discovered

THE HZDR RESEARCH MAGAZINE

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TWENTY YEARS OF CANCER DIAGNOSTICS
About radioactive drugs and molecular imaging

TURNING TIME BACK INTO THE FUTURE
A Dresden art project on radioactive waste disposal

LABORATORY OF THE EXTREMES
New experimental facility at the European XFEL

HZDR
HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

COVER IMAGE: She has already climbed a few important steps on her career ladder. After completing her PhD with outstanding results, Claudia Arndt is now working on ways to use the antibodies she studied in future cancer therapy. Photo: André Forner

DEAR READERS,

Success in science would be impossible without young talent! And since the world's best minds have their pick of research institutions around the globe, it takes a genuine, substantial effort to recruit them. Excellent infrastructures and excellent lab conditions certainly help attract young scientists. But sometimes, coincidence plays a role, as well. Josefine Metzkes, for example, who had just graduated in Halle, Germany, with a major in physics, happened to hear a report about the inauguration of our high-power laser DRACO on German radio. It made her curious about Dresden, and today, as she is about to complete her doctorate, she knows that coming here was the right decision, even though the conditions for experimentation were not always ideal. For more than a year, DRACO was packed away under several layers of plastic film to prevent damage to its sensitive optics while construction was under way to expand the ELBE Center for High-Power Radiation Sources.

A decisive asset for Dresden as a science location is its University of Technology, which trains excellent young scientists in the natural sciences. When it comes to choosing their PhD program, the graduates are spoilt for choice. Various institutions are vying for gifted students: There are three Max Planck institutes as well as three Leibniz institutions, twelve institutes or departments of the Fraunhofer Association, HZDR and another Helmholtz location, the University Hospital Carl Gustav Carus and the TU Dresden itself. Leaders of the Dresden scientific community understood early on that despite all competitiveness, true success requires close collaboration. Therefore, the non-university institutes and TU Dresden joined forces in an alliance called DRESDEN-concept. It is partly due to this alliance that TU Dresden was able to earn the coveted status of University of Excellence, which in turn attracts even more international top scientists to Dresden.

It would not be possible to support and train the approximately 150 doctoral candidates currently at HZDR without supervisors who were particularly dedicated and firmly rooted in their area of expertise. In our section 'Portrait', you will meet Stephan Winnerl, who is one of these body-and-soul scientists. You will also meet cancer researchers Esther Troost und Manja Kubeil. However, we can't introduce you to every top junior researcher from each of our eight HZDR institutes – for one, because we are fortunate enough to have several bright and ambitious doctoral candidates and post-docs leading each field. But also because we want to showcase the diversity of our research activities, which is why the topics covered in this issue of 'discovered' range from functional materials and nano-filters to chemical reactors, a regulatory mechanism on the cellular level, accelerator research and immunotherapeutic treatment of cancers.

We hope you enjoy meeting our talented young researchers!

Christine Bohnet
Communications and Media Relations at HZDR

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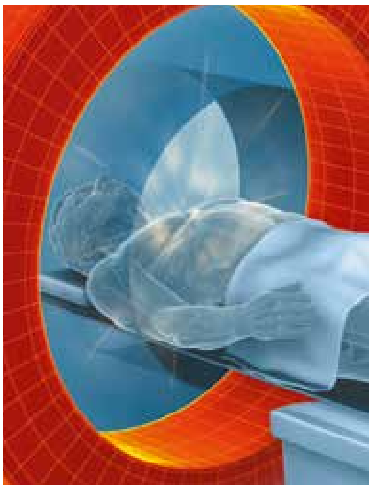
Photo: André Forner



FOCUS
Great Young Talents!

RESEARCH

PORTRAIT

PANORAMA – HZDR NEWS

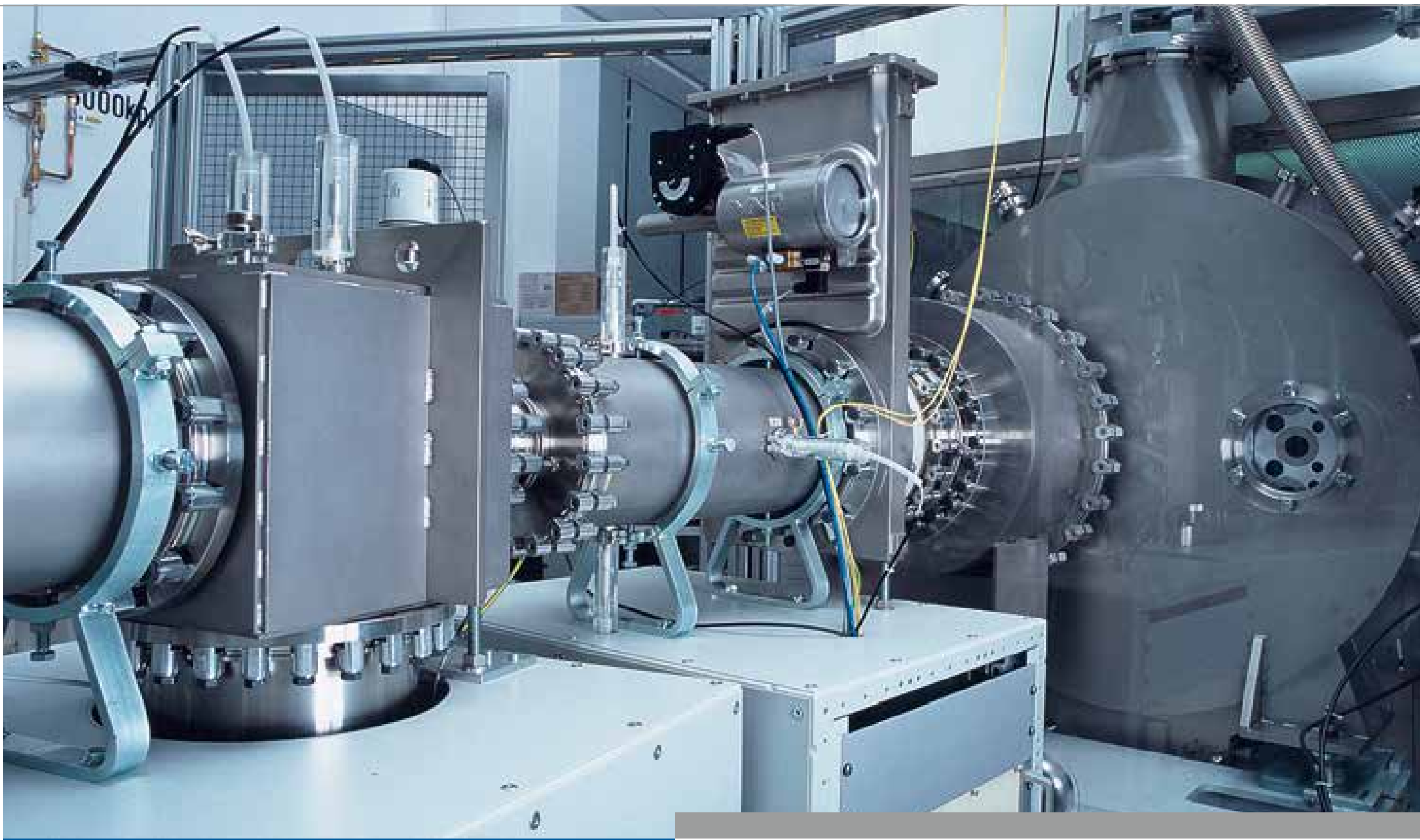
// Modern microelectronics is a divided field: it either uses tiny electric currents, as in a computer processor, or magnetic fields on the built-in hard drive. The Helmholtz Junior Research Group on 'Functional Materials' uses manganese doped semiconductors to bring the two worlds together. This might eventually lead to computer chips with additional magnetic switches.

THE FUTURE OF ELECTRONICS

_TEXT . Roland Knauer

For half a century, semiconductors have been a sort of engine driving the global economy. They can be found in almost any appliance that has helped advance the everyday technological revolutions of the past decades: television sets and computers, cell phones and solar cells. The functioning of such semiconductor elements has always been the same. Materials such as phosphorus or aluminum, carbon or tellurium are implanted into materials such as silicon or gallium-arsenide, which are basically non-conductive. The foreign atoms in the crystal lattice change the electric properties. This way, a small electric current from the outside can switch such a semiconducting element on or off. Whether it is in the processor of a computer or the image sensor of a digital camera, the chips always work according to this principle of tiny electric switches. That is exactly what Shengqiang Zhou and his junior research group at HZDR are looking to change. The researchers already successfully introduced ferromagnetism into semiconductors in addition to these electric switches. Their goal is to open up whole new potentials for applications. →

PLAYING POOL WITH IONS: Shengqiang Zhou likes to compare shooting ions into a material's surface to playing pool billiards. Photo: André Forner



ION MACHINE: Low-energy ions knock atoms out of their normal positions in the crystal lattice. Photo: Claus Preußel

Cured crystals

In order to insert foreign atoms into the semiconductors, Shengqiang Zhou and his team generate electrically charged atoms, accelerate these ions with an electric voltage and shoot them into the semiconductor. All over the world, semiconductors are ‘doped’ this way, as electronics experts call the process. Except that normally, the semiconductor gallium-arsenide is doped with carbon or tellurium, while HZDR researchers are using manganese. Like iron, manganese belongs to the group of ‘transitional metals’.

First, the physicist directs a beam of manganese ions, accelerated to one hundred kilo-electron volts, onto a gallium-arsenide crystal in a high vacuum. The surface of the semiconductor is loaded with manganese atoms at a depth of a mere ten thousandth of a millimeter – one hundred nanometers. However, in addition to this intentional doping, the rather brutal bombardment of the crystal surface also damages the structure – up to the point where the semiconductor stops working. So HZDR researchers then proceed to shoot the material with a laser, using short light pulses that flash for a mere 20 to 30 billionths of a second (20 to 30 nanoseconds). This is sufficient to melt the top one hundred nanometers while the crystal underneath remains intact. Also, the surface does not remain liquid for very long. After about one hundred nanoseconds, the melted material re-crystallizes, supported by the intact crystal underneath. The surface that had been damaged by the ion beam heals, while some of the gallium atoms are replaced by manganese.

Electronic and magnetic switches

Just like any atom, manganese consists of an atomic nucleus that is embedded in shells of electrons. Electrons not only have an electric charge, but also a ‘spin’. This quantum-mechanical property acts like an intrinsic momentum that either rotates towards the right or the left. Manganese, like iron, has an incomplete inner shell, which is why each atom carries a net spin. These net spins of nearby atoms communicate with one another, making the material magnetic.

A similar phenomenon occurs in the manganese-doped gallium-arsenide semiconductor that Shengqiang Zhou produced with the help of ion beams. Each manganese atom generates a spot of positive electronic charge, which in semiconductor technology is called a ‘hole’. These holes move, which makes the manganese atoms interact with one another. This way, the material can become ferromagnetic.

‘You can control the magnetic properties with an electric field, just like the logic circuits in a computer processor,’ Shengqiang Zhou is happy to report. This kind of magnetic semiconductor could revolutionize the electronics industry. The journey will be long. So far, the dual material only works at low temperatures of -100 degrees Celsius. ‘Next, we want to try to produce the same material in such a way that it can work in a computer at room temperature,’ the HZDR physicist explains. →

Solar cells with sulfur and tellurium

Shengqiang Zhou is trying to drive the development of semiconductors in yet another field of application. In typical solar cells, a semiconducting material transforms light into electric current. However, such photovoltaics are not very efficient. Tandem solar cells made from two different semiconductors are a more effective option. One of these might be silicon doped with sulfur, selenium or tellurium. 'This means implanting a thousand times more foreign atoms into the silicon than for a semiconductor in a computer chip,' the HZDR researcher explains. This is a very tricky task, as these elements do not fit as well into the silicon crystals as phosphorus that was previously used: a perfect challenge for Shengqiang Zhou and his team, which is considered to be the expert task force for unsolvable problems.

PUBLICATIONS:

S. Zhou et al.: 'Hyperdoping silicon with selenium: Solid vs. liquid phase epitaxy', in Scientific Reports 2015 (DOI 10.1038/srep08329)

M. Khalid, E. Weschke, W. Skorupa, M. Helm, S. Zhou: 'Ferromagnetism and impurity band in a magnetic semiconductor: InMnP', in Physical Review B 2014 (DOI 10.1103/PhysRevB.89.121301)

Eleven Junior Research Groups at HZDR

Funds for excellent young researchers to set up their own research group can, for example, be obtained from the German Research Foundation (DFG) in the Emmy-Noether-Program. One of these researchers is Helmut Schultheiß, who leads his own HZDR group on 'Spin waves bridging Spintronics and Photonics'. The purpose of the five-year DFG program is to get gifted young scientists on a fast track towards a leadership position in science, such as a university professorship.

The Helmholtz Association is highly committed to supporting outstanding young scientists. Three HZDR junior research group leaders each receive up to 250,000 euro annually: Alina Maria Deac and Shengqiang Zhou for their work in the field of semiconductor research, and Moritz Schmidt for basic research on the issue of radioactive waste storage.

HZDR itself also gives qualified young scientists an opportunity to lead their own research group and manage their own budget. After a period of three and five years, the junior research groups are evaluated by a committee of HZDR scientists; if successful, the leaders can be offered a permanent employment contract. Currently, there are seven junior research groups at HZDR: one group is dedicated to cancer research, two of them work on energy-related topics, and four groups conduct research on materials and accelerators.

TEAM WORK: Shengqiang Zhou (left) with his colleagues and research group members – Wenbo Luo, Yutian Wang, Danilo Bürger, Slawomir Prucnal and Kun Gao (left to right).

