discovered

THE HZDR RESEARCH MAGAZINE

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Extreme Matter

RAW MATERIALS UNDER THE MICROSCOPE
Freiberg researchers are examining old tailings dams

PREMIERE AT THE DELTAX SCHOOL LAB
New set of experiments for the study of radioactivity

AND THE RESEARCH CONTINUES...
Safety and innovative fuel cycles for new nuclear reactors

HZDR

HELMHOLTZ
ZENTRUM DRESDEN
ROSSENDORF

COVER IMAGE . LANDED IN A DEFECT: If a positron meets an electron, both particles trigger energy flashes that rapidly spread in different directions in the form of hard radiation. Diagram: AIFilm

DEAR READER,

the focus of this current issue of *discovered* is ELBE, Saxony's largest research machine. Although unlike in the Elbe river, there isn't any water flowing in the HZDR's ELBE but rather electrons that are racing at 99.9 percent the speed of light through pipes, windows, and apertures. As in a switch yard, these light-weight, electrically charged particles are sent from the accelerator into one of many labs where they power different radiation sources. This allows for the generation of invisible infrared light in the terahertz range, which is so very popular with researchers, as well as X- and gamma rays or neutrons and positrons. The heart of our substantially expanded experimental center is the ELBE accelerator (the acronym stands for **E**lectron **L**inear Accelerator with High **B**rilliance and Low **E**mittance). Cutting-edge high-power lasers are also capable of effectively accelerating electrons and even protons. Over the next several years, the ELBE building will be housing the new petawatt laser system PENELOPE, and existing laser DRACO is currently being upgraded to perform at 500 terawatts. Our new Center for High-Power Radiation Sources unites these different facilities under one roof; to keep things simple, we opted to stick with the former name, ELBE.

The stories that were included in this issue - fittingly entitled "Extreme Matter" - are all about large-scale devices and the fact that matter and materials are exposed to extreme conditions of intense radiation, high pressure, low temperatures, or very strong magnetic fields. In the end, however, machines are only ever means to an end, for excellent science is always done by exceptionally talented people. This current issue of *discovered* introduces you to a few of them at our major user facilities.

Meet Liz Green, a young American physicist, who, as the High Magnetic Field Lab's local contact, is in charge of supervising external users like Cedomir Petrovic. Wolfhard Möller, on the other hand, is a highly renowned Professor Emeritus. Read an interview with him about the EU project SPIRIT and how it helped keep the HZDR's Ion Beam Center open for business. Möller's efforts have benefitted Andreas Kolitsch, CEO of HZDR Innovation GmbH, as they have allowed him to offer up unique, ion beam based services to industry.

Find out about our liquid sodium research platform DRESDYN and learn that the attribute "extreme" is not an exaggeration when talking about an experiment. An interview with DRESDYN's Frank Stefani and Peter Kaever offers the reader exciting glimpses into the unexpected hurdles and major challenges that must be overcome in the planning and set-up of these types of experiments. Unlike ELBE and the Dresden High Magnetic Field Laboratory, both of which are currently undergoing substantial expansion as part of our future projects initiative, DRESDYN has to be re-invented, re-calculated, and re-simulated from scratch. All of them tasks that can prompt many a sleepless night.

Wishing you a refreshing read

Yours,

Christine Bohnet
Communications and Media Relations

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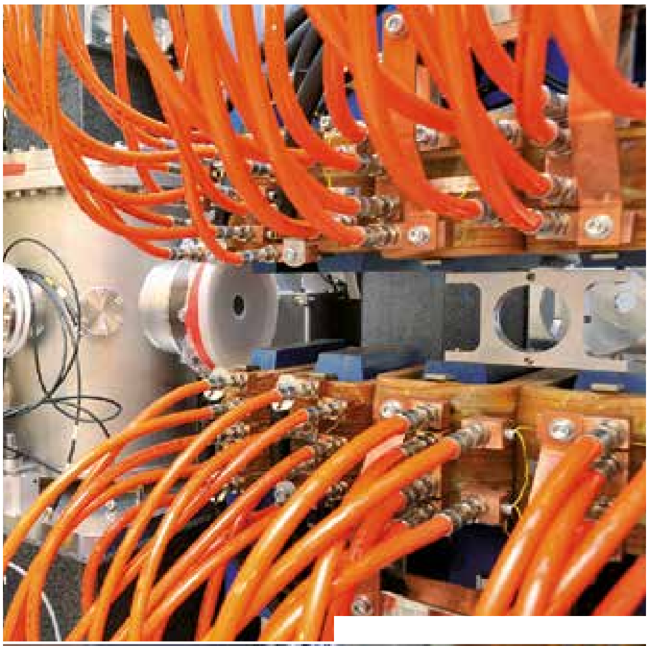
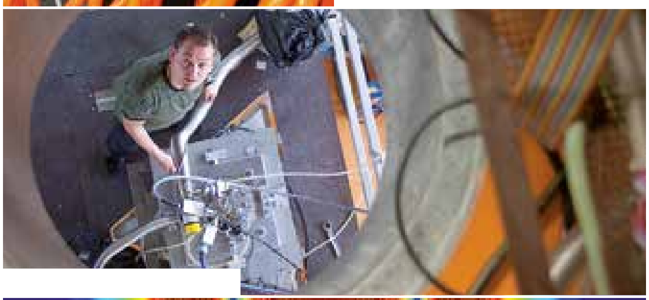
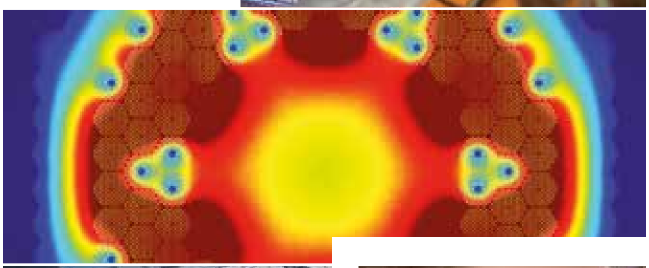

// Quanta, antiparticles, neutrons, and more.

THE HEART OF THE ELBE: In an effort to enhance experimental options at the new Center for High-Power Radiation Sources, electron pulses from the electron accelerator that has been in operation for years have to be shortened and intensified by an entire order of magnitude. The electrons are used by the two free electron lasers, two new terahertz sources, as well as for the facilities for the generation of gamma and X-rays, positrons, and neutrons.
Photo: Frank Bierstedt

THE NEW ELBE

_TEXT . Roland Knauer

The photoelectric effect was first described back in the 19th century and no other than Albert Einstein himself offered a theoretical explanation for it in 1905: When a particle of light has sufficient energy, it is able to knock electrons out of an atom. Yet the most popular physicist of all time could scarcely have imagined how the photoelectric effect would one day prompt the development of large-scale scientific facilities, like ELBE – the Electron Linear Accelerator for Radiation of High Brilliance and Low Emittance – one of the Helmholtz-Zentrum Dresden-Rossendorf's pillars. Here's how ELBE works: Initially, laser light shoots electrons out from a semiconductor and accelerates them to almost the speed of light by exposing them to very strong electric fields. Next, the electrons start to emit different forms of radiation, from positrons and neutrons to infrared light and gamma rays. And because the electron accelerator is based on superconductor technology, there isn't any need for a cool-down period. Instead, the facility continuously delivers pulses of a half a billion electrons each within a closely bundled beam, which offers unparalleled research options. →

"In addition, our electron beam can be coupled to a high-intensity laser," explains Peter Michel, head of ELBE. In this way, the researchers are able to produce brilliant X-ray light similar to modern-day synchrotron sources albeit in a smaller space. Furthermore, lasers are capable of greatly accelerating particles and the goal is to further increase their energy. This could mean compact laser accelerators that are considerably smaller than conventional facilities for cancer patient irradiation. The basic idea: the scientists accelerate hydrogen nuclei off of a foil surface. The protons that are produced are slowed down as they pass through an organism's tissues and explosively emit a large burst of energy before getting stuck. Physicians could potentially focus the rays to target the tumor while sparing the surrounding tissues in the organism's more highly sensitive, vital parts like the brainstem. True, the HZDR experiments are currently performed only on cell cultures - but they do set the stage for important improvements in cancer therapy. Although, admittedly, Einstein couldn't possibly have conceived of their tremendous potential.

FREE ELECTRON LASER: Researchers are using intense flashes of light produced by two free electron lasers to study material states at the atomic level. Photo: Frank Bierstedt

One simple push of the button

On February 28, 2013, Saxony's Minister President Stanislaw Tillich officially inaugurated the new ELBE Center for High-Power Radiation Sources. "My hope is that the new center's unparalleled experimental facilities will help generate outstanding research findings. Both Dresden's and Saxony's scientific landscape will benefit from this as much as the economy and, by definition, all of us will."

With the entire ELBE staff present at the ceremony, Minister President Tillich and ELBE director Peter Michel together pushed the button that gave the official signal for research to commence in the newly expanded building. The new ELBE is supported by funds totaling 55 million Euros, 34 million of which are contributed by the Free State of Saxony.

Saxony's Minister President Stanislaw Tillich inaugurating the new Center for High-Power Radiation Sources together with the HZDR's Scientific Director Roland Sauerbrey (right), Peter Michel, the head of ELBE (second from the left), and Administrative Director Peter Joehnk (left). Photo: Oliver Killig

The Minister President took the occasion to personally tour the new lab facilities including the new terahertz source, which will allow for extensive research opportunities that are not limited to HZDR researchers alone. Like all the other guests, Tillich had to don protective clothing when touring the high-power laser DRACO as not a spec of dust is allowed to come into contact with the highly sensitive laser optics.

At the HZDR's annual reception which followed, Tillich was quick to point out ELBE's great versatility. "ELBE is the biggest research facility in all of Saxony. Along with the building expansion, the center's international renown has also increased. This kind of leading research activity with its potential for attracting top researchers from all over the World is just what Saxony needs."

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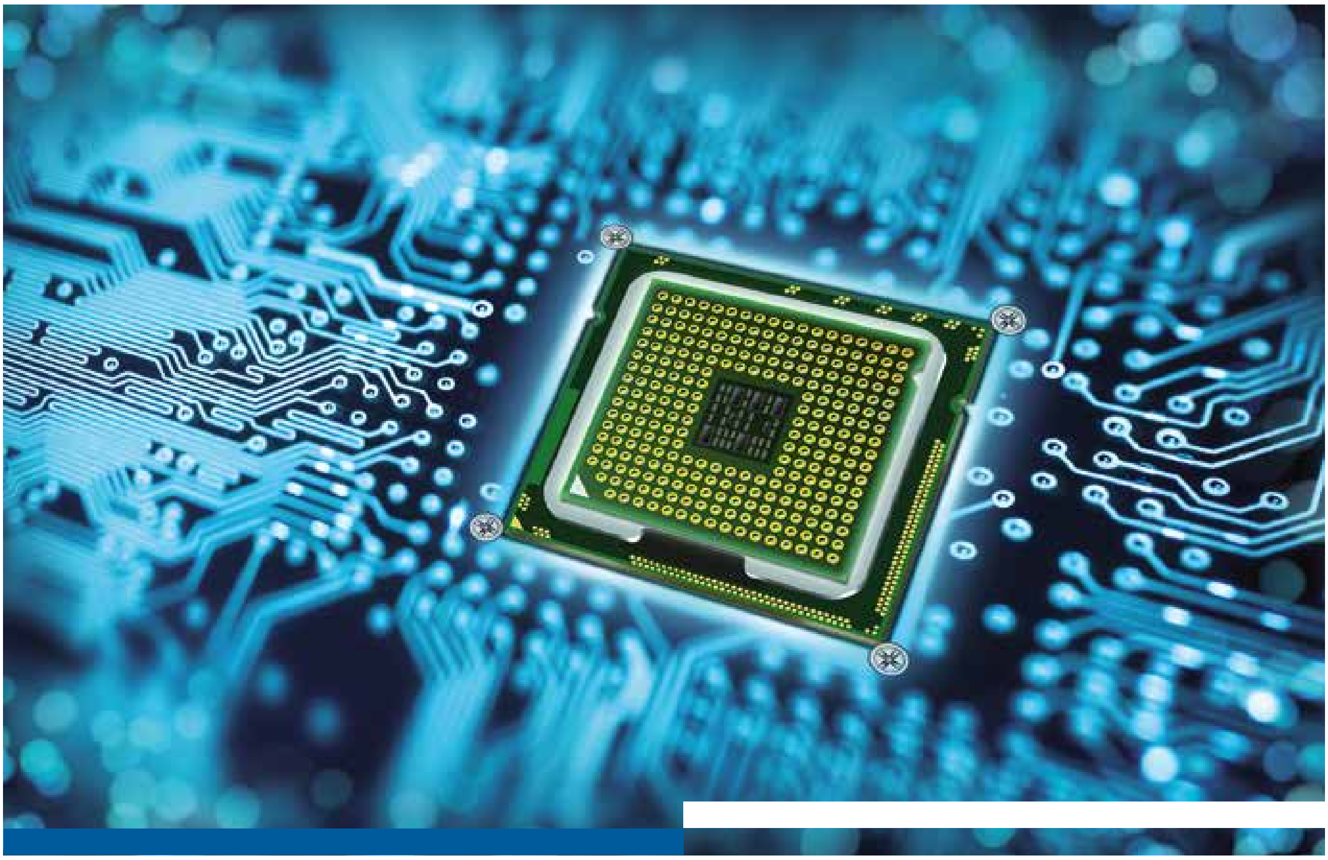


FASTER PROCESSORS: Tiny defects speed up the switching processes of computers and mobile phones. These holes or imperfections lend themselves extremely well to study at the EPOS positron source to yield important clues for improving modern materials. Photo: edelweiss – fotolia.com

DEFECTS FOR THE FUTURE

_TEXT . Roland Knauer

// Positron source EPOS measures irregularities in semiconductors, solar cells & Co.

Whenever Andreas Wagner of the Institute of Radiation Physics at the Helmholtz-Zentrum Dresden-Rossendorf says he is interested in defects, he usually provokes confused looks on the part of lay people. Solid state physicists, on the other hand, know immediately what he's talking about: minute defects in solids, like when individual atoms have gone missing. Such defects influence the properties of materials like solar cells but they can be examined only with great difficulty. Andreas Wagner is the man in charge of the positron facility EPOS, which allows for the analysis of solid state defects.

To better understand this method, let's take a closer look at the structure of atoms. The atomic nucleus is made up of positively charged protons and uncharged neutrons. At a considerable distance from the nucleus, the significantly smaller-sized electrons, which carry a negative electrical charge, are orbiting about the atomic nucleus. Normally, the number of electrons equals the number of protons in the nucleus so that their charges cancel each other out, giving the atom an overall net charge of zero.

If, because of some defect, an atom gets lost from a solid, the positively charged atomic nucleus is now missing, which leads to re-arrangement of the electrons. As such, there are a few more electrons in the defect's immediate vicinity than in the undisturbed areas. "In these types of defects, the missing tiny positive electrical charge acts like a vacuum →

cleaner on the positrons," explains Wagner. After all, positrons are the electrons' sister particles with largely identical properties except for the fact that they are positively instead of negatively charged. But since opposite electrical charges attract, positrons are being sucked in by the defect's partial negative charge.

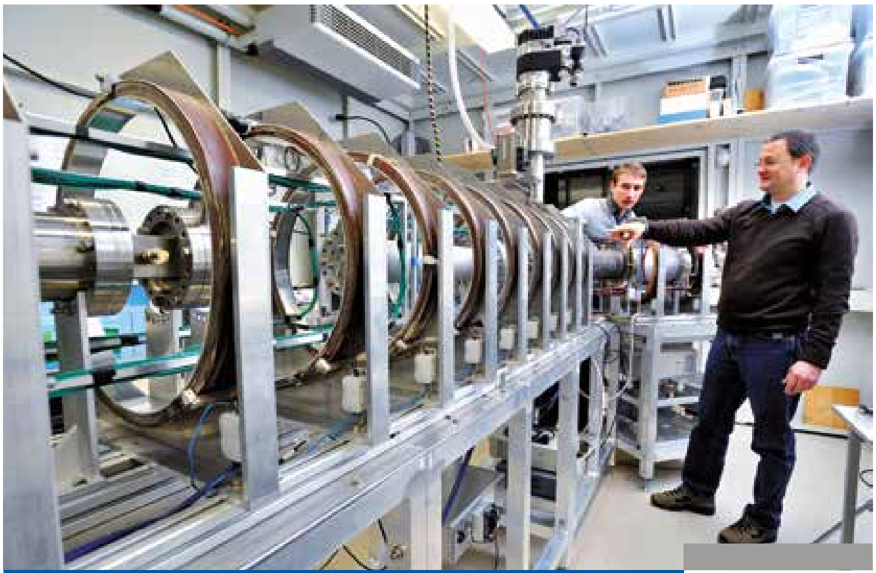
Once the positrons have made it to the defect, the positively charged atomic nuclei in the area repel the tiny, positively charged positrons, encapsulating them. This "captivity," however, isn't a permanent one: If a positron encounters an electron, the fate of these two oppositely charged but otherwise largely identical elementary particles is sealed and they dissolve in two or three bursts of energy that rapidly dissipate in different directions at the speed of light in the form of hard radiation. "We are calling this mutual annihilation," explains Wagner.

Positron life time

But the physicist is only marginally interested in the energy of the annihilation flashes, which is known to be 511 kilo electron Volts (keV) for each of the two resulting flashes. "Instead, we analyze the positrons' lifetime - the time it takes from their creation to their annihilation," explains Wagner. Their typical lifetime lies somewhere between one tenth and one hundredth of a billionth of a second and depends, to a large extent, on defects in the material. What do these defects look like and how many are there? Which is why, upon closer scrutiny, the time distribution until positron deradiation can tell scientists a thing or two about the nature of the defect. As such, the positrons turn out to be a good way of analyzing vacancies and other defects, even though they won't allow you to actually see them.

But what is the source of positrons produced at the HZDR's EPOS facility? One important hint is built into the acronym, which stands for **E**LBE **Po**sitron **S**ource or the Positron Source at the **E**lectron **L**inear Accelerator for Radiation of High **B**rilliance and Low **E**mittance (or, as it were, ELBE for short). If this electron beam hits solid material, the tiny particles begin to decelerate. In the process, they emit energy in the form of X-ray radiation. Contrary to how the mutual annihilation of positrons and electrons is able to generate two X-ray flashes, a tiny quantum package of this bremsstrahlung in a vacuum is capable of producing a pair consisting of one electron and one positron. But this only works if a nearby atomic nucleus →

SISTER PARTICLES: Positrons are similar to electrons, although they carry a positive rather than a negative charge. They are attracted by excess electrons in the material defects and are thus the perfect tool for defect analysis.
Photo: Frank Bierstedt



UNDER SCRUTINY: The HZDR facility for positron experiments offers scientists Andreas Wagner (right) and Maik Butterling the option of a much more precise analysis than do other positron sources. Photo: Frank Bierstedt

actually takes up this X-ray quantum's impulse: At the HZDR, this job is performed by a Tungsten sheet. The resulting positron beam consists, just like the ELBE electron beam, of short pulses between five and ten trillionth of a second in duration and that, compared with other positron sources, are sharply delimited. This means the researchers know more exactly how much time it takes the positrons to be created and determine their lifetime with greater precision than with the help of other positron sources. "In short, the defects can be analyzed much more precisely with the help of EPOS positrons than at other facilities," explains Reinhard Krause-Rehberg of the Martin Luther University in Halle, Germany, who was instrumental in EPOS' development.

