travels just under one kilometre through the 240 sqm system. POLARIS is based on the technique of »Chirped Pulse Amplification«. A low-energy start pulse is stretched in time and then amplified over several orders of magnitude. The amplified pulses are finally compressed to generate a pulse with an extreme peak power, »as the energy is released in an extremely short space of time«, explains Kaluza. The fact that POLARIS is currently only running at »half power« is owed to the sensitive optical components. The mirrors, gratings and amplification crystals can become damaged when the power is too high. »Even tiny defects on the coating of a mirror can lead to the next shot being the last«, summarizes Kaluza. Several researchers and technicians spend around half of the operating time adjusting, maintaining and servicing the optics to set them up to produce a laser beam profile that is as homogeneous as possible.

After all: the more evenly the laser illuminates the sensitive surfaces, the less likely it is that it will be damaged by the laser radiation. Without the perpetual testing of all optical components, it simply wouldn't be possible to achieve very precise peak performance at any given time. And only with a uniform and even beam profile it is possible to achieve higher pulse energy with POLARIS and, therefore, to run the system »on full power«.

»It is a really fiddly job. Often you just have to try and see«, says Kaluza. As a result, it is not just specialist knowledge and patience that is required; but a playful nature too. But what are world records when you get to play with such an amazing »toy«? ■

Bright nights

Both humans and animals suffer when night-time is no longer dark. What can we do to prevent the increasing light pollution?

COMMENTARY BY STEPHAN LAUDIEN

Attractive LED light: Entomologists use it to attract butterflies and moths in the South American rainforest, but it is leading to the downfall of the animals in our brightly lit cities.

Where there is a lot of light, there is also a lot of shade. In other words: there is a dark side to having a lot of light. It may sound like a platitude, but it actually relates to a serious problem: light pollution. An excess of nocturnal light has a negative impact on both humans and animals. The effects are especially disastrous for nocturnal insects. Although moths and other insects don't burn in lamps, the draw of the lamps has enormous consequences: »The animals neglect their search for food and partners, and pollinate fewer flowers«, says Dr Gunnar Brehm, zoologist at the Phyletic Museum.

There is no reliable data for light pollution in Germany; but it is highly likely that there is a correlation with the decline of certain species. Increasing light pollution also has a negative impact on humans. »The intensity of light at night means that we are losing our starry skies; the Milky Way can no longer be seen in many places«, says Brehm. It also has an impact on our health, for example through a disturbed night. The sheer number of light sources is only one side of the coin, however. With the increasing use of modern LEDs, conventional sodium-vapour lamps are disappearing. The old lamps emit an orange light; whilst the new lamps shine in a white colour and often appear brighter. »Insects notice this shortwave light emitted by the LEDs«, says Gunnar Brehm.

How can light pollution be reduced to make the nights darker again? On the one hand, street lighting could be dimmed on side streets. On the other hand, lights don't need to shine the whole night long. Gunnar Brehm thinks the following: »It is not about making cities pitch black at night«. Small alterations could have an effect. The use of long-wave light would protect the insect world. This redder light would take some getting used to, but it would still fulfil its principle purpose.

»Protecting the night« is a declared goal of Jena City of Light

In Jena, the city council has responded to the problem: in December 2017, a resolution was passed to »protect the night«. The Kommunal Service Jena (KSJ) has been tasked with presenting a lighting concept for public spaces in the city by the end of 2018. The objective is to »reduce [light pollution] to as great a degree as possible through the avoidance of excessive lighting and to reduce lighting based on the local situation«, amongst other things. Flora and fauna, as well as public health, are to be protected through adapted light spectra, light distribution and operating hours, taking natural spaces, protected natural environments and the plains near the Saale river into account. The justification for the proposal refers to the impact that biologically effective blue colour components in LEDs have, which attract nocturnal insects. Around 620 of a total of 700 butterfly species in the city centre remain active at night. The illumination of bridges even has an effect on the fish in the Saale.

Take the example of the Austrian capital Vienna. After ten o'clock at night, the street lamps run at half power—there have been few complaints. An encouraging sign. ■

Haeckel's study is renovated

Next year marks the 100th anniversary of Ernst Haeckel's death (1834–1919). The home of the zoologist will be carefully renovated during the preparation to the anniversary, the historical authenticity being preserved. This panoramic image shows Haeckel's study prior to refurbishment in the »Villa Medusa«, the Ernst Haeckel Memorial Museum at the University of Jena. The museum will be re-opened in 2019.

