discovered

THE HZDR RESEARCH MAGAZINE

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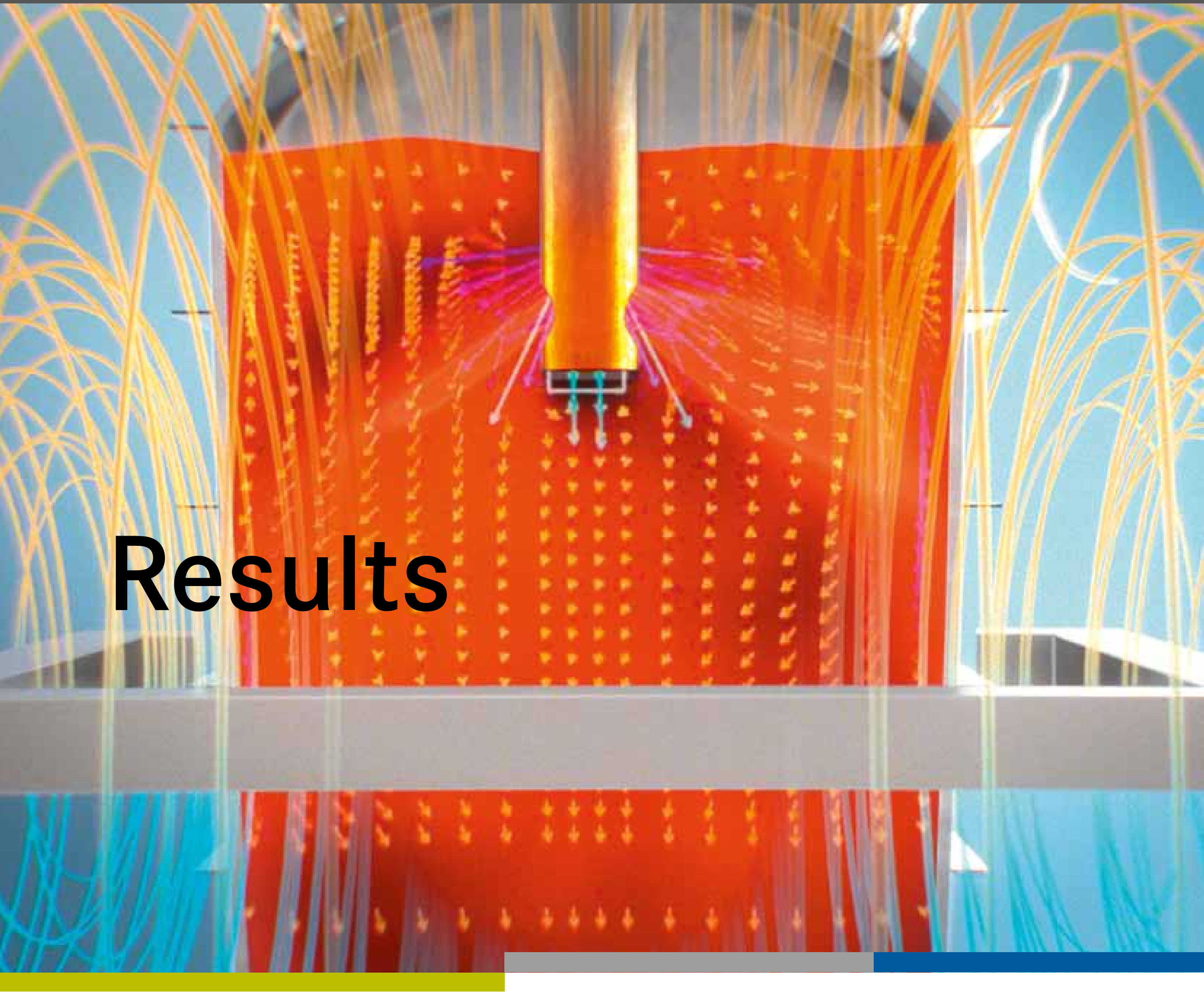

Results

SUMMER IN THE LAB

First international summer school program at HZDR

ESRF UPGRADE PROGRAM

Excellent research conditions for European users

ENERGY EFFICIENCY OF CHEMICAL PLANTS

Markus Schubert receives starting grant from the European Research Council (ERC)

HZDR

HELMHOLTZ
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ROSSENDORF

COVER PICTURE: When liquid steel is being poured into a mold, the frequently turbulent stream also has an effect on the final product’s quality. Scientists at the Helmholtz-Zentrum Dresden-Rossendorf are investigating how externally applied magnetic fields could improve the steel cast’s efficiency and quality. Diagram: AIFilm

DEAR READER,

What you are holding in your hands right now is the first English-language issue of our research magazine “discovered,“ which we have decided to give the short but sweet title “Results.“ Because it is exactly that – the results from research – which society, the industry, and politicians all expect from a research institute like our own Helmholtz-Zentrum Dresden-Rossendorf – if only because they want to know what happens with their taxpayer Euros in terms of the portions of that money, which end up flowing into scientific research.

Which have been the most important findings in the field of cancer research here in Dresden over the last few years? Will the results help increase the chances of curing different types of cancer for good? Which methods are researchers using these days to arrive at new insights in the field of materials research – like, for instance, in the case of the highly promising material graphene – and why are associated research facilities as gigantic as they are? In what ways might industry be able to contribute to Germany‘s energy transition proposal? A number of different processes in industries that stand out as some of the all-time biggest consumers of energy like, for example, the metal processing or chemical industries, are carefully being scrutinized by HZDR‘s researchers. What did they find out? What are some of the new approaches to addressing security concerns at nuclear power plants that are still currently in operation all over Europe? And what about the exact nature of international collaborative efforts in this area? Is it possible for the various highly toxic – and durable – substances that were produced as radioactive waste over the years to somehow escape from the permanent repositories and enter into our environment?

It is the answers to these very questions we are investigating in this current issue of “discovered.“ These are questions whose answers society is entitled to – in a format that can be easily understood by all. And because our scientists are sharing this view, they have thrown their full support behind the editorial staff in helping them put together this issue of our magazine. The results are eight cover stories drawn from the HZDR‘s three major research areas: matter, health, and energy.

A separate section of “discovered“ is dedicated solely to featuring three of the most successful collaborations. We are very proud of the fact that our most important collaborator, the Technische Universität Dresden, has recently joined the ranks of Germany’s elite universities. The HZDR would like to take this occasion to once again extend our heartfelt congratulations to the TU Dresden! The magazine‘s “Portraits“ section will introduce you to two successful HZDR scientists, while the brief articles in the “Panorama“ section are intended to round off the magazine towards the end.

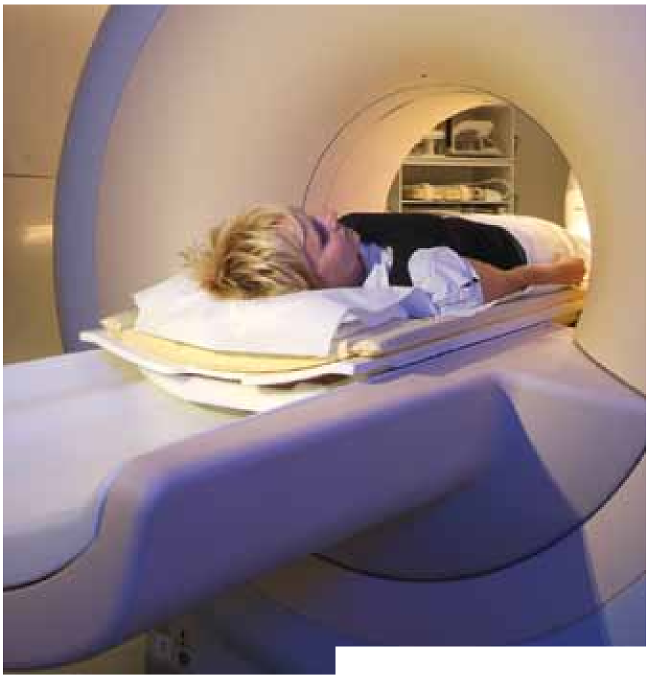
Going forward, we plan on publishing our research magazine, “discovered,“ in German twice a year, but, at this time, only one annual English-language issue is planned. We will make our very best effort to try and select the most suspenseful – and informative – topics so that you can easily find out which of the many research findings that come out of the Dresden Helmholtz Center will in the future most impact our lives. For our first English-language edition of “discovered“ – our usual German-language version is also due for publication in the very near future – it is my sincere hope that we will have many interested readers. I look forward to receiving your feedback, which, as always, is most welcome.

Yours sincerely,
Christine Bohnet

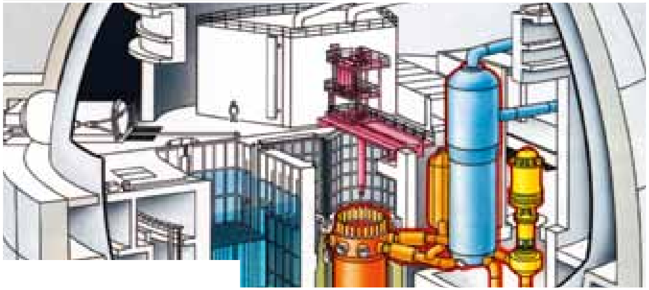
HZDR Department of Communications
and Media Relations

CONTENTS

RESULTS



COLLABORATIONS



PORTRAIT

PANORAMA

// The casting process is a fundamental technology that uses a considerable amount of energy. As a result steel production is one of the most energy-intensive industrial processes around. The new Institute of Fluid Dynamics at HZDR hopes that its research will be able to redress this energy balance.

STEELMILL: The metal processing industry is one of Germany's biggest energy consumers. Image credit: © LE image – Fotolia.com

GERMANY'S NEW ENERGY TURNAROUND – SAVING ENERGY IN STEEL CASTING

_TEXT . Christine Bohnet

TRANSLATION . Sarah Gwillym-Margianto

In 2011 the German Federal Government announced an energy turnaround for sustainability, meaning that in the future Germany will not source its energy from nuclear power but will instead rely mainly on renewable energy sources. Energy efficiency is also being talked about more than ever. Private households have quite a lot of untapped potential to become more energy efficient by modernizing old homes with the latest thermal insulation or upgrading heating systems with state-of-the-art technology. On a much larger scale however, industry can contribute to energy efficiency by developing and using new technologies that are resource- and energy-efficient.

As part of its new focus on energy, the Helmholtz-Zentrum Dresden-Rossendorf is looking at resource-intensive and energy-intensive production processes, like for example steel and aluminium casting or crystal growth. Similarly, in the production of raw chemical materials (the chemical industry

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STEEL CASTING IN THE LAB: Physicists Klaus Timmel (right) and Michael Röder are getting ready to take a measurement. The LIMMCAST facility offers the unique possibility to conduct realistic experiments using an alloy that is steel-like in many of its properties. Image credit: Rainer Weisflog

is, together with the automobile, engineering and electrical industries one of the largest employers in Germany) energy and raw materials can be saved by an order of magnitude that private households could never match even after making considerable efforts in terms of energy-saving measures. Nevertheless: every effort counts as a step towards achieving energy efficiency and a fair distribution of energy.

Looking at old technologies through the eyes of researchers

The standards are high for steel plants: nowadays the metal that is produced is not allowed to have even the slightest material defects. This is because one should be able to convert it into increasingly larger and at the same time thinner and lighter parts. Energy-savings can be made at this point, if the steel is perfectly produced during the first casting without having to be melted again. Further, one can save considerable energy – and thereby save costs – if the casting process itself is sped up. However, the molten metal is subject to the laws of thermo-fluid dynamics: faster casting processes can lead to unwanted swirls that in turn increase the rate of rejection.

Externally applied magnetic fields control flow.

Approximately 90 percent of the world's steel is manufactured using the continuous casting process, which enables a high casting speed and productivity. It is based on the fact that the hot molten metal is poured at approx. 1,500 degrees into a copper mold, which is open at the bottom and which uses water as a coolant. There the outer part of the molten mass cools off and can be pulled off. At this point the core of the strand is still liquid, but gradually cools off in the air. Today's casts take on different forms, depending on their respective requirements. Modern factories for example produce very thin metals, which are then directly processed into forms (i.e. car bodies) in rolling mills. It is easy to see why this kind of solution benefits from dramatic cost and energy savings.

What does casting have to do with magnetic fields?

Due to the fact that hot molten metals are practically always electrically conductive, one can use magnetic fields as electromagnetic brakes to control the flows of these molten metals. These brakes are based on a law that many of us know from school: Lenz's law. It is common knowledge that an electric current sets up a magnetic field. According to Faraday's law a magnetic field however also produces a current in an electrical conductor, if these move relatively towards each other. Lenz (1804 - 1865) was the first to recognize that the interaction between an induced current and an applied magnetic field produces a force that counteracts the original force. This inductive force is known as the Lorentz Force. It is the workhorse for HZDR experts in this fascinating field of magnetohydrodynamics.

Flows of the molten steel usually also affect the properties of the final product. Only when the flow is stable and reproducible, can high-quality steel be produced; if on the other hand there are swirls, problems often arise in terms of the quality of the material or even rejects, meaning that it must be melted again incurring additional costs. The idea behind implementing electromagnetic brakes that have been used now for approx. the last fifteen years is that externally applied magnetic fields control the flow, suppressing unwanted swirls. If the magnetic brakes in the steel factory work well, then the casting speed can be increased and the quality, productivity and efficiency increase proportionately. Bearing in mind that steel strand casting is a 70-year old technology, one would think that the process would have been optimized a long time ago. However, nothing could be further from the truth. There are several reasons for this. On the one hand with today's conventional methods for taking measurements one cannot look directly at the molten steel and its flow, on the other hand the effect of the electromagnetic brakes have thus far only been conceived and tested on the basis of calculations and integral results. An investigation of the flow in the mold was based exclusively on experiments with water however, but water behaves completely differently from molten metals.

Electromagnetic brakes do not brake

The experimental work at the LIMMCAST plant from the Helmholtz-Zentrum Dresden-Rossendorf is now for the first time ever able to provide realistic data on flows of molten steel. Barely published, these results had a great response in the scientific community and the steel industry, although they readdress many of the assumptions that for many years were considered to be the basis for using electromagnetic brakes. The experimental results were surprising: in steel casting, electromagnetic fields do not always work solely as brakes, but can also make the flow become unstable under certain conditions and even increase the level of swirls. Hence, it is hardly any wonder that the Rossendorf scientists' results provoked an overwhelming response at international conferences. The good thing is that industry partners have also expressed a serious interest in the results. Gunter Gerberth, Director of the Institute of Fluid Dynamics at HZDR remembers how, when LIMMCAST was set up some five years ago, there were a few rather critical objections. In the meantime however these voices of dissent have fallen silent.

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Today discourse takes place face to face, where scientific efforts were once scoffed at for being too far removed from the harsh industrial world. Besides the steel plants, there are also one or two manufacturers of electromagnetic brakes that have become involved with the LIMMCAST plant and the first projects with partners from industry are already underway.

The LIMMCAST plant offers unique possibilities for conducting fundamental experiments using an alloy that is similar to steel with respect to its thermo-physical characteristics. The experiments are carried out resembling the realistic material processes in the steel industry, even if the model metal only heats up to approx. 200 degrees Celsius. Just like in a real company there is a tundish, from which the liquid alloy is regulated using a stopper rod, before it is first poured into the submerged entry nozzle and then into the mold. The stopper rod is used to adjust the flow rate and to inject argon gas. If the metal flows out too quickly or uncontrollably from the submerged entry nozzle into the mold, then the turbulent flow carries impurities with it such as toxins or oxides, which become entrapped in the molten metal. This leads to internal material defects of the finished steel product. Furthermore, surface defects can form, if unintended interactions take place between the molten metal and the casting powder, and finally in a worst-case scenario the strand can be broken allowing the molten metal to flow out, when the rigid outer cast coating of the strand melts again due to the uncontrolled impact of the molten metal.

Measuring flows directly in the molten metal

“We won’t run out of ideas for experiments at LIMMCAST over the next ten years“, says Sven Eckert, Head of the Magnetohydrodynamics Division (MHD) at the HZDR. “After finding out in our experiment, which physical variable had been neglected in previous assumptions about electromagnetic brakes, we are now also using our own

Researching liquid metals

Liquid metals are the focus of the new Helmholtz Alliance LIMTECH – the acronym stands for “Liquid Metal Technologies“. The HZDR and the Karlsruhe Institute of Technology (KIT) are pooling their competencies with those of the other Helmholtz centers and universities in Germany and abroad.

Liquid metals can store large amounts of energy or effectively conduct heat. They occur in many branches, e.g. in steel or light metal casting processes. Furthermore, they are becoming increasingly more important for future technologies, as for instance in new liquid metal batteries for storing energy, in the CO_2-free production of hydrogen or in the production of solar cells among others. Because liquid metals are very suitable for cooling high-energy processes, they also contribute to higher energy and resource efficiency. This is due to the fact that the degree of efficiency of thermo-dynamic processes increases with temperature. Two sub-projects of the alliance have thus also been devoted to the implementation of liquid metals in solar power plants.

LIMTECH’s goal is to conduct research on liquid metal technologies for a wide range of applications that will be developed further and made available. Funding in the amount of 20 million Euros is available – 50% from the Helmholtz Association’s Initiative and Network Fund, the other 50% from the participating Helmholtz centers and partners. Within the framework of the alliance a graduate program will also be set up. Another focus is the close collaboration with partners from industry in order to apply the results to technology as quickly as possible.

Participating Helmholtz centers: Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Karlsruhe Institute of Technology (KIT), Forschungszentrum Jülich (FZJ), German Aerospace Center (DLR)

External partners: Technische Universität Dresden, Ilmenau University of Technology, Leibniz Universität Hannover, TU Bergakademie Freiberg, University of Potsdam, Georg-August-Universität Göttingen, RWTH Aachen, Institute of Physics Riga (Latvia), Coventry University (UK)

Gunter Gerbeth is the coordinator of LIMTECH, a new Helmholtz Alliance.

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calculations. For the first time ever our results take into account the electrical conductivity of the mold wall as an important variable for the flow of the molten metal." Sven Eckert and his team are planning further experiments on the effects of electromagnetic brakes, for example with different mold volumes and forms. But they are also considering new innovative electromagnetic stirrers. While today's electromagnetic brakes control the flow of the liquid steel at the entrance to the mold, in the future magnetic stirrers could be used in the lower part of the strand. Through electromagnetic agitation in the solidification zone the grain structure of the metal can be positively altered and non-homogeneous material can be avoided.

But to get back to the electromagnetic brakes, which themselves also consume energy: Sven Eckert is already dreaming of the day when the brakes will only be switched on when absolutely necessary. For this, one would have to be able to look in real time at the molten metal and be able to measure the flow, but at 1,500 degrees Celsius any material that comes in direct contact with the molten metal simply disintegrates. For this reason innovative measuring techniques are also on the research and development agenda. A new magnetic method has already been patented, which works from the outside without coming into contact with the molten metal. Magnetic fields can influence the flow of conductive liquids, but the reverse is also the case, because any current distorts a magnetic field in a specific way. This flow-dependent distortion can be measured outside of the molten steel. In this way the MHD team (in particular Frank Stefani and Thomas Wondrak) managed to successfully develop the first tomographs that were able to compute and make visible the flow of the liquid from external magnetic field signals. The technology is known as CIFT (Contactless Inductive Flow Tomography).

The first projects with industry using the CIFT technology have been extremely promising, so the goal now is to develop a sensor on the basis of CIFT for molten steel. In the future this kind of sensor will only switch on the electromagnetic brakes when a steady flow of the liquid metal threatens to become turbulent. Furthermore, the most innovative idea is one of planning a sensor-actuator system, i.e. a magnetic sensor and magnetic brake combined as one system that constantly monitors the molten steel during the real casting process and is able to intervene and control it as needed.

Metal production and processing assume a crucial position when looking at the proportion of energy costs of the gross value of production in the processing trade. This point was also mentioned in the July 2011 Federal Government's sixth energy research program with the goal of "coming up with innovative developments to considerably slow down energy consumption in the German metal-producing industry".
Sven Eckert and his team want to further explore the use of magnetic fields in steel casting in order to make an important contribution to Germany's new energy turnaround. ┤

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MULTIMAG: This facility is used in model experiments for optimizing crystal growth processes. Here, the scientist's face is being reflected onto the gallium indium zinc-filled container's free surface. Image credit: Rainer Weisflog

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DANCE FLOOR: One of five magnet cells at the HZDR's Dresden High Magnetic Field Laboratory. Superconductivity experiments are performed here. Image credit: Uwe Tölle

WHEN ELECTRONS PAIR UP AND TROUBLEMAKERS ARE FORCED INTO A CORNER

_TEXT . Roland Knauer TRANSLATION . Sarah Gwillym-Margianto

// Strong magnetic fields have an effect on superconductors that was already predicted back in 1964.

Joachim Wosnitza of the Helmholtz-Zentrum Dresden-Rossendorf and Peter Fulde, Founding Director of the Max Planck Institute for the Physics of Complex Systems (MPIPKS) in Dresden share the same problem with many physicists in materials science: The applied physicist from the Dresden High Magnetic Field Laboratory can understand the MPIPKS theoretician perfectly, whereas non-physicists listening to conversations between the two researchers would have difficulty following. Needless to say, when Joachim Wosnitza and his colleagues conducted a refined experiment and found significant proof for an effect Peter Fulde had already predicted back in 1964, both scientists and their colleagues were delighted. Unfortunately, it didn't make the headlines in the Saxon metropolis because this kind of research is highly complex. It concerns a topic, however, that should interest the general public in times of Germany's energy turnaround:

How can we conduct electric currents without energy dissipation?