Fast processors, efficient catalysts, and robust materials

There is a wealth of materials that are needed for cutting-edge technologies and whose structure can be explored and, in the end, even improved with the help of positrons. One example is silicon dioxide, a key component of modern-day computer processors - even though moving electrical charges through this material is decidedly difficult. This, however, significantly slows down the switching mechanisms that take place continuously and at a high frequency inside a processor. In fact, if one were able to lower the dielectric constant, a processor would be notably faster. Material scientists are able to make this happen by incorporating tiny holes approximately one millionth of a millimeter in diameter directly into the material. This produces a kind of microsponge with a significantly lowered dielectric constant. And these tiny holes can again be nicely examined with the help of positrons and their annihilation.

Membranes with this type of microsponge structure play a critical role in catalysts that are key components of many different chemical reactions. However, they only work if the tiny holes are interconnected to permit the flow of fluids. And again EPOS' positron beam allows for a close analysis of these defects, which in turn allows scientists to conclude whether the membrane will perform its job reliably.

The energy of the X-ray flashes that are produced in the course of annihilation is not always exactly 511 keV. As such, if the positron meets an electron that orbits around an atomic nucleus, depending on the atomic nucleus and orbit, this electron has a precisely measurable energy. This energy, however, is also taken up by the annihilation flashes, which changes their keV values. Using these new keV values, the researchers are able to analyze the chemistry in the defect's immediate vicinity to obtain valuable information about the material they are studying.

EPOS could potentially also play an important role in an energy source that has been under development for a number of years now: nuclear fusion. Here, light-weight atomic nuclei melt together into heavier ones and, in the process, give off massive amounts of usable energy. Scientists all around the world are still puzzling over the specifics underlying this fusion reaction. What they do know is it results in neutron production. Over time, these rather heavy uncharged elementary particles shoot defects into the steel wall of such a reactor, which means the metal atoms have a harder time gliding past each other and the steel becomes brittle and could, in extreme cases, break or tear. With the help of EPOS positrons, however, Andreas Wagner is able to study the origin of these kinds of defects. This knowledge could help with developing a type of long-lasting steel that won't get brittle as quickly in the face of high neutron flow in these types of fusion reactors. ELBE positrons could thus play a key role in the development of a number of important future materials.

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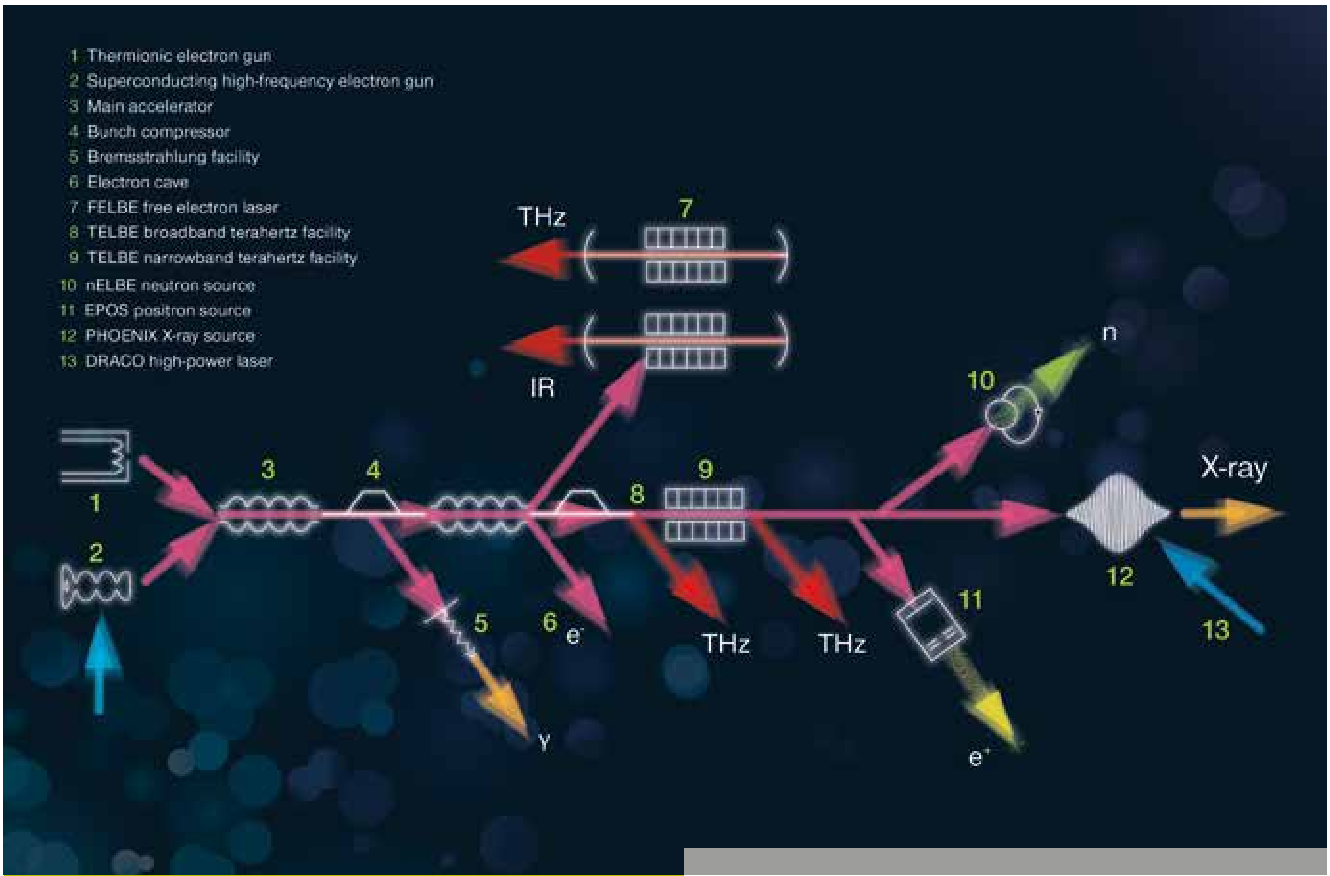
SMALL BUT BRILLIANT: THE HZDR'S NEW X-RAY SOURCE

_TEXT . Anja Weigl

PHOENIX: Inside this new experimental chamber prototype, laser researchers are focusing light emitted by high-power laser DRACO on the ELBE accelerator's electron beam. Ph.D. student Josefine Metzkes is adjusting the mirror for an experimental setup. Photo: Frank Bierstedt

// Brilliant X-rays are in demand - in the most varied of scientific disciplines. They allow for ever deeper insights into the structure of materials, cells, molecules, and atoms as well as biological, chemical, and physical processes of an extremely short duration. New X-ray sources are popping up all over the place, including at the HZDR, where researchers have successfully coupled an accelerator-powered electron beam with intense high-power laser light at the new PHOENIX X-ray source. The result: brilliance.



UNIVERSAL DEVICE: Electrons | *pink* | from the ELBE particle accelerator are converted into light in the infrared and terahertz range | *red* |, into X- and gamma rays | *orange* | and into neutrons | *green* | and positrons | *yellow* |. The PHOENIX facility for extremely short-wave and intense X-ray light (12) is one of the latest developments at the ELBE. X-rays are produced by coupling electrons and light | *blue* | from a high-power laser.

ELBE, the HZDR's new Center for High-Power Radiation Sources, combines two high-intensity lasers with an electron linear accelerator that produces a whole spectrum of secondary radiation. And you could take this quite literally: The building recently underwent extensive expansion and at this point offers optimal conditions for coupling laser light and the ELBE electron beam to produce brilliant, hard X-rays to allow for the in-depth study of matter. Ph.D. student Axel Jochmann's and scientific associate Dr. Arie Irman's research group registered its first major success back in September 2011. Still, it wasn't quite perfect as the vacuum chamber that was set up for the experiments was intended as a prototype and first and foremost was meant to demonstrate the project's feasibility - which the junior researchers →

successfully realized. By now, they have moved into their own experimentation room - a "Cave" - in the new ELBE building. They also expanded their facilities by adding a second, new and improved experiment chamber.

X-ray light can be produced by alternately accelerating and decelerating electrons; during the process, the electrons give off a small portion of their energy in the form of photons, or light particles. Current light sources continually repeat this process by getting the electrons to vibrate regularly. To do so, they guide them through specially arranged magnets called undulators. An alternative to using these devices is to use short, intense light pulses like the ones produced by the HZDR's DRACO and PENELOPE lasers to "optically" vibrate the electrons. The laser pulses' short wavelength determines the electrons' movements and they in turn determine the wavelength of the X-ray light emitted by the electrons every time they change direction. Its wavelength is around 800 nanometers but relativistic effects act to further decrease it to 0.1 nanometers. Since this corresponds to the intramolecular distance between atoms, researchers are able to study the structure of matter at the atomic level. The light pulses' extremely short duration, which is transmitted equally to the X-ray photons - and which is found in the range of one picosecond to one hundred femtoseconds, one trillionth and one hundred quadrillionths of a second, respectively - makes fast processes accessible.

Just like synchrotron radiation

"The X-ray light we produce has properties that are very similar to modern-day synchrotron light," explains Thomas Cowan, Director of the Institute of Radiation Physics. Since interactions between photons and electrons are occurring across much shorter distances - that is, the wavelengths of light - than the mechanically delimited distances between the undulator's magnets, the overall dimensions of the HZDR's X-ray source PHOENIX (**PHO**ton **E**lectron Collider for **N**arrow Bandwidth **I**ntense **X**-Rays) are noticeably smaller. Axel Jochmann points to a tiny spec on a blueprint of the not-quite-finished experiment chamber in the new Cave. Here, the electron beam enters from the side and the laser light from below in order to get them to collide. "What we're talking about here is an area of a few square micrometers," says Jochmann. The chamber itself will be approximately six meters in length and less than two meters in width, and will be cloaked in aluminum with several windows that can be opened. That is the scale of the experiments the laser researchers are looking at - they are referring to their setup as "table-top" - experimental stations on more or less large laboratory tables.

The high degree of precision the scientists are having to work with is almost unfathomable: "We have to precisely focus both research facilities spatially onto a spot the diameter of a single hair and with a precision on the order of one picosecond," Jochmann explains. The laser pulse and electron beam, which in turn is made up of even smaller electron bundles, are very densely packed. "They each contain some 500 million electrons and over one quadrillion light particles," says the Ph.D. student. "With each pulse, we are able to generate some 100 million X-ray photons. That is, if we use the new superconducting electron source, which allows for a higher electron density than previous sources."

Preliminary experiments for Helmholtz Beamline at XFEL X-ray laser

Going forward, the perfect synchronization of laser and electron beam at the HZDR is also supposed to be used to prepare experiments at the planned Helmholtz International Beamline for Extreme Fields (HIBEF) at the European X-ray laser XFEL, which is currently under construction at the Hamburg-based accelerator center DESY. The goal for the beamline is to combine brilliant X-rays with high-power laser light. "This would allow us to conduct experiments in new research areas, giving us unprecedented scientific opportunities," says Cowan, who heads the international user consortium in charge of setting up the beamline. This way, certain structural biological or geophysical processes can be examined by activating probes using intense laser light and, immediately thereafter, examining them under bright X-ray light. By the time XFEL will be sending out its first X-ray flashes in 2015, the HZDR's X-ray source is also supposed to be operational again. "We expect that the demand will be high for conducting experiments at both the XFEL laser and at the Helmholtz beamline – plus it'll be very costly. Which is why we want to prepare it perfectly by pouring our collective know-how into the whole affair," says Cowan.

Jochmann is already thinking one step ahead. "At our X-ray source, we have the option of combining the laser beam with laser-accelerated electrons." What this means is entirely new technical dimensions because in that case you could do without large-scale accelerator facilities, and that vision is appealing from a business point of view as well. In other words, for laser researchers like Jochmann the playing field remains impressively big.

LITERATURE

A. Jochmann, A. Irman et al.: "Operation of a picosecond narrow-bandwidth Laser-Thomson-Backscattering X-Ray source", in Nuclear Instruments and Methods in Physics Research (2013), Section B: Beam Interactions with Materials and Atoms (DOI: 10.1016/j.nimb.2013.01.065)

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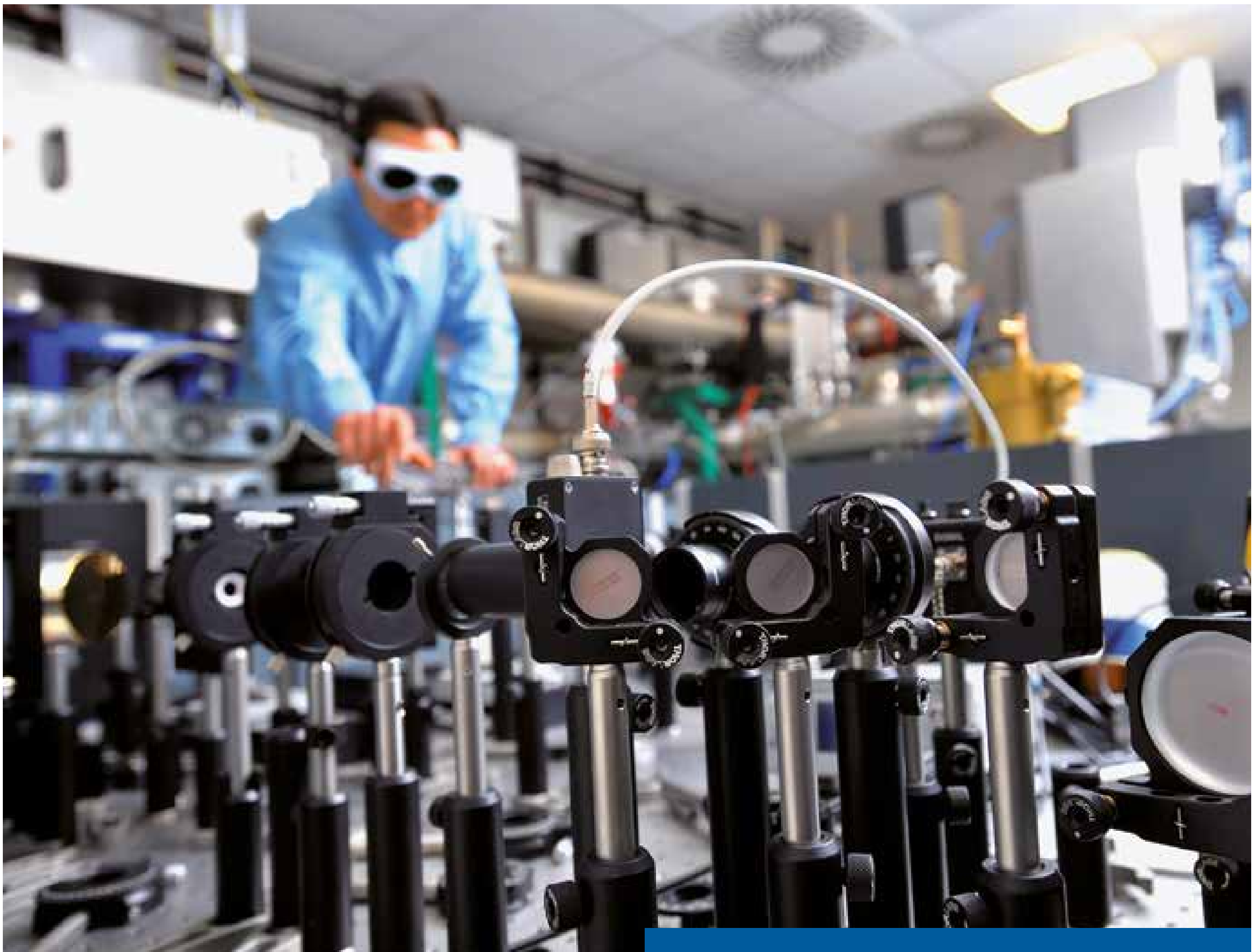
// For many years, intense pulses in the invisible terahertz range have provoked much interest among scientists, because of this longwave radiation's rather unique properties. At the present time, the strongest terahertz pulses are produced by using electron accelerators as drivers.

SUPERRADIANT TERAHERTZ SOURCE

_TEXT . Christine Bohnet



DIAGNOSTIC LAB: Going forward, innovative types of experiments using terahertz radiation can be performed in this ELBE lab. Photo: Frank Bierstedt

A recent addition to the ELBE Center for High-Power Radiation Sources is a unique terahertz facility. Terahertz radiation is invisible as its wavelength far exceeds that of the visible light spectrum, bridging the gap between distant infrared light and microwaves. In contrast to X-rays, it is non-ionizing and therefore safe for humans. The HZDR already has two strong free electron lasers in the terahertz range, both of which emit radiation of a precisely defined wavelength - in other words, in just one color; the wavelength can be freely selected. The new TELBE source extends the spectral range of the terahertz radiation that is available at the ELBE Center →

by an entire order of magnitude and is meant to significantly expand experimental opportunities for internal and external researchers.

Why is terahertz radiation so popular? At wavelengths of 0.03 to three millimeters, this light is particularly well suited to trigger or study reactions of matter. Researchers from the life sciences are dreaming about using terahertz radiation to study key organismal processes like the conduction of nerve impulses or the processing of different stimuli. And accelerator experts are hoping to use terahertz facilities to measure the temporal characteristics (e.g. arrival time and duration) of the ultra-short electron pulses.

Accordingly, the new HZDR facility is set up as a precise diagnostic laboratory for electron pulses that are produced by the ELBE accelerator, given that the latter will soon yield more highly-charged and shorter electron pulses than was previously the case. Electron pulses with those features are also the reason why a superradiant terahertz source is even possible in the first place at a comparatively small electron accelerator like ELBE. Simply put, superradiance means high-intensity light is produced in an avalanche-like, short process without the need for mirrors as resonators - as is the case with a free electron laser. Provided that the accelerator physicists are able to reach the predetermined parameters, going forward, TELBE will cover the entire spectrum all the way from the gigahertz range up to 3 terahertz or from three millimeter to 0.1 millimeter wavelength with still more intense pulses. In case they are successful, TELBE is supposed to become an international user facility for materials and life sciences researchers in the future. Here, another benefit TELBE has to offer comes into play: it was conceived for continuous operation. "With the help of this facility, and in contrast to all the other comparable machines, a continuous-wave operation is a real possibility," explains physicist Michael Gensch. "Other sources have to take a break on the order of a few thousandths of a second after every short series of ultrashort flashes. Our superconducting electron accelerator, however, renders these interruptions superfluous and allows for a continuous-wave operation."

Successful start-up of operations

Michael Gensch's machine passed its first radiation time in March 2013 with flying colors. Physicist colleagues from DESY had traveled all the way from Hamburg where one of TELBE's "competitors" is located: The FLASH free electron laser's terahertz source. Gensch views this pilot facility as a model for TELBE, however, his radiation source - and this is the main challenge - is supposed to be powered by electrons from a much smaller accelerator across a very short distance. But although, just like the costs, the dimensions of the Dresden project are also moving within entirely different orders of magnitude, the plan is to be able to keep up with the global accelerator community after all. "In the Helmholtz accelerator research and development program, we are collaborating with the big players DESY and KIT, the Karlsruhe Institute of Technology. What's also important for us is the close collaboration with international partners from the two big US national accelerator labs, SLAC and Jefferson Lab, as well as with the PTB, the German national metrology institute. Our common goal with the PTB is to develop methods that will allow us to precisely determine our terahertz flashes' energy. Because in this spectral range, this is a thus far unresolved task."

