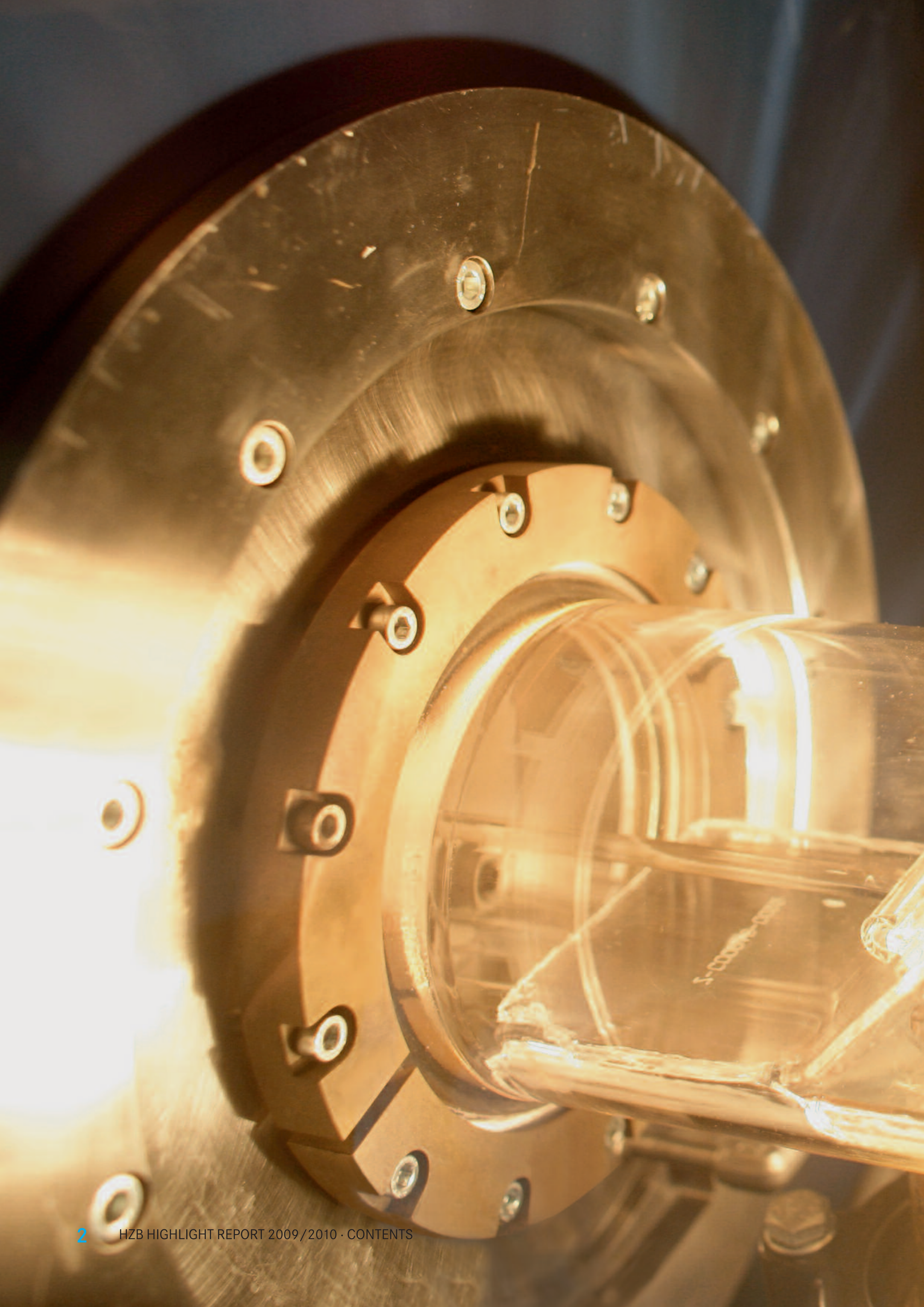
HZB Helmholtz Zentrum Berlin

BUNDLING ENERGY REALIZING VISIONS

HIGHLIGHTS 2009/2010

Annual report with research highlights at the

Helmholtz-Zentrum Berlin für Materialien und Energie



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THE MERGER IS STARTING TO BEAR FRUIT

It was a good two years ago, to be exact on the 28th of January 2009, that we celebrated the formation of the Helmholtz-Zentrum Berlin für Materialien und Energie (HZB) in the Berlin Tempodrom. The motto chosen by the centre "Bundling energy – realising visions" has been our guiding principle since then. With fundamental research studies on the structure and dynamics of complex materials, we make sure that this principle is realised. Here at HZB, we develop the basics of materials science for a wide field of applications – from energy conversion, chemical technologies and information technology to research issues hailing from the world of art and cultural studies.

The management board of Helmholtz-Zentrum Berlin für Materialien und Energie (L–R): Prof. Dr. Dr. h.c. Wolfgang Eberhardt, Prof. Dr. Anke-Rita Kaysser-Pyzalla (spokesperson) and Dr. Ulrich Breuer

With its neutron source BER II and the synchrotron radiation source BESSY II, HZB runs attractive research facilities which as well as being open to HZB's own researchers, are also open to external users from all over the world. And the aim of our user service is to make sure that our external users receive comprehensive scientific support. The new user platform ensures optimum use of all instruments and facilities, something which has already led to excellent scientific results.

The HZB is one of the few places in the world where neutron and synchrotron radiation for complementary studies on the structure and function of matter can be offered in a coordinated manner. This is of benefit to both HZB's own researchers and to external users.
It is therefore of prime importance to us that the enormous potential which both sources offer together is made optimum use of. In combination with the consolidation of often complementary information, both sources of radiation can make it easier to answer difficult questions in the field of materials and energy research and to open up new fields of science. With this in mind, we will not only continue to offer comprehensive scientific advice and support to the external users of synchrotron radiation and neutron scattering, but will also make a targeted effort to encourage these users to fully exploit the complementarity of both.

And with our solar energy research, we are tackling another important task: we are laying the foundation stone for the development of effective thin-film solar cells of the next and future generations. This ranges from basic research to the development of prototypes for specific applications and components. Here too, the ability to work with the synchrotron radiation source BESSY II and the neutron source BER II paves the way towards a better understanding of the interrelation between structures and properties. The "Competence Centre Thin Film and Nanotechnology for Photovoltaics Berlin, PVComB" established by HZB, the Technische Universität (TU) Berlin and other university and college partners stands for the rapid and efficient transfer of knowledge and technology to bridge the gap between basic research and industrial application. It has been sponsored since 1 December 2009 within the framework of the "Top-level research and innovations in the new Bundesländer" programme.

With respect to the programme-oriented funding of the Helmholtz Association, HZB came out outstandingly well with its programme proposals for the second funding period 2010 to 2014 in the research programmes photons, neutrons, ions (PNI) and renewable energies. Very pleasing was that the Helmholtz Senate also approved the large-scale development projects that needed to be assessed separately. After approving reconstruction of the flight time spectrometer NEAT, the Helmholtz Senate decided at the end of 2010 to also tackle the B*ERL*inPro project. This is a feasibility study for a new and innovative accelerator technology which will be developed at the Adlershof research facility. The engineering of this new accelerator offers excellent opportunities to further develop the know-how in accelerator technology already available at HZB in cooperation with university partners, especially the Humboldt University (HU) Berlin.

The actual translation into practice of the 2009 merger of the former Hahn-Meitner-Institut Berlin with BESSY naturally determined the nature of the work at HZB over the past two years in many respects. It was a great challenge not only to establish new structures, to breathe life into them, to guarantee operation of the large-scale equipment and to make progress with research, but also at the same time together with the FU Berlin, HU Berlin, TU Berlin, University of Potsdam and other German universities to successfully conclude several appointment procedures with the resultant acquisition of top-level scientists.

HZB sees itself well equipped for the future due to the merger. We have laid important foundations which will permit us to reach our ambitious goals. We are very well aware that we need to pay particular attention to educating the upcoming generation of scientists. And at the same time, we want to integrate ourselves even more strongly into the scientific landscape, especially in Berlin and Brandenburg. The joint research teams we have set up together with the universities are a clear indicator of this, just as are the joint professorships.

For every member of staff, the last two years were strongly influenced by the transition to the structures and routines of the new centre along with all the associated difficulties and problems. The management is extremely thankful that it was nevertheless possible to keep the scientific performance on its customary high level and to achieve a whole series of results that have received a lot of attention in the scientific world during this time of transition. You can convince yourself of this by dipping at leisure into this HZB Highlight Report 2009/2010.

Prof. Dr. A. Kaysser-Pyzalla | Prof. Dr. Dr.h.c. W. Eberhardt | Dr. U. Breuer

HELMHOLTZ-ZENTRUM BERLIN AT A GLANCE

Since its foundation in January 2009, the Helmholtz-Zentrum Berlin für Materialien und Energie (HZB) has been offering as a single-source partner both **neutron** and **synchrotron radiation** in a coordinated manner for complementary studies. Core research topics at HZB are magnetism, functional materials and materials for solar cell and solar fuel research.

The Helmholtz-Zentrum Berlin is one of 17 centres belonging to the Helmholtz Association, the largest scientific organisation in Germany. Around 1100 employees – thereof 800 in Berlin-Wannsee and 300 in Berlin-Adlershof – carry out basic physical research with two large-scale scientific facilities. HZB works in close cooperation with the universities and technical colleges in the Berlin-Brandenburg region. One offshoot of this cooperation is that all HZB institutes are headed by professors appointed in collaboration with the universities. Besides these institutes, every field of research has its own departments and/or young investigator groups. Over and above this, joint research groups have been set up which are run by university members. Outside the Berlin-Brandenburg region, HZB cooperates with some 400 partners at German and international universities, research institutes and companies. The same goes for solar energy research, in which HZB has been doing top research for more than 20 years.

Large-scale research facilities

To permit research on the structure and function of matter, HZB operates two large-scale scientific facilities, namely the research reactor BER II – for experiments with neutrons, and the electron storage ring BESSY II – that produces an ultra bright photon beam ranging from Terahertz to hard X-rays. Both facilities provide research opportunities for the study of matter and provide a highly specialised sample environment. This means that experiments can be carried out under the most sophisticated conditions – under application of high magnetic fields, cryogenic temperatures and extremely high pressures. The continued development of these unique instruments is a major focus of the centre. Every year, HZB's user service enables some 2000 members of the international scientific community to access measuring methods which in some cases are quite unique. The declared aim is to further the complementary use of neutrons and photons to gain a more complete picture of matter.

Besides these two large-scale facilities, HZB also operates two other facilities for external institutions: An accelerator is reserved in Wannsee for Charité Berlin, which for many years has produced the proton beams for their highly successful eye tumour therapy. This proton therapy for eye tumours was originally developed at HZB but is meanwhile carried out under the responsibility and at the cost of Charité Berlin. And at the research location Berlin-Adlershof, HZB operates the Metrology Light Source (MLS), an optimised storage ring, on behalf of the Physikalisch-Technische-Bundesanstalt (Germany's national metrology institute). The PTB uses the storage ring as a synchrotron radiation source for metrological and corresponding applications for research and industry. As another external

Wilhelm-Conrad-Röntgen Campus in Berlin-Adlershof: a view of the outside facade of the synchrotron radiation source BESSY II.

assignment, the State of Berlin has commissioned HZB to assume the function of a state collection point for the treatment and disposal of radioactive waste.

Lise-Meitner Campus in Berlin-Wannsee: the exterior facade of the new infrastructure building for the high-field magnet.

Materials for tomorrow

What is the relationship between the technical properties of a material and its microscopic structure? Making progress with the study of matter is a central task of the HZB scientists. In their research, they address the atomic and magnetic structure of solid state matter and how it functions on the atomic scale. The structure-property relationship of materials is a focal point, just as are the inner dynamics and phase transitions in condensed matter. Topics which advance the development of instrumentation and methods – for example topics from the fields of materials research and analysis, are a major area of investigation. Besides at HZB, the complementary use of photons and neutrons for research purposes is only possible at very few other scientific locations in the world. Outstanding results are achieved in a number of fields, for example those of magnetism and superconductivity.

Research for new solar cells

The field of solar energy with all its different facets is a further research focus at HZB. HZB scientists conduct research on the next and future generations of solar cells, including new classes of materials and innovative cell structures. The long-term goals include efficient and competitive thin-film solar cells and multispectral cells. HZB is already the largest institutional unit in Germany in the area of thin-film solar cells, not only developing new materials but also investigating innovative technologies for the manufacture of solar cells at the same time. Thin-film technologies are being developed above all at the centre of excellence for photovoltaics (PVcomB) co-founded by HZB, to a stage at which industrial research can take over.
Photovoltaics and large-scale facilities in one location – this is the unique constellation that enables many questions from the field of solar research to be investigated with new possibilities, for example events at the interfaces or charge carrier dynamics. These new research approaches will succeed not only in pushing HZB's own solar research ahead, but will also enable HZB to attract new users from the field of photovoltaics.

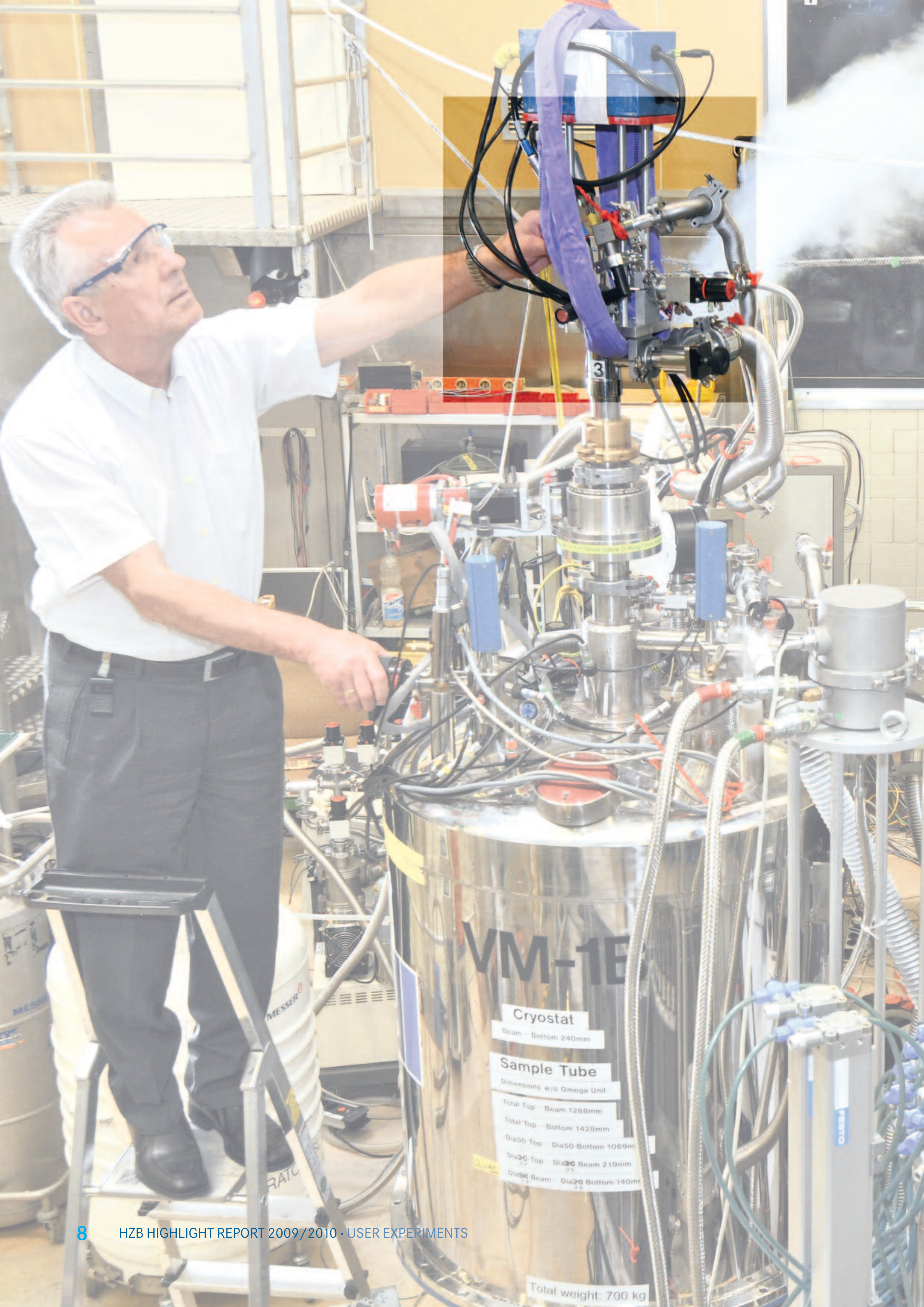
The institutes, working groups and young investigator groups at the Helmholtz-Zentrum Berlin