Not a problem of luxury

Jena philosopher Lambert Wiesing is researching an unusual topic: luxury. But this luxury doesn't refer to opulence and pomposity. Rather, Wiesing sees luxury as an escape from the drive towards efficiency and expediency, and thus as an expression of direct humanity. This portrait presents this year's winner of the Thuringia Research Award.

BY SEBASTIAN HOLLSTEIN

The office of Lambert Wiesing has a rather functional appearance. There is no extravagant seating area, no expensive pens, no embellishments—on the contrary: the shelves contain file folders and the desk is noticeably tidy. Colourful watercolours and a framed sculpture—works by artist Silke Rehberg, who has been married to Wiesing for over 20 years—are the only things adorning the walls. The front cover of a comic, which they published together in 2016, is stuck above his computer. Whether the owner of the office considers these images to be a luxury is not clear.

»I am often asked about my own personal luxuries, but I have never answered the question«, says Lambert Wiesing laughing, as he sits back in his desk chair and briefly crosses his arms above his head. This refusal is somewhat surprising for a philosopher, who spends his time at work searching for and providing answers. Over the last four to five years, Wiesing has conducted in-depth research into the topic of luxury; has published a much-praised book through the Suhrkamp Verlag publishers; and was recently awarded the Thuringia Research Award for his work. He has discussed the topic a lot with colleagues, readers and journalists in recent times. Even though it has become routine, he hasn't lost his interest in exchanging interesting ideas. It is only for this highly personal question that he concocts a nothing answer: »I always say that I love old, leather-bound folio books.«

It may sound like a clear line is being drawn; but in actual fact there is nothing more than a thin membrane between the scientist and his area of research. Wiesing is a phenomenologist. Put simply, he investigates how people perceive things, which experiences they have and how they create a world from these experiences. He is always an object of his own research. »Phenomenology begins from personal experience, to find the necessary structures within the observed phenomena«, he explains. This means, each phenomenological realization always represents a small act of self-disclosure from the philosopher.

Against the drive towards expediency—luxury as an internal experience

The trigger for choosing to study luxury came from an immediate experience. Five years ago, Wiesing conducted research as a guest professor at the University of Oxford, and, whilst there, observed a fascinating parallel between luxury and education: »The two are only available to people who deny the pursuit of efficiency and expediency«, he says. After grappling with this thought for a long time, he realised that philosophy had barely touched upon the subject of luxury as a phenomenon to date. For a philosopher, this is like winning the lottery—it is very rare to find areas that have not already been studied in detail.

The lack of research in this topic is particularly surprising, as luxury is so very present in society. However, it is often based on an error: »Luxury is often equated with showing off—in other words, displaying wealth to win prestige«, explains Wiesing. »Yet, in actual fact, it has nothing to do with self-expression. Luxury is a deeply internal experience that humans can express in highly individual ways.« While one person might consider an expensive sports car to be a luxury; someone else sees it as trying a special cheese. Although there are different numbers on the price tag, shoppers can enjoy the same aesthetic experience with both—an experience that cannot be seen from the outside: both are owning and using something that detracts from expediency; both are thus refu-

Luxury researcher Lambert Wiesing lives and works in relative modesty.

sing to think efficiently: »Luxury cannot be defended rationally. Luxury is waste, luxury is irrational—and its importance for humans lies precisely in this deep-lying experience of refusing efficiency«, says the philosopher. »We can use luxury to escape the drive towards expediency. And that is what makes it something so fundamentally human; only humans can take a stand for something that is considered to be reasonable and decide whether to realize it or not.« Wiesing says that recently he has often heard the phrase: »We don't really need it«. »It may be true, but the question is: What conception of man are we defending when we reduce ourselves to what we need? Should we talk about people in the same way as we talk about machines—where we can say what they need and consume?«

In the tradition of Schiller—the freedom of play and the freedom of irrationally expensive possessions