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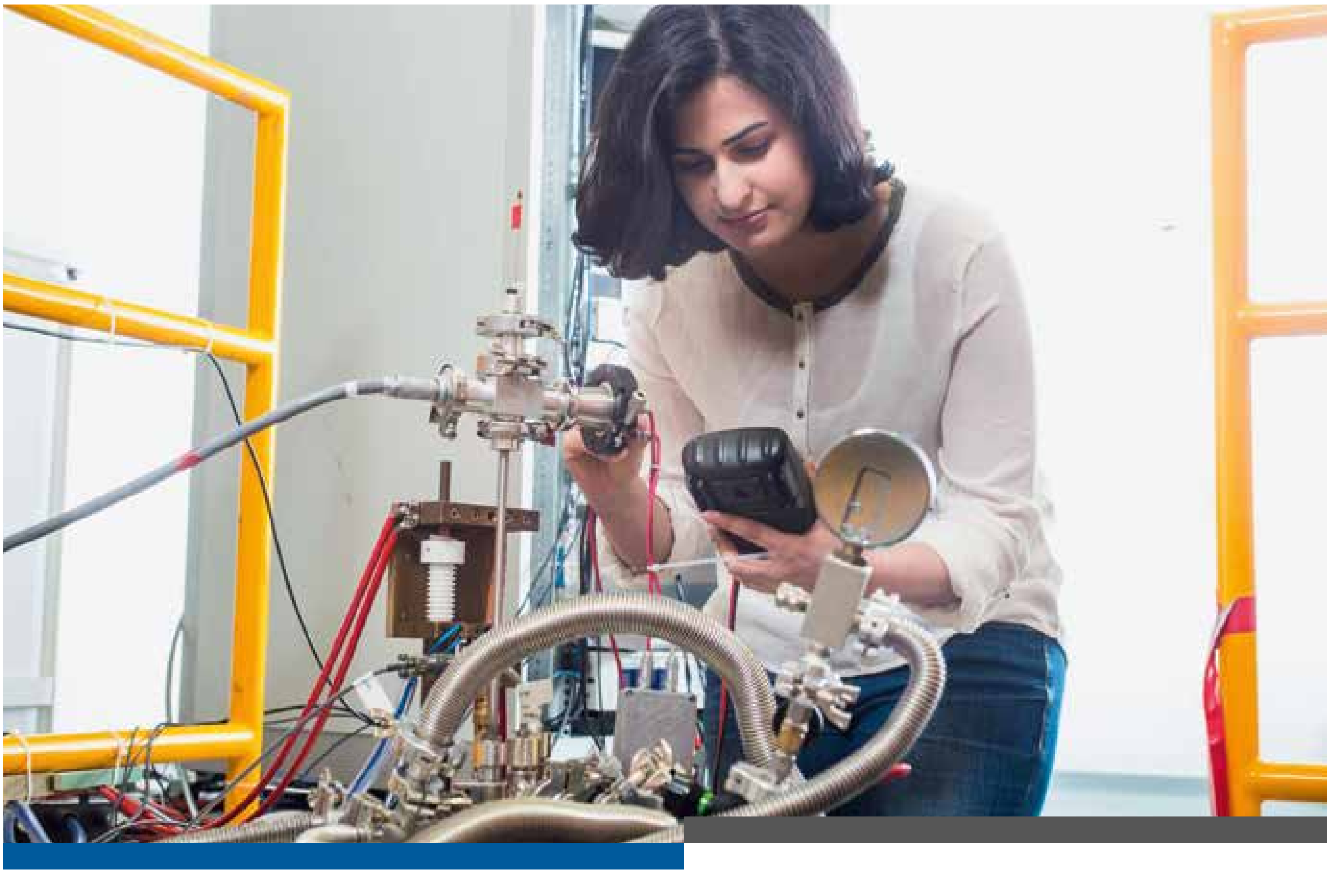
// At HZDR's Dresden High Magnetic Field Laboratory, Mahdiyeh Ghorbani Zavareh studies materials whose special properties can be used for innovative cooling devices. This cooling technology is based solely on a magnetic effect. Soon, stores may sell appliances that not only cool more efficiently, but are also quieter, safer and more eco-friendly.



MEASUREMENTS: Mahdiyeh Ghorbani Zavareh carefully checks the set-up for her experiments in high magnetic fields at low temperatures. Photo: André Forner

NEW MATERIALS FOR MAGNETIC COOLING

_TEXT . Christian Döring

Whether they are in supermarkets, air-conditioning systems or in your kitchen – cooling technologies are used in many aspects of our daily lives. Yet the ubiquitous and constant operation of these devices requires large amounts of energy: according to a 2011 study by the German Engineering Association, 14 percent of Germany's annual energy consumption is used for cooling.

Even though many manufacturers have been able to produce more energy-efficient appliances in recent years, it is becoming increasingly difficult and costly to achieve further energy savings, because the vast majority of refrigerators and freezers are based on the principle of compression cooling, which has virtually remained unchanged for almost 200 years. A cooling agent is introduced into a closed circuit, absorbs heat inside the appliance and releases it via condensers at the back of the appliance. What eats up large amounts of energy in this process is the compressor that condenses the gaseous cooling agent into the liquid state. What is worse, most cooling agents are greenhouse gases or highly flammable. →

About 30 percent more efficient than traditional technologies

An alternative could be magnetic cooling, which works without any traditional cooling agents or compressors. 'If we could harness the magnetic properties of certain materials, we could build refrigerators that are 30% more efficient,' explains HZDR doctoral candidate Mahdiyeh Ghorbani Zavareh. At the Dresden High Magnetic Field Laboratory (HLD), the 31-year-old Iranian examines materials and alloys whose magnetocaloric effect is particularly strong: 'Magnetocaloric materials heat up when exposed to a strong magnetic field. As soon as they are removed from that field, however, they cool down again.'

Physicists use the basic thermodynamic principle that entropy – which, in very simple terms, is the degree of disorder in a system – cannot decrease in a given closed circuit. If a magnetocaloric material is exposed to a magnetic field, the magnetic moments in the material align, the magnetic entropy decreases. To compensate for it, entropy in the atomic lattice must increase: the atoms vibrate more strongly, leading to a temperature rise of the material. This heat can be released outside of the refrigerator. Once the magnetocaloric material is removed from the magnetic field, the magnetic order is lost and the atoms in the material respond accordingly: they oscillate less, the temperature drops. The now cooled material can take up heat again – in this case, from inside the device – and the cooling cycle can start anew.

Search for the best material

For some time, scientists have been using this interaction between magnetism and thermodynamics to achieve extremely low temperatures close to absolute zero. Besides that, some first prototypes for household use already exist: attached to the back of such a refrigerator is a permanent magnet, next to which a disk with a magnetocaloric material rotates. So far, however, a commonly used material in this process is the rare-earth metal gadolinium, which would be far too expensive for mass production. 'Initially, I also used gadolinium in order to test my set-up. For later applications, however, it would be interesting to find alternative compounds with similar properties. With my experimental set-up, we can now study various magnetocaloric materials,' says Mahdiyeh Ghorbani Zavareh.

The scientist tests these various samples under strong magnetic fields. High currents are fed through special HZDR-produced coils at short time intervals; this generates intensive magnetic pulses. Up to a certain limit, which is different for each material, a simple rule applies: the stronger the magnetic field in one pulse, the higher the temperature change. For practical applications, however, what matters is the duration of the magnetic pulses: 'Here at the HLD, the pulses last between 10 and 100 milliseconds. That is exactly the frequency of 10 to 100 Hertz at which future magnetic refrigerators could operate in real life,' the physicist explains. The cooling performance is measured in the lab under realistic conditions and can thus be transferred to potential applications. In her experiments so far, the temperature could be lowered by up to ten degrees centigrade per cooling cycle – more than enough to keep butter and cheese fresh in a normal household.

Mahdiyeh Ghorbani Zavareh

Mahdiyeh Ghorbani Zavareh studied physics at the University of Technology in her home town of Isfahan (Iran). She was one of the best of her graduating class and completed her Master's degree with a theoretical thesis on the interaction of electrons in graphene-nanoribbons. Together with her husband, she moved to Dresden at the end of 2011. 'After my husband had been accepted as a PhD candidate at the Institute of Ion Beam Physics and Materials Research at HZDR, they also advertised a position at the Dresden High Magnetic Field Laboratory.' The young Iranian began her doctorate in February of 2012.

PUBLICATION:

M. Ghorbani Zavareh et al.: 'Direct measurements of the magnetocaloric effect in pulsed magnetic fields: The example of the Heusler alloy $Ni_{50}Mn_{35}In_{15}$', in Applied Physics Letters 106 (2015, DOI 10.1063/1.4913446)

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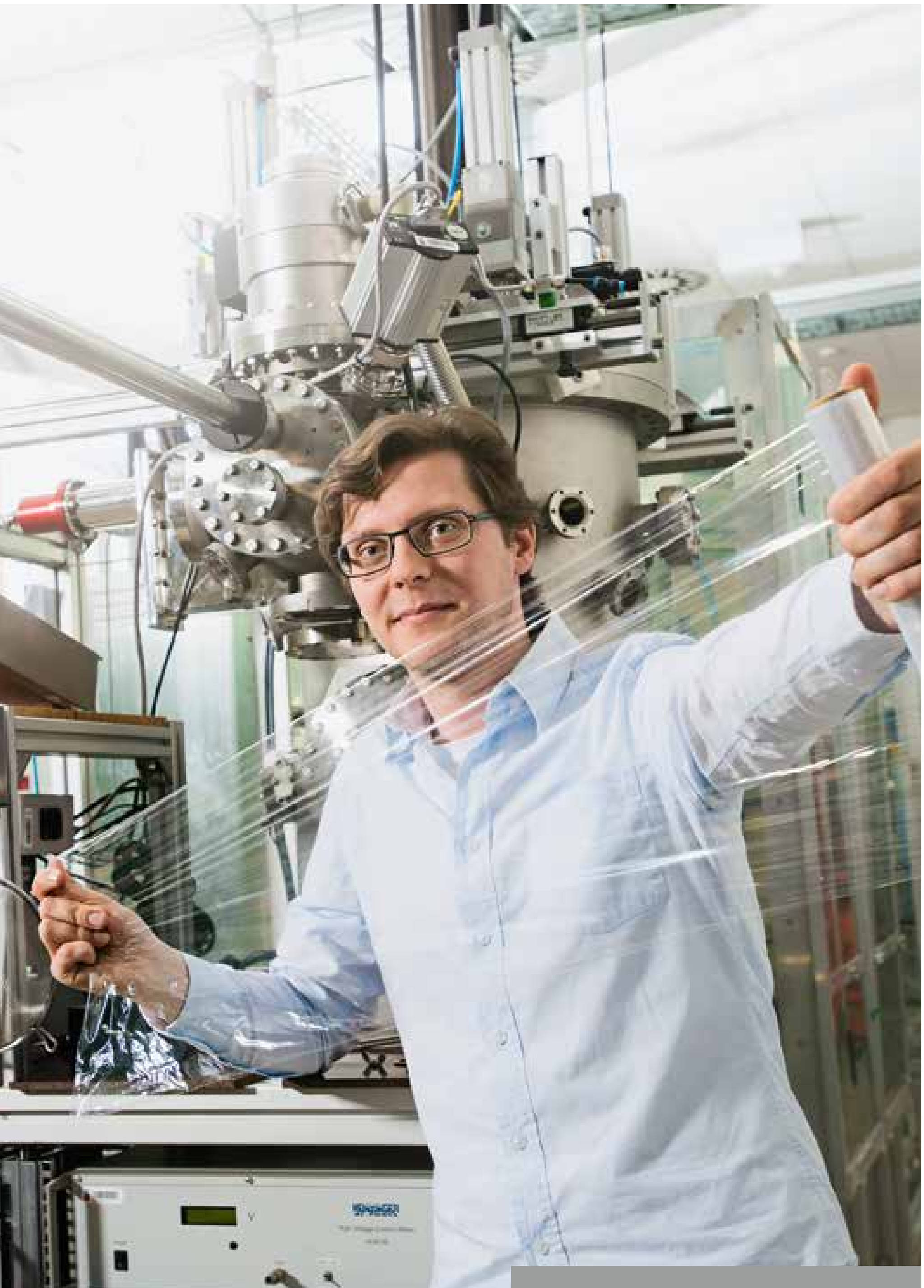
// While working on his doctorate at HZDR, Richard Wilhelm made an astounding observation: when highly charged ions fly through a nanomembrane, they are either almost completely unaffected or they suffer a massive loss of energy.

A SIEVE FOR MOLECULES

_TEXT . Roland Knauer



A FLIMSY AFFAIR: Richard Wilhelm studies membranes that are no thicker than a few layers of atoms. Photo: André Forner

The ultra-thin membrane looks as if it had been hit by a hail of bullets. Well, that is more or less what happened, except that the bombardment could not be observed with the naked eye because it happened in the nano-world. The membrane itself is only one nanometer thick, which means one millionth of a millimeter. The diameters of its pores also measure mere nanometers. Many bio-molecules, such as proteins, are a good deal larger than that and can therefore be sifted out with such a nanosieve. This is similar to the process of washing the blood of a patient with a failed kidney: a membrane allows small molecules, such as urea, to pass though tiny pores, while larger proteins cannot fit through and are thus channeled back into the body where they are still needed. Many other applications in technology and science require such molecular sieves. Yet the mission of Richard Wilhelm from the Institute of Ion Beam Physics and Materials Research at the Helmholtz-Zentrum Dresden-Rossendorf is not to develop such applications - his field is basic research, and he came across nanosieves as he tested a well-established scientific phenomenon.

When it comes to ultra-thin membranes, statistics fail

'Normally, the energy loss of ion beams increases with the thickness of the penetrated material,' the physicist explains. If one material is twice as thick as another, the ions also lose twice as much energy and are decelerated at twice the rate. Researchers have been able to confirm this relationship time and again, and it is a simple enough notion: ions lose a tiny fraction of their energy and speed as they pass each layer of atoms. After passing a million atomic layers, they will have lost this fraction of energy a million times and will thus have been decelerated accordingly.

And secondly, only few other institutes in the world are able to shoot slow highly charged ions onto surfaces as the HZDR researcher has done.

Initially, the HZDR facility generates electrons, which in turn knock some electrons out of the noble gas xenon. Each single xenon atom has 54 electrons in its shell, 44 of which the facility is able to remove – in theory. In practice, this process works well up to 40 electrons. The xenon atoms thus lose their electron coat, one could say that they are stripped down to their atomic underwear, their inner layer.

> Another theory assumes that the intense energy contained in the extremely highly-charged ions heats up the small area.

