LICHTGEDANKEN

The Research Magazine **11**

INTERNATIONAL YEAR GLASS AND SUSTAINABILITY

GALLERY GLASS OBJECTS IN UNIVERSITY COLLECTIONS

PHOTO REPORTAGE HOW A GLASS FIBER IS MADE

FRIEDRICH-SCHILLER-UNIVERSITÄT JENA

THE SOLID LIQUID

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Highlight and beacon of hope

Have you looked out the window today, put on your glasses or typed a message on your phone? We come into contact with glass in almost everything we do in our everyday lives. The material is omnipresent today—so much so that we often don't even notice it. Quite naturally, we look through it or fill it as a vessel, we illuminate buildings or adorn ourselves with it, and send data through glass in real time to every corner of the world.

It wouldn't be an exaggeration to say that we are living in the »age of glass«. This has been underlined by the United Nations, which have declared 2022 the »International Year of Glass« (IYOG) with the aim of giving the material the awareness that does justice to its importance. Glass is nothing less than the cornerstone of our modern civilization—it has been human-made for thousands of years and has become the high-tech material for future technologies thanks to its mechanical and chemical properties, its versatility, colourfulness, brilliance and transparency.

Glass is the main topic of this issue of LICHT**GEDANKEN.** To mark the IYOG we present the history of glass research in Jena, which was founded here by Otto Schott in the 19th century (p. 32). We will highlight various glass chemistry research projects and show how glass is being used in a variety of ways. For example, researchers are developing bioactive, soluble glass implants to help regenerate bone (p. 20), unearthing the secrets of natural glass (p. 24) and studying glass that predates our solar system (p. 26). A photo reportage documents the production of optical fibres as thin as human hair (p. 34) and a picture gallery highlights glass testimonies from the university's collections (p. 28).

In addition to its importance for our modern world, glass is also a real beacon of hope for a more sustainable future. Thanks to the material's chemical resistance, it can be recycled almost infinitely and can survive undamaged for up to a million years. This is another reason why 2022 is the »Year of Glass«: clean drinking water, sustainable energy supply, infrastructure and architecture—glass plays the decisive role to achieve the majority of the Sustainable Development Goals formulated by the United Nations in its 2030 Agenda, as glass chemist Prof. Dr Lothar Wondraczek explains in the LICHT**GEDANKEN** interview (p. 12).

I hope that our latest edition provides you with plenty of enlightening insights and new perspectives on the special material that is glass. As always, I welcome any feedback, suggestions, or criticism you may have. You can contact the editorial team and me at presse@uni-jena.de.

Jena, June 2022

PHOTO: JENS MEYER

FEATURE

The solid liquid

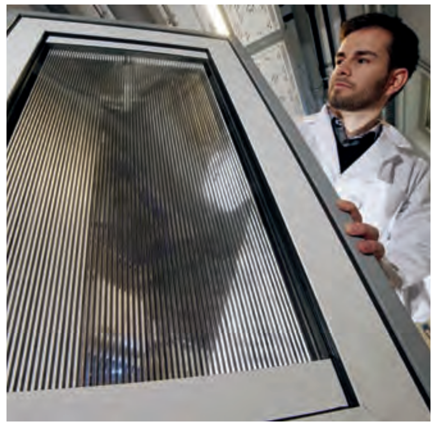


PHOTO: JAN-PETER KASPER

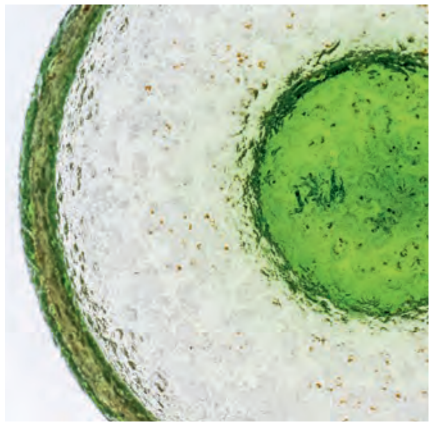


PHOTO: JENS MEYER

PHOTO: JENS MEYER

PHOTO: CHRISTINE RÖMERMANN

PHOTO: JENS MEYER

PHOTO: JENS MEYER

Colliding neutron stars

Prof. Dr Sebastiano Bernuzzi has received a Consolidator Grant from the European Research Council (ERC). His project »InspiReM« will be funded with almost two million euros over the next five years.

They are among the most extreme and most complex events in the universe: collisions of neutron stars. When two of these highly compact and massive celestial bodies merge, space-time becomes highly distorted and high-energy radiation and matter are hurled into space. The collision is so violent that it can be observed from Earth—even over millions of light years—as both gravitational waves and light.
»Such events are unique astrophysical laboratories,« says Prof. Dr Sebastiano Bernuzzi (photo). The 40-year-old researcher and his team from the Institute for Theoretical Physics are developing theoretical models with which the dynamics of such cosmic collisions can be understood. For his research project, »InspiReM«, Sebastiano Bernuzzi is receiving funding from the European Research Council (ERC)—a Consolidator Grant totalling almost two million euros over the next five years.
Bernuzzi was already funded with an ERC »Starting Grant« in 2017. His working group is a leader in the field of numerical simulation of neutron star mergers. To this end, the researchers use Germany's largest supercomputers to make detailed predictions for gravitational waves and electromagnetic observations emanating from such events, by solving Einstein's theory of general relativity. »By simulating what happens to space-time as stars merge, we can create detailed models for interpreting the radiation we observe.«
Just recently, Bernuzzi was part of an international team analysing data taken by NASA's Chandra X-ray Observatory in object GW170817 (p. 50). US

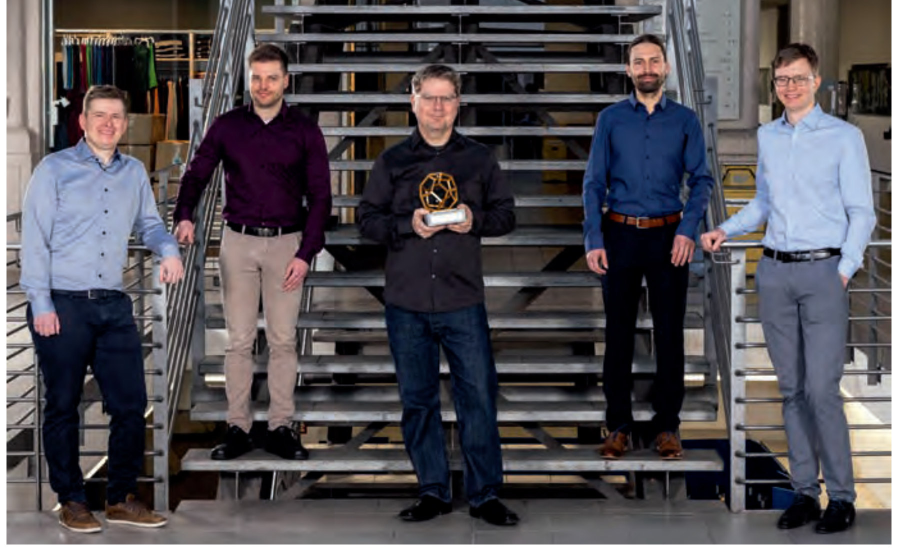
PHOTO: JENS MEYER

The path to clean catalysis

Prof. Dr Martin Oschatz is funded with a Starting Grant from the European Research Council (ERC).

PHOTO: ANNE GÜNTHER

The chemist Prof. Dr Martin Oschatz (photo) wants to develop new concepts for catalysis within the framework of the »CILCat« project and is being supported with a Starting Grant from the ERC in the amount of approx. 1.5 million euros. The production of almost all basic chemicals and the products derived from them is based on the principle of catalysis. The principle of what is called heterogeneous catalysis is based on the fact that small particles such as molecules or ions bind to the surfaces of solid substances.
The particles are »activated« by this interaction, which means that their conversion into other substances is accelerated. »However, rare metals are often needed for catalytic processes,« says the 34-year-old, describing one challenge that he wants to tackle in his research project to develop catalytic forms that do not require rare, expensive or toxic metals. The goal and the hopes associated with it are to make chemistry and its processes more sustainable and less harmful. AB



Prof. Dr Sebastian Böcker, Chair of Bioinformatics, 3rd from left, holds the Thuringian Research Prize 2022 in his hands. Dr Markus Fleischauer, left, Dr Kai Dührkop, 2nd from left, Dr Marcus Ludwig, 4th from left, and doctoral student Martin Hoffmann, right, were also awarded. · Photo: Jens Meyer

AI identifies small molecules

Bioinformatics team has been awarded the 2022 Thuringian Research Prize in the Applied Research category.

A team from the University of Jena is once again among the winners of the 2022 Thuringian Research Award. The bioinformaticians led by Prof. Dr Sebastian Böcker have been honoured for the development of machine learning methods for identifying small molecules and have received prize money of 12,500 euros.
Small molecules—called metabolites—are ubiquitous. Every living thing produces metabolites. »For humans, they play a huge role as active substances,« Prof. Böcker explains. However, identifying new active substances from nature and making them usable is time-consuming, costly and labour-intensive. »In addition, we often don't even know which unknown molecular structures we're actually looking for,« says Böcker. In order to detect small molecules in cell and tissue samples, for example from medicinal plants, a mass spectrum is recorded and compared with data from reference measurements. This method can only find molecules of which the structure is already known and recorded in a database.
And this is precisely where the work of the Jena bioinformaticians comes in. They are developing methods that enable researchers to use mass spectrometry data to identify previously unknown molecule structures. The researchers use machine learning methods for this purpose. With their search engine »CSI:FingerID«, they have developed a tool with which mass spectrometry data can be »translated« into information about the chemical structure. US

Batteries with self-healing properties

Interdisciplinary team from Friedrich Schiller University Jena gains funding from DFG for new research unit »FuncHeal«.

The »FuncHeal« led by Prof. Dr Ulrich S. Schubert has been awarded funding by the German Research Foundation (DFG) worth more than 3.5 million euros over the next four years. The aim is to develop a new generation of self-healing materials, which can not only repair mechanical damage, but also restore functional properties.
Materials developed by the new Jena research unit are to be used primarily in flexible energy storage and conversion materials. Unlike in previous approaches to self-healing materials, the aim is not only to heal cracks and other types of mechanical damage.

PHOTO: JENS MEYER

It should also be possible to restore functions and properties in a targeted manner, for example the conductivity of electrode materials in batteries or the optical properties of organic solar cells.
For example, organic, flexible solar cells (photo) are damaged by incident light over time, so that they are no longer able to convert solar radiation into electricity. In the FuncHeal project, the researchers in Jena want to find ways of ensuring that the molecular structure of the materials in the solar cells is restored, so that they regain their functionality. US

Elias of Crete writes a commentary on Gregory of Nazianzus. · Photo: Universitätsbibliothek Basel

Two new research training groups

DFG funds two new research training groups in materials sciences and humanities to be launched at the start of 2023. Another international research training group has also been extended.

Over the next five years, the German Research Foundation (DFG) will be providing more than twelve million euros in funding for two new research training groups at the University of Jena.
The first new research training group, entitled »Materials-Microbe-Microenvironment: Antimicrobial biomaterials with tailored structures and properties«, will bring together researchers from the fields of physics, chemistry, biology, clinical medicine and microbiology from the University of Jena and Jena University Hospital. The aim is to develop a tailored platform for antimicrobial biomaterials to better prevent infections associated with biomaterials. The research training group will be headed by materials expert Prof. Dr Klaus Jandt and physician Prof. Dr Bettina Löffler.
The second new research training group, »Autonomy of Heteronomous Texts in Antiquity and the Middle Ages«, will focus on texts that take on older texts and reproduce and update their content in a new form, including commentaries, sermons, retellings, and paraphrases. These texts can be found in all classical disciplines: philosophy, literature, jurisprudence, medicine, and Jewish, Christian, and Islamic theology. Prof. Dr Katharina Bracht and Prof. Dr Matthias Perkams are the spokespersons for the research training group.
An extension has been granted for »Tree Diversity Interactions: The role of tree-tree interactions in local neighbourhoods in Chinese subtropical forests«, a research training group with members from the University of Halle-Wittenberg, the University of Jena, Leipzig University and Chinese partners. AB

Supra-regional centre for quantum photonics

Carl Zeiss Foundation funds cross-location and multi-discipline consortium in Ulm, Stuttgart and Jena.

PHOTO: STEFFEN WALTHER

The first national centre for quantum photonics has opened at the universities of Ulm, Stuttgart, and Jena. The centre has received twelve million euros in funding from the Carl Zeiss Foundation and will offer around 50 scientists a cross-location and multi-discipline platform for research and exchange.
Photonics is a key technology in the field of quantum science. Photons are used as sensor elements, data transmitters and quantum systems. The networking of quantum technologies and photonics forms the basis of the »QPhoton« centre. The aim is to develop a new generation of imaging and sensor technologies with greater sensitivity and faster data processing. Marquardt

Iwi kūpuna during a repatriation ceremony in the university assembly hall in February 2022. · Photo: Jürgen Scheere

Thuringia's colonial legacy

The universities of Jena and Erfurt have received a total of 300,000 euros in state funding for the establishment of a cross-university coordination office to deal with Thuringia's colonial legacy. This was initiated by the historians Prof. Dr Christiane Kuller from the University of Erfurt (pictured left) and Prof. Dr Kim Siebenhüner from the University of Jena (pictured right).

PHOTOS: HAMISH JOHN APPLEBY/JENS MEYER

The issue of »colonial legacy« is currently generating a great deal of debate, not only in Thuringia. Christiane Kuller explains what motivated the historians to set up the coordination office: »We wanted to respond to the increased interest shown by educational institutions, the media and civil society in our colonial past«. The aim is to raise awareness of the contribution that universities can make to the social debate. »Moreover, we already have research projects, courses, and lecture series on the topic. So, the initiative basically builds on existing expertise«.

Networking research activities in collections

Kim Siebenhüner points out the special importance of university collections when it comes to dealing with colonial legacy. The exact number of objects with a colonial connection is still unknown. »But the activities that are being carried out to get to the bottom of this are largely unconnected. This means that we can't systematically work through the research questions by tapping into the great potential of structured scientific exchange and the synergistic bundling of processes«. This situation gave rise to the idea of networking and further expanding the activities carried out by the universities of Erfurt and Jena with regard to research, teaching and social discourse.
Over the next three years, the coordination office will set up a network for scientific exchange that will not only focus on scientists but will also include civil society initiatives and other groups with post-colonial goals. The coordination office is also planning to cooperate with museums and archives, educational institutions such as the State Centre for Political Education, memorial sites, and schools.
To name a concrete example, there will be a regular colloquium involving representatives of the universities of Erfurt and Jena, where current university and non-university research work will be presented and discussed. In addition, the researchers want to highlight the current »gaps in their knowledge« and create a map of colonialism in Thuringia. Ideas for courses, for Master's and qualification theses and for cooperative third-party funded projects are to emerge from this. Objects and analyses will be presented on a website or in an anthology connecting science and »public science«. And last but not least, the work will be presented in public lectures, in a blog and on social media channels. Voigt

Newly formed working group on colonialism

A scalp from Namibia, skulls from Tanzania and Papua. These are examples of human remains from collections at the University of Jena that were brought to Germany during the colonial period. Extensive research has been necessary to uncover the precise origins and history of these human remains, as identification is nearly always difficult and labour-intensive. The University of Jena has been involved in such provenance research for years.
For some months now, the working group »Colonial Heritage and Education Critical of Racism« has been deployed to study this topic, which includes the historians Joachim Bauer and Stefan Gerber, biology educationalist Uwe Hoßfeld and Archaeologist/Anthropologist Enrico Paust, and receives support from collection staff and other areas of the university.
The team of experts has recently produced new results, which it has published under the title »Ernst Haeckels koloniale Schädel«. Using eight skulls from the former Osteological Collection and the Phyletic Museum as examples, the publication shows the routes taken by such objects from collections in the 19th and 20th centuries, as well as the possibilities and limits of reconstructing their provenance a century later. AB

The glass bead necklaces from the 6th/7th century come from Hungary. They are part of the collection in the department of Archaeology of Prehistory to Early Middle Ages at the University of Jena. · Photo: Jens Meyer

FEATURE

The solid liquid

Glass—our revolutionary companion

Glass is one of the oldest man-made materials—and yet it continues to baffle researchers to this day. Glass is a liquid that doesn't flow. Although it is hard and capable of remaining largely intact for millions of years, it is more fragile than almost any other material. Glass has shaped the world as we know it and repeatedly facilitated scientific and social innovations—the Internet would be unimaginable without optical fibres. Since the United Nations has declared 2022 the »International Year of Glass«, this issue focuses on the glass research conducted at our university, which started with the work of Otto Schott and continues to inspire researchers to this day, where new types of glass and futuristic applications are being researched and where glass testimonies to the history of humankind and the earth still hold new, fascinating insights.

Living in the Glass Age

The United Nations (UN) has declared 2022 the International Year of Glass. Lothar Wondraczek, a glass chemist at the University of Jena, is part of the central organization team for the themed year. In this interview, he explains why the ancient material deserves more attention and how glass can help us live more sustainably.

INTERVIEW: UTE SCHÖNFELDER

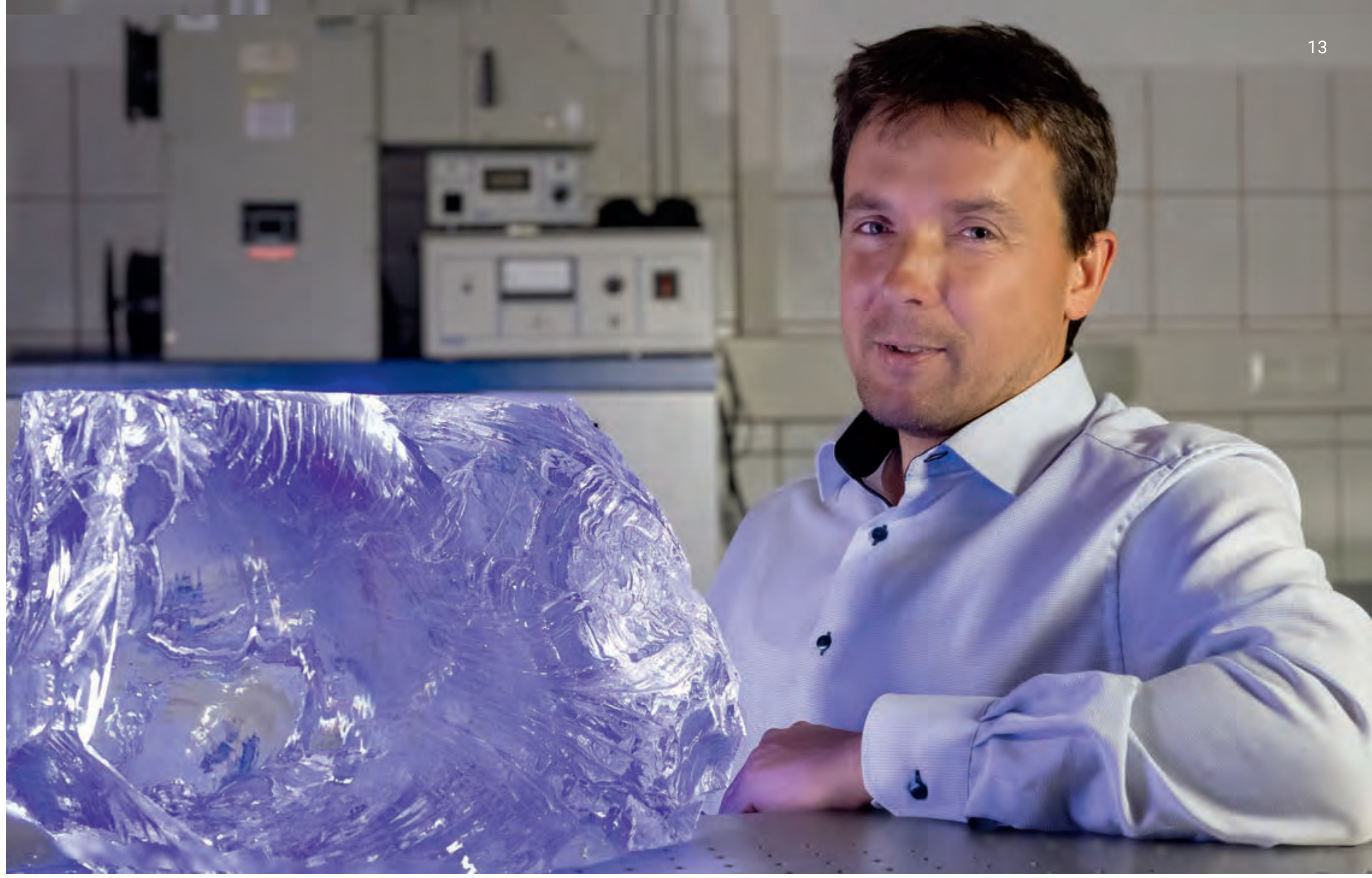
Mr Wondraczek, why has the UN declared 2022 the International Year of Glass?
The primary motivation is to generate awareness for the ubiquitous role of glass in human history, culture and modern technology. Glass innovations have repeatedly led to transformative societal advances, including the first tools made from obsidian, glass containers for storing food or pharmaceuticals, and window panes that enabled building interiors which became both warm and bright. These and many other glass products have fundamentally changed the way we live and are continuing to do so.
Discoveries have been made thanks to microscopes or telescopes containing optical glass, and our current data networks, communication channels and the internet are ultimately made from optical glass fibres. So, it seems fair to say that we are living in an age of glass; without glass, our everyday live would be radically different. But yet, the prominent role of glass in all its aspects remains hardly visible to most. The themed year is to change that.

What is so special about glass as a material?
Everything and nothing, really. Along with crystals, glass is one of the two most important states that solid materials can assume. The variety of glass-like materials is practically infinite: In addition to everyday items like window panes, bottles and mobile phones, the term »glass« involves all classes of materials in terms of chemical compositions and resulting properties. What makes glass so special is its internal structure, that is, the way by which the atoms that make up the glassy state are arranged in a spatial network. This arrangement is fundamentally different to that of crystals. Glass is formed from a liquid that becomes increasingly viscous upon cooling. A point is eventually reached at which the movement of the atoms can no longer be observed on human timescales; at this point, a frozen state is achieved—this is what we refer to as »glass«. The glassy state of matter has numerous fascinating, sometimes even metaphorical aspects: disorder, imbalance, chaos, infinity, the interplay of being solid on the one hand, but visually transparent and liquid-like on the other.

Glass has been manufactured and used in many different ways for thousands of years. What can we still discover about it today?
There are actually a surprising number of unanswered questions. First there is the question of the fundamental nature of glass. Why does glass form in the first place? Why is it solid? How can we describe its structural disorder and dynamics in a way that allows us to predict certain properties, as has long been established for crystals? These are some of the basic research questions that are yet to be answered.
And then there is the social significance of glass materials. Many glasses are mass-produced in an energy-intensive process, with very high material throughput. Glass is almost ideally suited to the circular economies of the future—it is an archetypal example for cradle-to-cradle recycling. However, modern glass technology requires completely new ways of thinking in terms of energy consumption, carbon-neutral production, raw materials, and product design.

The International Year of Glass draws attention to the fact that glass will play a vital role when it comes to achieving the UN Sustainable Development Goals (see info box, p. 17). Can you give an example?
Let us take recycling as an example: glass containers can contain up to 90% of recycled waste glass—and even that can be increased further by appropriately adapting our production technologies and consumer perception.
Other examples can be found in the buildings sector, which is one of the greatest contributors to CO_2 emissions across Europe. Here, modern glasses in the form of insulation materials, multiple glazing and »smart windows« are making a very important contribution to achieving our climate goals. It is interesting to note that in this particular field, glass materials cannot and should not be substituted—after all, they themselves could be substitutes for less sustainable materials. For example, future residential buildings could comprise a much larger fraction of recyclable glass (in the form of glazing and insulation materials) and wood.