Institute	Department head
Silicon Photovoltaics (E-I1)	Prof. Dr. B. Rech
Heterogeneous Materials Systems (E-I2)	Prof. Dr. M. Lux-Steiner
Technology (E-I3)	Prof. Dr. H.W. Schock
Charge Carrier Dynamics (E-I4)	Prof. Dr. C. Pettenkofer*
Materials for Photovoltaics (E-I5)	Dr. R. Eichberger*
Solar Fuels and Energy Storage Materials (E-I6)	Dr. S. Fiechter*
Methods and Instruments for Neutron Scattering (G-I1)	Dr. K. Habicht
Methods and Instrumentation for Synchrotron Radiation Research (G-I2)	Prof. Dr. A. Föhlisch
Accelerator Physics (G-I3)	Prof. Dr. A. Jankowiak
SRF – Science and Technology (G-I4)	Prof. Dr. J. Knobloch
Nanometre Optics and Technology (G-I5)	Prof. Dr. A. Erko*
Complex Magnetic Materials (M-I1)	Prof. Dr. A. Tennant
Applied Materials Research (F-I1)	Prof. Dr. J. Banhart
Soft Matter and Functional Materials (F-I2)	Prof. Dr. M. Ballauff

Working Groups	Department head
Undulators (G-A3)	Dr. J. Bahrdt
Magnetisation Dynamics (M-A1)	Prof. Dr. A. Tenannt*

Young Investigator Groups	Department head
Interface Design (E-N1)	Dr. M. Bär
Simulations of ERL Designs (G-N1)	Dr. A. Matveenko
Magnetism and Superconductivity (M-N1)	Prof. Dr. B. Lake
Functional Materials in Liquids (F-N1)	Dr. E. F. Aziz Bekhit

* provisional department head
Note: You will find an overview of the joint research groups on Page 51 and an overview of the user platform in the organisation chart on Pages 66/67.


Cryostat
Sample Tube
Total weight: 700 kg

HIGHLIGHTS FROM USER EXPERIMENTS

The external researchers have optimum and in some cases unique facilities for carrying out their experiments using the research reactor BER II in Berlin-Wannsee and the electron storage ring BESSY II in Berlin-Adlershof. The HZB staff who take care of the instrumentation and beamlines do everything to always keep the test assemblies abreast of the latest research requirements. First-class user support is a central concern at HZB. Berlin is therefore a top-drawer address for scientists from all over the world to perform experiments that address a great variety of research issues.

For example, at the BESSY "µSpot" beamline, new measuring methods were developed and linked direct to synthesis processes. This makes it possible to map the growth mechanisms of nanoparticles and even to control them. Black holes definitely belong to the most fascinating phenomena in the universe. Researchers from the Heidelberg Max Planck Institute for Nuclear Physics attempted with experiments using highly ionised iron to replicate the conditions at the edges of black holes in a realistic manner. The Dead Sea Scrolls, found in Qumran at the Dead Sea in 1947, exercise a particular fascination over researchers. An Israeli scientist is working together with other HZB researchers using X-ray fluorescence analysis, infrared spectroscopy and microscopy to unravel the secrets of the scrolls' genesis and to classify the many thousand fragments. And Polish molecular biologists have succeeded in the three-dimensional representation of a molecular complex that plays a key role in the pathogenesis of AIDS. These experiments might just pave the way towards development of new AIDS therapies in the long term.

These are just a few examples of numerous user experiments at HZB which are described in more detail on the following pages.

WORKING ON THE FUEL TANK OF THE FUTURE

Dr. Arndt Remhof at HZB is researching new solids for storing hydrogen. This will do away with the costly liquefaction of the gas for mobile solutions.

Hydrogen will be a major player among energy stores in the future," Arndt Remhof is convinced. The global energy demand is increasing, fossil fuels are finite and renewable energies are on the advance, but are not available at all times. Enter hydrogen – which can serve as an energy carrier or an energy store. Produced from water using renewable energy, it can deliver heat by combustion and can produce electricity in fuel cells for electric cars, for example. "Hydrogen is especially attractive for its high energy content. It contains three times more energy per unit weight than petrol," explains Remhof. The German physicist investigated hydrogen storage at the Eidgenössische Materialprüfungsanstalt EMPA in Dübendorf near Zurich, Switzerland. Hydrogen is a gas and therefore likes to fill a large volume, which poses a particular challenge when it comes to storage, especially for mobile applications. To fit a large quantity of hydrogen into a small tank, you can either compress it, liquefy it at very low temperatures or integrate it into chemical compounds such as solid materials. "The latter allows the most compact storage," says Remhof.

Assuming it is generated from renewable energy sources such as wind or solar energy, hydrogen could become the energy carrier of the future for mobile solutions.

In the search for a suitable storage solid, the most promising materials so far are the 'light-metal hydrides'. One of these is lithium borohydride ($LiBH_4$), a compound of lithium, boron and hydrogen. It has a huge capacity to store hydrogen compared to other materials. Comprising three of the four lightest elements in the periodic table, it is also very light. This is very important for mobile applications – cars, for instance. Remhof and researchers are working on methods to produce this substance as efficiently as possible. They are looking at which chemical reactions are required, what bonds the elements form and how to optimize the integration of hydrogen. They are also interested in the chemical processes for releasing the hydrogen. This release must be as rapid and complete as possible, and essentially indefinitely repeatable for a storage medium to be of practical use. Such a solid-state storage medium, incidentally, cannot be likened to a sponge, from which you can simply squeeze out a liquid under mechanical pressure. The solid-state storage medium involves complex chemical processes that bind and release the hydrogen.

Lithium borohydride under neutron fire

"The neutron rays at the research reactor BER II are ideal for studying all this," says Remhof. Neutrons are especially sensitive for investigating light elements and can penetrate materials easily, like the walls of the special oven the researchers use to produce the lithium-borohydride under high temperature and pressure. The neutron beam then interacts with the atoms of the storage material, escapes again and is then analysed by a detector. Using so-called neutron diffraction, the researchers can draw conclusions on the chemical structure of the material. They can determine the moment in time when lithium borohydride actually forms, for example, or whether intermediate products such as LiB are formed.

The most straightforward approach to producing $LiBH_4$ is direct synthesis from the individual elements. Lithium and boron are prepared as solids and hydrogen is introduced into the oven as a gas. Unfortunately, this method requires high temperatures of 700 degrees Celsius and hydrogen

Are we going to be filling our tanks with hydrogen in the future? Scientists such as Arndt Remhof are working on solutions as to how hydrogen can be stored and utilised more efficiently to achieve a more eco-friendly mobility.

pressures of up to 150 bar. Accordingly, Remhof and his colleagues have developed an alternative approach, which they tested on BER II: Using a chemical reaction, they first prepared a compound of boron and hydrogen, say B_2H_6 consisting of two boron and two hydrogen atoms. They then reacted this with lithium hydride LiH. This produced $LiBH_4$ at a temperature as low as 100 degrees Celsius and a pressure of only 20 bar.
On the first go, however, only 50 percent of the starting materials employed were actually converted into the desired end product. The researchers figured out why using electron microscopy. Their starting solid came in the form of tiny granules, ten microns in diameter. It turned out that, on average, $LiBH_4$ only formed on the surface of these granules. There, it formed a kind of protective layer, preventing further penetration of B_2H_6 into the core of the LiH granule and thus preventing the complete reaction. Since then, the researchers have increased the yield significantly by ball-milling the material into a fine powder during the reaction. This continually breaks open the granule surfaces, releasing the cores for further reaction.

Don't fill your tank – swap it

To trace the path hydrogen takes into the material, the researchers turned to an alternative measuring technique called neutron spectroscopy. Their results show that hydrogen travels not as single atoms or H_2 molecules, but bound to boron as the negatively charged $[BH_4]^-$ ion. Only on the surface of the grains are three of the four hydrogen atoms released. "Comparing the rate of hydrogen delivery with the mobility of the $[BH_4]^-$ ion, we can conclude that the limiting factor is the detachment of hydrogen atoms from boron taking place on the surface," resumes Remhof. The researchers are yet to study exactly how this happens and how to speed it up.

This test model equipped with a fuel cell was exhibited in 2005 at HZB as part of the "Long Night of Science".

The process of hydrogen absorption is technically more complex than its release. Remhof therefore sees the real-world automotive application of such solid-based hydrogen tanks so: You would have easily exchangeable tanks that, when empty, are not filled up in the classical sense, but are swapped for full ones instead. The empty ones must be processed in an external plant and refilled with hydrogen. Such practice, however, still requires essential developments, the physicist points out. "Our studies are still very basic and deal with fundamental questions that have to be clarified before the technology becomes marketable." One such question, for example, is whether a catalyst can be used to accelerate the binding and release of hydrogen.

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BRINGING STARS INTO THE LABORATORY

A research group led by **Dr. José Crespo Lopez-Urrutia** of the Max Planck Institute for Nuclear Physics in Heidelberg has for the first time produced plasma in the lab as it is created around black holes in space.

Black holes are ravenous. They suck in all matter that comes too close to their so-called event horizon. Even light emitted by this matter remains trapped within the black hole. As a consequence, no information ever escapes to tell us what happens inside black holes. A frustrating circumstance, since astronomers rely on visible light and other electromagnetic radiation to learn about the materials of the universe, about black holes and distant galaxies, their composition and their motion. They must glean information from the intensities and wavelengths of light waves and their relative shifts. Astronomers have therefore turned their attention to the light emitted by matter just before it is lost forever beyond the event horizon. Matter spirals inwards as it falls towards the black hole, compressing ever tighter as it draws nearer. Collisions occur, in which atoms lose electrons, becoming ionized, and the temperature rises to the order of a million degrees. Matter in this state is called plasma. Shortly before it crosses the event horizon, the plasma emits one last burst of X-ray light. This light burst can also ionize matter. More importantly, it can ionize the more distant matter that is not close enough to the black hole to have collided and lost electrons. Such X-rays produce relatively "cold" plasma.

Black holes – before matter gets swallowed up in a black hole, it emits light.

Doppler effect in space

Dr. José Crespo and his team are the first to produce such cold plasma in the lab. To achieve this, they constructed a special ion trap in which iron atoms would form a string of ions when bombarded by an electron beam. The researchers brought four tonnes of equipment to the synchrotron radiation source BESSY II to study the further ionization of this plasma using X-ray light. They overlaid the thin plasma beam longitudinally with a very thin X-ray beam. They varied the wavelength of the X-ray light while observing the efficiency of ionization. In doing so, they discovered which X-ray wavelengths produce the effects observed in space. "Our experiments benefitted from the very fine X-ray beam that BESSY II can deliver, and from the very broad spectrum of wavelengths, which can be very precisely adjusted," says Crespo. The researchers thus determined the properties of this plasma at rest. On its spiral path in space, by contrast, the matter is racing along at enormous speed. That means the wavelengths of the light emitted will be superimposed and distorted. This so-called Doppler effect is familiar from the siren of a racing ambulance, which appears to wail at a higher note as it approaches and a lower note as it recedes than the actual note it produces. Only if you first know the wavelength at rest can you then determine the speed of the vehicle – or the material emitting light – from the measured Doppler shift. "There is already a series of calculations on this problem, but only our reference measurements are reliable and precise enough to allow astronomers to interpret their data from space with certainty," emphasizes Crespo. His plasma studies are of interest not only to astronomers. A precise understanding of plasmas is also crucial for fusion reactors. *ud*

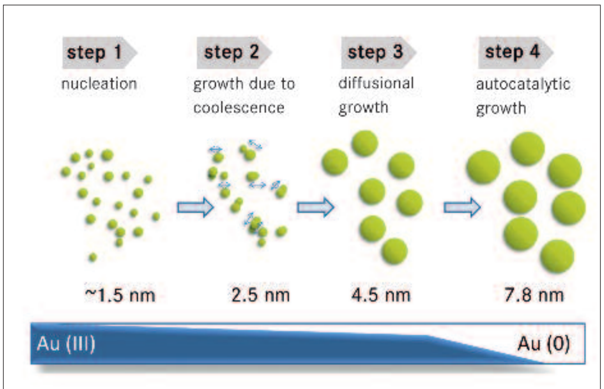
Phys. Rev. Lett. 105, 183001 (2010): Resonant and Near-Threshold Photoionization Cross Sections of Fe^{14+}, J. R. Crespo López-Urrutia et al.

NANOSCALE PRECISION WORK

A group of scientists led by **Dr. Ralph Krähnert** and **Dr. Franziska Emmerling** at HZB have controlled nanoparticle growth to the greatest precision yet.

Nanoparticles consist of a few to some thousand atoms or molecules. Given their unique properties, they are some of the most intensively researched materials in the field of nanotechnology. Yet, although we have been synthesizing them for more than 150 years, we are still largely in the dark as to how they grow. To resolve such fundamental questions was the motivation behind physicist Jörg Polte's doctoral thesis in the workgroup X-Ray Structural Analysis of Dr. Franziska Emmerling at the Bundesanstalt für Materialforschung (BAM) in Berlin. Together with a team led by Dr. Ralph Krähnert, junior research group leader at TU Berlin, these studies have been pursued further over the past three years. Krähnert is chiefly interested in using noble metal nanoparticles for catalysis. Their size can influence the adsorption of reaction partners on the catalyst and thus influence the entire catalytic behaviour.

The growth processes of nanoparticles are little understood because no reliable experimental data exists. "Only when we understand the mechanisms of the creation of nanoparticles can we control their size – and thus produce targeted particles that are optimal for specific applications," says Ralph Krähnert. The Berlin scientists therefore developed experimental methods to observe the processes of nanoparticle synthesis both time-resolved and "live". They did this using novel combinations of established measuring techniques at HZB. They combined, for example, small angle X-ray scattering (SAXS) with X-ray absorption near-edge structure (XANES) at the BESSY-II storage ring. SAXS allows you to follow the growth and concentration of particles while XANES allows you to study the kinetics of the underlying chemical reduction of a metal salt. "I had plenty of methodical groundwork from Emmerling's workgroup to fall back on," reports Jörg Polte.