That sounds alluringly simple. Yet when Richard Wilhelm, in cooperation with Friedrich Aumayr from Technische Universität Wien, shoots extremely highly charged xenon ions at ultra-thin membranes, the assumption does not hold true. 'A certain portion of the ions lose a great deal of energy while the rest continue to fly at almost unchecked speeds,' the physicist ascertained to his amazement. What happened in his experiment? What did the researcher do differently from his colleagues?

Stripped atoms

First of all, Richard Wilhelm uses extremely thin membranes with a thickness of one nanometer, which is merely three layers of atoms. This extremely thin membrane is not a standard product, but rather a specialty of Armin Gölzhäuser from Bielefeld University.

Richard Wilhelm

Hailing from Erfurt, Richard Wilhelm first became acquainted with the HZDR Ion Beam Center while taking his degree in physics at TU Dresden. After a research stay at the University of Stockholm, he returned to Dresden where he completed his doctorate on the topic of 'Interaction of slow, highly-charged ions with surfaces and membranes'. In 2014, he and two colleagues received the HZDR Research Award for outstanding research. Today, the 28-year-old is helping to build a new nano-engineering facility with low-energy ions.

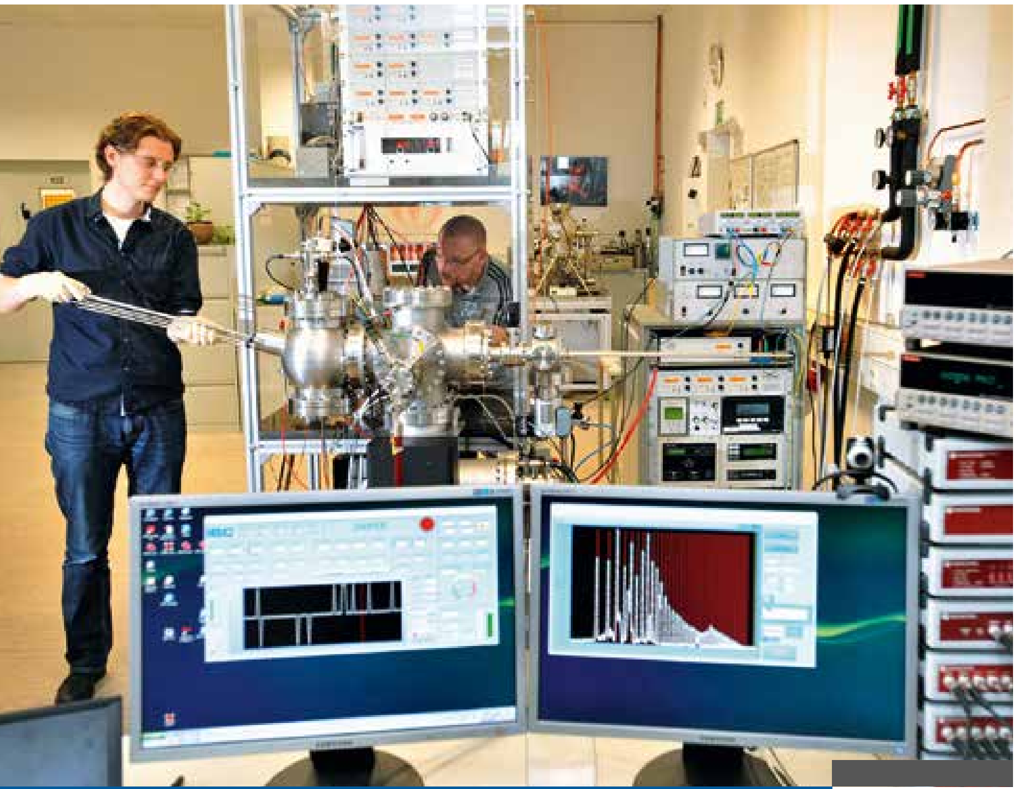
The atoms not only lose their shells, but with each electron, also a negative electric charge. What remains are stripped atoms that possess as many positive charges as they have lost electrons. Scientists call atoms that are charged this way 'ions'. At 30, 35 or even 40 positive units, these xenon ions are extremely highly charged.

These ions are generated with a variety of different charges and are accelerated with a voltage of 4,500 Volts. Subsequently, a bending magnet diverts the generated xenon-ion beam at a 90-degree angle. Researchers can now adjust the strength of the magnet in such a way that, for example, only ions with a charge of 35 are diverted at exactly 90 degrees. All other ions are diverted a little more or a little less. What remains is a beam of ions which each carry 35 positive charges.

Using such homogeneous ion beams, researchers often obtain much clearer results than with a mix of differently-charged ions. Before the beam hits the nanomembrane, however, the ions are significantly decelerated. A certain portion of these slow ions then passes the three atomic layers of the ultra-thin membrane without losing much energy at all, picking up only two or three electrons from the membrane as they pass. The remaining xenon ions, however, are decelerated significantly and pick up a lot of electrons from the membrane, thus losing their extremely high positive charge down to a mere two or three units.

Gaps for ions

There is actually quite a simple explanation for this surprising discovery: A single atomic layer is not a solid wall, but contains relatively large gaps through which ions can pass. There is a pretty good chance that an ion can pass unimpeded through the gaps of an ultra-thin membrane with only three atomic layers. If on the other hand – as is the case almost everywhere else in the world – the experiment is conducted →



NANO-STRUCTURES: This facility will make it possible to implant individual ions into a surface of mere square nanometers like precision projectiles. Richard Wilhelm (left) and René Heller calibrating the ion beam. Photo: Frank Bierstedt

with much thicker membranes, this chance decreases as the thickness of the membrane increases. At one million layers, the ions are sure to miss a gap and thus cannot pass through unimpeded any more. Since researchers are unable to detect at which precise layer a single ion is decelerated, they only register the ions once they exit the membrane. With normal materials, they usually find virtually all of them strongly decelerated. Only with ultra-thin membranes, such as the one from Bielefeld, can a portion of the ions manage to fly through gaps in all three of the atomic layers they pass.

If ions do not find a gap in all three of the layers, they are not only decelerated, but also pick up lots of electrons from the membrane. Since each xenon ion carries a high positive charge and thus absorbs many electrons, a small spot in the membrane will suddenly be missing a large amount of electrons. This obviously destabilizes the membrane, hurling out many hundreds or even a couple of thousand atoms. The spots in the membrane where an ion was decelerated are thus perforated with tiny nanopores. The ion beam turns the membrane into a sort of molecular sieve.

It is as yet unclear how exactly these holes are generated. 'I could imagine that very many electrons are released at the spot of impact on just a few square nanometers, and that a very high positive electric charge is thus concentrated on a tiny area', Richard Wilhelm ponders. This highly concentrated charge could in turn cause what is called a 'Coulomb explosion' where atoms are ejected out of this very small area, creating tiny holes with a diameter of just a few nanometers.

Another theory assumes that the intense energy contained in the extremely highly-charged ions heats up the small area to the point that the material evaporates, which would also leave a nano-hole. Regardless of the exact mechanism that generates the tiny pores, another observation is of interest: the higher the positive charge of the xenon ions, the larger the amount of ions that get stuck and tear holes into the membrane. A high ion charge is thus more effective for perforating the membrane with pores of a well-determined nano-size. Since Richard Wilhelm and his colleagues are able to control the charge of the xenon ions, their ion beams are very well suited to producing tailor-made nanosieves. Thus the researchers now have a pretty practical, high-precision recipe for producing molecular sieves.

PUBLICATIONS:

R. Wilhelm, E. Gruber et al.: 'Charge exchange and energy loss of slow highly charged ions in 1 nm thick carbon nanomembranes', in Physical Review Letters 2014 (DOI: 10.1103/PhysRevLett.112.153201)

R. Ritter, R. A. Wilhelm et al.: 'Fabrication of nanopores in 1 nm thick carbon nanomembranes with slow highly-charged ions', in Applied Physics Letters 2013 (DOI: 10.1063/1.4792511)

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// HZDR doctoral candidate Josefine Metzkes pursues an ambitious goal as she conducts her research in the field of laser-particle acceleration: her mission is to develop compact ion accelerators for radiation therapy.

LASER ACCELERATOR: Josefine Metzkes wants to know how exactly light accelerates charged particles. Photo: André Forner

SHEDDING LIGHT ON DARKNESS

_TEXT . Sara Schmiedel

‘For me, the research results are pieces of a puzzle that make up a larger picture’, Josefine Metzkes says about her latest publication. She is a doctoral candidate at the HZDR Institute of Radiation Physics. While not a huge breakthrough, the results are another small step towards her goal, which is a lofty one: using laser-particle accelerators for medicine, in particular cancer therapy.

Smaller facilities, lower cost

Protons are already being used to radiate tumors. In contrast to X-rays, their energy can be deposited in the tumor tissue with much greater precision, preserving the surrounding tissue. Since 2014, Dresden can also boast a proton-beam therapy center – the UniversitätsProtonenTherapie Dresden (UPTD) at the University Hospital Carl Gustav Carus. Protons are generated in a cyclotron, accelerated to 60 percent of the speed of light and channeled to the patient via beamlines that are several meters long. The individual components are huge and weigh tons. Add to this, walls that are several meters thick, which are necessary to shield the accelerator and the beam guidance on its way to the patient. Scientists like Josefine Metzkes want to reduce the bulk of such a facility. ‘In theory, laser-driven accelerators can be placed really close to the patient, you only have to shield the light and the therapy room itself, which is much easier to do,’ the young researcher explains. The facilities would be much smaller and potentially cheaper.

A lot of basic research remains to be done before this can become a reality. Dresden-Rossendorf does have an extremely powerful laser, the ultra-short pulsed high-power laser DRACO, but its energy levels fall far short of what is required for medical applications. →

When a DRACO laser beam is shot onto a solid target, a two-micrometer titanium membrane, the electrons in the laser field are accelerated, generating strong electric fields on the surfaces of the target. Atoms from the membrane and impurities that are stuck to its surface – tiny amounts of hydrocarbons – are ionized and accelerated in these electric fields. Most of the ions are protons. Currently, these protons can achieve energy levels of 20 mega-electronvolts (MeV). Medical applications would require approximately 180 MeV.

Tracking down a mysterious phenomenon

One problem is the energy of the accelerated particles, another the stability: particle accelerators have to operate steadily and guarantee high reproducibility. 'We have partially achieved that,' says Josefine Metzkes. 'Together with OncoRay colleagues, we have been able to radiate cells with many thousands of proton pulses under very constant conditions and examine the biological effect with great precision.' While doing so, the group of researchers almost incidentally discovered an effect that had so far been unknown in the parameter range under investigation. When laser energy is continually increased in order to boost the energy of the protons, at a certain point their properties begin to change. 'The proton beam virtually breaks up into filaments,' Josefine Metzkes explains. 'This is very significant for medical application, because we need homogeneous and predictable beams.' It is as yet unclear what causes these instabilities or whether they depend on the energy of the laser. This is now to be studied using the DRACO laser, which is currently being revamped to increase its power by a factor of five. In the future, scientists will be able to accelerate protons at a laser power of one petawatt. By comparison, Germany's power plants generate an overall output of about 194 gigawatts – the new laser system will be able to achieve a wattage that is 5,000 times stronger for a 30 femtosecond light pulse.

RADIATION SOURCE: In this chamber, a high-intensity laser hits an electron beam, thus generating X-radiation. Photo: Frank Bierstedt

Josefine Metzkes

Josefine Metzkes is from Brandenburg and studied medical physics in Halle (Saale) and Toronto. Since 2008, she has been working in Dresden. She hit on the topic of her Master's thesis, which is also the topic of her doctoral dissertation, while listening to the radio. 'I just happened to hear a report about the installation of DRACO here at HZDR,' she remembers. 'And since I was about to finish my degree, I applied.'

Josefine Metzkes has accompanied the experiments on the DRACO laser from the start: from setting up the experimental chambers to adjusting the optics and analyzing the results.

Looking into the black box

Scientists are not only interested in the protons, but also in the process of acceleration as such. It occurs on a length of just a few micrometers and within a few femtoseconds, that is, quadrillionths of a second. Josefine Metzkes is currently describing this process in her dissertation. She has examined exactly what happens at the target when the laser hits. 'We want to find out whether and when a plasma builds on the membrane, in other words, when exactly the laser pulse starts to alter the target. The whole thing is a sort of a black box. But we must understand what is happening inside to be able to systematically vary the parameters of the laser.' In order to shed light on the proverbial darkness, the scientists split off a portion of the DRACO pulse, change its frequency to generate blue light, and capture the reflection on the plasma with a camera. 'To put it simply, imagine using a very fast flashlight to flash light onto a target and take a picture of it,' Metzkes illustrates. This generates ring signatures that vary in size depending on the plasma conditions, thus providing information about changes in the target. For Josefine Metzkes, this means a few more pieces of the puzzle.

PUBLICATIONS:

J. Metzkes et al.: 'Experimental observation of transverse modulations in laser-driven proton beams', in New Journal of Physics 2014 (DOI: 10.1088/1367-2630/16/2/023008)

K. Zeil, J. Metzkes et al.: 'Direct observation of prompt pre-thermal laser ion sheath acceleration', in Nature Communications 2012 (DOI: 10.1038/ncomms1883)

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// Hans-Ulrich Härting, doctoral candidate at HZDR, has built a completely novel chemical reactor. Compared to traditional reactor types, this one achieves significantly higher yields.

SLANT, SPIN, SPLIT – HOW TO GET THINGS FLOWING

_TEXT . Sara Schmiedel

THE ART OF ENGINEERING: Hans-Ulrich Härting is looking to sustain and improve the foundations of our lifes by increasing efficiency in the chemical industry. Photo: André Forner

Hans-Ulrich Härting's prototype is about 1.2 meters long, roughly 10 centimeters in diameter and is made of gleaming stainless steel. Small catalyst particles are firmly fixed inside. While this chemical reactor is significantly smaller than its industrial counterparts, it is quite impressive compared to reactors for study purposes at universities, which are usually just a couple of centimeters in length. And there is another difference – it is the first inclined rotating fixed-bed reactor, a concept developed by Härting's boss, HZDR scientist Markus Schubert.

At the moment, however, the reactor is standing still. 'We have completed our experiments for now and I am currently writing publications for journals as well as my dissertation,' says Hans-Ulrich Härting. The engineer is taking a doctorate in process engineering, and he studies how to systematically control flow in chemical reactors. His goal is to achieve optimized reaction control inside the reactor.