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HIGH MAGNETIC FIELD LAB: High magnetic fields like those available at the HZDR have hinted at the existence of the Fulde effect, which was originally proposed back in 1964.

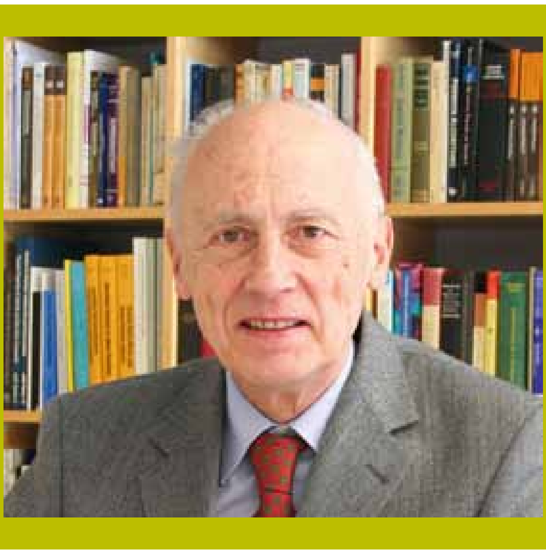
How is superconductivity destroyed?

“Superconductor“ is the term physicists use to refer to substances that do not show any electrical resistance. In the everyday life of an electrical engineer, however, the superconductivity of an electric current without energy dissipation has two flaws: it normally only works at very low temperatures and reacts very sensitively to strong magnetic fields. Therefore, although superconductivity was first observed back in 1911, it is only applied today in very special cases.

To overcome these obstacles one must understand the processes at work. “We are therefore examining how superconductivity takes place and how it is destroyed“, says Joachim Wosnitza about the experiments that are being conducted at the HZDR’s High Magnetic Field Laboratory. Theoreticians explain this superconductivity without dissipation using what are known as “Cooper pairs“, which consist of two electrons. Electrons are negatively charged elementary particles that are not only fundamental components of all matter, but also conductors of electric current. In addition, electrons like many other elementary particles also possess a property physicists refer to as “spin“. In the case of electrons this spin can be either up or down.

The dance of the electrons

If two electrons with an opposite spin are paired, they become a Cooper pair, whereby the net spin then becomes zero and considerable changes take place regarding the pair’s quantum mechanics. Joachim Wosnitza uses an analogy to illustrate this phenomenon: “the Cooper pairs formed in a superconductor join together and as if they were dancers start to move in unison.“ Whereas with normal metals the slightest influence would divert an electron and thus disturb the conductivity of the electric current, the Cooper pairs moving in unison only lose their rhythm with a substantially higher expenditure of energy. Due to the fact that this hardly ever happens at low temperatures, such superconductors are able to conduct the electric current without resistance and thus without energy dissipation. →



This situation changes as soon as a magnetic field affects the superconductor. “The electrons then attempt to realign themselves with the magnetic field and thus the Cooper pairs try to split“, Joachim Wosnitza explains. Since individual pairs cannot dance out of sync however, the magnetic field has to be relatively strong and has to invest a great deal of energy to make the dancers lose their rhythm and interrupt the superconductivity. This minimum amount of energy that is required is known to materials researchers as the “critical Zeeman energy“.

Nano spots are still a mystery

Together with Richard Ferrell, Peter Fulde already demonstrated back in 1964 (at least theoretically) that superconductivity should still be possible beyond this Zeeman energy, representing some kind of hybrid state: tiny, normally-conducting areas alternate with “superconducting nano spots“. “To be precise these are not really spots but rather a wave of superconductivity and normal conductivity that evolves in the material“, describes HZDR researcher Joachim Wosnitza. Because around the same time two other physicists also predicted this superconductivity state beyond the Zeeman energy, it is now called the “Fulde-Ferrell-Larkin-Ovchinnikov superconducting state“.

To non-physicists however this effect abbreviated as “FFLO“ still remains a mystery. In order to explain these processes to laymen, Peter Fulde uses a very vivid analogy, even if it tends to oversimplify the process. If we imagine that the electrons with a downward spin represent the men, then the electrons with an upward spin would represent the women. In human societies women and men unite in a similar way as the electrons that form Cooper pairs, which are important for superconductivity.

When there are too many males

If for some reason there are more males than females in society, this soon leads to unrest: “the surplus males also

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Professor Peter Fulde

The founding director of the Max Planck Institute for the Physics of Complex Systems (MPIPKS) likes to spend a lot of his time these days in South Korea, where he is very much in demand as a consultant – and as an emeritus director he also has sufficient time for it. As of this year he has had a seat on the Scientific Board of Directors at the Korea Basic Science Institute while also being president of the Institute’s Central Election and Evaluation Committee. Since 2007 he has also been a professor at the Pohang University for Science and Technology (POSTECH) and president of the Asia Pacific Center for Theoretical Physics that is also located in Pohang, South Korea.

Saxony also has a lot to thank Peter Fulde for. Not only for the fact that, after his time spent as director at the Max Planck Institute for Solid State Research in Stuttgart, in 1993 he founded the Max Planck Institute for the Physics of Complex Systems in Dresden, whose director he was until 2007. He was an active consultant here (as well as in many other places) for many years in various institutes and boards, and has a very high reputation. In this way Peter Fulde was able to considerably influence the development of the Helmholtz-Zentrum Dresden-Rossendorf, for which he was awarded the status of honorary member in 2009. During his time as a member on the supervisory board of the center from 2000 to 2008 he had other roles in an honorary capacity such as being on the supervisory board of the PTB (Germany’s national metrology institute) and on the supervisory board of the Frankfurt Institute for Advanced Studies (FIAS) or as chair of the Material and Technology Section of the Max Planck Society. To name only a few national as well as international offices and stations: member of Saxony’s Research Council as well as the Scientific Council of the Federal Republic of Germany, trustee of the German-Israeli Foundation, founding member of the Berlin-Brandenburg Academy of Sciences, member of the Leopoldina in Halle as well as the German National Academy of Science and Engineering (acatech).

The list seems endless for the exceptional physicist born in Breslau in 1936. Admittedly, Peter Fulde has already received numerous awards and honorary titles, but this magazine’s editors are convinced that the discovery of the “Fulde effect“ named after him certainly merits yet another scientific award.

want a female“, describes the theoretician. If only a few men are looking for a female, very little happens because the well-connected pairs don’t allow themselves to be influenced by the few troublemakers. If the surplus of males increases too dramatically however, then the system rapidly breaks down and the pairs separate from each other. Similarly, a weak magnetic field produces a smaller surplus of electrons with a certain spin in a superconductor that does not yet disturb the Cooper pairs. However, if the critical Zeeman energy is exceeded, then the surplus will grow too rapidly and the superconductivity breaks down.

“Even under this scenario however one can reduce the influence of the troublemakers for a while by forcing them into a corner“, the Dresden physicist continues. From this corner they are less able to disturb the pairs – irrespectively of whether we are dealing with humans or electrons. Since the pairs try to keep away from the corner with the isolated ones they tend to be in certain places, as can sometimes be observed very well on a dance floor. With a superconductor it is the same concept: the density of the Cooper pairs varies from place to place.

Sometimes, theoreticians need to have a lot of patience

This “electron motion“ does not however take place on the dance floor but under the laws of quantum mechanics. Also the “corner“ is not in the “real space“, but in the “momentum space“, both of which are difficult to imagine for physicists let alone for non-physicists. “That doesn’t matter, the basic principle is still the same“, Peter Fulde reassures us.

Even with this very vivid explanation, the FFLO effect under the influence of strong magnetic fields was still only a theory. Numerous attempts had been made to support the theory with laboratory experiments. “For this, however, very clean superconductors are essential that preferentially are in the form of very thin layers“ explains Joachim Wosnitza – and naturally an outstanding magnetic field technology such as the one at the HZDR. None of the earlier experiments were able to meet all of these prerequisites and Peter Fulde had to wait for almost half a century until Joachim Wosnitza (the scientist with whom he had often discussed this theory) from the Helmholtz center in Dresden came up with the crucial evidence that the FFLO effect that had been named after Fulde (among others) did actually exist in practice.

Strong magnetic fields and thin layers

“We tested the theory using organic superconductors, the layers of which at 1.8 nanometers are only a little thicker than a millionth of a millimeter“, reports Joachim Wosnitza. By comparison a human hair is twenty thousand times thicker. These organic superconductors consist of many thousands of organic layers approx. one nanometer in thickness and similarly thin layers of insulating molecules. When HZDR researchers placed these superconductors absolutely in parallel with a magnetic field with the strength of approx. eleven tesla, the Zeeman energy had clearly been exceeded. Nevertheless the material was still showing superconductivity. Did this mean that the long sought after FFLO effect had finally been proven in practice? Did this mean that the magnetic field had actually relegated the troublemakers for the Cooper pairs to certain corners?

When pairs are no longer in sync

If the answer is yes, then the effect should disappear when the researchers slightly tilt the superconductor towards the magnetic field. In this case the magnetic field is able to penetrate through the superconducting layers and interrupt the swinging Cooper pairs that now risk losing their rhythm and the troublemakers resist being pushed into a corner. If the researchers swivel the superconductor by 0.1 degrees with respect to the magnetic field, the superconductivity is maintained at first. Even after rotating it by 0.2 or 0.4 degrees not much would happen. By contrast, if the sample was turned by half a degree, the superconductivity would disappear completely. The troublemakers would have the upper hand, just as FFLO had predicted. After almost half a century the theory could finally be proven in practice.

For fundamental physics however this experiment has tremendous meaning because the FFLO effect cannot only be observed for human pairs or electrons. Similar pairs are also formed with other elementary particles such as quarks, but also with neutrons and protons, which atomic nuclei are made up of, and also with certain ultra-cold atomic gases. In the meantime the FFLO superconducting state has also been found with ultra-cold lithium atoms. “As a component in superconducting electronics this kind of state has a very practical significance“, Peter Fulde suggests. Joachim Wosnitza and Peter Fulde, the two Dresden physicists, have started a new chapter in the history of physics, which is waiting to be completed by other researchers. ⊣

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// In the near future, cancer patients could potentially benefit from the therapeutic application of radioactive substances capable of destroying malignant cells directly from within the tumor or from inside metastases. Scientists at HZDR are currently working on the basics of this internal radiotherapy, which would be used as an adjunct therapy to state-of-the-art external beam radiotherapy. Along with their OncoRay Center colleagues, the scientists have presented promising preliminary basic science research results regarding radionuclide therapy – or endoradionuclide therapy – gleaned from experiments on animal models.

TINY TRANSPORTERS FOR RAYS THAT CAN CURE CANCER

_TEXT . Christine Bohnet TRANSLATION . Sarah Gillym-Margianto & Dennis Schulz

INTERNAL RADIATION: Shielded by 10 centimeter lead glass panels for protection, Silke Fähnemann (right) and Manja Kubeil are working with radioactive substances that someday will be used to irradiate cancer cells “from the inside out.“ Image credit: Frank Bierstedt

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Surgery, external beam radiotherapy, and chemotherapy are the three pillars of current-day cancer treatment. Using these different types of treatment, approximately 50 percent of cancer patients can successfully be cured. The odds of being cured are compromised significantly, however, if cancer cells are allowed to spread from the primary tumor to form metastases in other, more distant parts of the body. Today, the primary modality for attacking metastatic cancer is systemic chemotherapy. However, only very small metastases containing only a very small number of cancer cells – oncologists refer to these tumors as micrometastases – can be permanently eradicated by application of currently available chemotherapeutic drugs. Therefore, new and more efficient therapeutic approaches are urgently warranted. Cancer researchers at the Helmholtz-Zentrum Dresden-Rossendorf are committed to the development of novel radioactive substances, which might be used to improve detection and combat of primary tumors and their associated metastases. As such, research conducted at the HZDR‘s Institute of Radiopharmacy is focused on the development of radiopharmaceutial tracers and drugs capable of specifically targeting and destroying tumor cells as well as on evaluation and improvement of novel combined imaging methods like the positron-emission tomography and magnetic-resonance imaging (PET/MRI) hybrid. The successful clinical application of this research both now and in the future depends upon the close collaborative partnership that exists between the HZDR and the University Hospital Dresden at the OncoRay Center.

Micrometastases

Microscopically small metastases, or small clusters of only a few cancer cells, frequently evade detection and thus, by definition, diagnosis – a condition known as a subclinical disease. Even the most modern-day imaging techniques, including those capable of simultaneously producing PET- and MRI-scans of the entire body at high resolutions – which are available at the HZDR – are only able to detect metastases with diameters of give or take a few millimeters. However, if metastases go undetected, doctors may not prescribe the necessary systemic therapies as they may be under the (false!) impression that the tumor has not yet spread to other parts of the body. Or, conversely, based on past experience, doctors might prescribe systemic treatment for every single patient who is statistically at a risk for metastases, which would lead to over-treatment of a substantial number of patients in whom the primary tumor did not metastasize. Therefore, it is very important that new radiopharmaceutical substances and imaging technologies capable of tracing smaller metastases are being developed to help doctors make more personalized decisions based on a patient‘s individual risk profile. Equally as important is the continued development of new radiopharmaceutical anti-cancer drug treatments capable of targeting microscopic – and macroscopic – metastases and tumors.

At this time, radioiodine therapy of the thyroid has proved an extremely successful example for imaging and internal radiotherapy using radionuclide iodine-131. For the past 70 years, radioiodine therapy has successfully been used in cancer diagnosis and treatment and as a diagnostic and treatment tool in thyroid disease. Since only those cells of the thyroid that are normally in charge of making thyroid hormone store iodine, radioactive isotopes of iodine specifically target only the hormone-producing cells – regardless of whether the thyroid has become enlarged, or cancerous, or if cancer cells have metastasized. This clinically approved radionuclide therapy (or endoradionuclide therapy) is the archetype for new internal radiation therapeutic approaches in oncology.

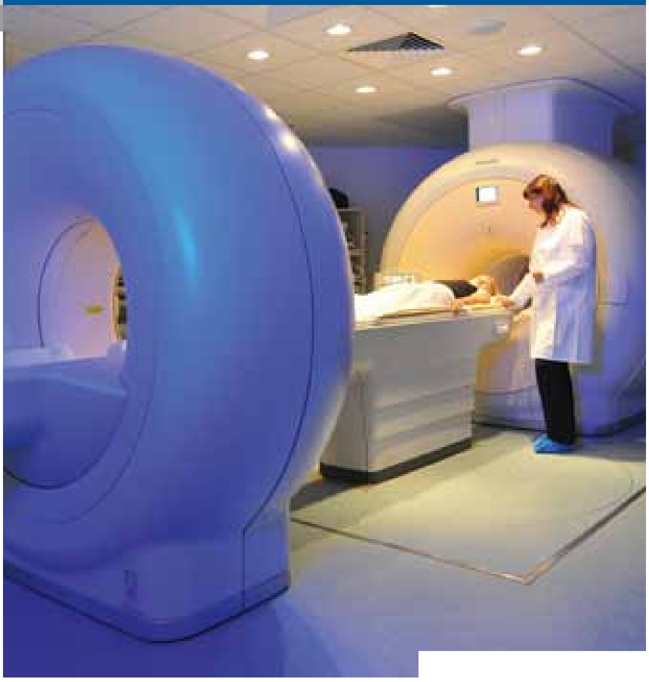
A mere ten years ago, research aimed at broadening the spectrum of radiopharmaceutical drugs for use in cancer therapy was only done by a handful of groups – and, unfortunately, all too often the new drugs turned out to be nonspecific and ineffective, precluding their introduction into the clinical setting. Fairly recently, substantial progress has been made by combining external beam irradiation, which is well established in clinical cancer radiotherapy, with novel and the more highly specific internal radiation modalities.

Exploiting the tumor’s metabolic profile

“Our plan is to use our new radioactive substances to enhance the effects of external beam radiotherapy on the primary tumor and at the same time destroy metastatic cells, which may be hiding out somewhere else in the body. This would allow doctors to increase the overall radiation dose to the primary tumor without inflicting more damage on the surrounding healthy tissues. At the same time, any potential metastases would also be targeted for destruction. Doctors are hopeful that this approach can widen the therapeutic window and that more patients can ultimately be cured,“ explains Hans-Jürgen Pietzsch, head of the HZDR‘s Radiotherapeutics Division. To reach this ultimate goal, he and his team are currently pursuing two different research strategies: one based on antibodies for transporting radioactive nuclear components that stay in the circulation for a longer period of time; the other based on using smaller molecules like peptides or small proteins capable of quick dispersal within the body.

Regardless of which one of these two very different approaches ultimately proves more successful from a radiopharmaceutical vantage point, what is important is that the unique properties of cancer cells are exploited to facilitate the transport of molecules for delivering the radionuclide to the site of the primary tumor or the metastasis. Given their uncharacteristically high degree of metabolic activity, tumor cells consume a lot more energy than do healthy tissues. This difference in a tumor‘s metabolic profile has been exploited successfully for many years by the intravenously injected, radioactively labeled sugar 18-fluorodeoxyglucose, which is used in detecting cancer as tumor cells take up this sugar at higher rates than do normal cells. Other options for utilizing the increased metabolic activity of cancer cells for medical imaging purposes include radiotracers based on amino acids or nucleic acid components. →

THE FUTURE OF CANCER THERAPY: Scientists at the Institute of Radiopharmacy are studying the basic principles underlying internal radiation. It is important to know and exploit the special properties of cancer cells in order to deliver the radioactive molecules to the tumor or metastasis. Image credit: Frank Bierstedt



CANCER DIAGNOSIS: As of June 2011, Germany's first ever PET/MRI device has been in use at the HZDR for patient examination. So far, more than 600 cancer patients could be examined using the device. Image credit: Frank Bierstedt

With a nod to the future, Hans-Jürgen Pietzsch and his team emphasize the great potential of antibodies and their ability to attach to docking stations on the surfaces of cancer cells. "Antibodies can be reliably produced in the lab using modern-day biotechnological methods. And what's more is they can be precisely modified in such a way as to change their biological characteristics. Antibodies normally have an exceptionally high binding affinity to specific docking stations on the surfaces of cancer cells, which is why they naturally accumulate in the tumor tissue. Using suitable methods for radioactively labeling different substances as well as being able to guarantee their stability in the human organism for use in diagnostic and therapeutic application is one of our central research topics at the Institute of Radiopharmacy."

Radiopharmaceutical toolbox

Radiation damages cellular DNA. When cells are not able to repair this damage, they die off, most likely during one of →

the next few cycles of cellular division. As this is the case for both tumor cells and healthy cells, the dose that can be applied to the tumor by external beam radiotherapy is limited by the potential risk of radiation-induced damage to healthy tissue. High-precision radiotherapy techniques like, for instance, proton therapy (protons are hydrogen nuclei), can help minimize this problem significantly. However, further improvements are absolutely necessary in order to be able to help more patients in the future.

What is helpful here is the fact that radiation of different qualities and energies can be used. The HZDR researchers have access to a host of options for different radiation sources in their "toolbox." In addition to megavoltage X-rays from clinical linear accelerators or clinical proton beams, they use beta emitters such as yttrium-90, lutetium-177, or rhenium-188. These emit electrons from the atomic nucleus with a typical half-life. The half-life of lutetium-177, for example, is 160 hours, whereas that of yttrium-90 is approximately 65 hours. Radioactive half-life is an important factor for the preparation time in the laboratory and, later, in the clinical setting for the kinetics of dose-delivery in the tumor. On the other hand, the energy from the emitted electrons determines their range. Overall, the range of electrons compared to external beam radiation therapy is considerably less. Therefore, healthy tissues surrounding the cancer receive substantially lower doses than does the tumor itself.

The toolbox has more to offer yet: depending on the size of the respective tumor or metastasis, using suitable radionuclides, tailor-made substances may be developed for internal radiation. In this way, for example, yttrium-90 with a maximum penetration depth of eleven millimeters would be used for treatment of relatively larger-size tumors, while electrons emitted by lutetium-177 with considerably lower energy (maximum range 1.8 mm) may be better suited to micrometastases. The combination of different radionuclides would also be a way to optimize efficacy. But the toolbox holds more potential still. Generally speaking, alpha emitters are also suitable for internal radiation. Compared with electrons, their large mass, made up of alpha-particles (i.e. helium nuclei), has a very low range on the order of several tens of micrometers in the tissues, meaning that they transfer their energy (of several megaelectron-volts) to the tissue along the way, resulting in severe damage to irradiated cancer cells, and thereby making this a highly effective potential anti-cancer weapon.

COMBINATION: By combining diagnostic X-ray and computer tomography with state-of-the art radiation therapy, tumors can be irradiated more precisely. Other advantages include less damage to healthy tissues and fewer side effects. Image credit: Rainer Weisflog.

Whichever radionuclide is used, the challenge is always one of accurately directing it to the cancer cells using mini-transporters without causing damage to other organs, such as bone marrow, the kidneys, or the liver. Therefore, the HZDR scientists have been hard at work on a variety of cancer-specific transport molecules – a very innovative and successful road to go down.

Radiating transport with precision landing

Using antibodies marked with radionuclides in an animal model, Dresden scientists were able to prove that internal radiation therapy combined with external beam radiation substantially increases tumor eradication rates. Antibodies are exceptionally large molecules that move only very slowly from the bloodstream into the tumor or metastasis. In this way, sometimes, it could take several days for such an antibody to accumulate in the cancer tissue. The long circulation time may lead to relatively high doses in healthy tissues. "Therefore, we are exploring the lock-and-key principle, according to which the radioactive component is only administered after the antibody has already attached itself to the cancer cells. In this way, the healthy tissues are much less exposed to unnecessary radiation. The radioactive substance (the 'key') is injected several days after the antibody. In the body, the key quickly and very specifically recognizes the matching antibody (the 'lock') and binds to it so that the radiation directly targets those tumor cells with the attached antibodies," explains Hans-Jürgen Pietzsch.

