discovered

THE HZDR RESEARCH MAGAZINE

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Undiscovered Worlds

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HZDR physicists explore the vacuum

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Microorganisms in radioactive waste repositories

HZDR

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COVER PICTURE: The Earth's magnetic field has a major impact on our everyday lives. But we still do not exactly know how it comes about. HZDR researchers set out to find the answer. Illustration: ESA/AOES Medialab

DEAR READERS,

"Science knows no boundaries" – for just over a year, this phrase has adorned the entrance to our Dresden Campus. It reflects, on the one hand, the reality at all scientific institutions. From talented Ph.D. students via ambitious postdocs to established professors – excellent research opportunities attract the world's best. And they bring along novel ideas and creative approaches. On the other hand, the phrase "Science knows no boundaries" also has a metaphorical meaning because, time and again, it is the curiosity of many individuals that has pushed back apparently insurmountable barriers of thought and knowledge.

This edition of our research magazine "discovered" looks at the undiscovered worlds researchers enter when they allow their thoughts free reign. They engender superlative experiments such as those on the Earth's magnetic field, the precise origins of which are still unknown. In our project for the future DRESDYN, researchers around Frank Stefani are seeking to solve this puzzle using liquid sodium (p. 4). The experimental set-up for the world's first precision dynamo is, however, also a challenge for our construction specialists as well as for the planners, builders and industrial companies involved. The foundations alone, which require seven reinforced concrete pillars to be anchored 22 meters into the granite bedrock, illustrate the dimensions.

Most of all in this edition of "discovered", we want to showcase visionary research ideas. But elaborate projects and novel experiments are impossible without the bright people in the background who help to ensure that ideas are turned into reality. One such "facilitator" is certainly Peter Joehnk, HZDR's Administrative Director, who developed a master plan for the Dresden Campus as long ago as 2002 (p. 27). Since then, all measures are assessed according to economic, ecological and aesthetic criteria. The aim is to create an attractive site with outstanding working conditions for world-class research.

I look forward to receiving your comments and suggestions and hope you enjoy reading the latest "discovered".

Christine Bohnet
Department of Communications and Media Relations at HZDR

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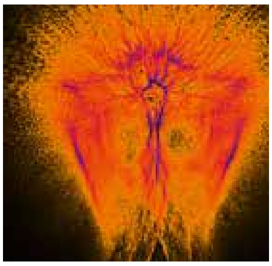
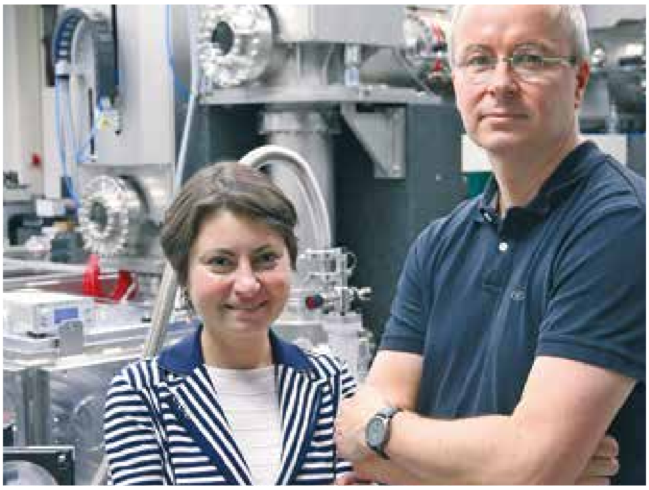
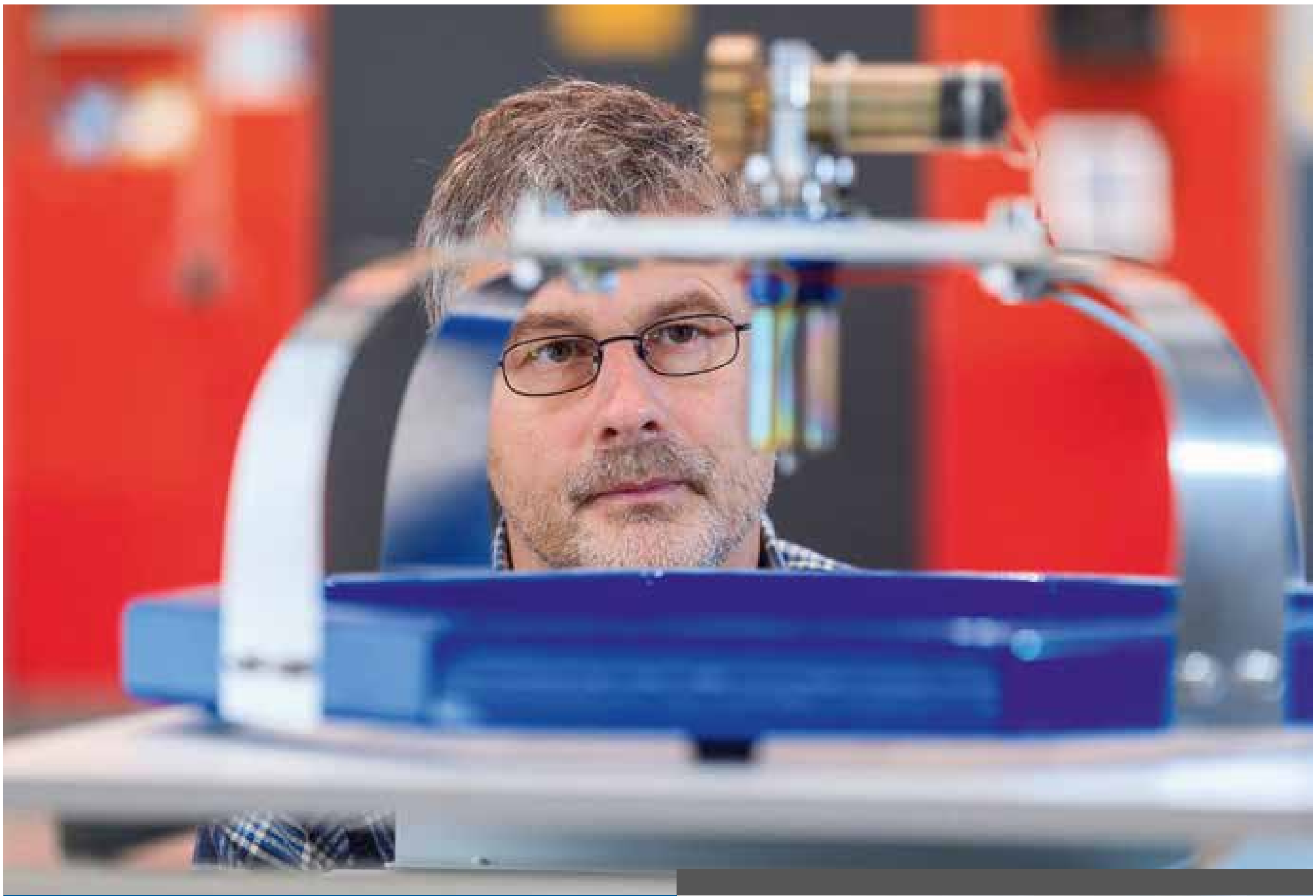




// At the new DRESDYN research facility scientists are planning diverse experiments involving liquid metals.

GEODYNAMO, STAR FORMATION AND BETTER BATTERIES

_TEXT . Frank Grotelüschen

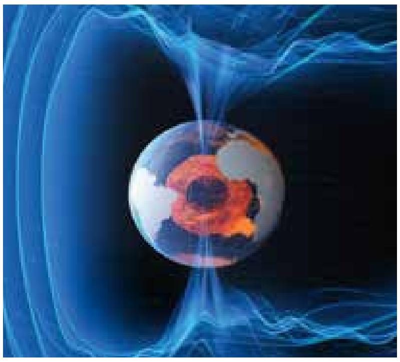


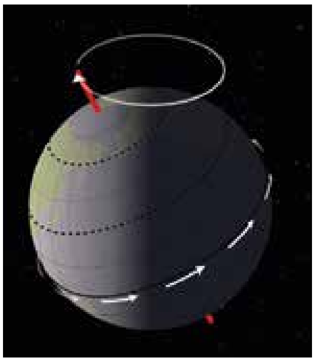
DYNAMIC: Frank Stefani wants to elucidate the Earth's magnetic field, the formation of the stars and processes in novel batteries. Photo: Rainer Weisflog

Frank Stefani stands in front of a brand new building in the farthest corner of the HZDR site. When he opens the massive gate, a surprise awaits. In the middle of the vast hall there is another building, almost as big as a house. This "house within a house" is a safety containment for a spectacular experiment due to start in 2018: An enormous steel drum containing eight tons of liquid sodium will rotate around its own axis while concurrently rotating on a huge disk. The experimental set-up is designed to help solve one of the most exciting problems facing geoscience: Is it possible that the pole reversal of the Earth's magnetic field, which has occurred sporadically in the course of history, is caused by certain movements of the Earth during its orbit around the sun?

This is one of several experiments the Dresden scientists, participating in the HZDR project for the future DRESDYN (DREsden Sodium facility for DYNamo and thermohydraulic studies), intend to perform. Moreover, the researchers around Frank Stefani will construct further experimental set-ups to explore how stars might be formed out of huge dust disks in space and what processes take place in novel, high-performance batteries. But all the experiments have one thing in common: The use of liquid metals, particularly liquid sodium.

The Earth generates a magnetic field because its core operates like a dynamo. The center of our planet consists of a solid iron core some 2,500 kilometers thick surrounded by a layer of liquid iron. "The flow of this layer induces an electrical current that triggers the magnetic field," Frank Stefani →





MYSTIFYING: The magnetic field protects the Earth from solar wind. But we still do not exactly know how it comes about. The precession of the Earth's axis could play a key role. Illustrations: ESA/ATG Medialab (left) // Robert Simmon/ NASA GSFC (right)

explains. "Specialists call it a geodynamo." The detailed principle of the process, however, is still unclear because the swirling of the iron in the Earth's core behaves chaotically. Turbulence is always occurring and this causes the Earth's magnetic field to fluctuate. From time to time – on average, every 250,000 years – the direction of the magnetic field is even reversed.

Some theories assume that the geodynamo is decisively influenced by what is known as precession: At present, the Earth's axis is tilted at roughly 23 degrees from an axis which is perpendicular to the ecliptic plane. With a time period of 26,000 years it tumbles around this perpendicular axis. This tumbling motion in space is being discussed as a possible source of energy for the geodynamo. Combined with the periodically-changing axial inclination and the simultaneously varying ellipticity of the Earth's orbit, this motion might also trigger pole reversals of the Earth's magnetic field.

phenomena really be produced, this would support the theories that precession has an important impact on the Earth's magnetic field.

However, there are extreme experimental demands on the technology and material: Due to the superimposition of the two rotations, a huge imbalance is created which pulls and wrenches on the components with massive forces – the torque reaches up to eight million Newton meter. To illustrate the point, Stefani stretches out his arms. "It's as though the right one was being pulled up by 400 tons and the left arm was being pulled down by 400 tons."

This exerts a gigantic force on the floor. In order to cushion it, the experts have constructed special foundations, one and a half meter thick. They are separate from the rest of the hall and rest on seven pillars reaching 22 meter into the ground where they are embedded in granite rock. "Even so, it

From astrophysics in the lab to batteries for the energy revolution

Dizzy steel drum

In order to test these hypotheses, Stefani and his colleagues in Dresden are setting up an experiment that is quite unique: a steel cylinder, two meter in diameter, filled with eight tons of sodium. The metal, which is actually solid, is heated up to 130 degrees Celsius and then becomes fluid. "Liquid sodium conducts electricity very well and is therefore excellent for our experiments," Stefani explains. The cylinder is revolvable and can rotate around its longitudinal axis ten times per second. Moreover, it is mounted on a large, solid disk that can revolve around itself once every second. The liquid sodium in the cylinder consequently gets a double dose of "dizziness" – a precession comparable to the gyration of the Earth.

The following questions are of particular interest for the researchers: "Can we trigger a dynamo effect? Will we observe pole reversals?" Stefani asks. Should such

is very likely to vibrate tremendously during the experiments' performance," Stefani guesses.

Stainless steel wallpaper

He opens the door to the experiment hall and points to the walls. "For safety reasons we have completely covered the inside in stainless steel," he says. "If a jet of sodium were to escape through a leak in the installation, it would cause major chemical reactions when it hit the concrete." The "stainless steel wallpaper" on the other hand is robust enough to withstand the reactive metal.

If sodium really did escape through a leak and made contact with the oxygen in the air, the liquid metal would immediately ignite. This would be the signal for a very special kind of extinguishing system to leap into action. "It works using 15 tons

→

of liquid argon and can flood the containment with noble gas in two minutes." The temperature plummets immediately, the sodium solidifies. The argon also forces out the oxygen in the air and the fire dies. "In January 2016, we successfully tested the extinguishing system," Stefani explains. "I believe we can deal with any incident."

The physicist then marches up a metal stairway, enters the as yet unfinished control room and points to a window that looks out on the installation. The pane is made of fireproof, bulletproof glass and is designed to protect the researchers from all eventualities. "We started our planning seven years ago," Frank Stefani explains. "We cooperate closely with HZDR's Department of Research Technology as well as TU Dresden. As time went by and we started calculating the details we soon realized the enormous forces a machine of this kind might set free. In many respects, we are teetering on the edge of the technically doable."

This is the case, for example, with the bearings which help to set the cylinder and rotary plate in motion – all custom built parts that challenge the ingenuity of the manufacturers. All the components are supposed to be completed and installed by the end of 2017. Then, the test phase will last for one year during which the installation will be driven by water instead of sodium to discover whether the mechanics work as expected.

SOLID: During the dynamo experiments, the facility is subjected to gigantic forces. Strong foundations provide the necessary stability. Photo: Oliver Killig

If everything goes according to plan, the researchers want to fill the cylinder with liquid sodium in early 2018. "I'm pretty excited," Stefani admits. "It'll be intriguing to explore in which parameter ranges the dynamo effect is activated."

Rotating cylinder under high voltage

But DRESDYN offers even more: Right beside the bunker for the precession experiment, technical staff is installing a second experimental set-up – a metal frame gridding a cylinder of three meters height. In fact, it is an ensemble of two pipes, one inside the other: The inner cylinder is about 40 centimeters in diameter, the outer one about 80 centimeters. The inner one can rotate at a speed of up to 20 revolutions per second, the outer one up to six times per second. Between the cylinders, a ton of liquid sodium will flow. When both cylinders rotate, a circular current will be generated – faster inside than outside but stable.

Researchers will then send electrical currents of several thousand amps through various coils and conductors generating complex magnetic fields. The crucial question aims at the impact of the fields on the liquid sodium. Will the steady current applied become unstable under certain conditions? Experts refer to this phenomenon as magnetorotational instability (MRI).

The background to these experiments is surprising: Astrophysics is the motivating force. "MRI seems to be important for understanding the formation of certain structures in the cosmos," says Frank Stefani. "It provides an explanation for the way stars and planets are formed out of →

STORAGE: A physicist prepares a novel liquid metal battery for tests: flows play an important role in its security and stability. Photo: Oliver Killig

accretion disks." Accretion disks are huge, flat collections of gas which hoard so much material in their center that a planet or star can form and subsequently continue to grow.

Stefani explains the problem: "Accretion disks should really be very stable. The material should spin round the center without running the risk of collapsing." An additional mechanism seems to do the trick: The rotating gas, which is partially able to conduct electricity, generates a magnetic field in the disks. This field in turn interacts with the gas particles, makes them, figuratively speaking, lose their step and tosses them into the center. "This magnetorotational instability is currently the best explanation we have," Stefani asserts. Experiments reproducing the phenomenon in the lab would support this hypothesis.