At HZB, the four-step process of nanoparticle growth was analysed.

Control to atomic layer precision

The researchers from BAM and TU Berlin have resolved the mechanism of one of the most common methods of gold nanoparticle synthesis: the Turkevich method. At temperatures above 60 degrees Celsius, a gold-containing compound is reduced by sodium citrate in watery solution. The researchers revealed growth in four partial steps: At the beginning of the reaction, only a small part of the gold compound is reduced, forming gold clusters less than one nanometre in size. These then merge into particles of around three to four nanometre radius. Crucial here is that this step already decides the final particle count and size distribution. The next phase is characterized by slow growth of the particles, where reduction of the gold compound is the rate-limiting factor. Only at the end of this synthesis does the process accelerate and the particles obtain their final format by complete conversion of the gold compound.

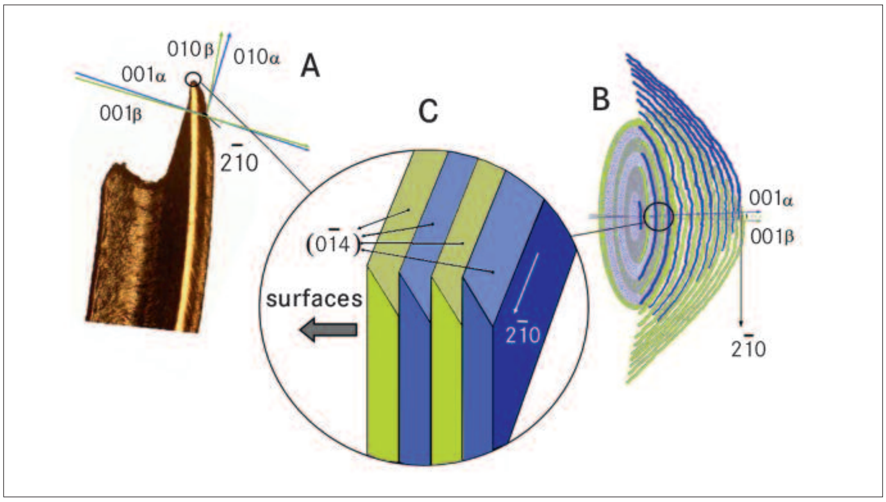
In subsequent experiments at HZB, the experimental setup was optimized by performing SAXS measurements on a free liquid jet. The new data confirmed the described mechanism and showed that the four growth steps correlate with four phases of chemical reduction. "With these new insights, we can now control the growth of nanoparticles with almost atomic layer precision," Franziska Emmerling says with delight – a great step towards "tailored production" of particles with desired properties. *rb*

J. Am. Chem. Soc., 132 (4), 1296-1301 (2010): Mechanism of Gold Nanoparticle Formation..., J. Polte, F. Emmerling, R. Krähnert et al.

A DUO FOR THE BIOWORLD

Prof. Oskar Paris and **Dr. Maxim Erko** used the radiation sources at HZB to learn more about phenomena in nature. Why do sea urchin teeth stay sharp, for example, and where is the density minimum of frozen water?

Paracentrotus lividus is a fascinating creature. The sea urchin grinds its way into rock as it feeds on algae. One would think its teeth would become blunt over time, since they are made of the very same material as the rock: both are made of mineral calcite. What happens is in fact the complete opposite: the teeth sharpen themselves. How they do this and how this might be reproduced in technical products such as drills or chisels is what Oskar Paris and colleagues intend to find out. Paris, currently Professor at the Institute of Physics of Montan University Leoben in Austria, was at the time with the Biomaterials department, headed by Peter Fratzl, of the Max Planck Institute of Colloids and Interfaces in Potsdam-Golm, and collaborated closely with colleagues from the Israeli Weizmann Institute of Science to solve this problem.



Only under the high-resolution X-ray beam from BESSY II does the sea urchin tooth (A) reveal its secret: It consists of staggered crystal layers (C) that overlap at the tips (B). Even with abrasion, they always stay sharp.

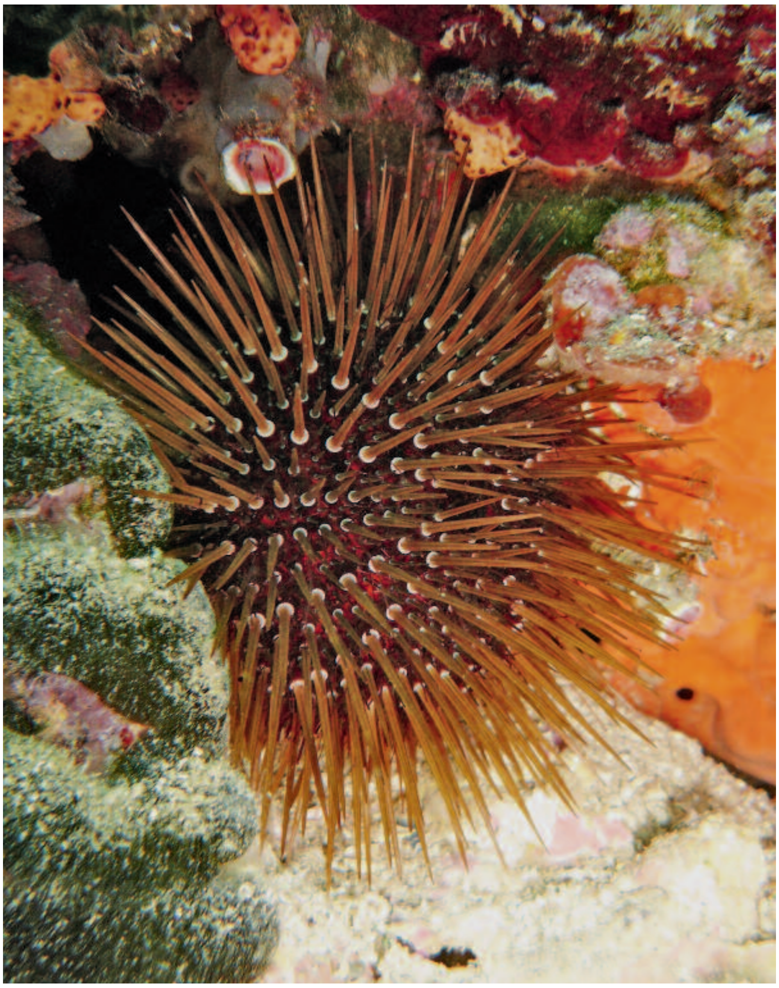
To study the biological structures on a nano scale, the researchers of MPI in Golm, Helmholtz-Zentrum Berlin and the Bundesanstalt für Materialforschung (BAM) developed a microfocusing beam tube to deliver a particularly fine X-ray beam at BESSY II. This can be used to measure crystalline structures and the chemical composition of the studied areas. “The fine X-ray beam also allows a differentiated image of crystallites just a few microns in size. This is especially helpful for explaining hierarchical structures in materials that play an important role in biology,” says Paris. Hierarchical materials stand out for the way they are structured on different scales, such as on the micro and the nano scale. Such materials can unify very different, often contradictory properties. The teeth of the sea urchin, for example, have to be very hard to work the rock but not too brittle, as is usually the case with technical ceramics.

BETTER RESULTS WITH TWO RADIATION SOURCES

Neutron scattering proves to be an ideal complement to microstructural X-ray analysis, especially when it comes to biological or natural materials. While X-rays deliver information about the structure of materials at very high spatial and temporal resolution, neutrons have the advantage of being especially sensitive to the lighter elements that occur abundantly in nature, such as hydrogen. That means the two methods combine perfectly for investigating the unusual properties of water. For instance, unlike most other materials, the density of water does not continuously increase as temperature drops, but rather reaches a maximum at around four degrees Celsius. Further cooling then leads to expansion. As water ultimately freezes at zero degrees Celsius, it expands even further.

How sea urchin teeth stay sharp

Indeed, the research team discovered that a sea urchin’s tooth consists not of a single crystal, but of multiple thin layers, where two calcite crystals tilted slightly towards one another alternate in neighbouring layers. For their analysis, they scanned the tip of the sea urchin tooth with the micro-X-ray beam, producing diffraction images of various, very closely neighbouring areas of the tooth. “These measurements can only be done using high-brilliance synchrotron radiation, as BESSY II delivers, for example. Only so is it possible, at such small beam diameters, to measure effects large enough to obtain the desired information,” says Paris. The layered structure in the teeth is crucial for their self-sharpening behaviour, stresses Paris. The tooth becomes sharp, namely, after a fresh edge break. Self-sharpening means that, as the tooth is used, the crystal frequently breaks along preferred crystal planes, as with every crystal. If the tooth consisted of a single crystal, then it would break as a whole and soon there would be nothing left of the tooth. With the layered structure of two ‘interdigitated’ or interlocked crystals, however, a split cannot propagate as far. It stops short at the boundary because it does not meet up with the preferred break plane in the neighbouring crystal. This results in a sawtooth-like structure, a kind of ‘rasp’, and the tooth stays sharp without significant material loss.



The sea urchin (*Paracentrotus lividus*) not only has an extraordinary appearance, but is also an interesting research object by virtue of the laminar structure of its teeth. The teeth are made of mineral calcite and sharpen themselves automatically as they rub against the stones covered with the plankton that the sea urchin feeds on.

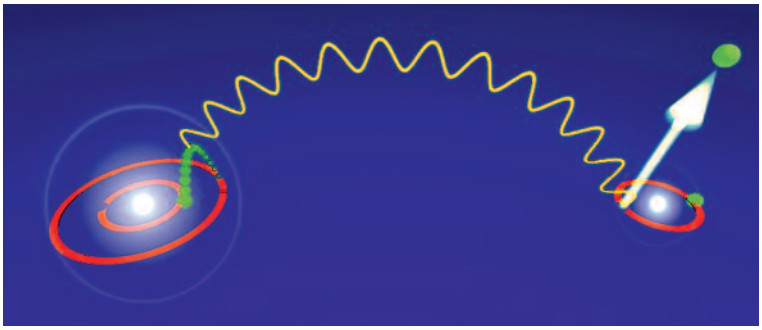
In search of water’s density minimum

In Oskar Paris’s workgroup at Montan University Leoben, Maxim Erko is devoting his full attention to the nature and structure of water under extreme conditions; specifically water that is locked into tiny spaces. So tiny that only a couple of water molecules fit next to each other. This is no mere pastime – it is a model system for nature: Plants have water conduits of minute diameter and rocks develop pores only nanometres in size. To understand how such systems behave in icy winter temperatures and why they are not continually destroyed by growing ice crystals,
Erko studied the freezing behaviour of water in his model systems. “Clearly, the tiny volume supresses the normal freezing mechanism of water,” says Erko. American researchers had already studied trapped water by neutron scattering. Their interpretation of the results was that the still-liquid water reaches a density minimum at about minus 50 degrees Celsius. Erko adds “but we still don’t know exactly what happens in this instance.”
With the support of Berlin colleagues Dr. Thomas Hauß at the neutron source BER II and Dr. Armin Hoell at BESSY II, Erko then used a combination of neutron and X-ray radiation at HZB to learn more. He studied water in cylindrical nanovessels of amorphous silicon dioxide with an internal diameter of only two nanometres. While Erko’s neutron measurements confirmed the data from the American researchers, “if the observed effect had been due to a density minimum of the water, then our X-ray data ought to been very different from what we measured,” says the physicist. To interpret the effects of both measurements logically, he suggested a different model: “The strong interaction of the water molecules with the hydrophilic, or water-attracting, porous wall caused them to be distributed irregularly across the diameter. We are therefore not dealing with a homogeneous density – if we can even speak of density for so few molecules.” Erko cannot say anything more specific yet. After combining X-ray measurements with neutron measurements, however, it seems clear that the density minimum postulated by the colleagues probably does not exist at all. *ud*

TWO BIRDS WITH ONE STONE

Prof. Reinhard Dörner and his group from the Institute for Nuclear Physics at the University of Frankfurt am Main have performed the first experiments on helium dimers at HZB.

The helium dimer, consisting of two helium atoms, is a bizarre molecule held extremely weakly together. No other molecule is so fragile. The weak bond gives its components a lot of freedom, with the two helium nuclei dozens of atomic diameters apart. "Between them is practically nothing," says Prof. Reinhard Dörner, head of the workgroup at the Institute for Nuclear Physics of the University of Frankfurt am Main. Nevertheless, there are mighty quantum mechanical forces at work. These forces create a relatively strong coupling between the electrons in the dimer considering the immense distance between the helium nuclei. In theory, this makes it an ideal model system for studying quantum processes like those that take place in complex chemical compounds and superconductors.



In a helium dimer, consisting of two helium atoms, one of the atoms (left) is excited by a photon. This produces a new photon whose energy (yellow line) is transferred to the second atom (right). There, it knocks out an electron (green).

A team led by Prof. Reinhard Dörner and his colleague Dr. Till Jahnke are the first to have succeeded in performing practical experiments on a helium dimer, with surprising results. "We managed to ionize both atoms in the dimer, that is, tear an electron away from each atom, using a single photon," reports Jahnke. That would be like a hunter hitting two animals standing metres apart from each other with a single bullet – evidence for the strong coupling between the electrons of the giant molecule. The scientists worked with helium dimers kept at a few degrees above absolute zero, which they fired photons at from the synchrotron radiation source BESSY II and studied in a COLTRIMS spectrometer. This way, they were able to measure the kinetic energy of the electrons from a sample of helium dimers and reconstruct the physical processes from it.

Radiation damage needs reassessing

To achieve this feat, a large amount of the photon energy has to be transmitted lightning fast between the two atoms. Two different processes come into play here: Either the electron loosened from the first helium atom slams into the second atom and – like two billiard balls colliding – knocks out another electron. Or, the photon leaves the first struck atom behind in an energetically excited state. The excess energy is released shortly thereafter in the form of a new photon, which can in turn ionize the partner atom.

This mechanism of energy transfer – the physicists speak of interatomic Coulomb decay – could be of significance far beyond the quantum world: "The same kind of interplay exists between water molecules," says Till Jahnke. Here, too, ionization of one water molecule – by X-ray or nuclear radiation – causes among other things the emission of an electron from a neighbouring molecule. Slow electrons thus produced can cause genetic defects in biological tissue. "They contribute significantly to radiation damage," explains Reinhard Dörner. Yet, the action of interatomic Coulomb decay has so far been ignored when calculating the risks of radiation. It is quite possible that this effect, which Dörner and his team have now clearly demonstrated in further measurements at HZB, will necessitate a reassessment of the risks of radiation damage. *rbr*

Phys. Rev. Lett. 104, 153401 (2010): Single Photon Double Ionization of the Helium Dimer, T. Havermeier, T. Jahnke, R. Dörner et al.

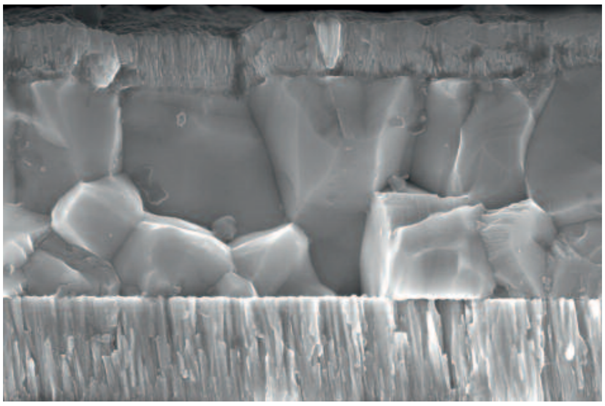
DEPLETION IN THIN FILMS

A research group led by **Dr. Iver Lauermann** and **Dr. Harry Mönig** have gained new insights into processes occurring within the surface of thin-film solar cells.