The scientists are using two individual complementary DNA strands for their experiments. One strand is attached to the antibody, while the complementary strand is transporting the respective radionuclide. Once the two strands meet, they very quickly connect and become very stable – similar to the way a zipper works. Christian Förster, a scientist working in the Radiotherapeutics Division, has done research on this principle as part of his dissertation. "For the lock-and-key approach, we did not use naturally occurring DNA," Förster explains. "Instead, we modified the individual DNA strands in such a way that they were no longer recognizable by the

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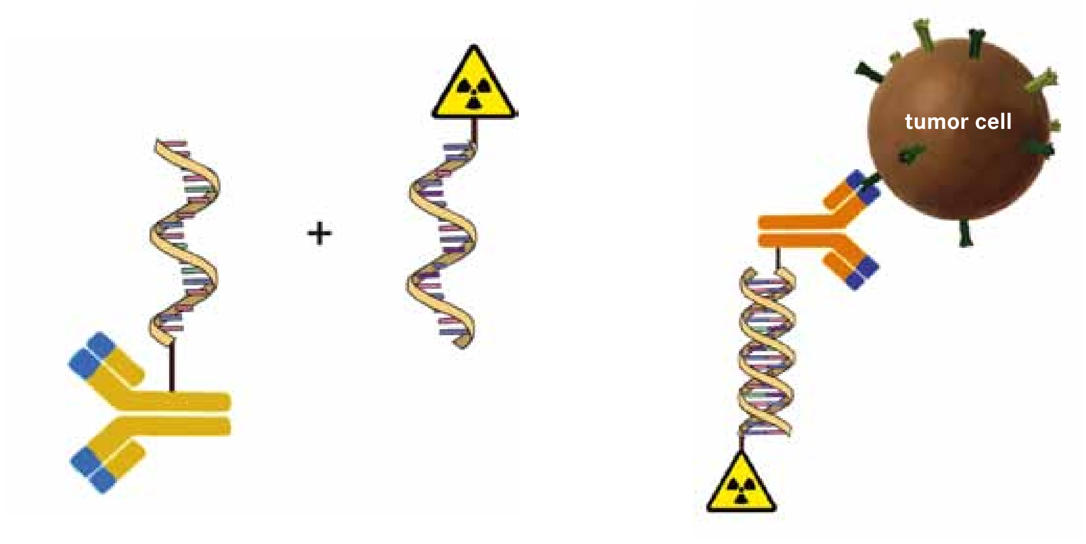

NATURE AS THE MODEL: Artificial DNA strands allow for the quick and precise delivery of radionuclides to scattered tumor cells. A single DNA strand is attached to a tumor affine antibody, which is introduced into the patient's body, followed by the complementary strand with the radionuclide attached. In the body, the two strands combine, binding each other firmly (right). Such a staggered approach ensures that the radionuclides destroy only the tumor cells while preserving healthy tissues.

organism as DNA. Thus, the radioactively labeled single DNA strands don‘t get digested in the bloodstream and there is only one possible binding site in the entire organism: the one on the antibodies that have accumulated in the tumor tissue and that carry the complementary DNA strand.“

Radioactive twins

The use of radioactive substances for targeting cancer cells for destruction holds yet another advantage: there exist, if you will, “twin partners“ (so-called radioisotopes) of suitable radio-metals used in therapeutic applications. Yttrium-86, the lighter twin of yttrium-90, can be used for PET imaging to show whether a specific antibody is accumulating in the tumor tissue of a given patient – with only a very low dose of radiation given off to healthy tissues. Only if the antibody does accumulate in the tumor tissue, the larger of the twins, the therapy nuclide (Y90) with the identical antibody attached is administered to effectively destroy the cancer cells in the body. “In the future, this theragnostic principle will allow us to personalize internal radiotherapy and to apply the active drug in only those patients in whom it attacks the tumor and not the normal tissues,“ says Jörg Steinbach, director of the Institute of Radiopharmacy. To give another example: copper-64 is used in research for future radiodiagnostics whereas copper-67 is considered a very good candidate therapeutic radionuclide.

All of this is still a far cry from development of a custom-tailored internal radiation therapy approach that has been approved for patient use. What is also clear is that these new approaches have to be combined with today's state-of-the-art anti-cancer treatment modalities such as modern-day radiochemotherapy. This requires the close collaboration between two medical disciplines: nuclear medicine for internal radiotherapy and radiation oncology for external beam radiotherapy, or radiochemotherapy. Thanks to a fortuitous collaboration at the OncoRay Center, Jörg Steinbach is convinced that Dresden is the ideal site for putting such innovative concepts on the map.

However, even with these new exciting perspectives for cancer research and cancer care, prevention is by far the most effective strategy for reducing cancer deaths. Cancer specialists estimate that the risk of getting cancer during one‘s lifetime can be cut in half simply by a healthy lifestyle without smoking and without long periods of exposure to the sun, with plenty of exercise, a healthy diet, and alcohol in moderation. Most of us probably know this already and should really be making a conscious effort to put this awareness into practice.

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// From basic science research to preclinical studies, to the effective – and personalized – radiation treatment of malignant tumors: these are the major steps along the ambitious path pursued by Dresden-based OncoRay partners. In the hope that particle therapy can one day be made available to every single cancer patient who might derive a potential benefit from it, scientists at HZDR are currently working on a compact accelerator technology based on high-power lasers.

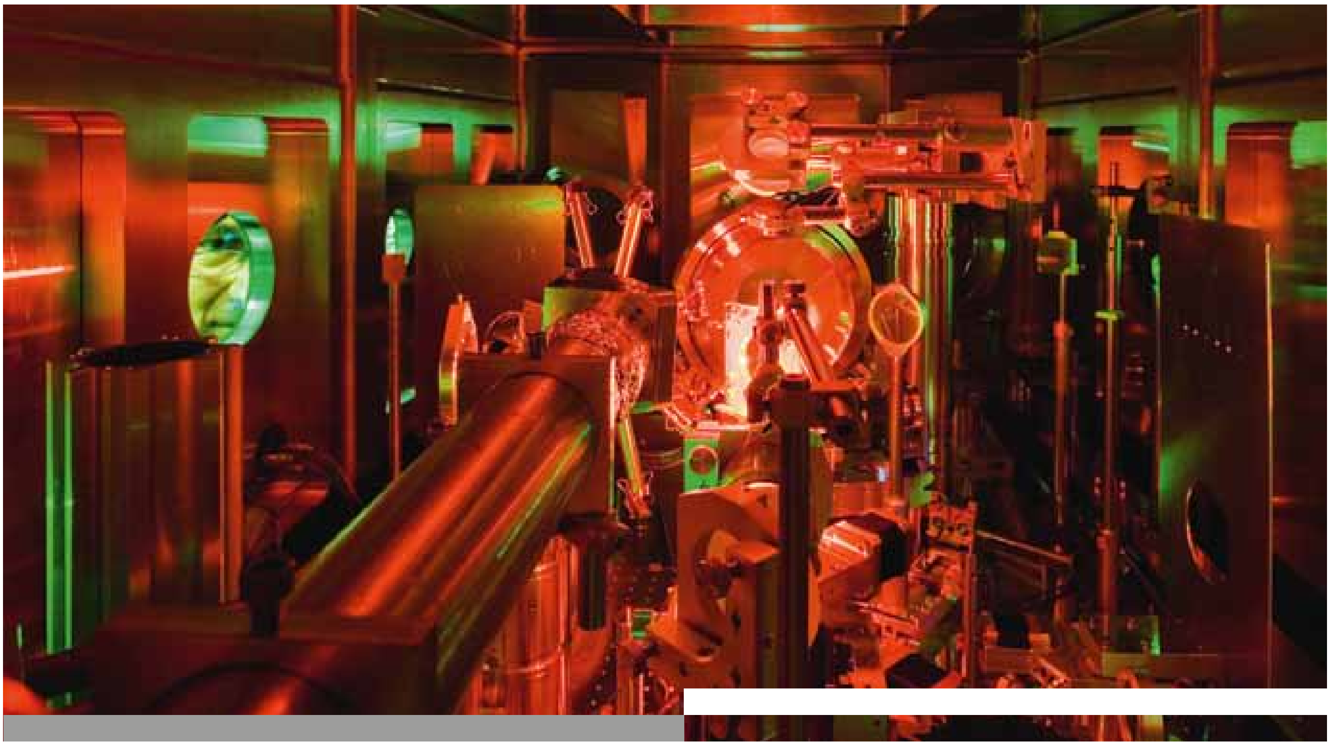
TARGETING THE TUMOR WITH JUST THE RIGHT DOSE

_TEXT . Christine Bohnet & Sara Schmiedel

TRANSLATION . Dennis Schulz

More than 450,000 Germans are diagnosed with cancer each year - a number that is expected to go up over the next few years given the country‘s aging population. All over the world, researchers are in a race against time to discover ever better, ever faster, and ever more affordable options for the successful diagnosis and treatment of cancer. Over the last few years, the city of Dresden, Germany, has developed into an internationally visible cancer research hub. The OncoRay Center is, as its name implies, a site with an especially strong focus on radiation research. At OncoRay – the National Center for Radiation Research in Oncology – University Hospital Dresden, the TU (Technical University) Dresden, and HZDR are also closely working with colleagues at the German Cancer Research Center (DKFZ) and University Hospital Heidelberg →

DRACO: Taking a peek into the target chamber; here, the proton beam is generated in vacuum. Image credit: Jürgen Lösel



PROTON THERAPY: Using DRACO, the high-power laser, HZDR scientists have confirmed that it is theoretically possible to irradiate cancer cells using laser accelerated protons. Image credit: Rainer Weisflog

as well as with eight of Germany's universities and the DKFZ as part of the German Consortium for Translational Cancer Research – one of Germany's six official health centers. These are all powerful alliances – all of them committed to furthering translational research. What this means is that findings from basic science research – like molecular reactions taking place in test tubes or a brand new idea from, say, the field of technology – can be quickly picked up for development and application – all in the name of benefitting cancer patients.

Major areas of health research at the HZDR include new radioactive drugs for diagnosis and treatment of different forms of cancer as well as innovative approaches to molecular medical imaging. In addition, HZDR scientists are focused on the continued development and testing of laser-based technologies for future use in proton beam therapy. Here, the OncoRay Center's particular strengths also come into play. While the Rossendorf physicists are propelling this development along in terms of the necessary technology, it is the University Hospital doctors who are providing the exact specifications for how the laser-based particle beam should be designed to produce the desired effect in the human body. And medical and general physicists alike, at OncoRay, the University Hospital, and HZDR, are concerned with solving the rather tricky problem of determining the proper particle beam dose prior to and during therapy. Collectively, all of this makes the Dresden collaborative partnership very unique.

Sparing healthy tissues by using focused rays

In contrast to X-ray radiation, proton radiation is more precise and thus less destructive to healthy tissues in the tumor's immediate vicinity. Currently, X-ray radiation therapy is used in as many as 60 percent of all cancer treatment regimens. Whereas X-rays give off energy along their entire path of travel – from their point of entry into the body to the site of the tumor and beyond – protons can be much more precisely targeted to the tumor itself. Protons – hydrogen atoms that were stripped of their electron – are the smallest and lightest ions – with the potential to completely obliterate tumor cells in the body. Their energy can be adjusted so accurately that the dose that was calculated prior to radiation is released once inside the tumor and in a controlled manner so that the healthy tissue in front of the tumor is exposed to only very minor doses of radiation and the tissue behind it to no dose at all.

Today, proton therapy is used most effectively to treat patients with inoperable tumors of the base of skull or near the spinal cord in order to better protect the sensitive, healthy tissues in this region. But also children with cancer are deriving increasingly greater benefit from this new method of treatment. It is a well-known fact that new malignancies can develop several years or even decades following radiation therapy of healthy tissues that were at one time exposed to radiation. In spite of the low overall risk, the chances that someone would, at a later point, develop a new malignancy from having been previously treated with radiation therapy, are increased the longer the person lives post-successful cancer treatment. It follows, then, that the risk is much more pronounced in children and younger patients – a risk, which could be potentially minimized through a more precise, proton-based form of radiation therapy. At this point, however, for most of the roughly 500 different diseases that are collectively grouped under the umbrella term "cancer," conclusive data concerning the benefits of proton therapy over X-ray therapy are still lacking. And although doctors believe that new therapies may in the future bring about significant advances in the treatment of lung cancer or soft tissue neoplasms, this has to yet be confirmed extensively through clinical trials. The general hope is that their assumptions concerning the advantages of proton therapy will be validated and documented through clinical trials for a growing number of different cancers, which in turn would warrant their comprehensive clinical application.

The problem is that, at this point, only a handful of university hospitals, whose mission it is to conduct this type of clinical research, actually have proton therapy capabilities. In Germany, Heidelberg and, soon, Essen are the only clinics with the proper equipment for administering this form of therapy. The cost of construction and operation of the necessary large-scale facilities lies somewhere in the order of hundred million Euros. And because the Dresden scientists, with their well-known expertise in the field of radiation research, firmly believe in the tremendous potential

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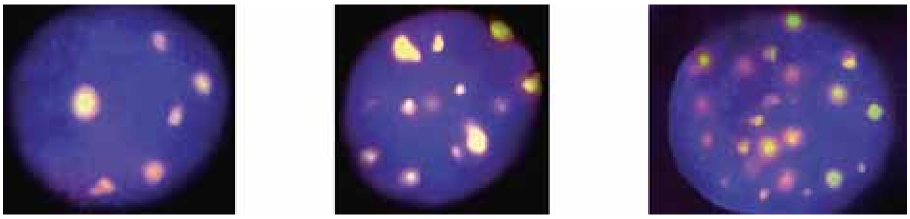
INNOVATIVE TECHNOLOGIES: Saxony's Minister of Science, Sabine von Schorlemer, along with Roland Sauerbrey (Scientific Director of the HZDR), Michael Albrecht (Medical Director, Dresden University Hospital), and Michael Baumann (Spokesman, OncoRay Center, left to right), lays the cornerstone for East Germany's first-ever proton therapy facility on January 20, 2012.

LASER SMARTIES: Using a model, PhD student Florian Kroll explains the principle of laser-based particle acceleration during the 2012 “Dresden Long Night of the Sciences“ event. Image credit: Stephan Floss

inherent in proton therapy research and development, a new proton therapy facility is currently under construction at the University Hospital campus using as its platform a conventional circular accelerator (see info box, p. 23). Initially, this facility will be used to treat cancer patients who are subjects in clinical trials - all in the interest of furthering the research in this area. Later on, the plan is to also use protons generated by the accelerator as direct reference radiation for an innovative device designed right here in Dresden: a laser-particle accelerator, for application in proton therapy. If accelerating the protons along tracks that measure only a few short micrometers in length proves a success, the facility‘s overall size can be substantially decreased, which in turn helps keep associated costs at bay. To reach a given tumor in the body and unfold their destructive potential, the accelerated protons must give off an energy on the order of 200 megaelectron-volts (MeV) – which corresponds to something like two-thirds the speed of light. Until now, no laser has ever been able to do this; the energy of any laser anywhere maxes out at around 67 megaelectron-volts. But HZDR‘s Ulrich Schramm and his team are not stressing about international competition in the race to develop higher energy lasers, considering their track record already boasts a number of impressive research and developmental feats.

HZDR‘s high-performance laser, DRACO, is capable of generating protons and accelerating them along an extremely short path of less than ten micrometers (by comparison, the thickness of a single human hair measures roughly ten times that value). At this point, following two rounds of experiments, DRACO has shown that cancer cell irradiation using a laser accelerator is definitely possible. What‘s more, for the first time ever, we are dealing with a highly controlled form of radiation that, in the future, could potentially be used to treat cancer patients. Although a number of international researchers are currently working on developing laser-accelerated particles for clinical application, so far only the Dresden research team is in a position to actually produce and monitor laser-generated proton beams that can be targeted to cancer cells at just the right dose – no more and no less. This is important because the new rays are highly precise and therefore make for a uniquely potent anti-cancer weapon. What is important is to ensure at all costs that they give off their energy only once inside the tumor and not as they are traveling through healthy tissue. The Dresden team of laser-based particle therapy developers around Jörg Pawelke and Ulrich Schramm are careful to make sure that this is the case, seeing as their long-term concern lies with the cancer patient.

Jörg Pawelke, who heads one of the OncoRay Center‘s research teams, is in charge of supervising the applied proton radiation dose. Current experiments are performed on cells from the SKX cell line taken from a tumor of the head and neck region. These cells are highly sensitive to radiation. →



CELLULAR DAMAGE: The image shows three cell nuclei following their irradiation with laser-accelerated protons using doses of 1.5, 2.7, and 4.1 Gray, respectively. The double-strand breaks in the DNA molecule (shown here in yellow) are a measure of cellular damage. The number of double-strand breaks increases as a function of the radiation dose.

Two are better than one

Nowadays, radiation therapy is typically administered over the course of several weeks, with the absolute dose split into individual daily doses. For each respective tumor, the radiation oncologist prescribes both the target volume and the required dose, and the medical physicist makes sure that the absolute dose, which is dependent upon both the physical form of radiation and the hospital‘s particular type of accelerator, ultimately makes its way to where the tumor is. The laser accelerator-generated proton beams consist of ultrashort, high-intensity pulses and present a major challenge for the Dresden scientists who are looking to record the exact dose immediately and in real-time. To this end, they employ two different methods – one for measuring the absolute dose, the other for real-time surveillance (known as dose monitoring). Using two different independent measuring systems, one of the things they developed was a special device for determining the exact radiation dose for the cells. In the case of the experiments with SKX cells at the HZDR, they were on the order of 0.5 to 4 Gray – a range that is especially relevant to clinical application of proton beams.

The result: a dose-response curve, which plots cellular damage as a function of dosage. “We finished the first trial using laser-based precision radiation, which is comparable to the current gold standard for conventional accelerators used in medicine,“ explain Schramm and Pawelke – a real highlight of their collaborative effort and, at the same time, a research highlight! “We have not been able to observe any problems with efficacy, nor did we expect to find any evidence of it. Which means that the proton beams from the compact laser have the same effect as those from a large accelerator like, for instance, the one at the Heidelberg Ion-Beam Therapy Center. And that‘s a good thing, as it spares us having to do a lot more research, allowing us instead to continue to develop the laser accelerator more quickly, getting it ready for patient application.“ Many more experiments using different types of tumor cells have yet to be performed, but for now what‘s important is enhancing the DRACO laser’s performance.

DRACO and PENELOPE

The flying dragon and Odysseus‘ faithful wife, who was condemned to wait for her husband‘s return home for twenty long years - clearly, the HZDR laser physicists had considered these two mythological references when naming their lasers. Whereas PENELOPE, the new petawatt facility, is, as of now, still in the building stages (the designated rooms in the ELBE Radiation Source, which were expanded especially to house PENELOPE, are already eagerly awaiting the new equipment’s arrival), 150-terawatt DRACO has already made research waves. The plan is to enhance DRACO’s capacity to 500 terawatts by adding an additional amplifier stage. Which means DRACO will reach a new order of magnitude, becoming one of the world‘s top performing lasers. After all, 500 terawatts exceed the performance of all of the world‘s power plants taken together, albeit only for an ultrashort, 30-femtosecond moment.

As a modern-day accelerator technology, light-based particle acceleration offers several major advantages over conventional facilities, since the accelerator track is shorter by several orders of magnitude and associated cost potentially lower – yet energy values are still insufficient for successful application in laser-based proton beam cancer therapy. As part of the expansion stage, the ultimate goal is for DRACO to generate proton beams with energies that are suitable for radiation treatment of small animal models. There is only one system likely to compare to DRACO, and that is the high-performance laser at the Lawrence Berkeley National Laboratory in California, USA. That particular lab‘s laser system, however, is used for basic science research and not for application to cancer therapy. One other laser that deserves mentioning is one operated in South Korea, albeit at a very low proton pulse rate of repetition.

“With the DRACO expansion stage, we have realized exactly what we set out to do. And we are once again breaking new ground by incorporating two crystals into the new amplifier stage, which did not as such exist even a few short years ago,“ explains Ulrich Schramm, head of the Laser-Particle Acceleration Division at the HZDR. At a diameter of twelve centimeters, the crystals are visually perfect and are only manufactured by a single company. Whereas initial DRACO

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studies on small animal models are planned for 2013 and 2014, the goal is to get PENELOPE to a stage where it can deliver the energies necessary for proton beam cancer therapy. According to Schramm, "our Munich laser colleagues are also currently working on a petawatt system. And while we are definitely looking forward to the race, more importantly, we are looking forward to our collaboration in this area. At any rate, Germany has already gained high visibility as far as the development of lasers for use in medicine goes."

A long way to go

A lot more research needs to be done before laser-accelerated proton beams can be used in human cancer therapy. Work, which is reliant upon the close collaboration between radiation oncologists, radiobiologists, medical physicists, dosimetry experts, and laser physicists. Following is an outline of the more essential research questions:

- // How can the energy from the generated protons be increased to enable them to reach deeper-lying tumors?
- // How can the intensive short laser pulses be delivered from accelerator to patient?
- // How can laser-based proton pulses be used to customize the beam to the specific tumor within the patient's body?
- // Moreover, how does one determine the proper beam energy and beam spot size in order to precisely and effectively irradiate the entire tumor volume bit by bit?
- // How can the proper dose needed for a given patient's radiation treatment plan be ensured and how can sensitive normal tissues be best protected?

In answer to the second question, one important step has already successfully been taken, thanks to the magnet technology available through the Dresden High Magnetic Field Laboratory at the HZDR. In order to target the radiation for patient delivery, until now, magnetic systems are needed, which are very heavy, take up a lot of space, require an elaborate shield, and on top of that are very expensive.