Does glass have any disadvantages?
Sticking to the topic of sustainability, the comparatively high weight of glass is certainly critical. Glass bottles are heavy, which can have a major impact



Prof. Dr Lothar Wondraczek has been working with glass for around 20 years. After pondering whether to study art or »something else«, he decided on materials science at Clausthal University of Technology and then spent many years working in the glass industry. What fascinates him about glass to this day? The material's tangibility and the metaphorical qualities of its disordered state.· Photo: Jens Meyer

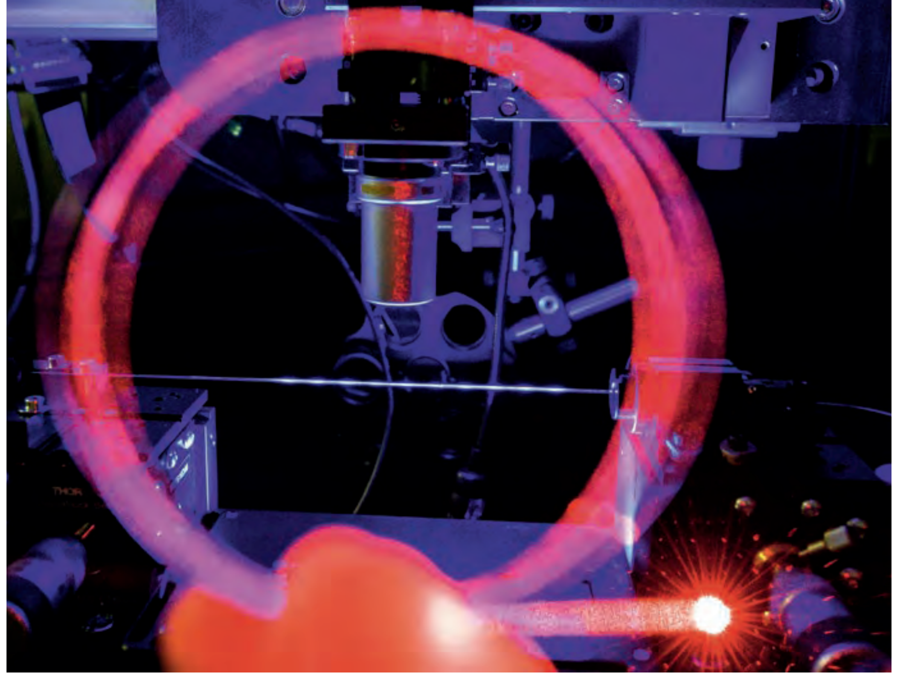
on the energy balance. In addition, there is the well-known fragility of glass, which will require a lot of research and development work to overcome in the future.
Of course, there are also fundamental properties resulting directly from the nature of glass and its structural disorder. Compared to crystalline materials, structural disorder can have a negative impact on optical properties, in particular, in what is known as »optical activity«. This can be partially offset by fabricating glass in the form of long fibres, which enable an increased interaction length between light and material in optical applications.

Are there any areas of life where glass is found but you don't really notice?
Yes, absolutely. Strictly speaking, PET bottles are also made of glass. Many variants of plastics are actually frozen-in, supercooled liquids, by definition, glasses. More obviously, fine glass particles can also be found in cosmetics, toothpaste and many other household products, or can even be added to drinking water so as to help keeping pipes free of deposits. Finally, glass plays a central role in almost any electrical appliance.

What is Jena's role in glass research and the International Year of Glass?
Jena is one of the global centres of academic glass research (see article on p. 32)—not only through the university, but also thanks to the large number of local research institutions in the field of optics and photonics. In addition, the local landscape is dotted with industrial research institutions of different shapes and sizes.
Jena's researchers have been involved in numerous activities as part of the International Year of Glass: Having drafted the programme for the UN opening ceremony in Geneva, they will also be coordinating the world's largest glass congress in Berlin and attending the closing event in Tokyo.
We've just launched a junior researcher programme to sponsor young talent identified as »Glass Future Fellows«. Around 70% of them are young women. In autumn, we'll be hosting the 10th Otto Schott Colloquium, a high-ranking academic conference at our university with guests from all over the world. We're also trying to raise general awareness about glass by organizing various events in cooperation with schools and museums.

What questions about glass are you hoping to answer yourself through your work?
My research group is currently working on three core topics. Firstly, the mechanical properties of glass materials, e.g., how glass can be made thinner without losing its mechanical resistance (see p. 18). We're also dealing with the targeted configuration of certain optical properties of glass such as light refraction and optical activity, e.g., in the form of fluorescence. This is related to our third field of work: the search for new and unusual ways of producing glass. These include gas-phase and solution-based methods, as well as high-pressure synthesis and alternative melting processes that enable the production of novel glass materials (see p. 23) and could even give rise to more energy-efficient and sustainable technologies in the future. ■

These Roman unguentaria from Mount Gerizim (Palestine) date from the 3rd to 4th century AD and belong to the antiquities collection of the Institute of Classics at the University of Jena. · Photo: Jens Meyer



Picture left: Glass fibres in a laboratory at the Institute of Applied Physics at the University of Jena. · Photo: Jens Meyer

Picture below: Glass façade of the Thuringian State and University Library. · Photo: Jan-Peter Kasper

Human history: a tale of glass

The possibility of producing glass, forming it and providing it with a wide variety of properties has repeatedly led to significant advances in human development: Glass containers allowed food to be stored and preserved for long periods of time; glass windows and bulbs brought light into gloomy buildings; fundamental discoveries have been made with the help of microscopes, telescopes and other optical devices containing glass lenses, mirrors or prisms; and fibre optic cables now span the entire globe, enabling real-time communication with maximum data capacity.

BY UTE SCHÖNFELDER

Glass has accompanied us for thousands of years. The use of naturally occurring glass can be traced all the way back to the Stone Age, when sharp tools, spearheads and blades were crafted from volcanic materials such as »obsidian«. Other materials were formed when meteorites rained down on the Earth's surface, melting sand and stone, as is the case with »tektite«. This could be used to make everyday objects and jewellery. For a good 4,000 years, people have mastered the craft of making glass themselves and this has now found its way into almost every aspect of our lives. And yet, glass, arguably among the oldest man-made materials, is still shrouded in mystery. Glasses fascinate with their transparency, purity and gentle shapes. They are simultaneously solid and proverbially fragile. How do these qualities fit together? And what is glass anyway?
There are a few different answers to this question. Answer 1: Glass forms one of the two states that a solid can adopt. A solid either occurs as a crystal, i.e., its atoms are arranged in a periodic structure. This is the case with salts and metals, for example. Or the atoms of a solid are in disorder and there is no periodic lattice structure. This is known as an »amorphous« solid—and that is exactly what glass is.

The liquid aspect of glass

Answer 2: If we see glass from the perspective of its formation, it retains many aspects of a »liquid«. However, it is also solidified, and therefore, per se, not liquid. This is despite the transition being literally »fluent« and depending above all on the length of time for which the state is observed. Theoretically, if we stared at a window pane for long enough, we might well perceive it as a »waterfall« (although admittedly, not even the time that has passed throughout the universe's existence would allow for that).
It is interesting to note that from both answers it follows that almost any melt can be converted into a glass: It is not the chemical composition that determines the glassy state, but structural disorder and the thermo-kinetic conditions. The widely known »quartz glass« consists of silicon dioxide (SiO_2), just like crystalline quartz. In both forms, the material consists of silicon and oxygen atoms arranged in symmetrical tetrahedra. While these structural units in the crystal are linked to one another at fixed angles and thus form a highly ordered structure in which every atom has a fixed place, these crosslinking angles vary in the glass. This difference arises when the liquid melt cools down: If this happens very slowly, the structural units have enough time to arrange themselves in an ordered structure. If the melt is cooled down quickly, however, there is not enough time for the structural units to form a crystal. Instead, the melt solidifies in the form of a glass. Glass is therefore defined as a thermokinetic state. Due to its character as a »frozen-in liquid«, glass also has properties very similar to real liquids. For example, it does not scatter light, it has a glossy surface, and it exhibits fracture properties similar to those of liquids (on different timescales).

How glass is made

In order to produce glass, we only need a few raw materials that are available almost everywhere in the world: quartz sand, lime, soda or potash. The first methods of glass prowduction are thought to have been developed in Mesopotamia and Egypt around 3,000 BC, where crushed quartz stone was mixed with vegetable ashes and then melted in several steps into glass ingots, which were further processed into items such as jars, goblets, and jewellery. The glass could be stained in various shades by adding metal oxides or aqua regia.
When the glass-blowing tube was invented around 100 BC, larger vessels with thinner walls could be produced such as drinking glasses, carafes, and other containers. In the 12th century, round windowpanes were then used in church windows (crown glass), which were given their shape by spinning out a pre-blown glass sphere. The development of more sophisticated rolling processes in the 17th century then allowed larger windowpanes to be produced.

The Glass Age

Today, glass can be fabricated for specific applications in almost any shape and composition—from optical glasses and glass ceramics to flexible displays, optical fibre cables, solar module covers and building materials. Depending on the desired properties of the glass, other additives can be used: For example, boron oxide changes the thermal, chemical, and electrical properties of glass, while aluminium oxide increases its fracture strength.
In addition to classic silicate glasses, other forms of glass can be produced that use other oxides or non-oxide components as the glass-forming substance instead of silicon dioxide, such as phosphorus and boron oxides, leading to the formation of bio-active phosphate glass or highly resistant borosilicate glass. For laser optics, glass is doped with various exotic components which help to conduct, generate, and intensify light.
In even broader terms, many further engineering materials are also glasses, i.e., »frozen-in liquids«. For example, we can find high-strength metallic glass, infrared-transparent chalcogenide glass and many more varieties. This much is sure—glass isn't just glass. It is diverse, versatile and ubiquitous. The world today is a world of glass. ■

Glass in figures

1,000,000

years can pass before glass dissolves. The reason: glass can be absolutely chemically inert. This means that a glass vessel does not react with its surroundings or its contents. This is a great advantage for the shelf life of food and medicines. It also means that the material can be recycled almost indefinitely by being repeatedly shaped into new bottles, glasses or building materials. Due to its chemical stability, glass is considered one of the most important options for the permanent containment of radioactive elements.

30,000,000

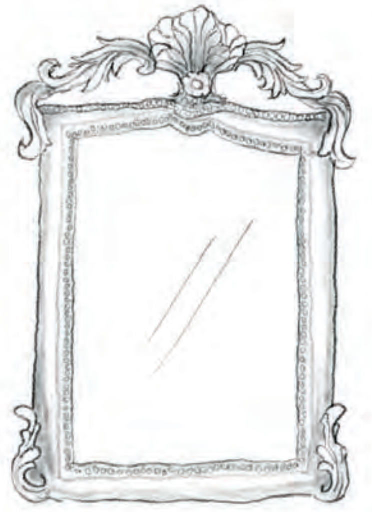
years ago, a meteorite hit the desert of North Africa and melted the desert sand in the region, resulting in millimetre to decimetre-sized pieces of quartz glass in different shades of colour. Jewellery was made from this »Libyan desert glass« in ancient Egypt. For example, a scarab made of this glass adorns the breastplate that was discovered in the tomb of Pharaoh Tutankhamun exactly 100 years ago.

1875

is the year Otto Schott obtained his doctorate from the University of Jena, where he gave his name to the Otto Schott Institute of Glass Chemistry in 1967 (now the »Otto Schott Institute of Materials Research«). Otto Schott is considered the founding father of systematic glass chemistry research.

1,710

degrees Celsius is the melting point of crystalline quartz, which consists of SiO_2 (silicon dioxide), the main component of quartz sand. If this chemical compound is melted, the SiO_2 molecules arrange themselves in a very specific pattern: the oxygen atoms form tetrahedra—pyramids with four triangular faces—and the silicon atoms can be found in the middle of each tetrahedron. In a quartz crystal, this tetrahedral structure continues periodically without any deviation. If the tetrahedra do not form a continuously periodic structure and if further components are added to the melt, a silicate glass is produced. This can be formed at temperatures of 500 to 800 degrees.



ILLUSTRATIONS: LIANA FRANKE

1665

is the year Louis XIV, King of France, granted financier Nicolas Dunoyer and his partners the exclusive right to manufacture mirror glass. The royal mirror glass manufactory developed the revolutionary table rolling process and the world's first industrial glass company was established in the small village of Saint-Gobain in Normandy. Saint-Gobain mirrors have adorned the gallery in the Palace of Versailles near Paris since 1684.

1847

is the year when glass Christmas tree decorations were »born out of necessity« in Lauscha, Thuringia. The story goes that a glassblower and his family had become so impoverished that they couldn't afford to decorate their Christmas tree with the usual fruits, nuts and sweets. So instead, he formed fruits and nuts out of hollow glass—the forerunners of today's Christmas baubles. The department store founder Frank Winfield Woolworth made the Christmas tree decorations from Lauscha an export hit around 1880, and they have since been sold all over the world.

4,000

years, glass has been made by people. The Egyptians first made hollow glass around 1500 BC. It was used as a container for ointments and oils. The oldest known glass vessel can be dated back to around 1450 BC. It is a chalice bearing the name of Egyptian Pharaoh Thutmose III.

39,000

kilometres is the length of the longest optical fibre in the world's longest submarine cable, »Sea-Me-We 3«. It spans the internet network between Germany, Japan, and Australia.

650

BC the first written formula for glass was recorded on papyrus and kept in the library of Ashurbanipal, King of Assyria. It said: »Take 60 parts of sand, 180 parts of seaweed ash and 5 parts of chalk—and you get glass«.

International Year of Glass

The United Nations (UN) have declared 2022 the »International Year of Glass« (IYOG) to raise awareness of the significant contribution this material has made over several millennia of human history and the important role it will continue to play in the future.

It is impossible to imagine the modern world without glass. And the immense challenges of the future cannot be overcome without this material, which stands for innovation and transformation like no other. The aim of the »IYOG« is to highlight the important role to be played by glass when it comes to achieving the 17 Sustainable Development Goals (SDGs) included in the UN's 2030 Agenda. Here is a selection of those goals:

SDG 3: Good Health and Well-Being

Bioactive glasses are used as implants, glass-based nanoparticles can transport drugs to specific parts of the body, and inert glass vessels protect vaccines and pharmaceuticals—not least during the ongoing pandemic.

SDG 6: Clean Water and Sanitation

Millions of people still die every year from diseases caused by contaminated water. Porous and coated glass filters can effectively and affordably remove harmful substances and impurities from drinking water to help supply the global population with clean water. Photocatalytic reactors and treatment systems based on glass materials make freshwater drinkable.

SDG 7: Affordable and Clean Energy

Glass can be used to manufacture highly transparent protective covers for photovoltaic systems. Solar thermal power plants work with glass mirrors that reflect sunlight to heat fluids in glass tubes that drive generators. Glass photobioreactors can also be used to grow microorganisms that convert solar energy into chemical energy. Composite materials reinforced with glass fibres are used in turbine blades to convert wind energy into electricity.

SDG 9: Industry, Innovation, and Infrastructure

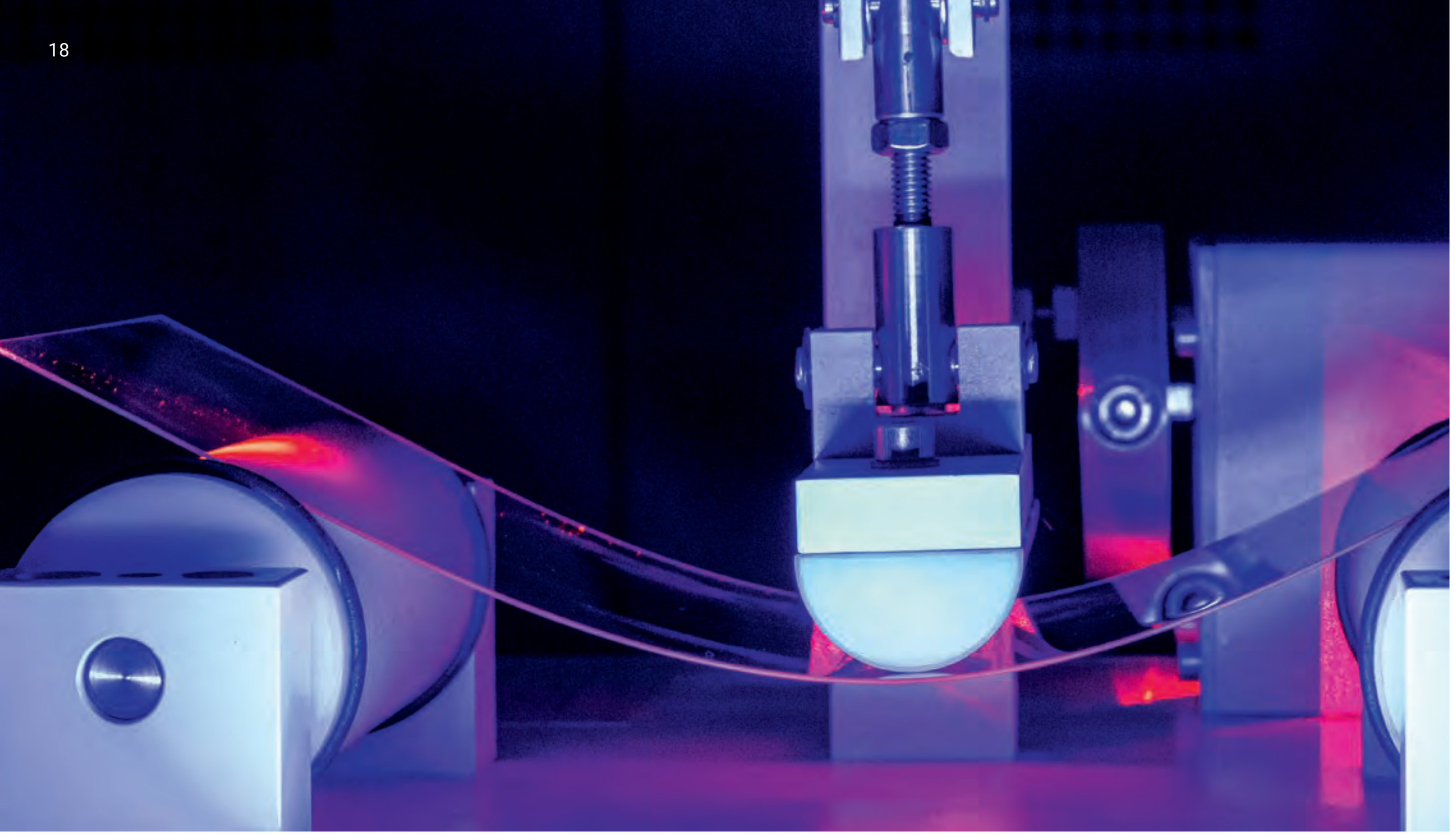
Global communication systems function with optical fibres that transmit data quickly with minimal losses. Fibre lasers use glass doped with rare earths, which has now become standard practice for many applications. Ultra-thin glasses for flexible, even foldable displays are currently under development. Flows of information are managed using circuits with components made entirely or partially of glass such as spherical lenses, prisms, and beam splitters. Special glasses enable information to be visualized using augmented and virtual reality devices.

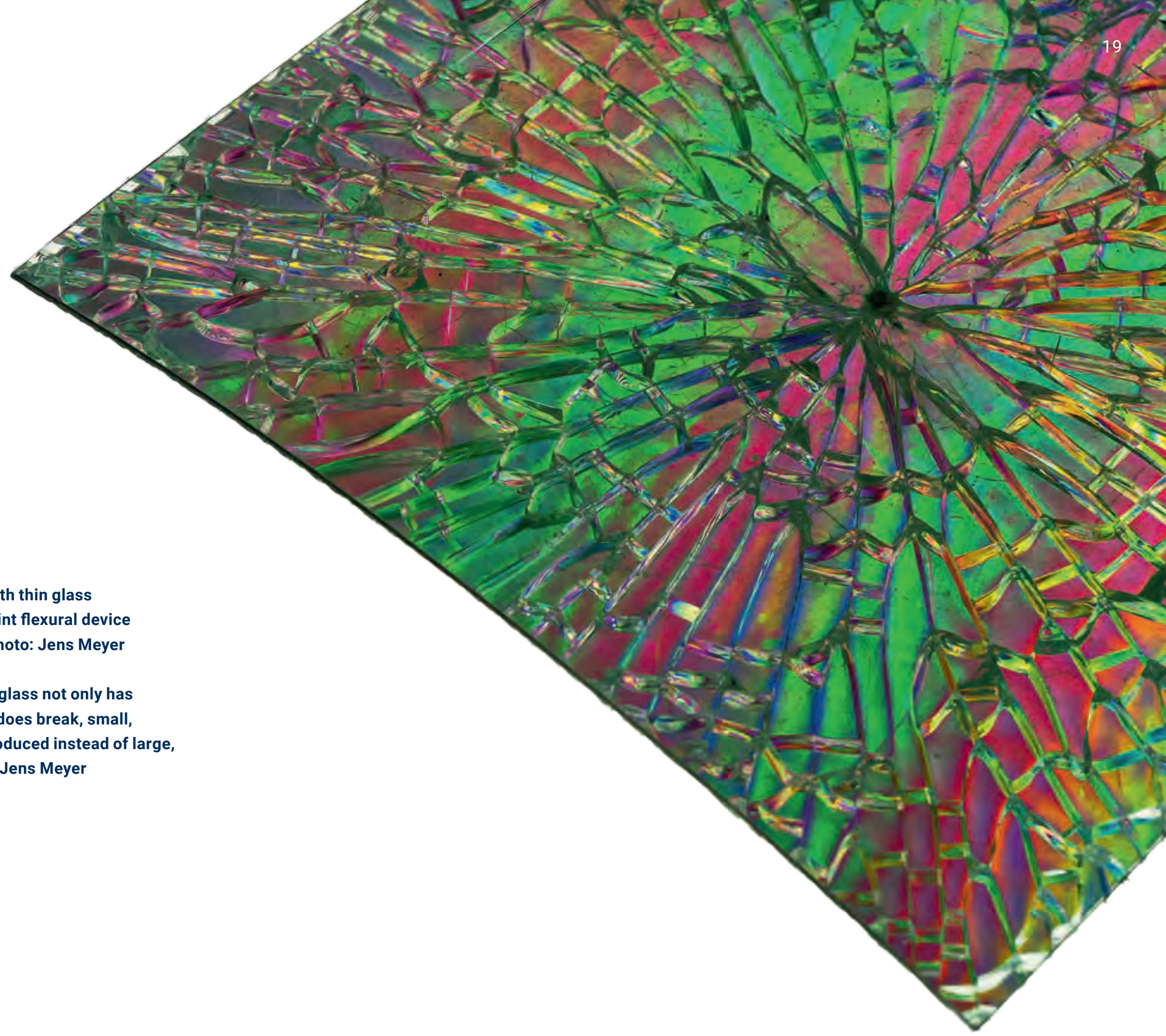
SDG 11: Sustainable Cities and Communities

Modern land-based vehicles and aircraft feature windscreens and cockpit windows made of chemically reinforced glass; this improves safety, boosts fuel efficiency by reducing weight and allows certain display features to be integrated. Coated windowpanes help make buildings energy-neutral and can even be used to produce energy if photovoltaics and other innovative technologies are integrated into the glazing.

SDG 12: Responsible Consumption and Production

Glass is eco-friendly by nature. Most glass is made of natural raw materials that are readily available. The recycling rates are high. More energy-efficient melting technologies and optimized glass compositions could further reduce our carbon footprint. The International Year of Glass can help to spread the word about sustainable practices.





Picture left: High-strength thin glass is clamped in a three-point flexural device to check its stability. · Photo: Jens Meyer

Picture right: Tempered glass not only has increased strength. If it does break, small, harmless crumbs are produced instead of large, sharp splinters. · Photo: Jens Meyer

Order in disorder

Unlike crystalline solids such as common metals or salts, glass does not have a regular internal structure. It is disordered, and heterogeneous on atomic scale. This poses a challenge for both glass research and industrial applications, because the internal »chaos« makes it difficult to predict and control the mechanical properties of glass. Nevertheless, scientists at the Otto Schott Institute of Materials Research are trying to find principles of order in glassy disorder—termed »correlated disorder«. Such principles can be used to improve the mechanical performance of glasses.

BY UTE SCHÖNFELDER

Publilius Syrus is quoted as saying, »fortune is like glass—the brighter the glitter, the more easily broken«. And absolutely everyone is familiar with the sight of broken glass, whether it be a window that is mercilessly smashed by a football or a wine glass that breaks while washing the dishes. And yet there is also glass that can withstand tons of weight, such as the glass floors of viewing platforms or building façades. But how can the very same material be strong and fragile at the same time?
»In theory, glass is one of the strongest materials we could ever produce«, emphasizes Prof. Dr Lothar Wondraczek from the Otto Schott Institute of Materials Research. »But the actual strength is usually much lower than what we would theoretically expect«, adds the professor of glass chemistry. This prevents us from exploring its full range of possible uses and poses a long list of questions that are yet to be answered by researchers. In particular, it is difficult to predict the mechanical properties of glassy materials such as their scratch and fracture resistance. This is due to the disorder of their internal structure: predictive theory used for regular crystalline structures is not applicable for glasses.