Magnetic fields in batteries

Preceding experiments at the HZDR experimental set-up PROMISE (Potsdam Rossendorf Magnetic InStability Experiment) have already demonstrated two special versions of MRI. However, the installation only runs on six liters of gallium-indium-tin – a mix of metals that is already liquid at room temperature. In the years to come, the Dresden researchers want to investigate other versions of the phenomena using the new experimental set-up in the DRESDYN hall. It provides a much bigger liquid metal volume and allows the cylinder to spin at higher speeds – all of which enables the physicists to study a significantly larger parameter range.

DRESDYN will, however, host even more experimental set-ups using liquid metals for potential technical applications in the field of battery research. Batteries play a leading role in the energy revolution as they are promising candidates for buffer storage of power generated by solar cells and wind turbines. "Batteries like this are composed of three layers," Frank Stefani explains. "At the top is liquid sodium, in the middle a thin layer of liquid salt and at the bottom liquid bismuth or lead."

If these batteries are to be economically viable, they will have to be of a certain size. But in large batteries, high electrical currents of several thousand amps are inevitable. "These currents generate magnetic fields," Stefani notes. "And these fields can lead to instabilities that might interfere with the battery." In an extreme case, these instabilities could even mix up the liquids in the battery and cause a short circuit which would let the stored power go down the drain or the battery might even be destroyed. "Thanks to our equipment, we will be able to study these processes in detail," says Stefani. "This will be the basis for the construction of large and therefore more affordable liquid metal batteries in future."

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M. Seilmayer, V. Galindo, G. Gerbeth, T. Gundrum, F. Stefani, M. Gellert, G. Rüdiger, M. Schultz, R. Hollerbach: Experimental evidence for nonaxisymmetric magnetorotational instability in a rotating liquid metal exposed to an azimuthal magnetic field, in Physical Review Letters, 2014 (DOI: 10.1103/PhysRevLett.113.024505)

F. Stefani et al.: Magnetohydrodynamic effects in liquid metal batteries, in IOP Conference Series: Materials Science and Engineering, 2016 (DOI: 10.1088/1757-899X/143/1/012024)

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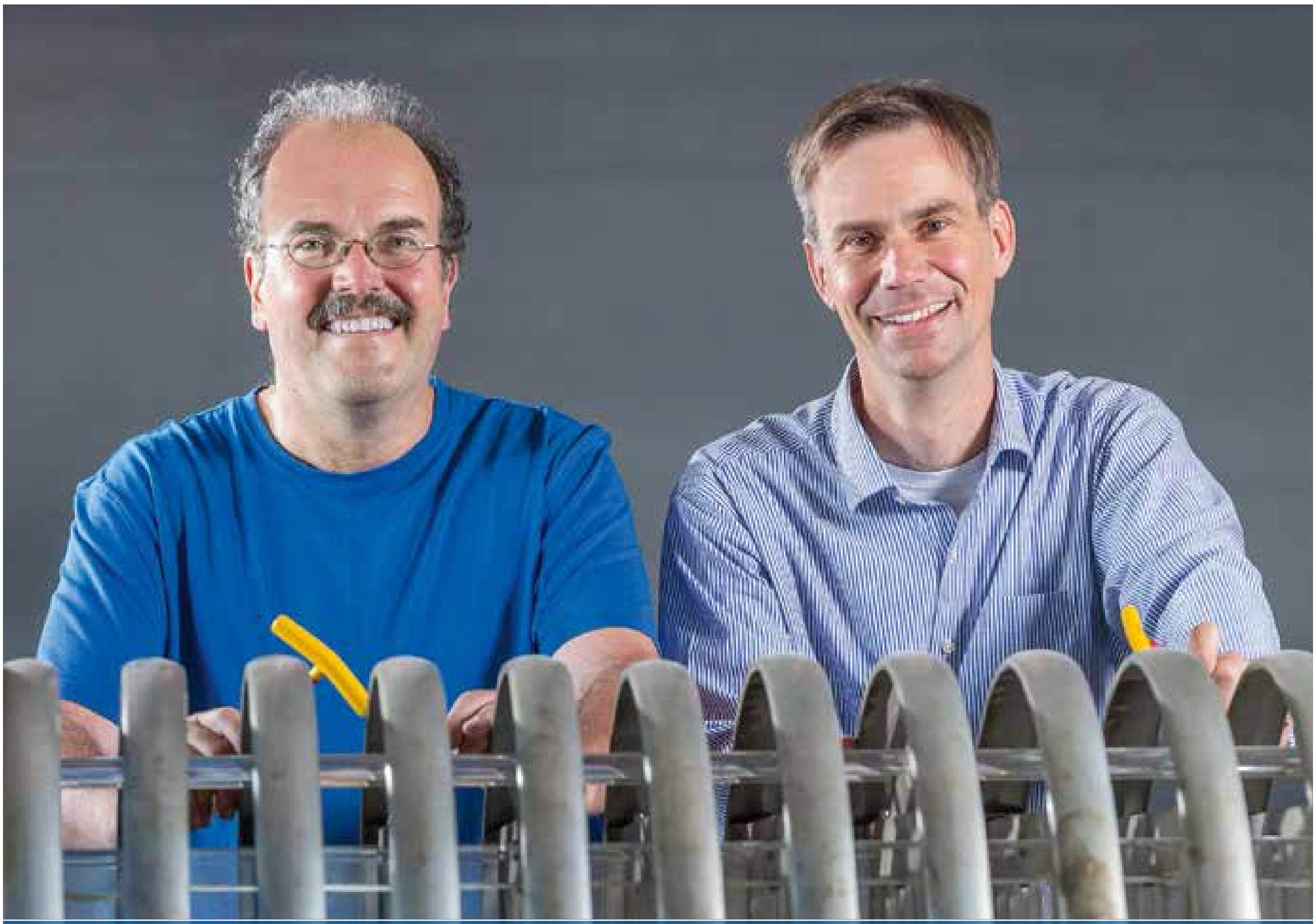
// HZDR and TU Dresden are currently building Germany's only underground particle accelerator. Researchers aim to examine stellar processes.



A LOOK INSIDE THE STARS

_TEXT .Uta Bilow

The valley ‘Plauenscher Grund’ at the southwestern edge of Dresden is a location that offers many great features. In 1719, King August the Strong took advantage of its romantic flair to host an extravagant celebration on the occasion of his son’s wedding. Then the *Felsenkeller* (rock cellar) Brewery, founded in the mid-19th century, took advantage of the cool temperatures in this deep valley to dig over 70 meter long tunnels into the rock walls as ice cellars. In the days before the refrigerator was invented, large blocks of ice were stored in these long tunnels to preserve the fresh brews. Now scientists are about to install a unique laboratory there: HZDR and TU Dresden researchers are currently building an experimental site to study processes that occur inside stars. You could say that the new *Felsenkeller* accelerator will reach for the stars … and take them underground.

VISIONARY: Physicists Kai Zuber (left) and Daniel Bemmerer (right) want to imbue the old *Felsenkeller* tunnels with new life. Photo: Rainer Weisflog

Stars like the sun and the other countless bright lights on our night sky are enormous power plants. They produce energy by fusing atomic nuclei in their interior at unimaginably hot temperatures. The sun, for example, is up to 16 million degrees centigrade hot in its core, fusing hydrogen into helium. Stars of greater mass and size work with other fuels, generating heavier elements, even iron. With the exception of hydrogen, helium and lithium, which were generated shortly after the Big Bang 13.8 billion years ago, stellar nucleosynthesis – the scientific term for these processes – thus delivers a large part of our universe's

SUBTERRANEAN STARS: The Felsenkeller (rock cellar) in the south of Dresden offers ideal conditions for researchers to investigate the processes that occur inside stars. Photos: SchiDD (CC-BY-SA 4.0) (left) // ESA/Hubble & NASA Accknowledgement: J. Schmidt (right)

inventory. Even though the principles of these processes are known and understood, much remains to be scientifically studied, as HZDR physicist Daniel Bemmerer points out: "Each element in the universe has a characteristic frequency of occurrence. And we have no plausible explanation for this distribution, not even for the frequency relationship between carbon and oxygen."

This is because stars generate the various chemical elements in an extremely complex network that involves many atomic nuclei and possible reactions. When two atomic nuclei collide, they rarely fuse. A measure of how often fusion occurs is called the effective cross section of the reaction. And these reaction rates are often only very imprecisely known, especially at the temperatures present inside stars. Yet without exact parameters it is difficult to model the evolution of stars and to understand how the elements emerged and why they occur at certain frequencies. This has motivated Daniel Bemmerer and nuclear physicist Kai Zuber from TU Dresden and their colleagues to conduct experiments at the new *Felsenkeller* lab and help expand the data basis for nuclear astrophysics, thus creating a solid experimental foundation to understand processes inside stars.

An accelerator in a tunnel

These experiments have been made possible by two former ice storage corridors of the *Felsenkeller* Brewery. At the center of it all is a particle accelerator, because, as Bemmerer explains: "The first fundamental phases that occur in all stars can be simulated with an accelerator. In the lab, we can copy the reactions that occurred in stars after the Big Bang, and are still occurring today. And we can then determine very precise reaction rates." The facility is designed to direct accelerated particles onto a stationary target, like shooting a proton beam onto a nitrogen target and measuring the products generated with a detector. The fusion of protons with nitrogen nuclei is one of the central fusion reactions in the hydrogen burning cycle. Such experiments can help determine the effective cross section and to gradually unravel the complex system of nuclear reactions.

One of the challenges facing such analyses is the fact that reaction rates in nuclear fusion reactions are very small. Only a few measurable signals are generated over a long period of time. Concurrently, however, a multitude of other signals is triggered by other particles, such as the cosmic radiation that hits Earth from space and is detectable all over its surface. This is why the experimental set-up must be shielded from outside influences. The former ice storage tunnel is the perfect location: About 50 meters of rock piled up above the tunnel protect the experiments by providing a powerful shield against cosmic radiation, attenuating it by a factor of 40. This has already been shown in preliminary measurements taken in the tunnel with a muon telescope.

In the past, accelerator experiments of this kind could only be conducted at LUNA (Laboratory for Underground Nuclear Astrophysics) at the Gran Sasso lab in Italy. This unique accelerator is located deep within a mountain, covered by one and a half kilometer of rock. Gran Sasso mainly studies nuclear reactions that occurred shortly after the Big Bang or that are happening inside the sun. The *Felsenkeller* →

accelerator is more powerful than LUNA: It can boost atomic nuclei to energies ten times higher, up to five million electron volts, which opens a window on processes that occurred at later points in the timeline of our universe's development, with helium or carbon as the fuel. This includes, for instance, the fusion of a carbon and a helium nucleus into an oxygen nucleus – a reaction that is central to modelling stars.

Eliminating interferences

Currently, the Pelletron-type accelerator is still housed at HZDR. The tank-like, six-meter, ten-ton apparatus was previously used in the development of pharmaceuticals in England. It is now being fitted for its future use with an additional ion source for hydrogen and helium nuclei as well as a new electronic control module. At the same time, researchers are preparing the detector systems. The *Felsenkeller* lab will use highly sensitive germanium detectors to measure the reaction products. Additionally, a veto-system will be installed - detectors to identify interfering signals, the so-called background, which is then removed from the measurement. These tricks, as Daniel Bemmerer explains, will make the Dresden detector almost as sensitive as the one inside the Gran Sasso, which is located much deeper underneath the earth's surface. A Master's student is also currently studying natural radioactivity in the entire tunnel system for his thesis, enabling the researchers to take these parameters into account as well.

In the meantime, construction is well underway inside both tunnels. The old flooring has been removed, a new floor plate is being manufactured and installation of the technical equipment is being prepared. Humidity is extremely high in the cellar corridors, which is why the tunnels must be lined with a second layer, an enclosure, inside which the climate can be controlled to protect the facility from untimely corrosion. Researchers expect to install the facility and be able to start their experiments next fall. Kai Zuber is eager to study the fusion of helium-3 and helium-4 cores into beryllium in order to better calculate and compare solar neutrino flows. Daniel Bemmerer's research program will focus on the formation of oxygen-16 nuclei.

Scientists from around the world will, moreover, have access to the *Felsenkeller* accelerator lab. They can apply for beam time, as Dresden-based researchers will only use the facility part of the time. There is a great deal of interest among the relevant research groups. Dresden students will also be able to enjoy unique training and research opportunities at the new accelerator lab. After all, the 25-kilometer drive from HZDR to the valley 'Plauenscher Grund' is a lot easier than the journey to the Gran Sasso lab in Italy – and TU Dresden is just 3.7 kilometers from the *Felsenkeller*.

PUBLICATION:

F. Cavanna, R. Depalo, M. Aliotta, M. Anders, D. Bemmerer, A. Best, A. Boeltzig, C. Broggini, C.G. Bruno, A. Caciolli, P. Corvisiero, T. Davinson, A. di Leva, Z. Elekes, F. Ferraro, A. Formicola, Z. Fülöp, G. Gervino, A. Guglielmetti, C. Gustavino, G. Gyürky, G. Imbriani, M. Junker, R. Menegazzo, V. Mossa, F. R. Pantaleo, P. Prati, D. A. Scott, E. Somorjai, O. Straniero, F. Strieder, T. Szücs, M. P. Takács, D. Trezzi: Three new low-energy resonances in the $^{22}Ne(p, \gamma)^{23}Na$ reaction, in Physical Review Letters, 2015 (DOI: 10.1103/PhysRevLett.115.252501)

WEIGHTY RESEARCH: Kai Zuber, Bernd Rimarzig and Daniel Bemmerer (from left to right) will soon erect the particle accelerator in the ground below Dresden. Photo: Rainer Weisflog

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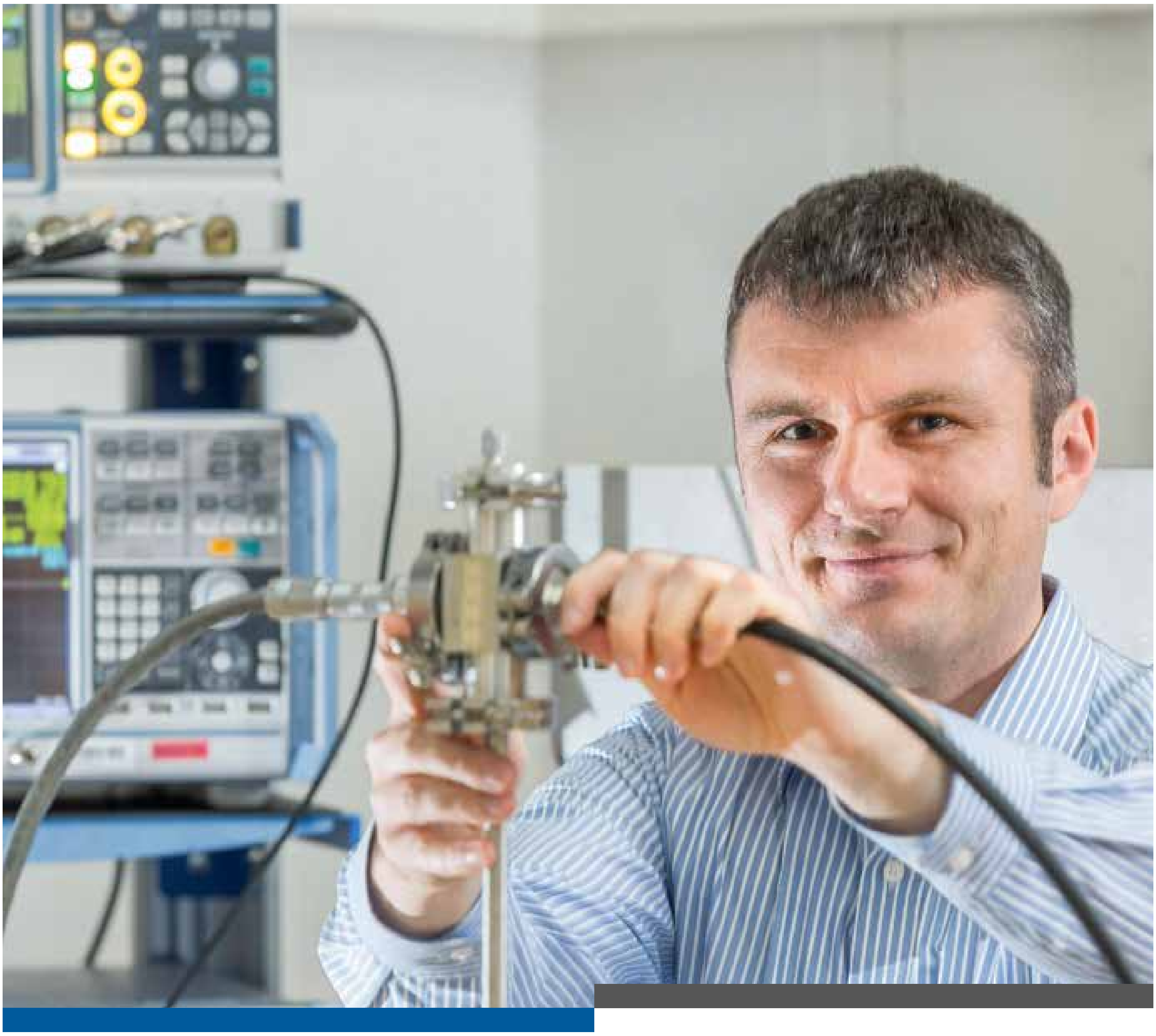
// The Dresden High Magnetic Field Laboratory improves on a method, which can deliver images from the inside of materials without causing damage.