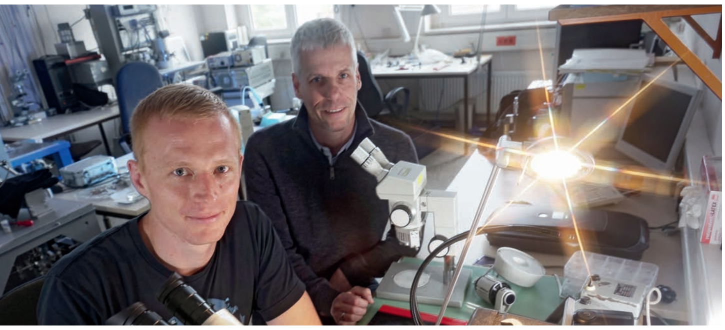
With his research, the philosopher is not just providing a definition of the term luxury; he is also extending the range of possibilities through which we can have aesthetic experiences. »According to Kant, only the indifferent, sensory perception of an object can cause aesthetic experiences, for example, looking at a picture. But simply owning something can have a similar aesthetic effect«, explains Wiesing, who dedicates his work to picture theory, alongside phenomenology. Furthermore, with his observations on the »personal experience of humans«, the philosopher is following the tradition of a famous predecessor. »Friedrich Schiller claimed that humans can fall into a bad way in two different manners: they can either become a totally instinct-driven hedonist or an equally one-sided, ruthlessly rational being. And it is the aesthetic experience of freedom that prevents this«, explains Wiesing. »Schiller believed that play offered a way to provide the experience of freedom. Nowadays, it seems that for many people, this is found in the possession of irrationally expensive objects—this could be owed to the increasingly pervasive efficiency-based thinking.
The University's namesake provides a key reason as to why the Münster-born philosopher is so happy in Jena. »On the one hand, I am continually amazed when I discover the excellent reputation that Jena has abroad—not least thanks to its history«, explains the 55-year-old, who is due to take on a guest professorship in the USA in the upcoming winter semester. »On the other hand, I consider the local Institute for Philosophy to be one of the most fascinating of its kind in Germany.« And there are few people who would know this better, as Wiesing has been at the University of Jena for over 20 years. After his degree in Münster, he studied for his doctorate in Chemnitz before becoming the Deputy Chair for various positions in Jena. In 2001 he became a professor and in 2009 became the Chair for Philosophy focused on Picture Theory and Phenomenology.
Lambert Wiesing, who calls himself a »university lecturer« rather than a »philosopher«, lives with his family in the country. He believes that this combination makes his work better. »When I am in Jena, I enjoy taking an active part in university life. And, when at home, I can relax and find the peace and quiet to read and think.« After all, that is really all he needs for his research. He also benefits from exchanging ideas with other people. The fact that the »luxury book« was so well-received is extremely helpful. »I regularly receive letters from readers, which provide me with new examples and perspectives«, says the author. And perhaps one day, he will reveal his personal luxury to them in return. ■

A safer gallop

Kinesiologists have found an answer to the question why humans break into a gallop, i.e. gain momentum with one leg and pull the other along behind, for example when moving quickly downstairs (DOI: 10.1098/rsos.172114).
»Galloping provides a greater stability and requires less control«, explains Dr Roy Müller. This is because the leg that touches the ground first is the only one that make adjustments to guarantee stability. This single-sided movement does not have a negative effect on stability—quite the opposite: »We applied our observations to a model and discovered that the selected adjustments make the entire system more robust.«
There is, however, one disadvantage to this way of moving: the gallop is too strenuous for adults over long periods, as it requires more energy and puts more strain on the knees. sh

Fossa Carolina was never finished

The study by researchers from Leipzig, Hildesheim, Jena, Kiel, Berlin, and Munich proves that the canal Fossa Carolina (»Karlsgraben«) in Middle Franconia (top photo: oak posts on the embankment) was never finished (DOI: 10.1016/j.quaint.2017.12.021). Over 1,000 years ago, Frankish King Charlemagne wanted to build a canal linking the Rhine to the Danube. The construction began in 792/793 AD, but the ambitious project became a victim of technical problems. The researchers conducted investigations on a stretch of at least 700 metres between the remains of the canal in the town of Graben and the river of Altmühl. There they found no signs of a navigable canal. Thus, they concluded that the construction remained unfinished. Inspite of this discovery, the researchers believe that the Fossa Carolina represents an enormous engineering feat from the Early Middle Ages. PR