Same composition—different properties

»Even though people have been producing glass for over 4,000 years, we're yet to answer some of the fundamental questions about the material«, says Wondraczek. For several years now, he and his team of researchers have been focusing on the mechanical properties of glass and the development of high-strength, scratch-proof, and shatter-proof glass. »For example, we're interested in finding out how the material's properties can be controlled and manipulated during the production process«. In order to determine this, however, the researchers first have to understand how the molecular structure of glass (i.e., the lack of regularly arranged bonds) affects its mechanical properties.
»Even if two types of glass are exactly the same in terms of their chemical composition, they can still have completely different mechanical properties«, explains Wondraczek. After all, properties fluctuate even within the exact same object. As glass consists of »harder« and »softer« regions, it is difficult to predict the material's macroscopic properties.
This is where Wondraczek and his colleagues come in: They are using spectroscopic methods to investigate the degree of disorder in glass and the fluctuating bond energy density within the material, in order to subsequently draw conclusions about macroscopic properties. By conducting such experiments, they can determine the distribution functions for the fluctuation of a property within a spatial ensemble. These functions can then be used to create models for predicting a material's properties. At the same time, a very large number of artificial glasses can be created on the computer, and, with the help of machine learning, links can be identified between local disorder and the practical properties of glass.
In addition to internal disorder, surface defects (tiny flaws that are usually imperceptible to the naked eye) play a crucial role in the mechanical strength of glass. »These have a much greater influence on the properties than chemical composition«, states Wondraczek. The extent and distribution of such flaws mainly result from the production process. »We've shown that glass that has almost the exact same chemical composition but is produced differently reacts very differently to mechanical stress«.

Blowing hot and cold

The glass chemists now want to transfer their basic theoretical findings to practical applications and make glass surfaces more resistant to defects. In addition to glass composition and production, this can be achieved through post-processing methods. Wondraczek and his team are currently optimizing an established industrial process known as »thermal tempering«, which is used to manufacture high-strength windscreens, covers for solar panels and other glass components. Thermal tempering causes glass to break into small crumbs in a controlled manner—instead of splintering—in the event of an accident or other damage. However, this has so far only worked for glass of a certain thickness. It must be at least two millimetres thick. For many modern glass products, however, much thinner layers play an important role today.
After obtaining a Proof of Concept grant from the European Research Council, glass chemist Wondraczek is now developing a thermal tempering process for thin-walled glass with a thickness of under one millimetre.
In essence, the principle is similar to conventional tempering. The glass is heated up to over 600°C and then suddenly quenched. As the surface cools down much faster than the inside of the glass, a temperature gradient is created that results in compressive surface stress that persists when the glass is completely solidified.
While thick glass is quenched simply by air, the temperature gradient created in this way is not sufficient for very thin-walled glass to generate compressive surface stress. Therefore, instead of air, the researchers are using a liquid quenching medium based on gallium alloys that melt close to room temperature, which allows them to stabilize significantly thinner glass. ■

Doctors have a bone to pick with glass

After many cycles in the dishwasher, our drinking glasses often appear cloudy. This is usually not caused by limescale deposits but by corrosion. Contact with water and cleaning agents—and the associated chemical and physical processes—roughen the material's surface and alter its structure. Put simply, the glass begins to dissolve. As irritating as this process may be when it comes to household items, it is interesting for other uses of glass—even in the human body.

BY SEBASTIAN HOLLSTEIN

Picture above: Bioactive glasses form an apatite surface in the human body on which endogenous cells can grow. · Photo: Jens Meyer

Glass is usually made of silicates. But if pure silicon dioxide were used in its production, processing would only be possible at very high temperatures, making it very difficult. That is why metal oxides such as calcium or sodium oxide are integrated into the silicate network. This facilitates the production process—but reduces durability because the resulting glass reacts more rapidly with water. The increased solubility isn't necessarily a disadvantage. For example, for around 50 years scientists have been working on compositions referred to as »bioactive glasses«, developing applications for them in the medical field, such as for repairing damaged bone. At the time, glass was the first synthetic material that could form an integrated bond to human tissue.

Natural bone cells grow on glass implants

»When body fluids react with bioactive glass, calcium and phosphate ions are released«, explains Prof. Dr Delia Brauer, who is a professor for this special material at the Friedrich Schiller University Jena and one of the world's most renowned experts in the field. »During this chemical process the glass surface gets covered with a calcium phosphate layer. This calcium phosphate mineral, apatite, is also the inorganic component of our bones. Bone cells attach to this layer and form new bone tissue«. All substances that make up the glass naturally occur in the human body, and the apatite surface in particular ensures that the glass is not rejected as a foreign material. In addition, dissolved silicate species further promote the healing process by stimulating bone formation.

Once the implants have performed their function, they are gradually broken down until they have completely disappeared. The exact duration of this process can be adjusted via the glass composition.

Degradable glass implants are mainly used when bone defects need support during healing, such as after removal of a tumour or a cyst. Doctors usually insert the glass into the bone defect in the form of granules or gel. Brauer and her team are currently optimizing the design and mechanical structure of porous three-dimensional scaffolds which are intended to guide the bone cells during bone tissue formation. »Glass is probably not the first material that comes to mind when we think about regenerating human tissue—and yet its variable composition makes it extremely suitable for this purpose«, says the chemist. »That's what makes it so exciting«. Although the use of bioactive glasses as implants has now become established, Brauer and her team are constantly looking for new ways to optimize their application.

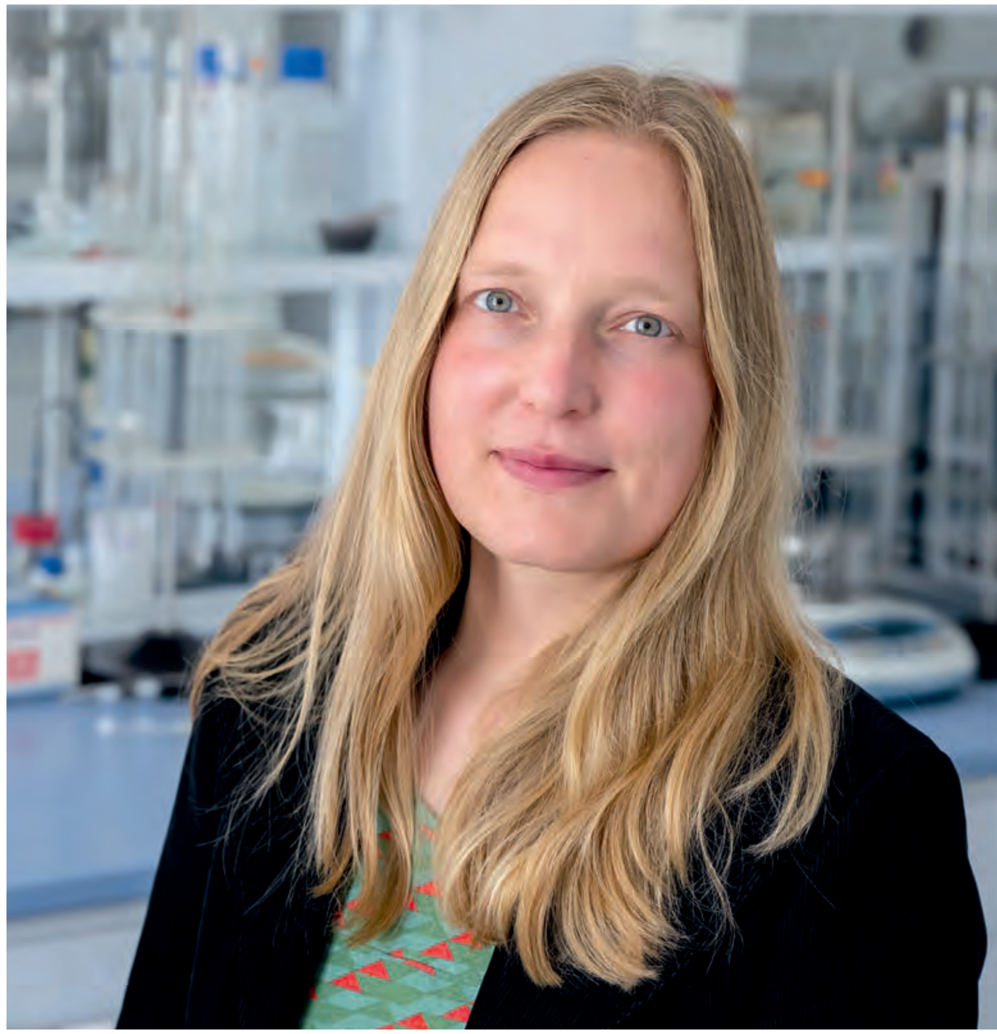
Compared to other implant materials such as ceramics, the advantage of glass is that further components can be added with a high degree of flexibility. For example, silver ions can be integrated into the glass to give implants antibacterial qualities that prevent inflammation and eliminate the need for antibiotics.

Oral hygiene with glass

Apart from bones, bioactive glass also is used in oral applications. For example, Delia Brauer has helped to develop a toothpaste that contains bioglass particles. These particles adhere to the tooth surface and are not washed away during rinsing. When they come into contact with saliva, they release calcium, fluoride and phosphate ions, stimulating the formation of apatite—which is also the main component of tooth enamel.

Jena's glass expert was recently approached by a team of researchers from King's College London. »After discovering that lithium ions promoted the formation of dentine, our English colleagues were looking for an effective and targeted method of introducing lithium so that it could be released in a controlled and continuous manner«, says Brauer. »Together we developed a now patented cement system based on lithium-containing bioglass«.

In addition to such applied material developments, Delia Brauer's research is mainly centred around gaining a better understanding of bioactive glass and its processing. After all, many questions are yet to be answered. »As bioactive glasses start to crystallize faster than other glasses during melting, this limits the processing options«, she says. For this reason, she is currently observing the crystallization process at nanometre level in cooperation with researchers from the University of Erlangen-Nuremberg and the Fraunhofer Institute for Microstructure of Materials and Systems in Halle (Saale). The scientists hope to develop their understanding of the process and ultimately avoid it. This basic research will pave the way for bioglass to be used in many other fields. ■



Prof. Dr Delia Brauer and her team are developing soluble glass implants that help to regenerate bones after an operation. · Photo: Jens Meyer

Metallic glass looks like an ordinary metal from the outside. On the inside, however, it lacks a crystalline lattice structure. This makes it strong and brittle. · Photo: Jens Meyer

Shock-frozen metal

Glasses are commonly known as transparent materials. For example, glasses in façades enable the interior of buildings to be illuminated by sunlight, while glass vessels allow to check their contents. However, Dr René Limbach and his team are investigating completely different types of glasses—made of opaque metals.

BY MARCO KÖRNER

»Metallic glasses aren't transparent«, says Dr René Limbach. They even look the same as ordinary metals: silvery-grey and shiny. According to the engineer from the Otto Schott Institute of Materials Research, these materials are yet very different in terms of their mechanical properties: Metallic glasses are very hard, strong, and wear resistant. These attributes make them suitable candidates for applications as structural materials in gears, drive shafts and protective coatings. »Wherever there is friction between components, metallic glasses can be used to reduce wear and tear«.

But what exactly is a metallic glass? Dr René Limbach describes the fabrication process: »To vitrify a metal, its melt has to be cooled extremely fast«. This is often done by suction casting into »moulds«: Water-cooled hollow cylinders with a double wall made of materials of high thermal conductivity, such as copper. The metallic melt is poured into the cavity, causing it to freeze-in very rapidly. This requires ultrafast heat extraction, which restricts the dimensions of metallic glasses—typically about two to three millimetres in diameter with lengths of up to around five centimetres. The engineer describes how metals are transformed into glasses: »Thanks to the rapid cooling, the metal solidifies in the mould without the atoms having enough time to rearrange themselves in an ordered crystalline structure. Good glass-forming alloys are multi-component systems with significant atomic size differences«. This results in a highly disordered structure upon solidification. »The material still exhibits a short-range order around the individual metal atoms but no long-range order within the material as a whole. Such an amorphous structure is inherent to glasses».However, the absence of long-range order also results in a major disadvantage for metallic glasses: They are extremely brittle, admits Dr René Limbach. He is searching for strategies to overcome this drawback.

»In crystalline metals, the atoms are arranged in a well-defined lattice structure. An external interference can easily be dissipated through the lattice. In amorphous metals, on the other hand, shear bands are formed, which propagate through the material without hindrance, eventually leading to fracture«.

Current strategies to neutralize the propagation of shear bands rely on the creation of microstructural features by means of phase separation or the presence of crystalline precipitates.

A completely different approach is considered by Dr René Limbach in collaboration with researchers at the Leibniz Institute for Solid State and Materials Research Dresden: »We use thermal and mechanical processing routines to increase the number of shear bands formed, which then interfere each other«. For this purpose, structural units of lower mechanical stability are introduced, thereby increasing the structural heterogeneity. By doing so, the number of shear bands created, and their interactions are maximized. This in turn enables plastic deformation and accompanied by this, an increased service life before fracture occurs.

From curiosity to functional alloys

»Transferring this material to application would obviously be the Holy Grail«, explains the engineer. »Metallic glasses were originally a curiosity. Scientists were initially asking themself: Can metals exist in a glassy state? Indeed, metallic materials can be transformed into glasses, and they exhibit an interesting set of mechanical properties. But the brittle fracture behaviour restricts a widespread use«. If this problem can be solved, metallic glasses could replace numerous structural and functional alloys, adds Dr René Limbach. At least on a small scale: »Metallic glasses still have very limited dimensions due to the way they're fabricated«. ■

THREE QUESTIONS FOR

Prof. Dr Thomas Douglas Bennett

Department of Materials Science and Metallurgy, University of Cambridge
Visiting Professor in the Jena Excellence Fellowship Programme.

What is your main research focus?
The focus of my research group is on a topical class of materials, called metal-organic frameworks (MOFs). These three-dimensional porous materials consist of inorganic »nodes« linked by organic molecules and have come to great prominence in materials science over the past three decades (see box on the right). Specifically, we focus in particular on the thermal and mechanical properties of MOFs in order to improve their processability and use them in hybrid glasses, for example.

What is characteristic about hybrid glasses?
Hybrid glasses differ from inorganic glasses by their highly tuneable chemistry. At present, we are working on better understanding their mechanical properties in order to be able to produce and use such materials in a targeted manner.

Prof. Dr Thomas Bennett from the University of Cambridge will be conducting research in Jena for three months in 2022. · Photo: privat

What is the aim of the project you are going to work on at the University of Jena and with whom are you collaborating?
This project seeks to develop new materials at the interface between inorganic glasses and MOFs. It is about understanding how the crystalline or glassy states of MOFs can be integrated into inorganic glasses. Planned future applications include glass facades in buildings in arid climates that capture water from the air at night and release water during the day, or mobile phone screens capable of detecting blood alcohol or blood sugar levels.

Our concept is to combine the processability and stability of inorganic glass with the chemical functionality of MOFs. To do this, we want to try on the one hand to impregnate inorganic glasses with crystalline MOFs and on the other hand to blend inorganic and MOF melts and thus create new classes of materials. We then need to struc-turally characterise these new materials and analyse their optical, thermo-mechanical and porous properties.

In Jena, I will be working intensively with Prof. Dr Lothar Wondraczek and his team, as well as with Dr Alexander Knebel, who is working with his junior research group in the field of membrane technology. ■

Hybrid materials from classical glasses and metal-organic framework compounds (MOFs)

Metal-organic framework compounds (MOFs) form three-dimensional molecular networks, whereby the size of the pores formed by the lattice structure can be precisely adjusted down to a few nanometres. This allows the chemical properties of this class of substances to be specifically adapted to a wide range of applications. MOFs are used, for example, as separation diaphragms, as storage for gases and liquids, as catalyst support, and for electrical energy storage. So far, MOFs have only been used in their crystalline, ordered state. However, the fact that they can also be melted and quenched into glass has only been known for a few years. In addition to the existing inorganic glasses, organic plastic and metallic glasses, MOFs form a fourth type of glass that is interesting for a variety of applications due to its porosity and mechanical properties.

However, pure MOF glass is complex to produce and therefore expensive. That is why the research teams from Cambridge and Jena are seeking to develop new hybrid glasses that combine the properties of inorganic and MOF glasses.

Jena Excellence Fellowship Programme

This programme is part of the »LIGHT, LIFE, LIBERTY—Connecting Visions« strategy pursued by the University of Jena with the aim of promoting the university's international visibility and its appeal to the world's top researchers. It is open to senior fellows and postdocs who would like to research in Jena. All professors at the University of Jena can nominate potential fellows. Around four senior fellowships and four post-doctoral fellowships are awarded every year www.uni-jena.de/en/excellence-fellowship.

Glass as a geobarometer

People have been making glass for thousands of years. However, numerous natural glasses are also formed, for example, by meteorite or lightning strikes. Dr Franziska Scheffler is a mineralogist who is studying natural glass that forms when lava shock-freezes or minerals get under pressure.

Picture right: Various obsidians (e.g. from Mexico, Iceland, Hungary and Italy). · Photo: Jens Meyer

INTERVIEW: LAURA WEISSERT

What is volcanic glass and how is it formed?

Volcanic glass is solidified lava that reaches the Earth's surface when a volcano erupts. When lava cools slowly, it becomes rock because there's enough time for small minerals to form, such as basalt or rhyolite. But when lava cools quickly, for instance when a volcano erupts into the sea, it becomes volcanic glass such as obsidian. This is usually a deep black glass and when you hold it up to the light, it often gleams transparently. And when it falls on the floor, it shatters into sharp pieces like window glass.

You're dealing with volcanic glass as part of a research project. What material are you studying exactly?

I'm not looking at classic volcanic glass in a common sense; I'm studying melt inclusions, which are tiny portions of lava that are entrapped in minerals and preserved as glass. They're not necessarily of volcanic origin—they can also occur in metamorphic rocks when melting is involved. The important thing that connects them is the fact they've been exposed to high temperatures and high pressures. One example is eclogite, a subduction related rock formed when an oceanic plate is subducted underneath another tectonic plate. If we look at such rocks, we can find indicators that have preserved the high pressure: the mineral composition on the one hand, and these small glass inclusions on the other.

What do you hope to achieve through your research?

I'd like to learn more about how those rocks were formed. The melt, solidified into glass, has preserved the

Mineralogist and glass researcher Dr Franziska Scheffler. · Photo: Anne Günther

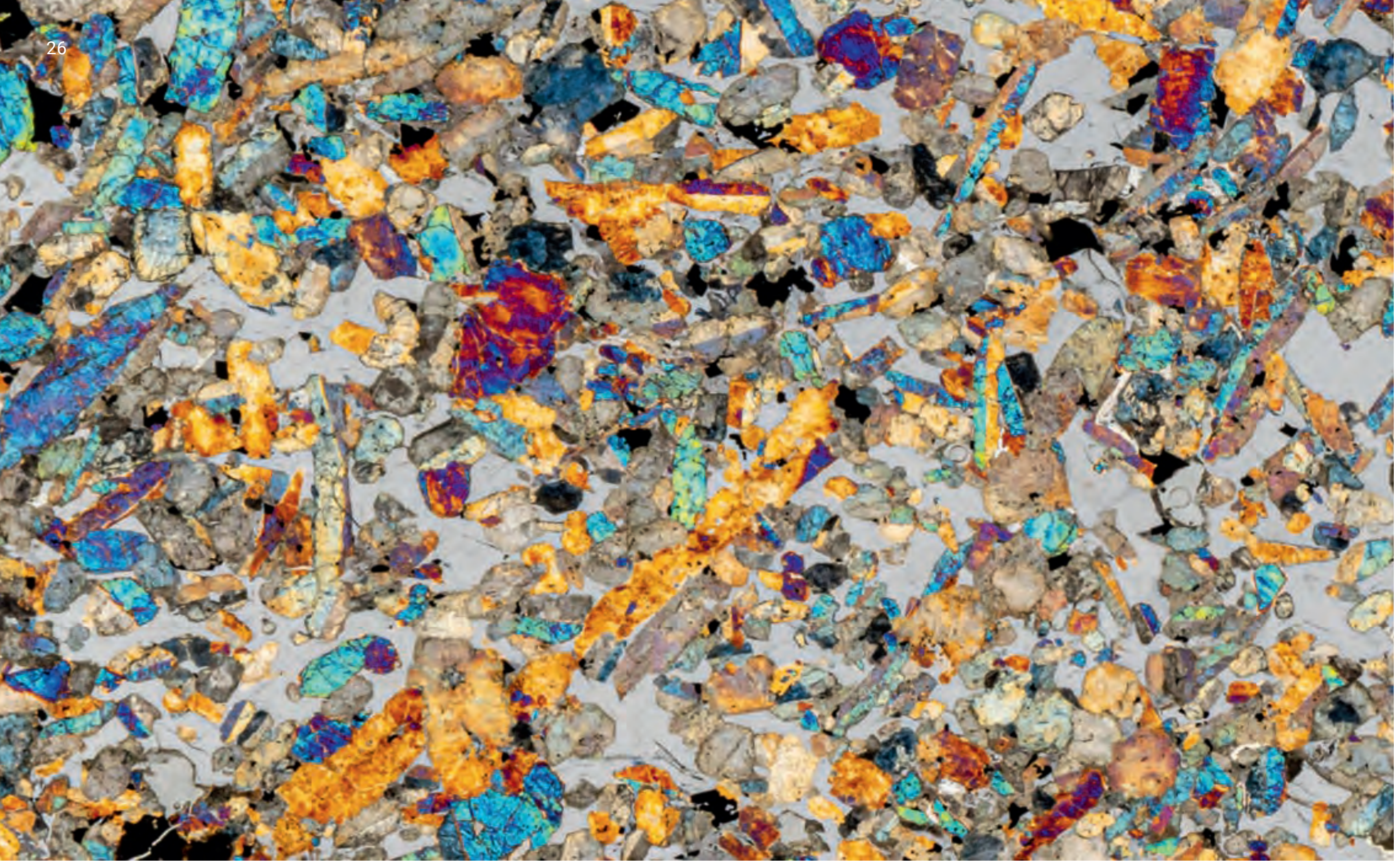
pressure and temperature conditions from the time of its formation thanks to the mineral that surrounds it. I want to study the melt inclusions to reconstruct the pressure under which the rock was formed. The objective of my investigation is to develop a kind of »geobarometer« that could be used not only to complete existing methods, but also to examine rocks whose composition was previously unsuitable for determining the pressure under which they were formed. And perhaps it could even be used to develop a method for determining the pressure in magma chambers—that would be a huge step for volcanic risk analysis.

How are you examining the melt inclusions?

Glass that cools under pressure shows changes in its material properties, because the chemical structures are compressed. We can use this by measuring the spectrum of the inclusion and then producing a glass of the exact same composition, applying certain pressure, and measuring that glass as well. This comparison allows us to estimate the pressure under which the glass was originally formed. In order to experimentally verify the effects of pressure, we're using diamond indentation and high-pressure cell experiments.

What do you find most exciting about your research?

After studying mineralogy, I'm now working as a post-doc in the field of glass chemistry in material sciences. There are many similarities, but also a few differences. Now I have the opportunity to combine my strengths in mineralogy with my newly acquired knowledge of glass science. Mineralogy gives us a better understanding of crystalline solid matter, such as the structure of the Earth and its mountains. However, it also shapes technical progress and our daily lives—from semiconductor technology to the melt-in-the-mouth properties that chocolate is supposed to have. What I find so exciting about glass research is the fact that I can produce my own lava in the lab furnace and then use it to make glass. The properties of the glass are determined by its composition and various other factors. There are hardly any limits and there's about as much to be explored as there are elements and element combinations in the periodic table. ■



Our glassy universe

The matter found on Earth also exists in space—after all, that's where it came from. It is mostly crystalline, but various processes have also produced glass from the same chemical components. Scientists at the University of Jena are analysing this glass from space and simulating its formation. This is opening a window for them to explore distant regions of the universe, back in time to the infancy of our solar system—and sometimes even beyond.