TERAHERTZ: The new facility emits radiation over a wide range of wavelengths, expanding the electromagnetic spectrum available at the ELBE. Photo: Frank Bierstedt

For Gensch and his HZDR colleagues, the next important step on the road to a prestigious light source of the future is to shorten and intensify ELBE's electron pulses by more than one order of magnitude. As such, they want to gradually start operations and test TELBE with the support of partners and pilot users. "We have a long road ahead of us in terms of development and are hovering at the border of that which is technologically feasible. Our hope is to be able to decide, by 2015, whether or not TELBE is actually operational as a regular experimentation facility," explains Gensch. And, he adds, "either way, we're looking at an internationally unique facility for the study of electron pulses and development of concepts for the operation of large-scale research facilities like the European XFEL in Hamburg."

LITERATURE

F. Tavella, N. Stojanovic, G. Geloni, M. Gensch: "Few femtosecond timing at 4th generation X-ray lightsources", in Nature Photonics, vol. 5 (2011), p. 162 (DOI: 10.1038/NPHOTON.2010.311)

M. Foerst et al.: "THz control in correlated electron solids: sources and applications", in K.-E. Peiponen et al. (eds.), Terahertz Spectroscopy and Imaging, vol. 1, Springer-Verlag Berlin Heidelberg 2012 (DOI: 10.1007/978-3-642-29564-5_23)

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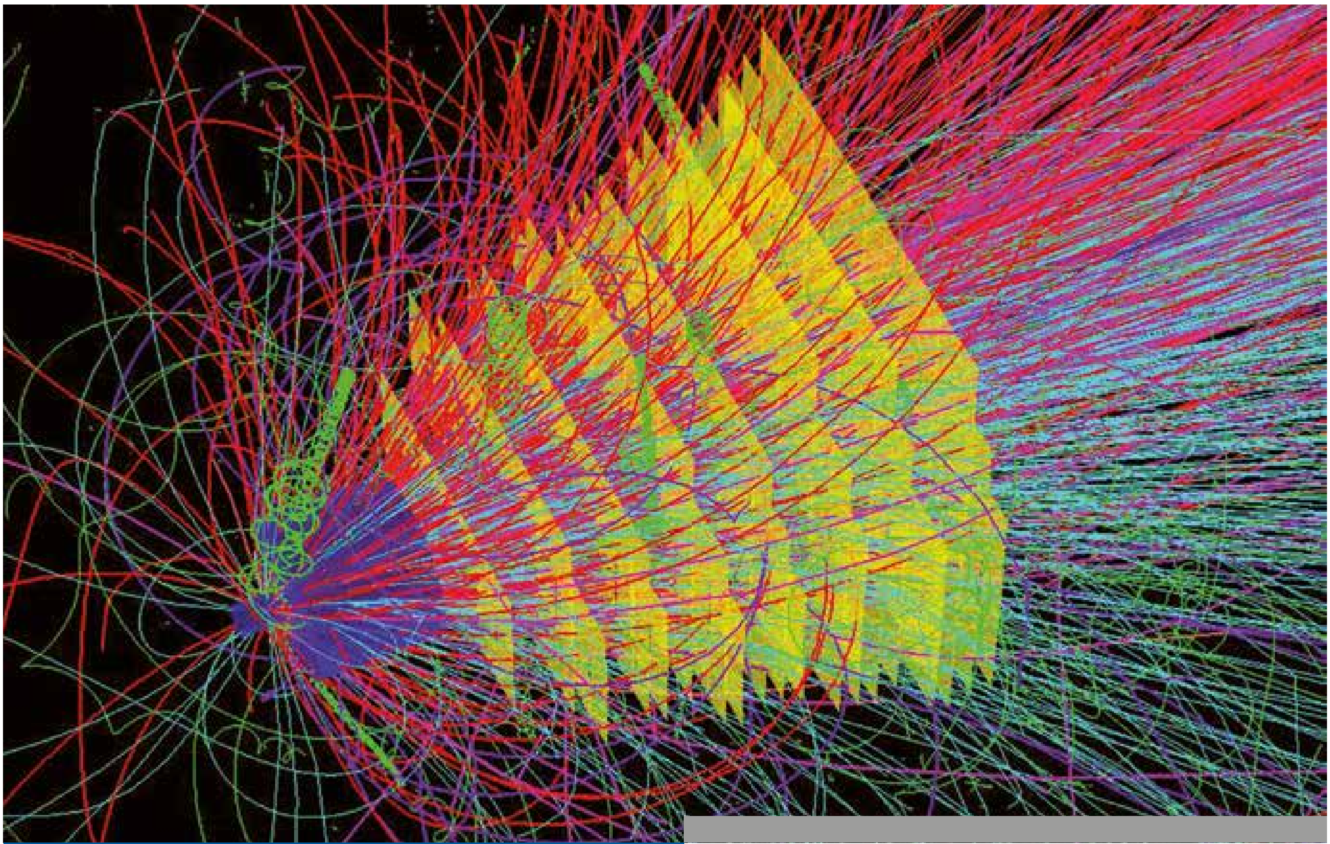
// Physicist Lothar Naumann and his HZDR colleagues are in the process of developing high-performance - and fast - detectors for the CBM experiment at the planned FAIR accelerator center in Darmstadt, Germany. The collaboration is looking for traces of quarks, one kind of elementary particles of matter.



HAIL STORM OF PARTICLES: Detectors have to be extremely efficient and fast to be able to register millions of particles in a short amount of time. Illustration: CBM Collaboration

ULTRAFAST DETECTORS FOR ION RESEARCH AT FAIR

_TEXT . Anja Weigl

What comes next after Higgs? Or, to put it differently: which scientific topic has what it takes to attract as strong of a public interest (and keep the interest for as long) as did the search for the Higgs particle at CERN, the research center based in Geneva, Switzerland? In any case, particle physics, which has gained a considerable degree of public attention from all this, still holds many unresolved questions and physics problems.

Like the evidence for one single quark particle. While we can say with a high degree of certainty that Higgs has in fact been discovered at CERN, no one has yet observed an isolated quark particle – which actually belongs to a whole family of particles. Elementary quarks do not exist in isolation but are, instead, elementary particles involved, according to the Standard Model of particle physics, in the formation of other particles such as protons and neutrons. Just as they have →

FAIR: 3D view of the planned Darmstadt accelerator center FAIR for antiproton and ion research. Diagram: FAIR/GSI Helmholtzzentrum für Schwerionenforschung

been looking for traces of Higgs particles, nuclear physicists are now hoping to record quark signals. By doing so, they could potentially consolidate their assumptions regarding the origins of our Universe and the nature of matter.

US physicist Murray Gell-Mann was the first to coin the term "quark" back in the 1960s in order to describe the basic building blocks of hadrons, in other words, particles similar to protons and neutrons held together by a strong, reciprocal force. Gell-Mann received the 1969 Nobel Prize in Physics for his hadron classification and interaction scheme. The patron saint for the then newly postulated elementary particle was – you guessed it! – the popular Old World dairy product known as "quark." Gell-Mann is said to have come across the word in a novel by Irish novelist James Joyce, who, in turn, is alleged to have first heard it in a market on a trip through Germany.

Dense nuclear matter straight from the lab

Considering the required immense research equipment and the number of necessary experiments, an undertaking such as the hunt for the Higgs particle or the search for quarks can only be realized in the context of a large research collaboration. Darmstadt, Germany, will be a new future location people will identify with this branch of physics. In Darmstadt, construction of FAIR (the acronym stands for the "Facility for Antiproton and Ion Research") is already well under way. Its mission is to supply antiproton and ion beams to facilitate investigations into the structure of matter and the origins of the Universe. One part of this is the CBM experiment.

Protons and neutrons are made up of three quarks each, which are held together by a special kind of glue consisting of elementary particles called gluons. The project – its full name is "The Compressed Baryon Matter Experiment (CBM)" – is, in effect, named after the baryons, the class of nuclear particles belonging to the very confusing world of small and smallest building blocks of matter. "If you pack the nuclear constituents more densely, you are able to examine the behavior of essentially free quarks," explains HZDR physicist Lothar Naumann. As part of the CBM project, the Rossendorf team is collaborating with 400 scientists from 50 research facilities in 15 countries. Together, they want to develop and investigate this state of dense nuclear matter →

in the lab setting. "It allows us to probe deep into the past, approximately 14 billion years all the way back to the Big Bang, albeit only its first few minutes," says Naumann. The scientists are assuming that, back then, all matter was highly concentrated into a "primordial soup," which ultimately gave rise to all elementary particles and then, later on, to all of the various chemical elements.

"Quark-gluon plasma" is the proper term for this dense state of matter. To generate it, the CBM researchers are planning to get heavy atomic nuclei to collide with each other. "This happens if, for instance, an accelerated ion beam hits a gold target," Naumann explains. When individual heavy atomic nuclei containing lots of quarks and gluons – in contrast to lighter nuclei that contain fewer of these particles – collide, hundreds or even thousands of new particles can result. For this to work, high-performance accelerators like the ones that are planned at FAIR have to direct the nuclei at each other and they have to be able to overcome the strong forces between the nuclear constituents. If protons and neutrons then collide and overlap, quarks would be able to directly interact with each other – and, voilà, there you have a novel state of matter and your quark-gluon plasma.

The particles they contain are much more densely arranged than they normally are in other types of matter. The CBM experiment will yield high-density plasma: The researchers accelerate the original particles to "moderate" levels of energy, which allows the particles to interact intensively. These kinds of states of plasma are also being examined at CERN and at Brookhaven National Laboratory in the US, albeit at higher particulate energies and lower densities.

Ten million particle collisions per second

Only a small portion of the newly created particles will result from the central collision of two atomic nuclei. The next step is to filter them from the multiplicity of signals given off by the individual particle collisions – on the order of up to ten million per second. To put it another way, the scientists are in need of extremely high-performance detectors. To develop these, they use new kinds of materials and technologies that will allow them to incorporate the vast number of particles. The CBM experiment is thus planned as the combination of several individual detector systems, each of which performs a different function.

One of these includes measuring the time of flight for which Lothar Naumann and his HZDR colleagues are developing central detector components. At around 100 square meters, the entire time of flight detector is roughly as big as the area of a single-family home. Therefore, the underground bunker, which will house the CBM experiment, needs to have the proper dimensions. Construction of the new facility is expected to begin in 2017 at the earliest. Until then, what is important is to complete development, testing, and construction of the detectors. A detector consisting of many small individual segments with a total area of roughly one square meter is currently being built at the Helmholtz-Zentrum Dresden-Rossendorf. Using the electron beam at HZDR's ELBE accelerator, the researchers have already very successfully finished testing the prototype. In addition, their CBM colleagues from Tsinghua University Beijing in China and the Institute for Theoretical and Experimental Physics in Moscow, Russia, and a number of other research groups, have started using the ELBE electron beam to test their respective detectors for FAIR.

Special ceramic detectors

According to Lothar Naumann, the HZDR components must meet two major requirements: "First, they must be able to register the speed of a large number of individual particles with – secondly – very high precision." In this, Naumann and his team proved successful a while ago – at this point, the tests are already three years old. The result: the new detectors are capable of determining with high precision up to one million particles per second in a one square centimeter area in the 100 picosecond range - the time it takes a particle moving at near the speed of light to travel a distance of 30 millimeters. Since most of the particles are passing through the gigantic time of flight detector's center at a very high probability, the fast HZDR components are applied right there.

"The detectors have exceeded all our expectations," Lothar Naumann admits. "We developed them in partnership with the Dresden Fraunhofer Institute for Ceramic Technologies and Systems IKTS and are very happy with our partners at the Institute." The test was preceded by an almost two-year period of development, during which time the scientists were actively searching for a suitable material to use. "In order to be able to build innovative detector components, we needed a kind of material with very unique electrical properties. Now, unfortunately, you can't just go to the store and buy that sort →

> „Our detectors have to be able to register the speed of a huge number of individual particles with very high precision."

of material," the physicist explains. At first, the scientists were considering using doped plastics but then rejected the idea, since these materials are not sufficiently resistant in the high radiation environment. Next, they researched ceramic systems and, together with specialists from the Fraunhofer IKTS, finally developed a type of ceramic material that resists radiation while also meeting all of the other materials requirements.

The time of flight detector is unable to detect individual quarks, but, on the other hand, the fact is that quarks aggregate to form new particles like pions and kaons far too quickly. But even electrons and their antiparticles, positrons – neither of these are made up of quarks, but can penetrate the quark-gluon plasma non-encumbered – are supposed to be captured by the time of flight detector. From this, the scientists will be able to draw conclusions regarding quarks and the initial processes of the young universe.

LITERATURE

B. Friman et al. (eds.): "The CBM Physics Book – Compressed baryonic matter in laboratory experiments", in Lecture Notes in Physics, vol. 814 (2011; DOI: 10.1007/978-3-642-13293-3)

L. Naumann et al.: "Ceramics high rate timing RPC," in Nuclear Instruments and Methods in Physics Research A, vol. 628 (2011), p. 138 - 141 (DOI: 10.1016/j.nima.2010.09.121)

NUCLEAR MATTER: Diagram of the Compressed Baryon Matter (CBM) experiment for the study of highly dense nuclear matter. It will consist of multiple detectors arranged in series, with the tallest ones approximately ten meters in height. Diagram: CBM Collaboration

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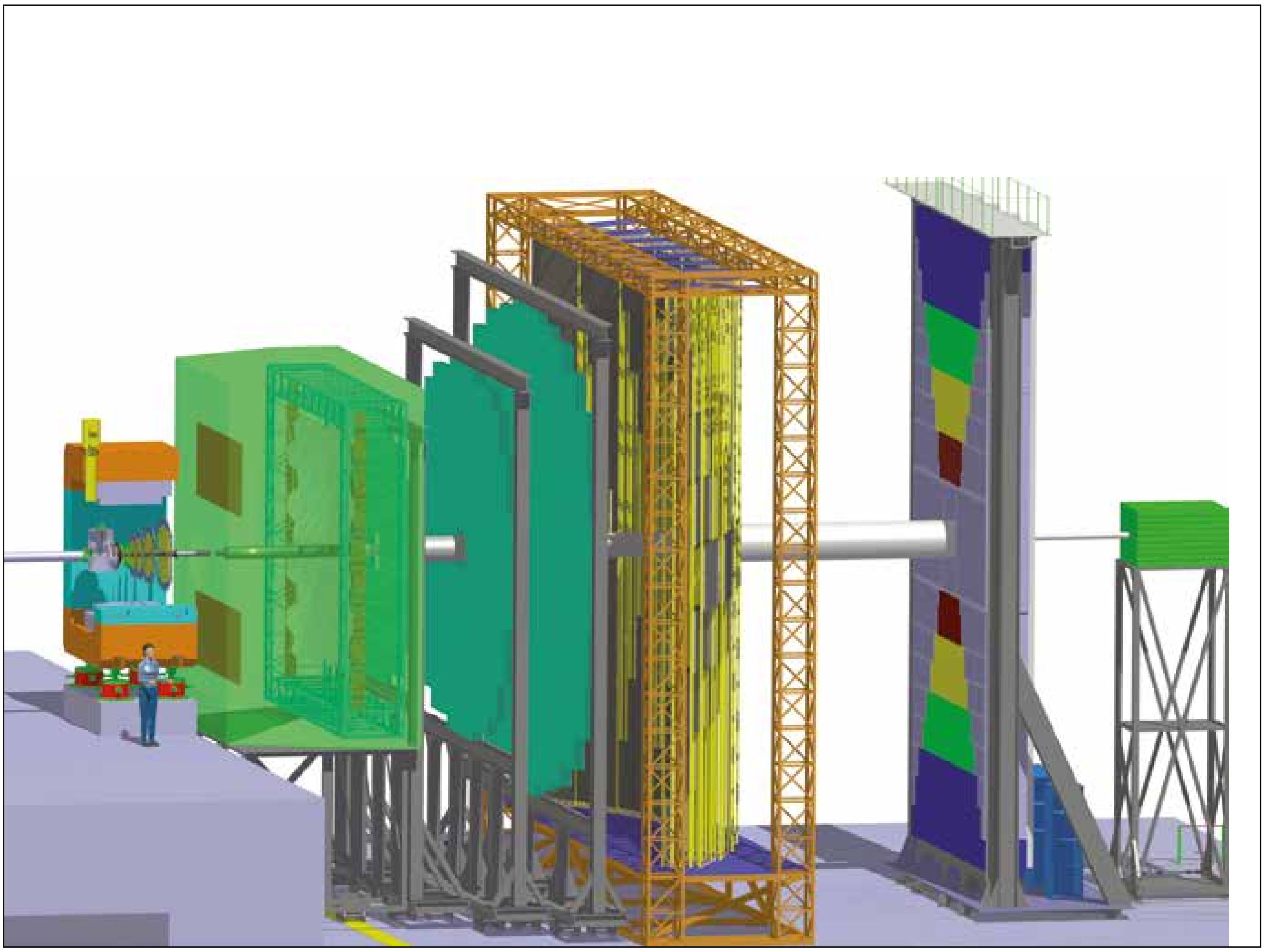
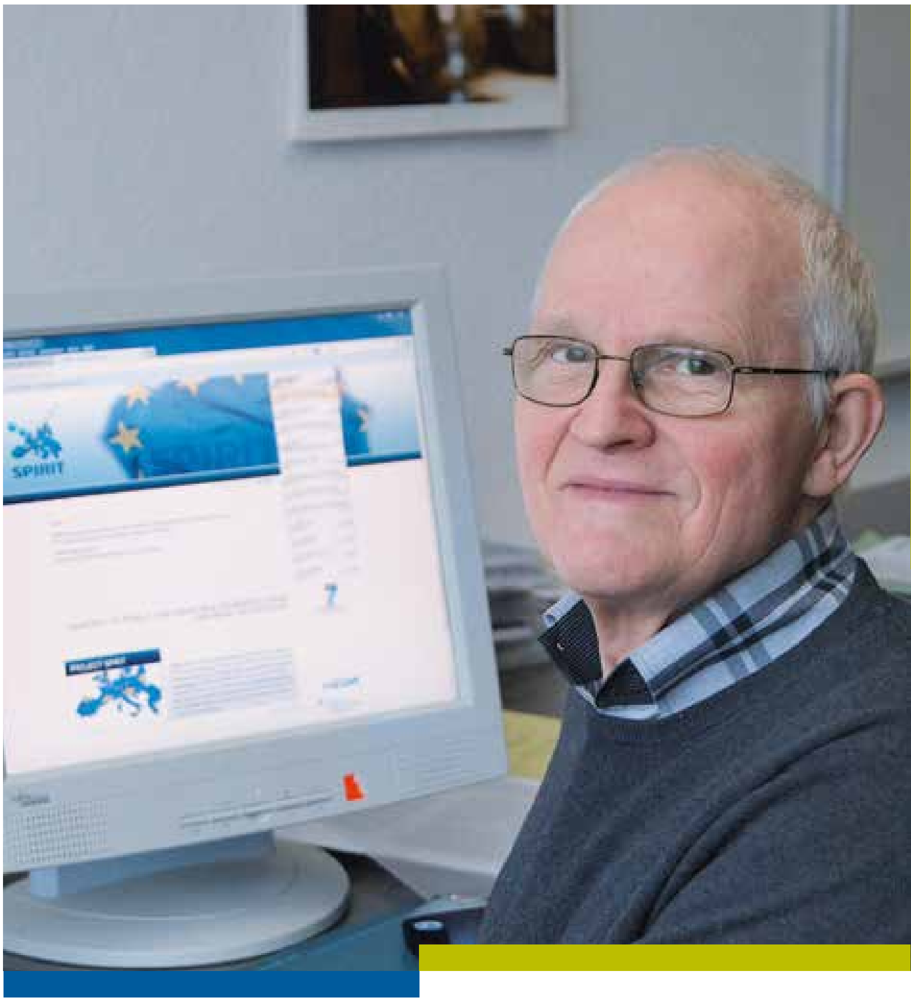




COORDINATOR: Wolfhard Möller, the former Director of the Institute of Ion Beam Physics and Materials Research, heads the EU project SPIRIT.