EXTREME: At the lowest temperatures and with the highest magnetic fields: Hannes Kühne wants to investigate materials even more precisely without destroying them. Photo: Rainer Weisflog

ULTRASHORT PULSES SHARPEN THE VIEW

_TEXT . Roland Knauer

Three times altogether – in 1952, 1991 and 2002 – the Nobel Prize Committee honored scientists for developments in the field of nuclear magnetic resonance, or NMR for short. At first glance, this would seem to indicate that the potential inherent in this method, which allows doctors to take a non-invasive look inside their patients' bodies without employing a scalpel or x-rays, and scientists of diverse disciplines to examine the inside of materials, should already have been largely exhausted. But physicists Hannes Kühne of the Dresden High Magnetic Field Laboratory (HLD) at HZDR and Jürgen Haase of Leipzig University are convinced that even after three Nobel Prizes, there is still room for decisively improving the NMR method.

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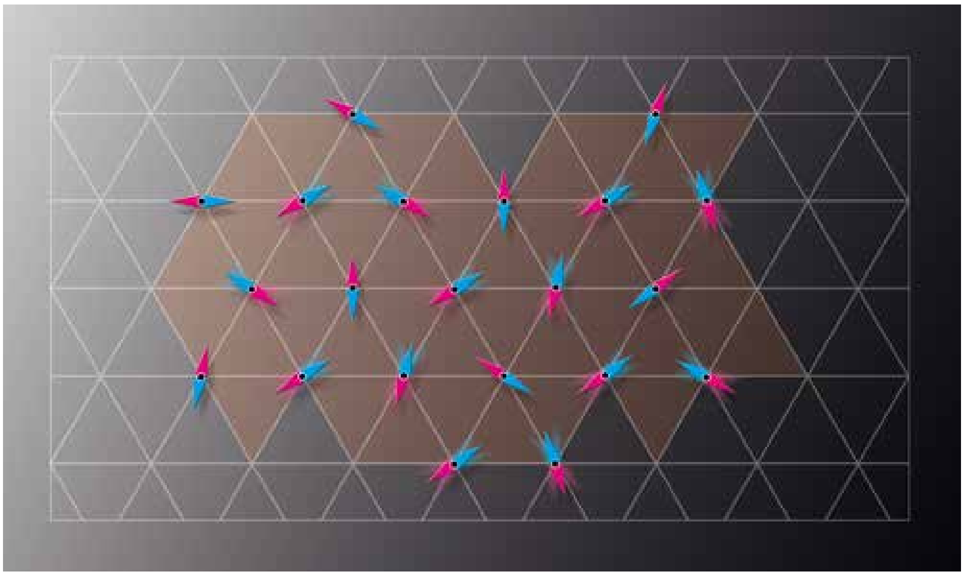

CONFUSED: In the absence of external influences, the spins in hydrogen atoms – here, indicated by compass needles – point in all directions. It takes a magnetic field and the lowest possible temperatures to achieve the desired order.

Teamwork between Saxony's metropolitan areas

After all, there is a clear correlation in this technology: The lower the temperature and the stronger the magnetic field, the sharper the view of the inside. At HLD, Joachim Wosnitza has brought together experts on super-strong magnetic fields who often also work at extremely low temperatures. For his part, Hannes Kühne has specialized in NMR technology and since 2013, he worked on expanding the research spectrum at the laboratory. Since then, the door has been open for closer cooperation with NMR specialist Jürgen Haase and his team in Leipzig.

In order to explain what they do, the researchers first have to digress somewhat and start with the fundamentals of magnetism which have been known for the last two hundred years: When electrical charges move, they generate a magnetic field which itself impacts the electrical charges. For non-physicists, this initially sounds rather mysterious – but a simple bicycle dynamo demonstrates how it works: When the wheel rotates, it drives a permanent magnet made, for example, of an iron alloy that spins in a coil of metal wire. Unlike in non-metals, in these metal wires some electrons can easily move over considerable distances. Thus the field spinning with the magnet drives these electrons, which then flow in a tiny electrical current through a wire to the bicycle lamp and light it up.

Atomic roundabout

This electromagnetism also plays an important role in atoms, which are the building blocks of matter on the Earth and in the solar system. A hydrogen atom, for instance, is nothing other than a positively-charged nucleus around which, at a relatively great distance, a much smaller, negatively-charged electron zooms. Both the hydrogen atomic nucleus and the electron behave like tiny magnetic particles. We can visualize this magnetism in an electron as a miniature electric circuit, which physicists refer to as "spin". Just as with road traffic, however, on a roundabout of this kind in an electron there are only two possible directions: either the electric current flows clockwise or anti-clockwise.

The situation in the nucleus of a hydrogen atom is similar, only here, a positive electrical charge spins in a considerably larger mass that is as heavy as 1,836 electrons. "That's why the magnetism of this atomic nucleus is much harder to influence than that of a single electron," explains HZDR researcher Hannes Kühne. But it is precisely this influence from outside that plays a crucial role in the NMR method: If a cloud of hydrogen atoms were to float in a vacuum, finely dispersed and free of any external influences, their spins would turn in all directions. But if researchers place a magnetic field alongside the hydrogen cloud, the atoms behave just like little compass needles and they align with these field lines.

Atomic compass needles

However, hydrogen atoms are not good at keeping still and constantly move back and forth. The lower the temperature, the slower these movements become until, at the lowest possible temperature of minus 273.15 degrees Celsius they come to a halt. At significantly higher temperatures, by contrast, the atoms churn around so enthusiastically that only some of them are attracted towards the magnetic field lines. The stronger the magnetic field, the more the atoms are attracted to it. If then the temperatures are as low as possible, most of the atomic nuclei turn towards the field lines. And the better this works, the sharper the view into matter using the NMR method becomes.

Physicians therefore examine patients in NMR apparatuses using a magnetic field with the strength of roughly one tesla. This is vastly more than the Earth's magnetic field which in Central Europe is about twenty thousand times weaker. Even the magnet at the door of a refrigerator only manages about 0.05 tesla, while scientists in NMR labs use approximately ten tesla to investigate materials. "However, there are now →

facilities that work with up to 23.5 tesla," Hannes Kühne reports. At HZDR, on the other hand, Joachim Wosnitza and his colleagues have already achieved 95.6 tesla, if only for a fraction of a second, and thus holding the European record. It is precisely those extremely high magnetic pulses that Jürgen Haase would like to utilize in order to sharpen the view with the NMR method.

When atomic nuclei flip over

During an NMR analysis of this kind, researchers beam energy in the form of radio waves into the material to be examined. This energy is sufficient to make the spin of certain atomic nuclei flip over along the field direction. Some of these tiny compass needles thus turn around in the material and can be pinpointed. In a typical NMR experiment, researchers beam various radio wave frequencies into a sample, one after the other. Every frequency delivers an energy package of a precise size. As the researchers know exactly what energy is required to flip over the spin of a certain atomic nucleus, they can specifically reverse the polarity of hydrogen atoms, for example. These atoms are, however, often not alone; they have neighbors whose electromagnetic properties exert a considerable influence and thus slightly change this flipping energy.

At the same time, electrons which have a negative electrical charge zoom around the atoms involved and thus also influence the magnetic field. So, an atomic nucleus is subjected to a whole array of different magnetic fields which, taken together, change the energy and cause the spin to flip over. If hydrogen atoms change their polarity at another frequency, researchers can infer from this change what the neighborhood is like and uncover the structure of the material being examined. The NMR method thus opens up the view of the inside of materials without destroying them. It comes as no surprise to anyone that this method has been one of the most important tools used by scientists for decades.

Forcing the limits

Unfortunately, in some areas researchers reach their limits: There are materials in which the electrons are so strongly linked or "correlated" that the conventional magnetic fields in NMR labs are unable to break these correlations and therefore cannot "see" them. But these correlated electrons play a crucial role in future technologies such as high temperature superconductivity and giant magnetoresistance. "The extremely high magnetic fields at HZDR can manage it and enable us to understand these important materials better," Hannes Kühne explains. But before he gets to that point, he will have to invest a great deal of effort in the method. An NMR apparatus usually takes measurements in constant magnetic fields – the record fields chronicled in Dresden, on the other hand, can only be achieved for fractions of a second.

Hannes Kühne will therefore have to adapt the method to short time periods and, moreover, translate the experiments already conducted with high magnetic fields into a standard procedure with which Jürgen Haase and his staff as well as other guests can work. And in this, Hannes Kühne makes good progress: Working together as Team Saxony, researchers have now analyzed, for example, the magnetic pattern in the compound strontium-copper-borate, which is an important model system for investigating magnetism – at minus 271 degrees Celsius in a magnetic field of 54 tesla. This measurement, with which the researchers have pushed open the door to further experiments with many novel materials, lasted a mere six thousandths of a second.

PUBLICATION:
J. Kohlrautz, J. Haase, E. L. Green, Z. T. Zhang, J. Wosnitza, T. Herrmannsdörfer, H. A. Dabkowska, B. D. Gaulin, R. Stern, H. Kühne: Field-stepped broadband NMR in pulsed magnets and application to $SrCu_2(BO_3)_2$ at 54 T, in Journal of Magnetic Resonance, 2016 (DOI: 10.1016/j.jmr.2016.08.005)

TEAMWORK: Physicist Hannes Kühne and doctoral candidate Daryna Dmytriieva prepare NMR measurements. Photo: Rainer Weisflog

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// Construction of the Dresden High Magnetic Field Laboratory was a demanding new challenge for all involved.

AN ARCHITECTURAL GEM FOR SCIENCE

_TEXT . Sara Schmiedel

OPEN, PULSE CELL: Physicist Thomas Herrmannsdörfer has been involved in the construction of the High Magnetic Field Lab from the word go. The huge lab doors are just one aspect of the elaborate security strategy.
Photo: Rainer Weisflog

"An engineer will always find a solution," Matthias Herold chuckles. The construction engineer and CEO of Baubüro Freiberg GmbH (BBF) knows what he is talking about – he is not a man to shy away from complex challenges – such as building a facility brimming with superlatives: the Dresden High Magnetic Field Laboratory (HLD). Using the world's largest capacitor bank, researchers are able to store energies of up to 50 megajoules, generating the highest-pulsed magnetic fields in Europe without destroying neither the sample nor the electric coil. Their mission: to boldly go where no physicist has gone before.

One of these ambitious scientists, who was involved in the construction of the facility 14 years ago, is Thomas Herrmannsdörfer, solid-state physicist and head of department at HZDR's High Magnetic Field Lab Dresden. "We all knew our solid-state physics, but we didn't know much about generating high magnetic fields," he admits. It was helpful, he says, to tap the experiences of international colleagues who were already operating magnet labs – and who also had cautionary tales to tell about technical failures. "We knew we had to have a special focus on safety," Herrmannsdörfer tells us.

Special materials required

It quickly became clear that to avoid any interaction between the building and the magnetic coils, no magnetic materials whatsoever could be used in the construction of the facility. "We had to use non-metallic high-grade steel inside the concrete. That's ten times more expensive than standard steel," Matthias Herold reports. "At first, we even had to find out who actually produces that kind of steel and how the material behaves when you work with it." That caused a problem right off the bat: The first extremely large delivery was magnetic. "We refused to accept the steel and insisted on a new delivery, because a magnetic pulse would hammer away at the magnetic wall with short, intense thrusts like a jackhammer – no building could withstand that in the long run," Thomas Herrmannsdörfer says. Before the concrete was poured, the scientists checked every single high-grade steel beam with a hand-held permanent magnet.

At about 70 centimeters, the walls in the actual lab chambers are almost three times as thick as regular apartment walls. The custom-made steel doors look like giant bank-vault doors. In addition, the ceilings of the small rooms are fitted with rupture disks – metal-foil pressure equalizers that work like safety valves in the event of a rapid rise in pressure inside. "During the development phase, we had an expert evaluate the risk of bursting and took it into account in our further planning," the physicist reports. "This is how we found out →

that if a coil fails during an experiment, we'd be looking at a blast impacting the building with a force equal to about 26 pounds of TNT in the worst case." This is because the world's most powerful capacitor bank, which supplies energy to the coils, is a formidable apparatus: For a fragment of a second, it can release millions of horsepower, roughly the equivalent of a large carrier rocket at launch. This energy could escape – a not too improbable scenario which the magnet cells inside the HLD building must be able to withstand.

Exceptionally good cooperation

Matthias Herold never doubted that they could master the challenge and meet these requirements. Nor was he anxious about the first experiment in the new lab. "I knew what we had planned and calculated. We were also lucky enough to have found highly competent companies to help us execute the project – even though many aspects were completely new territory to them as well."

Scientist Herrmannsdörfer was a little more nervous than master-builder Herold, especially after the first major coil accident that could be heard in the neighboring town eight kilometers away. But when they looked inside the HLD, they could breathe a sigh of relief – the decisions they had made during the planning phase had been sound: the doors had held, the building was in one piece.

Herold found his collaboration with scientists exciting from the start, even though it was sometimes a little taxing: "We made lots of changes even during the planning phase, because people kept having new ideas," he remembers. "But the HLD is a special kind of lab where the normal rules and experiences just didn't apply."

Beautiful looks inside and out

"What matters is the inner function of the building, but we also created an architectural gem," Matthias Herold believes. The exterior façade made of dark gray ceramic tiles is timeless, highly durable, and largely fitted with glass panels. The interior sports colorful walls and support beams. This was not originally the case: "At first, the whole thing was quite plain, we didn't attach much importance to architectural aspects," Herold remembers. But then Peter Joehnk, Administrative Director of HZDR, got involved: He wanted a cutting-edge super lab that looked the part and allowed visitors to look into the lab facilities.