BY SEBASTIAN HOLLSTEIN

When meteorites land on Earth, space is sending us a postcard from the distant past. Many extra-terrestrial pieces of rock are ancient and originate from celestial bodies like asteroids, which were formed a little more than 4.5 billion years ago and have hardly changed since then. These primitive, unmodified meteorites are also known as »chondrites«. Their name is derived from »chondrules«, tiny silicate globules minerals measuring just a few millimetres in diameter that make up most of the meteoritic material that falls on Earth. These globules often contain glass.
In the solar nebula, the cloud of gas and dust from which our solar system emerged, there were processes early on that led to sudden increases in temperature. We are yet to discover what exactly caused those temperature excursions. In this environment, the siliceous matter formed melt droplets, which then cooled and solidified. »If they cooled down quickly, glass was formed«, explains Prof. Dr Falko Langenhorst. »Today, we can use thermal analysis methods to work out how quickly the heating event took place. These data tell us more about the temperature distribution and fluctuations in the solar nebula, which ceased to exist billions of years ago«.
Even older glass could be found in comets. They contain dust particles, some of which originate from the interstellar medium, the region between a galaxy's stars. The tiny particles were released into space when ancient stars died, making them older than our solar system. The particles became embedded in planets, asteroids and comets during the emergence of our solar system. »We're unable to directly retrieve samples from the distant regions between the stars. But we were able to collect such dust in regions of space that are closer to us, such as from the tails of comets as was done by the Stardust mission, or from celestial bodies such as the Itokawa asteroid from which the Hayabusa space probe brought back soil samples to Earth in 2010«, explains Langenhorst. »If we examine the isotopic composition of the samples, we can then identify particles originating from the interstellar medium«.
It is believed that the siliceous stardust in particular was originally amorphous and had the best chances of surviving in such a glassy form in comets, because they have never been heated up since the formation of our solar system. However, it was very difficult to detect those glasses, because the particles are usually smaller than a millionth of a metre. Some of the samples collected during the Stardust mission also ended up in the hands of Prof. Dr Falko Langenhorst, who worked with his team to successfully locate the glass particles using a transmission electron microscope, an imaging method with almost atomic resolution. »The glass in stardust is essentially formed by cosmic radiation, a stream of high-energy elementary particles, such as protons, which emanate from stars and convert crystalline matter into glass. Such processes are happening constantly in space and, as the dust mostly consists of silicates, we can assume that there is a lot of glass in the interstellar medium«, says Langenhorst.

Picture left: In this polarization optical image of the Martian meteorite »Zagami« crystalline minerals are shining as coloured components in the homogeneous grey glass. · Photo: Jens Meyer

Mineralogist Prof. Dr Falko Langenhorst is conducting laboratory experiments that simulate the extreme conditions under which glass is formed in space. · Photo: Jens Meyer

The effects of space weather

However, the bombardment with high-energy elementary particles not only changes the matter in the interstellar medium, but also the surfaces of celestial bodies in our solar system that have no atmosphere and are therefore exposed to the barrage of particles without protection. This is referred to as »space weathering« which, in our solar system, is mainly caused by streams of charged particles from the sun known as »solar wind«. Just as terrestrial rock is eroded by the weather and the associated chemical processes, celestial bodies such as asteroids and the moon are also altered by external influences. And when high-energy microparticles hit the surface, this often leads to the formation of glass. The particles only penetrate the matter by fractions of a millimetre, giving the surfaces a glassy film.

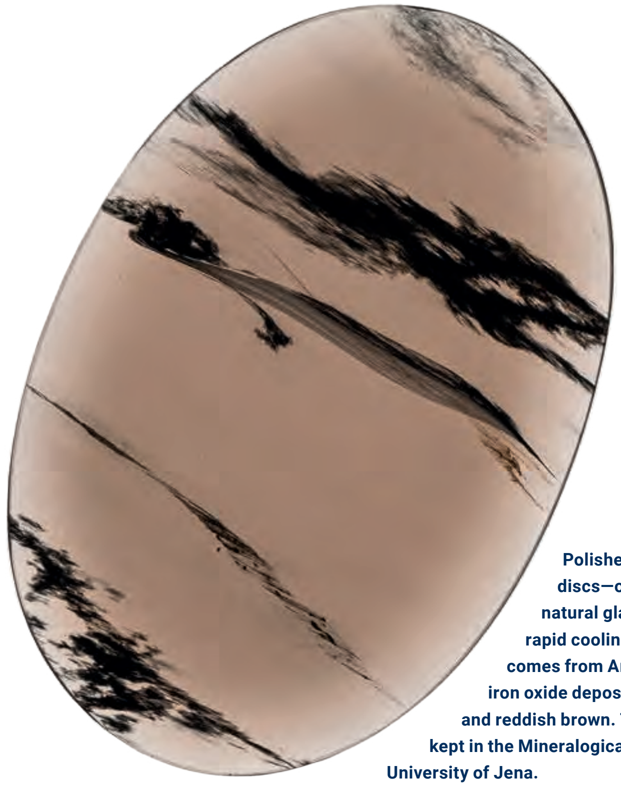
In order to understand exactly how such weathering processes take place, Langenhorst and his team have simulated high-speed collisions with the help of gas guns and laser bombardment. As a result of their experiments, they have found that the weathering not only alters the surface structure of celestial bodies without an atmosphere, but also causes chemical elements to be redistributed in space. For example, contact with solar wind transforms sulphides into amorphous structures on Itokawa and the moon, releasing gaseous sulphur into space. »What remains is iron, which is deposited on the surface like needles«, states Langenhorst. »This information is helping us to interpret the remote spectra and to explain, for example, why asteroids have highly variable concentrations of sulphur: They must have been affected by varying degrees of space weathering«.
Extra-terrestrial influences and regions also produce a glass that was formed in a very unusual way. While the raw material of chondrules is melted at high temperatures and then quenched to form a glass, »diaplectic glasses« are formed when a mineral's original crystalline structure is destroyed under high pressure, which also brings about its key distinguishing feature: a higher density. »The pressures required for this process are in the range of hundreds of thousands of bars and occur on Earth primarily when an asteroid or comet hits the planet«, explains the expert from the University of Jena. »It is often difficult to find evidence of such impact events on Earth because plate tectonics, erosion and weathering have eliminated the morphological traces of the craters. However, one clear indication is the presence of this glass in the materials ejected from impact craters, some of which are distributed throughout the planet«.
For example, diaplectic glass can be found in the ejecta from the meteorite impact that caused the depression in the Nördlinger Ries, a region located to the east of Stuttgart that was hit by an asteroid measuring one kilometre in diameter around 14.6 million years ago. Falko Langenhorst and his colleagues at the German Electron Synchrotron (DESY) in Hamburg are researching exactly how such glass is formed under pressure by subjecting samples to high pressure in a diamond anvil cell and observing when the sample vitrifies in the course of the experiment. »We've found out that vitrification doesn't happen straight away—the material goes through a metastable intermediate stage first«, explains the mineralogist from the University of Jena. »The glass isn't formed randomly in the volume of the crystal, but in the form of thin strips. The initial crystal is streaked with amorphous layers, which then widen under increased pressure until the entire crystal has been converted into a glass«. Their research results lay the foundation for diaplectic glasses to be used for specific applications in the future. ■

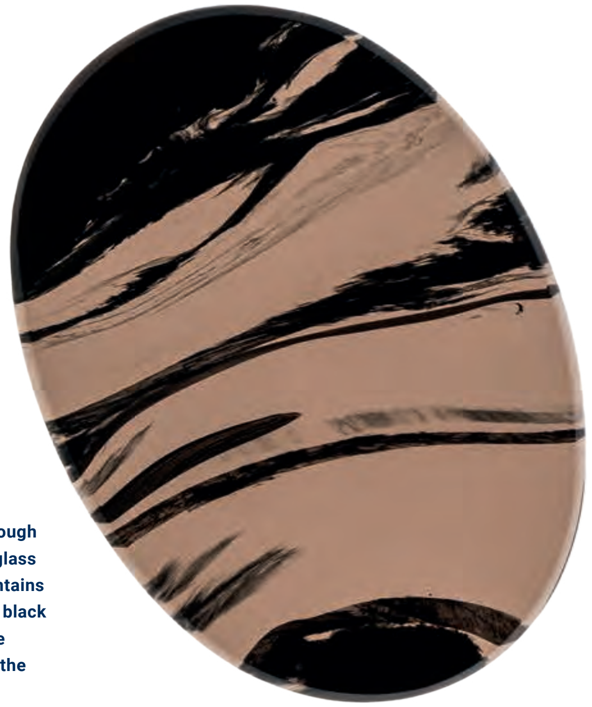
These fragments of leaded stained-glass windows, dating back to the late Middle Ages, were found in Vogelsberg (Thuringia). They are kept in the Prehistory and Early History Collection at the University of Jena.

These late antique twin balsamaria from Mount Gerizim (Palestine) were made in the 4th or 5th century AD. They are part of the Antiquities Collection at the University of Jena. · Photos from page 28—31: Jens Meyer

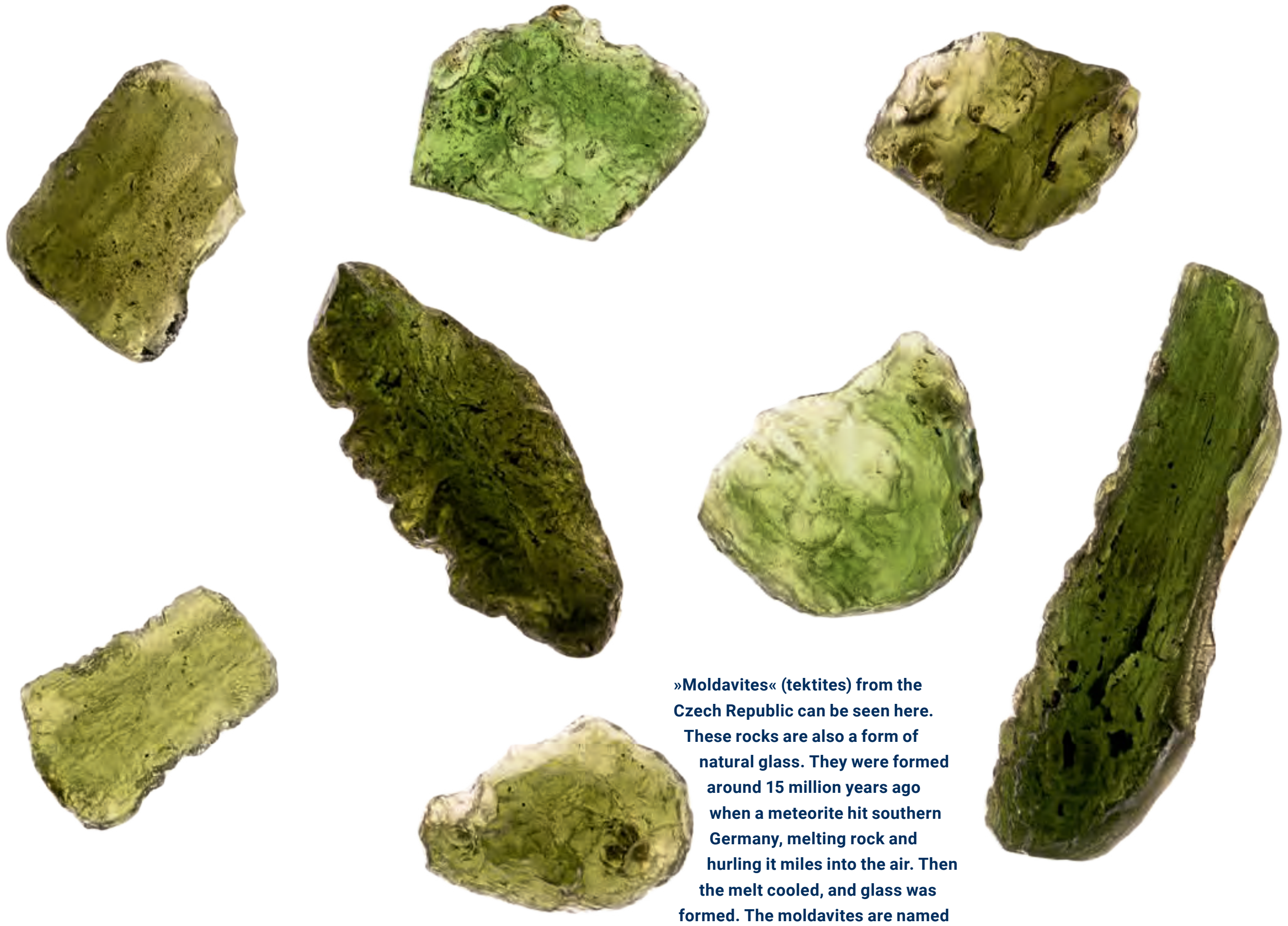
This fragment of a wine decanter neck was recovered from a sewer next to the monastery at »Collegium Jenense«. The object dates from the 16th or 17th century and is part of the Prehistory and Early History Collection at the University of Jena.

This Roman glass bowl from Mount Gerizim (Palestine) dates from the 3rd or 4th century AD and is in the Antiquities Collection.





Polished obsidian discs—obsidian is a natural glass formed through rapid cooling of lava. The glass comes from Armenia and contains iron oxide deposits that appear black and reddish brown. The objects are kept in the Mineralogical Collection at the University of Jena.



»Moldavites« (tektites) from the Czech Republic can be seen here. These rocks are also a form of natural glass. They were formed around 15 million years ago when a meteorite hit southern Germany, melting rock and hurling it miles into the air. Then the melt cooled, and glass was formed. The moldavites are named after their main place of discovery in today's Czech Republic and are kept in the Mineralogical Collection at the University of Jena.

These fragments of leaded stained-glass windows (above and below) from Vogelsberg in Thuringia date from the late Middle Ages and are part of the Prehistory and Early History Collection at the University of Jena.

The history of glass research in Jena

Jena and its university can look back on a rich tradition of glass research and production—not least thanks to the »glass trio« of Zeiss, Abbe and Schott. Let's take a look at some of the milestones.

BY SEBASTIAN HOLLSTEIN

Melting glass in the garden

In the early 19th century, there was only one way to find out the right material composition for optical glasses: trial and error. That's why Friedrich Körner set up a small glass melting furnace next to his house at Grietgasse 10 shortly after taking on a position as a university mechanic in Jena in 1816. His little project was even funded by Grand Duke Charles Augustus himself. He wanted to produce flint glass, which was well suited for eyepieces and telescopes due to its optical properties, and which was usually imported from England at the time. He tried out different furnace designs. Körner then produced several hundred kilograms of glass in numerous high-profile experiments, but the material was not up to scratch. Most of it had a coloured cloudiness; Körner was actually pleased with one glass, but it failed the quality control run by Joseph von Fraunhofer, the most respected expert in the field at the time. In order to advance the experiments, the Grand Duke provided Körner with an assistant, Johann Wolfgang Döbereiner, who was a professor at the University of Jena. The chemist focused primarily on the stoichiometry, i.e., the correct ratio of all components. Their cooperation was a success. For example, the team was able to produce baryte glass in 1828. One journal reported that it was »clearer, harder and specifically heavier than the best crown glass—and had a greater refractive index«.

Calculating optics

Körner laid the foundations for Jena's glass tradition not only as a scientist, but also as the teacher of someone destined for greatness: In 1834, an 18-year-old Carl Friedrich Zeiss began a four-year apprenticeship with Körner, who was working as an associate professor. Zeiss ultimately opened his own workshop in 1846 and produced his first microscopes just one year later. Zeiss began to deal intensively with the scientific foundations of mathematics and optics because he wanted to move away from manufacturing lens systems by trial and error, where he would try out different lens combinations, and instead wanted to perform precise calculations. In addition to his own studies, he could fall back on the expertise of a scientist who was 24 years his junior, Ernst Abbe, who had qualified as a professor at the University of Jena in 1863 before working as an associate professor and freelance research assistant at Zeiss' workshop. In 1870, he became a professor at the University of Jena. His research—above all his theory of microscopic imaging—ultimately allowed the scientists to achieve their goal: In 1872, Zeiss sold the first microscopes whose optics were based on calculations and whose performance was unmatched by any other product on the market. In order to further advance the production of their equipment, they just had to find an appropriate manufacturer of optical glasses who met their high standards.

»Schott & Co.«

Glass research in Jena is inextricably linked to one name: Friedrich Otto Schott. Born in Witten in 1851, he developed a fascination for the transparent and fragile material at an early age. His grandfather was a glazier, and his father ran a sheet glass factory from 1853. So, it's comes as no surprise that Otto Schott decided to study chemistry in Aachen. He went on to specialize in glass at Leipzig University before graduating from the University of Jena in 1875, writing his doctoral thesis on the topic of »Contributions to the Theory and Practice of Glass Manufacture«. However, another much less extensive written testimony was more important in promoting Jena as a location for glass research: On 27 May 1879, Otto Schott wrote a letter to Ernst Abbe to inform him that he had succeeded in producing a glass »containing a significant amount of lithium«. »I assume that the glass in question will have outstanding optical properties in any direction and wanted to take the liberty of asking you whether you would be willing to test its refractive and diffusive properties—or to have them tested by one of your apprentices—to verify whether my assumption is correct. Thanks to your connections to the local Zeiss Optical Institute, it will be easy for you to have the necessary grinding work done on the glass without having to expend any effort yourself«. Abbe and Zeiss were unable to do much with the material sent by Schott, but they saw great potential in the young glassmaker. They were especially impressed by the fact that Schott had managed to produce melt samples in small crucibles. In 1883, they joined forces to set up a »Glass Technology Research Station« in Jena, which was renamed the »Glass Technology Laboratory, Schott & Co.« one year later—and soon developed into a reliable supplier of optical glasses.

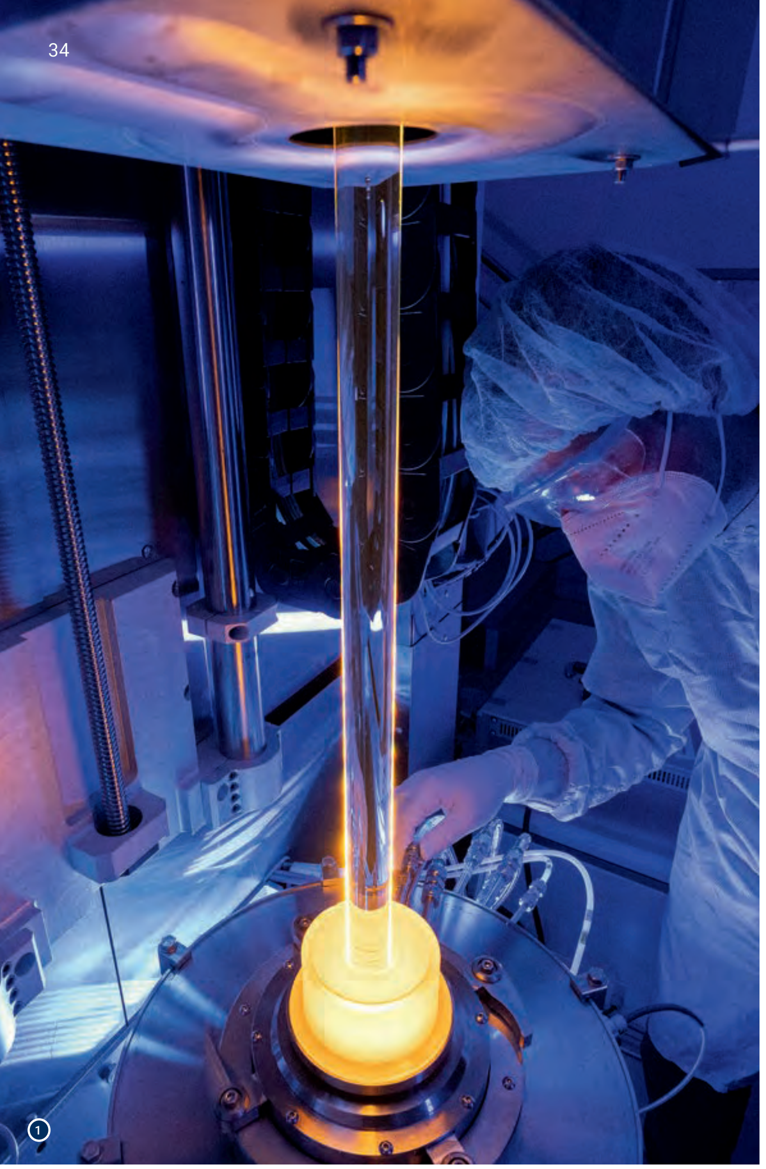
One of the largest glass archives in the world: Around 94,000 glass samples produced at Schott's factory can be found in Jena. The »German Optical Museum« has taken ownership of the samples. · Photo: Jens Meyer

The reinvention of glass

Three years later, in the newly founded company, Otto Schott made a ground-breaking invention that cemented the role to be played by glass in the natural sciences and technical fields. The established types of glass at the time, soda-lime glass and lead glass, were attacked by chemicals and even water. In addition, they often broke due to excessive heat and rapid changes in temperature. A new material was therefore required for experimental investigations in the laboratory—and Schott came up with the solution. He added boron oxide to the traditional glass component silicon oxide, thus eliminating the weak points of the other types of glass. His borosilicate glass quickly established itself on the market: the company initially used the new material to produce thermometer glass from 1891, and the first laboratory vessels such as beakers and conical flasks were sold two years later. The range was subsequently expanded with the addition of glass cylinders for gas lamps. The portfolio grew steadily thanks to different variations in glass composition, including household glass—the famous glass from Jena that was produced by Schott from the 1920s. Borosilicate glass still has a wide variety of applications today. It is even used in space telescope optics in the form of highly thin float glass.

Phase separation in glass

The development of electron microscopy offered glass chemists around the world—including Jena—new opportunities for in-depth research into the structure of glass. In 1955, Werner Vogel started using this instrument to carry out an extensive, ground-breaking series of experiments on beryllium fluoride glasses at the Schott & Co. glassworks, in order to investigate the phenomenon of phase separation in glass, which had already been observed by Otto Schott. After all, contrary to what was commonly assumed, glass components do not necessarily mix to form a homogeneous material, but can form micro-heterogeneous areas during production which, as shown by Vogel through his investigations, take the form of tiny droplets and look cloudy to the naked eye. In the early 1960s, scientists still believed that such separation phenomena were exceptions that could possibly even be traced back to microscopy itself; however, phase separation in glass subsequently emerged as one of the most important branches of research in this field. Werner Vogel, who researched and taught at the University of Jena from 1969 to 1990, achieved international recognition through his work. His research paved the way for new optical and technical glasses to be developed. ■



How a fibre is made

Insights into the fibre competence centre of Fraunhofer IOF, Leibniz-IPHT and the University of Jena

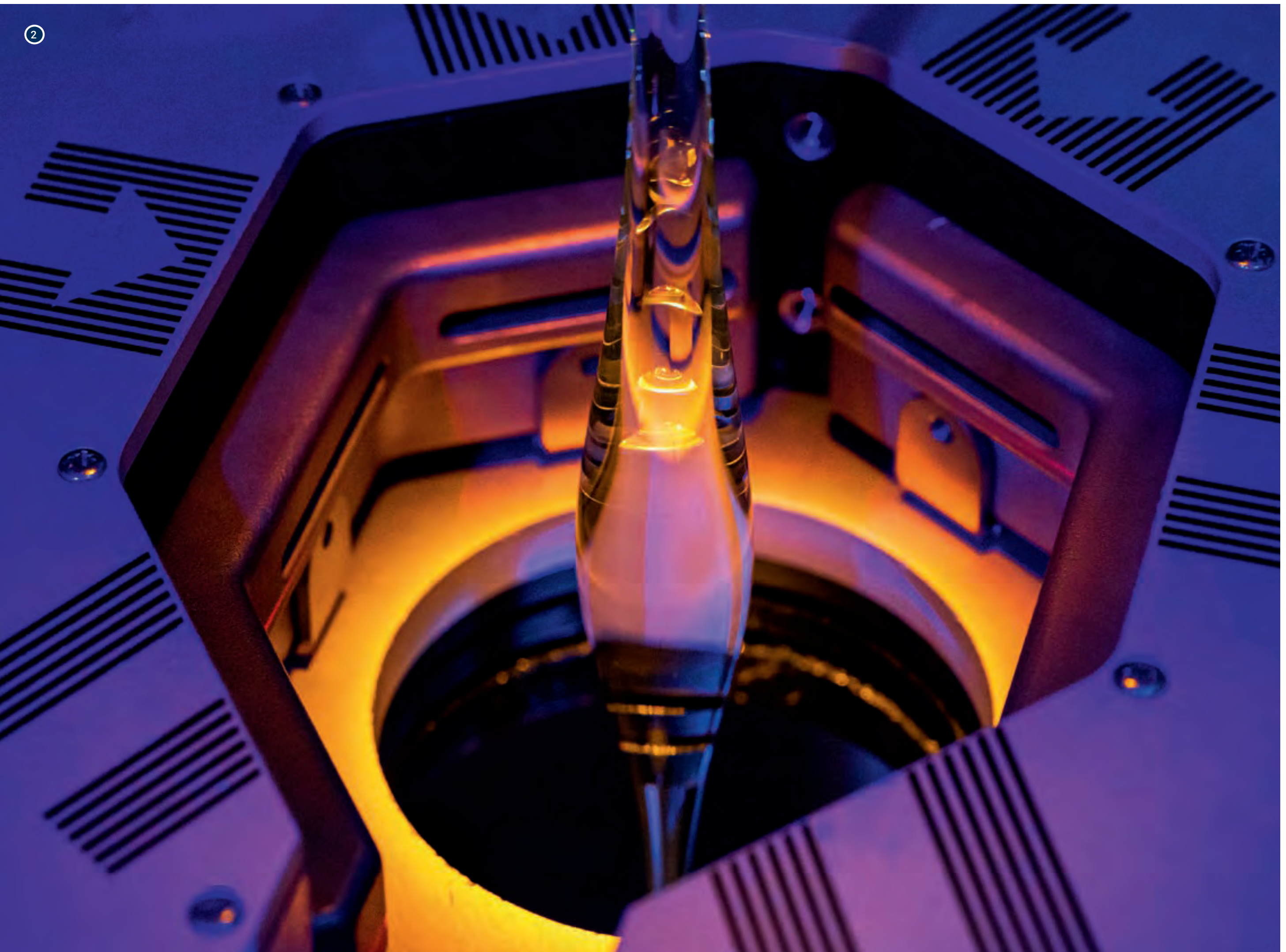
1 Furnace
The fibre pre-form—a glass rod measuring around one metre in length and weighing around two kilos—is heated to 2,000°C.