Illuminated nanocomponents

Physicists have developed a method for measuring active nanoscale components, for example those built into chips, diodes or transistors in mobile phones, and computers (DOI:10.1126/sciadv.aao4044).
They can use it to retrieve information about the composition of the elements, their oxidation state, and about internal electric fields—all this while the component is active. The test method is based on the interaction between a very fine X-ray and the material itself, as Prof. Dr Carsten Ronning explains (on the photo on the right, next to Dr Andreas Johannes, who carried out the experiment). The X-ray induces an electric current into the material. At the same time, the energized material emits a characteristic radiation spectrum, which is then analysed. sh

No fear on the dentist's chair

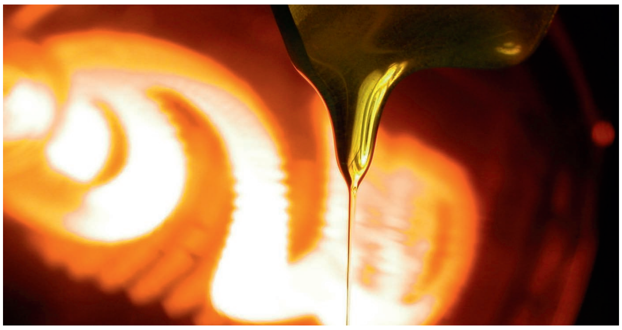
During a meta study, researchers from the University Hospital Jena investigated the efficacy of various non-medical interventions against stress and anxiety related to dental treatments. They came to the conclusion that detailed information, music, relaxation, and distraction all work against light to medium dental-related anxiety. Hypnosis proved to be the most effective treatment (DOI:10.1016/j.jdent.2017.11.005.). »We were surprised by the fact that almost all of the interventions had been effective in reducing the psychological stress«, explains psychologist PD Dr Jenny Rosendahl, who led the study. The authors want to use their findings to encourage dentists to utilize non-medical measures in addition to standard treatments for tense and anxious patients. vdG

Only sustainable is just

The economist Dr Wolfgang Bretschneider from the Chair of Economic Policy has written a book about equity in supplying people with drinking water (»Das Menschenrecht auf Wasser als Allokationsproblem« or The Human Right for Water as a Problem of Allocation).
The implementation of the human right, which was recognized by the United Nations in 2010, has failed by now. According to Breitschneider, this is partly because it is not clear what it means. »Providing unlimited and free water is not only impossible, it is also unsustainable. Firstly, the human right can only be fulfilled if the spatial, temporal and pecuniary barriers are shifted to a framework that is reasonable for every individual. And secondly, these barriers also must function so they promote the sustainable use of the valuable resource water, highlights the researcher. US

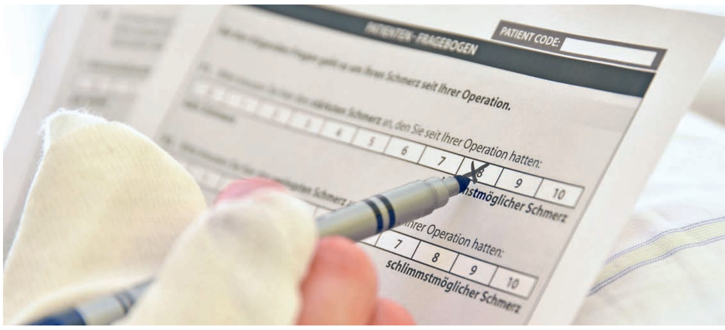
An early start of the spring

Botanists have been investigating the changed start of flowering caused by the global climate change. »Generally, the climate change leads to an early beginning of flowering«, says Patrizia König. The early-career researcher from the Plant Biodiversity Group evaluated data from over 550 plant species in 18 locations across Europe and North America, and investigated how they react to the changing environmental conditions (DOI: 10.1111/geb.12696).
The functional features of the plants, for example, as the plant height and leaf size, are decisive. When it comes to shrubs, herbs and grasses, the smaller the plant, the clearer the change in the beginning of flowering. The researcher from Jena believes that this is to pre-empt the large-growing competitors which screen the sunlight from the smaller plants later. US