// Europe's big ion beam centers stand united in SPIRIT. The EU project is coordinated by HZDR's Wolfhard Möller who is scientist, manager, and passionate musician rolled into one.

BUNDLED IRRADIATION POWER

_Interview . Christine Bohnet

SPIRIT stands for "**S**upport of **P**ublic and **I**ndustrial **R**esearch Using **I**on Beam **T**echnology." Ion beams – rapid, charged particles – are tools for modifying or analyzing material surfaces. In a truly European spirit, eleven European ion beam centers from six EU member states as well as two associate states have joined forces and are opening up their facilities and technologies to users from science and industry. Research topics range from material and biomedical science all the way to cultural or environmental research and technologies.

Mr. Möller, you initiated the SPIRIT project as director of our Institute of Ion Beam Physics and Materials Research and brought it to Dresden. This is now your fourth year as the project's coordinator – in spite of the fact that you are a professor emeritus. What's the appeal?

SPIRIT is a model for success – thanks to a number of factors like solid in-house support. I'm very happy about this since it was the EU's involvement in SPIRIT that ultimately kept our Ion Beam Center open, which I directed between 1993 and 2010. I am especially grateful to my successor, Jürgen Fassbender, who never once made us question his commitment to the →

FIRST VIOLIN: As Europe's leading Ion Beam Center, the HZDR shows users the many opportunities afforded by ion beams, opens up its facilities to them, and ensures access to top-notch institutions. Photo: Oliver Killig

center or to SPIRIT. And when, in 2010, I was getting ready to retire, I was given the chance to stay on part-time as project coordinator. I couldn't and didn't want to miss that. My main incentives were my highly reliable team and the fact that SPIRIT attracts a large number of external users who are coming to Dresden to conduct research asking fascinating questions. And thanks to SPIRIT, our Ion Beam Center, which also means a great deal to me personally, can continue to play first violin in the European research concert orchestra.

A lot of scientists would view this project as a burden and potentially a monster of bureaucracy. Doesn't the coordinator get really involved, or, to put it differently, is it not sometimes tedious to get all the various partner institutes to tune their instruments in unison, so-to-speak?

Naturally, this type of project isn't always smooth sailing. There have been moments of despair and disappointments no doubt. Imagine having the EU hold you accountable for every last penny you spend. And we're talking seven million Euros over a four-year-period. Luckily, in Rossendorf, we have many years' experience with the EU's infrastructure programs. Ever since the fourth framework program, EU infrastructure funds have been pouring into our Ion Beam Center; SPIRIT is part of the seventh EU framework program. A big difference, however, is that the first couple of grants were given exclusively to our Institute; what we're looking at now is a large international consortium. Because I was fully aware of the challenges inherent in this, when the project started, we had to invest a lot of time and effort into selecting eligible partner institutes. The EU general guideline at the time was: no more than ten partners – and somehow we ended up with eleven. In Europe, there are some 35 ion beam labs with comparable equipment. Choosing partners was a delicate task because everyone really wanted to be a part of it.

At the time, we sent out carefully crafted questionnaires to over 30 labs and then evaluated them in light of the following criteria: as much as possible, all of the different protocols that exist for processing and examination of materials with the help of ion beams should be represented in the SPIRIT →

consortium, the institutes' scientific quality and their ability to accommodate external users should be well-established, and at the end of the day, having as many nations as possible represented also played a role.

Time and again, the word from Brussels is: "SPIRIT is running beautifully." By the time the project will near its end, we will have checked off all the milestones and have reached all of our declared goals. I am so proud but, naturally, without the exceptional contributions by our international partners, it would never have worked. And I can only repeat: The many diverse in-house support functions, whether we're talking about our EU liaison officer and her colleagues from the International Projects area, the administration, and the other HZDR scientists and technicians involved in the SPIRIT project, were and are key ingredients to our success.

Mr. Möller, you seem as excited, level-headed, and youthful as always. Tell me, are you finding that you have more time to yourself now and for your passions like your music?

Well, to be perfectly honest, this part-time coordinator position is not keeping me all that busy. I am happy, of course, that, since I retired, I have been able to once again pursue my professional passions. I am able to do research on my own and have revisited an old topic I had been working on in the past: a computer simulation about the interactions between ions and solid bodies that I programmed years ago and which has been used all over the world ever since. I have greatly enjoyed extending this program to three-dimensional simulations in the nanometer range. One of the things it allows you to do is model surface erosion using finely focused ion beams or compute how regular surface structures form under bombardment with ions. This is directly relevant to experimental and other theoretical works at the institute.

What's also especially exciting is that I have a lot more time now for conversations with younger and older colleagues. And it goes without saying that music also has its place in my life as it always has. Of course I have a lot more time for it now – both passively and actively. I play in two string quartets on a more or less regular basis, which is a nice mix of very young and – let's just say – rather more mature musicians.

Let's get back to the topic of ion beams: Would you mind telling us more about ion beams in practice? What are some of the advantages of rapid charged particles compared with other technologies?

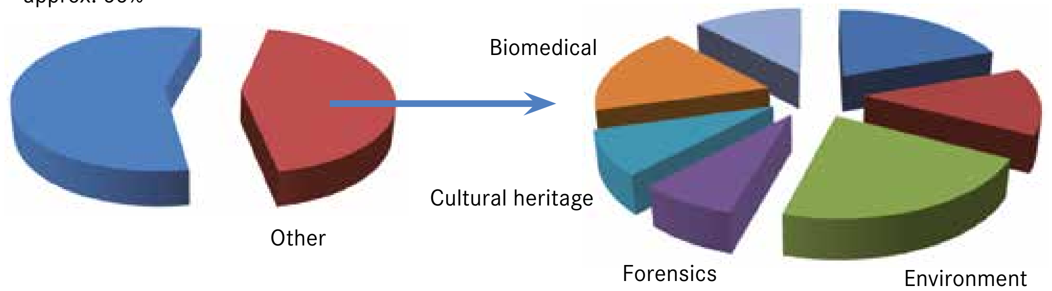
It's difficult to conceive of very many areas of life without ion beam technologies. Without foreign atom implantation in semiconductor materials, computer, cell phone, or digital camera processors or storage chips simply wouldn't exist. And yet ion beams basically operate like tools that allow one to customize the properties of different materials. This affects their electronic as well as their optical, magnetic, and mechanical properties. In the last few years, there has been considerable progress made in research in these areas but industry still isn't – or isn't always – fully aware of their inherent potential in terms of their applicability. Which is why one of SPIRIT's main goals is to familiarize users from all walks of life with the potential inherent in ion beams and to grant them access to top institutions.

At the same time, ion beam based processes are relatively elaborate and costly in terms of their application. In other words, you have to clearly identify those areas in which they can be of use to industry. Besides electronics, I can also imagine photovoltaics or even treatment of specialized tools. Just imagine, say, a large injection molding tool worth several tens of thousands of Euros. It isn't uncommon for this kind of tool to be exposed to a wear-and-tear only at distinct small fractions of the overall surface. I can see tremendous innovation potential in the implantation of ions into these wear-and-tear points.

Ion beams are exceptionally versatile tools and can even help with tracking down murderers.

At this time, one very hot topic is single ion implantation. It's actually something the HZDR is already working on: If we succeed at positioning individual atoms on a material surface with great precision in a nanometer range, this would represent an important step in the direction of quantum computing. Quantum computers, whatever they may end up looking like, could also become an important ion beam technology market.

Ion beams also offer unique opportunities for analysis that in many cases are preceded by extensive development and pilot stages. As such, there exists a tailored analytical technique for light-weight elements like hydrogen or boron that cannot be detected using X-ray analysis or other technologies. Why is this relevant? In semiconductors like solar cells, hydrogen is used for purposes of passivation. On the other hand, the often times uncontrolled entry of hydrogen in thin functional →



USER DIVERSITY: Use of the infrastructures as part of SPIRIT is intensely multidisciplinary and international. More than half the projects can be categorized as materials research; the remainder is divided among a broad spectrum of different research topics.

layers is undesirable. With the help of ion beam analysis, the presence of hydrogen can be detected with great precision both in terms of concentration and depth profiles. Another example is how one of our partners, the University of Surrey, actually uses ion beams in forensic analysis. Using elemental analysis, scientists are able to figure out things like the exact geographic location in England that a piece of dirt at the bottom of a murderer's or victim's shoe came from.

These days, much research is aimed at accessing the nanometer range for use in ion beam analysis - an exciting new challenge. In fact, the HZDR recently invested in a helium ion microscope for probing the nanoworld.

Let's wrap up by taking another look at SPIRIT. What are the project's major advantages?

Let's start with a home advantage: the EU is pouring money into our cash registers. Thanks to the rate of remuneration in exchange for the times we make our measuring instruments available, we were able to take home a nice six-figure amount. And we're talking about real and flexible income we can use to, say, purchase a new ion implantation facility.

Another important motivation was that, prior to this project, no consistent procedures for the application of ion beams were in place. Thanks to the extraordinarily good collaboration by Europe's big ion beam centers, we are now able to build upon quality control, protocols, and standards. We have, in effect, been very successful.

Together we were also able to expand the European research landscape and familiarize new users with the many different options offered by ion beams. If nothing else, SPIRIT's success is confirmed by the fact that the University of Surrey, along with the HZDR and the SPIRIT partners, has been raising funds for the Marie Curie Initial Training Network SPRITE, which was launched in January 2013. This is a very positive nod towards the future. As Europe's leading ion beam center, we are very interested in being viewed as a user facility at the next EU framework program, Horizon 2020. My successor, Jürgen Fassbender, has declared this a personal goal and has already started work in a new proposal. Of course, I will still offer up my expertise during this stage but eventually it will be very nice to get to the point where I will have fond memories of my time at the FZR, FZD, and HZDR...

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// 2012 saw the wrap-up of HZDR Innovation GmbH’s first fiscal year. CEO Andreas Kolitsch is thrilled about being in the black, genuinely excited customers, and the prospect of future projects.

SPIN-OFF AS MODEL

_TEXT . Sara Schmiedel

INCREASING THE LIFESPAN: HZDR Innovation GmbH's clients come from the automobile and semiconductor industries, even medical technology. The incorporation of nitrogen as well as titanium nitride coating help make medical implants like artificial hip and knee joints better tolerable and more durable (in the picture: Gabi Steinbach, Ph.D. student at the HZDR). Photo: Jürgen Jeibmann

When asked how things are going with the spin-off, Andreas Kolitsch’s reply is a short "very good." Surface modifications are in high demand and the Helmholtz-Zentrum Dresden-Rossendorf’s Ion Beam Center has all the right equipment and technologies. "Most of our customers are from the semiconductor industry. They send us their finished wafers and we take care of the lifetime engineering part by implanting light-weight ions such as high-energy protons and helium ions." According to the chemist, "this minimizes a loss of power while at the same time increasing the switching speed of typical semiconductor components. For the high-energy implantation, we have a rather unique selling point as far as the quality of our equipment goes since similar accelerators are, for the most part, quite old already. Even in the US, there aren’t any facilities like this one which means customers from overseas have been knocking on our doors ever since we first got started." The company’s self-proclaimed goal: To handle several thousand wafers per month over the next few years. An important step forward for the future of electromobility as the range of electric cars is largely determined by the energy efficiency of their electric components. →

These days, manufacturers of automotive engineering turbo charger rotors are constantly knocking on the door. The reason behind it? "I predict that turbo charger rotors will soon be made out of ultralight titanium aluminides instead of heavy nickel alloys, which means greater power and fuel-saving. But this only works if you increase the high-temperature resistance. A highly promising solution based on ion implantation that was developed right here in Rossendorf."

The global players are coming to Rossendorf

Today, some 15 percent of the Ion Beam Center's total beam time is used to fulfill orders placed by regional, national, and international industry partners – a development which first began some 20 years ago and which is quickly gathering momentum. External users are bringing reputation, high capacity utilization, new projects, and third-party funding for reinvestments. In order to maximize these achievements, Kolitsch and a few of his colleagues decided, together with the HZDR Board of Directors and the second shareholder, GWT-TUD GmbH, to start HZDR Innovation GmbH. This was back in October 2011. Today, one and a half years later, the spin-off has already paid off: "We haven't burnt through any of the money - quite the opposite, we've made a nice profit and have set our focus on a large circle of customers, we have plenty of new inquiries and so much potential," says the CEO. And not from just anyone, either, but from the really big guys. "Currently, we are talking to five global players, some of them in the US, for whom we could become important partners in the long run," says Kolitsch. Alas, given the strict confidentiality agreements, he's not allowed to name any names.

SUCCESS STORY: Since 2011, Andreas Kolitsch is CEO of HZDR Innovation GmbH. The chemist has more than 30 years' experience with ion implants.

> "There are no comparable facilities, not even in the US, so that clients from overseas came knocking on our door right from the start."

How is it possible that such a relatively young company, with its staff of 25, most of them part-time, has been able to score such a major success? According to Kolitsch, it's because "here in Rossendorf, we have over forty years' ion implantation experience. Add to that our solid and long-standing partnerships, really good marketing, and technologies that - at least to some extent - are unparalleled and in high demand. Moreover, in GWT, our second shareholder, we landed a valuable partner to help us with business related issues."

Top-notch security standards, clean room quality, the whole entire scope of radiation protection authorizations, two state-of-the-art accelerators - the Ion Beam Center seems destined to get slammed with orders. So where's the catch? "There is in fact one catch, or rather there will be one once we get to the point where our machines are all working at maximum capacity," says Andreas Kolitsch. "Because: research always gets top priority, no questions asked!" An emergency beam time commission has already been set up although, luckily, they have not had to intervene yet.

Industry gets one fourth of the total beam time

Kolitsch is certain that over the next few years industrial orders will constitute twenty-five or thirty percent of the Ion Beam Center – a number that helps define the Center as an international user facility. →

Within the Helmholtz Association, a strategic subsidiary of the caliber of an HZDR Innovation GmbH is practically unheard of. "It's true we're something of a model and, compared with other centers, we are right at the forefront with our spin-offs," says Kolitsch, not entirely without pride. He admits to owing a lot to the HZDR's Technology Transfer and Legal Affairs unit.

A common roof for other spin-offs

HZDR Innovation GmbH has not sworn itself exclusively to ion beams but rather sees itself as a common roof for other spin-offs. The advantages inherent in this kind of holding are obvious: "Basically, you create your own in-house technology center, organize joint websites, appearances at conventions, marketing activities and - last but not least - help each other," explains Kolitsch. Adds Björn Wolf, head of the HZDR's Technology Transfer and Legal Affairs unit: "If research findings give rise to new products, in other words, if it's about revenue, Innovation GmbH comes into play." Already, there are a number of candidates: Take Gunter Gerbeth, for instance, with his patented ultrasound wave conductors, or Uwe Hampel with his grid sensors for measuring stream profiles, both of whom are drawing on HZDR Innovation GmbH. And the CEO himself is planning on launching a brand new product called i3membrane next year. Andreas Kolitsch lets us in on a little secret: "If we are successful at realizing this, it will be a hit." That's all.

For the second fiscal year, Kolitsch is counting on revenues in excess of one million Euros and on new medical technology projects. The company is currently in talks with manufacturers of artificial hip and knee joints and stents. Ion beams are supposed to help improve the tolerability and life of the "building components." So what's next? "I'm guessing that 2017 will be an important year for us when we have to ask ourselves whether our goal is to become a globally unique center for ion implantations – in that case we need our own accelerators and beam lines - or do we just stop growing?" By the end of this year, Kolitsch plans to present a concept for his preferred option – growth.

HZDR INNOVATION

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In-house builders

At the HZDR, Peter Kaever is head of research technology. With his team, he develops and realizes specialized research equipment for all eight of the HZDR's institutes. This ranges from equipping individual experiments all the way to comprehensive research facilities like DRESDYN. Together with the scientists, the research technicians are frequently involved as early as the brainstorming stage. Later on, they're in charge of construction and manufacturing, and finally, of on-site testing of the components.

These days, the research technology department is especially involved in four major construction and development projects that are grouped under the umbrella term "future projects" at the HZDR. In all, the Free State of Saxony is funding these with over 70 million Euros; an additional 50 million are contributed by the Federal Ministry of Education and Research (BMBF).

// At this point, it seems that DRESDYN is the one project at the HZDR that involves significant risk factors and thus deserves the full attention of Peter Kaever and Christian Steglich, head of the mechanical development division.

// Another focus is on the expansion of ELBE. Neutron and positron based experimental stations are under construction at the new Center for High-Power Radiation Sources and the research technology department's capacities are also tied up by the HZDR's two high-power lasers, DRACO and PENELOPE.

// The magnetic cells at the Dresden High Magnetic Field Laboratory's add-on are still vacant. The job now is to equip them; the second capacitor bank's switch towers are already open for tours.

// A lesser workload for Kaever's team is the Center for Radiopharmaceutical Tumor Research, which has to first experience additional building progress before the infrastructure for the transport of irradiated substances can be realized.

↗ www.hzdr.de/FWF

// Construction of the new European platform for dynamo experiments has only just begun. To Frank Stefani, the scientist in charge of the experiments, and Peter Kaever, head of research technology at the HZDR, knowing that you are able to fully rely on your partner within the team at all times is implicit since the early planning stages.

AN EXPERIMENT WITH OUR SWAYING EARTH

_Interview . Christine Bohnet

When we're talking DRESDYN (which, by the way, is short for "Dresden" and "dynamo") we're not talking about Dresden's local soccer team, even though sports and team spirit, stamina and an ability to quickly react to the unexpected, are a few of the gigantic Rossendorf project's hallmark features. Like, for instance, when the planned building requires a foundation that plunges twenty-two meters below the surface - to tame the dynamo's gyroscopic moments - without blocking the local otter traffic. Be that as it may - the new research equipment isn't exactly stingy with superlatives. Which is why Frank Stefani (FS) and Peter Kaever (PK) have stories to tell.

DRESDYN will allow for the unprecedented performance of liquid sodium based experiments. What are some of the scientific questions you're hoping to answer here?

_FS . The most challenging experiment focuses on the types of questions that increasingly play a role in geophysical and astrophysical fluid dynamics, specifically with regard to the generation of Earth's magnetic field. Changes in the parameters of Earth's orbit in general, and precession in particular, is currently **the** topic, especially for modeling Earth's dynamo. The term "precession" describes the phenomenon that Earth's rotational axis is also wobbling. With

STILL UNDER CONSTRUCTION: The drill is waiting to dive 22 meters deep and lay the deep foundation for the dynamo, which weighs tons. Photo: Matthias Rietschel our experiment, we would like to explore parameter regions that will remain inaccessible to numerical simulations for a long time, true to Richard Feynman's motto: "What I cannot create I do not understand." A large container is needed, one that we would have rotate about two separate axes. This way, we would set the liquid sodium it contains in motion, allowing it to flow freely - without propellers, apertures, or other built-in components. The flow of the homogenous liquid metal is supposed to set up a magnetic field by itself, similar to the way Earth's magnetic field is generated.