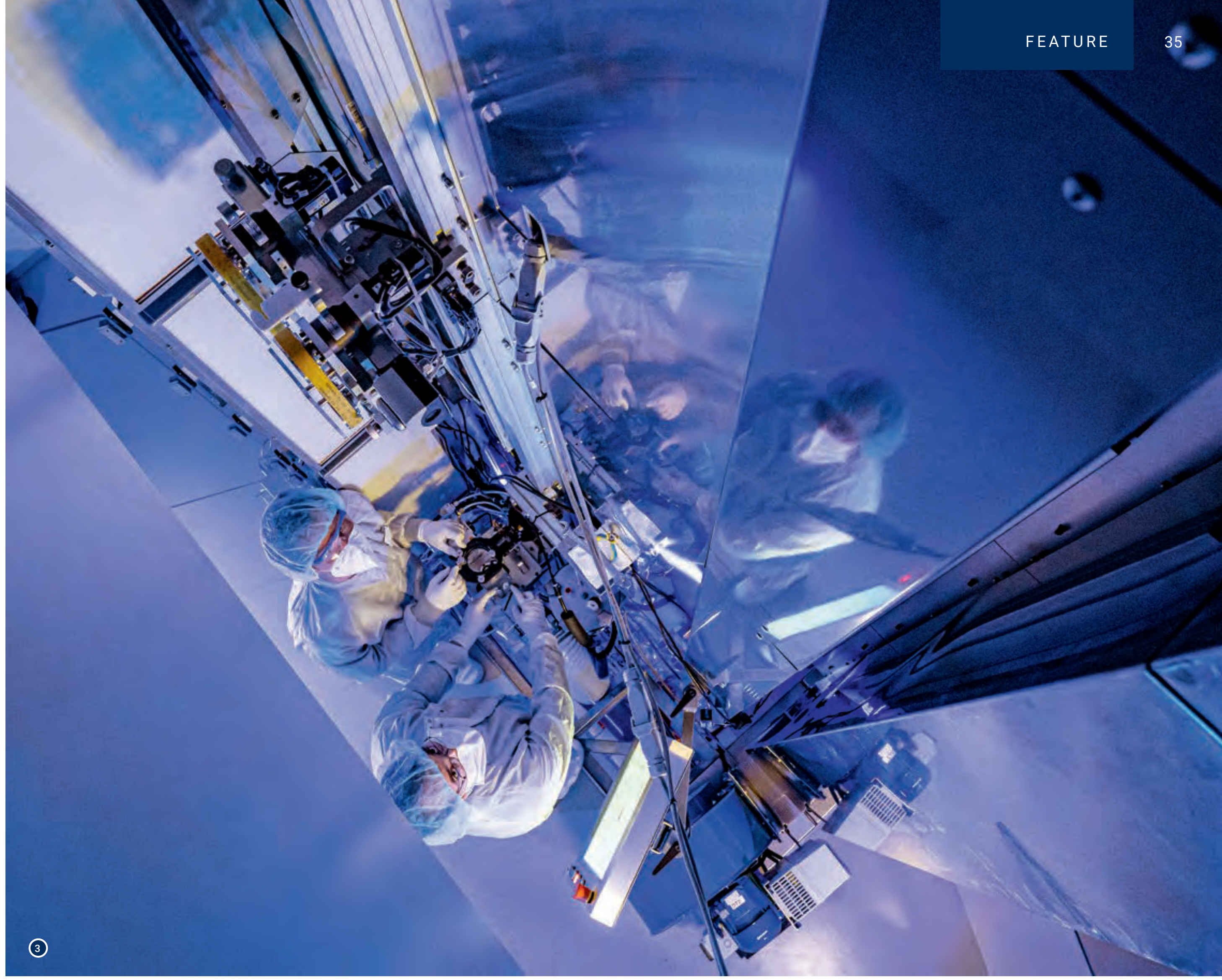
2 Drop-off
The heated glass becomes malleable and forms a thick drop due to its own weight. This is removed and the resulting strand is placed in the drawing plant.

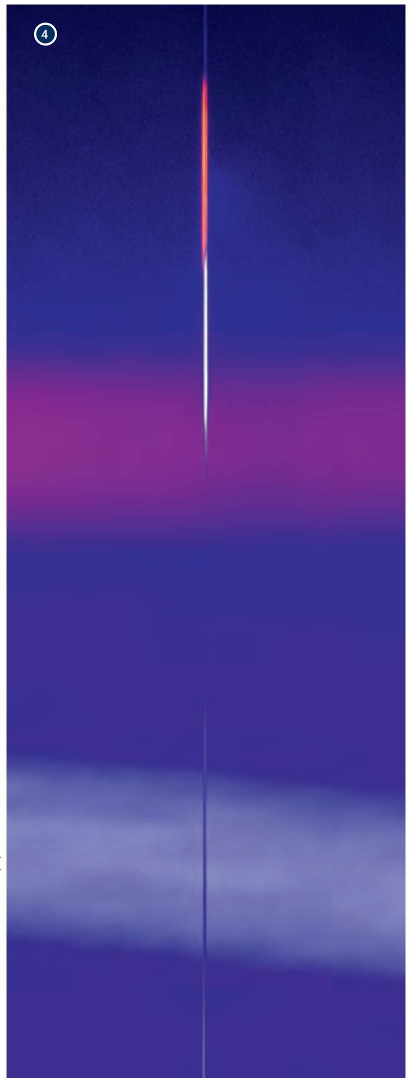
3 Drawing the fibre
On its way through the drawing plant, which extends over four storeys, the fibre can be coated with polymers that have tailored properties.

4 Hair's breadth
With a diameter of around 150 micrometres, the finished fibre coated with acrylate is only about as thick as a human hair.

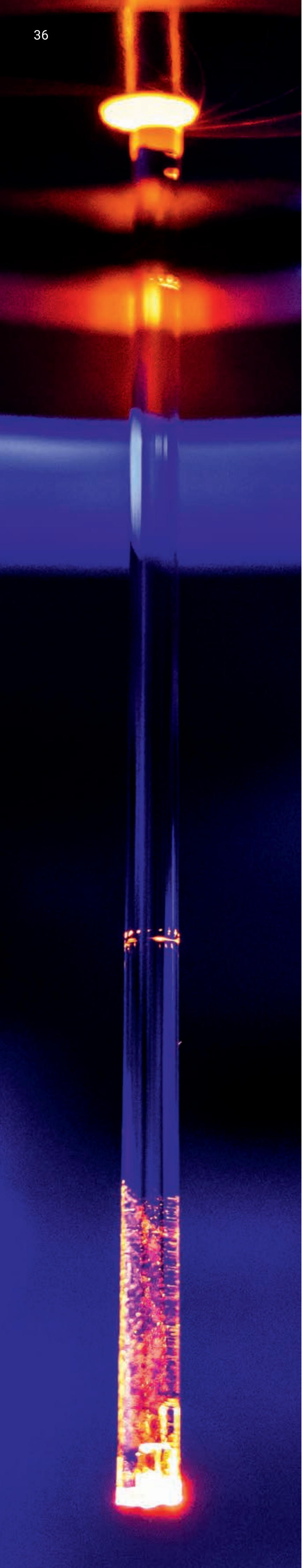
5 On a roll
Once the fibre has been drawn to lengths of up to several kilometres, it is then wound up in the basement of the building.







PHOTOS (5): JENS MEYER



Light as a boundary rider

Optical fibres play a central role in modern data transmission and communication technologies. However, guiding light through glass fibres more than one kilometre long and less than one millimetre thick is by no means a new invention—even in ancient times, light was guided along the interfaces of media with different refractive indices. In this interview, physicist Prof. Dr Andreas Tünnermann discusses how technology from the past millennium could make data communication processes more secure and efficient in the future.

INTERVIEW: UTE SCHÖNFELDER

What role does glass play in today's communication technologies?
A very important role. Practically all data is now transmitted via light signals. It wouldn't be an exaggeration to say that the Internet as we know it would be unthinkable without communication with light and without the use of optical fibres to guide the light.

What are the advantages of transmitting data via light signals?
By using light as a signal carrier, we can achieve much higher transmission capacities than with other materials such as copper cables or by other means such as radio transmission. What's more, data transmission via optical fibres is more energy efficient because optical fibres attenuate the signal much less than copper cables.
Energy efficiency has become an important issue in the field of information and communication technology, especially considering the immense increase in data volumes transferred worldwide each year. As the exchange of data continues to multiply through the use of streaming and cloud services, a significant amount of the global energy demand can now be attributed to the transfer and storage of data. So, we urgently need to reduce losses in transmission systems.

How is light conducted through an optical fibre?
What makes an optical fibre so special is the fact that light is guided in it via the mechanism of total reflection. A material with a high refractive index is surrounded by a material with a lower refractive index. The light propagates in the fibre and is almost completely reflected at the cladding interface, where it is guided back into the fibre. This protects it and prevents it from interacting with its surroundings.
This phenomenon has been known for thousands of years. Even in ancient times, people knew that light could be guided in a jet of water. In that case, water is the material with a high refractive index and the surrounding air is the material with a lower refractive index. The interesting thing is that you can guide light in any direction you want—even around corners. This is important for applications in communication, medical and production technology, where light is used to carry information and energy. Endoscope cameras are a prominent example here.

What does optical fibre have to be like to optimally transmit light?
In general, the aim is to transmit light with as little loss as possible. In addition, optical fibres have to be doped with foreign atoms to set a refractive index profile that enables total reflection. Different glasses are used to produce optical fibres, the most important being silica glass: silicon dioxide (SiO_2).
In the modern world, telecommunications fibres have been optimized to such an extent that they practically have no impurities and the attenuation of the signal in the fibres is almost entirely due to the material itself, the silica glass. This allows data to be transmitted over several hundred kilometres without having to be amplified. This freedom from losses is also important in production technology, where light is used as a tool for cutting and welding, and where excessive attenuation could lead to the destruction of fibres.

Prof. Dr Andreas Tünnermann is the director of the Institute of Applied Physics at the University of Jena and head of the Fraunhofer Institute for Applied Optics and Precision Engineering (IOF). · Photo: Jens Meyer

Picture left: Cut glass rod beneath a hot fibre drawing furnace in a fibre drawing plant. · Photo: Jens Meyer

What fibres are you and your teams working on at the University of Jena and Fraunhofer IOF?
Due to its material, traditional silica optical fibre has been exhausted in terms of its attenuation losses. So, if we want fibres with even lower propagation losses, we have to implement completely new principles for guiding light—and that's exactly what we're working on here. For example, we're trying to guide the light signal in the fibre within tiny air tubes surrounded by a glass jacket. This is because the signal losses are lower when light propagates through air than when it propagates in glass. The mechanism used to guide light in these fibres is then no longer based on total reflection.
A second focus we are working on is laser fibres. So, we're not only using optical fibres to transmit light, but also to generate light. Laser fibres aren't the same as data fibres—they're doped with rare earth metals such as neodymium or ytterbium, which amplifies the light.

To what extent do optical fibres also play a role in quantum communication?
The laser itself is a product of quantum physics. It's based on the use of collective quantum phenomena. As we're able to control individual quanta, including light particles (photons), we can now use quantum technologies to enable futuristic encryption methods and increase data security.
This is revolutionizing cryptography. By using specific quantum properties, we can generate »quantum keys« to encrypt data in a very secure manner. At the same time, we can even use specific protocols to ensure that not even the operator of the infrastructure is able to read the key. Both the data key and the data encrypted with it can be sent via optical fibres.
But when optical fibres are used in quantum communication, the attenuation losses have to be significantly reduced again, which is why we're continuing our research into optical fibres with new light guidance mechanisms.
Why is it so important to control losses in quantum communication? This is due to fundamental phenomena of quantum physics—unlike the classic transmission of light in optical fibres, the signal can't simply be amplified. Quantum states can't be cloned or restored. ■

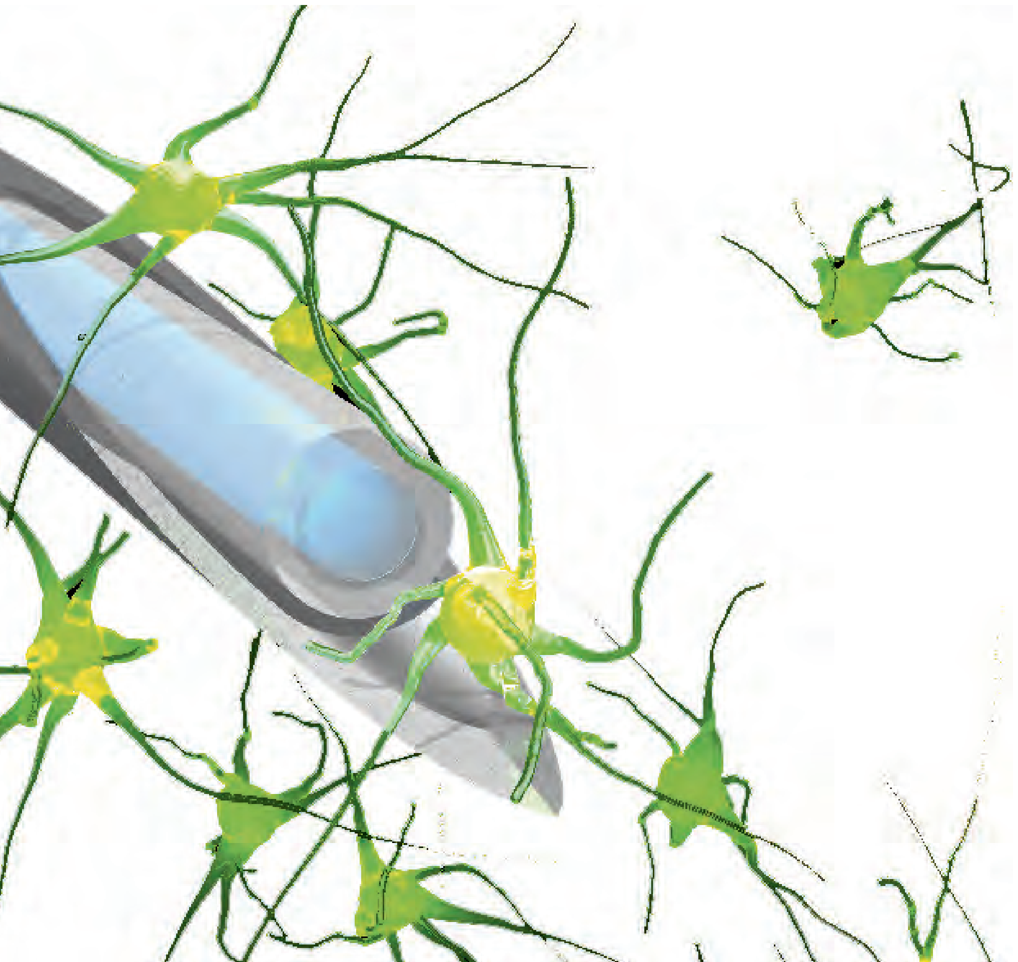
The window to the brain

In addition to data cables and fibre lasers, optical fibres also play a key role in modern imaging methods. At the Leibniz Institute of Photonic Technology (IPHT) and the Institute of Applied Optics and Biophysics at the University of Jena, a team of researchers led by Prof. Dr Tomáš Čižmár is using holographic endoscopy based on optical fibres to develop a method that will one day allow us to watch brain cells think and feel.

BY UTE SCHÖNFELDER

A number of non-invasive imaging methods already provide insights into the living human body, such as ultrasound, magnetic resonance and computed tomography. These allow doctors to diagnose illnesses and internal injuries and monitor healing and metabolic processes. These established methods enable the entire body to be examined down to the core, but they also have a major disadvantage: The images captured have a maximum resolution of around one millimetre; finer details cannot be reproduced. »If we want to visualize individual cells or even sub-cellular structures, we need other methods«, explains Prof. Dr Tomáš Čižmár. There are such high-resolution methods like electron microscopy. »However, they can only be used to take images of surfaces, or you have to look through very thin tissue sections, which limits their application for living organisms«, continues Tomáš Čižmár, who teaches Waveguide Optics and Fibre Optics at the University of Jena and is heading a working group at the IPHT.

Tomáš Čižmár and his team are trying to enable high-resolution images to be taken deep inside of living organisms. More precisely, the researchers want to develop an instrument that could be used to literally observe the brain at work. Many details of this highly complex organ are not yet understood. Čižmár identifies his motivation: »In the long term, understanding this complexity can help to treat or even heal diseases such as Alzheimer's or Parkinson's«.



Nerve tissue scanned by ultra-thin optical fibre

The research team is using ultra-thin optical fibres that are inserted into tissue to look inside the brain—but initially with test animals. Unlike conventional endoscopes, which are used for »keyhole surgery« and for diagnosing issues affecting the stomach or intestines and which consist of a bundle of fibres up to one centimetre thick, the endoscopic fibres here are only as thick as a human hair. With a diameter of 100 micrometres, the fibres are only slightly thicker than the nerve cells themselves (see illustration on the left) and have a sharp tip that penetrates the tissue like a scalpel, causing only a minimal injury.

The key technological challenge is to guide the light through the fibres in a controlled manner. The fibres consist of a light-conducting core made of silica glass and a cladding that has a slightly lower refractive index, which causes the light to be »trapped« in the fibre and guided through it (see p. 36). However, such »multi-mode fibres« lead to many different, unpredictable paths of light propagation, resulting in an apparently chaotic light distribution similar to that of a diffuse, opaque medium.

The researchers are sending coherent laser light through the fibre into the tissue to be examined. »Normally, the interference of light paths within the fibre core causes peaks to form in some places and troughs in others, creating a speckled ›map‹ of light and dark spots«, says physicist Čižmár. In order to obtain sharp images, the light is »pre-shaped« with a holographic modulator before it enters the fibre. This is a programmable micro-mirror array—each of the micro-mirrors can be quickly switched between two directions. »This enables us to focus the light tightly behind the fibre«, says Čižmár. Using a specific hologram and setting the micro-mirror array for each desired pixel of the image, the focus then scans the image section point by point, imaging details with a size of less than one micrometre.

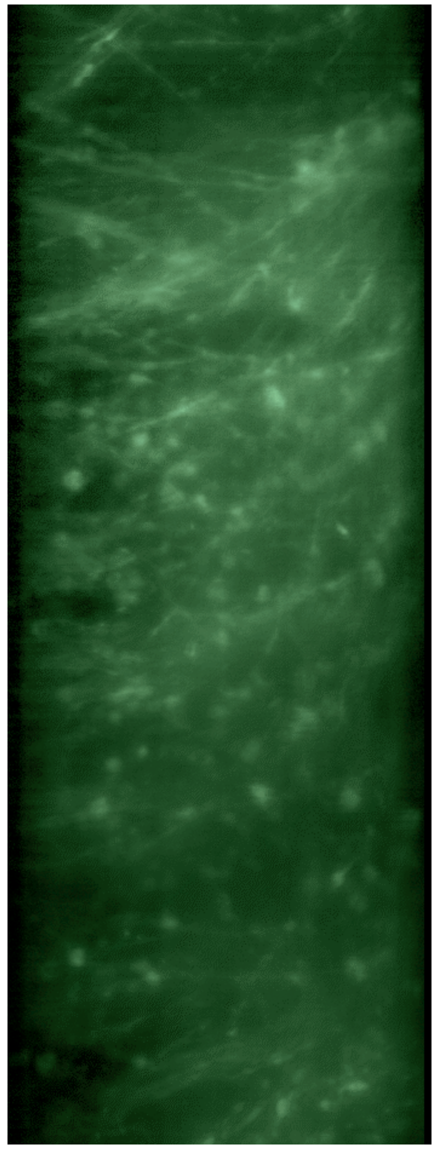
There is still a long way to go before holographic endoscopy will enable insights into the human brain. However, promising results have already been obtained with test animals. Tomáš Čižmár and his research teams in Jena and Brno, Czech Republic, have already used their technology to visualize nerve cells and the cellular extensions that cells use to communicate with one another, even in deep neurological structures.

Čižmár himself started developing the methodology a good ten years ago and has focused his research on it ever since. He has received a Consolidator Grant from the European Research Council (ERC) for his »LifeGATE« project, which aims to develop light propagation and imaging technology in multi-mode fibres. »We've made significant progress since then«, he reports. The areas examined can now be scanned at a much higher speed, which allows greater areas to be studied overall.

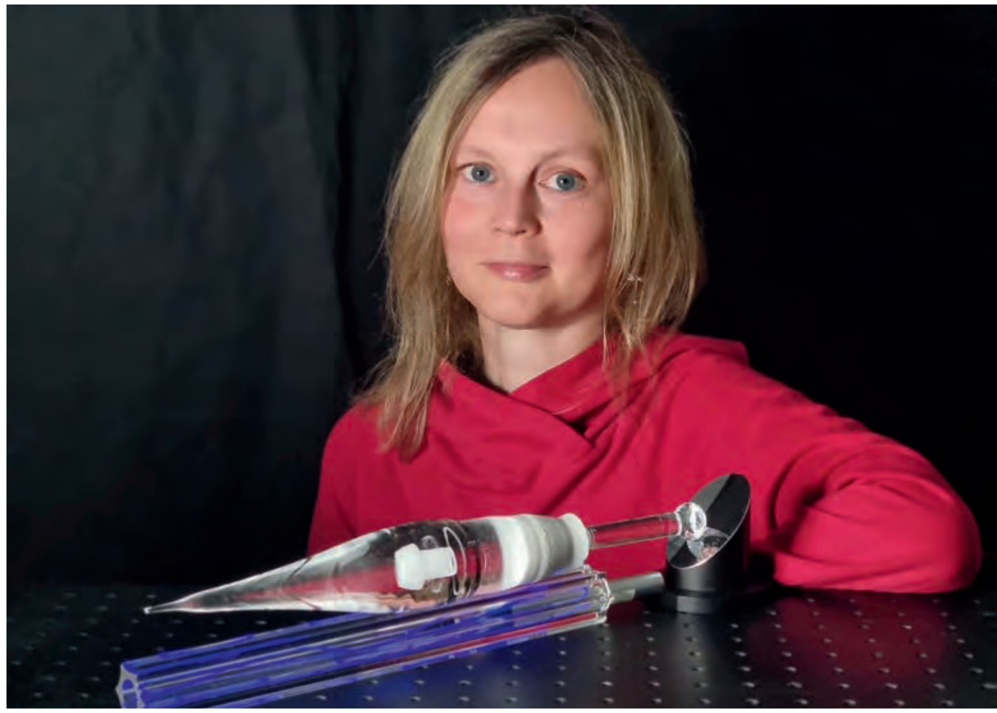
A start-up company is emerging from the research project

In the coming years, Čižmár and his team want to use their research results to create a start-up company and offer their services to potential users in neuroscience and medicine. Their spin-off project »DeepEn« (Minimally Invasive Endoscopes for Neuroscience and Medicine) is being funded through the EXIST programme for scientific start-ups run by the Federal Ministry for Economic Affairs and Climate Action (BMWK). The spin-off is planned for the coming year. Čižmár estimates that this could lead to the development of the first diagnostic and therapeutic applications within the next ten to fifteen years. ■

Prof. Dr Tomáš Čižmár and his team are developing fibre-optic-based endoscopes to gain insights into the living brain. · Photo: Anne Günther



Detail of an endoscopic image showing the processes of neurons (dendrites and axons) in the brain of a living mouse. · Photo: IPHT/ Institute of Scientific Instruments of the Czech Academy of Sciences



Picture left: »Modified chemical vapour deposition« is used to create glass rods from which fibres can be drawn. Here you can see the moment when a tube collapses at the end of the experiment. · Photo: Sven Döring

Picture right: Dr Katrin Wondraczek and her team develop preforms for optical fibres. · Photo: Lothar Wondraczek

Customization at ultra-fine dimensions

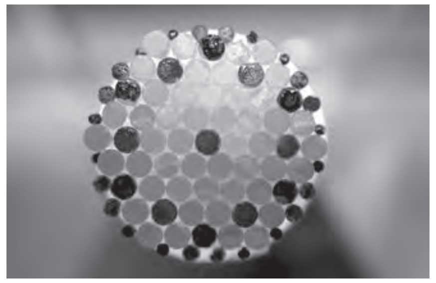
In the Optical Fiber Materials and Structures work group at Leibniz Institute of Photonic Technology (IPHT), fibres are being developed for hair-thin endoscopes of the future and other applications. After all, such fibres aren't available »off the shelf« and fibres can be quite different.