Thin-film solar cells promise to reduce the costs of solar energy considerably. A common choice of material for the absorber layers, where the conversion of sunlight into electrical energy takes place, are the chalcopyrites: chemical compounds of copper, indium, gallium and selenium. These semiconducting materials of chemical formula $Cu(In, Ga)Se_2$, or CIGSe for short, make especially strong light absorbers. Yet, "there is still intense debate about their exact chemical and structural properties," says Dr. Iver Lauermann, researcher at the Institute for Heterogeneous Materials Systems of HZB. New developments mainly build upon existing empirical knowledge – that the most suitable compounds tend to be those containing relatively little copper as measured by the chemical formula, for instance. "You can adjust the copper content within certain limits," explains Lauermann. "The best solar cells using chalcopyrite absorbers are produced with a low copper content."

Microscopic restructuring of the surface

Numerous measurements have shown that the copper content on the surface of the cells is in fact far lower than it ought to be according to the composition of the starting material – an effect that is critical to the efficiency of a thin-film cell. There has been very little reliable experimental data until now. Results from the doctoral thesis of Harry Mönig at HZB have shed light on the matter. The researchers used high energy photoelectron spectroscopy for their studies, where the material is bombarded with high energy photons from X-ray light. This knocks electrons out of the material, which can be caught and analysed. "It is excellent for making sensitive measurements on surfaces," Iver Lauermann enthuses. Thanks to the hard X-ray light from the storage ring BESSY II, his team is the first to look 24 nanometres deep into a chalcopyrite layer.
Their results came in the form of curves plotting the emission of electrons from the CIGSe. "To determine the copper distribution in proportion to depth, Harry Mönig had to complement the measurements with model calculations," says Lauermann. The only way they could reconcile theory with empirical results was to assume there is a thin surface layer that is completely devoid of copper. "The disappearance of the metal atoms in this layer, which spans only a few atomic layers, is probably caused by microscopic restructuring of the surface," explains Harry Mönig. "This leads to an energetically favourable state of the material."



Scanning-electron-microscope image of the layered structures of a CISGe solar cell.

New explanations needed

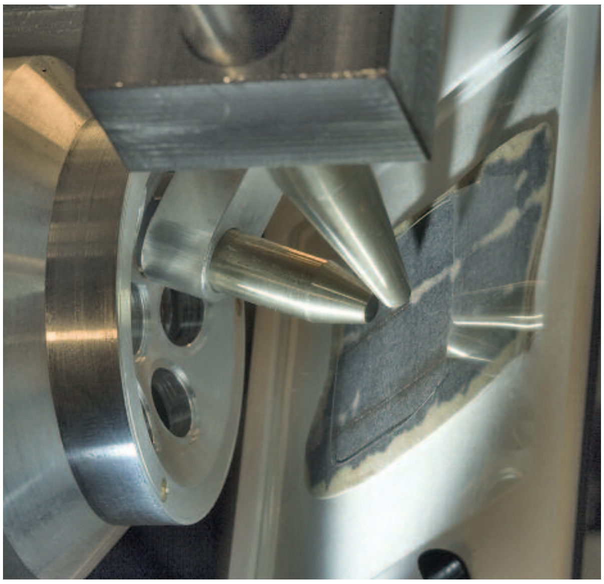
This finding dispels the previous favourite explanation for copper depletion, that the effect is due to crystal defects reaching much deeper into the material and forming a hidden boundary. Inevitably, this has led to controversy among the research colleagues. Little wonder, since "with the new findings, we had to rethink our understanding of the structure and function of thin-film solar cells from the ground up," says Lauermann. He is already preparing further experiments that should produce a solution to this puzzle. *rb*

Acta Materialia 57, (2009), 3645-3651: Surface Cu depletion of $Cu(In,Ga)Se_2$ films: An investigation by hard X-ray photoelectron spectroscopy, H. Mönig, H.-W. Schock, M.C. Lux-Steiner, I. Lauermann et al.

ON THE TRAIL OF THE QUMRAN SCROLLS

Israeli scientist **Dr. Ira Rabin** has long been investigating the 2000-year-old scrolls from the Dead Sea, some of which are mere fragments. Among other methods, her team has been using the instruments of BESSY II.

In 1947, Bedouins discovered seven scrolls in caves near the ruins of Khirbet Qumran on the northwestern bank of the Dead Sea. When the remains of another 900 scrolls were found in several caves over subsequent years and first estimates stated that they were around 2000 years old, it became clear that this was one of the most important cultural assets of humankind. The scripts, written predominantly in carbon ink on animal skins worked into parchment, are mostly in Hebrew, but also in Aramaic and Greek. They are Urtexts of the Old Testament and comments on biblical scriptures from the time between the third century BCE and the year 68 of our Current Era. Scientists were already involved in their study and dating in the 1950s. Yet, the scrolls still hold a series of hidden secrets. Where were they written? Which cave were they found in? No one ever kept a record of this – indeed several finds were in fact robberies. Are their place of origin and their site of discovery one and the same? The resear-chers would also like to know the circumstances under which the rolls were stored. Was it a library? Were they hidden in response to a threat?



Using the synchrotron radiation source BESSY II, the parchment and ink of a scroll fragment were analysed.

A puzzle of more than 18,000 pieces

Only the tiniest minority of scrolls were preserved in their metre-long entirety. Most had degraded into fragments – a giant puzzle with more than 18,000 pieces. The chemist Ira Rabin has been working on its systematic resolution for many years. With great dedication, she has headed the “Dead Sea Scrolls” project involving many scientists from all around the world. Today, Rabin works at the Federal Institute for Materials Research and Testing, BAM, in Berlin, Germany. In her investigations, she has been cooperating closely with researchers at Helmholtz-Zentrum Berlin, where she has been using the Bessy II synchrotron radiation source for measurements using X-ray light. This allows her to study the valuable fragments without damaging them.

Because the scientists involved can study only a fraction of all pieces, the project aims at putting together a portfolio of suitable methods by which the many thousands of fragments can be systematically characterized over the years, or decades, to come. “The fantastically bright radiation of Bessy is excellent for this,” Rabin emphasizes. “We can perform the measurements here at highest quality and thus determine how best to study the fragments and what results the individual methods can deliver.” Given this knowledge, normal laboratory standards will be sufficient for a massive-scale investigation later on.

Analysing chemical fingerprints

The researchers are looking for site-specific chemical fingerprints in the parchment and ink, such as regional-typical concentrations of certain elements in the water used to produce the parchment and ink. They also want to decipher the traces left on the parchment by their handling over the past 2000 years, which should differ depending how they were used and how and where each was stored – in clay containers, wrapped in cloth, lying on the floor, or in various different caves.

In the caves close to Qumran on the Dead Sea, numerous scrolls have been found over the years since 1947 which still present a gigantic puzzle to science.

One method Rabin and researchers have used is X-ray fluorescence. With it, they have measured the various chemical elements and their concentrations. Thanks to a special 3-D X-ray technique, developed by Birgit Kanngießer at TU Berlin, they were even able to create a depth profile of the elements. That means the elements can be pinpointed to different layers and thus identified as traces from treatment or storage. Another method, vibration spectroscopy, allows precise analysis of the chemical compounds. It can distinguish the various organic substances with which the scrolls were treated, for example. Each substance contains carbon bound to other atoms in different ways.

Painstaking reconstruction and restoration

The so-called Temple Scroll, also known as the 6th Book of Moses, has always been of particular interest. It already differs from the other scrolls in its external appearance – rather than the brownish colour of the others, it is white. The origin of this colour has long been a puzzle, yet it was believed that all parchments with biblical content must have been tanned by a method described in the Talmud. "Our analyses showed, however, that the Temple Scroll was pre-treated with alum, a pickling solution for leathers and textiles, and then covered with a plaster paste and collagen," says Rabin. They were also able to clarify the Temple Scroll's origin based on characteristic nitrate traces. Of all the caves, only one exhibits this chemical fingerprint since it is inhabited by bats, whose excrement contains nitrate.

Analysis of the ink provides clues as to where the scrolls were written. The researchers turned their attention to the unusual presence of chlorine and bromine and the ratio between these two elements. This was a clue to the origin of the water used to mix the ink. This chlorine/bromine ratio varies significantly in the region. The researchers' intention is to analyse the inks of all fragments and map them out. "This will be a painstaking process, but we can already show that it works and how," says Rabin.

Many tasks for future generations of scientists

The search for the origin of the Qumran Scrolls is made difficult not only by their natural degradation. The different kinds of treatment used to preserve and restore them have also drastically altered the condition of the scrolls in places. Ira Rabin calls this the "worst of all tortures", since it has frequently been done incorrectly or inadequately documented. As a result, the scientists now have the added task of trying to reconstruct the stages of restoration. "This is important in order to ensure the most lasting and suitable preservation and storage in future," stresses Rabin.

Some findings, even in science, are disputable. Ultimately, it will only be possible to unlock the secrets of the Qumran Scrolls by a combination of many methods and in close collaboration with archaeologists and historians. It is a painstaking path to be taken in tiny steps and with tiny successes, to which a number of generations of scientists will be adding their contributions for some time to come.

ud

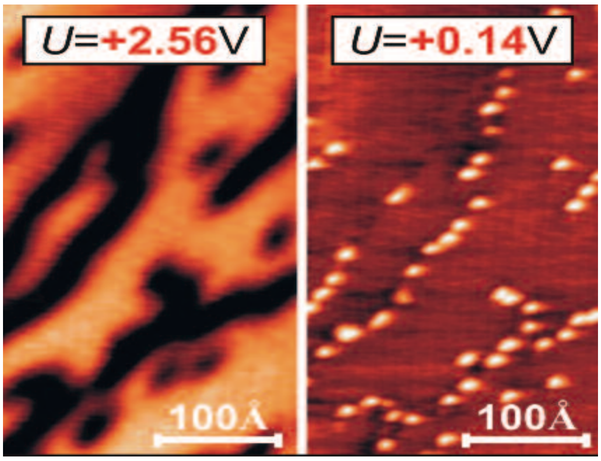
GRAPHENE – MOBILE ELECTRONS IN A HONEYCOMB STRUCTURE

Two research groups at HZB are developing a low-cost, large-scale process for producing **graphene as a future industrial component**.

Graphene, a single sheet of carbon atoms with a striking honeycomb structure, has fired the imagination of physicists since it was first successfully produced in 2004. Why? Because the electrons in graphene are extremely mobile. That makes it a hot candidate for new, smaller and faster electronic components that could supplant current silicon technology. Scientists around the world are researching into low-cost processes for industrial production of graphene. Dr. Thomas Seyller, Chair of Technical Physics at Erlangen University, says the ideal process "should apply the carbon with a good measure of control, over as large a surface as possible, in a perfect structure and onto substrates that, in turn, can be easily integrated into the application".

The physicist is a fan of silicon carbide (SiC), for example, which is a semiconducting crystal of silicon and carbon atoms. Graphene is relatively easy to produce from it, where the SiC crystal is heated according to a certain procedure. Silicon atoms evaporate from the surface, where the remaining carbon atoms form a single layer or multiple layers of graphene. However, given the relatively strong interaction between graphene and the SiC substrate, the properties of this layer are not yet optimal. Seyller discovered this when studying the boundary surface using photoelectron spectroscopy, among other methods.

This method involves knocking the material's electrons out of the sample with light and then analysing them. "With our measurements at BESSY II, we were able to image the electronic structure of various material layers quickly and very precisely. And by varying the wavelengths of the incident light, we were also able to regulate how deep we looked into the sample," explains Seyller. The researchers in Erlangen also demonstrated that they can manipulate the structure in their favour. They heat the sample in an atmosphere of hydrogen. Hydrogen atoms make their way beneath the graphene and detach it by binding to the SiC substrate as an intermediate layer, with the result of doubling the mobility of the charge carriers in the graphene.



Micrographs of a graphene layer on a nickel substrate. In the image at left, only dark stripes can be seen. Only by cleverly adjusting the photoelectron spectroscope is it revealed that fullerenes inserted under the graphene layer, that is C_{60} molecules, are the cause of the striped pattern.

Optimizing the graphene layers

Researchers led by Dr. Oliver Rader and Dr. Andrei Varykhalov from the Department of Magnetizing Dynamics at Helmholtz Zentrum Berlin used a very similar approach to optimize their graphene layers. However, they started with a different substrate. Instead of a semiconductor such as SiC, they chose metallic nickel as the catalyst and had heavy atoms push their way in under the graphene layer. "This way, we can also address the magnetic properties of the electrons in the graphene," says Rader, who had already demonstrated this with an intermediate layer of gold. This makes applications conceivable in the fields of spintronics and magnetic data storage. Hydrogen and gold atoms are relatively small. To find out how the methods can be performed with larger objects, the HZB researchers used fullerenes – molecules made of 60 carbon atoms. Photoelectron spectroscopy measurements again showed a positive effect on the electronic structure of the graphene. *ud*

Advanced Materials (DOI: 10.1002/adma.201000695): Imaging Buried Molecules: Fullerenes under Graphene, A. Varykhalov, W. Gudat, O. Rader

GENETIC QUALITY CONTROL UNDERSTOOD

Polish scientists led by **Dr. Marcin Nowotny** at HZB took a close look at an enzyme important for DNA repair.

When a cell divides, it first has to copy its entire DNA – a very complex process involving many individual steps. In simple terms, it goes like this: First, the enzyme helicase splits apart the DNA double strand. Next, the missing bases are added on, building up each daughter strand into a double strand again. To begin the DNA synthesis, the responsible protein – a polymerase – needs a kick-start from a primer. The primer is a piece of RNA, i.e. a single chain of nucleic acids. During the copying process, the primer and the DNA form a so-called hybrid molecule.

These hybrid molecules are critical: They trigger the copying process at the right place – but there should be none remaining by the end of the process. More importantly, polymerase sometimes accidentally incorporates RNA into the DNA. "That would need correction," says Marcin Nowotny of the International Institute of Molecular and Cell Biology in Warsaw. For precisely this job, there are special enzymes in the cells – one of which is RNase H2, which a research group led by Marcin Nowotny has now studied at greater precision than ever. "RNase H2 ensures the stability of the genetic information," explains the researcher. Yet it has never been truly clear how this genetic quality control actually takes place.

Nowotny and his colleagues have now determined the three-dimensional structure of the molecular complex of RNase H2 and an RNA/DNA hybrid molecule for the first time. They performed the crucial measurements for this at the electron storage ring BESSY II in Berlin. "We wanted to see how the process takes place at the molecular level," explains Nowotny. To do this, the scientists employed X-ray crystallography. Like most enzymes, RNase H2 can be made to form a crystalline structure under specific conditions. The pattern produced by the diffraction of X-ray light through the crystal lattice can then be investigated.

Divalent metal ions as catalysts

"High resolution was especially important to us," explains Nowotny. Their crystal was grown from an RNase H2 protein produced by genetically modified E. coli bacteria.