Liquid sodium is the type of material that rather takes some getting used to as it cannot be allowed to come into contact with air or water. However, for purposes of our geophysical and astrophysical experiments, sodium's high conductivity paired with its low density are a real benefit. In terms of safety, we're able to draw on our extensive experience with NATAN, our own small sodium facility, and with the large dynamo facility in Riga. It is there that, back in November 1999, the first ever successful hydromagnetic dynamo experiment was conducted - at almost the same time as the dynamo experiment at KIT, the Karlsruhe research center. In 2006, the experiment in French Cadarache followed, to which we also contributed multiple numerical simulations.

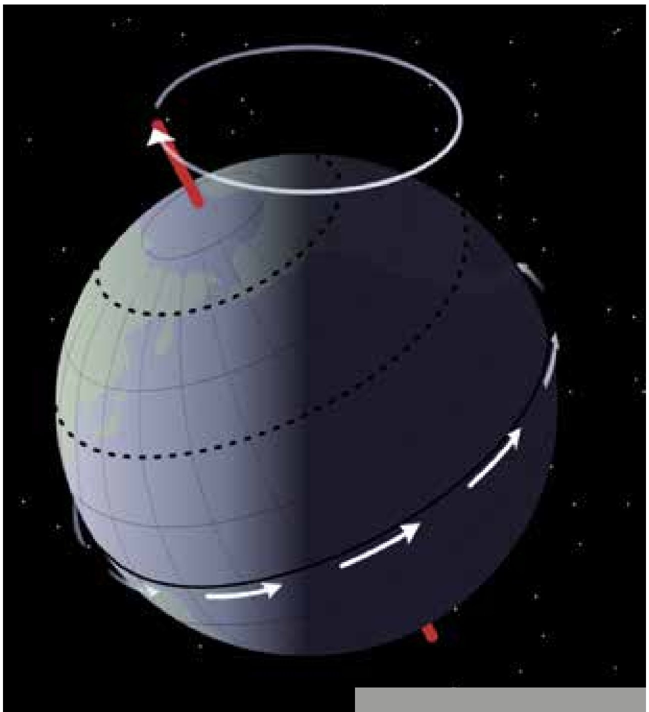
All of these were important milestones in the experimental investigation of homogeneous dynamos that are responsible for the generation of planetary, stellar, and galactic magnetic fields. In recent years, successful experiments on magnetically induced flow instabilities were added. Such instabilities help explain, among other things, the high speed at which stars and black holes grow. Until now, we were only able to perform these types of experiments using harmless liquid metals that were far worse conductors, however, and now, as part of DRESDYN, we're planning on continuing these experiments with sodium. Yet the precession dynamo is a whole nother ball game from both a mechanical and safety-related perspective.

_PK . Yes, with sodium we're looking at an entirely different order of magnitude. What's more, questions of safety with regard to the precession dynamo are infinitely more difficult to solve since current safety methodologies simply aren't applicable. If anything goes wrong, for instance if a flange should break, we can't immediately drain the sodium but have to wait until the machine has come to a standstill. Just imagine - eight tons of hot, liquid, flammable sodium inside a container weighing just under 20 tons! This behemoth can be adjusted in its tilt between 90 and 45 degrees in steps of five degrees each and also rotates simultaneously about two axes - all of them are degrees of freedom for reaching the desired flow parameters. We're looking at a gigantic machine here!

What exactly is precession? Why isn't even a single experiment concerned with it despite the fact that Earth's precession motion is a hotly debated topic even among climate experts?

_FS . This whole topic is rather complex. Changes to Earth's orbit and angle of tilt of its axis play a crucial role in climate change. But first, let's have a look at precession, which you can easily study yourself with the help of a small kid's toy called a spintop: If, during spinning, this spintop is upright, it doesn't change its own rotational axis and stays in one place despite the rotational motion. If, by contrast, you angle the spintop on a surface when you spin it, the breakdown torque will cause its rotational axis to sway - and that motion is what we call precession. If we now relate this idea to Earth, we find that Earth's rotational axis is not perpendicular to the level of Earth's orbit but instead is tilted roughly at a 67-degree angle. Additional forces are exerted on the Earth by the sun and the moon. Which is why, similar to a child's spintop, it executes a precession motion with a duration of 26,000 years. This is one of the Milankovitch cycles, the others are relating to Earth's orbit and the tilt of its axis. Both these parameters change over long time scales.

It's a well-established fact that the sequence of ice ages and interglacial periods is triggered to a large extent by such →



PRECESSION OF EARTH: If you allow a spintop to rotate perpendicular to a surface, the gyroscopic moment will cause the rotating axis to start to sway - this motion is called precession. In the same way, Earth's rotational axis is not perpendicular to Earth's orbit but instead is tilted at a 67 degree angle and both the sun and the moon exert forces on Earth. Which is why it undergoes precession movements similar to a spintop. Diagram: Robert Simmon (NASA GSFC) variations in the orbit and the tilt of Earth's axis. However, next to buoyancy forces, precession is a potential source of energy for the geodynamo. Interestingly, you will find several typical frequencies of the Milankovitch cycle in paleomagnetic data. And this is where it gets pretty exciting in terms of climate: Because it's not at all clear whether it was the chicken or the egg that came first. On the one hand, growing and melting ice sheets change the moment of inertia and are thus potentially able to influence the geodynamo. Or it could be that Earth's changing magnetic field affects the climate. I didn't want to go so far as to say that we're planning on conducting climate research in the context of DRESDYN, even though the relationships are fascinating no doubt.

_PK . To relate this complex topic to the precession dynamo: During operation, the sodium container (which weighs tons) will be spinning like the barrel of a washing machine. The goal is to get up to ten revolutions per second. The desired flow, however, depends upon the entire contraption including the turntable rotating about its perpendicular axis - up to once per second. Therefore, if we allow our dynamo container to rotate about two separate rotational axes at different angles of inclination, at some precession rate, the liquid sodium current will become turbulent and chaotic. I think we're setting up an internationally unique facility here. At the very least, we're looking at the mechanically most complex experiment I know.

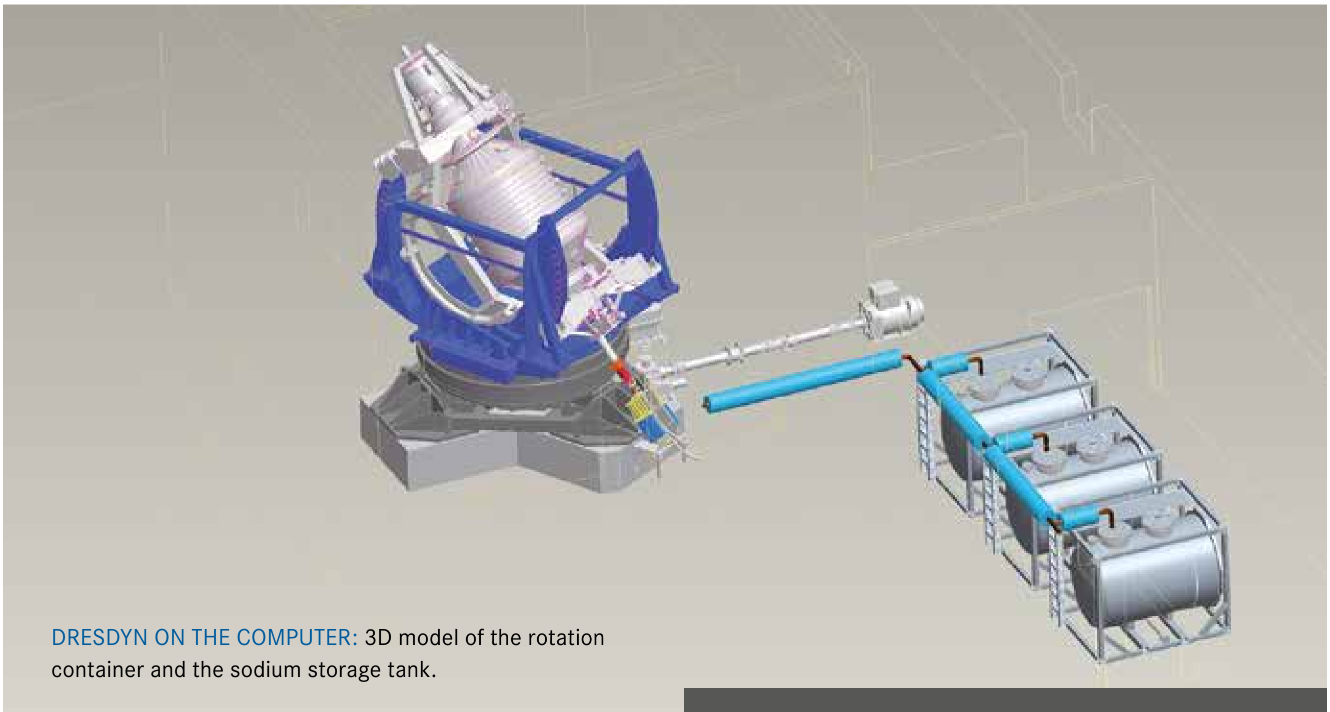
Meaning in a way, both of you are looking for chaos and turbulence. I'm guessing there are special challenges inherent in DRESDYN's planning and construction.

_PK . Definitely, just think of the mechanical impact alone. The sodium container will react to the superimposed rotations with a gigantic gyroscopic movement on the order of some five million newton meters that are conveyed to the ground through the precession experiment's support frame. There's really nothing you could compare it with. Typically, you have to imagine a machine sitting on a firm foundation, with only a downward pressure being exerted. However, in this case, the precession moment distorts the entire machine in such a way as if a 250-ton weight were pulling up on the cylinder, the complicated suspension, and the turntable on one side while pushing down on the other. And this all orbits about once per second. Anyone who has ever tried to use their hand to tilt their bike in the air, knows how unruly a gyroscope can be. Although, arguably, a bike is nothing like liquid sodium.

In other words, we're expecting enormous tensions resulting from the high torque within the machine. Add to that the arguably high operating temperatures. Temperature invariably means expansion: Both the sodium and the container will expand and it'll be up to us to compensate for this expansion using suitable technological counter-measures. Similarly, we have to address the question of cooling, a particularly delicate issue given sodium's chemical reactivity. Water and sodium just don't get along at all.

_FS . Constructing the foundation was also a real feat. Even though we haven't yet finished construction of the dynamo, we did have to definitively determine the foundation. Of course, when we did this, we tried to be as conservative as possible but dealing with all of this uncertainty isn't always easy for the companies involved.

_PK . And just to add to that: Experimental operation requires that we thread measuring instruments and all of the necessary media like electric current and protective gas into the liquid sodium container, right into this rapidly revolving system. In other words, we have to be minimally invasive in terms of the feed-through to ensure that we don't compromise the whole construction's load-bearing capacity. →



DRESDYN ON THE COMPUTER: 3D model of the rotation container and the sodium storage tank.

In other words, during development, we're constantly monitoring several very sensitive topics where we're charting new territory.

How do you get the building ready for the great dynamo experiment and what will it cost?

_PK . The new building will combine a number of functions. For one, we have an experimental hall with capabilities for different types of experiments that are not really critical in terms of safety. As far as safety goes, the precession experiment does occupy a special place. For safety reasons, we need to enclose the machine inside a protective containment and assume that this will help ward off mechanical threats and protect against fires. The HZDR's building department helps out with technological construction equipment; it ensures that the overall infrastructure like the power supply, climate, or cooling is safe and functional and protects against fires. For the scientists, however, the hall with its different experiments is the main focus.

_FS . Besides the containment, we're investing in a very elaborate argon fire extinguishing system, which would allow us to fill the containment within two minutes' time to extinguish a potential sodium fire. This extinguishing system also covers the deeper lying sodium storage tanks. The containment is on the ground floor. The dynamo it contains works on its own separate foundation, supported by seven posts that reach 22 meters below the surface of the Earth.

Construction of the building is projected to cost around eight million Euros, the dynamo itself seven million. The projected total budget is 23 million and that should just about cover it. We hope that we will also be able to use external funds for the applied topics. By the way, sodium is not expensive and you can get it for as little as two Euros per kilo.

In other words, liquid sodium is the brace which holds all the various experiments at the DRESDYN facility together?

_FS . Yes, and if you look closely, it's actually hidden in the acronym DRESDYN, which stands for DREsden Sodium facility for DYNamo and thermohydraulic studies. The deeper lying tanks are storing some twelve tons of sodium that will be apportioned for the various experiments. With DRESDYN, we want to bring our geophysical and astrophysical experiments under one roof and continue to advance them. After all, sodium is the sole liquid metal that allows us to realize this goal with a reasonable technological and financial effort.

One example I would like to mention is a combined experiment designed to help us find answers to many unanswered questions about two important magnetic instabilities: the magnetorotational and the Tayler instability. Both of these are important phenomena in the cosmos, and basically we were successfully able to confirm both of them in the lab: The magnetorotational instability in the framework of the PROMISE experiment back in 2006 and, more recently, the Tayler instability in a current-carrying liquid metal column. Now, for the first time ever, we're planning on studying both instabilities at the same time as part of the new experiment. We just submitted a theory-based work on this showing that the combination of both effects could prove extremely important to the development of turbulence in the relatively poorly conducting areas of protoplanetary disks or of accretion discs that feed black holes.

Yet our understanding of the pure magnetorotational instability is far from comprehensive. It is our hope that we might advance into the area of the standard version, starting from the "helical" version we're already familiar with from PROMISE. The key ingredients for this are sodium, a strong field, and real "speed." The planned experiment will consist of an inner and outer cylinder, each approximately two meters tall, with roughly one ton of sodium between them that will be set into differential rotation. Currents of several thousand ampere each are sent through an isolated copper rod at the center and also through the sodium itself. This way, we will simultaneously juggle five parameters and thus do a lot of very exciting astrophysics. This is what we're working on together with our colleagues from the Leibniz Institute for Astrophysics in Potsdam and the ETH in Zurich.

Applied research won't get the short end of the stick either. In close collaboration with the French Atomic Energy Agency CEA, we're planning what's known as an "in-service inspection" experiment to test measuring techniques for these types of flow phenomena as they will be occurring in the new, sodium-cooled fast reactors in France. My HZDR colleagues are also interested in sodium-based turbulence studies and in two-phase flow.

A new addition in the last two years is the topic of liquid metal batteries. As long as you make them large enough, they could potentially serve as economically feasible storage sites for renewable energies. However, it turns out that with these kinds of large-sized batteries, our Tayler instability would occur and potentially ruin the liquid parts' stratification. In a special test facility, we want to examine how we might be able to suppress this and other magnetohydrodynamic instabilities in large liquid metal batteries. In particular, it is this close proximity of astrophysical research and applied battery research, both in terms of content and location, which makes DRESDYN so appealing to me.

Mr. Stefani, as a scientist you're in charge of the experiments, and you, Mr. Kaever, are head of research technology at the HZDR. What exactly does your collaboration look like or rather what makes it so special?

_PK . From the perspective of research technology, DRESDYN is a very special project since a lot of the technical engineering contents have to be clarified with our external →

A SPECIAL PROJECT: Scientist Frank Stefani and heavy machinery engineer Christian Steglich, along with Peter Kaever, head of research technology (from left to right), are all collaborating closely to meet all of the major challenges posed by DRESDYN. Photo: Matthias Rietschel

partners. This highly networked system contains countless components we have to monitor and always evaluate precisely in terms of technology. Another distinctive feature is that we won't know whether or not the dynamo starts up until the machine runs at process speed and thus is capable of establishing the fluidic flow for the science we have in mind. Being an engineer, DRESDYN means that the design work cannot be done in small independent sections so that it won't be clear until the very end whether all the various pieces of the puzzle fit together. Which is why the scientists are depending on us to a greater extent than usual.

Our team member Christian Steglich, who has a good background in heavy machines design, focuses on the engineering side, whereas I'm involved in control and safety topics. His second focus is the coordination of the participating companies. We're quite happy that - after an elaborate Europe-wide call for bids - we were at last able to work with a Dresden-based company for the construction of the precession machine as it has various components that are critical to its function. The company - Saxon Bridge and Steel Construction SBS - was charged with producing two of the machine's essential components - the turntable and the dynamo's entire support frame.

_FS . To me, the planning complexity of DRESDYN is a real challenge, indeed. I am truly happy to have a research technology partner we collaborate and get along with so well. The colleagues have a lot of appreciation for science and for the fact that we don't yet know all of the various parameters in depth. By the way, we sit down together nearly every other day, in different constellations no less. For example, SBS is part of a typical meeting along with the Chemnitz-based company Liebers, which is the subcontractor that is building the container. Other regulars include Michael Beitelschmidt of the engineering faculty at TU Dresden and his team, which is in charge of mechanical stability calculations and prepping them for the MOT. Even if it's just one single parameter that changes for the machine, sometimes everything has to be completely recalculated. It's a multiple iterative process and I find these iterations to be rather nerve-wrecking, so I do admit I have a few sleepless nights here and there because of them.

I heard about an otter that nearly foiled DRESDYN. Would you like to share that story with us?

_FS . The otter was an unexpected variable but I didn't really lose sleep over that one. In a distance of 50 meters from the building, it commutes between two lakes. Our technical service was ultimately able to compromise with the environmental agency by agreeing to move the building over by about ten meters. We can definitely live with that, all the more as we've spent a lot of time pondering DRESDYN's ideal location. We had a few options but for reasons of safety and vibrations, we really wanted to be off the beaten track. The fact that the old heating house was slated for demolition ended up being perfect for us as it opened up the optimal location. →

Where do you stand now and what are the next milestones?

_FS . Construction started in April, we placed our order for the precession machine back in November 2012, we already have a rough draft for the experiments to model magnetic instabilities, and at this point we're hard at work filling in the details.

_PK . Exactly. We're right in the middle of a stage where the technological model is being tested in different directions and its plausibility validated with the help of computations done at the TU Dresden. Given the various control interfaces with the building management system and savings of almost one million Euros, we decided to design the control system within the department of research technology.

_FS . By this year, construction will be more or less complete. Next, construction of the dynamo and its various components will begin. The building will be built at the same time. Construction of the interior will commence in 2014 and that is the earliest we will be able to start to think about implementing the experiments. I'm guessing that we will tackle the first installations for the dynamo experiment in 2015. Initially, we will continue with the water experiments, not just as preparation but also because they have their own scientific value. After all, there have never been precession experiments at such high Reynolds numbers.

_PK . Of course, all of this has a high inherent technological value. Presently, it is not possible to simulate the entire machine including the different flux modes.

_FS . Because this time it's all about a completely free flow in all three spatial directions. Nobody is able to simulate something like this. Today, we perform computations with Reynolds numbers of up to 10,000, and the end of the flagpole follows soon thereafter. However, as part of our experiment, we're looking at Reynolds numbers of 85 million. We can only guess at the scaling of the precession powered flow in-between. Which is why we did the water experiment - with a Reynolds number of 1.6 million, after all - and are thus hoping to minimize the remaining risks. It's already yielded a few rather exciting results. As such, we were able to observe, for instance, abrupt changes from laminar to turbulent flow, with highly interesting effects.

We took initial speed measurements using ultrasound and we're in the process of installing a cutting-edge 3D particle-image-velocimetry system to allow us to measure the flow completely for the first time. All of this is of great importance to the sodium dynamo's success. But, in any case, we're looking at a scientific remaining risk and are not able to say with a hundred percent certainty whether or not - and if so, then in what parameter range - the dynamo will work.

Which collaborations are important for DRESDYN?