BY UTE SCHÖNFELDER

Many of the fibers for endoscopic holography (see p. 38) are developed in-house. In doing so, the researchers rely on the expertise at their own institute. Dr Katrin Wondraczek and her team at Leibniz IPHT specialize in the production of core materials for optical glass fibres that are »tailor-made« depending on their intended application and functionality. »It's a bit like baking a cake«, says the research group leader with a twinkle in her eye. »Depending on the cake you want, we put together the right recipe«. Just like cakes in an oven, the fibre preforms consist of various glass elements that are »baked« into a fibre and then drawn out in ultra-fine dimensions. For example, a flexible fibre produced for endoscopic imaging consists of dozens of individual fibre cores with different optical properties.

»Spaghetti bundles« extended ten thousand times

But how are such ultra-fine fibres actually made? »The starting point for every glass fibre—regardless of its composition—is a glass rod known as a ›preform‹«, explains chemist Katrin Wondraczek. »To make a preform, appropriately doped and undoped rods are combined to make a fibre with the desired design, although around 100 times thicker« It looks a bit like stacking glass spaghetti into a bundle a few centimetres thick. This »spaghetti bundle«, which is around half a metre long, is then drawn out into a fibre that can be several kilometres long (see p. 32). »In this process, the preform material is scaled down«, explains Katrin Wondraczek. If the diameter of the fibre is a hundred times smaller than that of the preform, the length increases by a factor of 10,000. As an example, a preform that is one centimetre thick is turned into a fibre with a diameter of around 100 micrometres—the thickness of a human hair.



Cross-section of a packing of doped and undoped quartz glass rods in a cladding tube. · Photo: Anne Matthes

The preform element, the »spaghetti«, consist primarily of silica (SiO_2), the common glass material. In order to create the function of specialty glass fibres, this base material is doped with additional substances. For example, ytterbium oxide is required for laser fibres, while data fibres usually contain germanium oxide. Katrin Wondraczek and her colleagues are now working on manufacturing doped glass in such a way that the doping agents are distributed as homogeneously as possible and are present in the exact concentration, which is crucial for the performance of the final glass fibre.

And here, at the latest, it becomes clear that the whole process is a bit more complicated than baking a cake. After all, when it comes to producing specialty glass fibres, selecting the right ingredients isn't the only important factor. The manufacturing process itself is also critical for the end result. And contrary to what one might assume, the glass materials developed by Katrin Wondraczek and her team do not come from a melting furnace either. Rather, they are made from gaseous, liquid, or solid starting materials.

Making glass from gas

In the case of endoscopic fibres, for example, germanium-doped glass preforms are needed that are produced with Wondraczek's team in a process known as »gas-phase deposition«. This is where the initially liquid chemical »ingredients«—silicon and germanium chloride—are fed through a glass tube with oxygen in a stream of helium and heated under a flame of over 1,800 °C. In this process, they vaporize, react with oxygen and form SiO_2 doped with GeO_2. This substance is deposited as a very dry powder on the inner wall of the glass, where it is heated further until it »vitrifies«. As the burner moves slowly along the tube during this process, a new glass layer grows inside. This tube is then collapsed into a glass rod: just about one centimetre thick and up to half a metre long.

»Compared to the traditional melting process, gas-phase deposition allows us to obtain glass rods with very homogeneous doping in the core area and high purity,« Wondraczek points out the main advantages of this technique. The materials produced using this method also have a very low attenuation loss, which is another crucial factor for their use in long data fibres. »However, the disadvantage is that we can only use gas-phase deposition to obtain glass rods with relatively small doped core areas of less than a centimetre in diameter, which limits the length and maximum core diameter of the fibres to be drawn from them«, adds Katrin Wondraczek. That's why the glass scientists are also working on other alternatives. One process in which glass is also not made from a melt but from solid starting materials is the doping of existing SiO_2 particles. As part of this method, known as »reactive powder sintering« (REPUSIL), silica nanoparticles and the required doping agents are processed into granular powder and pressed into solid cylinders. These green bodies determine the shape and size of the resulting glass rod after sintering and vitrification. During sintering, the material is heated but remains under its melting point, causing it to become vitrified. As the glass rods obtained in this way can be several centimetres thick, fibres with very large cores can be drawn out and the fibres can be much longer than obtained from gas-phase deposition.

Regardless of how the preform is made, it ends up as a unique fibre, with an individual design, a specific composition and structure depending on whether it is a laser fibre or a fibre for data communication, imaging, or spectroscopy. And yet the development of a fibre begins with the same basic prerequisites: quartz, high temperatures and the right know-how. ■

The eye of the laser

The POLARIS short pulse laser system is one of the most powerful of its kind, drawing its strength from a course of diodes, lenses, mirrors and a very homogeneous crystal. An inside look at where light is amplified to record-breaking levels and where not everything that looks like glass really is glass.

BY UTE SCHÖNFELDER

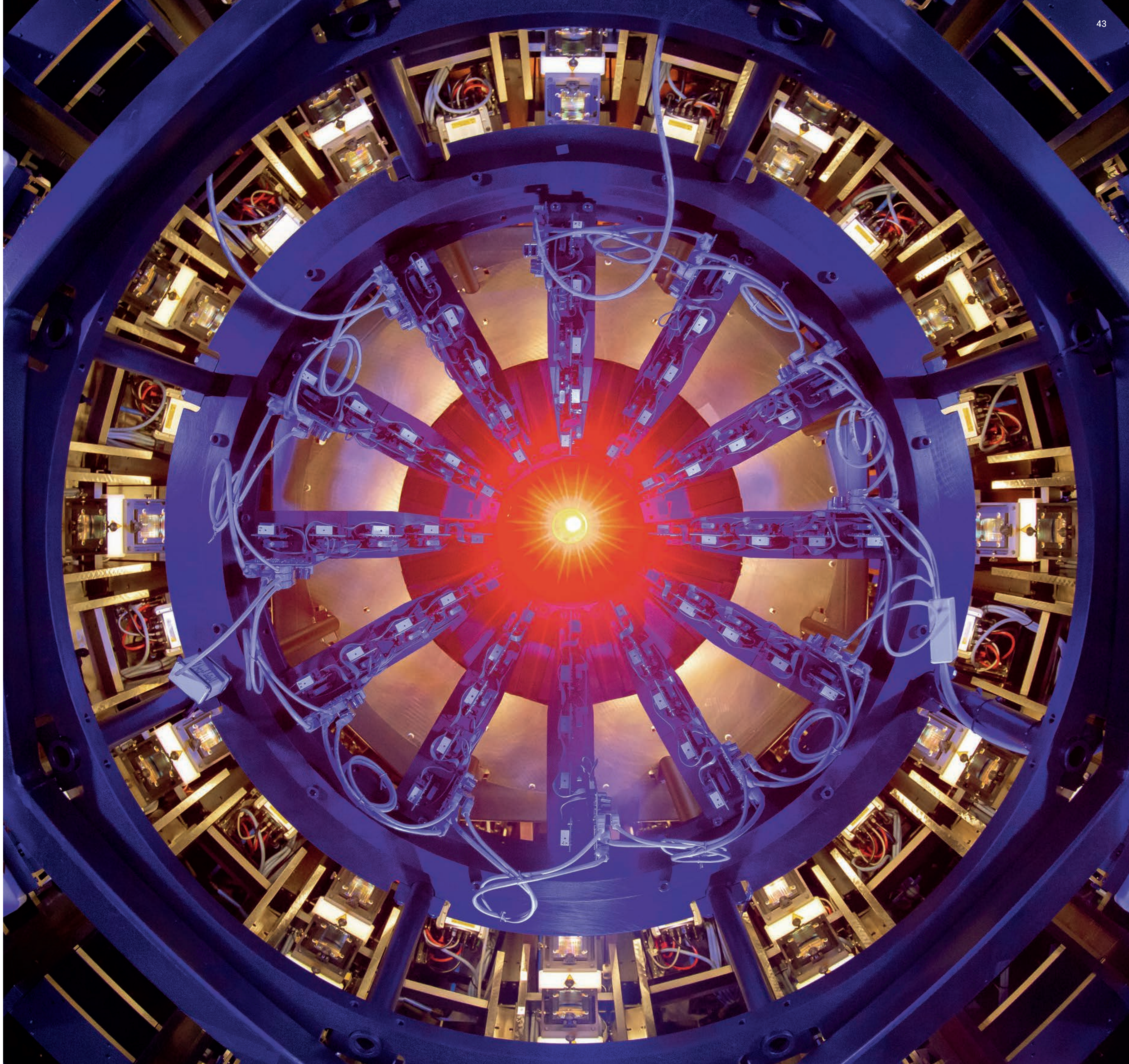
Jena is home to one of the world's most powerful fully diode-pumped laser systems. The POLARIS laser, operated by the University of Jena and the Helmholtz Institute, can reach over 170 terawatts at peak performance.

The heart of the laser system, which extends over three storeys, is the final amplifier stage: a steel frame measuring 2.5 by 2.5 by 2.5 metres, somewhat reminiscent of an oversized washing machine drum. This is equipped with 120 laser diode stacks and a massive number of cylindrical lenses. When the laser is in operation, the diodes emit synchronous flashes of light that are focused by the lenses onto a surface with a diameter of around 5 centimetres located in the middle of the steel frame (the orange area in the picture). This is where we can find the actual laser amplifier: a very homogeneous calcium fluoride crystal measuring around 6.5 centimetres in diameter and around 3.5 centimetres in thickness.

At first glance, the crystal looks like ordinary glass. But unlike glass, which has areas that are ordered and disordered to varying degrees, the crystal has a regular lattice structure. Just like glass (see p. 14), which mainly consists of SiO_2, calcium fluoride (CaF_2) also forms a tetrahedral structure. But unlike glass, this structure continues regularly throughout the crystal. The calcium fluoride crystal is additionally doped with ytterbium ions. When the bundled flashes from the laser diodes hit the crystal, the electrons of the ytterbium ions are excited, and the crystal is »pumped« with energy. When the actual laser beam is then guided through the charged crystal using several hundred mirrors along a path measuring several hundred metres, this energy is released again by the electrons and the laser pulse is amplified. For every laser photon that enters, another photon is emitted from the crystal; this process is known as »stimulated emission«.

The laser passes through the crystal seventeen times in total before reaching the target chamber in the building's basement at maximum peak power. ■

PHOTO: JENS MEYER



Distribution of the plant packages in the Botanical Garden of the University of Jena in March 2022 · Photo: Christine Römermann

Research for everyone

A growing number of researchers are including citizens in their scientific work. However, they are not just called upon as test subjects; »citizen science« is about conducting research together. The University of Jena also invites members of the public to participate in such projects. We present two examples here.

BY VIVIEN BUSSE

The Oxford English Dictionary defines »citizen science« as the »collection and analysis of data relating to the natural world by members of the general public«. They often work together or under the guidance of professional scientists or scientific institutions. In other words, it is lay people who help to collect, research, and evaluate research data in »citizen science«.

Observing plants from the outskirts to the city centre

The general public is currently helping scientists on the »PflanzeKlimaKultur« project. The aim of the cooperative project, in which the universities of Jena, Halle and Leipzig, among others, are participating, is to observe the phenology (i.e., seasonal development) of native plants. This is because plants reflect climatic changes; for example, their life cycle is heavily influenced by temperature.

The project team in Jena called upon citizens to participate by contacting nature conservation organisations, allotment associations and schools, and by posting an appeal in the local press. When the project was launched in March, the participants received plant packages and planted them in their own flower beds. They have since been observing their plants—and they will be doing so for two years. The phenological stages of the plants (e.g., budding, first flowering and leaf discolouration) are documented every week. The data is collected in a database via an app. The researchers also provided the participants with instructions for collecting and documenting the required observations and data. Alongside the manual assessment, sensors were installed in all flower beds to measure the air and soil temperature and soil moisture.
The mixture of private and public flower beds in Jena is spread throughout the city—from the outskirts to the city centre. Two model flower beds are located in the Botanical Garden of the University of Jena and at the »forum natura« discovery centre at Schottplatz. The former two are looked after by the Plant Biodiversity Group within the Institute of Ecology and Evolution at the University of Jena; the flower beds at the »forum natura« discovery centre are cared for by the Forestry Department within Jena's municipal services.
The model plants are insect-friendly wild plants that are easy to cultivate such as wild tulips, crown vetch, wild sage, and winter aconite. »We have a lot of passionate and committed citizens on board—and a number of schools are also involved in the project«, explains Prof. Dr Christine Römermann, who is heading the Jena section of the project. »They want to contribute to climate impact research.«. Environmental education also plays a role, says Römermann. For example, one school has created two flower beds with very different environmental conditions to observe differences on a small scale.
As the participants collect data, they exchange information with researchers as part of citizen dialogues and develop concepts for nature conservation and climate change adaptation. The researchers want to use the data collected to record the impact of the microclimate on the development of plants, which is particularly strong in cities.
They are also using the data in the »PhenObs« research project, which documents the phenology of over 200 plants in botanical gardens around the world. A comparative evaluation will provide information on the influence of the macroclimate compared to the microclimate.

Historical perspectives

Master's student Emilia Henkel is currently planning another form of cooperation between science and the general public. As the student of 20th century history and politics was writing her master's thesis, she wondered who was actually entitled to write down or tell historical stories. »How is a story influenced by the personal biography of the narrator or researcher? What do we see in sources and what remains hidden to us but is noticed by others?« Using the example of the first accommodation for asylum seekers in Thuringia near Tambach-Dietharz, she wants to get to the bottom of these questions together with citizens. »I'm particularly interested in how the events of the time are viewed differently by those affected: the former residents of the refugee centre and the neighbouring town; people who have had their own experience of fleeing and living in mass accommodation at other times and in other places; historians; and people who are not experts«, says the student. In order to get to her interviewees, she uses her contacts from previous work and from her research. Emilia Henkel wants to recruit participants for her project primarily through associations such as Camp Impact e. V., which hosts Christian camps for children in the former refugee centre.
In autumn, she will also invite young people from a migrant background and former residents of the refugee centre. Emilia Henkel hopes that engaging with the historical site will lead to exciting conversations that transcend generations.
The aim of the project is to find out how our personal experiences and backgrounds affect the way we interpret and understand historical sources. To do this, she will ask the participating citizens to interpret various text sources. The sources, which include a protest letter from former residents of the refugee centre and a local newspaper article, will be placed in the historical context of the refugee centre so that the project participants can find out when and under what circumstances the texts were written. Henkel and her team will give the respondents a few questions to encourage them to think about the content and interpret the sources. The questions will be used to generate a discussion in joint workshops.
Anyone who is unable to attend the workshops will be able to access a website to view the sources, background information and interpretations collected over the course of the project. There, the comment function makes it possible to add new perspectives, even from home. »Through the website, I would like to invite the public to reflect on the context in which historical knowledge is created, which is shaped by personal experiences, and also to look for the gaps. The refugee centre near Tambach-Dietharz is an excellent example to question what is lost when the story is written by a white, German student and not by a person with refugee experience.« ■

The »New House« near Tambach-Dietharz served as the first accommodation for asylum seekers in Thuringia between 1991 and 2003. · Photo: Emilia Henkel

PHOTO: JENS MEYER

Recognizing emotions with implants

Cochlear implants can help people with hearing loss to perceive acoustic stimuli. Unlike hearing aids, which usually only amplify sounds, electronic prostheses actually stimulate the cochlear nerve. A team of researchers led by Celina von Eiff at the Institute of Psychology have been investigating whether the implants also allow their users to pick up nuances, i.e., how something is said. The researchers have conducted an extensive study and found that the perception of vocal emotions is significantly reduced in cochlear implant wearers. The results of their study have been published in the scientific journal »Ear and Hearing« (DOI: 10.1097/AUD.0000000000001181). sh

PHOTO: JENS MEYER

High-energy proton beams

When proton beam therapy is used to treat tumors, large acceleration systems are still required. A team of researchers led by Prof. Dr Malte Kaluza are currently working on how proton beams can be generated with smaller laser systems using laser-plasma interactions and have analysed various parameters that play a role in this. Based on their results, which have been published in the journal »Physical Review Research« (DOI: 10.1103/PhysRevResearch.4.013065), they have devised a set of optimal conditions that maximize the energy yield of a proton beam. This will enable future laser systems to be configured in such a way that proton beams can be generated with a significantly higher energy yield than before. US

PHOTO: HEIKO GRANDEL

Green hydrogen on demand

Scientists from the »CataLight« Transregional Collaborative Research Centre have presented a solution approach to one of the greatest challenges of solar energy conversion. The team of researchers, including Prof. Dr Benjamin Dietzek-Ivanšić and Prof. Dr Ulrich Schubert from the University of Jena, has managed to develop a system that enables the light-driven production of hydrogen at any time of the day or year. Future areas of application for this photochemical unit range from needs-based heat generation to supplying hydrogen-powered vehicles »on demand«. The researchers from the universities of Ulm and Jena have presented their system, which is based on a single molecule that can absorb sunlight, store energy, and produce hydrogen, in the scientific journal »Nature Chemistry« (DOI: 10.1038/s41557-021-00850-8). Bingmann/AB

PHOTO: IDIV

Chemical distress call from trees

When forest trees are infested with caterpillars, they emit scents to attract predatory insects and birds and rid themselves of their pests. This phenomenon, which had previously only been detected in laboratory and garden experiments, has now been verified in a natural habitat—the 40-metre-high canopy of Leipzig Riverside Forest—by a team of researchers from the German Centre for Integrative Biodiversity Research Halle-Jena-Leipzig (iDiv) and the universities of Jena and Leipzig, led by Prof. Dr Nicole van Dam. The chemical distress calls are so effective that they have a major impact on the type of insects found in the canopy. In the future, this knowledge could be used for natural pest control in agriculture and forestry, as highlighted by the researchers in the journal »Ecology Letters« (DOI: 10.1111/ele.13943). Tilch

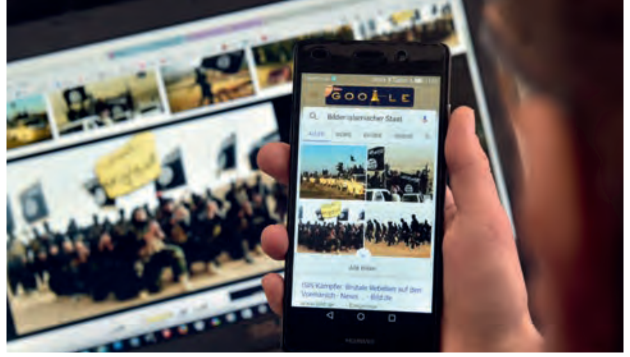


PHOTO: JAN-PETER KASPER

The phenomenon of terrorism

Historian Prof. Dr Carola Dietze from the University of Jena and her colleague Claudia Verhoeven from Cornell University have published »The Oxford Handbook of the History of Terrorism« (ISBN: 978-0199858569). In it, the researchers explore questions about terrorism and examine its social preconditions and consequences. According to the editors, terrorism today relies on mass media in order to have its effect—and the Internet is the ideal medium. Perpetrators can use the Internet themselves and provide the images that are important to them. The message of violence is always aimed at two target groups: a group of potential sympathizers and a group of people in whom they want to instil terror. sl

PHOTO: JAN-PETER KASPER

Renaissance of the concept of class

A team of sociologists have published the book entitled »Die Wiederkehr der Klassen. Theorien, Analysen, Kontroversen« (The Return of Class. Theories, Analyses, Controversies, ISBN: 978-3-593-51359-1). They take up the theory proposed by Prof. Dr Klaus Dörre, who refers to a »demobilized class-based society«. Indeed, there is still a class of the wealthy opposite the class of the wage-dependent. But the wage-dependents today look different from the working class as described by Karl Marx. In addition, new groups can be distinguished within the wage-dependent class: a successful class of »higher earners«, the traditional working class and a precariously employed lower class that fluctuates between jobs and state benefits. sl

PHOTO: JENS MEYER

Mushroom genus goes its own way

A team from the Institute of Pharmacy at the University of Jena, the Leibniz Institute of Natural Product Research and Infection Biology and the University of Freiburg have been studying the Cortinarius genus of mushrooms and discovered a previously unknown example of »convergent evolution«. The researchers have found that the mushrooms produce certain natural substances (anthraquinones) that are also found in bacteria, plants, and moulds. However, the mushrooms have developed their very own metabolic pathway for this purpose.
The team led by Prof. Dr Dirk Hoffmeister have presented their results in the scientific journal »Angewandte Chemie« (DOI: 10.1002/anie.202116142). Cortinarius is one of the most diverse genera of mushrooms. There are about 2,000 species around the world. US

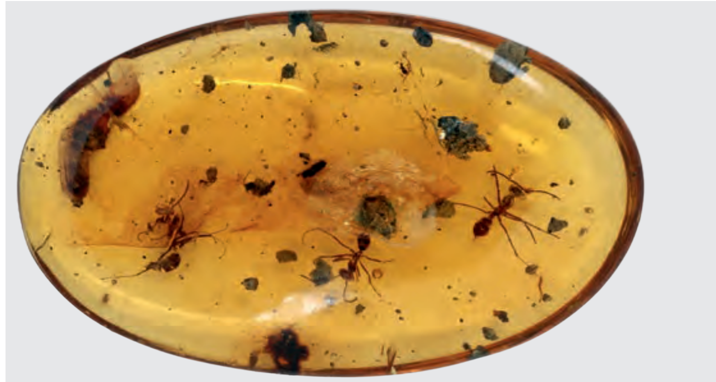


PHOTO: SHŪHEI YAMAMOTO

Division of labour in ants

An international research team led by biologists from the University of Jena has discovered the earliest evidence to date of cooperative behaviour in ants in fossils. The researchers analysed the body structures of the extinct Gerontoformica genus of ants encased in amber (see photo) and found that the insects followed a social system based on the division of labour over 100 million years ago, i.e., in the early Cretaceous period or at the time of the dinosaurs. The researchers obtained information about the species and body shape from micro-computed tomography images of the fossils, including the first ant pupa ever found in Cretaceous amber. The researchers have published the results of their work in the journal »Zoological Journal of the Linnean Society« (DOI: 10.1093/zoolinnean/zlab097). sh

Notes from Haeckel's lecture theatre

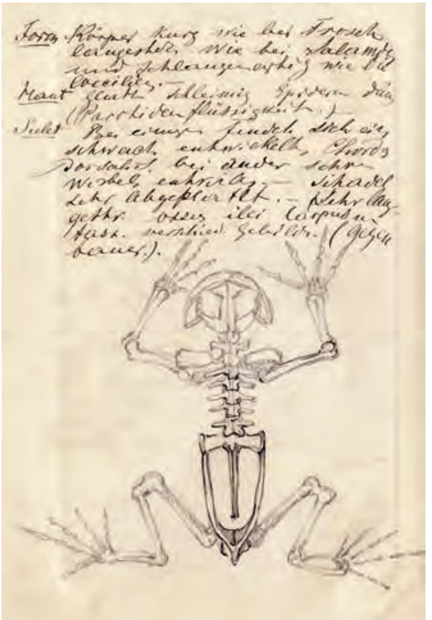
When the Russian explorer Nikolai Miklucho-Maclay attended lectures held by Ernst Haeckel and Carl Gegenbaur at the University of Jena in the mid-19th century, he recorded them with pencil and ink. Biology education specialists have unearthed these transcripts in the archives of the Russian Geographical Society and have now published them.