How solids turn to liquids

Materials scientists from Jena and their colleagues from an international team of experts observed what happens at the molecular level during melting in detail (DOI: 10.1002/advs.201700850).
The team of researchers succeeded in watching the melting process in slow motion. They revealed that it actually occurs in two stages: »When the temperature increases, the system reaches an energetic state first. This leads to randomly emerging disturbed areas although without the particles making up the crystal lattice making larger movements. It is only when, in the second stage, these particles also achieve the freedom to move that the disturbed areas also liquefy«, explains Prof. Dr Lothar Wondraczek from the Chair of Glass Chemistry. sh



How pain is perceived

Patients from the USA experience a significantly higher intensity of pain after identical orthopaedic operations than patients in Europe. Although the patients in the USA received more painkillers, their desire for more pain therapy was even higher than in the comparison group. These findings are based on the evaluation of around 14,000 patient surveys from the world's largest acute pain register PAIN OUT coordinated by the University Hospital Jena (DOI: 10.1016/j.bja.2017.11.109).
One possible explanation for these differences could be in the increased consumption of opioids by the American patients prior to the operation. The authors suspect that they may reduce the effect of the painkillers after the operation. vdG

The commemorative plaque in memory of the famous doctoral candidate in front of the main lecture hall in the main building of the University of Jena.

A doctorate »in absentia«

Karl Heinrich Marx was born over 200 years ago, on 5 May 1818. The philosopher, who accused his colleagues of having interpreted the world differently when they in fact should have changed it, had a special connection to the University of Jena. He submitted his doctoral thesis »in absentia« here in 1841. It was graded »with distinction«.

BY STEPHAN LAUDIEN

»A spectre is haunting Europe—the spectre of communism.« This rather often quoted sentence is the opening line of the *Manifesto of the Communist Party* by Karl Marx and Friedrich Engels. The programmatic work, commissioned by the Communist League and published in 1848, ended with the cry: »Workers of the world, unite!«

Learned citizens of the GDR were well-acquainted with the sentence. It adorned the top right-hand corner of the front page of the Communist newspaper *Neues Deutschland*. But it was not the »Organ of the Central Committee of the Socialist Unity Party of Germany«, as the newspaper was known, that adorned itself with Karl Marx.

The philosopher, who wrote as massive work as the three-volume *Das Kapital*, became one of the much praised heroes of the global communist movement. Enriched by the ideas of Vladimir Iljitsch Uljanow, known as Lenin, Marxism-Leninism became the doctrine of salvation for the Soviet Union and, later, for the entire Eastern Block. Even pupils were familiar with Marx. In the German Democratic Republic, the teachings of the class struggle were part of the curriculum and »ML« (standing for Marxism-Leninism) was a mandatory subject. In addition, the novel *Moor and the Ravens of London* was a compulsory literature in schools.