Are attractive surroundings better for research? "Definitely," Herrmannsdörfer assures us. "Our external users not only praise our experimental equipment and service, but also the bright hallways at HLD. They seem to feel happy here. They certainly like to come back." The look and many technical achievements have even found international followers in Europe and beyond.

HLD was inaugurated in 2004 after two years of construction. Seven years later, the foundation was laid for the HLD II extension, where research began in late 2013. Matthias Herold and Thomas Herrmannsdörfer agree: The joint projects have been a resounding success and still are. "The clients knew what they wanted, we just honed the requirements together. We stayed within our budget and schedule, and all the partners collaborated well – which, unfortunately, is not always the case," Herold explains. He still follows the press coverage of the lab and is a regular at the open lab days in Rossendorf.

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RECORD BREAKING: For a few fractions of a second, the world's largest capacitor bank generates the highest magnetic fields in Europe. Photo: Jürgen Lösel

// At the Helmholtz International Beamline for Extreme Fields HIBEF, physicists want to take a closer look at extreme states of matter.

X-RAY UNLEASHED

_TEXT . Frank Grotelüschen

Researcher Carsten Bähtz rides the elevator over 20 meters down to an underground room the size of a concert hall where technicians are hard at work cutting concrete, drilling holes, putting up walls. This bustle of activity is happening in Schenefeld, a small city in the German Federal State of Schleswig-Holstein, right on the border to Hamburg. In 2017, one of Europe's largest scientific infrastructures is scheduled to launch here: the European XFEL, the world's most powerful X-ray laser. One of the institutions behind this project is the Helmholtz-Zentrum Dresden-Rossendorf: It heads a user consortium called HIBEF, whose objective will be to take a closer look at extreme states of matter – material samples will be heated to temperatures found inside planets, exposed to the highest possible magnetic fields, or be subjected to high pressure.

OVERVIEW: Physicist Carsten Bähtz coordinates the construction of the Helmholtz International Beamline for Extreme Fields. Foto: Axel Heimken

The European X-ray laser will serve as a high-precision analytical tool. It is currently being constructed in Hamburg in a joint effort by eleven European partner countries under the leadership of European XFEL GmbH, a non-profit whose main shareholder is the Deutsches Elektronen Synchrotron DESY. The facility is based on a superconducting particle accelerator about 3.4 kilometers in length. It can propel electrons to velocities close to the speed of light, sending them through special magnetic structures called undulators. They force the fast electrons onto a sort of slalom course – which causes them to emit short, extremely strong X-ray flashes that end up in six different "beamlines", the six different experimental stations in the subterranean hall in Schenefeld.

Compared to synchrotrons, the most commonly-used intense X-ray sources, the pulses generated by the European XFEL will be billions of times brighter and have the properties of laser light as well. While X-ray lasers have been in use in Japan and the USA for some years now, they are not based on superconducting accelerator technology and are therefore limited to a maximum of 120 flashes per second. By contrast, the European XFEL will be able to generate 27,000 flashes. Because such a large number of images can be captured in a

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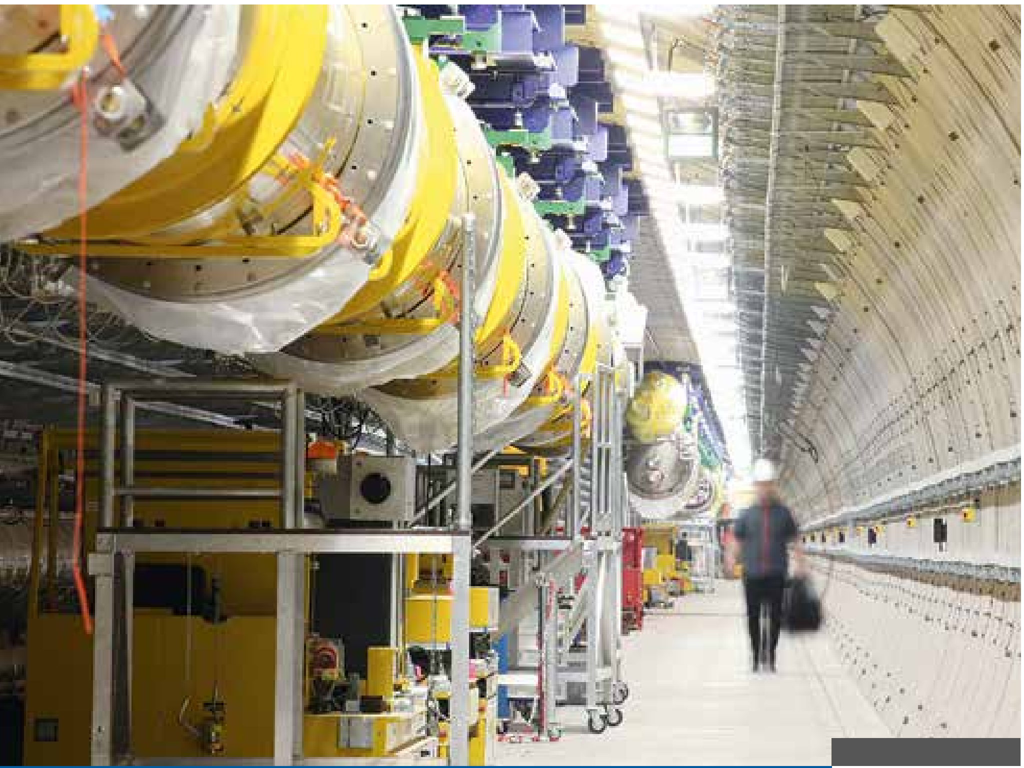


MILES LONG: In the accelerator tunnel of the European XFEL, particles are accelerated to top speeds. Photo: DESY

short span of time, the measuring time for each experiment is significantly shortened, giving more groups access to the facility – a decisive advantage given the high anticipated demand. The facility offers a variety of research opportunities. Thanks to the short duration and high intensity of the light flashes, chemists will be able to study reactions in detail, geoscientists will be able to investigate the impact of artificial shock waves on rock samples, and molecular biologists will be able to take pictures of individual proteins.

HIBEF coordinator Carsten Bähtz walks towards the back of the hall to show us a bare hut made of heavyweight concrete: "Our experiments generate high-energy electrons," the scientist explains. "Their radiation must be shielded, hence the massive concrete walls." The enclosure is part of the High-Energy Density Science Instrument, or HED for short, one of the six experimental stations at the European X-ray laser. The HIBEF consortium will provide some of the essential components, such as two special lasers, an ultra-strong magnetic coil and an extremely fast X-ray detector, to equip the measuring station for its mission of conducting research at extreme densities.

A power laser upstairs

Bähtz has now entered the experimental hut and his voice reverberates as if he were standing inside a cathedral. There is hardly anything to see in here yet, the classroom-sized space is bare and empty. Bähtz shows us an inconspicuous opening in the wall: "The ultra-short, high-intensity X-ray flashes will come out of this hole," he explains. Then he points up to the ceiling. "There will be another floor on top of the hut, and that's where our two lasers will be." One of them – financed by HZDR – will generate very short and powerful light pulses of up to 300 terawatts per pulse, which will be used mainly for plasma physics experiments. The other one, provided by the British HIBEF partners, is designed to generate high-energy pulses of up to 100 joules – this is vital for experiments that involve sending intense shock waves through material samples. Both lasers are able to fire up to ten flashes per second.

The principle behind the experiments: With their high-intensity pulses, the lasers will put a material sample into an extreme state, heating it to millions of degrees or compressing it to a fraction of its original volume. Immediately afterwards, X-ray flashes from the European XFEL will penetrate the maltreated sample – revealing details about what occurs during these extreme processes.

One of the things scientists want to discover more about are the inner workings of gas planets. Enormous pressures and temperatures reign inside of Jupiter, for instance. HIBEF researchers want to use experiments to simulate the occurrences inside the gas giant and find out about the exotic crystal structures which matter takes there. To achieve these extreme conditions, physicists will work with diamond anvils, pressing two diamonds together at high force, which can generate enormous pressure of up to six million atmospheres. During some experiments, the diamond tips are likely to shatter under the high pressure. This means that experiments will have to take place very fast and be captured securely before the diamond fails. →

Rapid shock waves

The shock wave experiments are quite spectacular, as well: Experts will embed the actual sample material into a thin sandwich of other layers. The British high-energy laser will virtually pulverize them, triggering a shock wave that will shoot through the sample at speeds of up to 5,000 meters per second. To help analyze this phenomenon, the ultra-short X-ray pulses from the European XFEL will provide an extremely high temporal resolution. "We will take a series of snapshots and create a video of how the shock waves spread through the material," Bähtz explains.

The high-performance laser from HZDR, on the other hand, is designed to support the research of plasma phenomena. The principle is this: It will fire short light flashes onto a sample such as a foil. Plasma, that is an extremely hot, electrically charged gas, will form on a tiny spot, followed immediately by an X-ray flash from the European XFEL that will reveal what is happening. By varying the time interval between the laser pulse and the X-ray flash, researchers can obtain a precise time profile of the process and combine the images to create a video afterwards. The method will provide a resolution of the plasma down to just a few nanometers – precise enough to reveal instabilities in detail. This type of experiment is particularly important for laser plasma acceleration. It promises to find a much more efficient mechanism for accelerating electrically charged particles than what is available to us in today's often gigantic facilities.

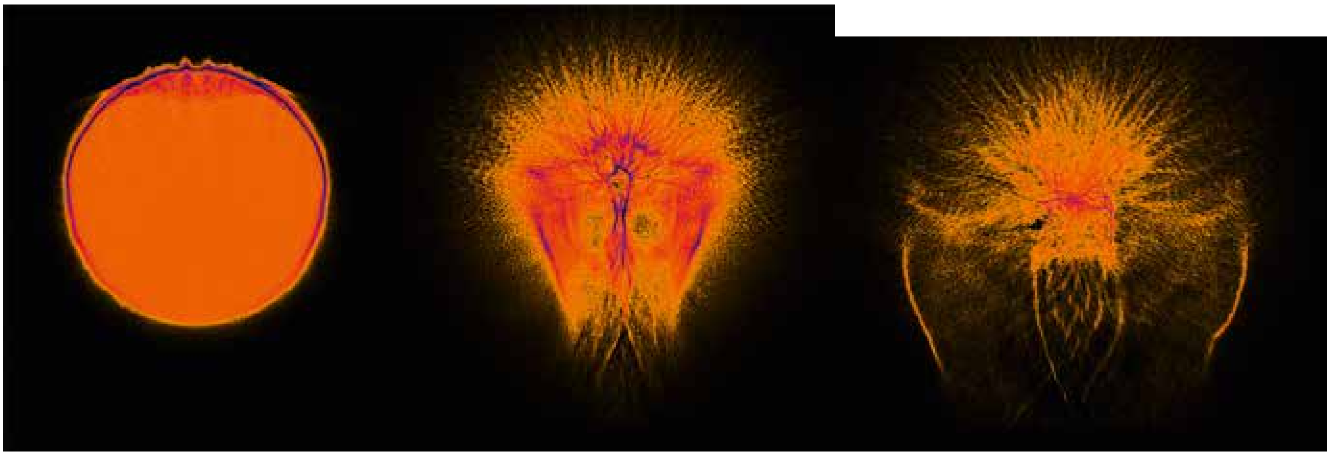
Extreme magnetic fields

Now Carsten Bähtz walks the length of the bare room, stopping after a few steps. "This is where we will put the test bay for the magnet experiments." The electromagnet in question is no ordinary specimen. "Magnetic fields of the magnitude we require can only be maintained for a short period of time," the researcher explains. "Therefore, we work with a pulsed magnetic coil that is activated for less than a millisecond at a time. Otherwise, it would burn up." While even the best DC superconducting magnets can generate a field of about 20 tesla, the pulsed magnetic fields of the special coil will achieve up to 60 tesla – an electric pulse will be shot through a coil, generating a magnetic field lasting for the blink of an eye that is 20 times stronger than a modern MRI scanner. →

International Cooperation

HIBEF stands for "Helmholtz International Beamline for Extreme Fields". HZDR coordinates an international user consortium consisting of about 80 groups from over 60 institutes in 16 countries. Their main partner is the DESY Research Center. The consortium comprises more than 350 scientists and about 300 Ph.D. candidates from a wide range of disciplines, from laser experts to X-ray researchers to plasma physicists. HIBEF contributes the major instruments for experiments at the "High-Energy Density Science Instrument" (HED). In addition to HIBEF, the Helmholtz Association supports two more projects at the European XFEL – "Serial Femtosecond X-Ray Crystallography" (SFX) and the "Heisenberg Resonant Inelastic X-Ray Scattering" (hRIXS) whose construction is being coordinated by DESY. Overall, the project received 29.8 million Euros in support funds from the Helmholtz Association, and a similar amount from international partners, as well as HZDR and DESY.

KNOWS NO BOUNDARIES: The XFEL tunnel runs between the Deutsches Elektronen-Synchrotron DESY site in Hamburg and Schenefeld in neighboring Schleswig-Holstein.
Photo: European XFEL



LASER PLASMA: At the Helmholtz International Beamline for Extreme Fields HIBEF, researchers want to investigate how materials behave under extreme conditions such as being shot at with a high performance laser. Here we see the simulated expansion of a spherical target. The XFEL will make it possible to actually image such processes.
Simulation: Axel Hübl

This technology allows material samples to be momentarily put into an exceptional magnetic state and simultaneously made observable by a round of pulses from the European X-ray laser. This will, among other things, make it possible to explore the crystal structure. Spectroscopic methods uncover information on the immediate chemical environment of certain types of atoms. And a special phase contrast procedure can even facilitate direct imaging. "In such high magnetic fields, we expect magnetic materials such as cobalt chromium oxide to rearrange to form novel, exotic crystal structures," Carsten Bähtz says. The experiments at the XFEL complement the work at the High Magnetic Field Lab in Dresden-Rossendorf. While the latter can generate even higher magnetic fields, it does not have X-ray laser capabilities to analyze the samples.

Bähtz leaves the experimental hut and, back in the main hall, shows us an opening at the top of the wall. "At HIBEF we are planning another building. It will be outside of the hall and connected with a tunnel that will end up there." Among other things, this new structure will house the capacitor bank that will supply power to the magnetic coil. It will also provide room for even stronger lasers with pulses that are supposed to reach a petawatt rather than 300 terawatts – ambitious goals for the future.

Densely packed

A few steps further down the hall, Bähtz's colleague Andreas Schmidt from the European XFEL awaits us on the still bare concrete floor. "This is where we will put the control room," the engineer explains. "We haven't even erected the walls yet, but soon this area will be full of monitors and keyboards – and I assume we'll have a coffeemaker, too." Then Schmidt points to the hall: "It's still quite empty, but in a few months' time, this hall will be packed with countless experimental hutches and tech rooms." To make the best possible use of the space, they are systematically building upwards: The rooms containing electronics racks, A/C ducts, cable lines and pipes will be constructed on top of the hutches.

Right now, they are still working on the basic set-up, but the fine detail will follow, such as building and adjusting the highly complex laser facilities. "The hutches are scheduled to be completed by early 2017," Andreas Schmidt explains. "The first experiments will start in 2018." Since some HIBEF structure will only be added in the years to come, the measuring station won't be fully complete until the year 2020.