Dr. Marcin Nowotny (left) and his IIMCB team in Warsaw.

From their measurements at BESSY II, the researchers produced diffraction images of the crystal, from which they calculated the geometry of the studied molecules using special software tools. The team working with Marcin Nowotny discovered that metal ions are crucial to the DNA/RNA hybrid splitting reaction.

It takes the presence of only a single RNA molecule in the DNA to initiate splitting by RNase H2. A highly specific amino acid residue, a tyrosine, first helps find and deform the junction between the RNA and DNA. Thanks to the deformation of the junction it can be split at the enzyme's active site. This catalytic process requires divalent metal ions, and in this specific case Mn2+ and Mg2+. "This was predicted, but now we have actually seen it clearly," says Nowotny.

These new findings may perhaps help to combat Aicardi–Goutières syndrome, for example. This hereditary disease is caused by a mutated version of RNase H2 that can only poorly split the RNA/DNA hybrid molecule. It will still be a long wait, however, before a gene therapy is available.

CS

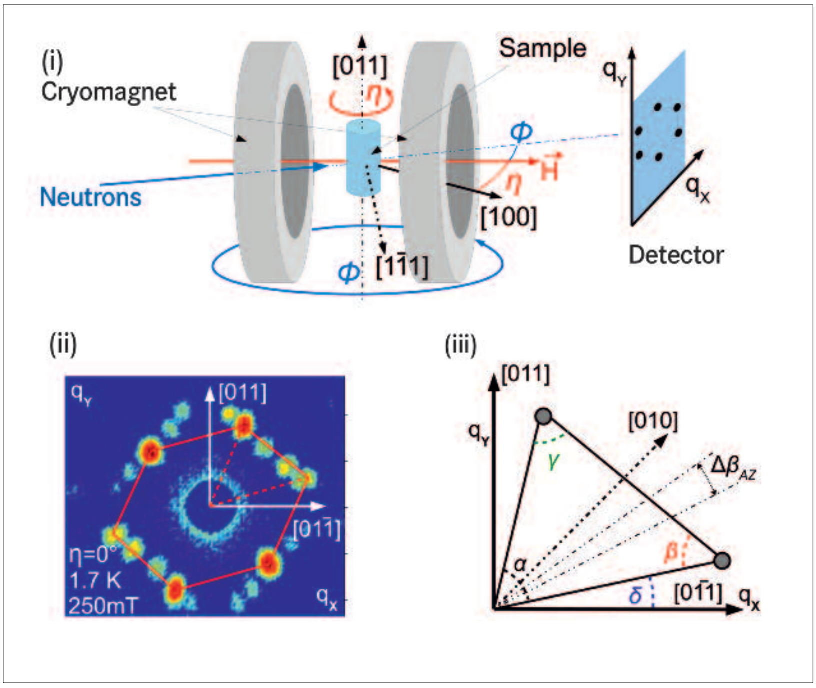
Molecular Cell, Vol. 40, 658-670 (2010): Crystal structures of RNase H2 in complex with nucleic acid reveal the mechanism of RNA-DNA junction recognition and cleavage, Marcin Nowotny et al.

SIGHTS SET ON FLUX TUBES

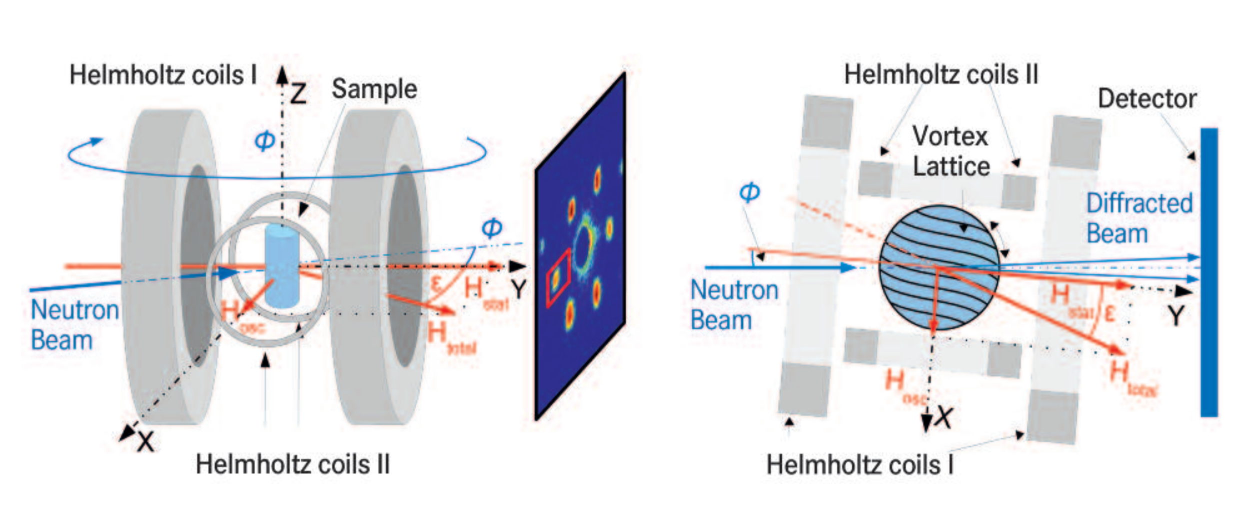
An international research group led by **Dr. Sebastian Mühlbauer** studied the morphology and dynamics of vortex lattices in niobium that emerge upon the metal's transition into a superconducting state.

When Dutch physicist Heike Kamerlingh Onnes experimented with liquid helium in 1911 to determine the residual resistance of high purity mercury, he made a surprising discovery: Below a certain temperature, mercury completely lost all electrical resistance. Superconductivity was discovered – and aroused hope for useful applications such as lossless transmission of electric current. 100 years later, technologies and devices still only scarcely use this physical phenomenon. One reason for this is the elaborate and expensive cooling of superconductors, as well as technical difficulties in processing the sometimes stubborn materials. "Another reason is because the theoretical basis of superconductivity – especially high-temperature superconductivity – is still far from adequately understood," says Dr. Sebastian Mühlbauer. The physicist works with magnetism and neutron scattering at the Laboratory for Solid State Physics of ETH Zurich. During his doctoral studies, he researched the magnetic properties of superconductive materials. He obtained important results in this field in 2009 and 2010 as head of a scientific team at Technische Universität München – with the help of neutron scattering experiments at Helmholtz-Zentrum Berlin. The team also included two physicists from the University of Birmingham in Great Britain. Mühlbauer and his research colleagues trained their sights on so-called flux tubes in Niobium. This metal becomes superconductive at temperatures of around 9 Kelvin – a little above absolute zero, which is at minus 273 degrees Celsius. Then, it demonstrates properties that physicists refer to as type II superconductivity: Unlike type I superconductivity, these materials do not fully expel magnetic flux from inside them. Instead, tube-shaped regions form in which a magnetic field can penetrate the material: flux tubes.

"Given their topological properties – the vortex structure – flux tubes have a particle-like character and arrange themselves regularly within the superconductive material," says Mühlbauer, "similarly to the atoms in a crystal lattice." Physicists therefore speak of a flux or vortex lattice. "Just as there are structural phase transitions and dynamics in crystal lattices, analogous effects can also be observed in flux lattices," explains Mühlbauer. An exact understanding of the structure of such lattices and their dynamic behaviour could deliver important indications on how superconductivity arises – for example in the ceramic or iron-containing high-temperature superconductors of present technological interest.



(i) Schematic of Sebastian Mühlbauer and colleagues' setup for measuring flux lattice symmetry, where a sample inside a magnetic field is irradiated with neutrons. (ii) A typical scattering pattern of the flux lattice. (iii) Geometric description of the symmetry of the flux lattice with angle calculations.



To measure the dynamics of the flux lattice in the niobium crystal, the sample (pale blue) was subject to two crossed magnetic fields (grey rings) while being bombarded with neutrons. By changing the orientation of the magnetic field, the intensity of the neutron scattering also changes. With these measurements, the scientists gained precise insights into the arrangement of the flux tubes inside the niobium crystal at extremely low temperatures.

Looking into the structure of superconductive materials

Niobium is an ideal model system for investigating the properties of the vortex lattice and thus to lay the foundation for further analyses of complex and unconventional high-temperature superconductors. Measurements were performed on the small angle neutron scattering instrument V4 of HZB with the aim of deciphering the various influences on the symmetry of the vortex lattice for a simple system. The researchers fired neutrons of 1.2-nanometre wavelength onto a sample of ultrapure crystalline niobium. This gave them a uniquely detailed view of the flux vortexes. The researchers gradually shifted the orientation of the magnetic field relative to the niobium crystal direction and measured the intensity of the neutrons that were scattered out of the flux tubes at various angles to the lattice. As a result of these experiments, done at temperatures between 1.5 and 5.5 Kelvin, the scientists gained a precise picture of the arrangement of flux tubes and how they rearranged themselves upon a change in temperature or magnetic field. “From this, we can draw conclusions on the physical mechanisms behind the symmetry of vortex lattices even in other, more complicatedly structured superconductive materials,” says Mühlbauer.

In another experiment, the scientists analysed the elasticity of the flux tubes, which are not rigid, but can move under the influence of electromagnetic forces. To do so, they generated a time-dependently tilted magnetic field that deflected and distorted the vortex lattice out of its position of equilibrium. “For this, we developed a setup specifically to create the special arrangement of magnetic fields needed for these experiments,” reports Sebastian Mühlbauer. After switching off the magnetic field, the flux tube lattice returned to its original position; it relaxed, as the physicists say. By a series of measurements under different conditions, the researchers determined the modulus of elasticity of the vortex lattice from its reaction – a characteristic parameter also decisive to the dynamic behaviour of crystalline solids.

Pioneering measuring technique developed

For future experiments, the measuring technique developed by Mühlbauer and his team will be of great interest for investigating the melting of the flux lattice – a process similar to the melting of an atomic lattice. The method is also suitable for microscopically analysing the “pinning” of flux tubes. Pinning is where imperfections in the material hold the flux tubes in place and prevent them from moving. This effect facilitates the technical use of superconductive materials: As a supercurrent flows within them, forces act on the flux tubes, pulling them. If this causes the flux tubes to move, then energy is lost in the form of heat – which limits the current that can be sent down a superconductive wire, for example. “Pinned” flux tubes, on the other hand, remain stable and let more current through. The new findings of Sebastian Mühlbauer and his colleagues demonstrate an experimental method for more closely investigating and perhaps testing various influences on the onset of superconductivity – and thus reveal a path that brings superconductivity a good deal closer to new applications 100 years after its discovery. *rb*

Phys. Rev. Lett. 102, 136408 (2009): Morphology of the Superconducting Vortex Lattice in Ultrapure Niobium, S. Mühlbauer, C. Pfleiderer, P. Böni, M. Laver, E. M. Forgan, D. Fort, U. Keiderling & G. Behr

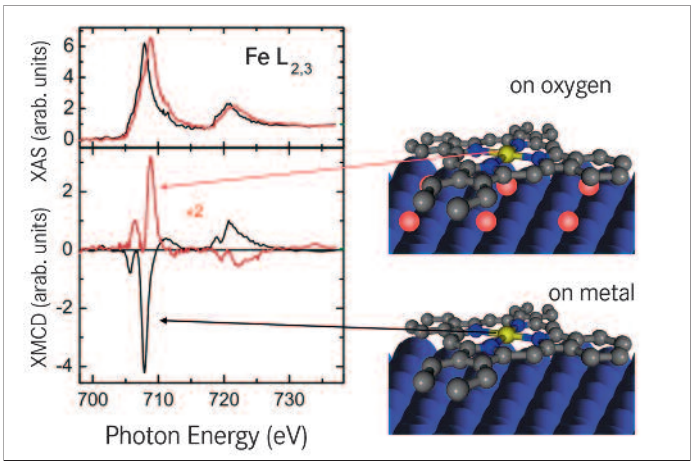
GOOD NEWS FOR THE COMPUTER INDUSTRY

At HZB, **Dr. Matthias Bernien** of FU Berlin achieved targeted coupling of iron-porphyrin onto a ferromagnetic substrate using oxygen atoms.

Since 1990, the Friends of Helmholtz-Zentrum Berlin e.V. have been awarding the Ernst-Eckhard-Koch Prize (EEK Prize) to distinguish outstanding theses on the topic of synchrotron radiation. In 2010, the committee's vote went to Dr. Matthias Bernien. At the Institute for Experimental Physics of Freie Universität Berlin, Bernien had studied iron/metal complexes on solid surfaces using X-ray spectroscopic methods involving synchrotron radiation. Together with scientists of Freie Universität Berlin, University of Duisburg-Essen and a group of theorists from Uppsala, Bernien managed to achieve an antiferromagnetic coupling between iron porphyrin molecules and monocrystalline substrates for the first time. This opened the path to targeted manipulation and control of the spin – the magnetic properties – of paramagnetic molecules. Paramagnets only become magnetized in an external magnetic field and are not intrinsically magnetic.
This should be welcome news to the information technology industry, since data storage now relies on the behaviour of single molecules. Only a few nanometres in size, molecules such as iron porphyrin are especially suitable for IT applications. The smaller the bit carrier, the more information can be stored per unit size of memory. Bernien's results are also highly interesting for spintronics. Spintronics is a relatively new field of nanoelectronics, which uses not only the charge but also the spin of electrons to represent and process information. Computers will thereby not only become faster, they will also consume less energy.

Pioneering work for molecular spintronics

The experimental physicist Bernien came an important step closer to producing a reversible and externally controllable alignment of the spins in paramagnetic molecules: a tailored magnetic coupling of iron porphyrin molecules with monocrystalline cobalt and nickel films. Iron porphyrin is an organochemical pigment with paramagnetic properties. Bernien characterized the coupling using electromagnetic waves, or more specifically synchrotron radiation.
His measurements at BESSY II in Berlin Adlershof have shown that, by introducing oxygen atoms between the ferromagnetic metal film and the iron porphyrin molecules, the direction of the coupling can be swapped from parallel to antiparallel in controlled fashion. Working from theoretical calculations, Bernien and colleagues showed that the magnetic interaction between the iron ion and substrate is a superexchange: an indirect spin coupling made via an intermediate particle. The antiparallel coupling was only observed in the presence of oxygen atoms; in the absence of oxygen atoms, the researchers found only parallel coupling with the nickel and cobalt substrates.
This pioneering work lights the path for molecular spintronics. Organic molecules have also gained considerable influence in solid state physics as components of molecular nanotechnology. It seems they can be used to integrate all kinds of functional properties into a single assembled material. *ve*



The X-ray absorption spectra (top) are similar for iron porphyrin molecules on nickel with oxygen (red lines) and for nickel (black lines), yet the XMCD difference spectra (bottom) diverge and thereby reveal the antiferromagnetic coupling.

Phys. Rev. Lett. 102, 047202 (2009): Tailoring the Nature of Magnetic Coupling of Fe-Porphyrin Molecules to Ferromagnetic Substrates, M. Bernien, W. Kuch et al.