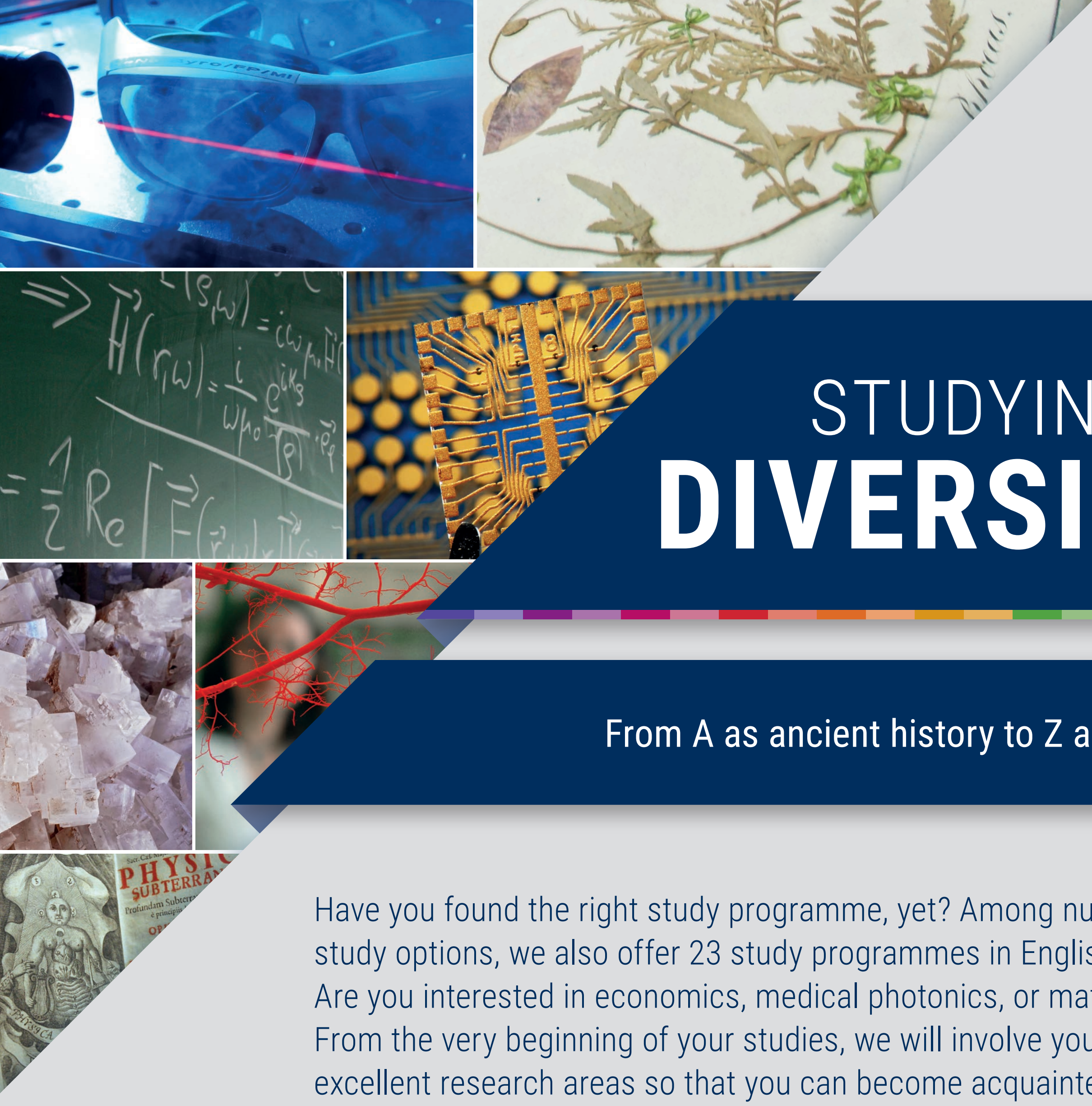
Yet, did anyone read anything else by Marx? What is sure, is the fact that Marx was considered sacrosanct. Lenin set the tone here: »The teachings of Marx are all-powerful because they are true.«

The young Marx was surely not aware of the fame that he was going to achieve later. Karl Heinrich Marx was born 200 years ago on 5 May 1818 in Trier. His father, Heinrich, was from a family of famous rabbis and converted to Protestantism. His mother, Henriette, was related to the poet Heinrich Heine. In 1835, after his *Abitur*, Marx began studying law in Bonn. He continued his studies at the Friedrich Wilhelm University in Berlin. In Berlin, the student increasingly neglected jurisprudence and instead turned his attentions to philosophy and history.

In April 1841, Marx first came into contact with the University of Jena. Professor of Literature Oskar Ludwig Bernhard Wolff arranged for the previously unknown student to submit his doctoral dissertation *The Difference Between the Democritean and Epicurean Philosophy of Nature* to the Faculty of Arts. His doctoral diploma shows that the work was graded »vorzüglich würdig« or »with distinction«. Since 1947, the document has been preserved in Moscow. The doctoral thesis can no longer be found.

A further connection between Karl Marx and Jena is a bust, which was created by the artist Will Lammert in 1953. Between 1959 and 1992, the sculpture decorated the entrance to the University and was then banished to the University's repository upon Senate's decision.

Marx's tumultuous life ended in London on 14 March 1883, where he came to rest at Highgate Cemetery. The grave has been a pilgrimage site for disciples of Marx from across the world to this day. Presumably, it is always decorated with fresh flowers. ■



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