Chemical reactors need improvement

Fixed-bed reactors are actually pretty common; they are used in the chemical and petrochemical industries. These upright cylinders can be as large as five meters in diameter and as tall as some ten meters. They are filled with a catalyst in the form of small beads that facilitates the chemical reactions of various liquids and gases. When gases and liquids flow or trickle through the reactor from top to bottom, chemical →

reactions occur at the catalyst and the final goods leave the reactor at the bottom.

But in practice, it is not all that simple. ‘With this typical trickling flow, you always get certain maldistributions in the reactor,’ Markus Schubert explains. ‘Many reactions also release heat that must be removed. But because the catalysts often conduct heat very poorly, and some areas are even not irrigated by the flow at all, hot spots develop, areas of high heat, which, in the worst case, can destroy the reactor.’ Another problem is undesired byproducts, which then have to be removed in a complicated additional separation step.

‘Maldistribution means that the catalyst packing is not used to its full potential,’ Hans-Ulrich Härting adds. This is an unnecessary cost factor for the facility operator - catalysts are often based on precious metals and hence ‘not exactly cheap’.

Eliminating hot spots

Markus Schubert had already worked with fixed-bed reactors in the context of his dissertation. He currently conducts his research with the help of a European Research Council ‘Starting Grant’. Based on the groundwork he laid in his doctorate, he has now developed and built an inclined rotating fixed-bed reactor together with doctoral candidate Hans-Ulrich Härting. The inclination of the reactor can be adjusted from upright to horizontal; its rotational speed can also be varied.

OPTIMIZED: Catalyst particles facilitate chemical reactions. Photo: Oliver Killig

Hans-Ulrich Härting

Hans-Ulrich Härting pursued his studies at the TU Dresden and the University of Sevilla (Spain). He graduated from TU Dresden with a degree in process engineering. The Leipzig-born 32-year-old is married and has a two-year-old daughter.

‘We can set it to different flow regimes by systematically combining the angle of the inclination and the rotational speed,’ Härting explains. The flow of liquids or gases can be sickle- or ring-shaped, dispersed or stratified.

Since the intended reaction can only take place inside the reactor with the help of the catalyst, it is imperative that the gas and the liquid reach the catalyst in the first place. In the Dresden prototype, the first step is splitting the phases, which means that gas and liquid flow at separate places in the reactor. ‘We rotate the reactor tube, immersing the catalyst beads again and again, we basically dip the catalyst in the liquid and then let it run dry again. That way, the gas also has better access to the catalyst,’ says Hans-Ulrich Härting, explaining the ideal operation with what is called a stratified flow. Also, when the catalyst is dipped in the liquid, the heat that is generated by the reaction is transferred from the catalyst to the liquid and is discharged, which prevents the formation of dangerous hot spots. Since gas and liquid flow separately from one another, they cannot get in each other’s way; the pressure on pumps and compressors is lower – which increases energy efficiency.

Industrial use still quite a way away

‘Our studies were able to show that there are operation points at which our reactor outperforms established reactors,’ Hans-Ulrich Härting emphasizes. The yields are significant. The output can be up to twice as high. A fact that should make industrial operators weep for joy. But it doesn’t. ‘Once they have built such a huge facility and have it running tolerably well, operators are reluctant to replace it,’ Härting knows.

‘So far, our work has been very fundamental, we have only demonstrated the performance enhancements in one model system,’ his boss explains and adds, ‘There are various processes and operating conditions with which our concept can increase reactor performance, but it is too early to draw a general conclusion.’ →

In order to really visualize what is happening inside the reactor, Hans-Ulrich Härting had to get together with the measuring technology experts in his department to develop a mobile, compact computer tomograph. As it rotates around the reactor, gammy-rays penetrate the flow and are more or less attenuated depending on whether they hit gas or liquid. Based on the intensity of the radiation that is measured on the other side of the reactor, scientists can generate sectional images of the flow, similar to medical imaging.

Next step: simulations

The two scientists have already submitted a follow-up application for a research grant because they want to conduct further studies with their reactor. The next step will be to start examining the impact of the novel operating system on undesired byproducts in complex reactions. They also want to simulate and model different flow regimes. 'If we can get this to work, it will be easier to transfer our results to other processes,' Markus Schubert says.

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TILTED: The inclination of the fixed-bed reactor can be adjusted at will – the distribution of liquids and gas can thus be controlled systematically. Photo: Oliver Killig

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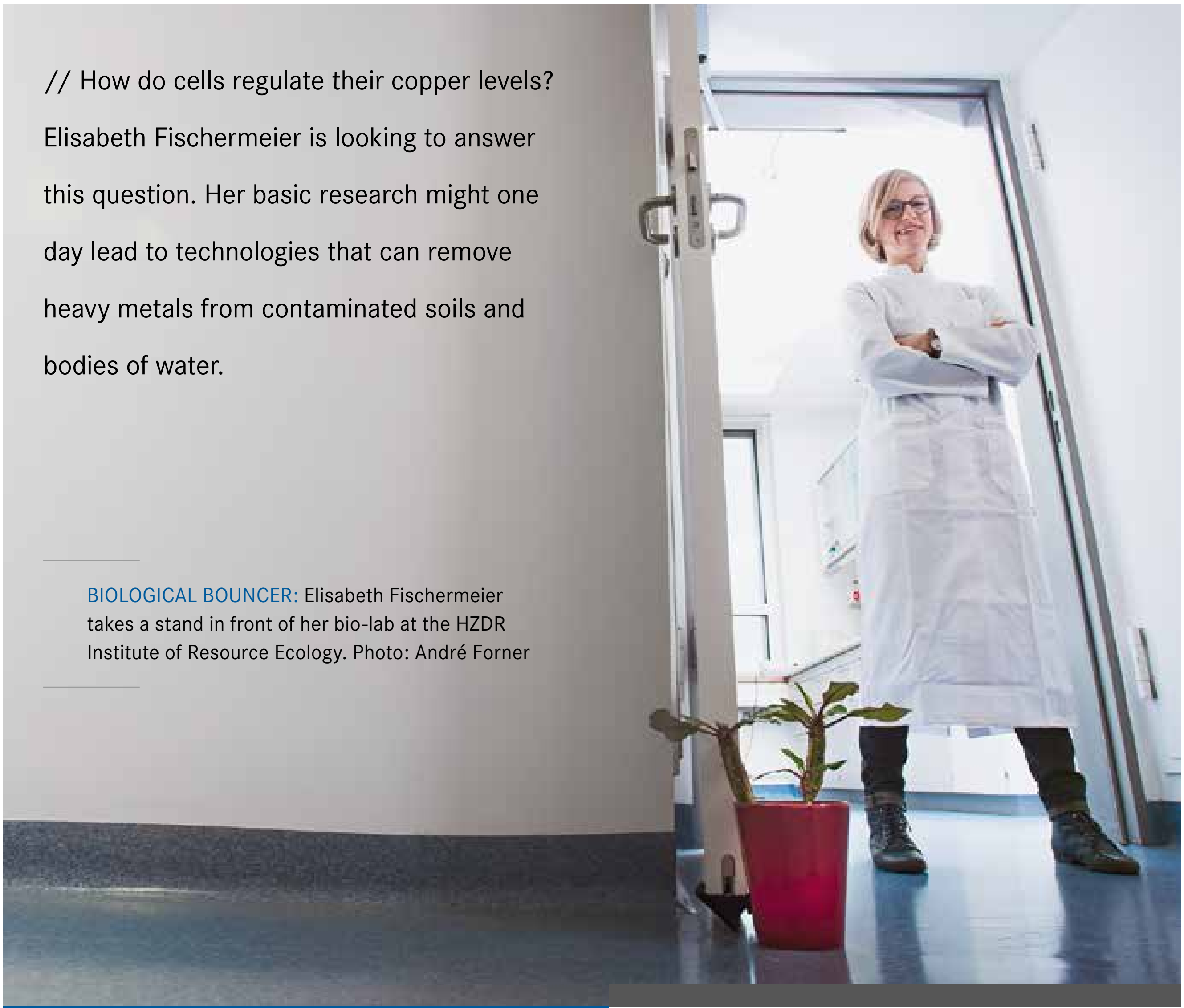

// How do cells regulate their copper levels? Elisabeth Fischermeier is looking to answer this question. Her basic research might one day lead to technologies that can remove heavy metals from contaminated soils and bodies of water.

BIOLOGICAL BOUNCER: Elisabeth Fischermeier takes a stand in front of her bio-lab at the HZDR Institute of Resource Ecology. Photo: André Forner

A CELLULAR WATCHDOG

_TEXT . Simon Schmitt

Elisabeth Fischermeier takes an interest in bouncers. Not the scowling, muscle-bound hunks in front of night clubs, but a much smaller type of watchdog: the protein CopA, which does a very similar job on the molecular level. CopA is a transport enzyme which ensures that only a certain amount of 'visitors' – in this case copper ions – can enter the hip hangout, which is a human, animal or plant cell. Copper is a heavy metal and a problematic guest.

On the one hand, copper is a popular visitor in the cell because it can really get the party going. Too much of it, however, can make the party derail and end in disaster. Elisabeth Fischermeier, doctoral candidate at the HZDR Institute of Resource Ecology, explains: 'Copper is an important trace element for the cell because certain enzymes need it in order to function properly. On the other hand, an excess of copper can poison the cell. Getting the amount just right is a tightrope act.' This is what stirred her interest in the topic.

It's all about the right mix

Fischermeier studies how cells regulate their copper levels. The 'bouncer', the protein CopA, plays a central role in this process. It is situated in the lipid bilayer that surrounds the cell. When the copper level is balanced, CopA does not interfere with the heavy metal. As soon as things get too crowded, however – that is, as soon as there is too much →

copper in the cell – CopA does its job and kicks out the excess copper. 'The question is how exactly this process works,' says Elisabeth Fischermeier describing the focus of her dissertation.

She packages the proteins in small particles called nanodiscs. 'Imagine moving a plant from your yard into a flower pot,' Fischermeier explains. 'In these nanodiscs, we simulate the natural cell environment under simplified conditions. This makes it easier for us to study the CopA.' The challenge is removing the protein from the cell. The doctoral candidate uses a special rinsing agent to remove the 'potting soil' – the lipid bilayer. Then, she puts the CopA into the 'flower pots', which measure ten to twelve nanometers. Elisabeth Fischermeier was able to demonstrate for the first time that the protein can be transferred to nanodiscs without being destroyed in the process. In the future, her procedure could also be used to study bio-molecules at the European X-ray laser XFEL in Hamburg.

A special task force of tiny creatures

The Nuremberg-born scientist, who started her doctorate at HZDR in 2011 after studying biochemistry in Regensburg and Berlin, is looking to gain a fundamental understanding of processes inside the cell: 'In my case, mainly the transport of copper.' Eventually, this research might yield new ways to remove heavy metals from soils and bodies of water. This idea is not new. Bacteria that can remove harmful substances were first discovered in the 1970s.

The euphoria about this discovery, however, did not last long. Scientists were unable to transfer their promising lab results into the real environment. In nature, the toxic substances and the microorganisms hardly ever come in contact, because there are too many other, highly impactful factors that were not considered in the lab. Some bacteria did indeed prove their potency. The microbe *Geobacter metallireducens*, for example, was used to remove uranium from the groundwater surrounding the abandoned 'Rifle Mill' mine in western Colorado.

Fischermeier thinks that in the past insight tended to be gained by chance: 'So far, science has only been searching for specific microorganisms that are able to fulfil a certain function on their own. In some cases, that has been successful.' But the biochemist wants to do the reverse: 'Once we understand precisely how cellular processes work, we might succeed in breeding tailor-made microorganisms for specific purposes. In the case of CopA, it might be microorganisms that are particularly resistant to heavy metals.'

Elisabeth Fischermeier knows that in order to achieve this, it is necessary to thoroughly decode the characteristics of these tiny creatures. Her research helps discover individual components and their interactions – even though she predicts that it will probably take another few years before they can be used in practice. Nonetheless, the 'watchdog' CopA could rise from cellular bouncer to a veritable security force against heavy metals for entire regions.

The brightest bioscientific minds

Elisabeth Fischermeier came to HZDR via the Dresden International Graduate School for Biomedicine and Bioengineering (DIGS-BB) where she also met her supervisor Karim Fahmy. The head of department for biophysics at HZDR wholeheartedly supports teaching and research in this program, which TU Dresden launched with numerous partners from the DRESDEN-concept alliance in 2006. Its mission is to offer optimal support to the best doctoral candidates in the fields of cell biology, biomedicine, biophysics and biotechnology.

At DIGS-BB, doctoral candidates are supported by an advisory committee of three or four experienced scientists. At regular meetings, the young researchers are given independent advice on how to systematically advance their work. At DIGS-BB, the candidates are subjected to a rigid selection process. Their knowledge and motivation is put to the test during an 'interview week'. At the same time, intensive discussions with participating scientists serve to assemble a suitable team of supervisors for each successful candidate.

DIGS-BB is funded by the Excellence Initiative of the German Federal and Länder governments. In cooperation with the International Max Planck Research School for Cell, Developmental and Systems Biology, it serves four scientific fields: regenerative medicine, biophysics and biotechnology, cell and developmental biology as well as computer biology. Currently, about 200 candidates are pursuing a doctorate at the Graduate School.

↗ www.dresden-ipp.de

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TOP AND BOTTOM:
Claudia Arndt makes antibodies click.
Photo: André Forner

// The mission of the radioimmunology group at HZDR is to develop universal drugs that utilize the body's own immune system to destroy cancer cells.