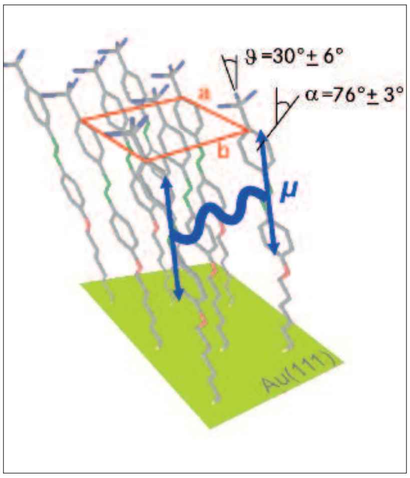
HOW TO GET MOLECULAR SWITCHES INTO SAMS

Dr. Cornelius Gahl of the Berlin Max Born Institute is working on developing interactive photoswitches based on azobenzene.

Molecular switches show great potential for electronics and sensor technology. In nanoelectronics, they allow miniaturization to scales where conventional semiconductor electronics can no longer keep pace. Molecular switches are molecules that can swap between at least two stable states, triggered by changes in their environment such as light, temperature or pH. Molecular switches that react to light are called photoswitches. Azobenzene, an organic molecule, exhibits such photoswitchable properties. It can exist in two different spatial arrangements of the atoms, i.e. it has two isomers with different properties.
Along with researchers of Freie Universität Berlin and of the Fritz Haber Institute of the Max Planck Society, Cornelius Gahl of the Max Born Institute studied the optical characteristics and geometric structure of self-assembled monolayers of azobenzene alkanethiols at the synchrotron radiation source BESSY II. Self-assembled monolayers, SAMs, are considered an ideal platform for arranging molecular switches on a single surface. As the name suggests, an SAM consists of a very thin layer of molecules on a substrate that forms spontaneously when the substrate is dipped into a solution such as azobenzene alkanethiol. To endow SAMs with molecular switches, i.e. to "functionalize" them and make them useful, the molecular structure still needs tailoring. For photoswitchable molecules, the coupling of the chromophores, the part that gives the molecule its colour, must also be controlled with the environment. In a densely packed SAM, the neighbouring molecules namely influence one another by excitonic coupling, for example. This is a common state of excitement across several molecules, which leads to a shift in the location of the energy level.

Controlling molecular switches

Gahl therefore turned his attention to the intermolecular interactions. An important analytical method for characterizing solid surfaces is near edge X-ray absorption fine structure spectroscopy, NEXAFS. Combined with the results of UV/Vis spectroscopy measurements, Gahl was able to calculate properties such as bond lengths and bond energy. The scientists managed to determine the molecular alignment of the azobenzene units and demonstrate excitonic coupling between the chromophores. Gahl and colleagues developed a consistent image of the geometric structure and optical properties of the SAM of azobenzene alkanethiol.
Given the high packing density of the molecules in the SAM, a strong interaction occurs between the chromophores, the coloured part of azobenzene. This interaction causes the absorbed light energy to be distributed very rapidly over many molecules. This strongly suppresses switching in the densely packed SAM. Gahl's detailed insight into inter-molecular coupling is an important step in the development of a functional SAM design featuring molecular switches. Many applications, such as biosensors, modified electrodes or molecular electronics, require large parts of the molecular layer to be switchable. The excitonic coupling Gahl and colleagues revealed opens up a new perspective for this field. *ve*



Geometric illustration of azobenzene alkanethiol: the orientation of the molecules (angles "alpha" and "theta") were measured to estimate the influence of the excitonic coupling on the switching behaviour of azobenzene in densely packed SAMs.

J. Am. Chem. Soc. 9 Vol., 132, 1831–1838 (2010): Structure and Excitonic Coupling in Self-Assembled Monolayers of Azobenzene-Functionalized Alkanethiols, Cornelius Gahl et al.

Solar cell production at HZB: Scientists are working on improving modules and developing lower cost processes for producing solar cells.

HIGHLIGHTS FROM OUR OWN RESEARCH

The scientists at the Helmholtz-Zentrum Berlin work to gain new insights into the fundamental scientific principles for the long-term solution of pivotal issues faced by society, industry and science. They therefore not only take care of operating and upgrading the large-scale facilities, but also maintain their own in-house research programme. In the pursuit of their research goals, they have repeatedly succeeded in decisively improving available equipment and methods with the aim of gaining new knowledge.

A group of HZB researchers succeeded in developing a new microscope for X-ray nano-tomography and were thus able for the first time to represent micro components of mammalian cells in a three-dimensional manner. And with the LiXEdrom, other researchers succeeded in building a new measuring chamber for the X-ray analysis of liquid samples. This improves the possibility of investigating the structure and function of proteins, e.g. during oxygen transport or the breakdown of fats. Based on this knowledge, it will be possible to develop medicines which take the place of missing proteins in the human body. Another group of researchers were able with the aid of EPR spectroscopy to gain new insights into the magnetism of molecules. This is the prerequisite for taking data storage to the molecular level, and is one of the most interesting approaches for the design of even faster and larger (molecular) data storage units. Especially efficient are also superconductors because they transport electric current without power loss. Up to now, this was only possible under application of elaborate cooling systems or with materials whose manufacture is extremely expensive.

HZB researchers have also gained new knowledge about the structure of superconductors from their research on iron compounds, and hope to be able soon to build more reasonably priced superconductors.

These are just a few examples of the basic research being carried out at HZB which are described in more detail on the following pages.

FRESH WIND FOR PRODUCTION

At HZB, scientists are searching for new materials and processes to produce more efficient and lower-cost **solar cells**.

The use of solar energy is booming. While crystalline silicon solar cells have dominated so far, the trend is now pointing towards thin-film solar cells. Their advantage is that the active layer that converts sunlight into electric current is only about a hundredth of the thickness of a conventional silicon cell. This means cells and modules could be manufactured more simply and at lower costs. The prerequisite is that the material must convert sunlight within the solar cell at high efficiency. Analysing materials that satisfy this requirement and developing efficient methods for their processing are focuses of research at HZB.
“Among other things, we are using synchrotron radiation from the electron storage ring BESSY II to investigate how semiconductor layers grow,” says Prof. Dr. Hans-Werner Schock, department head at the Institute of Technology and spokesman for the Solar Energy Research division. “We can follow what happens while applying the layers, for example, and adapt the processes accordingly.” The goal is to improve the efficiency of the cells and to lower production costs by shortening process times. “Our results are of huge interest to manufacturers of thin-film solar cells – and flow directly into production,” explains Schock.

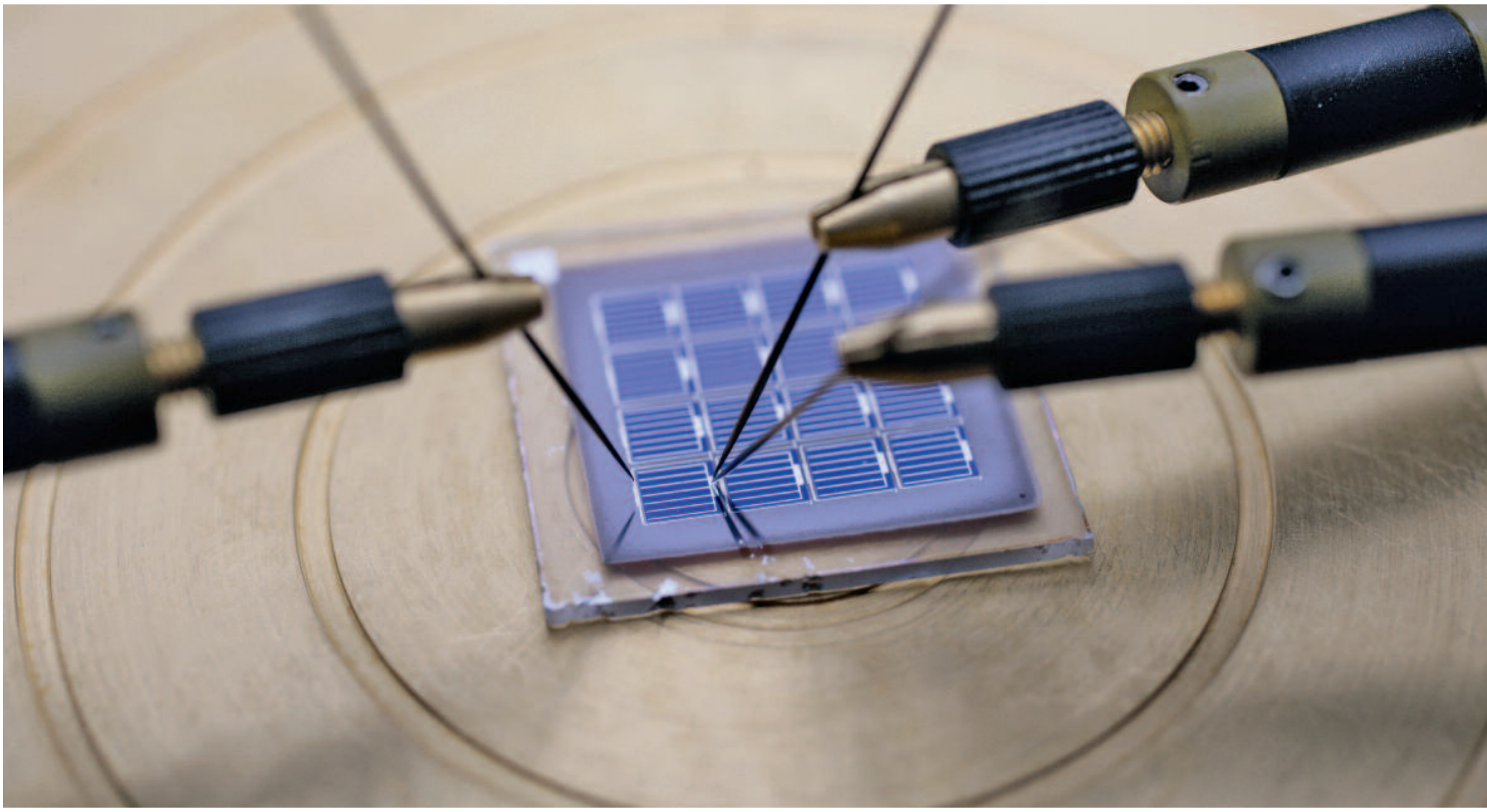
Studying solar cells in the lab.

Replacement for cadmium compounds wanted

It is little wonder that a number of companies from outside Germany are collaborating closely with the scientists at HZB. “Many companies come to us with the intention of a cooperative,” reports Prof. Dr. Martha Christina Lux-Steiner, who heads the Institute of Heterogeneous Material Systems at HZB. Various projects involving industry are running to research layers made of chalcopyrites – a class of chemical compounds comprising, for example, copper, indium, gallium and sulphur or selenium. The researchers refer to these as CIGS or CIGSe for short. Chalcopyrites are excellently suited to generating electricity from sunlight. Thin films of the material are also about as robust as silicon – and are therefore often used in solar cells.
“So far, however, these cells have required a cadmium compound as a buffer layer,” says Prof. Dr. Christian-Herbert Fischer, head of the workgroup Alternative Thin-Film Deposition and CISSY Synchrotron analysis at the HZB Institute of Heterogeneous Material Systems. Chemically bound cadmium is a danger to health and the environment, “yet large amounts of the substance remain as waste from production of the cells,” explains Fischer. That does not chime with the ecological ideal of photovoltaics. Furthermore, one hopes for even higher efficiencies from other materials. The scientists are accordingly looking hard for a replacement. At the moment, they have their sights trained on indium sulphide – a harmless material that can replace cadmium compounds. Nevertheless, until recently, there has been no easy, low-cost method by which to apply the alternative material nano-thinly onto a substrate. “Other production steps should not be slowed down by this,” emphasizes Fischer. A new concept is therefore only fit for production if every layer can be deposited quickly, precisely and at high quality.

New production method developed

HZB researchers have proven impressively that this can be achieved for indium sulphide. They used a novel production method, which they enhanced in the scope of the EU research project ATHLET 2010. The process is Ion Layer Gas Reaction, or ILGAR for short, and is special because it can



Thin-film solar cells of amorphous silicon as developed by HZB require about 100 times less light-active material (semiconductor) than silicon solar cells.

be used to produce thin layers of indium sulphide in only two process steps, which are cyclically repeated until the desired layer thickness is reached. First, an indium-containing salt, the precursor, is applied to the substrate. Next, a gas mixture chemically converts the salt layer into indium sulphide. Material consumption is low and the equipment required comparably affordable. "The ILGAR method is well suited to assembly line production of thin-film solar cells," says Christian-Herbert Fischer. That way it fulfils all prerequisites for use in industrial production.

Test facility set up for the ILGAR method

To demonstrate the performance of the technology, researchers and the company Singulus-Stangl Solar have set up a test facility at HZB that produces mini modules 30 by 30 centimetres in size – with impressive results: The solar modules from the ILGAR facility excel at efficiencies of up to 13 percent. That is only 0.3 percent less than cadmium-containing cells. And that is not all by far, Fischer is convinced. The chemist and his team are continuing to work on improving the long-term stability and efficiency of thin-film solar cells produced in this manner. Soon, they should be producible in larger formats: "We have come to where we can apply the technology on larger surfaces," institute director Lux-Steiner is pleased to report. That promises higher efficiencies and satisfies the demands of industry.

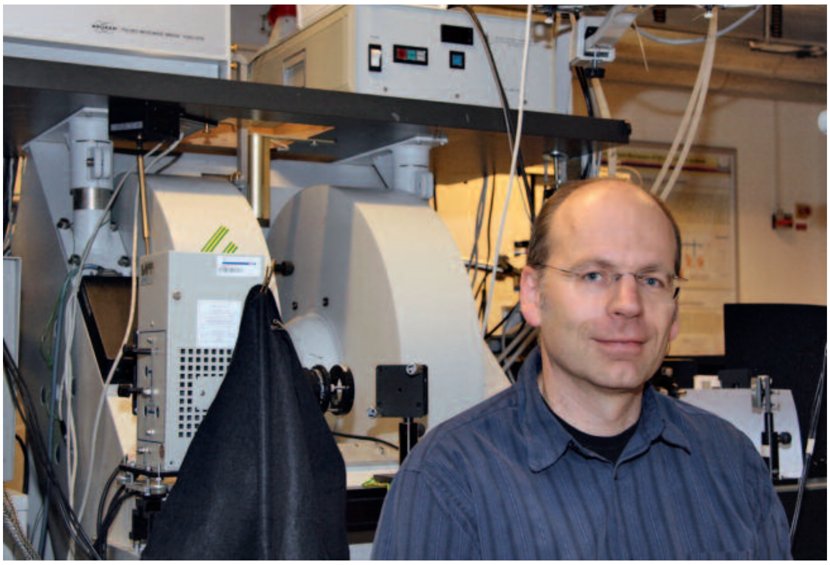
The manufacturer CIS Solartechnik has also set up a pilot plant based on HZB's ILGAR method at its factory in Hamburg. There, they apply indium sulphide onto steel strips. These flexible cells are already coming off the line in small batches, and series production should start soon. Global Solar also presented the first commercially available flexible solar modules in September 2010. "HZB researchers were involved in testing and developing the CIGSe thin-film solar cells they use for this," points out Dr. Christian Kaufmann, research assistant at the HZB Institute of Technology. Singulus-Stangl Solar, in their turn, have specialized in producing machines for industrial manufacture of photovoltaic elements, where they, too, have opted for the patented technology from Berlin: The company intends to offer the first ILGAR production plants soon.