_FS . DRESDYN was conceptualized as a European research platform and benefits from diverse collaborations. I think it's important to mention the Helmholtz alliance LIMTECH, where several projects that directly latch onto DRESDYN, are located. Including a project with Göttingen University and AIP, the Leibniz Institute for Astrophysics in Potsdam: Andreas Tilgner, one of the World's leading experts in this field, performs calculations for the precession dynamo, while the AIP wants to continue to work with us in the area of magnetic instabilities. In addition, it is our special concern that we coordinate with the international dynamo community like Dan Lathrop at the University of Maryland.

However, DRESDYN will not be a user facility in the strictest sense of the term; for safety concerns, that's just not possible. But we're happy about all the various proposals for sodium-based experiments we can work on together as part of long-term collaborations.

FUTURE PROJECT DRESDYN: Between 2013 and 2015, the World's first ever precession dynamo will be built on the HZDR campus. Image: Wörner & Partner Planungsgesellschaft mbH

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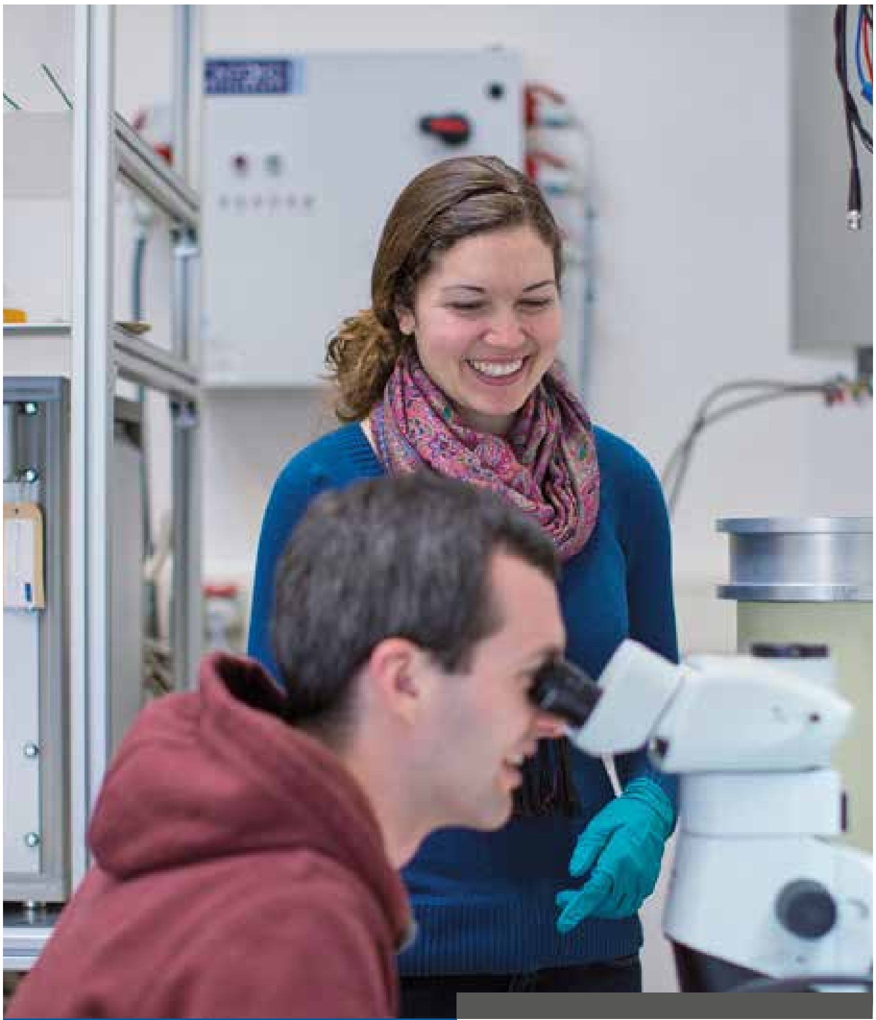

// "I love to challenge myself, pose my own questions," says Elizabeth Green. Since the middle of last year, the 28-year-old American physicist is studying the behavior of superconductors at low temperatures and in high magnetic fields at the Dresden High Magnetic Field Laboratory.

LOCAL CONTACT: Elizabeth Green supervises external users and mentors both Ph.D. and diploma students like Johannes Klotz during their research projects.
Photo: Oliver Killig

FLORIDA TO ROSSENDORF

_TEXT . Sara Schmiedel

Elizabeth Green's – she actually prefers to go by Liz – main interests include strongly correlated electron systems, quantum mechanics, and magnetic resonance spectroscopy. She also loves to compete in triathlons, plays the violin, and donates her long hair (whenever she gets it cut) to an organization that makes wigs for cancer patients. Plus, she is one of a handful of women in a largely male-dominated scientific discipline. "That's never been an issue, though, they take me as seriously as the next guy," the young physicist assures us.

The light bulb has to go off

Liz works in the High Magnetic Field Laboratory as a "local contact" – a scientist whose job it is to advise and help external users with their experimental setup and pulse magnetic fields. In addition, Liz mentors Ph.D. and diploma students who are working on their own research. "I really enjoy it. You learn about all these different techniques and meet these really interesting scientists – which actually helps me to grow, too." And to the junior researcher growing is a top priority. "I've no clue where I'm going to end up after my three-year Dresden postdoc stint is up – but I could see myself as a professor someday." Teaching is her thing. She did, after all, set out to become a physics teacher but, after finishing her bachelor's, decided she was really into the raw science. She ended up getting her Ph.D. at the National High Magnetic Field Laboratory in Tallahassee, Florida, despite the fact that she actually used to hate physics in high school. "I was really trying my best but back then it was difficult for me to grasp the concepts. I ended up getting a bad grade in the class which made me pretty upset." Thanks to "awesome physics professors who had a knack for really breaking things down for me, at one point that proverbial light bulb just happened to go off." →

The search for materials of the future

Cedomir Petrovic of Brookhaven National Laboratory in New York also came to Rossendorf to study innovative materials in high magnetic fields. In 2012, Petrovic spent six months conducting research at the Dresden High Field Magnetic Laboratory (HLD). The Humboldt Fellow is an adjunct professor at Johns Hopkins University in Baltimore, Maryland, USA.

What is it you are working on these days?

My focus is on new superconducting materials and their properties in high magnetic fields. Some of these materials are potential candidates for application in things like energy transport or wind power plants. My colleagues and I are trying to understand the microscopic mechanisms underlying unconventional superconductivity and improving the properties of superconducting materials. We are looking for new superconductors capable of improving the power grid's capacity, efficiency, and reliability.

What are some of the materials you are studying?

Many of them I produce myself – like, for instance, heavy fermion superconductors such as cerium cobalt indium, a superconductor with the highest known transition temperature of its kind, and the recently discovered family of iron-based superconductors with very high critical fields.

What are you using these high magnetic fields for at the HLD?

Very high magnetic fields are a perfect way for looking at the inner life of these newly synthesized materials in order to better understand and continue to develop them.

How did you like your research stay in Dresden?

I've been to a lot of different research sites and can honestly say that the Dresden laboratory is one of the more comfortable and well-organized research facilities. They have a highly competent support infrastructure in place and are always ready to lend a helping hand, which is nice. There is a plethora of different techniques and instruments available – and everything runs smoothly. I plan on spending another six months in Dresden in 2014 but until then I am certain there will be many more joint projects to work on with my Dresden colleagues.

Physicist with every fiber of her being

No, she honestly didn't know a single word of German when she first arrived at Rossendorf, promises Elizabeth Green, laughing. She enrolled in an HZDR language course but ended up dropping it because there simply weren't enough hours in the day. Liz doesn't worry about it too much though, since communicating is getting easier with each passing day. With hands and feet, if necessary, and most importantly with that heartfelt laughter the people she interacts with get to enjoy often – a testament to her perpetual good mood. But can you honestly be in a good mood when you're all alone in a foreign country where you don't really know the language, with ten-hour work days and a pile of scientific papers waiting for you when you get home? "Yea, but then that really is the job of a scientist," says Liz. "Since physics is my passion, I don't really mind having so little time to spare." →

UNDER OBSERVATION: From the control room, the scientists guide and supervise experiments that have to be performed behind thick walls for security reasons. Photo: Oliver Killig

PULSED RECORDS: HZDR scientists are developing internationally unique magnetic coils that are built at the in-house workshops and even used in industry. Photo: Oliver Killig

Being homesick is just a natural part of the deal

"Of course I feel alone sometimes and I miss my family and friends," Liz admits. It's especially hard on major holidays like Thanksgiving, "but I also realize it's part of this whole experience." Liz thinks her Rossendorf colleagues are simply the greatest. "My officemate Marc, my British colleague Joseph and his German wife have all been so supportive right from the start and helped us when we had to make our rounds at all these different agencies and offices when we first got here," says Liz, who holds Hungarian dual citizenship owing to her Hungarian father. And technically she isn't over here by herself either – Liz did embark on her overseas adventure with husband Bert in tow. He went to school for computer sciences and physics and, a few months ago, started working on his Ph.D. at HZDR's own ELBE accelerator. The two met at college and, in 2010, were married.

Asking questions and finding answers

What started out as a joke all of a sudden took a turn for the serious: Liz and Bert didn't get married in a traditional setting - a city hall or a church – but instead opted for a hybrid magnet at the High Magnetic Field Laboratory in Tallahassee as the best fit locale for their wedding – dressed in jeans and a T-shirt with the lab's logo printed across it. Ever since, Liz has been wearing a ruby ring on her left hand. No coincidence there: After all, it was exactly 50 years prior that an American engineer developed the first laser by shining a bright flashlight on a ruby crystal - a discovery, which by now, has become a staple of everyday life, communication, and science.

In 1960, this American engineer came up with all the right answers - just like Liz is hoping to. "I'm interested in finding solutions to problems that affect us all, like, for instance, how we might save energy," she explains. One thing she would like to find out is whether or not materials capable of conducting electricity at room temperature without a loss of current – in other words superconducting materials – actually do exist. But before the ambitious scientist will find her answer, she will have to keep asking a few more of just the right questions.

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// EU project EMFL unites the strengths of the top three European high magnetic field labs.

STRONG PARTNERS: Radboud University Nijmegen houses one of Europe's top three most important and largest high field labs. International users are able to rely on experienced and motivated staff like Hans Engelkamp. Photo: Dick van Aalst

HAND IN HAND IN MATERIALS RESEARCH

_TEXT . Sara Schmiedel

Generating high magnetic fields in the lab is anything but simple. Since, however, they are ideally suited for looking inside materials and to study their fundamental properties, high magnetic fields are a popular and important scientific tool. Worldwide, there are just a handful of institutes that have dedicated themselves to the generation of high magnetic fields and that make these fields available to international researchers for their experiments. The high-field lab in The Netherlands at Radboud University Nijmegen, the Laboratoire National des Champs Magnétiques Intenses with sites in Grenoble and Toulouse, and the Dresden High Magnetic Field Laboratory (HLD) are the three most important and biggest labs of their kind in Europe. Now, they are well on their way to become united as the European Magnetic Field Laboratory, or EMFL.

More than ten years of European collaborations are proof of the well-established strong links between the three labs. Much has been achieved already: A common selection committee meets regularly to rank the magnet-time applications. There is an active exchange of scientists and expertise, a joint yearly prize for outstanding scientists, and →

communication activities. "Now, the EMFL project takes things one step further to include structural and organizational aspects, giving it an advanced research-political importance," explains HLD's director Joachim Wosnitza. The EMFL is on the ESFRI list – the European Strategy Forum on Research Infrastructures – aimed at identifying and strengthening Europe's most important future research infrastructures. Since early 2011, international working groups have been examining how the three sites might be united in terms of technology, science, and personnel, through a series of EMFL work packages. Not exactly an easy task: "The three labs have markedly different origins and have developed in different directions, have different organizational structures, and should of course keep their roots within their respective parent organizations," says Joachim Wosnitza.

Despite their collaboration and close connection, the three labs will remain independent. The plan for next year at the latest is to declare the EMFL an association under Belgian law. "Which will make us more clearly perceived as a single unit to the outside world, and which in turn will strengthen our competitiveness," explains Wosnitza.

Shake hands, make friends

2011 saw the first ever "3to1" EMFL staff meeting. The underlying idea: From three to one. Over 150 scientists, technicians, engineers, and administrative staff from France, Germany, and The Netherlands spent three days in French La Colle-sur-Loup and got to know each other and each other's work. Across the board, the consensus was: "Awesome!" The next 3to1 meeting is scheduled for late 2013.

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Diagram: Oberüber | Karger Kommunikationsagentur GmbH

// What kinds of recyclable materials are slumbering inside the old mine tailings found all throughout the Ore Mountains [Erzgebirge]? Trying to find the answer to this question is the focus of a research project coordinated by the HIF, the Helmholtz Institute Freiberg for Resource Technology – one of the HZDR's institutes. An ensemble of cutting-edge analytic equipment is available for the researchers.

RAW MATERIALS UNDER THE MICROSCOPE

_Text . Anja Weigl

RESEARCH WORK: Before geologist Inga Osbahr is able to examine materials obtained from tailings and packaged inside PVC pipes to determine their constituent parts using an electron beam, the sandy mixture must first be prepped. Photo: VNG - Detlef Müller

Analytic equipment used to characterize raw materials at the Helmholtz Institute Freiberg:

// Scanning electron microscope with MLA software
// Field emission microprobe
// Mass spectrometer femto laser ICPMS
// Ion beam analytics/Ion beam microprobe
// X-ray camera high-speed PIXE
// X-ray powder diffractometer
// Raman microscope

VALUABLE SOIL: At the beginning of this year, Philipp Büttner and Inga Osbahr obtained soil samples from several former tailings dams in Saxony's Ore Mountains. The material that is thought to contain remnants of important industrial raw materials is prepared for measurement by Thomas Leißner (from left to right). Photo: VNG - Detlef Müller

Saxony's ore mining industry ceased operations early in the 1990s but large residual amounts of metals like tin, zinc, and lead exist to this day. They are contained in the remnants of mechanical and chemical processing of the ore that ultimately ended up inside tailings dams. "Archival data tell us that up to 50 percent of the original quantities of tin are being stored there," says Philipp Büttner of the Freiberg Helmholtz Institute. The project he coordinates is entitled "Strategic Metals and Minerals from Saxony's Mine Tailings." As part of the project, researchers from the TU Bergakademie Freiberg and their industry partners are hoping to determine the exact amounts and distribution of raw materials inside the tailings and how to recover them. The project is part of a larger program funded by the Federal Ministry of Education and Research (BMBF) that is concerned with the recycling and replacement of industrially relevant raw materials ("r^3" – Innovative Technologies for Resource Efficiency – Strategic Metals and Minerals).

In today's economy, resources that didn't hold much appeal in the past have suddenly become economically attractive. "Back then, nobody gave high-tech metals like indium, germanium, and lithium much thought and their occurrence and distribution were rarely studied," explains Büttner. "However, we suspect that the residual amounts that were produced during ore processing and that are now stored inside the tailings do include these high-technology metals. We're trying to find out how much of it is stored there and what the distribution is." The researchers have to carefully study the tailings and analyze large numbers of samples because in many cases the raw materials that are key ingredients of generators, batteries, and television or computer screens have a complex distribution and occur in only small concentrations.

Frequently, the minerals that contain the metals in question can only be seen using high-resolution microscopes or special probes. The HIF and the TU Bergakademie Freiberg have all the necessary analytic equipment available for these kinds of investigations. This cutting-edge equipment was funded by the BMBF and the Free State of Saxony. According to Anke Dürkoop, "it is available to all members of the "r^3" program, who are given preferential treatment, but other HIF research partners are also welcome to use the equipment." Dürkoop coordinates another project of the "r^3" initiative at HIF called "INTRA r^3+," which links up the 27 separate "r^3" projects. "Thanks to the HIF equipment pool, we have several options for quantitatively characterizing raw materials."

Under the electron beam

A number of research facilities are all working in parallel as part of the tailings project. At this point, the sample material, which was obtained from several different tailings in Saxony's Ore Mountains, is still being stored inside buckets or packed inside PVC pipes. Soon, it will hit the research labs. Inga Osbahr of the TU Bergakademie's Institute for Mineralogy is one of the first to work with the samples. Osbahr's job is to screen prepared mixtures of fine and coarse grain sand particles using a scanning electron microscope. The X-ray radiation that is reflected by the minerals in the process is unique for each mineral. This allows the researcher to learn about the composition of the materials inside the tailings and which minerals occur in combination. However, the method does not allow for an identification of the materials' distribution patterns. For that, the samples would have to be split into their atomic building blocks using high heat and then analyzed with the help of a highly sensitive mass spectrometer. An X-ray powder diffractometer can then be used to assess the samples' constituent elements in order to determine the minerals' exact structure.

Finally, the data are entered into a super-regional database along with related info from other German mine tailings. This tailing registry of sorts is being co-developed by several "r^3" partners. In the end, the data will show whether it is ecologically compatible and economically feasible to use the remaining raw materials that are currently stored inside the tailings. Progressive technologies could also play a role in the decision-making process. The researchers' guess is that they will know more within three years' time, which is how long their investigations will run for.

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// The name of the European project ENVISION gets straight to the point: the aim is to visualize the invisible particle beam inside the patient's body.