Experiments will run in shifts, seven days a week, 24 hours a day. The HIBEF experts will however have to share the X-ray flashes of the European XFEL with the neighboring measuring station. An extremely finely polished special mirror will redirect the pulses every twelve hours, channeling them to one of two beamlines. While experiments are underway on the HIBEF instruments, no one is allowed inside the hut for radiation protection. But the researchers will also keep busy during the twelve hours when it is the turn of the other measuring station. "This is the time we will prepare and mount new samples," says Carsten Bähtz. "We might end up being busier during the off-time than during the actual measurements."

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www.xfel.eu

// How HZDR physicists want to study the vacuum.

SHOOTING A LASER AT NOTHING

_TEXT . Frank Grotelüschen

EXPECTANT: Ulrich Schramm, Thomas Cowan and Roland Sauerbrey (from left to right) are keen to implement their vacuum experiment at the Helmholtz International Beamline for Extreme Fields HIBEF. Photo: Rainer Weisflog

The plan sounds like a complete act of folly: Physicists shoot a laser flash into the vacuum – that is, into absolute nothingness – and still hope to achieve spectacular measurements. This is an experiment that really is supposed to be undertaken in the years to come, at the Helmholtz International Beamline for Extreme Fields (HIBEF) at the European XFEL in Hamburg. If it is successful, it will either impressively confirm a basic theory of physics or – even more excitingly – discover evidence of new, previously undiscovered particles.

The idea for the experiment occurred to Roland Sauerbrey, the Scientific Director of the Helmholtz-Zentrum Dresden-Rossendorf, back in the last decade. Experts were already well aware that the vacuum is not really an empty space – one of the more curious findings of quantum physics. In particular, pairs of particles and anti-particles can constantly be created out of nothing and then immediately destroy each other again after an immeasurably short time. "If you look at a vacuum more closely, it's really a bubbling soup of particles and anti-particles, constantly being created and destroyed," Sauerbrey explains.

Admittedly, these particle-anti-particle pairs that pop up so briefly cannot be observed directly. But for an infinitesimal moment, they produce an electric dipole and this field can be verified indirectly because it results in electrical charges in atoms being slightly weakened or strengthened. In theory, these "virtual" dipoles should, however, also interact with light – after all, light is nothing other than an electromagnetic wave. It is precisely this that Sauerbrey and his colleagues want to demonstrate for the first time with their experiment. "We are planning an experiment that will allow us to observe the optical properties of the vacuum."

The only problem is that current technology simply does not allow these properties to be measured because the dipoles pop up somewhere at random, sometimes pointing in one →

direction and sometimes in the other. They are statistically distributed, which means that in their entirety they add up to zero. "In order to measure anything at all, one would have to align the dipoles," Sauerbrey explains. "That's the idea behind our experiment." What is a challenge, is that extremely strong electrical fields are needed to align the dipoles, and they can only be produced by lasers. These lasers deliver short, merely femtosecond-long flashes of light containing the phenomenal power of one petawatt – a quadrillion watts.

Vacuum interacting with light

Such extreme flashes should be sufficient to bring the virtual vacuum dipoles into line. And that should have an unusual effect on light: theoretically, just like quartz crystals, they should exhibit the property of birefringence and rotate the oscillation plane of the light slightly. If this change in polarization could be measured, it would prove that the vacuum really does interact with light – a physics world premiere.

The experiment is scheduled to take place in Hamburg where the strongest X-ray laser in the world is currently under construction – the European XFEL. Over the next few years in the HIBEF project, HZDR is constructing a petawatt laser. Its job will be to align the dipoles in the vacuum. The strong, ultra-short X-ray flashes from the XFEL will then act as a "trial balloon": If the oscillation plane changes, the new effect will be proven.

The setting will be a steel vacuum chamber in which the pressure will only be approximately 10^{-9} millibars – roughly a trillionth of atmospheric pressure. The actual range of measurement is just a few micrometers. "It mustn't contain even a single atom. That would ruin the measurement," emphasizes Thomas Cowan who coordinates the HIBEF user consortium. Consequently, the researchers have thought up a special kind of vacuum cleaner: They want to send in another flash ahead of the petawatt pulse that will ionize, that is, electrically charge, any atoms present. These ions will then be attracted by two highly-charged capacitor plates and thus neatly extracted from the measurement range.

The petawatt laser fires a flash into this cleansed region, focused by a parabolic mirror. "Normally, you use lasers like this to shoot at material samples," Cowan explains. "We are simply shooting at nothing." Shortly afterwards, the researchers will direct a polarized X-ray flash into the chamber. Then a refined detection apparatus will be able to verify very precisely whether the oscillation plane has undergone the slightest changes when passing through the vacuum.

HIGH-PERFORMANCE: The petawatt laser PENELOPE is currently under construction at HZDR. A similar high-performance laser will also be used at HIBEF. Photo: Oliver Killig

Petawatt power

"One of the major challenges is to precisely synchronize the flashes from the petawatt laser and the XFEL," explains HZDR expert for laser particle acceleration, Ulrich Schramm. "The sequence of pulses must be accurate down to ten femtoseconds." A sophisticated time comparison with the electron packets in the XFEL particle accelerator is supposed to guarantee accuracy. "It should really be possible to do the experiment in an hour of measuring time," Schramm hopes. "But first of all, we have to get it up and running, and that could take years, at least until 2021."

So far, there have been five researchers in the team – the initiator, Sauerbrey, and four other physicists from Dresden and Plymouth University in the UK. Now, when it comes to implementing the project, the research group is set to grow to 20 experts, including partners from the Helmholtz Institute Jena, DESY and XFEL. While Sauerbrey already has plenty of organization and administration to keep him occupied as Scientific Director of HZDR, he still takes time for the ambitious research project. After all, "It wouldn't be right to neglect science altogether."

If the experiment is successful, the result will certainly be interesting: "Either we'll be able to confirm the existing theory, quantum electrodynamics, in a completely different area from what we have known about so far," Roland Sauerbrey explains, "or we'll find something that deviates from the theory." Some experts are already speculating that hypothetical, as yet undiscovered, particles could reveal themselves in the measurement data by noticeably increasing or weakening the expected signal. And that, according to Sauerbrey, would be nothing short of a veritable sensation.

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// A new tumor therapy first marks cancer cells, then destroys them.

MARCHING APART, BATTLING TOGETHER

_TEXT . Roland Knauer

When a physician diagnoses a malignant tumor, the patient's life changes radically. Frequently, it is not only the often lethally dangerous disease itself, but the additional burden of chemo- or radiation therapy, which is designed to combat the cancer and its potential metastatic spread, but also has serious side effects. Hans-Jürgen Pietzsch at the HZDR Institute of Radiopharmaceutical Cancer Research wants to drastically reduce these negative side effects by dividing up inner radiation therapy with radioactive substances into two stages, thus shortening the time during which healthy tissue is exposed to radiation.

Mistaken for iodine

Nuclear medicine specialists have been using radioactive elements for decades – initially mainly for examinations, later also for treatment. Technetium-99m plays an important role in diagnostics. This radionuclide likes to combine with four oxygen atoms to form a "pertechnetate-ion", which the organism will mistake for an iodine ion because its size and electric charge are similar. Therefore, this compound will show up in parts of the body where a lot of iodine is needed, such as the thyroid. If a tumor with actively growing tissue is present, a large amount of pertechnetate will accumulate. Half of the technetium-99m decays within six hours, emitting gamma radiation, thus revealing its current location. In the process, measuring tools not only detect the "hot knot", that is the strong gamma radiation emanating from the thyroid tumor, but also secondary tumors, or what physicians call metastases, which are normally difficult to locate.

"Technetium-99m is built into a variety of other compounds that accumulate in various types of tissue, visualizing, for example, a change in blood circulation in the brain after a stroke or in the heart following a heart attack," explains Hans-Jürgen Pietzsch. Such radioactive substances not only detect tumors and metastases, but can also treat them because their radiation is harmful to the tissue. So when these substances accumulate predominantly in the tumor, that is where they cause the most damage. Instead of a gamma emitter such as technetium-99m, physicians use beta emitters in radionuclide therapy, such as yttrium-90. Its radiation is more powerful, more intense, and does more damage to the diseased cells than gamma radiation.

Radiation destroys tumors

To transport the radioactive substance to the cancer cells, nuclear medicine experts use antibodies that are normally produced by the body's immune system. They are able to precisely detect structures on the surface of pathogens and only attach themselves to them and nowhere else. This marker reliably alerts the immune system to an attacker, which can then be rapidly combated. These structures also exist on many tumors for which antibodies can be produced. Physicians use them to target the malignant growth and any metastases that may already have spread from it. Chemists at HZDR attach what is called a "chelator" to the antibodies, a molecule to which a metal ion can latch on. This creates a more stable complex. One such metal is yttrium-90, which the antibody transports to the tumor.

This method is very reliable, but it does have one significant drawback: "It takes up to 48 hours for the antibody to reach its greatest density in the tumor," explains Hans-Jürgen Pietzsch. During these two days, the tumor antibodies with their radioactive cargo are travelling through the organism, potentially harming healthy tissue. This particularly affects the blood and the bone marrow, where large numbers of blood cells are being produced continuously, as well as the liver and kidneys, where the antibody with its yttrium-90 attached is disposed of. →

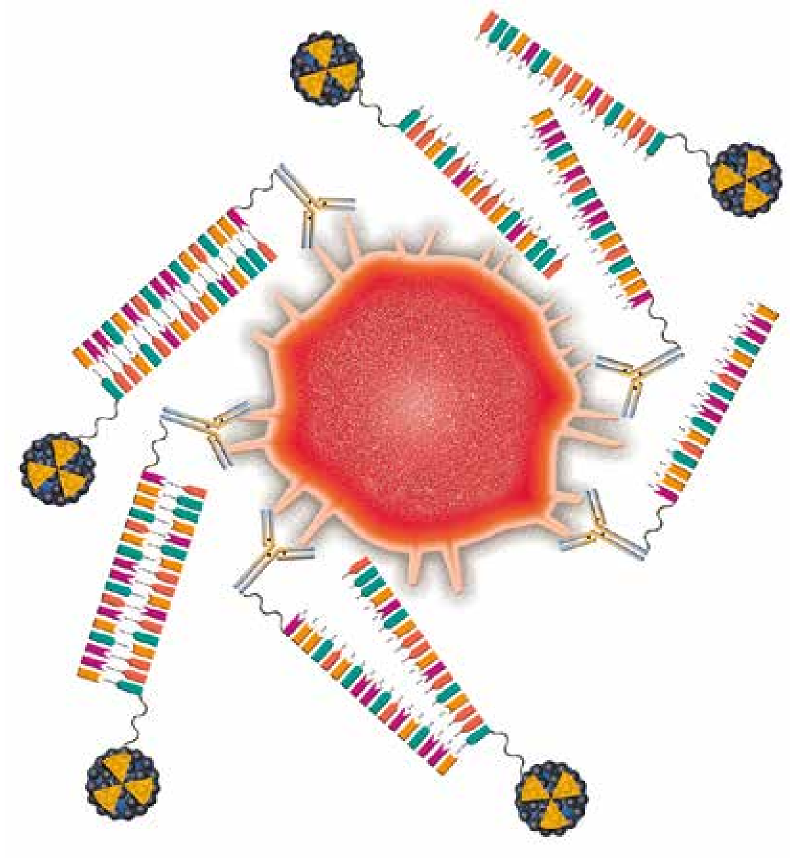
WORKING AGAINST CANCER: Dresden researchers want to use antibodies to destroy tumors. Photo: Frank Bierstedt

Coupling radionuclides

There is an elegant trick to significantly reduce such severe side effects. Bird eggs contain a relatively large biomolecule which biochemists call "avidin". This molecule likes to latch on to the much smaller molecule "biotin", known to laymen as vitamin H. "And to this biotin, we can attach the radionuclide yttrium-90," Hans-Jürgen Pietzsch reports. With or without radioactive cargo, vitamin H passes through the organism much faster than an antibody searching for a tumor.

This clears the path for a double-pronged strategy: First, the avidin molecule is attached to the antibody which systematically searches for the tumor. This large and rather stolid molecule can slowly but surely search for the tumor and potential metastases. Since it is not yet transporting any

STRATEGIST: Hans-Jürgen Pietzsch is pinning his hopes on antibodies, molecules and genetic material to discover and treat diseased cells. Photo: Rainer Weisflog



STRONG COMBINATION: In the so-called pre-targeting strategy, "scouts" like the peptide nucleic acid-antibody combination shown here are first sent ahead and congregate around the diseased cells. In the second step, equivalent combinations with radioactive markers couple with their partners. Illustration: Pfefferkorn

radioactivity, it will not harm any tissue at this time. Only when enough of the antibody with the avidin molecule has reached the target the nuclear medicine specialist will send biotin with yttrium-90 on its way. This will find its destination within minutes, thus causing a lot less harm to the healthy tissue than a two-day journey would. In the tumor, biotin will couple with avidin and eliminate the cancer cells.

Nucleic acid coupling

At present, this dual strategy is still quite complex and therefore costly. "It would be simpler and cheaper to use DNA or RNA to attach the radioactive element to the antibody," says Hans-Jürgen Pietzsch, describing his strategy. The genetic material consists of two strands of nucleic acid that combine tightly to form a double strand. If you attach an antibody to one of these strands and equip its counterpart with yttrium-90 or another radionuclide, this relatively small molecule will quickly travel to its partner in the tumor – and start destroying the latter.

This method does, however, have one grave disadvantage: An organism contains highly specialized enzymes which will quickly break down such one-stranded nucleic acids. Therefore, HZDR researchers are using artificial nucleic acid elements with a backbone consisting of peptides rather than sugar and phosphate. Another alternative would be a nucleic acid backbone where the natural sugar element is replaced by its artificial mirror-image molecule. Since such compounds are unknown to the organism, it has no enzymes to break them down. Scientists at HZDR are working on these projects in cooperation with the biotechnology company NOXXON Pharma Berlin.

"We attach a chelator that will bind technetium-99m or other radionuclides to one of these mirror-image nucleic acids," Hans-Jürgen Pietzsch explains. This construction soon reaches a tumor in mice, but shows up a lot less frequently in the liver than in traditional radionuclide therapy. "Next, we want to study whether these mirror-image nucleic acids in combination with a radionuclide will actually shrink a tumor in a mouse," the scientist explains. In the future, HZDR's investments in radiopharmaceutical cancer research could significantly reduce the serious side effects of tumor therapy on patients.

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// Radiopharmaceuticals for Positron Emission Tomography are an HZDR specialty – though the researchers are up against a formidable opponent.

THE DAILY RACE AGAINST TIME

_TEXT . Sara Schmiedel

In the mornings, time is of the essence. Synthesizing radiopharmaceuticals labeled with fluorine-18 should take no longer than 20 minutes, because scientists and lab assistants are up against a formidable opponent: radioactive half-life. After as little as two hours, half of the pharmaceutical will have decayed, which means it can only be used for fewer patients. "We work on a tight schedule," Frank Füchtner explains. "We start at 5am with the radionuclide production at our cyclotron, a particle accelerator. By 7am, the product is on its way to the user." Füchtner is the head of radiopharmaceutical production at the Institute of Radiopharmaceutical Cancer Research at HZDR. He and his small team of just 15 virtually operate an entire pharmaceutical enterprise.

RADIATING POTENTIAL: Frank Füchtner heads the production of radiopharmaceuticals at HZDR. Photo: Rainer Weisflog

Short-lived cancer detectors

Radiopharmaceuticals are radioactive substances used in Positron Emission Tomography (PET), mainly for tumor diagnosis in oncology, but also in cardiology and neurology. A small amount of the radioactive substance is injected into the patient prior to an examination. This substance is often fluorodeoxyglucose labeled with fluorine-18, or FDG for short, which accumulates differently in healthy and in cancerous tissue. The PET scan detects the radiation that is emitted during the decay of the radionuclides, providing insights into the size and location of tumors and metastases.