New research approaches for future applications

The researchers at HZB are already working on new approaches – involving the nanostructured boundary surfaces in thin-film solar cells, for example, and integrating a current buffer on the rear side of solar modules. Furthermore, they intend to simplify the production of the so-called window layer, through which sunlight passes into the cells. Companies from the photovoltaics industry will therefore soon be able to draw from a rich fund of innovations from the laboratory of the Berlin scientists. *rb*

INSIGHTS FROM THE TERAHERTZ MAGNIFIER

HZB scientists use **terahertz EPR spectroscopy** to research phenomena of molecular magnetism.

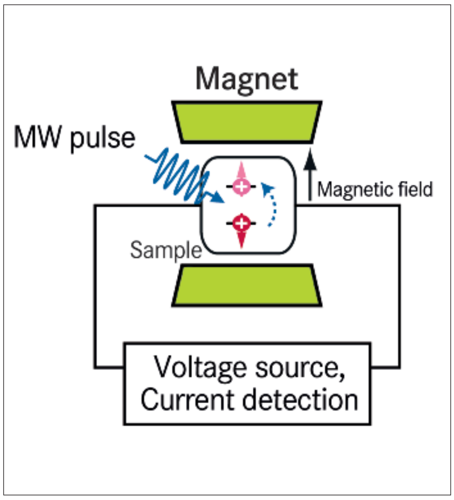


Dr. Klaus Lips of the Institute for Silicon Photovoltaics at HZB and fellow researchers have gained important insights into how to store larger quantities of data on molecular magnets.

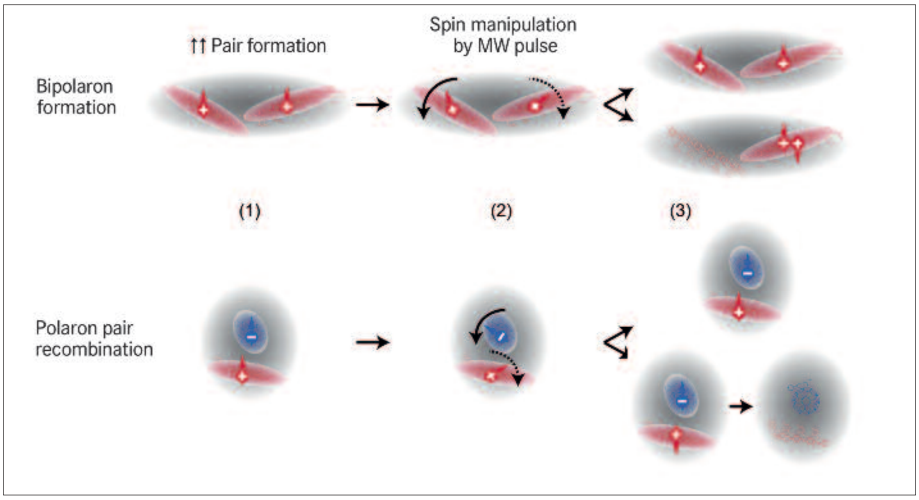
Magnetic materials are the key ingredients in data storage media, such as computer hard disks, for example. To pack as much data as possible onto a given storage medium, the carriers of individual bits have to be as small as possible. Molecular magnets make very attractive candidates for this. They are molecules that possess a spin and thus a magnetic moment. In a magnetic field, this moment aligns itself much like a rod magnet. Unlike most other molecules, molecular magnets still retain their magnetic orientation when the field is removed.
The one drawback, however, is that physicists have so far only observed molecular magnetism at very low temperatures, of only a few degrees Kelvin above absolute zero. This is the main obstruction to its application in technology. If researchers can gain a better understanding of the spin properties of molecular magnets, it will be easier to track down molecules that possess this unusual property at room temperature as well.
A group of scientists led by Dr. Klaus Lips and Dr. Alexander Schnegg of the HZB Institute for Silicon Photovoltaics, in cooperation with Prof. Robert Bittl at Freie Universität Berlin, have come a good step further in this direction using a novel technique in EPR spectroscopy. EPR stands for electron paramagnetic resonance (see infobox).
So that they can investigate all spin transitions of interest on the one instrument, they have to irradiate the sample with many different frequencies of light. A synchrotron radiation

TERAHERTZ RADIATION IN LOW-ALPHA MODE

Terahertz radiation refers to the spectral range between microwaves and infrared light, of about 0.1 to 1 millimetre wavelength. It can be used to look through materials, much like using X-rays. The accelerator physicists produce the terahertz radiation needed for their experiments by operating the electron storage ring in so-called low-alpha-mode. They carefully adjust the magnetic fields in this mode to shorten the electron bunches zipping at near light speed through the storage ring to about the same length as the distance between the wave peaks of the terahertz radiation. This makes the electrons give off coherent synchrotron radiation,meaning the waveforms oscillate in phase.
This coherent radiation in the terahertz range is up to 100 times more intense than from commercial sources. This gave Dr. Karsten Holldack and researchers at the Institute for Methods and Instrumentation for Synchrotron Radiation Research the idea to build a special measuring station. It is special because, using intense coherent radiation, they can run through a broad range of frequencies very rapidly and at extremely high resolution. Holldack's beam tube is thus an ideal platform for EPR experiments at terahertz frequencies.

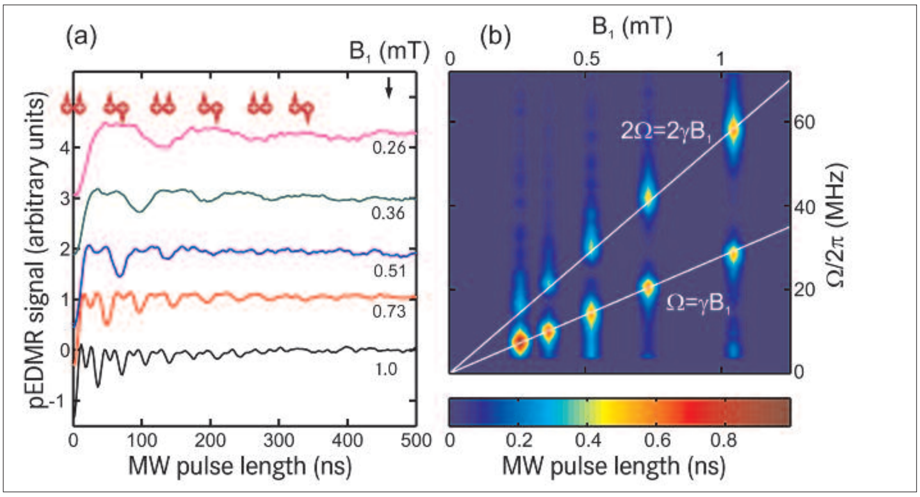


Principle of EDMR (electrically detected magnetic resonance): The sample is irradiated with microwaves and simultaneously exposed to a strong magnetic field.



Using synchrotron radiation and EDMR, researchers manipulate the electron spin of the current-carrying particles (polarons). The spin can be turned like a compass needle. Measurements reveal that current flows freely when the tiny magnets are oppositely aligned. When aligned in the same direction, the flow of current is blocked.

source is a perfect solution for this. HZB has combined a high-resolution Fourier transform EPR spectrometer with coherent synchrotron radiation in the terahertz frequency range – a setup that is so far unique, and which exploits the ideal opportunities offered at their BESSY II facility.
With it, they can investigate the interaction energies of all spins together and even alter the spin orientation in the magnetic field over time. The insights gained from this will lead to new developments in spin-carrying complexes for use in data storage.
It also gives rise to new applications in spintronics – a new form of electronics in which not only electron charges, but also their spins are exploited for information processing.



Characteristic fluctuations show up in the EDMR signal as a function of pulse length, indicating a polaron pair with spins oriented in parallel or antiparallel.

What puts the brakes on polarons?

Meanwhile, the research group led by Klaus Lips, Alexander Schnegg and Jan Behrends has made important progress of its own in understanding the physical processes going on inside organic solar cells. These cells are made mostly out of plastics and have appealing advantages over conventional silicon solar cells: They can be produced at significantly lower cost and with much less energy expenditure, and can be applied to flexible substrates such as plastic films.However, their electricity yield is still much lower than that of silicon cells. The HZB researchers have now detected the suspected cause experimentally. Using a special form of magnetic resonance spectroscopy called electrically detected magnetic resonance (EDMR) they used the "magnetic fingerprint" of particles to pinpoint exactly where electricity was being lost.
In "plastic" solar cells, solar energy is converted to electrical energy inside an approximately 100-nanometre-thick layer of polymers and fullerenes – soccer-ball-shaped carbon molecules. Sunlight striking this layer excites the polymers, resulting in so-called excitons. When an exciton bumps into a fullerene, an electron jumps over to the fullerene, leaving behind a "hole" in the polymer where the electron is missing. Electrons and holes distort their surroundings and physicists call the resulting combination of charge and distortion a polaron. As the negatively and positively charged polarons travel through the plastic solar cell, they create an electric current. Another property of po-

larons, however, sometimes interferes with their travel: their spin. The orientation of their spin ultimately influences the current flow through the solar cells.
To clarify this effect, the scientists first aligned the polaron spins in a magnetic field. They then analysed their magnetic properties using microwave pulses. The HZB researchers discovered that two polarons block each other's motion if their spins are oriented in the same direction. Holes with oppositely aligned spins, on the other hand, amiably pass each other by. This phenomenon was already known in theory as "bipolaron formation", yet its influence on electric current in organic solar cells had never been directly observed before.
The scientists at HZB have now provided the first experimental evidence supporting the theory. Their results may well lead to the development of plastics in which no such spin blockades occur,making organic solar cells more efficient, and thus more affordable. *rb*

Phys. Rev. Lett. 105, 176601 (2010): Bipolaron Formation in Organic Solar Cells Observed by Pulsed EDMR, J. Behrends, A. Schnegg, K. Lips, E. A. Thomsen, A. K. Pandey, I. D. W. Samuel and D. J. Keeble

EPR@HZB

EPR spectroscopy is a technique used to study the atomic structure and magnetic properties of materials. Spins inside a sample are made to act as tiny probes, being manipulated and queried from outside using electromagnetic waves. In EPR experiments, a strong external magnetic field is used to align the spins. The sample is then irradiated with electromagnetic waves to alter the orientation of the spins within the field. This is done at various specific energies. An analysis of these energies then delivers insights into the material properties. At its EPR laboratory, HZB's Institute for Silicon Photovoltaics puts the new information straight into practical development of novel solar cells, while an EPR experiment has also been set up on a beamline of the synchrotron ring BESSY II that delivers terahertz radiation.
To spur on important studies into thin-film solar cells, the German Federal Ministry of Education and Research (BMBF) is funding the network project "EPR Solar", coordinated by HZB. In this project, HZB scientists are co-operating with partner teams of Freie Universität Berlin, the Max-Planck Institut für Eisenforschung GmbH (Max Planck Institute for Iron Research, MPIE) in Düsseldorf, the Jülich Research Centre and Technische Universität München. The aim of the project is to study materials for solar energy research and to develop EPR instruments that allow EPR experiments that have never been possible before.
The potentials of synchrotron radiation in particular have opened the door to such experiments. The researchers at HZB have namely used the EPR Solar funds to set up a unique EPR spectrometer at the synchrotron, and have also created a 263-GHz EPR spectrometer that is unique in the world, set up at the Institute for Silicon Photovoltaics.

SUPERCONDUCTIVITY WITH IRON TETRAHEDRONS

HZB scientists investigate universal properties of iron-based **superconductor materials**.

Iron compounds are a recent subject of interest to physicists. Japanese scientists discovered in 2008 that this class of materials features previously unknown high-temperature superconductors. Superconductors are materials that completely lose their electrical resistance below a certain temperature, called the "transition temperature". One of their applications is in spools that carry high electric currents – to create the strong magnetic fields used in magnetic resonance imaging (MRI), for example, or to bump particles up to speed in accelerators.
Most superconducting materials enter a resistance-free state only when cooled to a few degrees above absolute zero, at minus 273 degrees Celsius. Only "high-temperature" superconductors boast significantly higher transition temperatures. This is an advantage for their practical application, since less effort is required to keep them cool. Unfortunately, the familiar high-temperature superconductors, made of copper oxide-containing materials called cuprates, are delicate and brittle. The newly discovered superconducting iron compounds, on the other hand, are much easier to process, making them much more attractive for use in technology. A team of scientists at HZB led by

Dr. Dimitri Argyriou of the Institute for Complex Magnetic Materials has now shown that these iron-containing superconducting materials also deliver new fundamental insights into physics. By performing neutron scattering experiments, the Berlin researchers discovered that applying high pressure induces superconductivity in these materials.

Iron has been produced for centuries. Some iron compounds show properties of high-temperature superconductivity.

Tetrahedrons of iron atoms

Superconducting cuprates are typically created by a process called doping, where foreign atoms are incorporated into the matrix of a base material. The foreign atoms distort the material's crystalline structure. HZB researchers have produced the same effect in an iron compound using a different method: When they put the material under very high pressure, the crystalline lattice deformed similarly to having been doped. The iron atoms gathered closer together, with groups of four atoms forming tetrahedrons – a conformation of the crystalline structure apparently critical for resistance-free flow of current.
The researchers created the crystals out of iron, tellurium and selenium. To analyse the compound, they irradiated it with X-ray light and neutrons. These were generated on HZB's research reactor BER II as well as on the research reactor of the Institute Laue-Langevin in Grenoble, France. The neutrons penetrated into the crystal, where they were scattered by the atoms inside. The way they scattered delivered detailed information about the arrangement of atoms within the irradiated material.
The same experimental method can be used to explain the magnetic properties of solids. Argyriou and his group used it to measure the signals of magnetic fields in superconducting iron crystals. It turned out that, while the symmetry of the magnetic order may differ in the various iron-containing base materials, this has no bearing on the onset of the superconducting state. Below the transition temperature, the same magnetic symmetry always arises, regardless of the choice of base material. There is most probably a universal mechanism responsible for this, which is characteristic for the superconductivity in iron compounds. This knowledge, the researchers hope, will in future be used to produce materials that lose their electrical resistance at relatively high temperatures. *rb*

Nature Materials, 2010; 9 (9): 718 (DOI: 10.1038/nmat2800): From (π,0) magnetic order to superconductivity with (π,π) magnetic resonance in $Fe_{1.02}Te_{1-x}Se_x$, T. J. Liu, J. Hu, B. Qian, D. Fobes, Z. Q. Mao, W. Bao, M. Reehuis, S. A. J. Kimber, K. Prokeš, S. Matas, D. N. Argyriou, A. Hiess, A. Rotaru, H. Pham, L. Spinu, Y. Qiu, V. Thampy, A. T. Savici, J. A. Rodriguez, C. Broholm

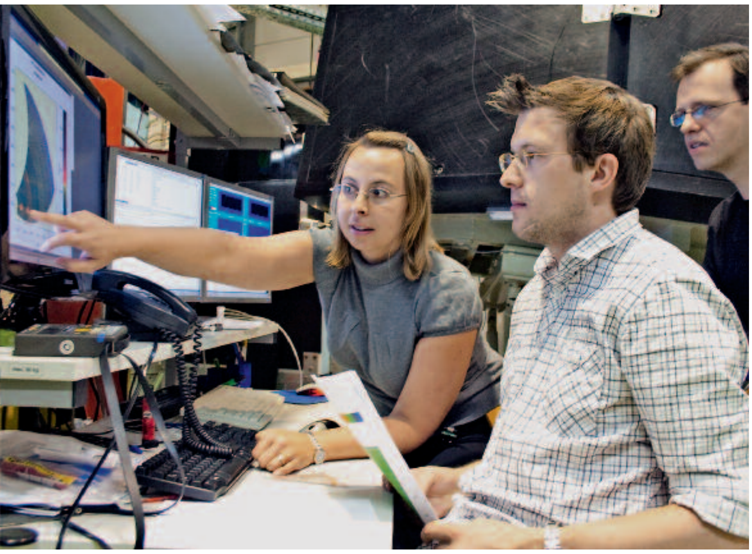
SUPERCONDUCTORS – THE OUTCOME IS DECIDED IN THE RING

Some materials become superconducting at low temperatures, others not. A hundred years after the discovery of superconductivity, physicists are still puzzling as to why this is so. They already know that, as a solid material is cooled, a phase transition takes place around the transition temperature, suddenly causing the material to lose its electrical resistance. The atoms rearrange themselves, lending the material new properties. Scientists, however, are divided as to whether the "germ" for losing all resistance already exists in the base material for the superconductor or not. An alternative theory proposes that the outcome of a "wrestling match" between two different phases decides whether the superconducting state will arise or not.
Experiments at HZB highlight this picture. Dimitri Argyriou and his researchers studied a compound of lanthanum, strontium and manganese. Although it is produced by similar means, by doping an insulator, this metallic material is not a superconductor at all. In fact, it is a considerably worse electrical conductor than most other metals. Argyriou and his group used neutron scattering to take a closer look at the structure and properties of this unusual compound. They came across yet another difference from "normal" materials. While the electrons move freely through the crystalline lattice of this material – physicists speak of an electron gas – they can only do so for a short time in lanthanum strontium manganate. After this short time, they become temporarily caged within the crystalline lattice, thus restricted in mobility. The electrons continually swap between an electrically conducting and an insulating state. The doped material appears to have a "memory" of its original insulating property. A germ for superconductivity, however, is clearly not anchored in the material.