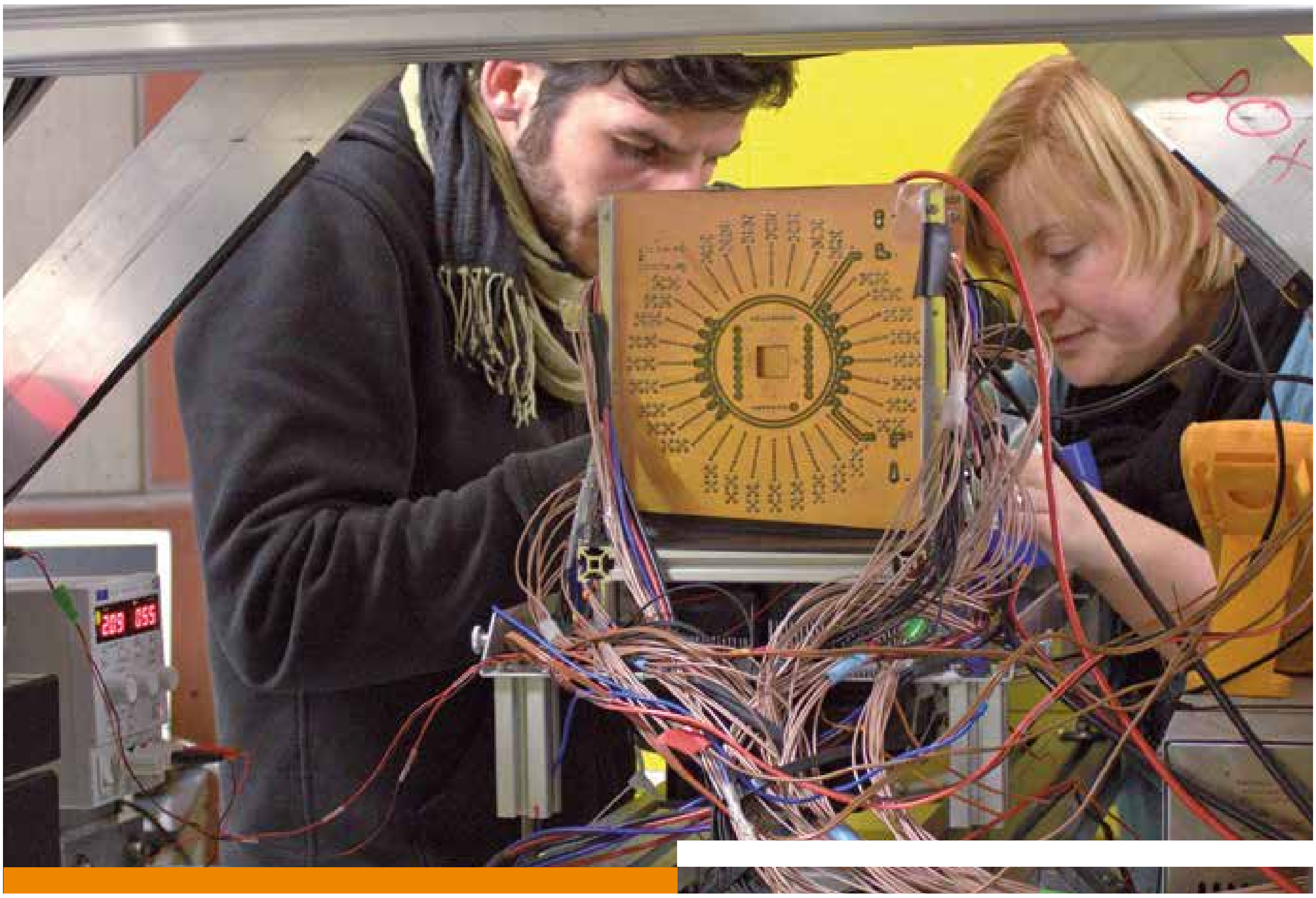
THERAPEUTIC BEAMS FOR CLINICAL APPLICATION

_Text . Christine Bohnet

For about 60 percent of cancer patients in modern industrialized nations, radiation therapy significantly contributes to curing this widespread disease. Experts are in agreement that, in addition to conventional photon therapy using ultra hard X-rays from linear electron accelerators, particle therapy will also become an established modality of cancer treatment in the future. Comprehensive studies are required to confirm the benefits of this type of therapy. Particles include protons – hydrogen atoms that were stripped of their electron –, electrically charged carbon atoms, or ions of other elements. As part of a joint project by the Carl Gustav Carus University Hospital Dresden and the HZDR, a new facility for clinical research and further technological development is currently being installed on the university hospital campus. The main goal is to establish proton beams over the next ten to fifteen years as an affordable and highly effective form of therapy in the clinical setting.

An important prerequisite is the ability to monitor therapeutic irradiation in real-time. This is especially important in the case of particle beams, since they deposit a substantial amount of their energy within a pinhead-sized volume in the body. The position of this volume can be very precisely →

EXPERIMENT: Christian Golnik and Anne Dreyer are mounting a camera prototype to measure high-energy photons. In particle therapy, the irradiated tissue sends out similar rays. If their site of origin can be identified, this would allow for real-time monitoring of the therapy. The ultimate goal is a camera system that can be used in the clinical setting.
Photo: Guntram Pausch/OncoRay



set by choosing the particle range in the tissue prior to treatment. This is exactly why radiation oncologists consider proton and ion beams a highly effective anti-cancer weapon. In the case of state-of-the-art X-ray based cancer therapy, refined techniques for optimal irradiation are available. These technologies cannot readily be adopted for particle beams because of their different physical behavior.

This status quo is what prompted the ENVISION project. Originally proposed in 2007 by Ugo Amaldi of CERN, the European Nuclear Research Center in Geneva, and Wolfgang Enghardt of the OncoRay Research Center in Dresden, the project has been coordinated by CERN ever since 2010. Scientists from 15 research institutes and one medical technology company are together developing imaging devices and protocols to visualize the invisible particle beam inside the patient's body. They are exploiting the fact that a proportion of the particles collides with atomic nuclei of the irradiated tissue. Because of the particles' high speed - they travel at up to 70 percent of the speed of light - nuclear reactions are taking place. This leads to secondary radiation like gamma radiation, fast protons and neutrons; they carry useful information about the radiation's degree of precision. The researchers are working on a number of topics simultaneously:

// Development of radiation detectors that precisely register secondary radiation, in particular its energy and its position of origin.

// Design of software capable of calculating from these signals highly informative images and clinically relevant conclusions in real-time for all therapeutic situations – in particular also for tumors that follow the breathing motion.

// Integration of this software into the planning of radiation treatment as a prerequisite for "adaptive" particle therapy; deviations from the treatment plan are immediately corrected by adjusting the radiation parameters.

HZDR department chair and physicist Fine Fiedler and her former Ph.D. supervisor Wolfgang Enghardt are working closely with five Ph.D. students to find answers to these questions. Says Fine Fiedler: "Our goal is to determine both the range of the protons and the applied radiation dose directly during radiation treatment. A major benefit to us is the close collaboration with the University Hospital and the TU Dresden at the OncoRay Center because it allows us as physicists to directly exchange ideas with experts from the fields of oncology, cancer biology, or computer science. This is very important: After all, ultimately, these devices must prove useful in the clinical context." Therefore Fiedler and her OncoRay colleague Guntram Pausch, who is head of the "In-vivo dosimetry for new types of radiation" group funded by the Federal Ministry of Education and Research (BMBF), make for a great team.

Nuclear physics meets medicine

Wolfgang Enghardt is the force behind nuclear physics making its way successfully into medical technology, since he is an international expert in this field. As part of the German Heavy Ion Therapy Project, years ago, he developed a PET camera to image the particle beam's path inside the patient's body following treatment. Today, Enghardt heads the corresponding part of the ENVISION project and is also the man in charge of the project overall here in Dresden. "Radiation oncologists need images that show how much of a given dose actually ends up at its target destination. But we're also working towards the implementation of protons as adaptive high precision therapy in the everyday clinical setting. Our new high-tech equipment is supposed to directly intervene in the treatment and make corrections if there are any deviations of the actual beam from the calculated dose or range."

Oncologists estimate that some 15 percent of all radiation therapy patients will benefit from particle therapy. The additional devices and techniques being investigated within the frame of the ENVISION project are indispensable. Only they are capable of creating the proper conditions to enable proton and ion beams to destroy the cancer completely while sparing the surrounding healthy tissue as best as possible.

Wolfgang Enghardt is a realist: "Ever since 1896, when X-rays were first introduced in cancer therapy, the challenges for physicians, physicists, and engineers have been the same, that is increasing the efficacy and precision of radiotherapy. The ENVISION project, which is funded by the EU through 2014, has yielded cutting-edge physical and technical solutions. A few of these important results may become clinically relevant over the coming years. However, rapid development of accelerator technology, radiation detectors, and IT solutions, will guarantee that, in 10, 20, or 30 years' time, as long as radiation therapy will continue to exist as a highly effective cancer treatment modality, research on this topic will go on and refined technological solutions will reach the clinical setting."

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// Dresden has a tight network of scientific and research institutes whose common goal it is to develop strategies for Dresden as a scientific hub and use synergies. To this end, they have joined forces as the DRESDEN-concept e.V. association. We sat down with Manuel Joiko, the association's new director.

"IMPLEMENTING THE FUTURE CONCEPT TOGETHER"

_Interview . Anja Weigl

Mr. Joiko, you have been head of this office since the beginning of the year. Pray tell us about some of the tasks that are keeping you especially busy at the moment.

Manuel Joiko: At this time, paying official visits to DRESDEN-concept members are at the top of my list. My main goal is to find out about their topics of focus as part of this alliance, what their expectations are of us, and what they're hoping to contribute this year. Until now, two clear-cut fields of action have crystallized that I am taking care of: There are already so many joint partner activities, but they are not nearly well-known enough. And there are such awesome ideas for how to increase the synergistic potential but in many cases these have not yet trickled down to the level of the workplace. What's most exciting is the fact that since the beginning of this year, many interested parties have approached DRESDEN-concept to discuss different options for collaborating.

The association was an important building block for the success of the TU Dresden as part of the federal excellence initiative. The main goal has been achieved: The TU is now counted among the universities of excellence. What are some of the plans the association has at this point?

True, it did allow the TU Dresden to join the ranks of the excellence league. Now what counts is implementing the future concept entitled "The synergistic university" as the TU strategy for the coming years and to achieve new levels of excellence in research, education, infrastructure, and administration. The two agreed upon excellence clusters as well as the graduate school are playing a central role in all this. The HZDR's involvement in these projects is as a partner. The HZDR is a very important partner, though, because it is part of the association's board, the DRESDEN-Board, and is also represented in the administrative and infrastructure committee.

> To get to a level of excellence in research, education, infrastructure, and administration.

What is the DRESDEN-concept partners' plan for using synergies in research, education, infrastructure, and administration? Could you name a few representative projects? What have been some of the successes?

First off, the common technology platform needs mention as it allows for a quick and easy retrieval of information as well as access to equipment and service offers by our members. We have made great strides in terms of the work and are currently in the process of successively adding additional →

partners through common points of intersection. Currently, this is the case with the HZDR. Although there is much more work ahead of us, which is why we're currently stocking up on our resources for that particular project. At the Genome Center, the use of the technology platform is already a lived reality. Both the DRESDEN-concept partners and the TU Dresden are conducting cutting-edge genome research at the Center on very expensive equipment. The Genome Center's strong appeal was confirmed when it recently received a donation by the Klaus Tschira Foundation.

But there is also a successful smaller-scale project: our Dresden Science Calendar, which, at this point, lists all the various scientific lectures and events that are being offered! Last year, some 1,600 events were listed in that calendar. The website frequently gets more than 10,000 hits per month. What's next is an event calendar app!

The association also includes Dresden museums and collections. What are some of the points of intersection and common goals that they share with science and research in Dresden?

The cultural institutions that are part of our association are themselves doing research. Incidentally, that is one of the crucial criteria that must be met in order to become a DRESDEN-concept member. As such, it's especially about initiating research collaborations between different kinds of partners and organizing them or rather letting them know about different options.

A central topic, for instance, is digitalizing our respective stocks. The partners could benefit from the exchange of equipment, methods, and experience. But there are other useful and successful collaborations as well: on the one hand, the preservation of cultural artifacts to prevent things like the decay of important papers and, on the other hand, using cutting-edge analytic methods to examine the clothes August the Strong wore that are kept in the armory as part of the Dresden state art collections, which has yielded very interesting results. As you can see, our cultural institutions are not standing next to science and research but right in the midst of them!

Photo: Claus Preußel

Meet Manuel Joiko

As of January 1, 2013, Manuel Joiko (age 59) is the new director of the DRESDEN-concept e.V. association. Born and raised in Leipzig, he studied information processing at the TU Dresden, where he was employed as a scientific associate. Since 1990, Joiko has occupied management level positions in different IT and management consulting firms as well as software companies including the Siemens Corporation, the SAP Group, as well as, most recently, Capgemini in Munich, Düsseldorf, and Frankfurt/Main.

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// New Institute of Radiooncology at the HZDR.

IMPROVING CANCER THERAPY USING "NEW" KIND OF RADIATION

_Text . Anja Weigl

CANCER EXPERT: Michael Baumann is Director of the Institute of Radiooncology. Photo: André Wirsig

For some time now, the HZDR, the Carl Gustav Carus University Hospital Dresden, and the Faculty of Medicine at the TU Dresden have been working together at the Dresden-based OncoRay Center in the area of radiation research in the fight against cancer. The mission of the HZDR's new Institute of Radiooncology – founded January 1, 2013 – is to further increase the presence of Radiooncology research in Dresden. One focus of the research is on proton-beam therapy.

The director of the new Institute of Radiooncology, Michael Baumann, is an esteemed leading international cancer expert. He is Director of the Department of Radiation Oncology at Dresden University Hospital and Chair of the OncoRay Research Center. And he is a former president of ESTRO, the European Radiation Therapy Association, and ECCO, the European Cancer Society. Michael Baumann also advises the German federal government on health research in the "Forschungsunion". And when asked how cancer might be prevented, the advice he offers seems simple enough: "Quit smoking, eat healthy, be physically active." Unfortunately, this is no patent prescription: As clinical director, who is dealing with cancer patients on a daily basis, he knows this better than anyone.

According to Michael Baumann, oncology – the science of cancer prevention, diagnosis, therapy, and follow-up care – has come a long way in recent decades. No other medical field has seen this much progress in offering patients personalized care based on the latest biological and technological research. This is also the approach taken by cancer research in Dresden. For many years, OncoRay Center scientists and physicians have been doing research into technologically optimized and biologically individualized forms of radiation therapy to help cure a larger number of cancer patients. Only close collaborations will ensure that new research findings make their way quickly out of the lab into the clinic and to the patient. The new Institute of Radiooncology is meant to help with promoting translation of the latest radiation research findings.

The Institute builds a scientific structure reflecting that of the University Hospital's Radiation Oncology clinic and OncoRay. Just as is the case there, the Institute will have four departments: radiation oncology, translational radiation oncology, medical radiation physics, and radiation biology. The clinic, OncoRay, and the Institute will also be close together geographically. Researchers are scheduled to move into the new proton therapy center, located right next to the clinic, later this year. Approximately in 2014, the center's proton beams will be used in cancer therapy and tested in clinical trials.

Particle beams are capable of destroying malignant tumors with higher precision while better protecting the surrounding healthy tissue than do conventional X-rays. Together with their HZDR colleagues at the Institutes of Radiopharmaceutical Cancer Research and Radiation Physics, the scientists are planning on developing a proton beam therapy technology using visualization methods that help characterize biological properties of tumors, which in turn would optimize planning the radiation treatment. Other topics include more precise irradiation of moving tumors, real-time monitoring of the radiation dose, or a new laser-based ion beam accelerator technology. A prototype of this technology is slated for testing in the following years at the new proton therapy center. Treatment of the first patients is scheduled for 2014.

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// Chemist Sibylle Gemming is a leading HZDR scientist. As of January 2013, she is also a professor at the TU Chemnitz Institute for Physics. For her work, Sibylle Gemming has received one million Euros in funding from the Helmholtz Association's "W2/W3 program for excellent female scientists."

CHEMISTRY TO PHYSICS TO MATERIALS RESEARCH

_Text . Christine Bohnet

Sibylle Gemming is a chemist by training - who earned both her university and Ph.D. degrees at the TU Munich. Her focus has always been on computer-based modeling rather than laboratory science. As a postdoc, she spent four years at the Max Planck Institute for Metal Research in Stuttgart and at SISSA in Trieste. Here she switched to solid state physics. Today, she is working at the Institute of Ion Beam Physics and Materials Research at the Helmholtz-Zentrum Dresden-Rossendorf and considers herself a material scientist. Along with her colleagues, she studies molecules and solid state systems at the nanometer scale. In contrast to materials as we know them, these very tiny structures are exhibiting completely new properties that have yet to be studied experimentally and by use of simulation.

WIRES, TUBES, LAYERS: Sibylle Gemming, Professor at the TU Chemnitz since January 2013, deals with molecules or solid state systems on the nanometer scale.

Gemming is also head of the MEMRIOX Virtual Institute, which has been funded by the Helmholtz Association since October 2011. The scientist is interested in wires, tubes, layers - all in the nanometer range. MEMRIOX - Memory Effects in Resistive Ion-Beam Modified Oxides - links up eight partners from Germany, Switzerland, and the US. The research focus is on passive electronic elements whose resistance can be set using an electric current. The goal is to miniaturize electronic components - in the nanometer range, of course - for a "green" kind of data processing.

Good relations with the TU Chemnitz

Many years of close collaboration connect the scientist to the TU Chemnitz. As such, she spent three years as a scientific associate at the Institute for Physics prior to earning her habilitation in December 2004 at the TU. In 2005, she received the *venia legendi* to teach physics. Sibylle Gemming wants to invest the Helmholtz Association's "W2/W3 program for excellent female scientists" funds in staff and equipment: "Our plan is to examine how contacts between different materials can be optimized for energy-efficient electronics or for the generation of renewable energies. We are especially interested in assessing the impact of the smallest changes at an atomic scale on the properties of the entire system. The HZDR's methods are the best premise for this."

To name one other of Sibylle Gemming's many activities and jobs: Her role as speaker of the Virtual Institute MEMRIOX and recent completion of an advanced training course in science management at the Helmholtz Management Academy predestine her for an active role in program-oriented funding, the tool used by the Helmholtz Association to finance research and coordinate the different centers' scientific collaboration. To reconcile her work with her family life, Gemming has recently gone on a sabbatical from directing the HZDR's Division of Scaling Phenomena. Through the end of 2014, physicist Artur Erbe will be in charge of the division's roughly 30 employees. "I have always been able to rely completely on the excellent members of my team," Gemming emphasizes. "Only together were we able to build up what we achieved over the last few years."

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// An HZDR junior research group is developing innovative fuel cycles for nuclear reactors and conducting research on how to improve the safety of the next generation of reactors.

AND THE RESEARCH CONTINUES...

_Text . Emil Fridman & Christine Bohnet

Neutron physics or nuclear technology? For the recently established Reactor Physics Junior Research Group at the HZDR the boundary between these two fields is somewhat blurred. The group consists of three doctoral students from the Ukraine, Israel, and the Czech Republic, and Emil Fridman as head of the group. Its main focus is on innovative nuclear reactors and advanced nuclear fuel cycles. In nuclear technology, however, experiments are very complex and costly, which is why the work of the scientists is all about computer simulations.

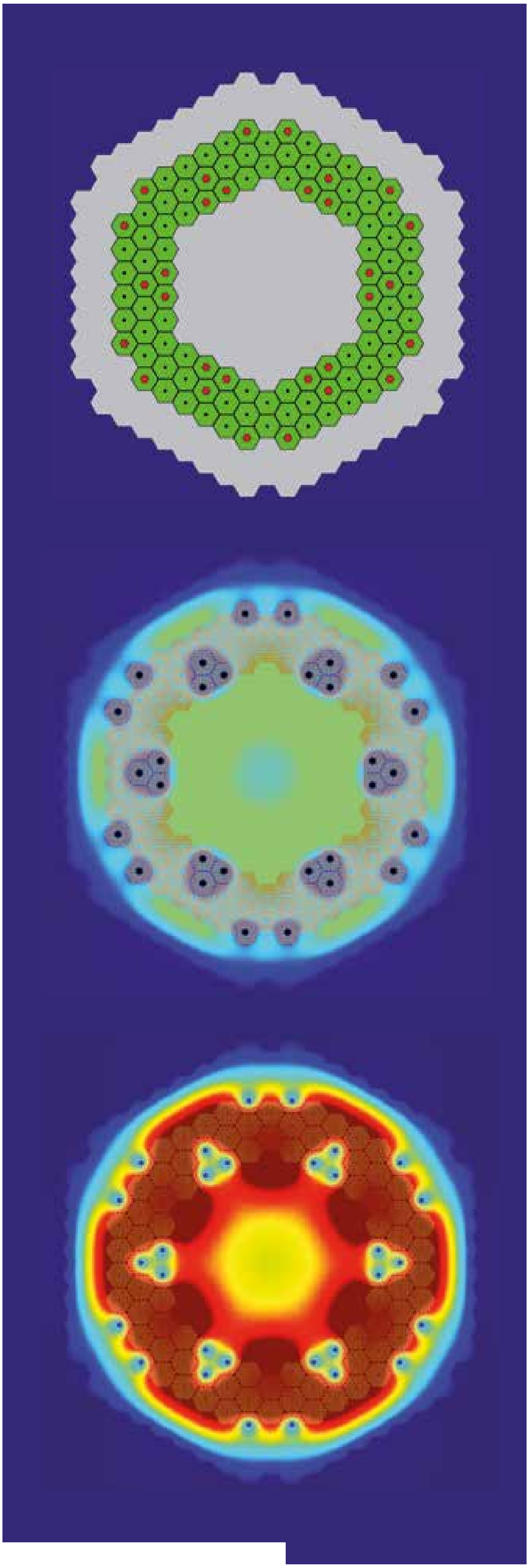
The current fleet of nuclear reactors, dominated by thermal-neutron light water reactors of Generation-II and -III, provides extensive experience in reactor operation and is presumed to be both safe and reliable. However, these reactors are characterized by inefficient fuel utilization. Innovative Generation-IV reactors could significantly improve the utilization of natural resources while minimizing radioactive waste. These reactors have to be designed in such a way that they comply with today's sustainability goals and modern safety requirements. The successful design of nuclear reactors depends to a large extent on the availability of sophisticated computer simulation codes which can accurately predict the behavior of nuclear reactors under normal and accident conditions.