In Rossendorf, FDG is also by far the most frequently produced radiopharmaceutical. In general, a radiopharmaceutical is manufactured in three steps. The first one is to generate the radionuclide using the cyclotron. To this end, scientists accelerate protons and bombard solid, liquid, or gaseous targets. The impact of the tiny particles triggers a nuclear reaction. To generate the radionuclide

fluorine-18, which is necessary to produce FDG, researchers use water enriched with the oxygen isotope O-18 as the radiation target.

Good manufacturing practice guarantees quality

In the second step, the radionuclide is harnessed for nuclear medicine by embedding it into a sugar or amino acid molecule. In the synthesis lab, the Dresden researchers create the real drug from the radionuclide and other substances – shielded in the cleanroom behind almost ten centimeters of lead walls. "We work with computer-controlled synthesis machines," Füchtner says.

The third step in radiopharmaceutical production is the quality control of special samples, which must be done for every single batch. This happens while the freshly produced pharmaceuticals are already packed into a transport container and on their way to Dresden University Hospital or other nuclear medical facilities. "As soon as we release the product, it is ready to be used on the patient," says Jörg Zessin, who is as a so-called Qualified Person responsible for this procedure, describing the daily routine.

The entire radiopharmaceutical production is subject to the rules of Good Manufacturing Practice, which are embedded in international and national laws and regulations. For instance, they lay out the requirements for the premises, the staff, and quality control. The facility must meet all requirements to be approved for production. HZDR is currently authorized to produce 14 different radiopharmaceuticals, delivering about 2,500 patient doses each year.

While most of the radiopharmaceuticals that are produced here have no official marketing authorisation, they are nevertheless legal to use. "You are allowed to produce radiopharmaceuticals and use them in house", radiopharmacist Füchtner explains. Until 2015, HZDR catered to its own patients, today, examinations are conducted at Carl Gustav Carus University Hospital in Dresden as part of the jointly operated PET Center. "Getting a new radiopharmaceutical licensed is very complex and costly," Füchtner explains. "We would have to conduct clinical studies, and we do not have the staffing capacity for that."

SHIELDED: In the cleanrooms at the Center for Radiopharmaceutical Tumor Research, HZDR chemists manufacture the in-demand radiopharmaceuticals. Photo: Rainer Weisflog

Higher energies and shorter paths starting in 2017

Nevertheless the team's portfolio is not yet complete. More, novel substances are thinkable. It takes at least a year to develop a substance from its theoretical description in medical literature to clinical application. "The process only works in close cooperation with medical partners," says Frank Füchtner. The new Center for Radiopharmaceutical Tumor Research, which is currently being established at the HZDR site, is a solid foundation for such cooperation. In the shielded bunker, a brand new cyclotron is waiting to be taken into use for radionuclide production.

The old Rossendorf cyclotron – the centerpiece of radiopharmaceutical production – got a bit old. "We would have had to replace the control electronics and modernize the transport system as well as other components, which would have triggered very high costs," HZDR's cyclotron engineer, Stephan Preusche explains. "In addition, the performance parameters have reached their limits." The new center will also integrate the cyclotron, the radiopharmaceutical production facilities and the research labs under one roof. And since the new particle accelerator is much more powerful than its predecessor, it will open up a variety of new research opportunities.

"We will be able to accelerate more protons to energies of up to 30 megaelectronvolts, up from the 18 megaelectronvolts we had in the past. This enables us to generate radionuclides with much higher activity," Füchtner predicts. It will also be possible to produce new radionuclides that are particularly suitable for nuclear medicine therapy. Routine operation is scheduled to the middle of 2017. Frank Füchtner is looking forward to it: "We will have really excellent conditions."

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// The Rossendorf Campus is just a half an hour's drive from the city center of Dresden – but is situated in the middle of the woods. "discovered" spoke to Administrative Director Peter Joehnk about the challenges posed by this unusual location.

"WE SET THE RIGHT COURSE"

_Interview . Sabine Penkawa

MASTER PLANNER: Administrative Director Peter Joehnk is at the helm of HZDR for many years. Photo: Philip Benjamin/NCT Dresden

Mr Joehnk, what is so special about the research campus?

There are lots of things. For one, the situation in the middle of the countryside, which affects all our activities. Nature conservation and climate protection have been part of our master plan for many years, as has sustainable construction. In our integrated climate and environmental protection strategy that will be completed in summer 2017, we are defining them even more clearly. For another, our top-level research and, above all, the people who work here make us special. Our doctoral candidates and trainees are often among the best in their year – just think of all the awards.

For nearly 15 years, HZDR has been renovating and building on the basis of sustainable criteria.

In order to advance the modernization of the site, we drew up a master plan in 2002. Since then, all measures are assessed before being implemented according to economic, ecological and aesthetic criteria. The master plan is still valid, although it has been updated three times, and the issues that concerned us then are still just as relevant. We want to create a site that is both attractive and offers excellent working conditions for world-class research. →

GREAT RESEARCH IN BUCOLIC SETTING: The HZDR Campus covers an area nearly as large as the city-state of Monaco. Photo: Jürgen-M. Schulter/Dresden-luftfoto.de

A lot has changed on the site since then. What has been your major focus?

When you look round our campus today, I think you will agree that we set the right course. The majority of buildings and labs have been renovated and with the newly-designed entrance area we have given the center a public face. But, above all, we have fundamentally modernized and extended the research infrastructure. And that is not a matter of course. Renovation is currently a hot topic in the Helmholtz Association because a number of centers were not able to do the necessary work in the past and still have a considerable backlog.

Why is sustainable construction so important to HZDR?

It is our contribution to conserving resources, but also to conserving our budget! To give you just a few examples: Our center is largely heated using renewable energies. We have a highly-efficient geothermal plant and our own cogeneration plant that provides energy as well as heat. We more than fulfill the legal requirement to cover at least 50 percent of the heat requirements in new buildings with renewables. When renovating the old buildings, we made sure they were properly insulated and so we have been able to save between 55 and 70 percent of heat loss per building.

How do the scientists benefit from these changes?

In the last few years, we have created unique opportunities for experimentation. Research facilities like our High Magnetic Field Laboratory, the Ion Beam Center and the ELBE Center for High-Power Radiation Sources offer outstanding conditions for researchers from all over the world. Our new Center for Radiopharmaceutical Tumor Research is approaching completion and will go into operation in 2017, further strengthening Dresden as a cancer research location. Another important project is our research platform DRESDYN, a unique facility for experiments on liquid metals. Here, too, we hope the first experiments will be launched in the course of the year. This is another project that is sure to attract a lot of attention in the research community.

Where do you see further need for action in the coming years?

We are on the right path. Rossendorf must remain future-proof, in all respects. We are working hard to make sure it does, and with visible results. One topic that is bound to be particularly relevant in the future is energy saving. Due to the new buildings and the additional research facilities we have a permanently growing demand for energy, which has a considerable impact on our operating costs. We have to do something about it. We have just recently completed a project together with other Helmholtz Centers called "Campus 2030" in which we gathered important data on medium consumption. Taking this as a basis, we are now working on an energy strategy together with other Helmholtz Centers and the Fraunhofer Competence Center at the University of Bayreuth that is supposed to act as a model for campuses with high energy needs. The aim is to achieve a sustainable and efficient use of energy. Our detailed data collection and our experience with a whole raft of construction measures and technical installations is flowing into the strategy. At the end, we will evaluate the results and, if they are compatible, implement them at the site here. The other centers are pursuing the same goal.

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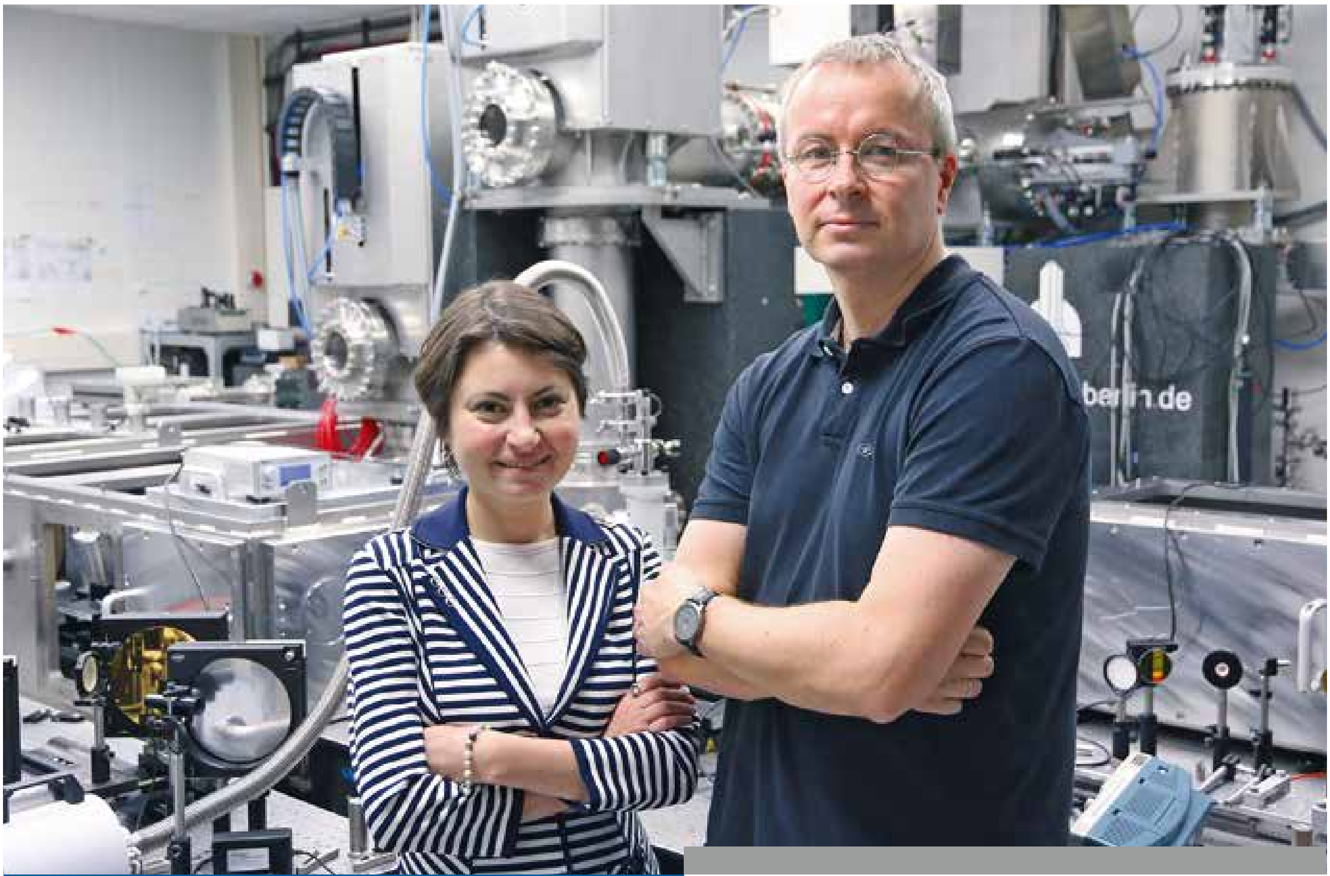
// Thanks to international networking, Alina Deac and Michael Gensch were able to launch the EU project TRANSPIRE. This promising endeavor could make data transmission networks significantly faster.

HARNESSING A TERAHERTZ SOURCE FOR A GIGABIT SOCIETY

_Text . Heiko Weckbrodt



TRANSNATIONAL TEAM: Alina Deac and Michael Gensch are working on new concepts for high-speed wireless networks.

Europe's path towards turbo-fast internet could be paved by Ireland, Norway, Switzerland, and Germany. The TRANSPIRE project unites researchers and engineers from these countries in a quest to get novel terahertz radio technology market-ready: Thin layers of highly magnetic materials will enable future data networks to transmit information 100 to 1,000 times faster than today's wireless networks. The European Union is contributing about 4.4 million euros in funding from its "FET Open" program to this project, which became possible mainly due to its cross-border networking between young and experienced researchers. Two groups from the Helmholtz-Zentrum Dresden-Rossendorf are part of this alliance.

One of these networkers is Alina Deac, a spintronics expert from Romania who had already worked in research in Japan, France, Switzerland, the USA and Germany before joining HZDR in early 2011. "I came to Dresden because I saw a lot of opportunities to drive my research and to work with colleagues who have special expertise in materials characterization," Deac explains. As leader of a Helmholtz Young Investigators Group, she has been tapping her international contacts time and again to connect young researchers and businesses in Saxony, Ireland, Norway and Switzerland.

"Alina was the central hub in our network, she's the one who established the connection between Trinity College Dublin and HZDR," Michael Gensch recounts. He and his HZDR group on "High-field THz-driven phenomena" are also involved in the project. "One day she showed up with these samples of thin magnetic films. Our Irish colleagues specialize in growing them, and the Max Planck Institute for Chemical Physics of Solids in Dresden uses them in experiments, as well." Alina Deac knew that Dresden-Rossendorf was home to TELBE, a special terahertz radiation source to analyze materials. "Our analyses showed that ultra-short laser pulses can very easily stimulate these films to emit terahertz radiation at a very precisely controllable frequency."

On the horizon: tiny LED-size terahertz sources

It was a minor sensation, because it usually takes very large and expensive facilities to generate spectrally tunable radiation in this frequency range. These extremely thin films, prepared at Trinity College Dublin, suddenly opened up a new technological approach to developing pinhead-sized terahertz sources in the near future, as Gensch explains. "As soon as this became evident, we had the idea of submitting a joint grant application to the EU to prove that we can build a ready-to-use new class of such sources. Our main selling point was that these light sources will be stimulated by electricity rather than laser light."

The joint project with the title "Terahertz RAdio communication using high aNistropy SPIn torque Resonators" (TRANSPIRE) was approved for funding in the European

> "For young researchers, international cooperation is a matter of course."

program "Future and Emerging Technologies – Open" (FET Open). Being chosen is a badge of honor in itself because the program is highly selective: Only 22 out of 544 grant applications were approved in that round. The fact that TRANSPIRE was among the select few, was partly because a compact terahertz source would be immensely useful for powerful data network transmitters and receivers. It is also a beacon project because it unites scientists from leading universities and research institutes as well as corporate developers from various countries in close cooperation.

The researchers from Trinity College Dublin prepare the thin films with their special magnetic properties. Michael Gensch's work group takes care of their characterization, while Arne Brataas from the University of Trondheim, Norway, is in charge of the theoretical side: His computer simulations shed light on the underlying physics behind the terahertz emissions in the material, which will help further optimize the "ingredients" of the films. Emile de Rijk of Swiss corporate partner "SWISSto12" brings the commercial perspective to the table – because terahertz sources will not be of any use to anyone if they only work in the lab. All these activities converge with Alina Deac's team, which will design the first prototypes.

Cultural diversity inspires research

Plamen Stamenov from Trinity College Dublin and the Irish science foundation AMBER are the leading partner in the project as a whole. "The grant is an acknowledgement of our work on the physics of spin-polarized materials over the past five to ten years, but also a recognition of the quality and expertise of our partners in Germany, Norway and Switzerland. I hope we will lay the foundations for the high-speed data networks of the future."