Until now that is – because the Dresden researchers and their colleagues from the GSI Helmholtz Centre for Heavy Ion Research in Darmstadt, Germany, and the Helmholtz Institute Jena, Germany, have recently come up with a new solution. →

Construction of new proton beam therapeutic facility

OncoRay, Dresden's center for Radiation Research in Oncology , which is run jointly by HZDR, the University Hospital Dresden, and the TU Dresden, continues to invest in proton beam therapy development. To this end, construction of a new treatment and research facility with state-of-the-art clinical proton therapy capabilities based on circular accelerator technology is currently under way at the University Hospital campus. Projected initial patient treatments are scheduled for 2014. As part of the ongoing research at the Center, Michael Baumann and his team have set out to investigate which of the 500 different forms of cancer could be effectively treated using the new beam technology. Children and lung cancer patients but also patients suffering from other tumors in the vicinity of sensitive tissues alike could be benefitting from this new form of treatment.

At the same time, the new Center is supposed to become a hub for testing and research of the new laser-particle acceleration facilities. Here, laser-accelerated particles can be directly compared to the particles from conventional circular accelerators. Clinical application on patients is not as of yet realistic, although it does represent an important long-term goal of the project. The OncoRay Center thus provides an internationally unparalleled research platform, which will benefit patients early on thanks to the diverse and application-oriented research projects. Collectively, these types of projects – the quick and focused application of basic science research findings to the clinical setting – are known as translational research.

↗ www.oncoray.de

Instead of using large, heavyweight electromagnets that provide a static magnetic field on the order of one tesla, the researchers used smaller, more lightweight magnetic coils that generate fields of up to 25 tesla. These pulsed fields are short-lived – sometimes for all but a few milliseconds – and are constantly being regenerated at very brief intervals. Since the laser light – and with it the protons – are also given off as pulses, a static magnetic field is not needed.

With the help of magnet coils that were developed and constructed especially for this purpose in the HZDR High Field Lab, the scientists were now able to demonstrate that the idea does in fact work by successfully bundling, aligning, and regulating the energy of the proton beam. With a nod to the HZDR‘s long-standing expertise in the area of magnetic technologies, Thomas Herrmannsdörfer, one of the physicists who is working in the High Field Lab points out that “for us scientists, the magnetic coils that are being used have a long-standing tradition and the energy supply is already at a mature stage, as well.“ The greater the magnetic field, the less space you need to redirect the protons. Thereby, the overall size of the entire setup decreases exponentially. According to Herrmannsdörfer, another important advantage of this new technology is its very low energy consumption, making it “a cost-effective alternative to existing facilities.“ The HZDR has already filed a patent application for this research.

Now, the scientists are setting out to test the extent to which their pulsed magnets can be linked up to conventional accelerator technology. A corresponding setup is expected to be realized at the University Hospital Dresden in the next few years. Should the researchers succeed, this would indeed be an important step towards cost-effective proton therapy facilities, which could subsequently be set up in clinics all over the world. ⊣

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Inside view of the GSI-developed five-meter-long linear accelerator for the Heidelberg Ion-Beam Therapy Center. Image credit: GSI Helmholtz Centre for Heavy Ion Research/G. Otto

GSI Heavy Ion Therapy

Launched in 1993, the Heavy Ion Therapy pilot project is a GSI partnership collaborative between the Darmstadt Helmholtz Centre for Heavy Ion Research, the HZDR, the Heidelberg University Hospital’s Department of Radiology, and the Heidelberg-based German Cancer Research Center (DKFZ). As part of the pilot project, since 1997, more than 400 cancer patients (primarily with tumors of the base of skull region) have been treated. Years of research and GSI’s large ion beam accelerator facility provide the basis for this new form of cancer therapy. Radiation treatments concluded in summer 2008 and were moved to Heidelberg University Hospital, where the Heidelberg Ion-Beam Therapy Center (HIT) has since picked up and continued operations. Each year, more than 1,000 patients are expected to be treated at the HIT.

↗ **www.gsi.de**

Link to short film clip illustrating how proton beam therapy works.

// High-performance lasers are excellent for accelerating particles. The more power you pack into an ultra-short laser pulse, the more energy the particles gain from the acceleration. Physicists at HZDR have come up with a new equation to describe the temperature and density of laser-driven electrons. If it is correct, then it will take higher intensity lasers than previously thought to produce the ion beams needed for applications such as cancer therapy.

SUPERCOMPUTER: To produce high parallel simulations, the "Computational Radiation Physics" junior research group headed by Michael Bussmann employs innovative programming techniques using state-of-the-art high-performance computers, as well as experiments with new kinds of analytic techniques.

SHEDDING NEW LIGHT ON LASER HEATING – ELECTRONS HEATED TO SEVERAL BILLION DEGREES

_TEXT . Michael Bussmann & Christine Bohnet TRANSLATION . Peter Gregg

We all take it for granted that water boils at 100 degrees Celsius, say, while making our morning cup of tea or coffee. But imagine if, one day, we suddenly had to heat the water to 200 degrees Celsius to get it to boil. We would have to double the power of our kettles and espresso machines to brew our beloved beverage in the usual time. Then, the power plants would have to put out twice the power so that we can all start our mornings in customary fashion. Sounds kind of strange, right? But that is pretty much exactly the situation doctoral student Thomas Kluge and colleagues at HZDR have encountered, although his kettle is a high-power laser and the water is electrons on the surface of a foil.

In short, it takes a much more powerful laser pulse than expected to heat electrons to a certain temperature in a foil. A high-power laser accelerates electrons and ions in the following process: First, an intense, ultra-short laser pulse strikes the front side of a thin foil, where it produces a plasma of ions (atoms that have lost some or all of their electrons) and hot electrons. The electrons are heated by the strong fields of the laser, similar to how water is heated in a kettle. The electrons then shoot out of the foil on the reverse side, pulling the ions along behind them, accelerating them to high energies. The scientists harvest these fast-moving ions for use in their research and, one day, in applications such as radiotherapy. →

LIGHT FIREWORKS: If the beam of a high-performance laser is focused in the air, it creates a filament – a range in which laser light and matter interact in such a way that a new light spectrum is produced. Here, white light, which, along its path of travel, meets dust particles in the air, is seen producing colorful laser light.

Electrons act as the energy transfer media in laser-ion acceleration. The hotter they become in their interaction with the laser, the more energy they are able to transfer to the ions, where the temperature of the electrons increases with increasing power of the laser. It follows that this temperature must be precisely known. Thomas Kluge has now discovered that the conventional, twenty-year-old models for determining the temperature of laser-heated electrons are too inaccurate for the new generation of high-power lasers. Together with colleagues, he has drafted a new theoretical model that considers entire clouds of electrons, taking relativistic effects into account. This model yields lower electron temperatures than previously anticipated.

At very high laser intensities – as can be expected at the DRACO laser or petawatt laser PENELOPE at HZDR and other future petawatt lasers, or indeed the existing petawatt laser in Austin, Texas – the previous models quickly reach their limitations. “It all comes down to how the temperature of the electrons increases with laser power,” Thomas Kluge explains. “When it comes to new high-power lasers, relativistic effects play a much bigger role than previously assumed. If we ignore these, then the plans for new laser systems will be based on unrealistic assumptions, meaning the facilities would most likely fall short of their targets.”

Einstein and particles

Instead of calculating the temperature for only a single electron, as typically taught in the textbooks, Thomas Kluge factored the entire electron cloud heated by the laser into his equations. This is considerably harder to do since it involves finding the correct average energy of all particles in the electron cloud. Adding to the difficulty are relativistic effects because the laser very quickly accelerates electrons to near light speed. Einstein’s theory of relativity states that clocks moving at different velocities tick at different rates. This time dilation effect is negligible for slow-moving particles, but becomes very important as they reach velocities close to that of light – as our laser-heated electrons do, for example.

If we imagine that each individual electron in the cloud produced by the laser pulse has its own clock and that it ‘rides the laser wave’ like a surfer riding a sea wave, then, at any given point in time, some electrons would be riding up on top, at the crest of the wave, while others would be riding down in the trough, and others still would be somewhere in between. The surfers on the wave crest experience the greatest acceleration. Given their greater velocity, their clocks

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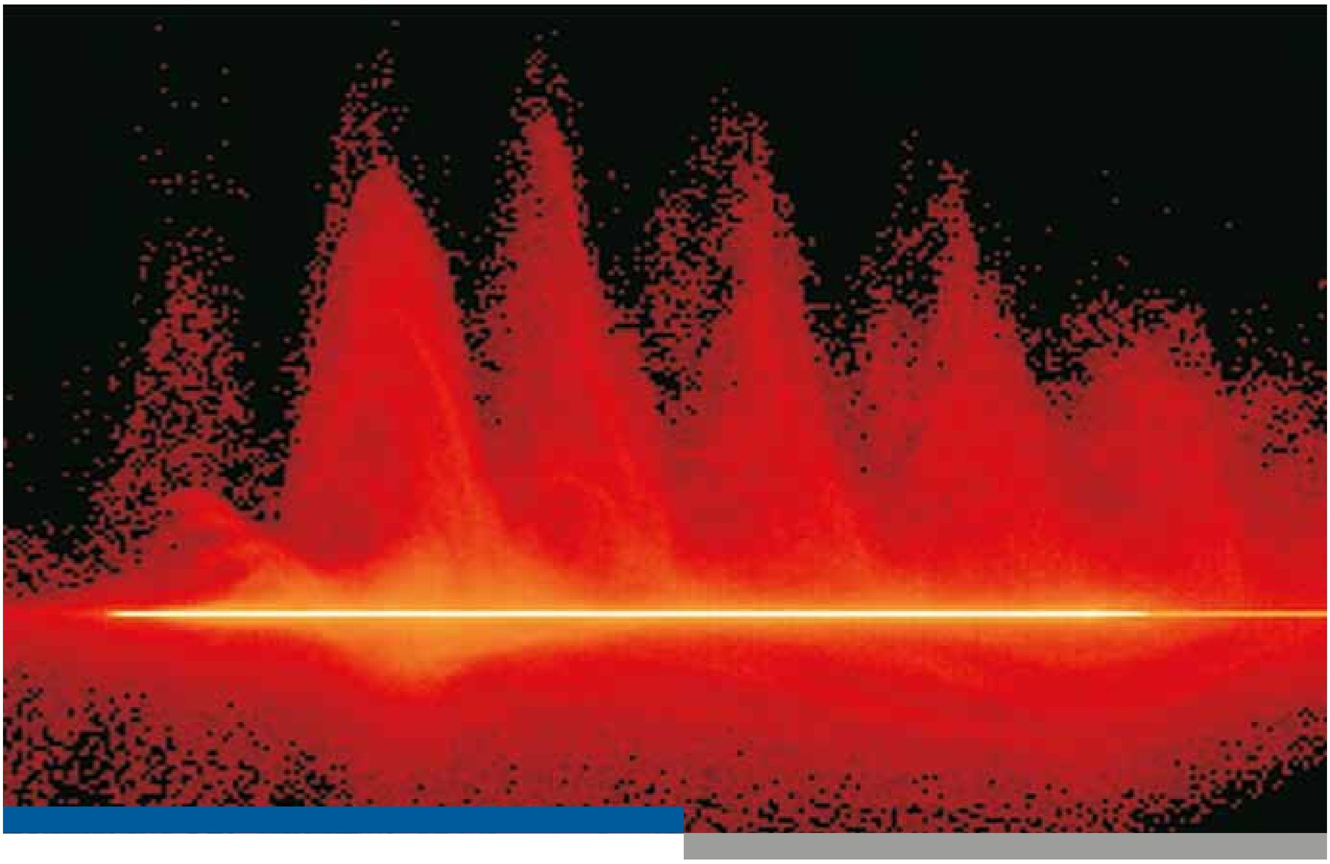

ELECTRON CLOUD: Each individual electron “sees“ the laser wave at a different point in time. But even though it is difficult to conceive of this relativity effect, it is essential for the exact determination of energy from laser-accelerated particles.

tick more slowly than those of the other surfers. That means each electron “sees“ the laser wave at a different point in time – depending on its position on the wave. This relativistic effect may not tally with common sense, but it cannot be ignored when correctly predicting the energy of laser-accelerated particles.

For the predecessors of DRACO and PENELOPE, the textbook predictions still match the experimental results very nicely. To continue our metaphor, the wave the electrons are surfing on is still so flat that relativistic effects hardly come into play at all. If Thomas Kluge’s model is correct, however, then future high-power laser systems capable of producing laser intensities tens to hundreds of times greater will experience an even bigger gap between the experimentally measured temperatures and the temperatures predicted by the conventional models. Since hot electrons are the intermediaries in laser-ion acceleration, in that they transfer energy from the laser to the ions, it is crucial that we gain a better understanding of these hot electrons and their behavior in the electron cloud.

Accurate predictions at last

The extended model for laser-electron interactions, which physicist Thomas Kluge developed with the support of Michael Bussmann, head of the junior group “Computational Radiation Physics”, now allows laser systems to be built on the correct power scale for producing the ion energies needed for future applications. “Our new insights improve on the decades-old models. For one thing, they provide an explanation for previous measurements and, for another, they allow us to make accurate predictions for optimizing future experiments,” Michael Bussmann says. Not resting on their laurels, the team from Dresden has already moved on. The two physicists are figuring out exactly how energy is transferred from electrons to ions in order to gain a better understanding of laser-ion acceleration. They are delving deep into fundamental issues of laser-matter interactions knowing that, one day, their work will advance the clinical use of laser accelerators in future cancer research and therapy. ⊣

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// What happens when water and steam meet in a pipeline system? What impact does this have on the safety of nuclear power plants or on the efficiency of chemical production processes? Researchers at the HZDR are using an experiment that is closely linked to industry to investigate when exactly the two phases block each other and are developing physical models based on their insights.

WATER VERSUS STEAM – COMPARING UNEQUAL FORCES IN INDUSTRIAL PLANTS

_TEXT . Christine Bohnet TRANSLATION . Sarah Gwillym-Margianto

The chemical industry is one of the largest branches of German industry. It is a branch with a particularly large consumption of resources, resulting partly from a high energy consumption and partly from the use of crude petroleum as a raw material. According to a study on behalf of the German Federal Office of Statistics, the chemical industry has in the past been responsible for using some 21.6 million tons of organic raw materials, of which about 75 percent were converted into the basic chemical substances: ethylene, propylene and aromatic compounds. This conversion takes place inside large chemical apparatuses, where steam is applied to split the crude petroleum (a process known as steam cracking). In order to maintain pure products, the substances then have to be elaborately broken down into separating columns.

Scientists at the Helmholtz-Zentrum Dresden-Rossendorf want to use the most modern measuring technology to glean insights into the processes used in such complex industrial apparatuses. Their new goal is to optimize the established production process of chemical elements in such a way that considerable amounts of costly energy and valuable organic raw materials can be saved. In this way they can also contribute to the energy turnaround as well as the international competitiveness of the chemical industry, which is among the world's large chemical producers.

Combinations of phases such as liquid-steam or gas-liquid-solid mixtures characterize the numerous steps in the process from crude petroleum to pure substances for the chemical industry, but they are also important for the safe operation of nuclear and solar power plants or for oil and gas extraction. Especially in nuclear engineering a reliable forecast of such flows is of great significance – they influence the safety of the plants. In a pressurized water reactor in the primary circuit only water flows under high pressure and at temperatures just below 300 degrees Celsius. The energy transported by this hot water is used in the steam generator unit to supply the turbines with steam in the secondary circuit. Leakages cannot be excluded surely in such large technical plants, but even then a safe cooling of the reactor core needs to be guaranteed. This has to be demonstrated by comprehensive safety analyses, whereby the computer models that are implemented must be able to predict flows with a high degree of reliability. When the pressure falls due to a leakage, these flows are often two-phase flows, meaning that water and steam occur simultaneously in the primary circuit. In the past the results from such safety analyses could not be transferred to other plants with a different geometry or size.

Experts at the HZDR have a lot of collective experience investigating multi-phase flows of steam and water in the primary circuit of a pressurized water reactor in the event of a potential failure – not only in experiments but also in simulations. Both research methods have to go hand in hand when dealing with such highly complex problems. One example from daily life illustrates this: if you turn on a tap in your home, the water flows in a steady laminar flow into the sink. However, if you turn the tap as far as it will go, the water gushes out of the tap in a turbulent flow, even dragging air along with it. Considering that flows of two or more phases are considerably more complex than those with only a single phase, it is understandable that a wide research field is open for turbulent multi-phase flows that will continue to preoccupy the next generation of researchers.

A simulation tool for every flow pattern

The type of flow determines how individual substances are either mixed or separated. Single-phase flows can already be calculated very well in simulations, whereby many expensive experiments (e.g. for new car and aircraft types in the flume) are no longer necessary. Instead, parameters like for example the friction of the air for the object of investigation depending on the geometry of the object but also on other variables such as temperature, velocity and gas flow rate can be determined both quickly and precisely using special computer programs. These CFD-programs (Computational Fluid Dynamics) are still very much in their infancy for multi-phase flows.

When steam and water flow through a pipe, they do not only come into contact with the pipe, but also the surfaces and the interfacial layers of both phases come into contact with each →

WITHSTANDING PRESSURES: Thomas Geissler (left) and Matthias Beyer in the process of assembling a test station for a density sample. In the background, the TOPFLOW facility's unique pressure tank can be seen. Image credit: Rainer Weisflog

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other. Many other parameters such as the different speeds of the phases, the viscosity or the surface tension of the water and steam and, last but not least, the pipe's geometry all have to be taken into consideration to achieve a reliable computer simulation. If other factors such as obstacles and bends in the pipelines or the typically high temperatures and pressures for pressurized water reactors are also taken into account, then the list of parameters to be considered seems endless. Neither is the available computer technology fast enough to reflect the processes for all scales in simulations, nor are the data obtained from each experiment sufficient as a basis for simplifying computer models. For this reason it will still take several decades to establish a universal simulation tool for multi-phase flows and it will still take a lot more experiments to reliably determine all of the relevant parameters and to feed these into the respective CFD-programs. At the same time, every successful and prospectively designed experiment is an important step towards an industrial benchmark, the results of which can be transferred immediately into CFD-codes. Consequently, the efficiency of separating columns or the safety of nuclear reactors can be improved step by step.

Penetrating intransparent walls

Production processes with multi-phase flows take place in industry behind thick pipes and intransparent walls and are neither amenable nor observable. Further, there is the fact that separation columns and primary circuits in nuclear reactors are not exactly set up simplistically – quite the opposite. A separating column is a large cavity with several intermediate floors with partly leveled superstructural parts, where, depending on the height, liquid mixtures can be thermally separated. In this respect, the different properties of the individual substances are utilized to capacity. A typical example of this is multiple vaporization and condensation – like for example in oil refinement, where eventually the water vapor chemically converts the crude petroleum. This is how multi-level processes are used to produce the required basic substances for diverse branches, i.e. in machine building and automotive engineering or for cosmetics and the food industry.

Whether or not the established production processes run quickly, efficiently and safely in the chemical industry has always been more or less a question of the skills and experience of the operators, and even planners of new plants have very little to go on in the way of insights gained from process operations. More reliable insights into the dynamics of material flows could however enable designs that would go hand in hand with considerable increases in efficiency. HZDR scientists therefore want to concentrate on this in the future. They aim to examine chemical plants from the inside using the most state-of-the-art measuring tools and to optimize flow. At the same time, they are conducting groundbreaking experiments on two-phase flows at the TOPFLOW test facility at the Helmholtz center, and with the results obtained they are improving the respective CFD-programs.

One particular highlight that was extended from an experiment to a new simulation model was the successful test series on counter-current flow limitations. For his PhD work on this topic, the nuclear engineer Christophe Vallée received an HZDR PhD award in 2011. A counter-current flow limitation occurs when a water flow is limited by a steam flow from the opposite direction, which could occur for example in the case of interference in the primary circuit of a pressurized water reactor and must therefore be dealt with.

A place of extremes

In a pressurized water reactor, hot water circulates under high pressure in the primary circuit, which cannot vaporize due to the high pressure. In the case of leakage however this changes. In this case, the cooling water leaks out and the pressure in the reactor core can fall to around 70 bars. With the subsequent vaporization, the water level in the reactor is lowered. The steam rises along the piping system towards the steam generator, where it condenses to water and flows back into the reactor. This is desirable because the water contributes to cooling down the reactor core and thus plays an important role in the passive safety of a nuclear power plant.

The water on the way back from the steam generator to the reactor vessel has to pass through a thick pipe with a diameter of almost one meter, where it has to demonstrate its force against the steam flowing in the opposite direction. As the boiling point of water is higher than under normal pressure, the density of the steam is greater while the density of the water is lower. In this way, the denser steam presses against the surface of the water and slows it down completely with a counter-current flow limitation. In order to be able to make sound statements about the process of leakage failure, and consequently about the safety of nuclear power plants, Christophe Vallée devoted his PhD thesis to this topic and came up with an outstanding experimental set-up. With a replication of the complex geometry of a reactor's hot leg, he exposed a steam-water flow to high pressure and high temperatures. While water rushed in from one direction, steam was fed into the system from the other side. The steam flow rate was gradually increased until it completely blocked the water flow. For the first time ever the window of observation for this kind of experiment was not only a few square centimeters, but one entire square meter. Consequently, Christophe Vallée was able to observe the behavior of the converging phases in detail with a high-speed camera.