LEGO TACKLES CANCER

_TEXT . Sascha Karberg

At 28, Claudia Arndt is still a young woman, but a bit too old to be playing with Legos every day. Yet that is exactly what the biologist has been doing for the past four years of her dissertation completed at the Institute of Immunology at the University Hospital Dresden and the Department of Tumor Immunology at the University Cancer Center (UCC) Dresden. Well, that is if you take her literally when she explains her research project – bispecific antibodies for cancer therapy: 'A bispecific antibody basically works like a Lego brick,' says Arndt. One end fits nicely on the surface of a cancer cell, the other one onto membrane structures of certain immune cells, which are called T-cells. 'That way, cancer and T-cell are connected. The T-cell is activated and can destroy the tumor cell.' →

Researchers are seeking to redeploy antibodies as cancer drugs because they are the tools of the body's own immune system. Normally, antibodies only fit one specific target structure – a molecule on the surface of a virus, a bit of pollen or a protein on a cancer cell. Each immune cell generates only one type of antibody, which binds to only one single target – the same way a Lego brick fits onto another. Upon docking on their target, the antibodies sit on the surface of the immune cell like the spines of a hedgehog, immediately causing the cell and the antibodies to multiply rapidly, spawning innumerous antibodies of a particular type, which can grab on to a foreign body. Scavenger cells can then annihilate it. Researchers had the idea that this immune reaction could be improved by constructing bispecific antibodies that can simultaneously identify two targets, just as a Lego brick can be connected at the top and at the bottom. When an artificial bispecific antibody connects with both a cancer cell and an immune cell, an immune reaction is triggered in the patient, leading to the destruction of the tumor.

Promising drugs

Patients already benefit from this principle. At the end of last year, US authorities approved 'Blinatumomab' as the first bispecific antibody cancer treatment. The drug, which was initially developed in Germany by Micromet, detects a structure named CD3 on defense cells and the receptor CD19 on cancerous blood cells in patients with acute lymphocytic leukemia (ALL), triggering a defense reaction that fights back the cancer. The system is so promising that pharmaceutical companies are currently developing many families of bispecific antibodies. But the drug isn't perfect, which is why pharmaceutical researcher and cancer immunologist Michael Bachmann and his research group, of which Claudia Arndt is a member, are on a mission to further improve the mechanism.

Arndt never envisioned a career in the medical field as such. 'But the idea of doing research close to human subjects has always fascinated me.' Immunobiology is 'a great way to combine biology and medicine,' the young researcher says. She is undaunted by the fact that it involves long hours of wielding pipettes and lengthy experiments that often lead to dead ends. 'You know why you're doing all this, you know that it could eventually save a patient's life.' And it could also help improve an effective therapeutic principle.

'When you're looking to develop a new bispecific antibody, you could actually keep the part that binds the immune cell and only change the part that detects the specific type of cancer,' says Arndt. But altering one end could in fact affect the binding properties of the other end, because the entire structure of the molecule changes. If you hold a lighter to one side of a Lego brick, the other side is deformed, as well. Which is why so far, it has been necessary to create new bispecific antibodies from scratch. 'Each new bispecific antibody must be tested to see whether it genuinely binds the T-cell,' says Arndt. This is a real nuisance. 'To address this, we have developed a modular system.'

An add-on system with a one-size-fits-all module

Instead of working with just one 'Lego brick', Arndt uses two of them – a target module and an effector module. The target module is an adapted (monospecific) antibody that can connect with a molecule on the cancer cell on one side and features an easily detected structure on the other – a unique 'peptide-epitope' created by the research group. The effector module is a bispecific antibody, which means it connects with this peptide-epitope as well as the immune cell.

'The outcome is the same: tumor and T-cells are connected,' Arndt says. 'The advantage is that we can use the effector module universally and combine it with any target module.' It is no longer necessary to run complicated tests to see whether the bispecific antibody has changed during its adaptation to a new cancer target.

This offers great advantages for patients. The modular system can target several structures on the cancer cell. 'We simply combine the effector module with two, three or more target modules that can detect various target structures on the cancer cells,' Arndt explains. This greatly increases the chances of therapy success because tumor cells are adaptable, and when they alter the surface structure at which a regular bispecific antibody is supposed to dock, the therapy is no longer effective. 'Yet it is less likely that a tumor will change several of our targeted surface structures at the same time.'

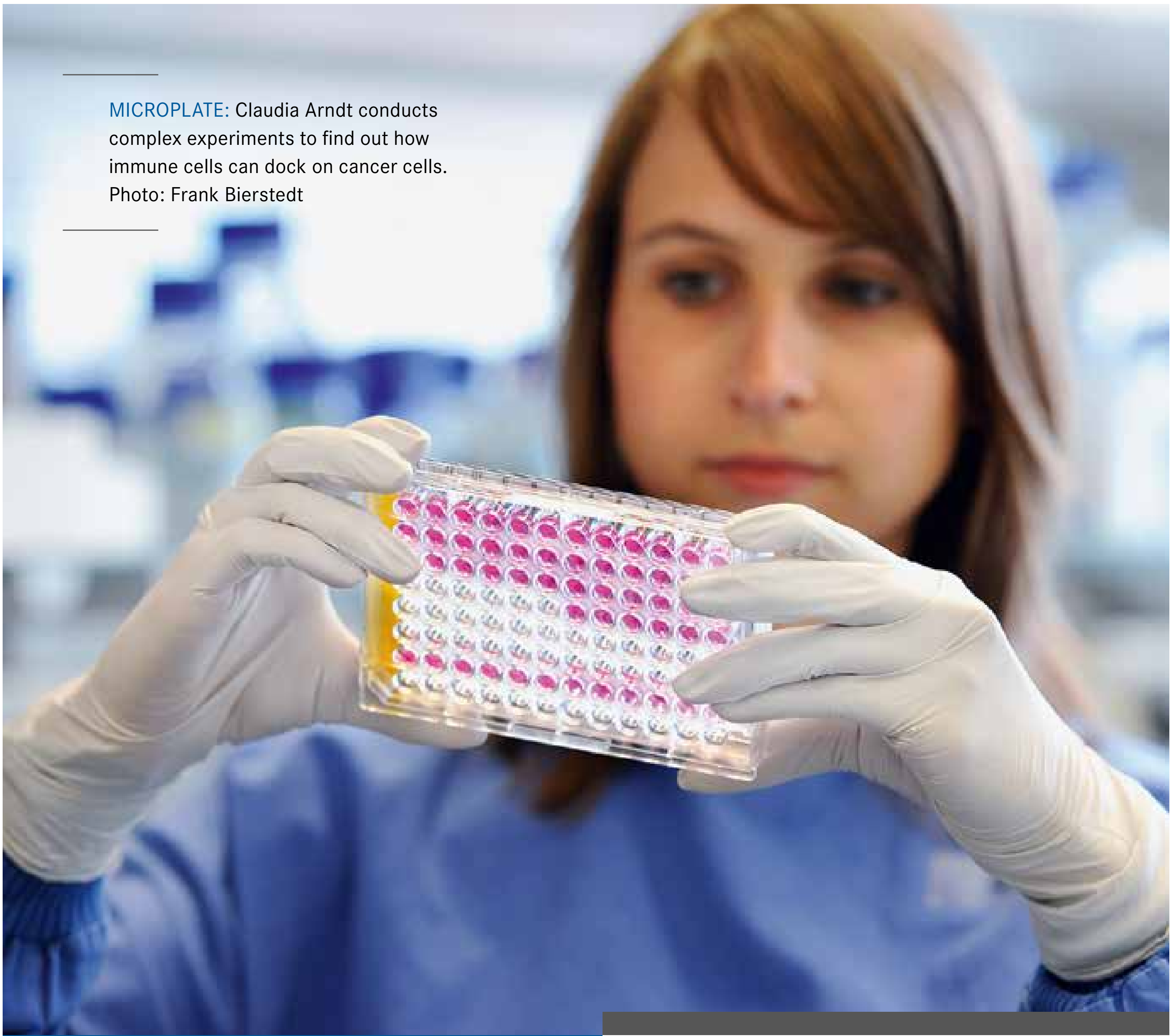
Immunotherapy plus radiation

The modular system is so flexible that it can also be combined with conventional cancer therapies such as radiation. When tumor cells are irradiated and destroyed, proteins are →

Claudia Arndt

The 28-year-old completed both her biology degree at TU Dresden and her four-year dissertation in the field of tumor immunobiology at the Medical Faculty Carl Gustav Carus with distinction. The talented junior researcher's name is on a total of 16 publications. Adding up the impact factors of the individual papers - that is a point value attributed to the status of the journal where a paper is published – she garners a whopping 80 points.

In 2015, Arndt won third place in the 'Young Investigator Award' at the 'Tumor Immunology meets Oncology XI' conference. Her future work at the HZDR Institute of Radiopharmaceutical Cancer Research will continue to revolve around universal antibodies for the immunotherapeutic treatment of cancers.



MICROPLATE: Claudia Arndt conducts complex experiments to find out how immune cells can dock on cancer cells. Photo: Frank Bierstedt

released from the nucleus of the cell. One of them is the ‘La’-protein, which sticks to the surface of the remaining intact tumor cells. Arndt’s and Bachmann’s modular system can exploit this because the effector module can bind the ‘La’-protein, which naturally contains the peptide-epitope. This feature alone allows the effector module to introduce immune cells into areas of the tumor that have already been treated with radiation – without any involvement of the target modules.

And if that is not enough to defeat the cancer, radioactive isotopes could be built into one of the target modules. In cooperation with her colleagues from the Institute of Radiopharmaceutical Cancer Research, Arndt wants to improve the modular system by introducing radionuclides and then test whether the target-seeking antibody will only accumulate in the tumor. In this way, radiation would only damage the cancer cells and not the healthy cells in the rest of the body. Arndt has just started this project, which means that she will continue to play with her molecular Legos for some time to come.

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C. Arndt et al.: ‘Costimulation improves the killing capability of T-cells redirected to tumor cells expressing low levels of CD33: Description of a novel modular targeting system’, in Leukemia 2014 (DOI: 10.1038/leu.2013.242)

C. Arndt et al.: ‘Redirection of T-cells with a first fully humanized bispecific CD33-CD3 antibody efficiently eliminates AML blasts without harming hematopoietic stem cells’, in Leukemia 2013 (DOI: 10.1038/leu.2013.18)

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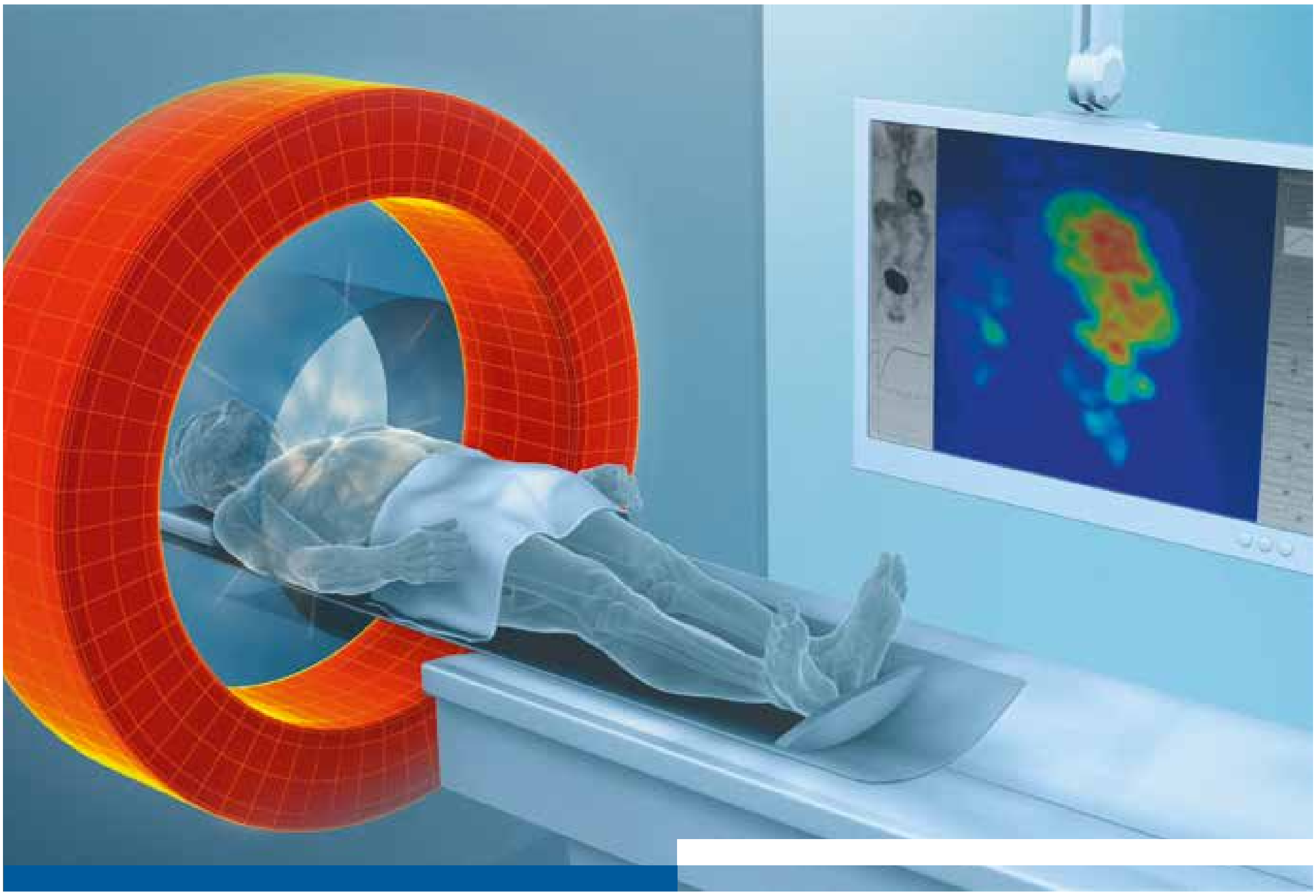
// The PET Center Dresden-Rossendorf did medical diagnostics for almost exactly twenty years.

Yet this is not the end of an era.



INSIGHT: Positron emission tomography (PET) is a highly sensitive method of diagnosing cancer. Illustration: AIFilm

20 YEARS OF CANCER DIAGNOSTICS

_TEXT . Christine Bohnet

In 1995, the first patient was examined in Dresden-Rossendorf using the then novel method of positron emission tomography (PET). Twenty years later, Jörg Steinbach, one of the two directors of the HZDR Institute of Radiopharmaceutical Cancer Research, declares: 'Mission accomplished! The method has become daily routine, still used on patients at Dresden University Hospital – and at the same time it will continue to be used as a basic research tool in the future.'