BY STEPHAN LAUDIEN

»This discovery is a sensation!«, gushes Prof. Dr Uwe Hoßfeld. The biology education expert and his colleague PD Dr Georgy S. Levit stumbled upon the lecture notes in 2018. They were taken during university courses held by anatomist Carl Gegenbaur and zoologist and evolutionary researcher Ernst Haeckel, both of whom worked at the University of Jena in the mid-19th century. The documents were found in the estate of the Russian explorer Nikolai Miklucho-Maclay, which is kept in the archives of the Russian Geographical Society in St. Petersburg. Hoßfeld and Levit have now published the two valuable sets of lecture notes in cooperation with other scientists.

Nikolai Miklucho-Maclay broke with Ernst Haeckel

»The notes give us lots of interesting insights into the history and visualization of zoology and comparative anatomy during that period«, says Uwe Hoßfeld. In fact, the two texts are the only surviving transcripts of those authors. They reflect the state of knowledge at the time and the teaching methods employed in the fields of zoology and comparative anatomy in the mid-19th century, specifically in 1865. The notes were written by one of Haeckel's students, Nikolai Miklucho-Maclay, who first travelled to New Guinea as an explorer in 1870 to study the indigenous Papuan population.
Miklucho-Maclay had a tense relationship with Ernst Haeckel. He was one of Haeckel's students who assisted him on research trips. However, the Russian scholar is thought to have severed ties with his professor after questioning and scientifically refuting Haeckel's views on human races.
»It would be fair to describe Miklucho-Maclay as the first empirical anti-racist in the natural sciences«, says Uwe Hoßfeld. His observations and experiences with the Papuan people show that Haeckel was wrong in assuming that there were different stages of development among the people of the world and therefore different human »species/races«.
It was also ironic that Ernst Haeckel himself had postulated that scientific knowledge presupposed observing and studying organisms in their natural habitat. Nikolai Miklucho-Maclay adhered to those criteria. The Russian also stayed with the people of New Guinea on several occasions.



Both the lecturer Ernst Haeckel and his student Nikolai Miklucho-Maclay were exceptionally good artists and aesthetes. Here are drawings of a frog skeleton (above) and a praying mantis by Miklucho-Maclay, which are taken from the notes on a zoology lecture held by Haeckel. · Photo: RGO St. Petersburg/Russland

Preparing the records was a mammoth task

The lecture notes, which have now been published, not only reflect the state of research at the time; they also reveal Haeckel, Gegenbaur and Miklucho-Maclay to be highly competent artists and aesthetes. The notes are supplemented by numerous detailed illustrations that were apparently shown in the lectures. »Nikolai Miklucho-Maclay created exact reproductions of the lectures in his notes«, says Hoßfeld. He sometimes wrote in German, sometimes in Russian—and his notes were full of abbreviations. Transcribing the texts was therefore a mammoth task that took three years.

Further experts from Jena were needed

This was only possible with the help of other scientists: Dr Rosemarie Fröber is an anatomist who contributed her knowledge of anatomical terminology and the context; the zoology lectures were also transcribed with the help of two other experts, Gerta Puchert and Achim Blankenburg. ■

Nikolai Miklucho-Maclay produced this depiction of a human skull to illustrate his notes on a lecture held by Carl Gegenbaur. · Photo: RGO St. Petersburg/Russland

Original publication:
Vorlesungen über Menschliche Anatomie von Carl Gegenbaur, THK-Verlag, Arnstadt 2022, ISBN: 978-3-945068-56-4

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An artist's impression of a kilonova that occurs after a neutron star merger. · Image: M. Weiss/CfA

A cosmic sonic boom

What does X-ray vision reveal about a kilonova? An international research team has been studying the aftermath of a gigantic cosmic explosion with the help of NASA's »Chandra X-ray Observatory«. The team also included physicists from the University of Jena, who provided detailed predictions and simulations that made it possible to interpret Chandra's X-ray data.

BY UTE SCHÖNFELDER

A »kilonova« is the massive explosion that occurs when two neutron stars merge. The »GW170817« kilonova in the Hydra constellation is the first ever object where both gravitational waves and electromagnetic radiation could be measured. It is called »GW170817« because it was discovered on 17 August 2017, when two laser interferometers—LIGO (in the USA) and Virgo (in Italy)—detected gravitational waves that coincided with a burst of gamma rays.

Jets of matter emitted from merged neutron stars

Scientists had previously assumed that the debris of merged neutron stars emitted visible and infrared light, which is produced when radioactive elements decay. In the case of »GW170817«, visible light and infrared radiation could indeed be observed several hours after the gravitational waves. However, the neutron star merger looked very different in the X-ray spectrum: Immediately after discovering »GW170817«, Chandra turned its X-ray vision to the object and detected… nothing. It wasn't until a few days had passed that Chandra was able to identify »GW170817« as a point source of X-rays.

The researchers have offered an explanation: The merged neutron stars emit a narrow »jet« of high-energy particles that is »off-axis«, i.e., not aimed directly at Earth. They suspect that Chandra was originally observing the narrow jet from the side and therefore did not see any X-rays immediately after detecting the gravitational waves. Over time, however, the emitted material slowed down and the jet cone widened as it collided with surrounding matter. This caused the jet cone to expand further and further into Chandra's direct line of sight, allowing the X-rays to be measured.

The X-rays emitted by the jet have been fading since the start of 2018 as the jet has continued to slow down and expand. However, the team found that the decrease in brightness stopped, and the radiation remained constant from March 2020 until the end of 2020.

One possible explanation for this new source of X-rays is the theory that the expanding debris from the merger created a »shock« similar to the sonic boom of a supersonic aeroplane. This shock heated up surrounding materials and the heating generated radiation, resulting in a phenomenon known as »kilonova afterglow«. An alternative explanation is that the new X-rays were due to matter falling into a black hole which must have formed after the neutron stars merged.

In order to determine which of the two explanations is correct, the researchers will have to keep observing »GW170817« and measure possible radio waves in addition to the X-rays. If it is a kilonova afterglow, the scientists expect the radio emission to get brighter over time. If it is matter falling into a newly formed black hole, however, the X-ray emission should remain constant or decrease rapidly and no radio waves will be emitted.

The observations can be explained by Einstein's theory of relativity

This is where Prof. Dr Sebastiano Bernuzzi and the former doctoral candidate Vsevolod Nedora from the University of Jena come into play. They have used a large set of simulations to analyse the mass outflows from which the kilonova signal emanates and to calculate the expected kilonova afterglow. They have found a match with the Chandra observations. While more radiation has recently been observed by the Chandra telescope, radio waves are yet to be detected in conjunction with the X-rays. ■

Original publication:
Evidence for X-ray Emission in Excess to the Jet Afterglow Decay 3.5 yrs After the Binary Neutron Star Merger GW 170817, The Astrophysical Journal Letters (2022); DOI:10.3847/2041-8213/ac504a

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The project is headed by Nils Boysen, Professor of Operations Management. · Photo: Anne Günther

The future of the last mile

The dogs of the future won't be barking at the postman—our parcels will be delivered by a mobile parcel station. Economic experts have conducted a study on novel delivery systems using specially developed optimization algorithms. Their aim is to make shipping processes as environmentally friendly as possible in our towns and cities.

BY VIVIEN BUSSE

We are increasingly hearing about an overwhelming rise in parcel volumes, delivery vehicles parked in the middle of busy streets and tough working conditions for postal workers. So, it's time for something to change on the »last mile«, the term used to describe the last leg of the supply chain between postal distribution centres and private households. A number of technology companies, such as the Swiss manufacturer Rinspeed, are currently developing mobile parcel stations that are controlled by algorithms and drive almost right up to your front door. Prof. Dr Nils Boysen and his team from the Chair of Operations Management are helping to develop and improve those algorithms. Their most recent study compared innovative delivery systems from different providers using optimization algorithms.

Algorithms for controlling mobile parcel stations

In the future, instead of the postman ringing our doorbell, we might get a smartphone notification telling us that a mobile parcel station has just arrived at the end of our street and the parcel can be collected there. For this solution to work, the parcel stations will have to know where to park and when. »Stationary parcel stations have been around for a long time«, says Prof. Dr Nils Boysen, who is leading the research project. »But they're still not very common, so people have to go a long way to find the nearest one and often prefer to collect their parcels by car rather than on foot. That defeats the purpose«. Dr Stefan Schwerdfeger, who is responsible for developing algorithms in the project, adds: »Mobile parcel stations would come much closer to customers and stop at the end of their street. Everyone on the same street would then be able to collect their parcels on foot. That would be better for the environment and would also save logistics providers time and money, especially if the parcel stations were also able to drive autonomously in the future«. Thanks to information provided by their project partners at Rinspeed, the university researchers have developed optimization algorithms that tell the mobile parcel stations where to stop and for how long. »That sounds simple, but numerous factors have to be taken into account«, says Prof. Boysen. First of all, customers will have to say when they will be at home or whether they would rather collect their parcel somewhere else, such as near their workplace. In addition, customers must be given enough time to collect their items before the parcel station continues to the next address. And a station can't just stop anywhere; safety must be ensured, says Boysen. With these factors and various other requirements in mind, the researchers are drawing up routes for mobile parcel stations to navigate towns and cities. »Our aim is to deliver a set volume of parcels at the lowest possible cost and with the smallest possible environmental impact«, says Stefan Schwerdfeger.

Comparing different concepts for mobile parcel stations

The researchers are using their algorithms to compare different concepts from various providers of mobile parcel stations. Stefan Schwerdfeger explains it like this: »Rinspeed, for example, doesn't want to have the entire vehicle parked at the end of the street with the parcel station attached—it wants the parcel station to be automatically unloaded and picked up again later. In the meantime, the vehicle can continue its journey and deliver other parcel stations«. Nils Boysen adds: »Our algorithms then tell us whether such a concept is beneficial. In this case, we've found that costs can be cut significantly by unloading the parcel stations, especially if you want to give customers more time to collect their items. After all, you won't always be able to drop whatever you're doing to sprint to the parcel station«. In the future, the researchers want to continue using their algorithms to improve deliveries over the last mile and help to deliver parcels to people in towns and cities as sustainably as possible. ■

Prototype of a mobile parcel station from the manufacturer Rinspeed. · Photo: Rinspeed AG

Original publication:
Who moves the locker? A benchmark study of alternative mobile parcel locker concepts (2022) DOI: 10.2139/ssrn.4063099

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Picture left: In the first two years of the pandemic, people in Germany could only access many public spaces with a negative COVID test · Photo: Jens Meyer
Picture right: Flavio Azevedo is the communication scientist who managed the Jena segment of the study. · Photo: Jens Meyer

A sense of community improves acceptance

A team of psychologists within an international research network have been studying the acceptance of measures imposed around the world to combat the spread of the coronavirus. They have found that a high level of national identification has a positive influence on a person's willingness to accept restrictive measures. It would seem that a strong sense of togetherness with our compatriots motivates us to do more for public health. More than 50,000 people in 67 countries were interviewed for the study.

BY SEBASTIAN HOLLSTEIN

As the COVID-19 pandemic swept across the globe, governments in almost every country introduced extensive measures that required and, in some cases, still require citizens to collectively change fundamental aspects of their behaviour. Especially in the first year of the pandemic, when vaccines were not yet available, it was parti¬cularly important that people followed instructions, such as limiting physical contact, refraining from travel, and wearing masks.
At the start of the pandemic, a network of over 250 scientists—including psychologists from the University of Jena—investigated the factors that promote the acceptance of such measures. Their study revealed that national identification plays a key role in motivating people to do more for public health. Those who have a stronger sense of shared identity are more supportive of public health policies. The researchers have published their results in the scientific journal »Nature Communications«.
»A national identity is the strongest predictor of support for public health measures during the pandemic«, says Flavio Azevedo. »Those who identify more closely with their nation are more willing to accept the heavy burdens associated with protective practices and support for public health policies«. It should be noted that a person's national identity reflects the degree to which they identify with their own nation. This was recorded using a questionnaire, some of which required respondents to assess their own feelings on a given scale. National identity is not the same as nationalism.
These findings have emerged from a unique study. In order to investigate how people around the world were dealing with the exceptional situation of a pandemic and the protective measures in their respective countries, a group of psychologists led by the US American Jay van Bavel reached out to colleagues on Twitter during the first wave of the pandemic, asking them to collect data in their respective countries. As a result, more than 250 scientists participated in the study. In April and May 2020, they interviewed around 50,000 people in 67 countries to find out how rigidly they were following the social distancing and hygiene guidelines and how strongly they supported the political measures.
The researchers then verified their results based on another study. They compared national identi¬fication data from the World Values Survey—a regular international survey of human values—from a period before the pandemic with mobility data collected by Google from the spring of 2020. This confirmed the results of the first study: In countries with a higher average level of national identification, the citizens restricted their mobility more during the months of April and May 2020.

Overcoming dangerous situations with a sense of community

»We know that three psychological factors promoted the spread of Spanish flu 100 years ago: an incorrect risk assessment; resistance to social isolation; and the inability to adhere to preventive measures against an invisible threat«, says Flavio Azevedo. »That's why it's particularly important for behavioural scientists like us to monitor such an exceptional situation in which people are collectively called upon to change their habits«, explains the psychologist. »It gives us fundamental insights into human behaviour and decision-making processes, helping to devise protective measures before and during a pandemic«. For example, the current research results show how important it is to promote a sense of community and togetherness when faced with such a globally dangerous situation.
The network will continue to evaluate the data collected and present further research results.

More information can be found here: https://icsmp-covid19.netlify.app/index.html ■

Original publication:
National identity predicts public health support during a global pandemic, Nature Communications, 2022,
DOI: 10.1038/s41467-021-27668-9

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Textbook knowledge revised

For around 200 years, numerous textbooks have stated that the magnetic field outside of a long coil is zero. But when this claim was questioned by the student Jonathan Bollig during a lecture held by Prof. Dr Gerhard G. Paulus in the 2020 summer semester, a subsequent experiment proved him right: The statement is not accurate. In this interview, the physicists explain what this is all about.

INTERVIEW: MARCO KÖRNER

Mr Bollig, it was your question that got the ball rolling—what exactly did you want to know?
Bollig: One of our online physics lectures in the 2020 summer semester was about the long coil through which an electric current flows. Using an online polling tool, Prof. Paulus asked us about the magnetic field outside the coil. There were different possible answers. Instinctively, I said that the magnetic field would decrease linearly with distance. But then I was told that there was no magnetic field outside of the coil, at least not along its axis. I gave it some thought and came to the conclusion that there should still be a magnetic field, namely along the winding. As if the coil were simply a wire. I then asked Prof. Paulus about it.

Paulus: With regard to Ampère's Law, there are only two possibilities that are easy to calculate: One is an infinitely long wire and the other is an infinitely long coil. And for an infinitely long coil, we get the following answer: Outside of the long coil, the magnetic field is zero. That's what it says in all the textbooks and that's what I've always taught—for over ten years. I was taught the same as a student. And then Mr Bollig turns up at my tutorial one evening and says: »But a small component of the current must flow in the direction of the coil's axis!«. I was taken aback at first and then it really bugged me that I hadn't noticed it myself over the past 30 years. I recognized immediately what the magnetic field must look like outside of the coil, but I still sat down on my patio the weekend afterwards, wound a coil and measured the magnetic field. Mr Bollig was right!

So why did we previously assume that the magnetic field outside of the coil was zero?
Paulus: That wasn't just an assumption—it was a consequence of the fundamental fact that magnetic field lines are closed curves. And that fact, in turn, comes from the well-known fact that magnetic north and south poles come in pairs.

Apart from the subtle detail discussed in our article, the magnetic field lines in a coil run parallel to the coil axis. The denser the magnetic field lines in the coil, the stronger the magnetic field. When the field lines emerge at the ends of the coil, they have to return to the other end by going around the coil—otherwise the field lines wouldn't be closed curves. Now you can imagine what happens when the coil gets longer and longer: The density of the magnetic field lines—and therefore the strength of the magnetic field outside of the coil—gets smaller and smaller.

Now, the coil you built on your patio wasn't infinitely long!
Paulus: Well, it's half a metre long. And its diameter is two centimetres. So, in comparison to the diameter, it's—almost—infinitely long.

Ampère's law put to the test

If a current flows through an electric conductor, a magnetic field is induced around the conductor; the field lines run in circles around the conductor. The strength of the magnetic field depends on the strength of the electric current. This is described by Ampère's Law, which was formulated by André-Marie Ampère in 1822. He also found that the magnetic field generated by a wire decreases proportionally with distance from the wire.

In the thought experiment of an extremely long—or infinitely long—coil, experts had previously assumed that a magnetic field could only be found inside the coil, where it was aligned parallel along the axis of the coil. Outside of the imaginary, infinitely long coil, the magnetic field was said to be zero. And that's exactly how it's been written in physics textbooks for around 200 years.

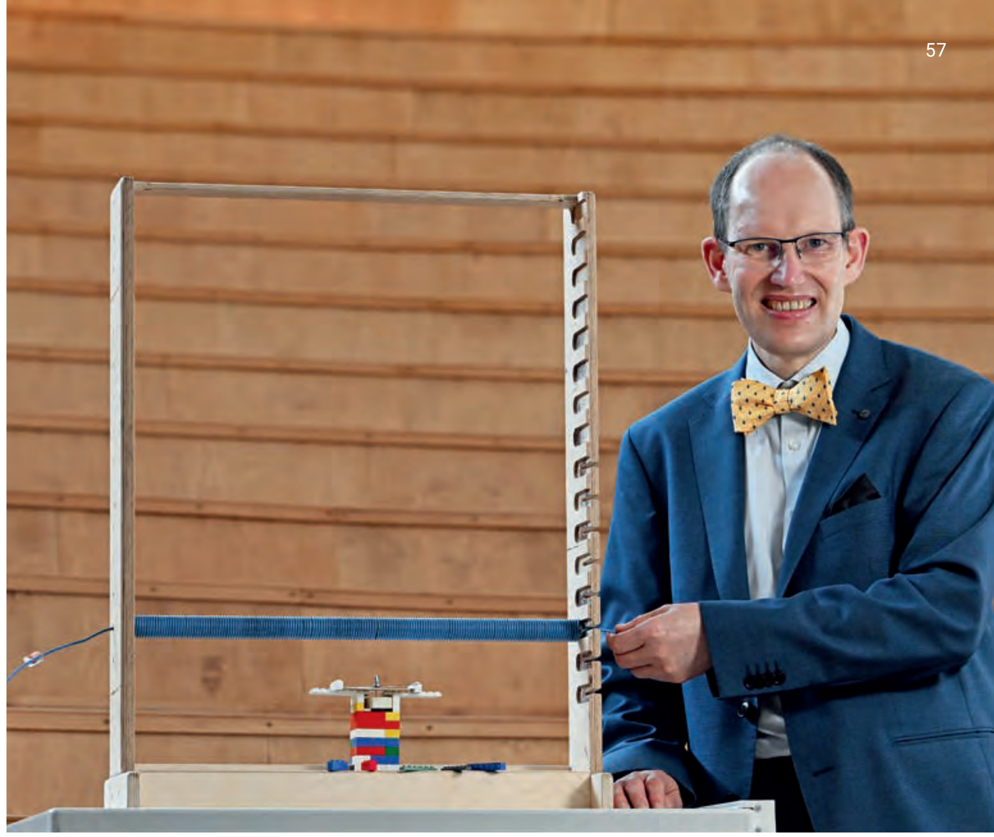
But this assumption is wrong, as physicist Gerhard G. Paulus and his student Jonathan Bollig write in the physics journal »Physik in unserer Zeit«. According to the authors, the magnetic field outside of a long coil is equivalent to that of a wire through which an equally strong current flows. The imaginary wire runs parallel to the axis of the coil. Although the magnetic field components outside of an infinitely long coil disappear in this direction and radially outwards, the component tangential to the coil winding does not.

The physics experts from the University of Jena have demonstrated this in a simple, self-made experiment where they wound a coil of standard insulation wire, which was not infinitely long but had 166 windings and a total length of 50 centimetres and applied a current. They placed a compass needle on a height-adjustable Lego structure beneath the coil and used it to measure the magnetic field outside of the coil as a function of the distance from it. This set-up can also be used to determine the local strength of the Earth's magnetic field.

Bollig: The set-up is very simple: The wire has to be insulated to prevent short circuits. It's wrapped around a tube and then an electrical current is passed through it.

Paulus: In order to measure the magnetic field quantitatively, we built a frame for the coil and a magnetized needle that allowed us to determine the magnetic field at different distances from the coil. The frame is oriented in such a way that the axis of the coil points north. When the current is not flowing, the magnetized needle aligns itself parallel to the axis of the coil—so simply according to the Earth's magnetic field. If I now turn on the power and regulate it until the magnetized needle is at a 45° angle (to the northwest or north-east), the magnetic field outside of the coil will be just as large as the magnetic field of the Earth. If I increase the distance between the magnetized needle and the coil, I have to increase the current flow accordingly to achieve the same deflection of the magnetized needle.

Have you been showing your experiment in your lectures?
Paulus: I have not done that so far due to time constraints. It's a subtle detail and could cause confusion if I don't take enough time to explain it. But it could be a good practical exercise.



Prof. Dr Gerhard G. Paulus presents the »do-it-yourself« experimental set-up with which he and physics student Jonathan Bollig have uncovered a scientific fallacy. · Photo: Jens Meyer

So, everyone who answers according to the textbooks would be wrong?
Paulus: We can learn from our mistakes! And the exercises won't be graded.

In the publication, you say that you're probably not the first to notice this. But you're amazed that such a mistake has remained in textbooks for so long. Apart from this publication, do you have any ideas how the textbooks could be corrected?
Paulus (laughing): The first step would be for me to bring up the issue in my lectures…

What exactly is meant by »textbooks«? Is Ampère's Law is taught in schools?
Paulus: Partially. In my 40-year-old collection of formulas from school, there is a formula to work out the size of the magnetic field inside a long coil. But I don't think the derivation is done in schools.

In your publication, you write that the Danish physicist Hans Christian Oersted observed as early as 1820—two years before Ampère—that an electrical current in a wire can deflect a magnetized needle; and this had even been published 18 years earlier by the Italian Gian Domenico Romagnosi.
Paulus: Romagnosi was a jurist and, as far as I'm aware, he published his observation in a daily newspaper, which obviously failed to attract a lot of attention. He probably didn't realize the significance of his discovery. Oersted, on the other hand, was »electrified« and had his observations immediately printed at his own expense. He sent the manuscript to all academies in Europe. That's how he became famous. For a while, the unit of magnetic field strength was even named after him—the ultimate honour for a physicist. ■

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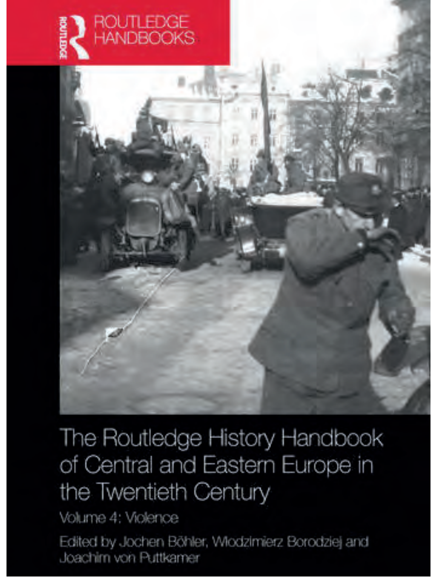
Violence in Eastern Europe

The »Imre Kertész Kolleg« at the University of Jena presents the fourth and final volume of its »History Handbook of Central and Eastern Europe in the Twentieth Century«.

BY STEPHAN LAUDIEN



The »Imre Kertész Kolleg« recently published a volume entitled »Violence«, marking the culmination of its four-part »History Handbook of Central and Eastern Europe in the Twentieth Century«. On the one hand, the volume examines the violence exerted on Eastern European societies by war-hungry powers and totalitarian regimes in the 20th century. On the other hand, it focuses on the violence caused by conflicts between ethnic, social and national groups and the interaction between the two phenomena. »In view of the war in Ukraine, it seems almost ironic that the final volume in the series deals with the history of violence in Eastern Europe«, states Prof. Dr Joachim von Puttkamer, the director of the »Imre Kertész Kolleg«.
The authors examined experiences of violence during the wars in the Balkans, which began in 1912 and only ended with the Yugoslav Wars from 1992 to 1995, as well as the history of both World Wars, which raged in Eastern Europe in particular.
The new volume also looks at how those experiences of violence have continued to have an impact since 1945, says Joachim von Puttkamer. Put simply, a gradual change in the experience of violence can be observed—from brutal violence to more subtle methods that nevertheless have the same self-destructive potential of violence. The chapter on Poland and Romania has also become the legacy of Włodzimierz Borodziej. The co-director of the »Imre Kertész Kolleg« passed away in 2021.