Putting experiments and simulations into practice

The fact that the experimental set-up with the window and the camera were able to endure a pressure of 50 bars and temperatures of around 275 degrees Celsius is due to the pressure vessel at the TOPFLOW plant. An ingenious set-up which guarantees pressure equalization allows thin-walled experimental set-ups as well as the use of special measuring techniques. This effort was necessary to obtain data for the phenomenon of the counter-current flow limitation, with

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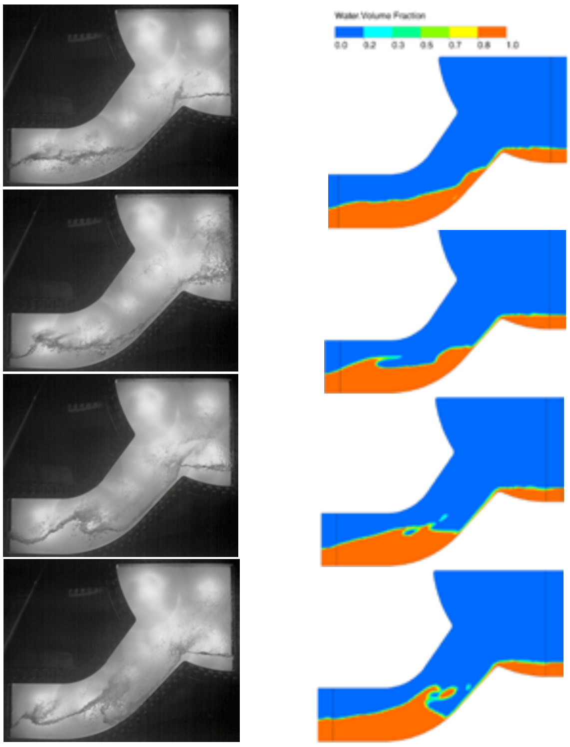

EXPERIMENT AND SIMULATION: Qualitative comparison of the experiment's stream structures (left) with the CFD simulation (right). In both instances, a large wave develops, which is broken by the steam flow.

which numerical codes could be compared and at the same time used as input and improved. Until very recently CFD-programs could not predict when exactly there would be a blockage of the back-flow water through the steam and when there would be a partial limitation. New data from Christophe Vallée's experiments have been able to help in this way improve the computer models that Thomas Höhne had also been working on meticulously in the ”CFD“ Division at the HZDR headed by Dirk Lucas.

“We have developed a new model, the Algebraic Interfacial Area Density Model, that can be used to determine the interaction of phases with different density at their interfacial layers much more accurately than before“, says Thomas Höhne. To simulate the experiment on the computer, a computer cluster comprising of several processors worked on this for around three months. In particular, the accurately simulated interactions at interfacial layers between water and steam were a significant factor. To convert the results into practice, the researchers are working closely with the CFD-developer ANSYS Germany, with whom the HZDR has a strategic partnership. “We were particularly happy about the support from our Indonesian colleague Deendarlianto from the Gadjah-Mada University in Yogyakarta, who received a Humboldt scholarship to work with us on this project for two years. Together we developed the simulations and we were overjoyed when the results turned out to be a really good match with the experimental data. In the meantime our simulation that is close to reality has been put into practice for counter-current flow limitations and can be implemented by companies“, reports Dirk Lucas.

The Institute of Fluid Dynamics at the HZDR is a long-term partner in the German CFD-network. It also has a special partnership with the Institute for Nuclear Safety Systems Tsuruga and the University of Kobe in Japan. Scientists there have used the experimental data from Christophe Vallée to validate a simplified model and they have also made their own simulations and experimental data available to test the HZDR-model. The authorization for the operation of the Japanese nuclear power plants depends among other things on the verification procedure also for the extreme case of counter-current flow limitation. This was tested for a maintenance phase when there is a lower pressure than under normal operation in the reactor vessel. Says Dirk Lucas: “True to the theory that only a validated code is a good code, our new CFD-model has already been tried and proven in practice. In the next step we want to calculate other liquids and heat loss. In the future we will then hopefully have a universal code for counter-current flow limitations.“

Simulation tool for crude oil and vapor

A great advantage of the CFD-programs is that they are extremely relevant for practical applications, as they can be used in a wide range of fields such as safety analyses for nuclear power plants and production processes in the chemical industry to the construction of fuel cells. If one considers the production of substances in the chemical industry, then cases of counter-current flow limitations are also possible there. The vapor in a separating column could press against the liquid crude petroleum, restricting its flow. Because we now understand this special flow formation as a result of the Rossendorf experiments and simulation calculations, we now have a lever for preventing this undesired phenomenon in the chemical industry. Further, this is an important step along the way to greater energy efficiency in the day-to-day running of industry. ┤

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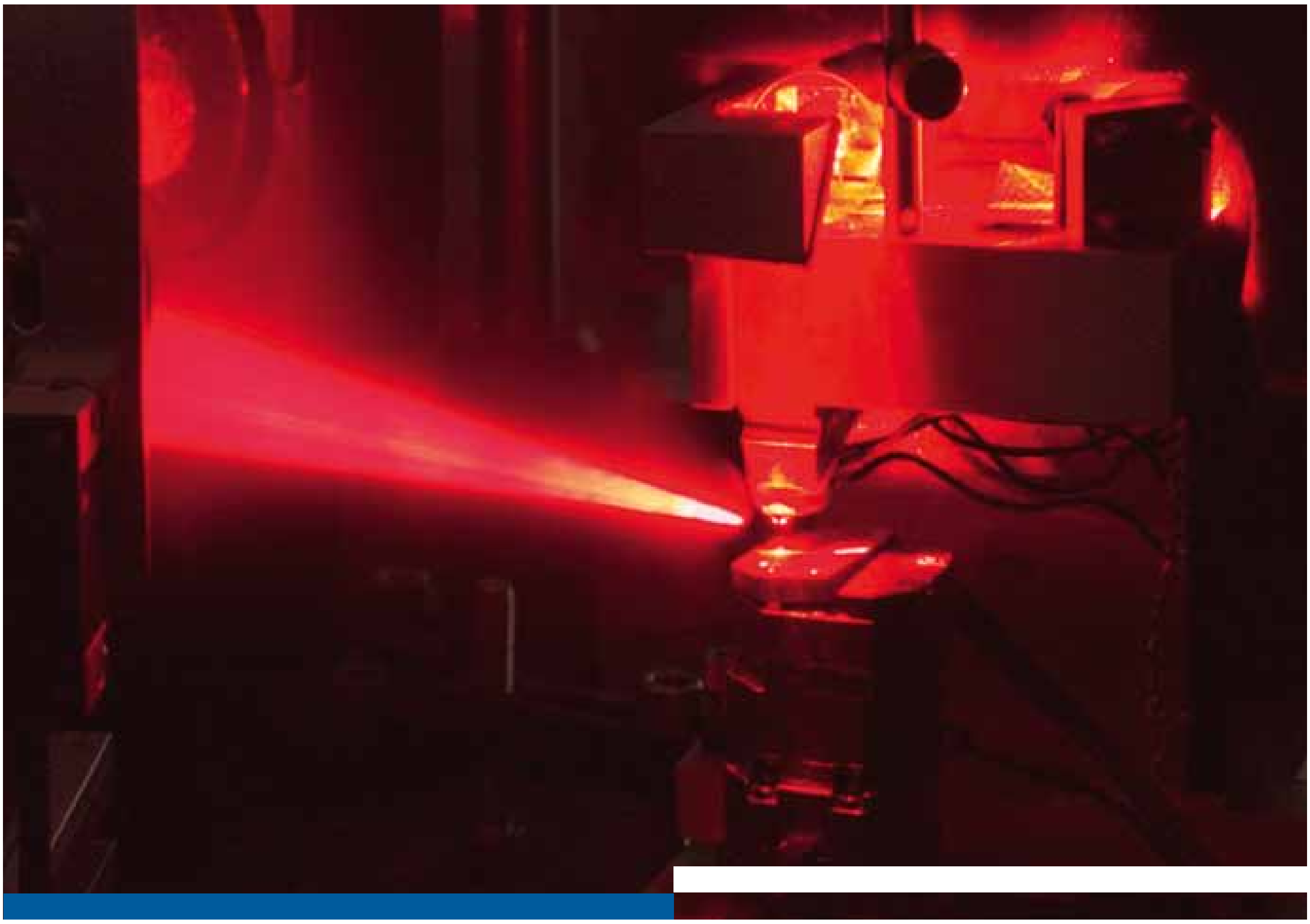
// Electrons lead a life of their own in a world of their own. Anyone talking to physicist Stephan Winnerl will surely come to the same conclusion. One of his fascinations is the astonishingly long life of electrons in the “wonder material“ graphene, for example. He is also working to improve our understanding of quantum dots in which only two or three electrons remain confined.



MEASUREMENTS: The adjustment laser focuses the microscope’s test prod. In the extension of the laser beam, the prod comes from above with the unit for positioning the sample immediately below.

THE STRANGE LIFE OF ELECTRONS

_TEXT . Christine Bohnet & Stephan Winnerl

TRANSLATION . Peter Gregg

There has been a veritable boom in research on graphene and everything related to it. Countless research groups around the world are concentrating on this special material, one conference after the other is dedicated to it, and thousands of scientific papers have appeared since graphene was discovered in 2004. Its discovery extremely quickly earned the Nobel Prize in physics in 2010. Graphene – a layer of carbon precisely one atom layer thick that looks like honeycomb under the scanning electron microscope – seems almost purposely made for our emerging technologies. Researchers are discovering a growing list of useful properties. To name but a few of its advantages, graphene is thin, transparent and stable, it can absorb light in the invisible infrared range, and its electrons behave like high-energy →

elementary particles much like the fast, charged particles boosted to near light speed in an accelerator.

Physicists like Stephan Winnerl of the Helmholtz-Zentrum Dresden-Rossendorf already have a very clear understanding of electron mobility in the crystal lattices of semiconductors. Electrons can be accelerated inside a semiconductor by applying electric potentials, where, as we know, the especially fast and mobile electrons act as charge carriers to transport the electric current and thus ensure the current flow. How fast electrons can become depends greatly on their effective mass. Every semiconductor possesses its own particular crystal structure, which physically determines the effective mass of its electrons. For fast electronic components, such as transistors in computers or mobile telephones, one naturally wants materials whose electrons can be accelerated very easily to high speeds. While graphene actually belongs in the class of semiconductor materials, its electrons behave radically differently. Their effective mass seems to disappear altogether, meaning they race through the one-atom-layer plane incredibly fast. It seems only natural to exploit this in future electronics.

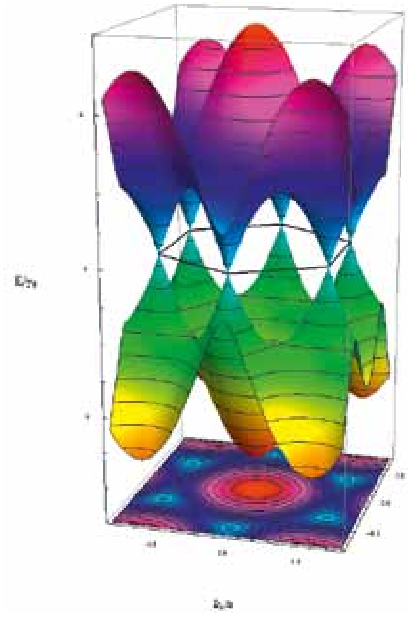
Aside from the effective mass of their electrons, the various semiconductor materials differ by another important property: their so-called band gap. Quantum mechanical laws dictate that electrons reside only within specific energy ranges, known as bands. Physicists speak of a valence band and a conduction band. Between these bands is a forbidden zone, which the electrons are not allowed to enter. This band gap, or energy gap, is exploited to produce light in LEDs, for example. As an electron jumps from the higher-energy conduction band “down” to the valence band, it gives off its energy in the form of light. The colour of the emitted light depends on the size of the energy gap.

Electrons without limits

Inside the extraordinary semiconductor graphene, there is no forbidden zone between the energy bands, meaning there are practically no limits set to the mobility of its electrons. They streak around at high speeds through the essentially two-dimensional space of the super-thin carbon layer. What is more, the valence band and conduction band meet in a special way in graphene: “The bands cross over in a Dirac cone, which I like to imagine as two ice cream cones, one standing with its apex touching the apex of the other, inverted cone,” Stephan Winnerl tries to illustrate the concept, which cannot be described in simple terms. Indeed, electrons do not actually move through space and time in the familiar sense, and the energy bands we are talking about, being a quantum mechanical property of electrons, belong in so-called momentum space.

Because there is no band gap, graphene cannot be used to build the transistor designs familiar from silicon technology. Instead, it offers completely novel approaches for using its fast electrons in high-speed switching processes. Nor can graphene be used for building light-emitting diodes or other optoelectronic technologies that otherwise exploit the light that electrons emit as they jump from the conduction band to the valence band. Yet, the very fact that it lacks a band gap and that the energy bands cross over in the special “ice cream cone shape” has a unique consequence for graphene’s optical properties: Graphene absorbs about two percent of the energy of incident light, while the remaining 98 percent passes through the graphene layer unhindered. That makes graphene almost completely transparent. Interestingly, the colour of the light does not matter, and the law applies even to invisible infrared radiation.

This unique optical effect makes graphene very attractive as a transparent material for electrodes, in flat screens or solar cells, for instance. Large companies have already developed successful prototypes for this. One major advantage of substituting graphene for the conventional transparent electrode materials is that the scarce – and therefore expensive – raw material indium can be omitted. Carbon is almost unlimitedly available for making graphene, and graphene is furthermore completely harmless. Manfred Helm, Director of the HZDR’s Institute of Ion Beam Physics and Materials Research, also sees future applications in optoelectronics, especially for converting infrared light into electrical signals. Furthermore, the flexibility and stability of the material allows it to be used in new applications such as electronic circuits that can be printed easily and cheaply onto flexible films. →



MIRACULOUS STUFF: The unique properties of graphene make it interesting to both basic and applied science research. The figure shows the energy of electrons according to their wavenumber. The “occupied“ (shown in yellow-green) and “unoccupied“ (shown in blue-red) states are in seamless contact with each other at exactly six exceptional points. Image credit: © Paul Wenk – Wikipedia

What has Stephan Winnerl newly discovered about the strange life of electrons in graphene? Working with colleagues from the Helmholtz-Zentrum Dresden-Rossendorf and with scientists from Technische Universität Berlin, the High Field Magnet Lab in Grenoble, France, and the Georgia Institute of Technology, USA, he determined the lifetimes of electrons in graphene within low energy ranges. This scenario had never been researched before. For their experiments, the scientists shone infrared light from the free-electron laser at the HZDR onto their graphene samples. In the relatively long-wave range, they adjusted the laser energy very precisely to the energy bands in the graphene, very close to the Dirac point, i.e. the point where the apexes of the two inverted “ice cream cones” meet. They discovered that the relationship between the energy of the photons and the vibrations of the atomic lattice significantly influences the lifetime of the electrons: If the energy of the photons is higher than the energy of the lattice vibrations, then the electrons change their energy state faster and live less long. Conversely, the electrons remain longer at a given energy level if the laser energy is lower than that of the lattice vibrations.

Model calculations at TU Berlin confirm the experimental data from Dresden and, accordingly, the international research team has contributed towards a better understanding of the electronic and optical properties of graphene. Yet there are still many open questions about the wonder material graphene to be researched, and the HZDR scientists are excited to be conducting more experiments together with the theoreticians from TU Berlin and scientists from the High Field Magnet Lab in Grenoble to observe the unique behavior of electrons in graphene under the influence of magnetic fields. Initial experiments there have revealed that it takes only a relatively low magnetic field to fundamentally modify the band structure of graphene. This modification prevents the electrons from moving freely and instead forces them into an orbit lying within the plane. In this state, they very much resemble their “comrades” held captive in quantum dots.

Confined inside pyramids

Unlike the especially fast and freely mobile electrons that graphene possesses in its normal state, electrons inside quantum dots live a very constrained life. In current experiments, the Dresden researchers took a closer look at such dots in indium arsenide and indium gallium arsenide by firing infrared light from HZDR’s free-electron laser at these tiny, pyramid-like dots.

Each nano-pyramid contains only two or three electrons. These electrons are essentially imprisoned, in that their freedom of movement is considerably restricted. One could say that the electrons “feel” the confining walls of the pyramid. Translated into physics, that means the energy of the electrons no longer extends over the large areas of the bands in proportion to their kinetic energy. Instead, they reside at highly specific energy levels inside the pyramids, where the

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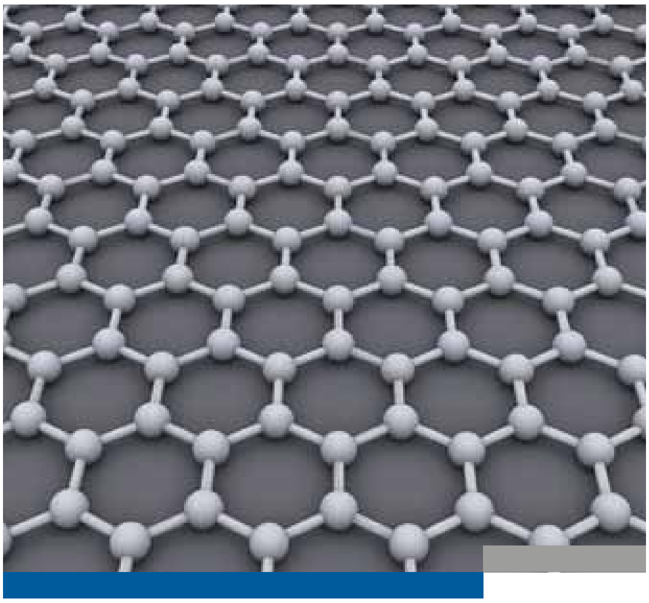
FREE-ELECTRON LASER: Inside the undulator (the structure in front), electrons from the ELBE accelerator are forced onto a wiggling motion – forcing them to emit light. Image credit: Sven Claus



HONEYCOMB STRUCTURE: Hexagonal crystalline graphene structure in the form of a honeycomb. Image credit: © AlexanderAIUS – Wikipedia

position of this energy level depends on the semiconductor material and on the size of the nano-pyramid. So, when dealing with quantum dots, one doesn't have the usual wide valence and conduction bands, rather sharply delimited sections or energy levels on these bands, thus resembling an artificial atom. "If electrons then jump from a higher energy to a lower energy state, they also give out radiation, just like LEDs emit light, but the colour of the light is much more precisely controllable. The Semiconductor Spectroscopy Division at HZDR, to which I belong, has concentrated more on quantum dots recently. We see great potential in them and we could use their special properties to develop very energy-efficient, quantum-dot-based lasers, and be able to adjust the colour of such lasers precisely," Stephan Winnerl explains his interest in these nano-pyramids.

As all too often, however, there is a snag: While the pyramids form spontaneously during a specific process of crystal growth, their size varies within a certain range. Studying them with infrared light, for example, one obtains blurred signals because electrons in different sized pyramids respond to different infrared energies. This is why the Semiconductor Spectroscopy Division scientists are so keen to obtain a detailed view of the electrons trapped inside a single quantum dot. Using a special method to focus laser light onto a single pyramid, the light donates energy to its electrons, boosting them to an excited state. This excitation is detected by measuring the amount of light that is scattered from the tip. The method of choice for these experiments is called near-field microscopy, and has been perfected for the free-electron laser in Rossendorf in cooperation with Lukas Eng of TU Dresden. The method is now very successful.

The researchers in Dresden were recently the first to succeed in determining states only within the conduction band in single quantum dots using infrared light. To do so, they exploited the special advantage of near-field microscopy: Laser light is shone onto a metallic tip less than 100 nanometers thick, by which the light can be strongly collimated to a hundred times smaller than the limiting wavelength of light that "conventional" optics using lenses and mirrors could ever achieve. While this involves major signal losses, the light beam is still strong enough to excite the electrons inside the observed pyramids. This allowed Stephan Winnerl and his colleagues from HZDR, Technische Universität Dresden and the Leibniz Institute for Solid State and Materials Research Dresden (IFW) to study the behavior of the electrons in great detail.

The free-electron laser is an ideal infrared radiation source for such experiments because the energy of its light can be adjusted to precisely match the energy level inside a quantum dot. The laser at HZDR also delivers such intense radiation that it more than makes up for the unavoidable losses inherent to the method. "Next, we intend to reveal the behavior of electrons inside quantum dots at lower temperatures," Stephan Winnerl says. "From these experiments, we hope to gain even more precise insights into the private life of these electrons. In particular, we want to gain a much better understanding of how the electrons interact with one another as well as with the vibrations of the crystal lattice." Thanks to its intense laser flashes in a broad, freely selectable spectral range, the free-electron laser offers ideal conditions for researching many other interesting things in the remarkable lives of electrons.

Stephan Winnerl's investigations are funded, among other sources, from the priority program "Graphene" of the Deutsche Forschungsgemeinschaft (DFG) and other resources of the European Union.

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// When steel containers used to store highly radioactive waste in nuclear waste repositories are rusting through, they still maintain part of their retaining efficiency. This was recently confirmed by a series of experiments using plutonium at the HZDR beamline ROBL, which is located at ESRF, the European Synchrotron Radiation Facility. Much of the credit for the success of this experiment goes to the networking between European radiochemistry facilities.