Today, as in the past, Helmholtz researchers are striving for greater precision in medical diagnostics, with a special focus on positron emission tomography. Depending on the diagnostic objective, this modern imaging technology involves injecting various radioactive tracers into the patients. Experts call these substances radiotracers or radiopharmaceuticals. Labeled with short-lived radionuclides, the radiotracer concentrates in a certain, often pathologically altered tissue where it will decay after a short period of time, emitting characteristic radiation which can be captured by detectors on the outside. Powerful software then processes the data to create 3D-images. The PET images show the areas with higher concentrations of the radiopharmaceutical as well as information on its pharmacokinetic properties over time – an important additional parameter. The physician thus obtains detailed information about the location and size of tumors, for example, or about the status of brain functions. →

Researchers and physicians have a whole arsenal of radiopharmaceuticals at their disposal, the main one being 'PET sugar'. This radiolabeled glucose derivative is effective because many types of tumors consume a lot of energy, and thus glucose. Radiolabeled amino acids, on the other hand, accumulate in brain tumors. Other radiopharmaceuticals serve to characterize tumors and provide important information for therapy plans. They are used to diagnose bone metastases and Parkinson's disease or to visualize brain processes (neurotransmission). Research is constantly expanding this 'toolkit'. HZDR staff manufactures radiopharmaceuticals in a certified GMP (Good Manufacturing

clinical practice. In April of 2015, the machine was relocated to the University Hospital Dresden, right near 'OncoRay', the National Center for Radiation Research in Oncology, which is a joint venture between the University Hospital Carl Gustav Carus, the TU Dresden Medical School and HZDR. In order to be able to continue its research, HZDR has its own reserved time slot at the PET/MRI machine.

Each year, 450,000 new patients develop cancer in Germany. Each patient, even each tumor is unique. Experts agree that the cure rate, which is currently about 50%, can only be raised further with individualized approaches to therapy.

Research focuses on radioactive drugs and molecular imaging.

Practice) area. It is legally authorized to process two of the most important substances: 'GlucoRos' ([F-18]FDG) and 'NaFRos' ([F-18]Fluoride). Of the twelve radiopharmaceuticals for clinical practice, available at the HZDR, six are commonly used.

Milestones from 20 years of PET imaging

As early as 2004, HZDR researchers developed an advanced method to correct patient movement during the PET scan. As one of the first research groups ever, they established a system for head scans with infrared cameras tracking the patient's movements. These motions are mathematically assigned to millions of measured data points, preventing a 'blurring' of the images in real time.

Another milestone is ROVER, a powerful and globally used software package. Marketed by 'ABX advanced biochemical compounds' in Radeberg, Saxony, ROVER guarantees fast and simple image processing as well as a standardized analysis of the generated images. Physicists and IT experts at the Institute of Radiopharmaceutical Cancer Research are constantly updating ROVER to reflect new developments – years ago, for example, it was adapted to combine PET and computer tomography (CT). Currently, it is being made compatible with facilities that combine PET and MRI (magnetic resonance imaging). The experts also make sure the software meets the needs of clinical practice. Radio oncologists, for example, are able to import the imaging data into their systems for radiation planning, which makes for a seamless integration of cutting-edge diagnostic methods into cancer therapy.

Germany's first PET/MRI whole-body scanner that was approved for use on patients was launched at the Helmholtz Center in 2011. This combination of PET and MRI was Europe's second and the world's third facility. 'We served more than 2,700 patients during its four-year operation in Rossendorf,' Jörg Steinbach explains. At the same time, intensive research efforts were made to optimize the innovative technology for

Progress in imaging technology makes it possible to detect, localize and characterize tumors with ever greater precision. Institute director Steinbach says: 'At our institute, one clear focus is the development of radioactive tracers, especially radiotracers that can show not only the location and spread, but also the behaviors and functioning of tumors.' That also requires biochemical basic research to find the best docking spots (i.e. biological target) for tumor-specific radiopharmaceuticals.

Radiotherapeutics for internal radiation

One of medicine's biggest challenges is to develop new and effective forms of cancer therapy. Once a patient's cancer has metastasized, the treatment method must be systemic, which means that the therapeutic agents must be transported to the metastases through the blood stream, as is the case in chemotherapy. New drugs that fight cancer cells either with radioactivity or via the body's own immune system could achieve significant progress in the therapy of certain tumors. HZDR researchers are pursuing multiple routes. They study specific radiolabeled substances as well as nanoparticles.

The idea is to use a carrier molecule or particle to transport radionuclides to the tumor, where the released radiation energy will kill the cancer cells. This presupposes radionuclides that remain where they are needed until the dose of radiation is released into the tumor. At the same time, it requires transport molecules or particles that are able to dock with great precision, at as many dispersed tumor cells throughout the body as possible. These are mainly peptides or proteins, such as antibodies. Their defined radiolabeling and characterization falls under the expertise of the institute.

'We are also working on innovative drugs that can destroy cancer cells by harnessing the body's own immune system,' explains Michael Bachmann, second director at the Institute of Radiopharmaceutical Cancer Research. 'One of our focus areas is antibodies that are able to detect two targets at once.' When such a 'bispecific' antibody makes contact with both cancer cells and immune cells, a targeted immune reaction is triggered against the tumor (see also our article on pages 19 – 21). 'We hope that this will allow us to fight cancers even better in the future.'

How it all began

This research goes all the way back to the GDR-era: At the former Central Institute for Nuclear Research (ZfK), scientists had already been experimenting with their own PET-camera, developing methods to create radionuclides and conducting early radiosyntheses for radiotracers. In the 1980s, they ran some initial studies with lab animals using a tiny experimental camera. At the beginning of the 1990s, a large PET-camera for patient examination was built on the same principle. The camera was, however, decommissioned when the Research Center Rossendorf (FZR), which was founded in 1992, received an experimental PET-system from Montreal, Canada. Even though the POSITOME IIIp-camera was in operation for only two years, it helped implement a 1991-recommendation by the Science Council, which is the German Federal and Länder governments' advisory committee for science, research and universities: Rossendorf was to be the home of eastern Germany's first PET Center.

Twenty years ago, patients were examined with the help of a glucose-based radiotracer ([F-18] FDG) and the Canadian camera. In May of 1997, a modern Siemens whole-body scanner replaced the experimental system, and 2011 saw the launch of the Philips PET/MRI machine. Until 2005, when the Dresden OncoRay Center was able to buy a PET/CT camera with funds from the Federal Ministry of Education and Research, the PET Center was Dresden's sole service provider in the field of PET diagnostics.

MOVING DAY: The components of the PET/MRI machine are safely packed.

More than 14,000 patients scanned at HZDR

Overall, more than 14,000 patients were examined. At the PET Center Dresden-Rossendorf, HZDR, the University Hospital and TU Dresden cooperated closely and with a clear division of labor: the University Hospital Dresden provided the medical know-how – especially the Clinic and Policlinic for Nuclear Medicine and the Clinic for Radiation Therapy and Radiooncology as well as the Clinic for Radiology. To this day, HZDR provides the necessary radiotracers as well as imaging expertise.

At the same time, research is and has been conducted in the fields of radiopharmaceuticals, medical physics and medicine. To pick an example: Within the EU project 'BioCare', scientists at HZDR and the Dresden Clinic for Radiation Therapy and Radiooncology studied the impact of the cancer cell's sugar metabolism on the effectiveness of external radiation therapy. They discovered that tumors that metabolize a lot of glucose are also more sensitive to an increased radiation dose. The sample data from this study demonstrate that biological information, such as the data gained with the help of PET, could be very helpful in creating the personalized cancer therapies of the future.

The past 20 years have not only seen numerous patient examinations; research synergies at the joint PET Center Dresden-Rossendorf have also benefited patients. This close cooperation between partners from research and medicine continues today on an even broader basis at OncoRay, the National Center for Radiation Research in Oncology – as well as with Heidelberg colleagues at the National Center for Tumor Diseases (NCT).

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// In a current publication in the journal 'Applied Energy', nuclear technology expert Bruno Merk explains how reactors can operate safely with fast neutrons.

SAFETY FOR GENERATION IV REACTORS

_TEXT . Christine Bohnet

UPSTREAM: For over 30 years, the sodium-cooled fast reactor BN-600 has been generating power in the Russian town of Beloyarsk.
Photo: Rosenergoatom

Germany is phasing out nuclear energy, but elsewhere nations are just getting on board. Peaceful use of nuclear energy is an important carbon-neutral option to satisfy the voracious demand for energy, not just in highly developed European countries such as Finland, the UK or France. Large Asian countries like India or China also bank on nuclear power. While Germany's nuclear power plants are exclusively 2nd generation light water reactors, Russia, France, Japan, India and China are planning Generation IV reactors. These facilities generate power with fast neutrons, using a coolant such as sodium.

Experts are divided on this issue. While proponents emphasize that sodium-cooled reactors have an inherently high degree of passive safety, opponents claim that they are fundamentally dangerous and cannot be operated economically. The US-based 'International Panel on Fissile Materials' is among the critics. In a research report of February 2010, it stated: 'The reliability of light-water reactors has increased to the point where, on average, they operate at about 80 percent of their generating capacity. By contrast, a large fraction of sodium-cooled demonstration reactors have been shut down most of the time that they should have been generating electric power.' (see: http://fissilematerials. org/library/rr08.pdf, page 9)

A catalyst for uranium

'Fast neutrons' means the energy range of particles needed for the chain reaction. In principle, nuclear power plants utilize the fact that neutrons can split atomic nuclei. In each fission reaction, more neutrons are released than were used.

START: Loading of the new, fast reactor BN-800 at Beloyarsk. Photo: Rosenergoatom

In order to control such a chain reaction, all nuclear reactors use neutron absorbers. In light water reactors, water as the cooling agent also decelerates the neutrons. In a fast reactor, the heat-removing agent is liquid sodium. In contrast to water, neutrons bounce off of a metallic atomic nucleus almost without any loss of energy, much like a pool ball that hits the rail.

Fast neutrons also facilitate the efficient breeding of plutonium. For opponents, this only adds more fuel to the fire, as this could also be weapon-grade plutonium. Supporters, on the other hand, consider this one of the great benefits of the technology. The idea is to always produce about as much plutonium as is burned in the operation of the facility. The substance is needed as a sort of catalyst for uranium-238, the almost sole natural form of uranium, which could otherwise not be used as fissile material. This kind of uranium does not require complicated enrichment or processing in order to be used in the fast breeder. What is more: sodium-cooled reactors can also burn many of the extremely long-lived, heavy nuclei that are generated in the operation of a reactor, thus transforming them into shorter-lived substances; this greatly relieves the problem of radioactive waste management. Even plutonium waste could be used as a fuel.

By comparison: Generation II versus Generation IV

HZDR-researcher Bruno Merk has studied the operation and shut-down times of fast reactors and compared them to particularly stable German light water reactors. His premise was that facilities with few unplanned down-times and maintenance intervals are technologically mature and safe. Together with colleagues from the US and India, and on behalf of the International Atomic Energy Agency IAEA, he analyzed data from the now shut-down demonstrator power plant Phénix in France and the Russian reactor type BN-600 in Beloyarsk, which has been in operation for over 30 years.

‘The technology is past its growing pains, as evidenced by few unplanned down-times, especially for the BN-600, which has operated safely for more than 30 years,’ says Merk. ‘We adjusted the data by subtracting scheduled revision times. In the past ten years, operation has been excellent with an adjusted availability of almost 97 percent. Only few light water reactors achieve such figures.’ In their study, researchers found that the German nuclear power plants Grafenrheinfeld (launched in 1981) and Emsland (launched in 1988) have similar availability rates of 96.2 and 99.8 percent. Merk emphasizes: ‘BN-600 has not undergone any major repairs either in this time period. The safety level of the fast breeder matches that of the best 2nd generation light water reactors. During scheduled revisions in this period, they even prepared the reactor for an extension of its operational life-span.’

Of course, Merk knows about the problems with sodium technology: ‘As nuclear scientists, we are aware of the issues that have come up. The steam generator and the pumps are the trouble spots.’ Leaks caused by poorly sealed welding seams can cause water or steam to come into contact with →

> ‘The French ASTRID reactor will be built, for sure. We need nuclear power experts in Germany whose voice will be heard when it comes to safety issues. And that will only happen if we assume an active role in large EU research projects.’

sodium – with the fatal result that this causes particularly intense reactions. This is why, many years ago, Germany and the UK decided to abandon breeder technology, shortly after, or even before launching their facilities.

In France, on the other hand, 'ASTRID' is a serious project, slated to be the first Generation IV reactor. It could be launched as early as 2025. Sodium fires did, however, break out at its predecessor project Phénix. 'Nuclear science has learned from these incidents and the facilities have been revamped accordingly,' the HZDR scientist says. This included automatic fire extinguishers and retention systems as well as double-walled pipes for the sodium. A sodium leak at Japanese reactor Monju in 1995 demonstrated another critical requirement: 'It is vital that the operating team is extremely well trained and able to react to an incident immediately. And of course, the population must be fully informed,' Merk explains.

Safety first

Light water reactors and fast reactors both have a high level of inherent safety. That means that the facility stabilizes itself in a physical sense. For example, the power production of a light water reactor will drop in the event of a loss of water and pressure. When fuel temperature rises, both light water reactor and fast breeder fuel will capture more neutrons without triggering a fission reaction. As soon as a fast breeder heats up, it expands – which also throttles its performance.

TEST: View of the BN-800 control room at the first stage of criticality. Photo: Rosenergoatom

Bruno Merk has been pondering a way to increase reactor core stability with the objective of capturing a larger number of neutrons in the fuel at rising temperatures. In order to achieve this, more neutrons must be safely decelerated. While water does decelerate neutrons, it isn't safe to use in a fast breeder due to the highly reactive sodium. The desired deceleration effect can, however, be achieved by binding hydrogen in a compound with a metallic substance such as yttrium and using this material in the spacers between the many individual fuel rods in the core of the reactor. In this process, it is important to finely disperse the yttrium hydride in the fuel assemblies. This idea has already been patented. 'German nuclear scientists are driven by the same kinds of issues as our international colleagues,' Merk says. 'We want to find out which methods achieve the highest safety levels.' Another goal is to further optimize the burning of fuel in fast reactors in order to minimize nuclear waste.