Junior researchers like Alina Deac and her peers network at international level early in their careers, tackling hot European topics like gigabit technologies. What is a matter of course to them is a relatively recent mindset that has evolved in Saxony over the past decade or two. Before, even brilliant young talents had to slowly work their way up the career ladder before they were allowed to head their own international team. Today, young researchers grow up with the notion that top-level international collaboration is a fundamental prerequisite for achieving outstanding results in natural science, and that international networks are essential for their own research careers. In addition, tools like junior research groups provide the brightest young scientific minds with opportunities to assume responsibility early on.

Research groups within the institutes have also become more cosmopolitan. "We are not just Germans here, we have American, Russian, Indian, Chinese and Turkish scientists in our groups," Michael Gensch tells. "This cultural diversity is very inspiring." And it is driven by aspirations of excellence. Gensch is convinced that "the world's brightest minds will go where they can collaborate with the best of the best, where they find the best research equipment and workplaces – like our TELBE."

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// Mechthild Krause has headed the HZDR Institute of Radiation Oncology as well as the OncoRay Center since the beginning of July. The radiotherapist is counting on the fast transfer of scientific research to clinical application.

FROM LAB BENCH TO HOSPITAL BED

_Text . Simon Schmitt

"The hybrid medical practitioner and researcher is a rare breed," a fact that radiotherapist Mechthild Krause finds problematic: "Both fields mutually stimulate each other. My experience at the hospital helps to direct my research in the lab. At the same time, scientific results can be translated into treatment much faster." It is this bridge between preclinical research and its application in cancer therapy that excites the new director of HZDR's Institute of Radiation Oncology and the OncoRay Center. "When I was a young resident physician, I was able to do fundamental research, which is rarely the case, regrettably."

Since 2001, she has been able to combine this knowledge with her experience of treating cancer at the Clinic for Radiotherapy at Dresden University Hospital. "This prototype of a clinician-scientist – a researcher who also works in the hospital – is still pretty uncommon," Krause explains. "But it could improve the transfer of knowledge from the lab to the hospital. Generally, the transition from innovative results in cancer research to actual clinical treatment is still sluggish. We want to alleviate this problem with dedicated departments that specialize in bridging this gap." Krause believes that this can be achieved by building on the strong network that she helped start and that has now established itself in Germany.

RESEARCH IN HER HEAD, PATIENTS ON HER MIND:
Mechthild Krause. Photo: Rainer Weisflog

In addition to her duties at HZDR and OncoRay, Krause is also a professor for the German Consortium for Transnational Cancer Research. At the beginning of November, she took the helm of the Clinic for Radiotherapy at Dresden University Hospital. The establishment of the National Center for Tumor Diseases in Dresden has strengthened cooperation with the German Cancer Research Center in Heidelberg. In her role as new institute director, Mechthild Krause aims to expand this network at international level, as well: "We are particularly keen to cooperate with other particle therapy centers such as the ones in Groningen, Aarhus and Manchester." One way to do this, according to Krause, is an exchange program for young researchers: "Strong personal relationships lead to strong connections that facilitate sound knowledge sharing."

Biological individualization is one of Krause's focus areas. "We still face the problem that one and the same treatment of similar or seemingly identical tumors may work for some patients and not for others. This discrepancy is caused by individual biological factors." Therefore, Krause wants to develop special biomarkers that can predict the effectiveness of radiotherapy. "This could allow us pinpointing and intervening in those processes that hinder the success of the treatment." As institute director, she is unlikely to evaluate data herself. "Nonetheless, I don't want to neglect my research too much because of increased administrative duties. Developing new ideas and projects, procuring third-party funding, coordinating inter-institutional research, and above all supporting young researchers will continue to be a large part of my day-to-day work." In this domain, she is sure to find the right balance, as well.

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// Under the leadership of Andrea Cherkouk, a group of young scientists is studying the microorganisms present in salt domes, which may be of great significance for radioactive waste repositories.

TINY INHABITANTS OF SALT DOMES

_Text . Inge Gerdes

Some microorganisms can exist under extremely hot, cold, and even salty conditions. "We study environments with high salt concentrations in which only very halophilic microorganisms can exist – these are organisms that like salt," Andrea Cherkouk explains. She is a geo-ecologist at HZDR's Institute of Resource Ecology. "Especially archaea, which are also known as primordial bacteria, are typical for unlikely habitats such as hot springs or, indeed, evaporates, which is rock salt."

The 38-year-old scientist leads the junior research group "MicroSalt" at the Department of Bio-geochemistry. She and her team examine microorganisms in evaporite formations. The group is advancing into a relatively unexplored microbiological area, one that is of particular interest to nuclear repository research – because if nuclear waste is stored in salt domes, the microorganisms present there could interact with the radioactive substances in various ways.

TRACKING DOWN SURVIVAL ARTISTS: Together with her doctoral students Madlen Franze (left) and Miriam Bader (right), Andrea Cherkouk studies microorganisms in rock salt. Photo: Matthias Rietschel

Delayed start

The idea of taking a closer look at these tiny microorganisms was born several years ago, but Cherkouk did not really embark on the endeavor until after the birth of her twins Malika and Jakob and her parental leave. In order to keep in touch with science, she returned to a part-time position eight months after having her babies. Another six months later, she increased from a 50 percent to a 75 percent position. HZDR supported her gradual return to work and helped her finding a nanny for her children. "That made it a lot easier for me to go back to work after my parental leave," the group leader tells us. "Otherwise, it would certainly have been a lot harder to strike the right balance between my family and my career."

Since 2014, Andrea Cherkouk has been back on a full-time position, building and leading her research group while at the same time preparing herself for this task by taking a special class at the Helmholtz-Akademie, the Helmholtz Association's professional development center. Miriam Bader was the first doctoral candidate in her new team of researchers. Last year, Bader spent two months at the Los Alamos National Laboratory – Carlsbad Operation in New Mexico for her dissertation on interactions between microorganisms and radionuclides in highly saline systems. Alongside her colleague, Julie Swanson, Bader studied the microorganisms present in the salt domes at the nearby "Waste Isolation Pilot Plant" repository, in particular their interactions with radionuclides. "She returned with useful results, which we will publish together," Andrea Cherkouk says.

A strong team

The group leader likes to use her professional network to arrange research visits abroad for her Ph.D. students. She also encourages them to →

TOUGH CONDITIONS: Even in salt, busy miniscule organisms can be found. Photo: Los Alamos National Laboratory

present their research outcomes at international conferences. In her experience, personal contacts are helpful for future collaboration. That is also true for her connections with the USA, which were deepened by Miriam Bader's work. Next year, the team's other doctoral candidate, Madlen Franze, will also travel to the US for research on halophilic microorganisms, this time with a focus on their resistance to radiation.

Andrea Cherkouk's team has now expanded to six members. In addition to her and her two doctoral candidates, there is post-doc Nicole Matschiavelli, Master's student Jennifer Steglich, and technical assistant Sindy Kluge. "We are an all-female team, which is not only my doing," the leader stresses. "The candidates were all selected by a committee."

The group owes its growth to projects like MIND or UMB. MIND is an EU-supported project to study microorganisms in waste repositories. The UMB project investigates the impact of microorganisms on bentonite transformation. This chemically weathered volcanic rock, which swells when it comes into contact with water, is supposed to be used as a barrier material and a sealant in waste repositories. These are exciting topics for the young scientists who are spending a lot of time in the lab these days, analyzing subterranean samples, trying to cultivate the organisms, or characterizing the tiny creatures using gene sequencing.

Research and family

Building the team, supervising doctoral candidates, overseeing experiments, publishing, keeping current projects afloat, developing new ideas and grant-writing – as group leader, Andrea Cherkouk is a busy woman. Yet, she still works on some smaller projects in the lab herself. She also networks with other institutes and fosters exchange with European and US partners. In addition to video conferences, she regularly travels to conferences and meetings.

Is there any time left for her family? "I must admit that it isn't always easy," says the mother of two. "But HZDR has created a supportive environment that helps to find a work-life balance." Shortly before eight o'clock, she takes the twins to kindergarten and picks them up in the afternoon. Since it is on her way to work, it makes the commute easier. Her husband also often takes the kids, which is a little harder for him because his workplace is in Freiberg. Whenever she travels for work, the grandparents support them.

"Of course, Jakob and Malika are curious about what mommy is doing all day," Andrea Cherkouk tells us. "They sum it up with the word 'experiments' and brag about how often they have come to visit me at work already." There are opportunities to do so, such as the annual Open House Day that showcases fun experiments.

Andrea Cherkouk is very happy that she is able to combine her family life and her scientific career. She is looking forward to continuing her work with her junior scientists and communicating the group's outcomes. In addition, she hopes she will be able to inspire students to pursue a career in her discipline by giving university lectures.

Family and career – no contradiction at HZDR

The Helmholtz-Zentrum offers a variety of family-friendly services to enable its employees to reconcile the demands of professional and family life: flexible work hours, part-time positions as well as telework. HZDR cooperates with two kindergartens and a nanny to provide its employees with easy access to childcare and follows consistent leave regulations so employees can take care of newborns or other dependents. A parent-child room at the HZDR guesthouse allows parents to bring their children to work if necessary.

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// She loves books and tennis – but her real passion are phenomena at the interface of physics and engineering. Kerstin Eckert is on a mission to discover the secrets of processes at interfaces, which still keep researchers guessing.

THE FRONTIER RUNNER

_Text . Sabine Penkawa

A PHYSICIST THROUGH AND THROUGH: For her research, Kerstin Eckert even uses zero gravity.

Kerstin Eckert has loved experiments since she was a child. "I always found physics exciting," she tells us. After attending the Martin-Andersen-Nexö-Gymnasium in Dresden, it was only logical for her to major in natural sciences at university. Today, she is particularly interested in what happens when various gases, liquids, and solids meet each other. What occurs at these points of contact? How can the processes be controlled?

"Especially since interface processes have such a major impact on material properties, it is important for us to understand them better," the scientist emphasizes. "We certainly aren't always aware of it, but we are dealing with interface reactions every day, for example, when a bike gets rusty. Whenever different materials come into contact with one another, processes occur at the interfaces, such as surfaces becoming soiled, or the self-cleaning lotus plant where water droplets roll off the surface of the leaves and wash away dirt particles."

Zero-gravity research

Since October, Kerstin Eckert has been professor for "Transport Processes at Interfaces" in the Faculty of Mechanical Engineering at TU Dresden. At HZDR's Institute of Fluid Dynamics, she heads a division of the same name. "In order for particles or molecules to accumulate at the interface, for substances to transfer, or for a chemical reaction to happen, they must first be transported there. We want to acquire a better understanding of the sub-processes that occur there and develop new methods to systematically control individual steps," the physicist explains. To achieve this, she even defies gravity, conducting research involving parabolic flight experiments, courtesy of the German Aerospace Center.

In September, Kerstin Eckert and her team used such a flight to study methods of separating rare-earth metal ions. "We apply magnetic fields to aqueous solutions containing such ions. Under certain conditions, due to their paramagnetic properties, they accumulate at interfaces if there is an inhomogeneous magnetic field. Research in a zero-gravity environment gives us the unique opportunity to obtain detailed insights into the individual sub-steps because gravity does not interfere with our observations. Magnetic separation could help reduce the consumption of solvents in recycling rare earths." →

Methods to optimize process engineering

Another research focus at the new division is flotation of fine-grained solids. This method takes advantage of the fact that gas bubbles easily attach to hydrophobic surfaces, that is surfaces that repel water, making these particles buoyant. "Flotation is the standard ore processing method and it also has great potential for further developing recycling procedures and waste water processing. We work with our colleagues at the Helmholtz Institute Freiberg for Resource Technology to better understand how certain resource particles adhere to bubbles under complex hydrodynamic conditions, and to optimize this process for various flotation methods," the professor explains.

When she is not in the lab, Kerstin Eckert loves spending time with her family, hiking with her husband and children. But even off duty, science is always on her mind. Her husband Sven Eckert – also a passionate physicist – heads the Division of Magnetohydrodynamics at the HZDR Institute of Fluid Dynamics. "Our research is also a big topic at home, of course. We counsel each other, which is very helpful."

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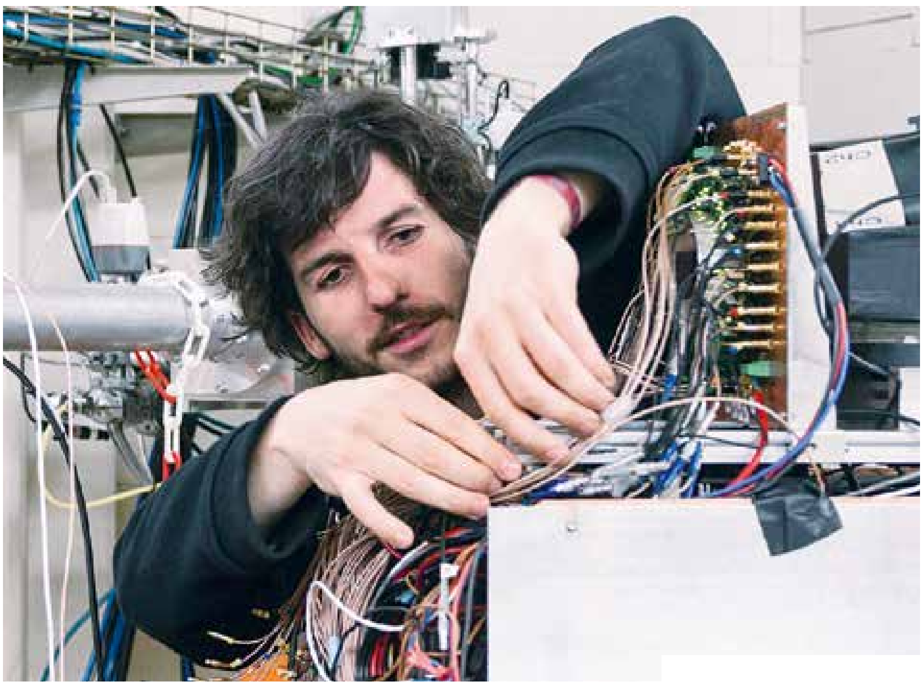
Nearly a full half dozen – Christian Golnik awarded the Behnken-Berger Prize

2012: Kristin Gurtner. 2013: Christian Richter. 2014: Karl Zeil. 2015: Kristin Stützer. And now Christian Golnik. For the fifth time in succession, one of the Behnken-Berger Foundation's prizes went to a researcher at HZDR or the OncoRay Center. Valued between 5,000 and 15,000 Euro depending on placing, the award addresses junior researchers in the field of radiation research. These successes also highlight the excellent collaboration between the two institutions. Christian Richter from OncoRay and Karl Zeil from HZDR's Institute of Radiation Physics, for instance, won the award for their joint research on the use of laser-driven proton acceleration in cancer therapy.

Kristin Stützer, who started her Ph.D. at HZDR and completed it at OncoRay, was able to build on the specialist knowledge of both institutions. On these grounds, she succeeded at enhancing the precision of the particle-therapy PET (positron emission tomography) in her Ph.D. project. And this year's winner, Christian Golnik, benefited from the close collaboration as well: some of his experiments were conducted at HZDR's ELBE accelerator and Ion Beam Center. The results are impressive: the cancer researcher's doctoral thesis led to a worldwide patent application. During his research, he discovered a new method of measuring the range of particle beams in tumor radiotherapy.

So far, the range of particle beams can be predicted prior to the treatment – but only with limited precision. That is why the potential of particle therapy has not yet been fully exploited. With the novel technique, however, the particle's path can be traced precisely without using invasive procedures. The method is based on a fundamental law of physics: When a proton beam penetrates tissue, some atomic nuclei are excited by nuclear reactions and emit gamma radiation. By using appropriate detectors, researchers can now determine the deceleration time – the time it takes the particles to travel through tissue till they are stopped – which allows them to check the stopping distance and thus the range of the particle beam. The novel technique has the potential to immediately visualize actual deviations from the irradiation plan.