WORK HORSE: Gloveboxes are standard radiochemistry equipment. Not only do they keep the researchers safe but, at the same time, they also shield the samples from environmental effects. Image credit: Oliver Killig

WHEN CONTAINERS START TO RUST

_TEXT . Anja Weigl TRANSLATION . Dennis Schulz

When characterizing the experiments, Andreas Scheinost likes to invoke the attribute “unprecedented.“ The scientist and head of ROBL in Grenoble, France, is not only talking about the experimental results themselves - although they represent an important step towards the safety of future repositories for high-level radioactive waste. More importantly, several European scientists shared their specific expertise for this project. Radiochemical experiments pose major security challenges. “For this particular project, a large number of experimental and radioprotection requirements came together, and they all needed to be fulfilled,“ says Andreas Scheinost. “Up to now, nobody has ever conducted a similar experiment.“

The Rossendorf beamline ROBL has two experimental stations - one for Materials Science, the other for Radiochemistry. It is one of only two places in Europe where the structure of radioactive substances as well as their interactions with the environment can be examined with atomic precision. Many ROBL experiments ultimately contribute to assessing the →

security of future nuclear waste repositories. Currently, the researchers are focusing on experiments with iron oxides. These minerals occur naturally in granite and clay rocks - together with salt the most important geological formations for storing high-level nuclear waste - but also on the surface of steel in the form of corrosion products. Which is reason enough for the scientists to focus on the interaction of plutonium, a very long-lived and toxic element, with these iron oxides because - quite evidently - it is of utmost importance to know what happens when the steel barrels containing waste from nuclear reactors begin to rust. Andreas Scheinost does not want to make a big secret out of his research findings. “The rusting containers still have a comparatively high capacity to retain their toxic content, as we were able to demonstrate for plutonium.“

Rust is inevitable

Even far below the Earth‘s surface, metals are susceptible to corrosion. The oxygen required to fuel this process is not provided by the atmosphere, as there is no air in those depths, but comes from the ground water. And it is quite easy to conceive of a scenario involving water when one considers, say, the fact that the host rock granite actually contains fissures for conducting fluids. “We have to assume that, with time, all waste containers will inevitably begin to rust, even when made from stainless steel. What we‘re talking about here are processes that will take several thousands of years to happen,“ concedes Scheinost - a timeframe that, for obvious reasons, is impossible to examine in an experimental lab setting. Instead, researchers are able to look at only short reaction times ranging between several months and a few years, and they then have to find ways to extrapolate their findings in order to make accurate, long-term predictions. Thus far, only those samples with the shortest reaction times of two months have been analyzed, but long-term samples of up to three years will follow.

It has been a long way to carry out those experiments - mostly due to the fact that they had to be conducted under experimental conditions mimicking those in real repositories, i.e. in the absence of atmospheric oxygen. That, of course, makes the results particularly valuable. In fact, the observed reactions deviate from previous work done under normal atmospheric conditions, i.e. in the presence of 20 percent oxygen. While the researchers had expected to find a much higher mobility under the - more realistic - anoxic conditions, this did not turn out to be true: plutonium was found to be firmly bound to the surface of the iron minerals.

In order to perform the actual measurements at the ROBL beamline, which took “only” twelve 24-hour-shifts last year, radiochemistry experts from all over Europe participated

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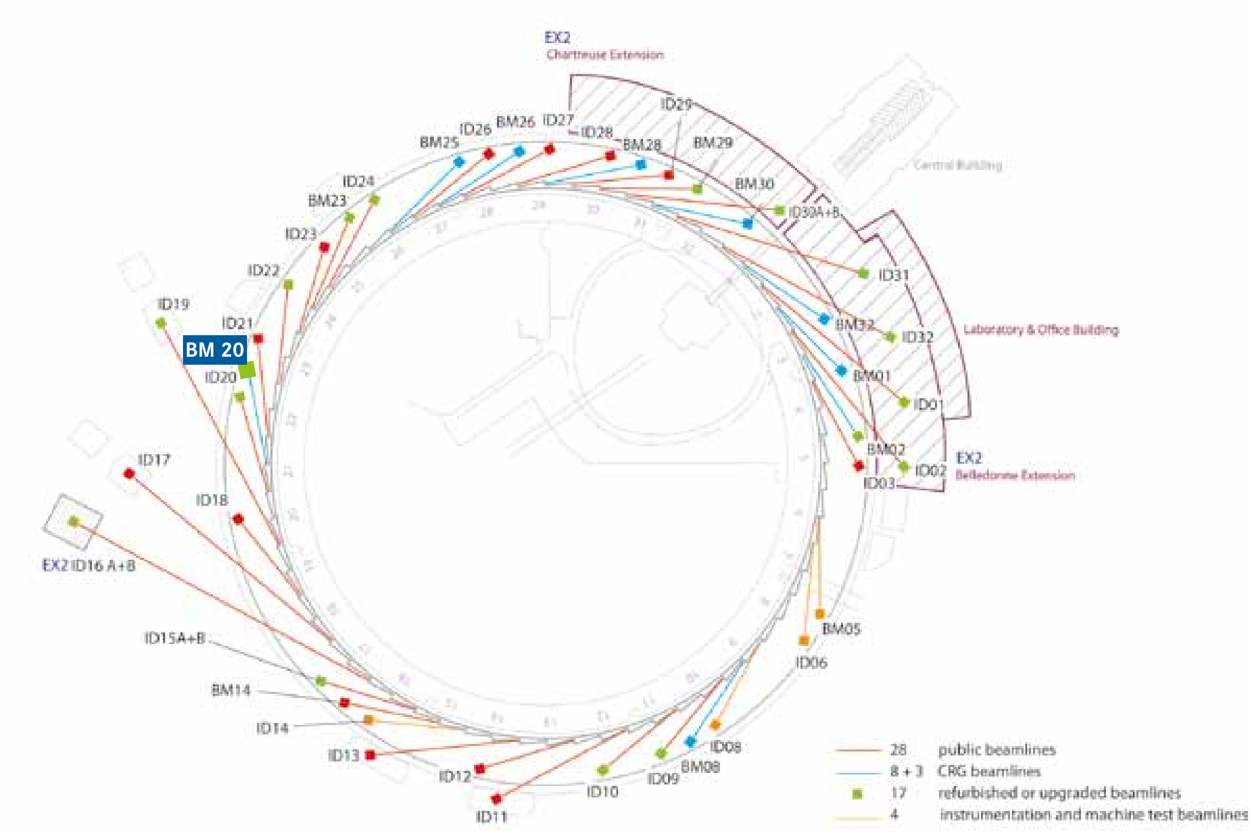

WORKPLACE: Sketch of the proposed 2015 ESRF beamline; the two HZDR measuring stations are located at the beamline 20 (**BM 20**). Image credit: ESRF

Current success with proposals

Currently Andreas Scheinost is not only pleased about the improved opportunities for experiments using the upgraded HZDR beamline, but was also able to score points for three larger proposed projects. Although he won't be coordinating any of these programs that are supported by third-party funding, the participation of the HZDR in the EU-project TALISMAN as well as in two projects funded by the German Federal Ministry for Education and Research (BMBF) is very honourable. In total we are looking at funding secured for the HZDR on the order of one and a half million Euros.

TALISMAN

Funding from the EU-project TALISMAN ensures that scientists working on the safety of future nuclear waste repositories have access to large-scale instruments and other important research facilities. With regard to the HZDR, this includes the Rossendorf beamline at the ESRF in Grenoble and the alpha laboratory with an array of spectroscopic methods of the HZDR Institute of Resource Ecology, both dedicated to the investigation of radioactive heavy metals (actinides).

A substantial part of the research on the safety of high-level waste repositories deals with actinides, since they play a central role in the nuclear fuel cycle, starting with the mining of uranium and the production of nuclear fuel, through the production of nuclear energy, to the treatment and disposal of radioactive waste. Above all, research on the very complex chemistry of actinides in burnt nuclear fuel and their interaction with the environment poses a tremendous challenge. The EU-project therefore places great emphasis on the training of the next generation of scientists, to ensure that Europe maintains its leading position in actinide research in the future. TALISMAN is set up as a European pool of research facilities, where the safe handling of radioactive materials under special protective conditions can be combined with state-of-the-art analytic tools and research methods.

IMMORAD

This research program is funded by the BMBF within the framework of the "Förderkonzept der Grundlagenforschung Energie 2020+" (Advanced Program for Fundamental Science in Energy Production). With the allocated funds, Andreas Scheinost plans to continue his research on plutonium under oxygen exclusion and to take up research on the actinide neptunium in his research portfolio.

Implementation of actinides in ceramics for radioactive waste repository

The project "Fundamental investigations towards the immobilization of long-lived radionuclides by ceramics (conditioning)," which is also funded by the BMBF within the framework of Energie 2020+, has also been initiated to advance research on the safety of radioactive waste disposal. The underlying principle is that certain ceramics are considered to be very insoluble and stable, even after many years of exposure to high radioactive doses. Therefore, these could be used in radioactive waste repositories as host phases for particularly long-lived actinides and also exploited for their transmutation to shorter-lived or even stable radionuclides. A lot of fundamental research still needs to be conducted: first to separate the actinides from the spent nuclear fuel and second to form stable bonds with the ceramics. Andreas Scheinost will contribute to this novel research approach by working on the actinides americium and neptunium.

Translated by Sarah Gwillym-Margianto

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in the long lasting and cumbersome process of preparing the samples. The chemists all knew each other through the ACTINET network, which is funded by the European Community to promote nuclear safety research. “By collaborating closely within the network, we were able to choose the best instruments and laboratories for our work,“ Andreas Scheinost explains. Nevertheless, it was a huge challenge for Regina Kirsch, the PhD student working on the project, to organize and conduct the research. She has recently completed her PhD at HZDR and Grenoble University in France, and will commence working as a postdoc at the Lawrence Berkeley National Lab in California, USA, in September.

High safety requirements

Some four years ago, Regina Kirsch started to synthesize the rust minerals at Grenoble University. The advantage of synthetic minerals is that their properties can be controlled very tightly. With a size of only a few nanometers, these particles closely resemble those actually found in nature. In order to be able to investigate the reaction between the rust minerals and plutonium, the scientists needed access to a highly specialized lab that protects them from the radioactive and highly toxic samples. This is commonly done by using gloveboxes running with underpressure, so that particles or aerosols eventually released from the samples would always remain inside the box. A number of such gloveboxes are available at the HZDR Institute of Resource Ecology. The problem with these labs, however, is that tiny amounts of oxygen are taken in from outside, “poisoning” the glovebox atmosphere. This is why normal anoxic gloveboxes are running with a slight overpressure inside. To fulfill both requirements, the underpressure needed for radioprotection and the extremely low oxygen level, the researchers were looking for a suited glovebox in all relevant facilities in Europe, and finally found a suited one at the Karlsruhe Institute of Technology (KIT). “We were searching for this glovebox for almost a year, and where then very happy to have an oxygen level of only 1 ppm, i.e. one oxygen molecule in one million air molecules”, says Scheinost.

“Our colleagues at KIT are also ideal partners as far as the very complicated plutonium chemistry goes. They prepared the plutonium stock solutions with just the right properties to conduct the subsequent experiments with the rust minerals.“ The solid components were then separated by centrifugation and, afterwards, meticulously packed into special sample holders with double confinement - another safety requirement for plutonium experiments. What is more, the materials used in the sample holders have to withstand low temperatures during the experiments, down to minus 263 degrees Celsius, and subsequent heating-up to room temperature. The design of the sample holders combining these features - a high level of security and resilience in the face of temperature changes - was ultimately provided by CEA, the French Atomic Energy Commission. Andreas Scheinost very much appreciates the expertise and long-time experience of CEA in this field.

To transport the samples from KIT to the HZDR beamline in Grenoble, France, support came from colleagues from the Swiss Paul Scherrer Institute, where scientists had recently built a specialized container for transporting highly radioactive substances using liquid nitrogen as coolant. This creates an oxygen-free atmosphere, and also slows down chemical reactions, preserving sample conditions for the beamline experiments.

When the samples finally arrived at the ROBL beamline facility, they were subjected to another safety procedure: the ESRF radioprotection group carefully checked them for surface contamination. In addition, the group was also responsible for ensuring that all samples leaving KIT actually arrived at ESRF, and that they go back to Germany after the experiment, which is required by international and national laws to prevent nuclear proliferation. Only after all of this was completed, were the samples cleared for the measurements at the beamline. They then revealed - under the intense light from the synchrotron beam source - how and where exactly the individual plutonium molecules were “sitting“ on the surface of the iron minerals, the extent to which they approached and interacted with each other, and whether they formed chemical bonds - and, if so, what type of bonds these were.

With these experiments, the researchers have determined that plutonium either accumulates at the rust minerals surface or precipitates in the form of a rather poorly soluble mineral compound. Regardless of its fate, however, what this means is that the radionuclides are firmly bound and that rusting waste containers are able to maintain their retaining function over thousands of years. Scientists assume that, with time, the nuclides may become incorporated into the rust minerals, producing even more highly stable compounds. They may also take up plutonium isotopes that have already escaped through the rust - which, again, would have a very positive effect on security at permanent nuclear waste repositories. All of these various processes will be further investigated as part of the new ACTINET follow-up project IMMORAD, with funding made available by the German Federal Ministry for Education and Research. “Our ultimate goal is to extend our work with plutonium to other elements and to be able to make still longer-term prognoses,“ says Andreas Scheinost. He is looking forward to continuing the fruitful ACTINET partnership once the preliminary work is now completed. ⊣

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// A round of applause for the TU Dresden: On Friday, June 15, the decision was made by the government and the federal states regarding the competition of excellence and the TU was able to score points in all aspects of its programs. Researchers at the Helmholtz-Zentrum Dresden-Rossendorf were also very pleased with these results, as they are participating in the two approved excellence clusters and the graduate school. The main activities are involved in the newly established excellence cluster cfAED (Center for Advancing Electronics Dresden) and the graduate school DIGS-BB (Dresden International Graduate School for Biomedicine and Bioengineering), which has been supported within the framework of the excellence initiative since 2006.

A SUCCESS STORY: THE EXCELLENCE INITIATIVE

_TEXT . Uta Bilow TRANSLATION . Sarah Gwillym-Margianto

In the excellence cluster cfAED everything revolves around microelectronics and beyond. Information and communications technology has developed at an unprecedented rate over the last few decades und has been at the impetus for innovations in the most varied fields of application, whether this be communication, entertainment, mobility or the world of business. Experts are concerned however that there is little potential remaining in terms of developing conventional electronics. Today's information and communications technology is based on the so-called CMOS-semiconductor technology. The structures on a chip are already incredibly small and compressed, and the limits to what is actually physically possible will soon have been reached. Hence, researchers in the cluster of excellence cfAED push forward research on completely new technologies for the electronic information processing of the future and hopes are high that they will overcome the current limitations.

Electronics with logic that can be reprogrammed

"There are a whole range of materials that could be candidates in the future of electronics", explains Artur Erbe from the Division of Scaling Phenomena at the HZDR. "This would include for example carbon nanotubes or nanowires made of silicon, which we are investigating more closely." Silicon nanowires are made from the same material as conventional components. Their potential, however, extends well beyond the conventional semiconductor technology. As demonstrated in seminal work by cfAED project partners at TUD's Namlab facilities, these incredibly thin structures enable a logic that can be reprogrammed, explains the physicist: "A gate-electrode is used to switch between such nanowires. One can therefore switch spontaneously between a p- and an n-type transistor." Conventional silicon on the other hand is fixed to one type through its doping.

The advantages of the nanowires are obvious: complex functionality can be achieved with considerably fewer components, providing brand new opportunities for software. The HZDR researchers have a lot of experience in reliably connecting such tiny wires individually using electron beam lithography. This is imperative, so that the properties of the nanowires can be calibrated with precision. In other experiments the scientists coated the wires on the surface to investigate what kind of effect this would have. Says Artur Erbe: "If we attach individual molecules to the surface, the conductivity changes as does the switching behavior of the wires." This effect can be used for gas sensors for example. Furthermore, it is possible to influence the behavior of the wire in a chemical way.

Nanotubes purposefully arranged

According to many experts, carbon in the form of nanotubes is yet another material that could play an important role in the future of microelectronics. Here scientists at the HZDR are primarily concentrating on purposefully arranging the nanotubes. "We are using defect engineering for this", explains Artur Erbe. Many materials are not uniform, but exhibit grains, domains, or even atom-scale relaxations which structure the surface into small sub-units. The carbon nanotubes adsorb differently on defect-rich and perfect surface areas and can be enriched at defect sites. "Some of the defects can be written optically, i.e. they can literally be determined by light. Hence, we are able to determine with a precision of up to ten nanometers how the nanotubes are arranged", says Erbe. To encourage the cooperation between the partners of the excellence cluster, a new research facility is slated to be built on the TU campus in the near future. As part of its inventory, the Rossendorf scientists will contribute equipment for etching as well as several measuring instruments. →

MATERIALS RESEARCH: At the HZDR's Ion Beam Center, Dresden scientists are using rapid charged particles from several particle accelerators and a broad spectrum of experimental methods in order to develop and analyze new materials for the field of electronics. Image credit: Oliver Killig

KNOWLEDGE CREATES EXCELLENCE: As of June of this year, the TU Dresden is counted as one of Germany's eleven university centers of excellence and has had their entire research proposal catalog successfully accepted. HZDR researchers are working on no fewer than three of the four total accepted proposals. Image credit: TUD/Eckold

International graduate program

The HZDR has been participating in the DIGS-BB graduate program for four years. Under the head of Karim Fahmy of the Institute of Resource Ecology one PhD thesis has already been completed, while three others are in progress. One of these is in the field of systems biology. "The topic is radiotoxicity and its influence on the level of an organism", explains Karim Fahmy. "We are using bacteria and nematodes to investigate how the metabolism reacts to environmentally relevant concentrations of heavy metals and radionuclides." One can measure this using a microcalorimeter. If an organism stimulates its metabolism, heat is released. "We are particularly interested here in the relationship to genetics", says Fahmy. The HZDR researchers are collaborating with the Max Planck Institute for Molecular Cell Biology and Genetics in Dresden on various strains of organisms. In this way, they want to elucidate whether the toxicity can be attenuated through a certain gene.

Two other PhD theses are investigating a bacterial membrane protein which is responsible for the export of copper from the cells. "This protein regulates the copper level in cells", explains Karim Fahmy, "this is very interesting for the role of bacteria in bioleaching". The process of bioleaching uses bacteria to win copper from ores. The membrane protein helps the microorganisms tolerate remarkable levels of metal, which is why the scientists would like to understand the precise mechanism of the protein.

DIGS-BB is regarded among the international graduate programs as a beacon project. "The PhD candidates work under excellent conditions", says Karim Fahmy, "they receive extensive supervision and are trained comprehensively". Every junior researcher is assigned three supervisors and conducts research in a number of laboratories. Every year there is also an intensive course of lectures and internships for the PhD candidates to learn about new methods. Almost 90 working groups in Dresden – at the HZDR, the TU Dresden, the Max Planck Institutes and other research Institutes – are offering research opportunities through the graduate school. In the meantime more than 1,000 junior scientists apply each year for this attractive program, which will be funded in the framework of the excellence initiative for another five years.

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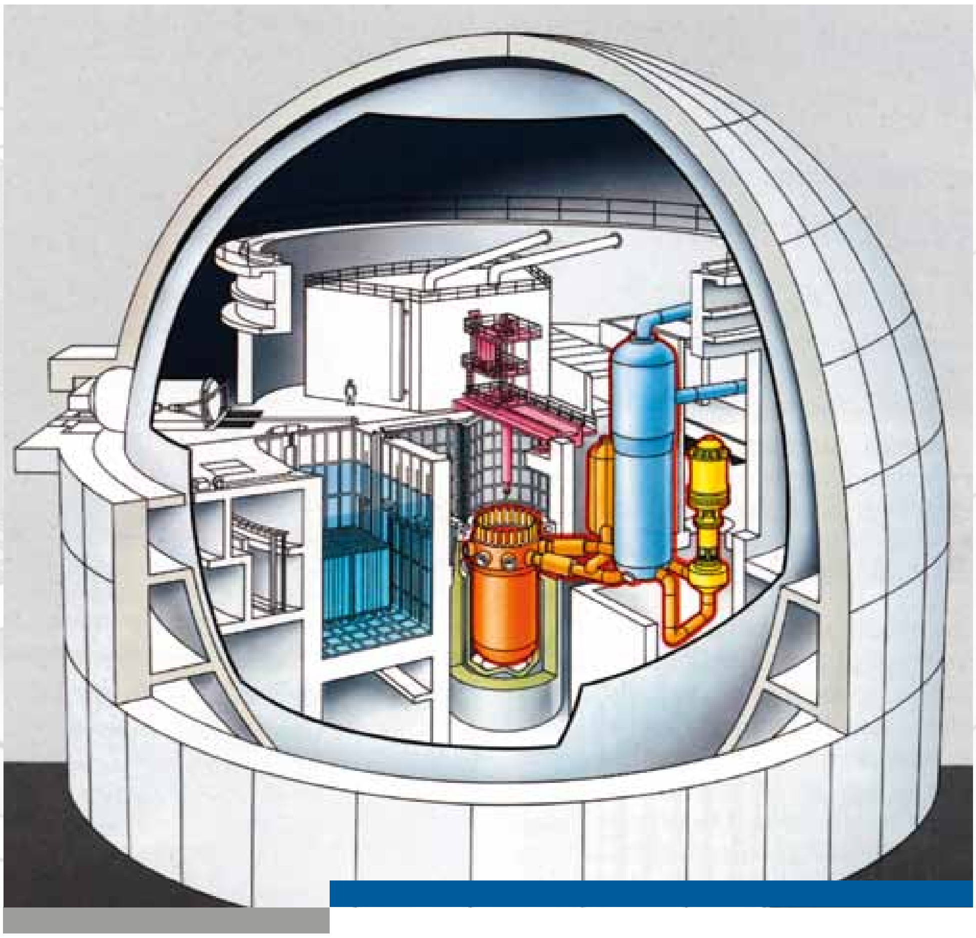
// Together with international partners, Rossendorf researchers investigate the physical phenomena behind the emergency cooling of reactor cores.