Other scientific fields also contribute to the safety of sodium-cooled reactors. In Germany, intensive research is being conducted on the topic of liquid metals, as they are also used in many other industries and are of increasing importance in future technologies such as innovative batteries or solar power plants. Liquid metal very effectively stores or conducts large amounts of energy or heat, with a heat conductivity that beats water by a factor of up to 100. New measuring methods, which are also being developed at the Helmholtz Center in Dresden, make it possible to fully monitor liquid metal flows. Recent years have seen a significant improvement in the operational safety of liquid metal technologies.

'At the end of the day, research will always just open up possibilities, point the way, and trigger informed debates,' Bruno Merk believes, now more than ever. Society must decide if it wants to use a technology, carefully weighing its risks and dangers. By 2022, Germany will have abandoned electricity production from nuclear power plants. Yet the country needs experts like Bruno Merk and his colleagues at HZDR and the Helmholtz Centers in Jülich and Karlsruhe to help ensure the safety of reactors that are being built just a few miles beyond our borders in Belgium, France, the Czech Republic or Switzerland.

PUBLICATION:
B. Merk et al.: 'Progress in reliability of fast reactor operation and new trends to increased inherent safety', in Applied Energy 2015 (DOI: 10.1016/j.apenergy.2015.02.023)

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// Medical researcher Esther Troost was recently appointed to a professorship for 'image-guided precision radiation therapy'. Together with her partner, medical physicist Aswin Hoffmann, she wants to drive radiation therapy in Dresden.

'WE LIKE TO TREAD NEW GROUND AND BUILD BRIDGES BETWEEN RESEARCHERS AND CLINICIANS'

_TEXT . Stephan Wiegand

'Let's put it this way: if there had been a comparable science location in London or New York, we would still have come to Dresden. The challenges we face here and the dual-career prospects are quite unique. We have been made to feel so welcome here - we are really enthusiastic about everything.' Esther Troost and Aswin Hoffmann meet briefly in the corridor of the OncoRay building and sit down together for half an hour in one of their offices. The atmosphere is comfortable, even without the typical personal accoutrements like photos and plants that often adorn a laden desk. The two scientists obviously see their life together as an exciting liaison, both in the lab and outside the hospital. →

TWO CULTURES: Germany – Netherlands, MRI – PET, medicine – physics. Esther Troost makes the connections. Photo: Stephan Wiegand

'Ok, if we get bored at weekends or on public holidays, then we work on an interesting article,' Esther Troost admits with a sidelong glance at her partner. Their offices are on the same floor and even back home in the Netherlands they spent many hours together on scientific questions. When she talks about her research, everything changes, not just her expression but the timbre of her voice. Suddenly the two of them are defining their own standards, analyzing radiation doses, classifying imaging modalities, and evaluating the impact of magnetic fields on a beam of charged particles. 'Esther's the woman for tumors in the head and thorax,' says Aswin Hoffmann, and 'he's more the one for the pelvis,' the professor interjects. Whether this division carries over into private life is anyone's guess. Esther Troost's field is medicine; Aswin Hoffmann devotes his time to medical physics.

Working to the power of two

'For a medical physicist like me there's quite a lot of routine work to be done here in Germany,' says Hoffmann. 'In the Netherlands, the areas of work are defined quite differently. Think of dosimetrists, for example. Back home, they are responsible for radiotherapy planning and quality control measurements.' Consequently, medical physicists have more scope for research and running innovative projects in the Netherlands. Here in Germany, Hoffmann has to work much choosing his words carefully. 'But we have to give it a try.' If the innovative plan works, it would be a significant step on the way to providing patients with more precise and effective cancer therapy. 'If you just propel the proton beam into the MRI's magnetic field, the beam of positively charged particles is deflected. This is precisely what we would have to work out when calculating the dose distribution.' The final goal will be to integrate the MRI and the proton therapy unit.

Here in Dresden the ground had already been prepared for a challenge of this kind, the researcher soon realized. 'It certainly has. In the Netherlands we don't have a constellation like this with the OncoRay Center and its partners, HZDR, the University Hospital and TU Dresden. It's a perfect environment for both of us to utilize theoretical research potential for clinical purposes, as well.' This was also what motivated Esther Troost to move several hundred miles east. 'Sure, the whole package, the colleagues, the professorship, the visionary boss – these were all good reasons for moving.' In the end, it was an easy decision for both of them because if you want to tread new scientific ground, a change of scenery is part of everyday life together. 'Sometimes you have to be careful not to let everything revolve around the job – but we manage quite well to give our brains an airing when we take our two dogs out walking along the Elbe river in the early morning.'

> Radiation oncologist and scientist Esther Troost is convinced that progress in imaging will bring about long-term changes in cancer therapy.

harder to find a niche, although in his particular case, things are working out extremely well because his work in Dresden stands on two pillars: 60 percent of his time is spent as the head of a research group – at the Helmholtz-Zentrum Dresden-Rossendorf, where he is employed in the Institute of Radiooncology – and 40 percent as a medical physicist at Dresden University Hospital. Both jobs focus on integrating magnetic resonance imaging (MRI) in radiotherapy, which is why he looks on his dual career as a real opportunity.

'With my research group, I want to integrate real-time imaging into proton therapy. This would allow us to determine and monitor precisely where the radiation dose is deposited in the patient's body while the treatment is being performed.' In the next ten years, the researcher hopes to combine MRI and proton beam therapy in one and the same piece of equipment. If he is successful, it really would be a world premiere. 'At the moment, we are still right at the beginning. We just have ideas but don't know whether they are technically feasible,' he says,

Understanding tumors better

Esther Troost focusses on imaging. 'Here on the medical campus, we now are benefitting from HZDR's combined unit that brings together anatomical information from MRI with metabolic information from positron-emission-tomography (PET) imaging.' Now, the medical scientist with the optimistic smile can almost constantly access countless patient records so that she and her colleagues in nuclear medicine and radiology at the University Hospital and the HZDR group around the physicist Jörg van den Hoff as well as other OncoRay colleagues can drive imaging in cancer research.

'It's fascinating! I'm sure progress in imaging will bring about long-term changes in cancer therapy,' says Troost. If you had not realized before, this is the moment when it becomes clear why Dresden is such an interesting base for the two scientists. 'In the past, you just had an X-ray showing the rough contours of the tumor. Then the patients were →

subjected to radiotherapy beams from the back and the front. You can't even say it was unsuccessful, but the cure rates were low and the side-effects were much more serious.'

Today, researchers around the world are working on ways of isolating and classifying tumors solely on the strength of image analysis. 'I have already been wondering what we can do in the short term to extract precisely these details from the data collected,' says Troost. To achieve this, the images of the patient's body would have to deliver parameters to answer questions like: Is it an infection or a tumor? How do the receptors on the surface of cancer cells differ from the healthy cells? Can receptors be classified using imaging procedures? Which data help to characterize tumors better?

At OncoRay, the National Center for Radiation Research in Oncology, ideas are continually perfected and bridges built. The two researchers are totally enthused: 'Using imaging during radiotherapy is already standard practice here. We can plan three-, or even four-dimensional, radiotherapy if you include the time factor.' Computer tomography (CT) and a combined PET/CT unit have been in use for years. Now the PET/MRI equipment for whole-body scanning from the Helmholtz Center has completed the unique OncoRay research platform. 'Where this journey will lead in the next three, four or five years, is almost impossible to tell today, but it's important to us that we are part of it.'

DIVISION OF LABOR: Esther Troost is the woman for the head; Aswin Hoffmann 'is more the one for the pelvis.' Photo: Stephan Wiegand

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// Carbon monoxide is not only a poisonous gas it is also a second messenger that relays signals from one cell to another. HZDR chemist Manja Kubeil wants to target its release in tumors in order to destroy them.

PEACE AND QUIET: Until shortly before leaving for Australia Manja Kubeil was still to be found in the lab at HZDR

FLATULENT NANOPARTICLES

_TEXT . Sascha Karberg

Perhaps it is a good thing that Manja Kubeil's next research project is taking her to the other side of the world. After all, she wants to build nanoparticles with something akin to flatulence: they are supposed to release carbon monoxide (CO) on demand. But there is no danger, not even for those with a sensitive nose. On the contrary: what the chemist from Holger Stephan's group wants to construct during her two-year stay at Monash University in Melbourne could one day help cancer patients. Carbon monoxide gas can cause damage to tumors. However, since it can also harm healthy cells, it can only be released in diseased tissue. And so the 31-year-old wants to construct the special molecules that are required to achieve just this. Equipped with a European Union Marie Curie Fellowship, she will work in the labs of her Australian collaborative partner – a project that is unlikely to leave much scope for surfing and kangaroo-spotting.

Broadening horizons

For Kubeil, who recently completed her PhD in radiopharmacy, the move does not just mean new grounds in geographical, but also in research terms. 'This is a completely new field for me,' says the Berlin-born scientist. But she is just as confident about this challenge as she was when she started university, coming to Dresden with the aim of studying →

chemistry and standing on her own feet. 'After finishing my PhD I really wanted to broaden my scientific horizons,' says Kubeil. Equipped with little more than a suitcase, she is now heading Down Under to investigate a young research field that is at least as unexplored as the Australian Outback. 'The first complexes for the targeted release of carbon monoxide were only developed around the turn of this century,' the chemist explains. CO, which can be used to treat issues like inflammatory diseases and high blood pressure, cannot be directly injected into the bloodstream. It can even be lethal if the doses are high enough because it bonds irreversibly with the red blood pigment hemoglobin. 'Then you suffocate,' says Kubeil. That is why CO releasing molecules, or CORMs, were developed, a class of metal carbonyl complexes. 'You can change the pH value, add enzymes or expose the carbonyl complexes to light so that they release CO in the right place at the right time.'

Releasing gas with light

Kubeil's task is to develop carbonyl complexes that release CO when they are exposed to light. But light in the visible spectral range barely penetrates the tissue – a disadvantage when trying to reach deep-seated tumors. Kubeil consequently uses infrared light that can penetrate further into the tissue, combined with so-called up-converting nanoparticles. Upon irradiation of these special nanoparticles with infrared light they convert it into visible light. This activates the carbonyl complexes that Kubeil attaches all over the surface of the up-converting nanoparticles and releases the carbon monoxide. The latter, in its turn, exerts the desired effect on the tumor. To accumulate the nanoparticles in the tumor, Kubeil will also equip them with target-seeking molecules. They attach themselves to structures in the cell membrane that occur particularly in cancer cells.

SEPARATION: Laboratory bottles with various solvents for a special HPLC procedure to separate and analyze the substances. Photo: Frank Bierstedt

First square meters, then nanometers

A tight schedule Manja Kubeil intends to get through with the help of her experienced mentors – the 2014 Helmholtz Award winner Leone Spiccia from the School of Chemistry at Monash University, who will be a visiting researcher in Dresden in 2015, and Bim Graham from Monash Institute of Pharmaceutical Sciences. 'They have a lot of experience with metal carbonyl complexes there, but there isn't one that can absorb light in the visible range,' Kubeil comments. When the chemical part of the undertaking is finished she wants to see how the 'flatulent nanoparticles' behave in the cells. Using spectroscopic methods and even the synchrotron on the edge of Melbourne the German chemist intends to trace the miniscule particles – less than one ten-millionth of a millimeter – in the cell.

What happens to the decomposition products of the metal complexes after CO has been released? Are they eliminated from the cell or do they damage the cell? Do the nanoparticles wander into the cell or stay outside? There are many questions still to be answered. But the first important one on Manja Kubeil's list has nothing to do with nanometers, but rather, square meters: whether she will be able to find a convenient apartment for herself and her husband in chronically crowded Melbourne.

PUBLICATIONS:

K. Zarschler, M. Kubeil, H. Stephan: Establishment of two complementary in vitro assays for radiocopper complexes achieving reliable and comparable evaluation of in vivo stability, in RSC Advances 2014 (DOI: 10.1039/c3ra47302c)

J. A. Barreto, W. O'Malley, M. Kubeil, B. Graham, H. Stephan, L. Spiccia: Nanomaterials: Applications in cancer imaging and therapy, in Advanced Materials 2011 (DOI: 10.1002/adma.201100140)

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// The National Center for Tumor Diseases in Heidelberg is currently gaining a partner institution in Dresden. Administratively, Heidrun Groß plays a crucial role in the process.

A FLAIR FOR DIPLOMACY

_TEXT . Simon Schmitt

COOPERATION: NCT coordinator Heidrun Groß makes sure that the interests of all partners in Heidelberg and Dresden are taken into account. Photo: Stephan Wiegand

‘Research institutions are sometimes a bit like small countries,’ Heidrun Groß explains. ‘They have their own agenda and do their best to make sure they get their way. So, just as with countries, compromises have to be found that satisfy everyone. The processes involved are fairly similar.’ Groß speaks from experience. After all, she engaged in international affairs at university, in her PhD and as a postdoc. This knowledge is now helping her to deal with a project that has many partners on board. Since the beginning of the year, she has been responsible for coordinating the development of the National Center for Tumor Diseases (NCT) in Dresden.

‘This means that at the moment, all administrative tasks converge on my desk, from coordinating appointments via drawing up contracts to designing a new website,’ says Groß, describing the range of her activities. Hardly surprising, because apart from NCT Executive Director Michael Baumann, she is currently the only member of staff at NCT in Dresden. But this does not worry the Saxony-born manager. ‘I gathered a lot of experience in science management during my time as the head of a transnational junior researcher group.’ She also acquired legal knowledge during her doctorate at TU Dresden, which focused on cultural diversity and copyright.

Constructive cooperation

And in this context she also developed a flair for diplomacy, which she illustrates with an analogy: ‘We can only make proper use of a table if the legs are all the same length. This reflects well the structure of the NCT. We have to take all the partners' interests into account. If one gets short shrift, the whole construction starts to wobble. But everyone involved is convinced that it is a great opportunity for Dresden to have the NCT located here, and therefore cooperation between the various institutions has been very constructive.' And that is not something to be taken for granted when one considers how many partners are involved. For the NCT partner site Dresden alone, Carl Gustav Carus University Hospital, the Medical Faculty at TU Dresden, the German Cancer Research Center (DKFZ) and HZDR have joined forces.