EXCELLENT RESEARCH: Christian Golnik

International young scientist award for high-performance computing goes to Axel Hübl

There are tasks which challenge even the most powerful scientific computers available. Simulating a laser beam, for example, impacting a foil at hundreds of trillions of watts. What is produced is high-energy plasma – a wild mix of billions of electrons and ions. In order to create a three-dimensional model of all these particles, enormous computing power and an efficient code are required. Axel Hübl and other junior physicists at HZDR managed to develop one. Since 2008, the team around Michael Bussmann at HZDR's Institute of Radiation Physics has been working on the open source software "PIConGPU".

The result is the most efficient simulation code known to laser plasma physics today. PIC stands for "particle in cell." The program describes the interaction between charged particles and electromagnetic fields in a virtual spatial grid by solving differential equations. Unlike standard solutions, however, it does not just use the normal main processor, the core of the computer, but GPUs as well – the computing units of graphic cards which can handle the processes much faster. Axel Hübl made a significant contribution to preparing the code for supercomputer use. As a result, the junior researchers from HZDR twice gained access to what is currently the third-fastest computer in the world.


Photo: Rainer Weisflog

In 2013 they were able to simulate the evolution of billions of electrons in plasma jets and calculate the light they emitted on TITAN at the Oak Ridge National Laboratory in the US state of Tennessee. Last year, they modelled the laser-particle acceleration of ions from a spherical target there, too. Their well-scaling code, utilizing the full size of the TITAN supercomputer, enabled them to simulate the entire acceleration process in three dimensions – so far this had only been possible in two dimensions. Consequently, the new models correspond much better with the results of experiments. For his major contribution to these achievements, the Association for Computing Machinery and the Institute of Electrical and Electronics Engineers awarded Axel Hübl the George Michael Memorial Fellowship at SC 16 in Salt Lake City in mid-November. The fellowship comes with funding of 5,000 US-Dollar.

Tobias Vogt awarded the Helmholtz Doctoral Prize for energy research


Photo: Rainer Weisflog

For the first time, a researcher from HZDR was awarded the Helmholtz Association's Doctoral Prize in 2016. During his Ph.D. studies, Tobias Vogt of the Institute of Fluid Dynamics investigated tornado-like turbulences, waves that occur in the Earth's liquid core, as well as mixing processes in steel recycling. The common link: turbulent flows. In all these areas, they play a key role. The Dresden researcher used conductive liquids in his experiments. In a liquid metal alloy of gallium, indium and tin, he produced – using a rotating and a travelling magnetic field – a contactless volume force, with which various phenomena could be visualized.

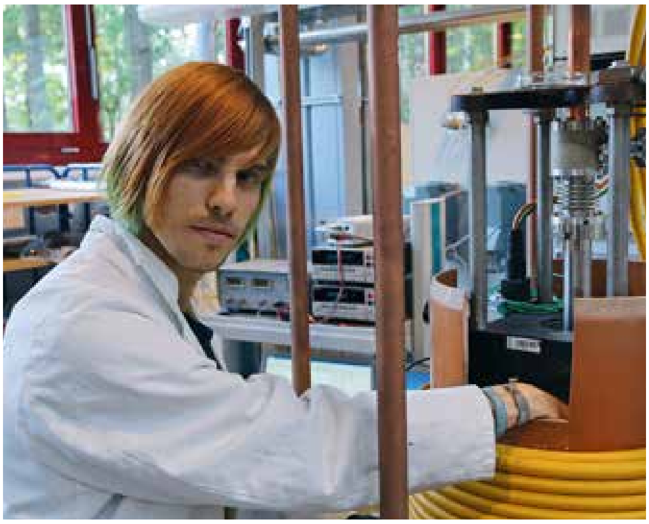
Taking ultrasound measurements, he was able to observe and describe the formation and the turbulent collapse of a tornado-like vortex funnel. The vortex exhibited the same fluid dynamic properties as a real tornado. In the second phase of his work, Vogt studied so-called inertial waves in liquid metal. These movements are caused by the Earth's rotation and occur, for example, in oceanic and atmospheric flows, but also in the Earth's liquid core. By applying tailored magnetic pulses, the engineer induced different kinds of waves in liquid metal rotational flows and collected detailed information on their dynamics.

Tobias Vogt was furthermore able to demonstrate that bubble flows, which are often used in the melting and processing of scrap steel to mix the melts, can be influenced by rotating magnetic fields. This facilitates better gas distribution which could significantly reduce the amount of energy used during these kinds of large-scale industrial processes. These findings earned him the Helmholtz Doctoral Prize in the research field "Energy", valued at 5,000 Euro, which he received at the association's Annual Meeting. Vogt intends to use the additional travel allowance of 2,000 Euro per month to spend time working on his research at the University of California in Los Angeles.

PANORAMA – HZDR NEWS

HZDR trainee best physics lab technician in Germany

First came Dresden, then Saxony and now the whole of Germany: with 96 out of a possible 100 points, Kevin Bauch was the nation's best physics lab technician to qualify last year. The former HZDR trainee received this accolade from the German Chambers of Commerce and Industry (DIHK) at the beginning of December. He had already been honoured by the Chambers of Commerce and Industry (IHK) in Dresden and Saxony for the excellent results of his apprenticeship. Kevin Bauch is now employed at HZDR's Institute of Fluid Dynamics. In August 2017, he wants to embark on in-service training to become a certified technician specialized in electrical engineering.


Kevin Bauch

This accolade also endorses HZDR's training strategy. It was the 17th time in succession that the IHK rated the Dresden research center as an excellent training organization. More than 200 young men and women have learnt the fundamentals of their occupations at HZDR in the last 24 years. Eighty-five percent of them completed their training with good or very good results. They were chosen 27 times as the best graduates of the Dresden regional IHK and 20 times as the best trainees in Saxony. At federal level, Joachim Wagner was also selected as the best physics lab technician in 2008. He has been on the staff of HZDR's Institute of Ion Beam Physics and Materials Research since 2011 and now trains physics lab technicians himself.

DeltaX celebrates its fifth anniversary

When the idea to set up a student lab at Dresden-Rossendorf was first mooted more than six years ago, it was still unclear whether it would work or not. "We started completely from scratch," says today's head of lab, Matthias Streller, who was involved from the very beginning as a doctoral student. "A project like this could only succeed, and can still only succeed, because of the great cooperation with all the various areas and departments at HZDR. The DeltaX team has a lot to thank them for."

Since the official opening in 2011, a great deal has happened: In addition to the pilot experimental day on "magnetism", three further such days have been introduced; there is a whole raft of one-day and multi-day vacation courses as well as events offering information for teachers. And the most important thing is that more than 11,000 school students from grades five to 13 have already participated.

"We are really pleased that the courses we offer in the school lab are so popular, both regionally and beyond," said Roland Sauerbrey, Scientific Director of HZDR, on the occasion of the fifth anniversary when he signed a cooperation agreement with Werner-Heisenberg-Gymnasium in Riesa. "We hope this will be the starting point for more cooperation with schools that have an ambitious science focus."

Science in the open air

What can tiny particles achieve in the fight against cancer? How often can an axolotl regrow its legs? And what materials make furniture fly? These and other questions were answered in an exhibition that ran from June to October 2016, designed by the partner institutions in the Dresden-concept alliance. At the Neumarkt they presented highlights of research in Dresden on interactive stelae. In their joint contribution, the OncoRay Center, Carl Gustav Carus University Hospital and HZDR, presented the potential for treating cancer with protons and the option of accelerating these tiny particles with lasers.

The exhibition was also part of the Science Mile which attracted many visitors to Dresden's Neumarkt for the celebrations to mark the anniversary of German unification. Alongside many other research institutions in Saxony, from October, 1-3, HZDR scientists explained their work with exhibits and experiments. The stelae have now moved to new locations, and some found their way to HZDR. In front of the entrance building there is now a CityTree, produced by the start-up Green City Solutions. Thanks to a symbiosis of ground-covering plants and moss substrate in nearly 1,700 small pots this natural air filter binds fine particles long-term. According to the manufacturers, the green walls equal the filtering capacity of 275 trees.

Helmholtz Institute Freiberg for Resource Technology moves to a new site

Five years ago, it all went downhill – literally. At a historic site underground – the teaching and research mine "Reiche Zeche" of TU Bergakademie Freiberg – the former Federal Minister of Education and Research, Annette Schavan, presented the key for the new Helmholtz Institute Freiberg for Resource Technology (HIF). Almost five years later to the day, in June 2016, the institute was able to move into its new home, which provides the HZDR researchers with an optimal infrastructure to work on innovative technologies for the sustainable extraction and recycling of raw materials.

With some 3,000 square meters of space, nearly all HIF groups are now united in one place. Over the last three years, the listed building in the Chemnitzer Strasse in Freiberg has been completely renovated. Altogether approximately 24 million Euro are flowing into the new research site funded by the Federal Republic of Germany, the Free State of Saxony and the City of Freiberg. During the inauguration, the Saxon State Minister for Science and the Arts, Eva-Maria Stange, underscored the central role of HIF and TU Bergakademie Freiberg, the institute's most important collaborative partner, in the Free State's resource strategy.

Together with the two HIF Directors, Markus Reuter (first from left) and Jens Gutzmer (second from right), recyling experts, Christiane Scharf (second from left) and Philipp Rädecker (fourth from left) explain solvent extraction to the Saxon State Minister for Science and the Arts, Eva-Maria Stange (third from left), the representative of the Federal Ministry of Education and Research, Michael Stötzel (third from right) and Freiberg's Mayor, Sven Krüger (first from right) at the inauguration of the new research site. Photo: Detlev Müller

Upcoming events

24.02.2017
Teacher education "Physics Meets Informatics"
HZDR | School Lab DeltaX

22.03.2017
Inauguration of the renovated laboratories at the HZDR Research Site Leipzig

24.05.2017
Foundation Stone Ceremony for the National Center for Tumor Diseases Dresden

16.06.2017
Dresden Long Night of the Sciences
HZDR stand in the Hörsaalzentrum at TU Dresden

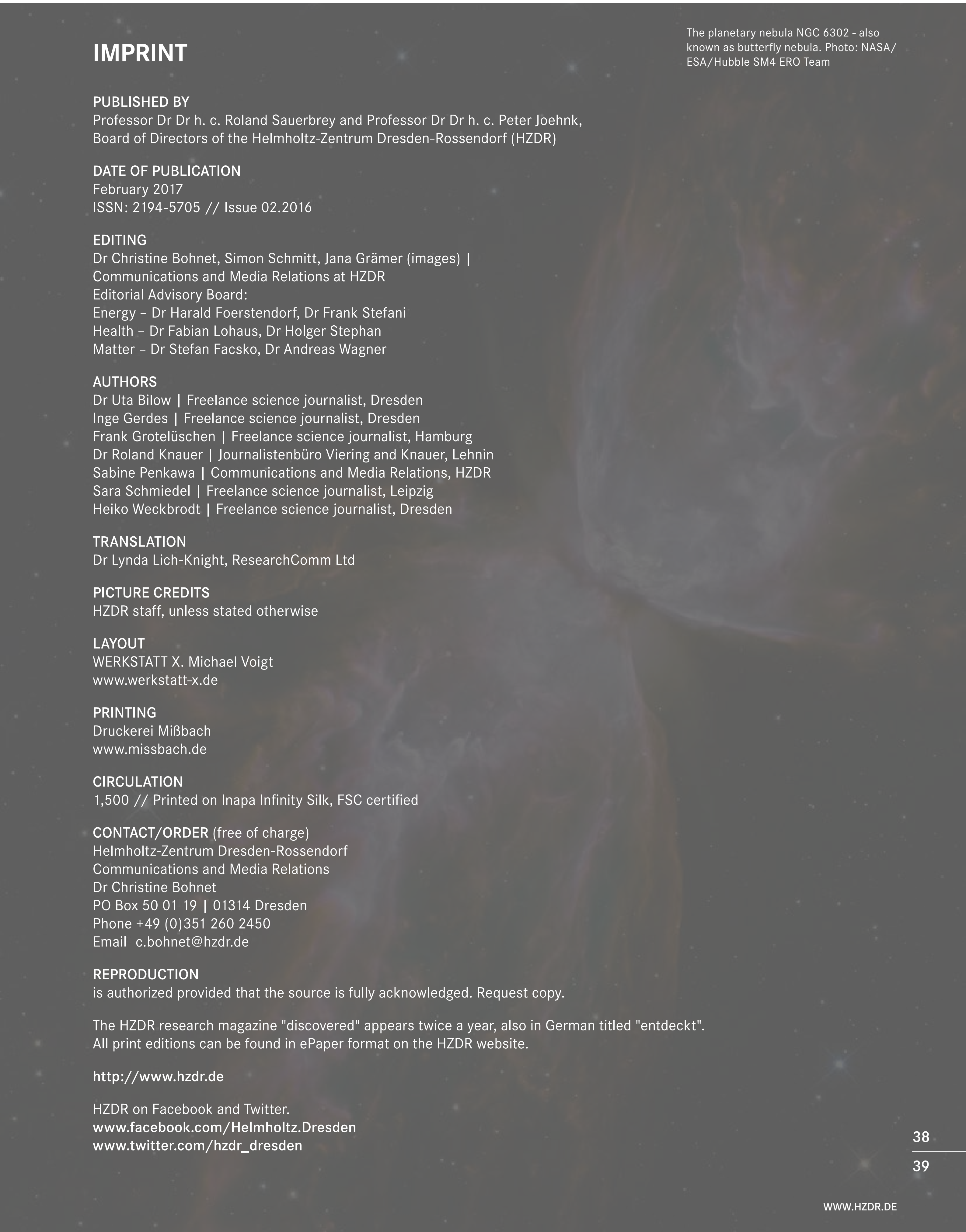
17.06.2017
Long Night of Science and Industry
Freiberg

Scientific events

13.-16.02.2017
Workshop "Towards Reality in Nanoscale Materials"
Levi (Finnland) | Co-organization by the Institute of Ion Beam Physics and Materials Research

23.-25.02.2017
Joint Meeting "Structural Transitions of Biomolecules in Experiment and Theory"
Hünfeld | Institute of Resource Ecology

14.-19.05.2017
22nd International Symposium on Radiopharmaceutical Sciences 2017 (ISRS)
International Congress Center Dresden |
Institute of Radiopharmaceutical Cancer Research



The planetary nebula NGC 6302 - also known as butterfly nebula. Photo: NASA/ESA/Hubble SM4 ERO Team

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22nd INTERNATIONAL SYMPOSIUM ON RADIOPHARMACEUTICAL SCIENCES

May 14 – 19, 2017 I Dresden I Germany

KEYNOTE SPEAKERS

Prof. Andreas Türler – Universität Bern & Paul-Scherrer-Institut (Switzerland)
Opening Plenary Lecture: Heavy Elements

Prof. Alberto Signore – Sapienza Università di Roma (Italy)
Plenary Lecture I: Alzheimer Disease / Diabetes

Prof. Dr. Sibylle Ziegler – Technische Universität München (Germany)
Plenary Lecture II: Radiotracer-based Imaging

Prof. Wolfgang Enghardt – Technische Universität Dresden (Germany)
Plenary Lecture III: Radiotherapy with Heavy Ions

THANK YOU FOR MORE THAN 560 ABSTRACTS.

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