ENDURANCE TEST FOR REACTOR WALLS

_TEXT . Uwe Hampel & Matthias Beyer

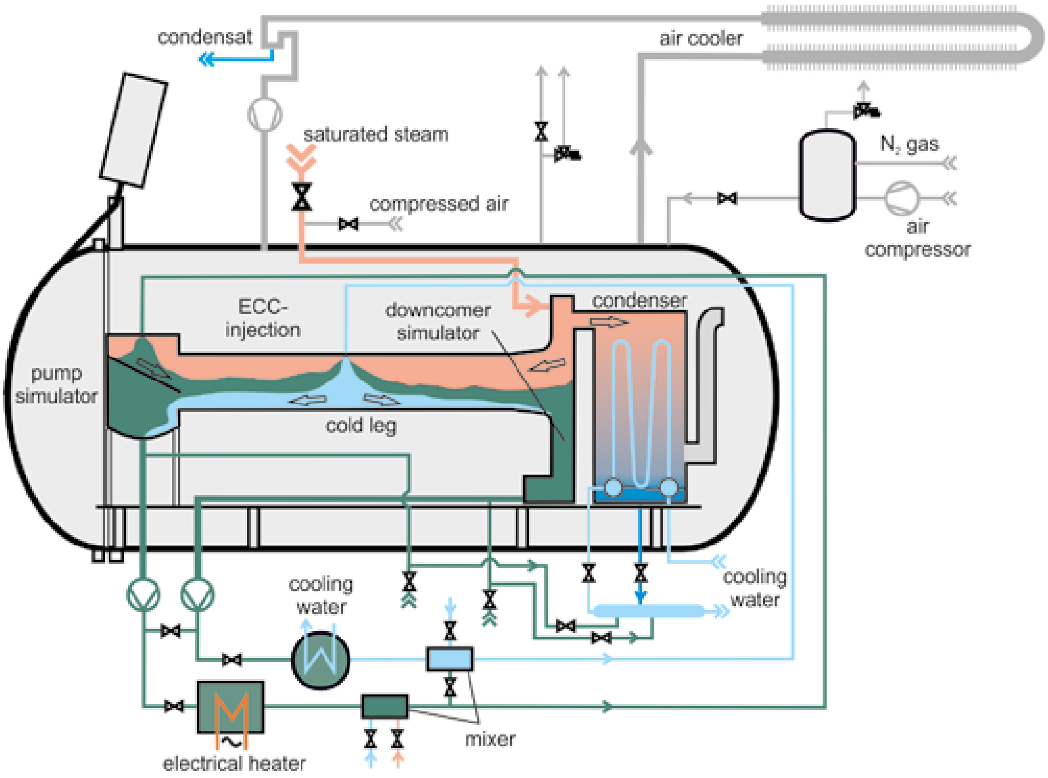
TRANSLATION . Sarah Gwillym-Margianto

For the safe operation of nuclear power plants there is a staggered safety concept with a whole range of measures intended to limit the impacts on the plant should technical components fail. One scenario of a potential failure in a pressurized water reactor is the loss-of-coolant accident. This type of accident can occur when a cooling-water pipe in the primary circuit (for example between the reactor pressure vessel and the steam generator) breaks. The chain reaction in the reactor is then interrupted immediately while neutron absorbers (control rods) automatically cave into the reactor core. Subsequently various emergency core cooling systems are switched on to remove the decay heat in the reactor core as well as to replace the coolant that is leaking out of the cooling circuit due to the failure.



PRESSURIZED WATER REACTOR: Sectional view of containment structure showing the primary circuit with the reactor pressure vessel, steam generator, and main coolant pump highlighted in orange, light blue, and yellow, respectively. Image credit: kernenergie.de (Information on the peaceful use of nuclear energy)

The additional emergency cooling water is fed from different storage vessels into the main pipes of the primary circuit that is under pressure. These main pipes connect the reactor pressure vessel with the steam generator (the hot legs, where the heated water flows away from the reactor) and the main coolant pump (cold legs, where the colder water flows towards the reactor). Under operating conditions, pressures and temperatures in those pipes with diameters of nearly one meter are 155 bar and up to 325 degrees Celsius, respectively. In case of a loss-of-coolant accident, steam will be produced in the thermal-hydraulic circuit due to water inventory decrease and the pressure drop and, consequently, during emergency core cooling cold water meets steam and hot water in the pipes. →



PRESSURE TANK: Functional principle of the test facility for analysis of thermal shock scenarios inside a pressurized water reactor.

Thermal shock with consequences

One safety issue concerning the emergency core cooling is the potentially large impact on pipes and structural components through a sudden cool-down. This applies especially to the walls of reactor pressure vessels as, following many years of constant operation, they have been bombarded with neutrons. A change in material properties (e.g. increasing embrittlement) could be the consequence. Furthermore, directly after an emergency shutdown, the pressure vessel still has temperatures extending well beyond 200 degrees Celsius. If the subcooled emergency water, which according to the plant can have temperatures between 10 and 60 degrees, were allowed to flow into the reactor vessel without being mixed, its wall would be exposed to considerable thermo-mechanical stress. The sudden cool-down of the wall (also known as PTS – pressurized thermal shock) could under certain circumstances lead to a cracking fissuration or even to the failure of the pressure vessel. The risk of such damage depends, on the one hand, on the wall's current mechanical properties and on the other hand on the temperature of the water entering the reactor pressure vessel. This temperature is a result of the flow mixture from the steam as well as the cold and hot water inside the main coolant pipe and is therefore governed by the thermal fluid dynamics of the fluids inside the pipe.

Researchers at the HZDR have been investigating this kind of scenario for years. The Structural Materials Division has been studying the fracture mechanical properties of the vessels' material, while researchers in the Fluid Dynamics Institute have been looking into how well the cold emergency water mixes with the hot water in the main pipe. The Experimental Thermal Fluid Dynamics Division as well as the Computational Fluid Dynamics (CFD) Division at Dresden's Helmholtz Center are both active in this field. The analysis of failure sequences as well as the evaluation and optimization of emergency measures is the specialty of the Reactor Safety Division. Investigations covering plant dynamics and the insights gained from experiments on thermal shock as well as CFD simulations and the emergency cooling supply help to increase the safety of nuclear plants today and in the future.

Mixing phenomena and plant safety

The mixing of cold and hot water in the main coolant pipe is one of the phenomena of fluid dynamics, on which the complex flow dynamics in the emergency core cooling and thus the safety of the reactor components ultimately depend. The water inside the pipeline evaporates at a certain temperature depending on the prevalent pressure. The cold emergency coolant that streams in comes into contact with

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hot water and saturated steam. Here, depending on the type of flow of the cold water being fed-in and thus the contact surface between the cold water and the steam, there will be different intensities of condensation. The mixing of the media, however, also depends on the impulse of the cold water flowing in.

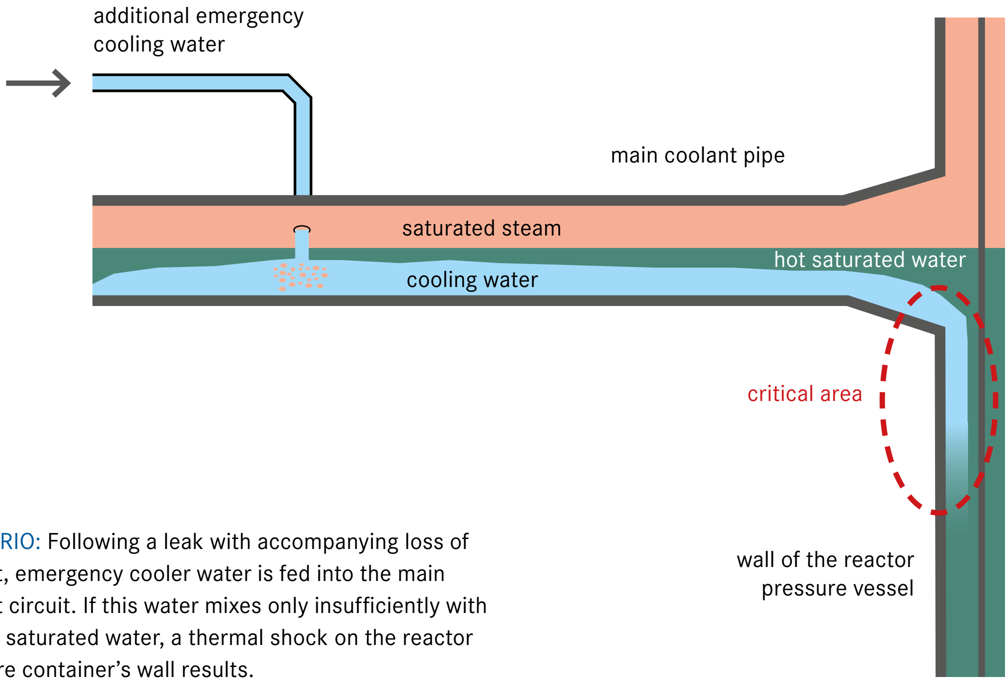
Additionally, there are other phenomena that play an important role: the shape and turbulence of the cold water jet or the type of steam bubbles and the extent to which they are carried away by the flow but also the turbulence in the saturated water. Furthermore, evaporation and condensation are always associated with questions of heat transfer since, for example, condensing steam gives off a large amount of heat to the water that surrounds it, whereby the water temperature can be raised considerably. Overall, the heat transfer and the type of flow depend in a complex way on the thermo-hydraulic boundary conditions, i.e. the flow rate and the temperature of the emergency core cooling water, the temperature and the filling level of the saturated water in the main coolant pipe as well as the steam density, which is determined by the system pressure.

Experimental subject: French pressurized water reactor

Within the framework of a consortium project that has been running since 2006 the last two and a half years have seen some very unique investigations conducted in the field of fluid dynamics by the HZDR from Germany, the energy enterprises EDF France and AREVA NP France, the publicly-funded IRSN (National Institute for Radiation Protection and Nuclear Safety) and the CEA (French Alternative Energies and Atomic Energy Commission) in France as well as the Paul Scherrer Institute (PSI) and the ETH Zurich in Switzerland.

For conducting experiments with flows of steam and water that are close to reality, the so-called pressure tank at the HZDR's TOPFLOW facility is particularly suitable: The experimental set-up uses a model with principal hydraulic components of a French pressurized water reactor to a scale of 1:2.5. It comprises a section of the cold leg with a main pipe including the pump casing, the downcomer section of the reactor pressure vessel (i.e. the area where the coolant entering the reactor flows downwards at the reactor wall) as well as the pipe for the emergency coolant. The test status section that is well equipped with measuring instrumentation delivers spatial and temporal high-resolution data regarding temperature distribution and flow pattern in the experimental set-up, for example. Over 200 different measuring points record temperatures inside the main pipe as well as inside the downcomer section of the reactor pressure vessel, an infra-red camera measures the exact temperature distribution of the pipe walls and finally a high-speed camera observes the flow of the emergency water as it enters the main pipe. Apart from that, wire-mesh sensors have been developed at the HZDR that are implemented to provide information on the gas phase - if any - within the liquid phase and record the water velocity inside this pipe.

Experiments have been performed for various combinations of parameters at operating pressures of up to 50 bars, corresponding to the pressure at a water depth of 500 meters. Due to the unique technology of the pressure tank no damages were inflicted in spite of extremely high pressures →



SCENARIO: Following a leak with accompanying loss of coolant, emergency cooler water is fed into the main coolant circuit. If this water mixes only insufficiently with the hot saturated water, a thermal shock on the reactor pressure container's wall results.

neither to the measuring technology implemented nor to the experimental set-up. Experiments are conducted within the closed pressure tank with pressure equalization, whereby it is not required to design components that are pressure-resistant or thick-walled. In this way, the experimental set-up can be equipped with thin metal walls and even optical glass windows. While the high operating pressure is compensated through the tank itself, good thermal insulation needs to be ensured during the experiment. This is imperative, on the one hand, to protect the expensive measuring technology in the pressure tank and to minimize heat loss in the experiment, on the other hand, as this would skew the results like, for example, an additional cooling of the water mixture. For this reason, a special mineral fibrous insulating material is used for thermal insulation, which also displays excellent isolation properties under high pressure.

European goals

The goal of such elaborate experiments at the Helmholtz–Zentrum Dresden-Rossendorf is to improve CFD codes with the help of high-resolution data from the experiment. These will be further developed in the European projects NURESIM, NURISP and upcoming NURESAFE. The series of experiments that was inter-coordinated by the project partners covered more than 90 experiments incorporating different operating parameters in each experiment, i.e. pressure, flow level inside the main coolant pipe as well as mass flow and temperature of the emergency water. These variations are imperative not only to fulfill the requirements of the most important thermo-hydraulic characteristic numbers that can be used to scale up individual effects to plant dimension, but also to cover a wide range of parameters for current and future CFD simulations. Last but not least, comparable experiments using air-water and steam-water combinations are able to assess the effects of steam condensation that is lacking in a pure air-water system, for example.

The data from these elaborate experiments already serve as comparative data to be used in the CFD calculations by the project partners. In addition, project partners within the large-scale European projects NURESIM and NURISP performed conducted comparative calculations to compare this complex thermo-hydraulic scenario with three different CFD codes (among which commercial ones). Preliminary results are already showing that further efforts must be invested in the future development of these codes – a field of research and development to which scientists at the Institute of Fluid Dynamics at the HZDR have dedicated themselves. ⊣

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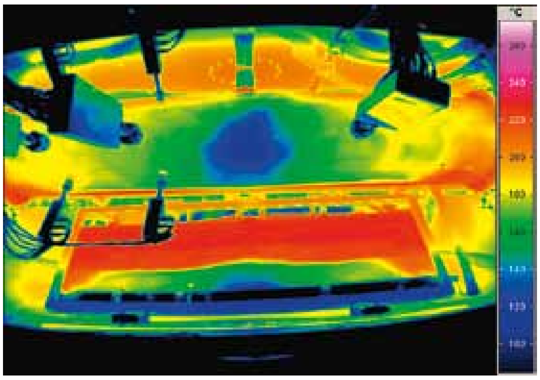
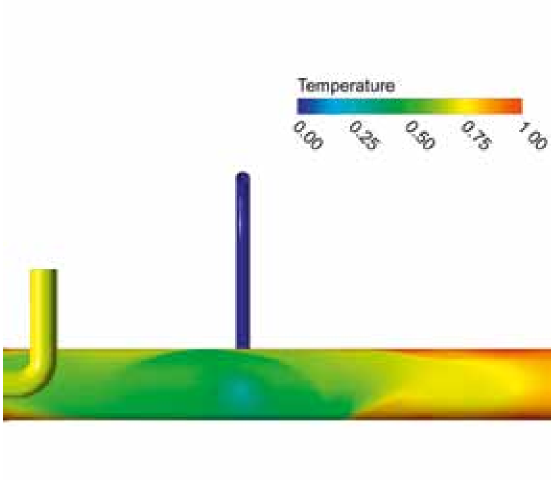
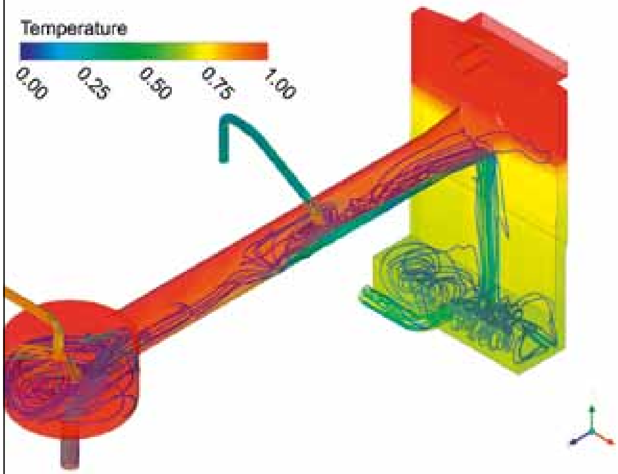


EMERGENCY COOLING: The thermal imaging camera shows the cold leg pipe wall in a steam-water experiment as seen from below (top half of picture) and a side view of the same pipe (bottom half of picture).





Temperature distribution on the cold leg pipe wall and the downcomer simulator’s surface based on results from CFD calculations.

// BM20 – this is the name by which the HZDR and the Rossendorf Beamline (ROBL) are known to the 1,000 people working on the site of the European Synchrotron Radiation Facility (ESRF) in Grenoble. BM20 is actually a house number, as it denotes the “bending magnet in sector 20,” where the brilliant beams of X-rays for the ROBL scientists are produced.

HALFWAY MARK FOR THE ESRF UPGRADE PROGRAM

_TEXT . Claus Habfast

Since late 2011, ROBL is proud to present itself to its users from Germany and Europe as a completely rebuilt facility. This refurbishment coincides with a seven-year, 180-million-Euro upgrade of the ESRF, which recently saw its halfway mark: between December 2011 and May 2012. For the first time ever since the program was launched in 1994, the whole complex had to be shut down for five months to allow the foundations to be laid for a 12,000 square meter new experimental hall and to install or modify many components of the existing installations. These construction activities had a major impact on the concrete floor of the accelerator, moving it up or down by as much as one centimeter at some points. A complete realignment was necessary, which fortunately did not hamper the machine restart in May. The upgrade will now continue without significant interruptions of normal user operations.

REAL-TIME RESEARCH: X-rays allow for the study of chemical reactions under extreme conditions. Here, a catalytic cell sample is heated under in-situ conditions. A major automobile manufacturer has successfully used this technology at the ESRF to improve catalyst longevity. Image credit: ESRF/B. Gorges

The idea of a major upgrade to the ESRF dates back to 2003. “The ESRF was operating extremely well at the time, so one option was to simply keep going,” recalls former ESRF Director-General Bill Stirling, “but after looking at other facilities and labs around the world, we realized that a major upgrade was necessary to maintain the ESRF’s position as one of the best – if not the best – X-ray sources in the world.” By 2015, the ESRF will have unleashed eight new beamline projects, comprising 11 beamlines and 15 stations that can be operated independently. In addition to refurbishments and improvements to existing beamlines and the construction of a science building, the upgrade will ensure that the ESRF meets the scientific demands of users for the rest of the decade. ID24, the first of eight beamline projects, was already completed back in November 2011. It is devoted to time-resolved and extreme-conditions X-ray absorption spectroscopy, exhibiting a performance 20,000 times better than its predecessor and 1,000 times better than anywhere else in the world. As of early 2013, more upgraded beamlines will go into operation one after the other.

Smaller, brighter beams of X-rays are the focus of the ESRF upgrade, with beams as small as just ten nanometers allowing users to address the behavior of matter in volumes comprising just a few thousand atoms. In addition to major improvements to the accelerator complex, most of which are

→

INAUGURATION: Francesco Sette, ESRF Director General, Roland Sauerbrey, Scientific Director of the HZDR, Jean Moulin, Chairman of the ESRF Council, and Thomas Roth, Head of Division of the German Ministry for Education and Research (BMBF), at the inaugural celebration for the remodeled Rossendorf Beamline BM20. Image credit: ESRF/C. Argoud.

now in place, the upgrade comprises longer beamlines in the new experimental hall to be operated with vastly improved optics, detectors and data-analysis tools.

Nanoscience and nanotechnology is one of the five core areas of applied and fundamental research addressed by the upgrade. The others are: pump-probe experiments and time-resolved diffraction (with time resolutions sufficient to “film” the movements of single atoms or even electrons); science under extreme conditions (providing the capacity to study minute quantities of matter under very high pressures, temperatures and magnetic fields); molecular biology and soft matter (elucidating, for instance, the basic mechanism of molecular machines and cellular reproduction), and X-ray imaging (with applications ranging from medicine to archaeology).

Every ESRF beamline will undergo at least some kind of upgrade, but despite the heavy works and installation of new equipment, the performance of the ESRF has not dropped significantly for its users, and its scientific output is higher than ever – producing more than 1,800 peer-reviewed publications in 2011 alone although several beamlines were temporarily shut down for reconstruction activities.

The ESRF upgrade program is implemented in two phases and with Phase I halfway through, it is now time to prepare for Phase II. A major task in 2012 is to consult with users about their scientific and technical needs, and to prepare a proposal to the ESRF Council before its spring meeting in 2013. The ESRF Council has also asked for a report from an independent group of experts addressing inter alia how the ESRF machine could keep its position as world leader and whether a major accelerator upgrade could be envisaged. Great progress has been made recently worldwide with ideas and plans for an “ultimate storage ring” to push the brilliance of X-ray beams by another factor of 50 to 100. In 2017, the accelerators at the ESRF will have been producing beams of X-rays for a quarter of a century. The decision about whether this is the right time to start building a successor will be on next year’s agenda. ⊣

HALF-TIME: Aerial view of the new experimental hall at the ESRF. The new hall will be able to accommodate setup of experimental stations 120 meters in length, which is necessary for X-rays of 10 nanometers diameter on the sample. Image credit: ESRF/C. Argoud

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ARIAL VIEW: The EMB-ESRF-ILL site at the junction of the Drac and Isère rivers. Image credit: Denis Morel

// A close research and development collaborative partnership exists between the HZDR and ROTOP Pharmaka AG, a pharmaceutical company with offices located on the Rossendorf research campus – to directly benefit patients.

THE IDEAL HEALTH RESEARCH COLLABORATIVE

_TEXT . Christine Bohnet   TRANSLATION . Dennis Schulz

CHECK: Cornelia Pretzsch, ROTOP Pharmaka AG Head of API Production, doing a quality check of a nuclear medicine product. Image credit: André Forner

ON CAMPUS: ROTOP Pharmaka AG office building. Image credit: ROTOP

In the planning of optimal therapies for cancers such as breast cancer or malignant melanoma, it is critical to know whether or not the cancer has spread, or metastasized, to the lymph nodes. Today, Sentinel Lymph Node Scintigraphy, a very promising diagnostic tool, which has fast become standard in all nuclear medicine facilities, can be used for scanning lymph nodes for potential metastases.