'This location is already an excellent example for sustainable, successful research cooperation as OncoRay or DRESDEN-concept illustrate,' Groß explains. Hence, this provides a good base for establishing the new NCT location. Dresden is thus becoming the partner site of Heidelberg where DKFZ, together with the University Hospital, the Medical Faculty at Heidelberg University and the German Cancer Aid, established NCT eleven years ago. As one center, Heidelberg and Dresden are now set to improve personalized cancer therapy. 'The idea is to boost our strengths and also build additional profile areas,' Groß explains.

Research for the patient

The approach taken by NCT is to combine research, treatment and prevention under one roof. Scientific results immediately flow into patient therapy – the experience of treatment feeds back into research. This cycle is designed to expedite the transfer of research results to clinical application. To this end, five new professorships are initially due to be created at NCT Dresden 'which will be integrated in the institutions involved,' Groß emphasizes. 'In addition, we are also planning various programs that will build bridges to existing structures in oncology.'

On this basis, the entire NCT strives to become one of the world's leading cancer research centers in the next ten years. Groß admits that this is an ambitious goal, but cooperation will generate the necessary potential, she believes. 'Admittedly, you do get on quicker when you are on your own, but you get much further when you work together.'

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AWARD WINNERS

Green Photonics Award 2015 goes to Dresden researchers

During SPIE PHOTONICS West 2015, the international meeting of the optics and photonics branch in San Francisco, the 2015 Green Photonics Award was conferred on a Dresden research team: Andrés Lasagni and Sebastian Eckhardt from the Institute of Manufacturing Technology at TU Dresden, Lars Müller-Meskamp from the Institute for Applied Photophysics and Mathias Siebold and Markus Löser from Helmholtz-Zentrum Dresden-Rossendorf. They were granted the award in the category 'Laser-assisted manufacturing and micro/nano manufacturing'.

The demand for highly-efficient, transparent electrodes, which do not use rare or expensive raw materials like indium, calls for a new generation of thin metallic films with both high transparency and electrical conductivity. A special laser-based method ('direct laser interference patterning') makes it possible to fabricate periodic hole-like surface patterns on thin metallic films. While it improves their optical transparency, it keeps the electrical properties of the very thin films at an acceptable level.

The two HZDR researchers developed a solid-state laser specifically for structuring super-thin metal electrodes. To this end, they had to precisely adjust the emitted wavelengths of the laser system together with a high-output impulse energy for the manufacturing techniques at TU Dresden and Fraunhofer IWS. Thus the PhD student Sebastian Eckhardt managed to structure metallic electrodes made of very thin films for use in thin-film solar cells and LEDs.

This successful cooperation between IWS and HZDR will continue in the joint LAMETA Project focusing on the manufacturing of embossing rollers with pattern sizes in the sub-micrometer range. Using laser technology, they will have to be manufactured so that they are suitable for the industrial production of plastic components with functional and microstructured surfaces.

HZDR doctoral candidate among best in the world

Karl Zeil from HZDR's Institute of Radiation Physics won the 2015 John Dawson Prize. In his doctoral thesis he sought to gain a better understanding of the mechanisms of laser particle acceleration – which is of high importance to scale the energy of the particles. The aim is to develop a compact laser accelerator for modern proton therapy cancer treatment.

Every two years, the two best theoretical and experimental doctoral theses in plasma acceleration are honored with the 'John Dawson Thesis Prize'. Karl Zeil received the € 1,000 award during this year's Laser Plasma Acceleration Workshop (LPAW) which was held on the island of Guadeloupe from May 10-15, 2015.

The American John M. Dawson (1930 - 2001) was a distinguished plasma physicist and one of the pioneers of accelerator research. Now Karl Zeil, who had already received first prize in the Behnken-Berger Foundation's awards for junior scientists, is following in his oversize footsteps. He recently became head of his own HZDR Young Investigators Group on laser-ion acceleration.

New Research Fellow

What do many passionate researchers dream of? Spending most of their time in the lab and as little as possible on meetings and mindless bureaucracy. What a bonus if an institution can offer selected top researchers precisely that. HZDR has now awarded the third 'HZDR Research Fellowship' to Stephan Winnerl.

'We are honoring his top-level research achievements,' said Scientific Director Roland Sauerbrey. 'The number and quality of his publications is outstanding and we hope that the Fellowship will drive his career further.' With this open-ended honor, the 45-year-old is following the example of Stefan Facsko from the Institute of Ion Beam Physics and Materials Research to which he also belongs, and Frank Stefani from the Institute of Fluid Dynamics.

Winnerl began his scientific career at Universität Regensburg (UR), where he completed an excellent PhD, having previously spent a year abroad at the University of Colorado at Boulder, USA. His specialization is in ultrafast spectroscopy of semiconducting materials, preferentially using terahertz beams in the spectral range between microwaves and infrared light.

With its two free electron lasers, HZDR offers the perfect radiation sources for this kind of research. Winnerl has

Stephan Winnerl receives the 2012 HZDR Research Award from Prime Minister Stanislaw Tillich and HZDR Scientific Director Roland Sauerbrey (right to left) Photo: Oliver Killig

already chaperoned many visiting scientists and is involved in long-term collaborations with colleagues like Lukas Eng from TU Dresden who established near-field laser microscopy. This helps physicists to track down exotic properties in semiconductors.

Nor is Winnerl indifferent to mentoring students and doctoral candidates either, as the outstanding results he has achieved with his group amply demonstrates. These have already brought him two HZDR Awards. Currently, he is in receipt of funding from the Deutsche Forschungsgemeinschaft (DFG) to focus on the 'miracle material' graphene.

Award granted by the journal 'Nuklearmedizin 2015'

Frank Hofheinz from HZDR's Institute of Radio-pharmaceutical Cancer Research received the award conferred by the specialist journal 'Nuklearmedizin' for his 2012 article, which was cited most frequently last year: F. Hofheinz, C. Pötzsch, L. Oehme, B. Beuthien-Baumann, J. Steinbach, J. Kotzerke, J. van den Hoff: Automatic volume delineation in oncological PET. Evaluation of a dedicated software tool and comparison with manual delineation in clinical data sets, in Nuklearmedizin 2012, Vol. 51, pp. 9 – 16.

Jörg Kotzerke, one of the co-authors and President of the Deutsche Gesellschaft für Nuklearmedizin, presented the award to Frank Hofheinz during the association's Annual Meeting in Hannover on April 25.

_Text . Christine Bohnet

PANORAMA – HZDR NEWS

Turning time back into the future

In early 2015, a ‘Flock of Happenings’ was initiated by the artist Florian Dombois who invited scientific institutions in Dresden to participate in performances for the public. His special interest was the phenomena of backward running time. Scientists from HZDR’s Institute of Resource Ecology illustrated this theme by considering the disposal of radioactive waste. Suitable repositories have to protect the biosphere from these substances for one million years. To illustrate such an enormous period of time, the scientists and the artist developed a ‘time rope’.

At the Postplatz in the inner city, one million years were initially projected into the past on a 200 meter long rope on the basis of historical events; then into the future via notional points in time and the decay rate of radioactive isotopes. In this way, the rope stretches right back to the beginnings of human life and simultaneously points out how long radioactive waste will need to decay to a natural level.

Photos: Konrad Kästner

Time for exhibitions

The exhibition 'Image Tactics - Reproduction, Creation and Presentation in Art and Science' was held in Dresden until July 2015, asking questions such as: Can we really trust our eyes? What effects do images, forms and presentations intend to achieve? To what extent is free interpretation possible? The pictures, objects and forms that covered three floors in TU Dresden’s ALTANA Gallery were sorted into three main categories: imaging, design, and representation.

HZDR was not only the patron of the exhibition but also contributed several ‘tactical image themes’. A massive magnetic coil from its Dresden High Magnetic Field Laboratory underlined that form and function are inseparably linked, not only in art but also in science. For the visitors – mainly students from TU Dresden – it thus became obvious that the famous statement that ‘form follows function’ could be applied to technical objects as well. Similarly, the fascinating images of minerals on two 3D TV screens could not be clearly defined as science or art. Besides, the graphic

Magnetic coil from the Dresden High Magnetic Field Laboratory – Exhibit in the ALTANA Gallery images challenged visual expectations because, although they were shown simultaneously, they were presented on the two screens from different angles. A special scanning electron microscope (SEM) was used in the production. Scientists at HZDR's Helmholtz Institute Freiberg for Resource Technology utilize this method to investigate the precise surface structures as well as the chemical composition of ore samples.

Another research object showed an 'explosion' taking place in chronological order. When a high-power laser pulse hits a target, the electrons on the surface heat up to several billion degrees leading to a particular state of matter: a plasma of electrons and ions. Just as in an explosion, the plasma expands and the electrons fly off, followed by the ions. The impressive pictures of simulated laser-particle acceleration were, however, not simply arranged one after the other but printed on Perspex that was hung on the wall in the form of a huge book.

Hi Lights! All about light

The big light exhibition at the Dresden Technology Collections (Technische Sammlungen Dresden) will be open until June 2016. It features several exhibits contributed by HZDR. For a whole year, old and young will be able to discover a lot of facts about the properties of light and what kind of research into light is conducted in Dresden. Hi Lights! illuminates the photonics spectrum and the secrets of light, tells the 'laser story' and delves into 'Science & Fiction'.

↗ **www.tsd.de**
↗ **www.altana-galerie-dresden.de**

New Film on Repository Research

Nuclear phase-out is declared policy in Germany, but the nuclear legacy will keep us occupied for many years to come. We have to store radioactive waste safely for a period of several ice-ages – a major debt we owe to future generations. Scientists at HZDR's Institute of Resource Ecology are therefore investigating the migration and retention mechanisms of radionuclides.

Now, a short film has been produced in which chemists, physicists, biologists and geologists present their work at HZDR's sites in Dresden, Leipzig and Grenoble. For their investigations the researchers use modern spectroscopic methods in order to acquire an understanding of processes at molecular level. When analyzing rock formations they also use positron emission tomography as an imaging technique. This important fundamental research is thus generating robust data which should help experts and politicians to identify potential locations for nuclear waste repositories. The video is available in the Media Center on HZDR's website and on YouTube.

↗ **www.hzdr.de/mediathek**

What's on?

05. - 13.09.2015
17th Annual Conference of the International Association for Mathematical Geoscience (IAMG 2015)
Freiberg | Helmholtz Institute Freiberg for Resource Technology and TU Bergakademie Freiberg

28.09. - 02.10.2015
The ThUL School in Actinide Chemistry
Karlsruhe | Karlsruhe Institute of Technology (KIT) and HZDR Institute of Resource Ecology

05. - 07.10.2015
Annual Meeting of the Biological Radiation Research Association (GBS)
Dresden | OncoRay – National Center for Radiation Research in Oncology

21. - 23.10.2015
Workshop on Methods of Porosimetry and Applications
Dresden | HZDR Institute of Radiation Physics
(organized together with Martin-Luther-University Halle-Wittenberg)

24. - 26.11.2015
HZDR & ANSYS Multiphase Flow Short Course and Conference
Dresden | HZDR Institute of Fluid Dynamics

01.12.2015
HZDR Colloquium: Physics of Active Soft Matter
Prof. Hartmut Löwen | Düsseldorf

Art exhibitions at HZDR

Opening at 17:00h

05.11.2015
Volker Lenkeit

Laboratory of the extremes

On June 24, 2015, the Helmholtz Association Senate gave the green light for a new experimental facility at the European XFEL in Hamburg. The Helmholtz International Beamline for Extreme Fields (HIBEF), which is due to go into operation in 2018, is a collaborative project involving DESY and HZDR. It will substantially extend the capabilities of the High Energy Density Instrument (HED). An international user consortium of up to 100 institutions is expected to contribute to the scientific focus and, in some cases, also to the financing of HIBEF. The UK has already committed to a high-performance laser valued at approximately 11 million euro; an overall budget of 30 million euro is envisaged for the project.

'This will allow us to do the kind of science and experiments that have not been possible so far,' says Thomas Cowan of HZDR, who is heading the international user consortium developing the HIBEF station. He illustrates the point with a simple example: 'If you hit a metal object with a hammer, you damage it in a way you may not be able to see, but it will have repercussions at the atomic level. Today, we understand these processes at a microscopic level. But we want to venture into the nano and sub-nano world, that is, the world of atoms.' And this will be made possible by combining the brilliant X-ray light of the free electron laser XFEL – the analysis tool – with the intensive light pulses of extremely powerful laser systems, which generate the extreme states in the samples.

XFEL's X-ray radiation will enable even deeper insights into the structure of materials, cells, molecules and atoms as well as extremely short chemical and physical processes. If matter is irradiated simultaneously with an ultra-short pulsed high-power laser this promises to uncover new knowledge about previously hidden processes. Furthermore, in addition to the planned laser systems, one provided by the British partner in the consortium and one by HZDR, HIBEF will also house a unit for generating the highest magnetic fields – which is why HIBEF is part of a new facility for High Energy Density Matter Experiments (HED) that is currently under construction at XFEL.

Extreme conditions for different areas of science

The unique combination of the Helmholtz Beamline facilitates novel experiments in magnetism which are destined to lead to both a better understanding of fundamentals and to innovative applications, in electronics for example. Investigating matter under extreme conditions is, however, also relevant for studies on the behavior of the Vacuum in strong fields. Plasma physics will be a further focus area. Plasmas are a special state of nature which occur in stars as well as in laser-induced particle acceleration. British and other project partners on the other hand, are particularly interested in matter which is exposed to extreme pressure. So the experiments planned will involve such diverse fields as materials research and geoscience, plasma physics and astrophysics.

↗ www.hzdr.de/hibef

Exploiting innovative potential

In order to improve the competitiveness of the European raw materials sector, the European Institute of Innovation and Technology (EIT) tasked an international consortium in December 2014 with developing a so-called 'Knowledge and Innovation Community' on Raw Materials.

HZDR is responsible for coordinating the partnership together with the Fraunhofer Association; the network brings together more than 100 European universities, companies and research institutions under one roof. This network is designed to simplify the exchange of ideas and research findings in order to fully exploit innovative potential in the European raw materials sector.

The goal is to create and develop new game-changing businesses across Europe that attract not only investment but also talented entrepreneurs and researchers.

↗ **http://eitrawmaterials.eu/**

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