Book series combines twelve years of research

»The Routledge History Handbook of Central and Eastern Europe in the Twentieth Century« crowns the work carried out by the »Imre Kertész Kolleg« in the twelve years since it was founded. The four volumes cover the entire belt of countries between Germany and Russia—from the Baltic States to Bulgaria—with a somewhat pronounced focus on larger countries such as Poland, the former Czechoslovakia, Romania, and the former Yugoslavia.
The volume entitled »Challenges of Modernity« explores profound economic and social change from the agricultural societies on the European periphery to state-socialist industrialization and the transitioning societies of the present. The volume on »Statehood« examines imperial and national, democratic, and dictatorial traditions in a century in which state institutions have reached deep into people's everyday lives. The volume on »Intellectual Horizons« focuses on views of history and identities, literature, and culture.
The authors take a transnational and comparative approach in considering key lines of development to create a deeper understanding of the region as a whole. The handbooks provide a comprehensive overview of the region's history, from periods of imperial domination before the First World War, to the long shadow of German occupation in the Second World War and the subsequent experiences of state socialism, followed by periods of continuous transformation and, to a large extent, membership in the European Union in the late 20th century. Written by a number of renowned, international authors, many of whom come from the region themselves, the handbooks will become standard reference works for the history of Central, Eastern and South-Eastern Europe in the 20th century. Even after the completion of this project, Prof. Joachim von Puttkamer assures that the »Imre Kertész Kolleg« will continue its work. After all, expertise in the field of Eastern Europe is urgently needed, especially in view of the war in Ukraine. In doing so, the Kolleg can build on its stable network of international experts—almost 170 researchers alone worked there as fellows. ■

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What happens after the pandemic?

Although the coronavirus pandemic is not over yet, most infection control measures at universities and schools were lifted at the beginning of April. And rightly so, from the point of view of pupils and students, says Prof. Alexander Gröschner. The Professor of Research on Teaching and Learning identifies how social relationships and interactions suffer when learners communicate with others exclusively or mostly online. Because learning is not just an individual process, but also a deeply social one.

BY ALEXANDER GRÖSCHNER


Prof. Dr Alexander Gröschner, Educational Scientist at the Chair for Research on Teaching and Learning. · Photo: Jens Meyer

Between »digitalisation euphoria« and »remote learning fatigue«

Remote learning, as one of our studies shows, leads to an increase in emotional anxiety (e.g., caused by reduced support from teachers) and exacerbates inequality between different social groups (e.g., due to a lack of technical equipment), especially within the context of schools. This situation has been emphasised as a characteristic of the German education system for many years. Recent studies in the academic context of higher education come to a similar conclusion: here, too, online teaching has led to an increase in the perception of stress and there are significant correlations between the perceived conditions for studying and symptoms of depression among students.
Learning is by definition an active, constructive and individual process. Teaching staff were all the more surprised during the coronavirus pandemic when students, who supposedly have—or should have—more individual responsibility, self-regulation and intrinsic motivation compared to school pupils, were increasingly unable and unwilling to cope with the new teaching routine and the freedoms provided by learning online from home.
At the same time, the circumstances of remote learning enabled rapid progress in digitalisation, in a way that many had not expected, in the schools of a German federal education system otherwise not noted for innovation. This is impressively demonstrated, among other things, by the schools that won the renowned »2021 German School Prize«. These schools have developed smart ideas and impressive measures to offer educational opportunities that have encouraged learning in pupils of all ages and school types.
At university, too, new technologies, such as the use of augmented and virtual realities in our Teaching-Learning Labs, have opened up new ways of acquiring knowledge. Virtual interaction, for example with students in the courses accompanying the practical semester of the teacher training programme, has made innovative formats of collaborative remote learning possible.
Despite the current relaxations in rules, protective measures against the coronavirus are generally important, and careful management of teaching will continue to be important for quite some time. For schools and universities, however, it has become clear that learning is not just an individual process, but also a deeply social one. Good technological facilities alone do not ensure successful communication. In addition to the virtual space, physical spaces are also necessary for face-to-face interaction and dialogue, as well as social contacts before and after a lecture.

What remains? The desire for internal differentiation and interactions that promote learning

If the best possible educational opportunities are to be provided for all school and university students, we need an increasingly differentiated view of the design of everyday teaching and learning. In our »toolbox«, new technologies offer us opportunities to take into account the individual learning pace of students, and to offer support formats, feedback systems and formative performance feedback.
In the future, teaching and learning should therefore include a more differentiated range of synchronous and asynchronous learning opportunities, both face-to-face and virtual. To achieve this, it is crucial for teachers to plan their courses with clear goals and keep in mind the individual requirements of the students. We still view learners far too often as a »homogeneous« group, with the same strengths and weaknesses.
The perspective that remains is a wish to establish how interactions that promote learning should be started in everyday university life. In this vein, Jürgen Habermas wrote in an essay on university learning processes published in 1986 in the Zeitschrift für Pädagogik: »The doors are open, at any moment a new face can appear, a new thought can enter unexpectedly.« May this creative start to the teaching-learning process return, even if much of what is new is allowed to remain. ■

Extensive plant archive

Dr Jörn Hentschel is the curator responsible for sorting specimens in the depository of the »Haussknecht Herbarium« at the University of Jena. With more than three million specimens of dried plants, a library containing around 170,000 bibliographic units and an extensive archive, the »Haussknecht Herbarium« is one of the 20 largest herbaria in the world.

The master of syntax

This year marks the 100th anniversary of Berthold Delbrück's death. The linguist is regarded as an important figure in Indo-European Studies in Germany, who researched and taught at the University of Jena for more than 40 years. He also served four terms as the university's rector, including in the important anniversary year of 1908.

BY SEBASTIAN HOLLSTEIN

PHOTO: UNIVERSITÄTSARCHIV

In his last term of office as »pro-rector« (the equivalent of today's rector or president), Berthold Delbrück introduced an important innovation that benefited scientists young and old: He allowed professors at the University of Jena to retire at the age of 70, so that they didn't have to wear themselves out into old age. This measure, which also brought about a reduction in the average age of teaching staff, was described by Delbrück's biographer, Eduard Hermann: »This probably gave many people the opportunity to leave their post when they were still fresh in the mind, leaving colleagues and students with a feeling of regret that the step had actually been taken too soon. Because a professor with healthy organs does not tend to age as quickly as other people due to his constant interaction with youth and a profession that he loves above all else«.

And the feeling of regret amongst students and staff must have been great when Delbrück himself retired five years later. After all, the »master of syntax« (Hermann) not only enriched his very young discipline of Indo-European Studies, but also left a lasting impression on the University of Jena as an institution.

Berthold Delbrück was born in Putbus on the island of Rügen in 1842 and moved to Halle/Saale in 1852 following the death of his father, who was a jurist. There he began studying comparative linguistics in 1859. He continued his studies in Berlin from 1861 and finished a year later in Halle. After subsequently taking the state examination, working as a teacher and completing a research stay in St. Petersburg, which resulted in his habilitation thesis, the University of Jena appointed him as an associate professor of Sanskrit and comparative linguistic research in 1870. He was ultimately appointed as a full professor in 1873.

Jena was an early centre for Indo-European Studies

Jena had established itself early on as a centre for the young discipline of Indo-European Studies—mainly thanks to August Schleicher, who became the first linguist to work intensively on the reconstruction of an Indo-European proto-language from 1857 to 1868. Two years later, Berthold Delbrück started researching Indo-European languages in Jena—and added an important aspect: »Not only did he bring together the knowledge that had been gained within Indo-European Studies up to that point—he also established a completely new field of research with regard to the syntax of Indo-European languages«, wrote his successor, Rosemarie Lühr, in 2011. His colleagues had previously focused exclusively on morphology and phonology. Some of his writings, such as »Old Indian Syntax« and »Comparative Syntax of Indo-European Languages« are still considered standard works to this day. In his later years, he devoted himself primarily to Germanic syntax. Delbrück frequently ventured into other disciplines such as law, and his research work went hand in hand with his passion for teaching.

The expert in Indo-European languages rubbed shoulders with other important contemporaries in Jena, engaging in lively discussions and even friendships with important scholars such as Ernst Haeckel, Rudolf Eucken, Ernst Abbe and Eduard Rosenthal. He was widely respected for his open-mindedness and many people asked him for advice. At the same time, Delbrück was not free from anti-Semitic ideas, even though he rejected legally entrenched anti-Semitism.

Delbrück was also a political activist. As an admirer of Bismarck, he joined the National Liberal Party and stood as a candidate for them in the 1887 Reichstag election. It was mainly his talent for speaking that got him to the run-off election, which he probably lost due to »fake news«. His competitors spread the rumour that the Liberals had put 20 pfennigs in some ballot papers to help voters make up their mind.

At least this meant that he could dedicate his organizational talent entirely to the University of Jena, where he served as rector on two more occasions after 1885: in the 1897 winter semester and in 1908, when his experience was required to organize the university's 350th anniversary celebrations. In addition to those celebrations, there were more important dates in 1908 such as the opening of the main university building and the Phyletic Museum. Over the course of the festivities, Delbrück was named an honorary citizen of the city of Jena. Even after his retirement in 1913, he continued his academic work, publishing writings and holding lectures until 1921. However, an eye condition that had plagued him for several decades made his everyday life increasingly difficult. Berthold Delbrück died in Jena on 3 January 1922. ■

Preserving Ethiopia's cultural heritage

Research team from the University of Jena creates a digital cultural heritage register with partners

Over the next two years, a team of researchers from the University of Jena headed by Prof. Dr Norbert Nebes will be cooperating with the German Archaeological Institute (DAI) to create an »Ethiopian Heritage Digital Atlas« (EHDA). The project, which is being carried out in cooperation with the Ethiopian antiques authority and Addis Ababa University, has received around 215,500 euros in funding from the Gerda Henkel Foundation. The aim of the web-based monument information system is to ensure the preservation of cultural heritage in northern Ethiopia, the region in which the ancient Sabean people left their mark almost 3,000 years ago. The core of the EHDA is a geographic information system that records archaeological sites, monuments and objects and links them geographic information on a map. US

PHOTO: KLAUS MECHELKE

Self-presentation practices

Project examines competences of young people with disadvantages when starting a career

How can young people with disadvantages better manage to get into work after school? This question is being investigated by researchers from the universities of Jena and Paderborn as part of a new research project entitled »Self-presentation practices—approaches to a self-determined, multi-modal skills assessment for young people with disadvantages/disabilities« (»SeiP«). The interdisciplinary project led by business educationist Prof. Dr. Petra Frehe-Halliwell is funded by the Federal Ministry of Education and Research as part of the »Inclusive Education« funding measure with a total of around 700,000 euros over a period of three years. The aim is to develop a further education programme to help young people recognize their own strengths and use them on their career path. Reckendorf/AB

PHOTO: JAN-PETER KASPER

Quantum chips

University invests in Q.ANT start-up

PHOTO: BESIM MAZHIQI

The Institute of Applied Physics (IAP) at the University of Jena and the Fraunhofer Institute for Applied Optics and Precision Engineering (IOF) are part of the consortium behind Q.ANT, a Stuttgart-based quantum start-up. The Federal Ministry of Education and Research (BMBF) is providing the consortium with 42 million euros in funding, and the consortium partners are contributing a further 8 million euros. The funds will be used to set up a demonstration and testing facility for photonic quantum computer chips. The project members from the University of Jena, led by Prof. Dr Andreas Tünnermann, are taking on development tasks worth 12.6 million euros, including activities related to light sources. In addition, they are contributing their valuable expertise in the field of hybrid assembly and connection technology. The project partners are looking to present their first prototype within the next two and a half years. Haak

AI at university

THInKI project strengthens the topic of AI in teaching

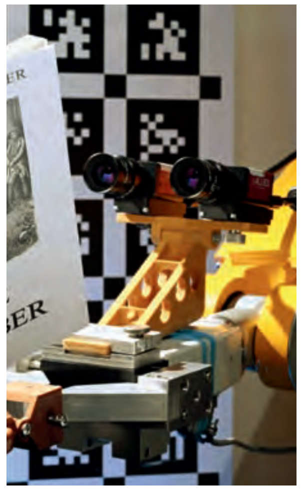

PHOTO: JAN-PETER KASPER

As artificial intelligence (AI) continues to permeate all areas of society, AI-related content is being developed for courses offered by the universities of Jena and Ilmenau as part of a new research project entitled the »Thuringian University Initiative for AI in Studies« (»THInKI«). The project is being coordinated by the Thuringian Centre for Learning Systems and Robotics (TZLR) as a joint institution of both universities. In the next four years, the project members will develop course content, teaching materials and qualification opportunities for teaching staff and employees to teach AI skills. Students and lecturers should thus be enabled to gain more knowledge and skills about artificial intelligence. The project will receive around 3.8 million euros in funding from the Federal Ministry of Education and Research (BMBF) over the next four years. Frezzella/AB

Digitalizing the sense of smell

EU project on the detection of altered body odours

The month of April saw the launch of a project entitled »Smart Electronic Olfaction for Body Odour Diagnostics« (»SMELLODI«). The project members include psychologist Prof. Dr Ilona Croy and Dr Alexander Croy from the Institute of Physical Chemistry. Over the next three years, they will be working with partner institutes in countries such as Israel and Finland to develop intelligent electronic sensors that can detect healthy body odours and those altered by illness and transmit them digitally. This technology is intended to pave the way for the digitalization of our sense of smell. In addition, it can help to make valuable information available and interpretable for medicine as a fast, immediate, and non-invasive diagnostic tool. The project is receiving around three million euros in funding from the European Union. AB

PHOTO: ANNE GÜNTHER

Streamlining administration with AI

Research teams develop AI-based solutions for the digitalization of public administration

The federal, state, and local governments in Germany have committed themselves to digitalizing administrative services as part of the Online Access Act (OZG). Researchers from the University of Jena, in cooperation with the Thuringian Ministry of Finance, Bielefeld University and the Institute of Data Science of the German Aerospace Centre, are now designing AI-based solutions as part of two research projects to prepare public administration for this. The projects are called »Canareno: computer-aided analysis of electronically available legislation« and »SimpLEX: simplifying the creation and processing of electronic documents through the use of machine-readable standards and document modules« and have received around five million euros in funding from the Federal Ministry of the Interior and Community (BMI). sh

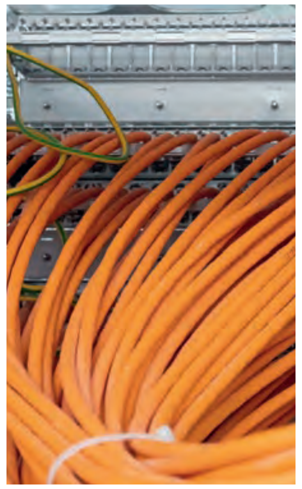

PHOTO: JENS MEYER

Jena4D

Virtual city history book to participate in

PHOTO: SANDER MÜNSTER

Would you like to stroll through Jena's city centre and see on your smartphone what it used to look like? Jena4D will soon make this journey back in time possible. The aim of the new project led by Dr Andreas Christoph and Junior Prof. Dr Sander Münster is to invite citizens to remember times of old and share historical photographs.
Jena4D will expand an existing browser application to display the entire city centre in 4D. The historical photographs will be supplemented with stories and anecdotes. In addition, participants will be able to create and design digital city tours to piece together a digital 4D history book for tourists, older residents, and future generations. The one-year project will receive around 200,000 euros in funding from the German Federal Cultural Foundation as part of the »dive in« programme. Barbutev

How do I want to be?

Teaching project supports personal development in medicine

PHOTO: UKJ

Medical studies convey specialist knowledge and practical skills—and patients, colleagues and society also high expectations of doctors' sense of responsibility and integrity. Jena University Hospital (JUH) wants to foster a scientific and professional ethos in prospective physicians by offering a new range of long-term courses aimed at developing a sense of medical professionalism.
The »Longitudinal Curriculum for the Development of Medical Professionalism« (»LongProf«) is currently in the pilot phase and is scheduled to last two years. The range of courses will be aimed at students from the fifth semester onwards. The project is headed by Dr Sven Schulz, whose Institute of General Practice and Family Medicine at the hospital is responsible for the overall coordination. vdG

A passion for rocks and minerals

Dr Birgit Kreher-Hartmann's heart beats for minerals and rocks. Even as a child, she was fascinated by the things that others carelessly overlooked on the side of the road. Today she is the curator of the Mineralogical Collection at the University of Jena. She wants to pass on her knowledge and passion not only to students, but above all to schoolchildren. We present the dedicated scientist and her passion.

BY VIVIEN BUSSE

When you enter the Mineralogical Collection, you can see cabinets full of rocks and minerals in almost every corner of the room, grabbing your attention as they glitter and shimmer in the light. The very first room features a particularly large and impressive exhibit—a piece of quartz that can be admired up close without a glass case. Dr Birgit Kreher-Hartmann is the curator of these glistening, colourful and sparkling pieces.

Love for inanimate nature

She developed a love for inanimate nature at an early age. As a child, she would collect stones and minerals when she was walking with her grandparents. »It all started in third grade when we looked at minerals from the Harz Mountains in class«, recalls Kreher-Hartmann. When she was still at school, she attended public lectures at the University of Braunschweig to learn about the physical and chemical properties of minerals and their occurrence and formation. She was particularly fascinated by mineral microscopy. She has remained an avid collector to this day.
In addition to endowments, donations and estates, some items in the Mineralogical Collection were collected on Kreher-Hartmann's private trips. When asked whether and how much her passion for collecting affects her private life, she can't help but laugh. »My husband soon learned that ›handpieces‹ are terrain samples that can only be carried with both hands«, she says.

There are now more than 80,000 exhibits in the Mineralogical Collection, which Birgit Kreher-Hartmann has been managing for just under 30 years. Founded in 1779, the collection is now housed at the Chair of General and Applied Mineralogy within the Institute for Geosciences.
The 58-year-old explains that starting out as a curator was far from easy. As she talks, her hands brush over her pendant—a polished, dark red stone. One of her PhD colleagues at the University of Würzburg told her about the position advertised in Jena. On her very first day as the head of the collection, she had to spontaneously lead a guided tour. »All my colleagues had gone home, but I was pretty bewildered and ended up confirming a guided tour for a school class on the phone. I had a lot to say about mineralogy after my studies, but I had absolutely no idea what was in the collection«. Of course, things are different today.

Green desires

Her favourite item in the collection is an emerald crystal from Muzo, Colombia. »It's strange because green isn't really my colour, even though I like to be in the countryside surrounded by nature«, explains the keen cyclist. »But that green is intoxicatingly beautiful«. The crystal in question is completely transparent and clearly stands out from the calcite crystals around it.
Birgit Kreher-Hartmann sees the collection as more than just a museum—it is also an important place of education. »We live in a world made of minerals. They're the building blocks and raw materials for everything we use in our everyday lives«. She's critical of the fact that mineralogy is only marginally included in school curricula. »If you can't tell a birch from a conifer, that's a problem. But if you can't tell basalt from granite, nobody cares«. That's why Kreher-Hartmann offers various workshops for schools and training courses for teachers. She also regularly takes guests from the university on guided tours of the collection. Her passion for rocks, minerals and the scientific collection has also been recognized outside of the university—the Thuringia Museum Association has awarded her the Bernhard von Lindenau Medal for her dedication.
But that's by no means the end of Birgit Kreher-Hartmann's commitment. She is a long-standing member of the jury for »Jugend forscht«, a youth research competition in Thuringia, she is the press officer for the German Mineralogical Society, and she also heads the minerals working group at the National Museum of Natural History in Braunschweig. She also spent many years acting as the spokesperson and deputy spokesperson for mineralogical museums and collections in German-speaking countries.
When Birgit Kreher-Hartmann is not busy with her professional and voluntary work, she likes to perform music. She has been playing viola in the Academic Orchestra Association for 25 years. The viola has been her instrument since the 10th grade—and before that she learned to play the violin for four years. Besides the orchestra, Kreher-Hartmann also plays in a string quartet. »Music gives me balance and inner peace«, she says. She also values the fact that music brings people together, for example when she participates in exchanges with a Japanese orchestra and travels with her fellow musicians to countries such as Italy and Denmark. And she also benefits from the exchange of ideas within the orchestra in Jena, where she talks to people from other parts of the university.

Balance on the bike

Kreher-Hartmann, who lives in Jena with her husband and son, says she always looks forward to a few quiet holidays with her family as a further balance to her work. »For example, we like to go cycling in Brandenburg«. But her love and keen eye for minerals won't let her go, even on holiday. So, she will continue to collect here and there or marvel at nature and its wonders. ■

Scientist, musician, collector—Dr Birgit Kreher-Hartmann in »her realm«, the Mineralogical Collection at the University of Jena. · Photo: Jens Meyer

»We should be thinking beyond Putin's era«

Ever since Russia launched its invasion of Ukraine on 24 February, the world has been shocked by scenes of ongoing violence. We asked Prof. Dr Joachim von Puttkamer, expert in Eastern European history and director of the »Imre Kertész Kolleg« at the University of Jena, to assess the situation. The interview was conducted almost seven weeks into the war.

INTERVIEW: STEPHAN LAUDIEN

Can you explain the war in Ukraine to us?
We historians can place things in a greater context to create a bigger picture. In doing so, we look well beyond the last ten or 20 years. In the 20th century, Eastern Europe was heavily influenced by wars and mass violence. We can differentiate between violence that originated in the region itself and violence that was brought in from outside by belligerent neighbours. This external violence was clearly more prominent. In recent times, specifically since 1991, Ukraine has been a peaceful country internally. There was tension, of course, but it wasn't until 2014 that violence was brought in from outside again.

The media often refer to the events as »Putin's war« or »Putin's invasion of Ukraine«. But Putin surely can't wage war by himself.
The »siloviki«, who control the power structure, are interesting in this context. We've seen Putin give those men a roasting on camera, not least to hold them accountable and share responsibility.

Yet Putin remains the dominant force. What drives the man?
I think Putin has been pursuing a project and sees this as an opportune moment to complete it. We can also see that he may have health issues—he's probably aware that his presidency won't last forever. The whole propaganda aims to conjure up the idea that Putin's plans are a national project.

But the president isn't Russia.
Of course not. And we should be thinking beyond the war and the post-Putin era. It remains to be seen how long the people will support the war when thousands—perhaps even tens of thousands—of Russian soldiers have lost their lives, when thousands of families have been affected.


Joachim von Puttkamer is a professor of East European History at the University of Jena and the director of the »Imre Kertész Kolleg«. · Photo: Anne Günther

Can we count on Russian civil society?
That's a difficult question. We're currently witnessing enormous pressure being put on protesters who speak out against the war. Any form of dissidence, or even the slightest suspicion, is met with fierce resistance from the authorities. Students who take a stand against the war run the risk of being expelled and drafted into the army.

So, can Putin not be sure of his own people?
The official version of events used to keep the Russian population quiet is »us against the world, the world against us!«. Hardly anyone can tell how long the consensus will last.

Some people like to look far back into history to explain the background to this war. Is the »sister nations« narrative even true?
Russia, Ukraine, and Belarus have common origins in Kievan Rus'. We're talking about the 9th and 10th centuries when the Christianization of Old Russia began. Large swathes of today's Ukraine later belonged to the Polish crown, and then both Ukraine and Russia were part of the Soviet Union. Since 1991, Ukraine has been an undisputed sovereign state whose borders were actually guaranteed by Russia in 1994. Of course, there are still many close ties between Ukrainians and Russians, but the current conflict is only helping to deepen the rifts between them.

Is the war in Ukraine affecting the work of the »Imre Kertész Kolleg« in any particular way?
Yes, in many respects. Journalists are increasingly asking us to assess the situation, we held a panel discussion right at the start of the war, which was very well received, and we're supporting our colleagues. For example, we've managed to bring Irina Scherbakowa from the Russian NGO »Memorial« to the »Imre Kertész Kolleg« for one year as a fellow with the support of the Körber Foundation, the Thuringian State Chancellery and the Buchenwald and Mittelbau-Dora Memorials Foundation. We're also offering a perspective at the Kolleg for a couple of Ukrainian scientists. ■