In the context of a collaborative research project with funding provided by the Free State of Saxony, Helmholtz-Zentrum Dresden-Rossendorf and ROTOP Pharmaka AG scientists have jointly developed novel radioactively labeled particles for use as a diagnostic tool. The findings from this research have resulted in the development of the recently approved new drug "NANOTOP," which is manufactured and marketed by ROTOP. The drug provides important information about the location of what are called "sentinel lymph nodes" that lie immediately beyond the location of the primary tumor. Following scintigraphy, the nodes are examined to help determine whether or not they contain potential cancer cells that have metastasized from the primary tumor site. Based on this information, doctors are able to make informed decisions regarding the scope of the surgery to be performed.

HZDR and ROTOP are able to look back on several years of a fruitful partnership that has yielded a number of successful research projects. In fact, one of the current projects has set out to answer questions about a major common disease. Since 2010, the company, with its more than 40 employees, has been located in a new office and production building on the Helmholtz center campus. In only a very short amount of time, ROTOP, which was founded back in 2000, has managed to distinguish itself both in Germany and beyond through the design and manufacture of different substances for use in nuclear medicine. But although, admittedly, we are talking about a niche market here, at this point, ROTOP is already very successfully marketing its product line (which currently consists of ten products) throughout Europe with plans of entering into the US market in the not-too-distant future. Says ROTOP CEO Monika Johannsen: "Our recipe for success sounds rather simple because our focus has been on becoming a consistently reliable partner for nuclear medicine facilities. Our products are manufactured using highly sophisticated technology and so far we haven't had any complaints." Which is important since the new drug "NANOTOP," for example, is used pre-surgery for Sentinel Lymph Node Scintigraphy in breast cancer at nearly all of Germany's breast centers.

The ROTOP recipe for success seems to be panning out rather nicely since the company is currently planning its expansion by building additional cleanrooms for the production of kits that are based on non-radioactive substances. Not until immediately prior to their clinical application in nuclear medicine are the little vials filled with a white "powder" actually transformed into radioactive drugs for use in the diagnosis of different diseases.

But ROTOP is also in the business of marketing drugs that are produced at HZDR's Institute of Radiopharmacy, like, for instance, the approved "GlucoRos" – a drug based on a specific glucose molecule that is labeled with a short-lived radionuclide and with whose help tumors can be both diagnosed and studied, and "NaFRos" – a drug used to detect bone metastases. The Institute's Director, Jörg Steinbach, is very happy about that: "Thanks to this collaboration, the center is able to not only secure additional research grants but also to very quickly turn the actual research findings into direct benefits to the patient." ⊣

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// Markus Schubert receives a “Starting Grant“ by the European Research Council. The young scientist plans to use the 1.2 million Euro grant to contribute fundamentally new and important insights that will benefit the chemical industry.

FIRST-EVER EUROPEAN “STARTING GRANT“ AT HZDR

Text . Anja Weigl

TRANSLATION . Dennis Schulz

CONVINCED: Markus Schubert is a methods engineer and the first HZDR researcher to receive a European Research Council “Starting Grant.“

“It is definitely something quite special – being awarded a European Research Council, an ERC, Starting Grant,“ explains Rainer Maletti, head of the Program Planning and International Projects Department at HZDR. Markus Schubert did what thus far no other HZDR scientist was able to do: on April 24 in Brussels, Belgium, he successfully presented his research proposal, which is aimed at an examination of the internal fluid dynamics that take place inside chemical equipment.

“Many of our everyday products and goods like low-sulfur fuels or plastics rely on these types of chemical reactors for their manufacturing processes,“ Markus Schubert explains. “But what it is that’s actually happening during these processes is something nobody quite understands – given the mostly pressure-resistant walls of the fluid containers themselves which are virtually impenetrable. Is the flow field configured in such a way that the process runs optimally? There is a definite gap in our understanding here, which we are looking to fill. Using novel experimental methods, we hope to shed light on the fluid dynamics in these types of reactors and use that knowledge to continue to develop appropriate simulation models.“

In the meantime, the European Research Council Executive Agency has drawn up and co-signed a contract with HZDR, which outlines the conditions and specifications of the research grant. “It allows Mr. Schubert to conduct his research without any restrictions, and to make autonomous decisions, like, for instance, picking his own staff,“ confirms Rainer Maletti who is intimately familiar with the whole gamut of grant options available to scientists, as he explains the idiosyncrasies of this particular European program tailored to young researchers. With the help of this grant – close to 1.2 million Euros in four years – Markus Schubert is finally able to put together his own research team.

A mere five years ago, he could have scarcely imagined his present-day success. At that point, he had just assumed his first post-doc position at HZDR. Now, he supervises his own PhD and other students who are working on various individual projects. Somewhere in there, he also managed to fit in a year conducting research as a guest scientist at Laval University in Québec, Canada.

Markus Schubert works at the HZDR‘s Institute of Fluid Dynamics, where processes involving complex flows are an important research emphasis. Until now, the scientists have focused on dynamics that play an important part in energy technology. In order to investigate the fluiddynamic processes in chemical plants under industry-like conditions, Markus Schubert is for now focusing his efforts on a highly specialized type of facility called a bubble column reactor. Inside it, gas is being distributed as evenly as possible and induced to react. A real “home-turf advantage“ for the young researcher are the many different kinds of measurement techniques the Institute has available for visualizing fluid dynamics. For his project, he plans on using high-speed tomography X-ray radiation. “In the end, it‘s all about making contributions to how such processes and facilities can be optimally designed to increase profits of the desired products while, at the same time, saving both resources and energy.“ ┤

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↗ http://erc.europa.eu/starting-grants

// Shengqiang Zhou is head of a Helmholtz Young Investigators' Group at HZDR that is currently researching novel magnetic semiconductor materials for future information technology. His contributions to this field recently earned him the prize of the international conference IBMM 2012.

INTERNATIONAL AWARD FOR SHENGQIANG ZHOU

Text . Christine Bohnet TRANSLATION . Peter Gregg

The 36-year-old physicist Shengqiang Zhou has been living in Dresden since 2005, where he first worked at HZDR as a PhD student of TU Dresden. He was working on implanting magnetic ions into zinc oxide to endow the semiconductor with new properties. At the time, zinc oxide – a completely harmless substance used in medical creams for example – had gained interest as a possible player in novel memory media for computer technology. Zhou discovered, however, that it is more difficult than expected to functionalize zinc oxide with specific magnetic properties. His findings, published in Applied Physics Letters in 2006, have accordingly been cited many times since.

After completing his doctorate, Shengqiang Zhou continued his research on the magnetic properties of materials as a postdoc at the HZDR, this time concentrating on more conventional semiconductors. "My dream is to advance these materials used in present-day micro- and nanoelectronics, that they may one day become magnetic semiconductors in a new generation of memory materials. My group and I are employing various methods in our experiments, including ion beam technology, for instance, to synthesize magnetic semiconductors or controllable magnetic nanoparticles targetedly into the surfaces of germanium and silicon," Zhou explains.

RECOGNIZED: Recipient S. Zhou (left) heads the HZDR's first-ever Helmholtz junior scientist group (left to right: W. Luo, Y. Wang, D. Bürger, S. Prucnal, and K. Gao).

After a one-year interruption to work as a research professor at Beijing University in China, Shengqiang Zhou returned to HZDR to head the Young Investigators' Group "Ion beam processed functional materials for spintronics and photovoltaics". This group is funded by the Helmholtz Association. In addition to extensive experimental and analytical facilities at the Rossendorf Ion Beam Center, Zhou and his Young Investigators' Group have access to the outstanding experimental conditions of the "HZDR Beamline" at the European Synchrotron Radiation Facility (ESRF) in Grenoble, France.

Distinguished in China

The HZDR researcher Shengqiang Zhou was awarded the IBMM Prize at the eponymous conference in Qingdao, China, held from 2 to 7 September 2012. This was the first time the conference was held in China. The prize, which comes with a 1,000 dollar cash award, is given every second year to an outstanding junior scientist working in the field of ion beam modifications of materials – which is what the acronym IBMM stands for. The IBMM Prize 2012 acknowledges Zhou's work on the implementation of ion beams for magnetic semiconductor materials as well as his careful analyses of the underlying physical mechanisms. Around 300 materials scientists and physicists interested in ion-solid interactions and their technological applications were present at the IBMM 2012.

LITERATURE

Dr. Zhou has produced a series of well-published scientific papers, such as the work mentioned earlier, appearing in Applied Physics Letters (DOI: 10.1063/1.3048076). Two of his papers have been cited even more often:

(1) "Crystallographically oriented Co and Ni nanocrystals inside ZnO formed by ion implantation and postannealing", in Physical Review B, vol. 77/3 (DOI: 10.1103/PhysRevB.77.035209)

(2) "Fe implanted ferromagnetic ZnO", in Applied Physics Letters, vol. 88/5 (DOI: 10.1063/1.2169912)

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THE “GREEN CAMPUS“ ROSSENDORF

Text . Peter Joehnk

TRANSLATION . Sarah Gwillym-Margianto

Back in 1972 the “Club of Rome“ was already talking about the fact that the limits to growth had been reached and that we should now be looking at securing resources for future generations. Last year the German Federal Government introduced guidelines for the self-commitment of firms and institutions to sustainability in line with the German sustainability code and now there is increased pressure from the expectations that as many organizations as possible (particularly those that are publicly-funded) will foster this code of sustainability in an effort to save resources. The “Green Campus“ has been developed to this end almost as a marketing idea for universities and research centers that are competing for the best ideas and talents. One might assume that this kind of approach comes from the USA – and as far as the marketing is concerned, this assumption is probably true. The concept of “sustainability“, however, was more likely to have been invented in Saxony: As early as 1713 chief mining officer Hans Carl von Carlowitz formulated this idea in his work “Sylvicultura oeconomica“ with the suggestion that only so much timber should be harvested as would be able to grow back through planned reforestation.

The Helmholtz-Zentrum Dresden-Rossendorf has been incorporating and realizing sustainability aspects into its various programs for over ten years, even if the term “green campus“ is still a fairly recent addition to our vocabulary. The master plan for the development of the center is a prime example of how one can realize construction with limited land consumption, restore land, modernize the heat supply, use renewable energies, encourage traffic calming, create a cyclist-friendly environment, manage rainwater and improve waste water disposal all in one master concept that not only reduces overheads but also leads to a noticeable improvement of the environment.

Incidentally, as a result of its new architectural improvements, the center has become considerably more attractive and one can only begin to imagine what it will be like after the remaining restoration work has been completed. All of this can be read in a brochure to be published by the HZDR in September. Following on from the ten-year master plan for Dresden-Rossendorf, the next steps for the years to come now need to be defined just as the master plan needs to be updated. This will include further steps towards optimizing the large cost pools of heat energy and electrical energy as well as providing “user guides“ for a more efficient operation of the buildings. But there will also be questions to answer: What kind of a research center do we want to be? What can we offer our employees and visitors –in addition to our excellent scientific facilities? The American marketing ideas have caught up with us, and in striving to attract the best employees we will also have to answer questions about the best work climate in the field of research.

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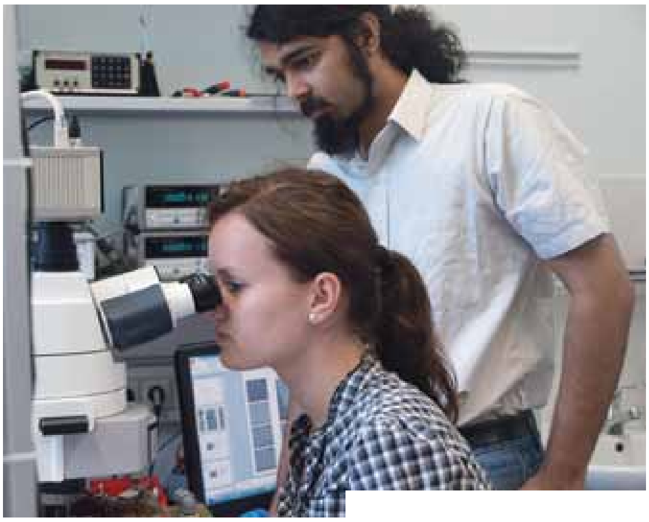
ON TWO WHEELS: Site development includes the traffic concept “biker-friendly.“ In addition to providing facilities for parking bikes and separate biker entrances and exits, a special bike lane was created from the federal highway to the Center.

A summer spent in the lab



Ewa Kowalska from Poland is one of this year's ten summer students. Here, she is seen examining materials using the Kerr microscope for boundary magnetism research with support from Rantej Bali.

Between July and September 2012, a group of ten students from Europe, Asia and Africa have been doing work at HZDR. The students were picked by a panel of referees and are part of a new international studies program here at the center. As part of the program, students are able to work on current research topics, ranging from radio-therapeutics and radiation physics to nanostructures and materials research and covering the breadth of HZDR's research in the areas of health, matter, and energy.

Participants are supported by stipends amounting to 250 Euros per week as well as receiving free accomodation in the new campus guest house. The program allows students to attend dedicated lectures given by various HZDR scientists. Individual laboratory projects within the program range in duration from five to twelve weeks. At the end of the internship, each student is expected to publicly present their project they have been working on during the summer. Guided tours of the HZDR research facilities ensure that students get a true sense of the scope of research conducted at Helmholtz-Zentrum Dresden-Rossendorf.

In order to give them a chance to get to know each other as well as Dresden and the surrounding area, Michael Bussmann, Kay Potzger and Annette Weissig, who organized the program, have scheduled a number of different activities.

In a first analysis Kay Potzger comments on the new program: "The experience with the students has been a very positive one. Since participants are chosen by a panel of four scientists, they experience their internship as a recognition and are putting all of their energy into their work." Michael Bussmann adds: "So far, we are very happy with the program and, thus, have high expectations for next time."

Upcoming Events

Scientific Events 2012

September 19 - 21
8th International Symposium on Ultrasonic Doppler Methods for Fluid Mechanics and Fluid Engineering
Dresden

September 30 - October 7
3rd EuroMagNET Summer School
Island of Ruegen

October 11 - 12
Symposium of the German Nuclear Technology Society ("Kerntechnische Gesellschaft KTG")
Dresden (HZDR)

October 15 - 19
MMM 2012 – 6th International Conference on Multiscale Materials Modeling
Singapore

November 5 - 7
International Workshop on Advanced Techniques in Actinide Spectroscopy (ATAS)
Dresden (HZDR)

Exhibition Openings (start at 5 pm)

2012	**November 8**	Tim van Veh
2013	**January 10**	Reiner Tischendorf
	March 7	Bernd Kalteich
	May 2	Andreas Kunath

International Mineralogist Competition

When it comes to analyzing complex mineral mixtures, mineralogists from Freiberg, Germany, are counted among the world‘s best. During a recent competition organized by the US Clay Minerals Society, Reinhard Kleeberg of TU Bergakademie Freiberg and Robert Möckel of the Helmholtz Institute Freiberg for Resource Technology once again showed that there is much truth to this claim. Entries into the competition include scientists and commercial laboratories from all over the world. Their task is to figure out the specific kinds and amounts of different minerals contained in each of three artificial mineral test mixtures. The Freiberg scientists placed third with analyses they performed at the University’s Mineralogical Laboratory.

Crystal aggregate consisting of chalcopyrite, galenite, sphalerite, and calcite; may contain, for example, indium, germanium, and silver. Such mineral and metalliferous raw materials are in the focus of the Helmholtz Institute Freiberg for Resource Technology, which aims at developing innovative technologies dedicated to a more efficient use of those resources. Image credit: Jürgen Jeibmann

The competition is known officially as the “Reynolds Cup,“ named after famed mineralogist Robert C. Reynolds. At this point, Reinhard Kleeberg, who competed for the first time back in 2002, has become something of a veteran of the whole event. “This time around, the samples we were told to analyze were mixtures of up to fourteen different kinds of minerals, including up to six clay mineral types, which, typically, are very difficult to identify and quantify,“ explains Kleeberg. The scientists were able to stake their claim at the top of the group out of a total 57 international contestants from 25 countries.

As part of the competition, the previous year‘s winner is in charge of putting together three different mineral mixtures and sending them out to colleagues at various labs around the world that are all competing during that year. The contestants‘ job is to determine exactly which kinds and amounts of minerals are contained in each of the three samples. Not only does the Reynolds Cup allow for comparisons on an international scale - it also provides scientists with clues to apply in their own research.

To analyze the test sample, Reinhard Kleeberg, who is head of the Freiberg Mineralogical Laboratory, and Robert Möckel used an X-ray diffractometer, a scanning electron microscope, and chemical analysis, all of which allowed them to correctly identify virtually all of the different kinds of minerals contained in the samples. These instruments and methods are part of the analytical infrastructure at both the TU Bergkademie and the Helmholtz Institute Freiberg, which is operated jointly by the University and the HZDR.

Delegates from India

On July 9, 18 students and young scientists from India visited the HZDR. They came here straight from the 62nd annual Nobel Prize winner conference in Lindau near Lake Constance in Southern Germany where, this year, 27 Nobel Prize winners and 592 junior scientists from 69 countries had been invited to spend an entire week exchanging ideas, studying, and networking. Topics of interest included particle physics, cosmology as well as discussing energy and climate issues.

In order to familiarize the group – some 150 Indian junior researchers had originally applied to participate in the highly coveted event – with science and research in Germany, the DFG, the German Research Foundation, had organized a week-long program that included visits to different research facilities and universities in the Dresden, Berlin, Potsdam, and Bonn regions as well as a scheduled visit to the DFG headquarter offices.

The visit to the HZDR included tours of the Ion Beam Center and the High Magnetic Field Laboratory. The lab‘s director, Joachim Wosnitza, knew the guests, although not personally: as a member of the selection committee in India he was instrumental in selecting the candidates by evaluating their written applications. The delegates were accompanied by a journalist from India‘s largest daily newspaper, The Times of India.

The Indian delegates from this year’s Nobel Prize winner conference visited HZDR’s Ion Beam Center and High Magnetic Field Lab.

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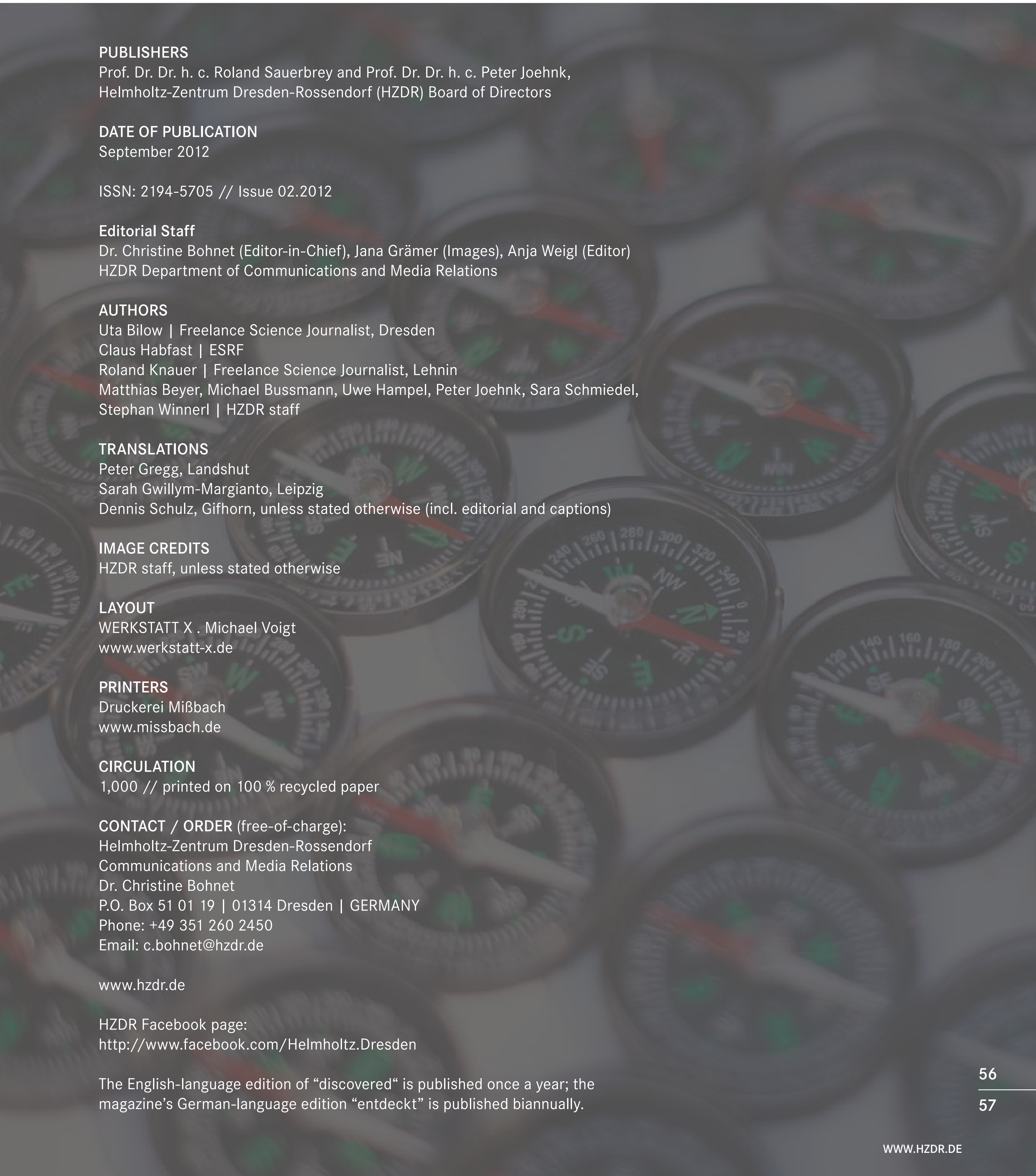

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