The Fridman Group contributes to the development of a computer code system to be used for the simulation of Generation-IV nuclear reactors including high-temperature gas cooled reactors, sodium-cooled and lead-cooled fast reactors. The code system is based on the reactor dynamics code DYN3D developed at the HZDR for the safety analysis of operating light water reactors and used by more than 15 research organizations in Germany and beyond. Generation-IV reactors differ considerably from the conventional light water reactors with respect to neutron physics behavior as well as thermal-hydraulic and thermal-mechanical properties. Consequently, the light water reactors' oriented DYN3D code has to undergo substantial modifications before it can be applied for the modeling of novel reactor types.

Codes must be fed

"In some sense, a reactor simulation code is similar to a car. Just as a car requires fuel to run, a code must be fed with the proper data describing the nuclear properties of the reactor core components. Only then can you reliably perform simulations." Yet, according to Fridman, "preparing the data is anything but straightforward." The methodology →

PROGRESS: Weekly meetings are very important to Emil Fridman (right) as they are a venue for scientists Susan Dürigen and Yurii Bilodid to present their research findings.



FOCUSSING ON GAS-, SODIUM-, AND LEAD-COOLED REACTORS: The figure shows the results of the neutronic simulation of a high-temperature gas cooled reactor core using the SERPENT Monte-Carlo code. The upper figure presents the top view of the reactor core | *green – fuel blocks* | *red – control rods* | *grey - graphite reflector* |; the middle figure shows the thermal neutron flux distribution; the lower figure the total neutron collision rates distribution.

for the light water reactors' analyses is well-known but not directly applicable to Generation-IV reactors. Therefore, new procedures have to be developed. Typically, nuclear data are prepared using deterministic computer codes. However, the group decided on a different course and to use the Monte-Carlo based code "Serpent," which is currently being developed at VTT, Technical Research Center of Finland. In contrast to the deterministic codes, Monte-Carlo-based simulators are able to handle the complex geometries of advanced reactors without any major approximations. Moreover, the capacity of computer workstations and clusters has increased to a level that allows computationally expensive Monte-Carlo methods to be used for production calculations. The young researchers help the Finnish developers to make "Serpent" a versatile and reliable nuclear data generator. As a result of the close collaboration, the first Serpent International Users Group Meeting was held at the HZDR in 2011 attracting 35 participants from 16 organizations from all around the World.

Fukushima as a turning point

"In the aftermath of the Fukushima accident, the future of nuclear safety research in Germany was unclear. After all, the German government quickly made the decision to phase out nuclear power entirely," Emil Fridman recalls. Today, nuclear safety research in Germany considers the evaluation of reactor prototypes that are built and operated outside German borders as one of its main tasks. For this to work, active nuclear technology research has to go on and German researchers must be represented in all relevant international bodies like the International Atomic Energy Agency (IAEA) and in the major European research frameworks that are currently working on Generation-IV reactors. The Dresden research group owes its existence to this very background as the HZDR Board of Directors agreed on its founding in the aftermath of the reactor accident in Japan.

In Europe, several innovative reactors are already in the planning stages. One of them, a fast spectrum lead-bismuth cooled reactor called MYRRHA, is currently being developed in Mol, Belgium. In contrast to other nuclear reactors, MYRRHA will be driven by an accelerator. The role of the →

accelerator is to supply the high energy protons to the spallation target acting as an external neutron source for the reactor core. Germany is involved in this global project as well.

By 2024, construction of a new sodium-cooled fast reactor called ASTRID is scheduled to commence in the South of France. Emil Fridman's group will contribute to its safety evaluation in the framework of a recently approved EU project called ESNII+ (ESNII – European Sustainable Nuclear Industrial Initiative). At the same time, albeit far off the shores of Europe, high-temperature gas cooled reactors are currently being developed in the US. One of the main advantages of this reactor type is its capability to provide both electricity and high-grade heat for energy-intensive industrial processes. High-temperature gas cooled reactors are also one of the topics of a common project that is currently being conducted at HZDR and Technische Universität Dresden.

Years ago, Germany, together with France, was a leader in Europe in fast reactor development. In fact, during the Seventies of the last century, a sodium-cooled research reactor was built at the Karlsruhe Nuclear Research Center, which in turn prompted construction of the first German sodium-cooled breeder reactor for generating power in Kalkar at the Lower Rhine. At the time, one of its most fervent supporters was Wolf Häfele who, later, following the German reunification became the Rossendorf Research Center's founding director. This "fast breeder," however, never began operations. A second innovative project was the high-temperature reactor in Hamm-Uentrop in the German state of North Rhine-Westphalia. The THTR-300 prototype began trial operations in 1983 and, in 1989, was permanently taken off the grid. Its job had been to optimize nuclear fuel utilization by breeding uranium from thorium.

Potential use of thorium in existing reactors

During the power production in light water reactors, a number of new isotopes are created from uranium including plutonium and other heavier actinides. Plutonium isotopes can be extracted from the spent nuclear fuel and used as new fuel for operating or future nuclear reactors. In some countries like France, spent fuel from light water reactors is routinely reprocessed to recover plutonium. Nowadays, large stockpiles of civil plutonium accumulated in the World have raised concerns associated with proliferation potential as well as the risk of environmental hazards. Keeping in mind that the massive deployment of commercial fast reactors is not foreseen in the near future, existing commercial power reactors are the only available facilities for plutonium recycling in the short to mid-term. Today's practice of plutonium recycling is the utilization of uranium-plutonium mixed oxide (MOX) fuel in 40 light water reactors licensed for that very purpose. Several of them are operated in Germany. Yet, MOX fuel has limited plutonium destruction efficiency. On the other hand, the use of thorium-plutonium mixed oxide (TOX) fuel instead of "classical" MOX can dramatically increase plutonium destruction rates. This is due to the fact that the replacement of uranium with thorium eliminates the generation of new plutonium. Together with scientists from Italy, India, Canada, the US, and the Czech Republic, the Dresden junior research group is participating in IAEA's coordinated research project entitled "Near Term and Promising Long Term Options for Deployment of Thorium Based Nuclear Energy." The Dresden researchers are responsible for assessing the feasibility of plutonium recycling in light water reactors using TOX fuel.

Other international collaboration activities of the junior reactor physicists are also related to computer codes. The US-based company Studsvik, for example, develops the most widely used industrial simulation tools for light water reactors. The Dresden scientists are currently in the process of testing one of them for use with fast reactors and their results will provide important clues for key methodological adjustments. Fast reactors are also what Fridman, together with the Swiss Paul Scherrer Institute (PSI) and Israel's Ben Gurion University, is working on. This shows his connections to his alma mater in Israel are still quite good. It is where he earned his Ph.D. and where one of his mentors first introduced him to the idea of weekly meetings.

The fact is that Emil Fridman attaches great importance to having weekly group meetings where Ph.D. students Yurii Bilodid, Daniela Baldova, and Reuven Rachamin give updates on their research progress. This allows him to quickly intervene if one of the students needs help with solving a problem. Having weekly meetings also helps students be aware of the group's ongoing research activities and thus to expand their knowledge and expertise. By now, these update presentations make for an impressive archive, which prevents things from quickly fading into obscurity, and they are an exemplary starting point for conference presentations, journal publications, and even Ph.D. theses. By now, the meetings have become popular with other doctoral students in nuclear technology and reactor physics as well and even the head of the HZDR's Division of Reactor Safety likes to drop in on occasion.

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PANORAMA – HZDR NEWS

Research for a future worth living

A new traveling exhibit by the Helmholtz Association is concerned with asking questions about the future of our society and the answers scientists can provide. Among the issues that are being addressed is how we can stay healthy into old age, where tomorrow's energy will be coming from, and how we might conserve resources in our economy.

The "Ideas 2020 – A tour through the World of tomorrow" exhibit guides visitors along seven steles meant to represent seven topics of the future. The steles were designed and built by artists and designers. Each stele has multi-touch-screens where visitors are afforded insights into the work the scientists are doing as well as given information on specific research projects, including ones that are happening at the HZDR like learning about different ways in which Dresden

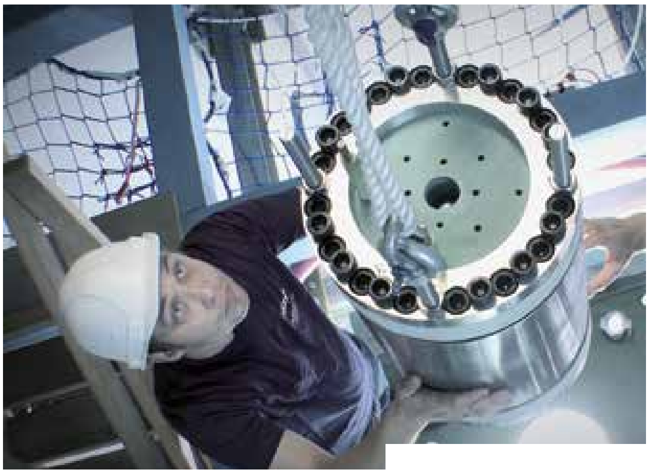
IDEAS 2020: The Helmholtz Association's new traveling exhibit opened in Berlin on March 13th; over the next two years, many German cities will play host to the exhibit.
Photo: BESL Eventagentur GmbH - David Goltz

Helmholtz researchers are continuing to develop and refine cancer radiation therapy, whether it be through new technology or new drugs.

According to a statement released by the Helmholtz Association's head office, one of the exhibit's major goals is "to illustrate the importance of science to our lives during a time when research is viewed by many as ever more complex and perhaps ever more unintelligible." The exhibit is funded by the Federal Ministry of Education and Research and is aligned with the Federation's emphases in research and innovation politics (high-tech strategy). It opened in Berlin in March and over the next two years will hit several German cities.

↗ www.ideen2020.de

The HZDR on the big screen



Unparalleled facilities, exciting new research findings, international teams of scientists – now, the HZDR offers glimpses into its laboratories and science projects on film, entitled "Fascinating Research."

The audience embarks on a tour of discovery through Saxony's largest research facility, is offered a peek behind doors and into highly complex facilities that are normally restricted areas only. "Our goal is to use the image film to show all who are interested that science is anything but dry and boring and that often our research findings are very practically-oriented," explains HZDR press spokeswoman Christine Bohnet. The HZDR image film is available with German and English language tracks.

The HZDR also has a part in another image film called "Research State Saxony", produced by the Saxon State Ministry for Higher Education, Research and the Arts (SMWK). The camera team follows staff at work at the Dresden High Magnetic Field Laboratory and the ELBE – Center for High-Power Radiation Sources. Impressive images document the great diversity and innovation of Saxony's research scene. The video will be available online on the SMWK's re-vamped website.

Both films were produced in collaboration with the Dresden-based film production company, AVANGA. For additional films about the research that is currently happening at the HZDR, please visit the HZDR's YouTube channel at: www.youtube.com/user/FZDresden

↗ www.hzdr.de/image
↗ www.smwk.sachsen.de
↗ www.avanga.de

Girls' & Boys' Day 2013 a huge success

Twenty-seven girls and boys took part in this year's national Girls' & Boys' Day at the HZDR. They started their discovery tour at the DeltaX School Lab and in the HZDR's chemistry and microbiology labs where real-world chemistry and physics experiments awaited the junior researchers. As part of their tour, all of the kids had to don lab coats and wear safety goggles. The girls and boys got to tour the research technology department and also visited the administrative offices where they got to watch HZDR employees at work in the different workshops, in purchasing, logistics, HR, and finance and were given the chance to ask all their questions. HZDR equal opportunity officer Heidemarie Heim and the organizers were delighted at the students' keen interest and active participation.

Backup for DeltaX School Lab

Although Denise Reichel is the latest addition to Nadja Gneist's school lab team, which she joined in May of this year, the thirty-year-old physicist is not new to the HZDR. Since 2008, Reichel has been working at the Institute of Ion Beam Physics and Materials Research, first as a scientific associate and, thereafter, as a Ph.D. student. She went to university in Freiberg and Newcastle-upon-Tyne and, in 2006, along with members of her cohort, founded the "Freiberg Science Café" – scientists who welcome you for lectures and discussions. She gained her first experience working with students as a science tutor and also volunteered in the DeltaX School Lab, where she contributed her expertise to various projects.

First-ever teachers continuing ed in Freiberg

More than 80 teachers from all over Saxony took part in this year's teachers continuing ed day on the topic of "Germany is a raw materials country: Resources on and under Earth's surface." Every year since 1998, the HZDR has been offering at least one continuing ed day on current research topics - this year, a new feature was the close collaboration between the HZDR and the TU Bergakademie Freiberg. Four scientists of the Helmholtz Institute Freiberg for Resource Technology from the fields of mineralogy, mining, and biotechnology vividly discussed their projects. Participants were even able to try and assess the densities of different types of rocks. The day ended with a visit to the minerals exhibit "terra mineralia" at Freiberg castle.

HZDR School Lab to start new set of experiments for the study of radioactivity

A first for the DeltaX School Lab: As of April 2012, students grade 9 and up are able to spend a day at the HZDR performing experiments on radioactivity and radiation.

"Our goal is to familiarize students with the topic of radioactivity in a factual and physical way," explains Nadja Gneist, the lab's acting director. "After all, radioactivity is a natural phenomenon in our environment." Part of what Gneist and her team do is point out to students the different places in our everyday lives where we encounter radioactivity. As such, the junior scientists are filtering room air in order to assess its radioactivity, they measure groceries and rocks, acquire knowledge about basic regulations, and glean insights into methods for radiation protection. Students will also get in contact with actual emitters, known sources of ionizing radiation. All measurements lie well below legal exemption limits.

Each week, the lab hosts up to four classes grades 7 through 13. Topics for study include "light and color" and "magnetism and materials research." With its third set of experiments, DeltaX is currently the only school lab in all of Dresden and beyond to offer experiments for studying radioactivity.

↗ **www.hzdr.de/deltax**

CALENDAR OF EVENTS

July 5, 2013 | 6 PM - 1 AM
11th Annual Dresden Long Night of the Sciences
The HZDR at the TU Dresden lecture hall, Bergstrasse 64
Motto: Research for the World of Tomorrow -
HZDR Future Projects

July 11, 2013
VON ARDENNE Physics Awards Ceremony 2013
HZDR

August 31, 2013
JUNIOR DOCTOR Award Ceremony 2013
Dresden

October 21 - 24, 2013
"Telecommunications and Broadcast Technology" - Fall Break Research Week at the HZDR DeltaX School Lab

Courses in Radiation Protection at the HZDR Research Site Leipzig

September 24, 2013
Update course

October 8 - 10, 2013
Skills course (Module GG, FA)

Scientific Events

June 5, 2013
3rd Dresden Workshop "Molecular Imaging in Life Sciences"
HZDR

June 26 - 28, 2013
537th Wilhelm and Else Heraeus Seminar
"Physics of Ionized and Ion-Assisted PVD: Principles and Current Trends"
Bad Honnef Physics Center

September 23 - 24, 2013
OncoRay Workshop
"Cancer Stem Cells: the Mechanisms of Radioresistance and Biomarker Discovery"
OncoRay - National Center for Radiation Research in Oncology, Dresden

October 10, 2013
International Helmholtz Research School for Nanoelectronic Networks: 1st Annual Workshop
HZDR

HZDR Art Exhibit

Official opening ceremony starts at 5 PM.

September 9, 2013
Kerstin Sigwart

110 TONS OF HIGH TECHNOLOGY: The upper part of the cyclotron sailing in through the roof of the new OncoRay building. The first patients are scheduled for treatment as part of clinical trials as early as 2014. Photo: André Wirsig

Final stretch for proton therapy building

Delivery of the circular accelerator at the new OncoRay Center for Proton Therapy proved nothing short of spectacular. Previously, the device had been on the road for several days from Belgium to Dresden via heavy-goods transport, covering a distance of more than 800 kilometers. It was developed and manufactured by Ion Beam Applications S.A. (IBA), the Belgian global leader for these types of equipment. Already, the company operates thirteen active proton facilities for cancer therapy all over the World and will soon also be in charge of operations in Dresden.

Be that as it may, the cyclotron arrived in the middle of the night of February 6, 2013, at the Dresden University Hospital campus. The proton accelerator, which was set on its foundation that very same day, weighs 220 tons. To ensure it could be installed with the help of a heavy lift crane, the roof of the building had actually been left open and, thus, media reps and local residents alike took the once-in-a-lifetime opportunity to photograph the two parts of the cyclotron gliding in and also to take a tour of the building.

The OncoRay Center's supporters - the Carl Gustav Carus University Hospital, the Medical Faculty of the same name at TU Dresden, as well as the Helmholtz-Zentrum Dresden-Rossendorf - have joined forces with the common goal of exploring options for an extremely precise form of proton beam based cancer therapy. The plan is to continue to develop the use of protons in Dresden over the coming years, both close to the patient and far off from commercial restraints.

↗ **www.oncoray.de**

New work group studies permanent repositories

At the beginning of this year, the leading research institutes investigating permanent nuclear waste repositories founded DAEF, the German Permanent Repository Research Work Group. The group's director, Horst Geckeis of the Karlsruhe Institute of Technology (KIT), outlines the group's implicit goals as follows: "We want to use our results to advise the German federal government and the responsible federal and state agencies as well as the German federal parliament (the "Bundestag") and other interested institutions through position papers and statements. However, it is just as important to us to inform the general public about current trends and findings in permanent repository research."

Three members of the Helmholtz Association of German Research Centers are founding members of the DAEF: the KIT, the Jülich Research Center, and the Helmholtz-Zentrum Dresden-Rossendorf. Vinzenz Brendler of the HZDR's Institute of Resource Ecology considers making confidential data available to all those who are part of the decision-making process about future permanent repository sites an important part of his job. "For years, our commitment has been to a centralized chemical substance database, in which we enter verified research data generated both here at the HZDR and globally. Experts and lay persons alike can use this database to find out about the different ways in which radioactive elements in our environment behave, for example, in different rock formations like clay, granite, or salt." This is why the HZDR researchers are studying the types of chemical bonds the actinides uranium, plutonium, americium, or neptunium form with other rocks. Since these radioactive heavy metals play a central role in the nuclear fuel cycle, it is extremely important that scientists determine whether or not their bonds easily dissolve in water that may infiltrate a permanent repository.

The new work group is committed to the education of future scientists in an effort to maintain and develop German competency in permanent repository research. Organizing workshops and conventions is meant to support scientific exchange. Participating institutes are planning on incorporating questions from the social sciences into their research portfolio so that it encompasses basic science research, safety and evidence concepts, as well as specific procedures for research site selection.

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"discovered" is published in English once a year; the German-language magazine "entdeckt" is brought out twice per year.

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