MAGNETIC MONOPOLES TARGET OF NEUTRON INVESTIGATION

HZB physicists prove the existence of **magnetic monopoles** in a solid by neutron scattering.

Magnetic monopoles are entities that carry only a single magnetic pole, either north or south, and do not exist in ordinary matter. There are several physical theories, however, that predict the existence of such exotic species under specific conditions. Among others, in 1931, British physicist Paul Dirac concluded from model calculations that magnetic monopoles ought to exist at the end of infinitely thin tubes that have a magnetic flux running through them. These have been named Dirac strings, after their discoverer. Researchers have since been trying to prove that monopoles can exist at the ends of these strings.
Now, physicists at HZB have provided the first experimental evidence that they do. They have detected magnetic

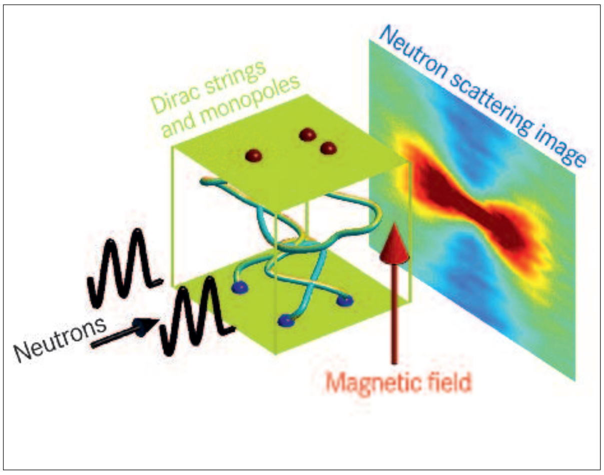


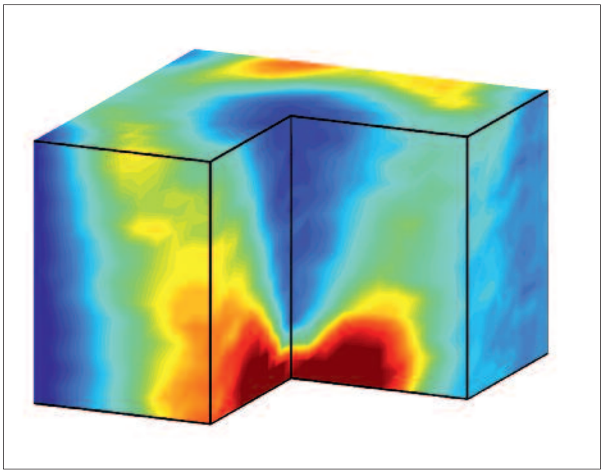
Part of the research team at experimental station E2 of the Berlin research reactor (left to right): Dr. Kirrily Rule, Dr. Jonathan Morris and Dr. Bastian Klemke.

monopoles in a solid crystal using neutrons. The research group led by Dr. Jonathan Morris and Prof. Alan Tennant of the Institute for Complex Magnetic Materials in Berlin worked on the project with colleagues from Dresden in Germany, Oxford and St. Andrews in Great Britain and La Plata in Argentina. The scientists studied a crystal of dysprosium titanate – a solid that crystallizes into a remarkable geometry called a pyrochlore lattice. By firing neutrons at this crystal lattice and measuring their scatter, Morris, Tennant and colleagues showed that the spins and magnetic moments in this crystal had organized into what can best be called 'spin spaghetti'. At icy temperatures close to the absolute zero point of minus 273.15 degrees Celsius, they form a complex network of contorted tubes – Dirac's famous strings. This structure was revealed by the neutrons the researchers fired at the deep-frozen material. Since they possess a magnetic moment of their own, neutrons interact with the weak magnetic fields of the spins in the crystal and therefore scatter in new directions.

Experiments at near absolute zero

During the experiments, the scientists applied a magnetic field to the sample to influence the symmetry and orientation of the strings. This way, they were able to thin out the spin spaghetti, reducing the density of the magnetic monopoles and thereby bringing these bizarre entities into view. At equally icy temperatures, the researchers at HZB yielded even more evidence for these magnetic monopoles. Physicist Dr. Bastian Klemke measured the heat capacity of dysprosium titanate near absolute zero. He did this in tiny steps at various temperatures between 0.4 and 4 Kelvin. He compared the resulting temperature-dependent heat capacity curve with results from theoretical calculations. It turned out the measured values deviated significantly from those expected for a material with magnetic dipolar properties. Instead, they fit nicely into the curve predicted by a theory for particles carrying electric monopoles. Their presence is a strong indicator that magnetic monopoles must have formed as well. More than demonstrating the mere existence of magnetic monopoles, the Berlin researchers have managed to explain how they are created – as emergent states resulting from the specific arrangements of dipoles.
Some 70 years after their first theoretical prediction, the German–British–Argentinian research team have finally de-





Left: Schematic diagram of the neutron scattering experiment: Neutrons strike the sample and are scattered at the strings. The resulting scattering pattern delivers information about the strings' properties. If a magnetic field is applied, then the Dirac strings – with the magnetic monopoles at their ends – align themselves with the field. On the right is a 3D simulation of the conical scattering pattern of the Dirac strings.

livered impressive evidence for the existence of these exotic magnetic entities. They have brought our fundamental knowledge of magnetism in solid-state materials a big step forward. With it, they have laid the basis for new technological applications such as high-capacity magnetic storage media, for example.

Three-dimensional imaging of magnetic domains

Other neutron scattering experiments performed at HZB have yielded similar advancements. A group led by Dr. Ingo Manke is the first to produce three-dimensional images of magnetic domains. Magnetic domains are microscopically small regions of a material in which the magnetic moments of atoms or electrons are aligned with one another and point in the same direction. Most magnetic materials consist of many such regions of varying size, which form a kind of magnetic patchwork within the material. These domains are invisible to the naked eye. Physicists can only detect them using elaborate measuring techniques – and until recently only in two dimensions, such as on the surface of metals.

Now it is possible to image the full three-dimensional structure of these domains using a novel method developed by the HZB researchers working with Ingo Manke together with experts from the Federal Institute for Materials Research and Testing in Berlin and the Paul Scherrer Institute in Villingen, Switzerland. The scientists demonstrated this on the crystal of an iron-silicon compound produced at the Leibniz Institute for Solid State and Materials Research, Dresden. Manke and colleagues took a close look at the domain walls – the regions where the magnetic domains meet. There, the alignment of the magnetic moments changes – and with it the direction of the magnetic field they generate. In order to map out these walls, the researchers fired neutrons at the crystal, which were diverted from their paths by the magnetic forces – similar to a ray of light bending at the transition from air into water.

Important in everyday technological products

To make this weak effect visible, which is normally overshadowed by many non-diverted neutrons, the researchers integrated several diffraction gratings into their experimental setup. This allowed them to separate neutrons diverted at the domain walls from the undisturbed neutrons. By rotating the sample during the measurement, the scientists scanned the crystal from all directions, finding the whole shape of each domain. A fully three-dimensional image of the domain network was generated on the computer. Magnetic domains play a major role in pure physics research, where they are extremely important for understanding the fundamental principles of matter. Their properties are significant in many everyday technological products, such as storage media and transformers for stationary or mobile applications. *rb*

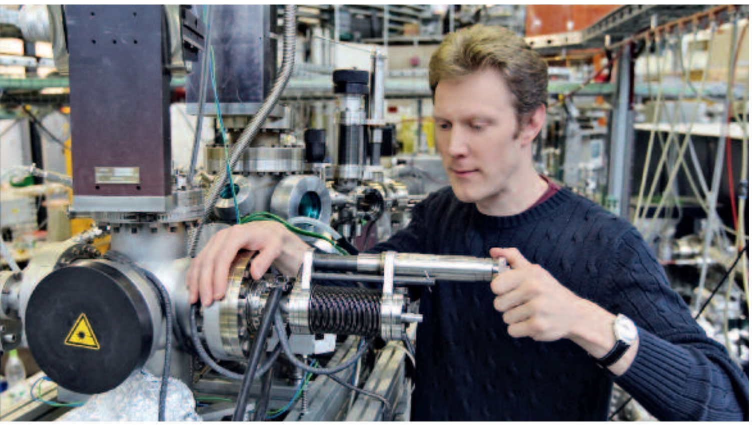
Science 16 October 2009: 411-414 (DOI:10.1126/science.1178868): Dirac Strings and Magnetic Monopoles in the Spin Ice Dy2Ti2O7, Morris, et al. bzw. Nature Communications (DOI: 10.1038 /ncomms1125), Three-dimensional imaging of magnetic domains, I. Manke, N. Kardjilov, R. Schäfer, A. Hilger, M. Strobl, M. Dawson, C. Grünzweig, G. Behr, M. Hentschel, C. David, A. Kupsch, A. Lange & J. Banhart

STORING DATA WITHIN FEMTOSECONDS

Novel data storage devices could be built out of magnetic memory components in future. HZB researchers led by **Dr. Christian Stamm**, together with scientists from Strasbourg, are the first to find out just how fast magnetic bits can be controlled.

Orbital moment – the term may sound like the expanses of the universe and distances measured in light years but, in fact, it involves quite the opposite. Orbital moment is the name for the motion of an electron around the atomic nucleus, which takes place not only within the smallest of spaces, but also at unimaginable speed. Curiously, an electron's orbital moment changes more quickly in response to influences than its intrinsic angular momentum, or spin as scientists call it. It took Dr. Christian Stamm and his colleagues at HZB six years of pioneering work to find this out. In that time, they built a worldwide unique experiment at the synchrotron storage ring BESSY II for performing what they call femtoslicing. This involves using ultra-short laser pulses to observe changes in spin, a process that takes place within a few hundred femtoseconds. That is a few tenths of a millionth of a millionth of a second.

"The ultra-fast processes contributing towards the phenomenon of magnetism can only be revealed by femtoslicing," says Christian Stamm in defence of the enormous effort and years of detailed work it took the several HZB researchers to set up the experiment. They fire ultra-short laser pulses at electrons moving at close to the speed of light in the storage ring. The electrons struck by these pulses subsequently differ from those that did not encounter the laser beam. The X-ray light these electrons emit during their circuit of the storage ring – the special synchrotron light – now also bears the temporal structure added by the laser light. Finally, these ultra-short X-ray flashes are used to study the magnetic sample. BESSY II is special because it is the only place where scientists will find the circular-polarized X-ray light required for slicing experiments. And it is this that is absolutely essential for studying spin and orbital moment – the phenomena underlying magnetism.



Dr. Christian Stamm at work on the BESSY II beamline for femtoslicing.

"Spin up" and "spin down" instead of "1" and "0"

The results Christian Stamm and his colleagues working together with the Institut de Physique et Chimie des Materiaux de Strasbourg achieved with their femtoslicing experiments provided a fundamental insight: "We were able to demonstrate by what path and how fast the energy added by the laser pulse gets into the electron spin," explains the physicist. And ultimately how fast magnetism can be influenced from the outside. For spintronics, a relatively new field of nanoelectronics that uses not only the charge but also the spin of electrons to represent and process information, this insight could be an important milestone. It could be used to build computers that are not only faster but which also consume less energy.

This could also benefit the semiconductor industry, who intend to build computers based on "spin up" and "spin down" to represent the binary parameters "1" and "0". Christian Stamm has namely shown in detail how the change in spin takes place. "The motion of the electrons in their orbit changes very rapidly when energy is added," explains the HZB scientist, unlike the spin reaction, which reacts at a delay. That means, "if you want to change the electron spin, the orbital path of the electrons must be disrupted first. Only then does the spin flip." This knowledge clears the path to even faster spins and thus faster computers. *cn*

Nature, Volume 465, 458–461 (DOI: 10.1038/nature 09070): Distinguishing the ultrafast dynamics of spin and orbital moments in solids, C. Boeglin, E. Beaurepaire, V. Halté, C. Stamm et al.

YOU SEE BETTER WITH THE THIRD DIMENSION

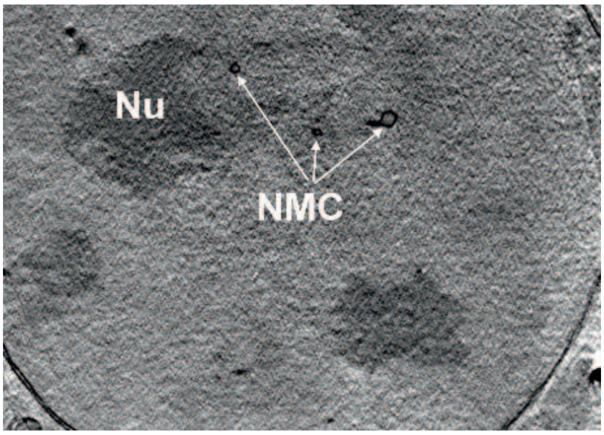
HZB scientist **Dr. Gerd Schneider** and researchers from the **American National Cancer Institute** were the first to produce three-dimensional, structured images of the smallest cell components of intact mammalian cells.

We can see deeper and with more detail into cells than ever before. Not content with the existing technology, HZB developed an X-ray nanotomography microscope that works with partially coherent light to gain higher resolutions and to allow more free space around the sample than previous setups. High-resolution electron microscopy can image a cell three-dimensionally by scanning many thin, desiccated sections, but this takes several weeks for each cell. The new X-ray microscope delivers a 3D view of the entire cell in one step. In optical microscopic studies, cell components are marked with dyes that produce an image of the structures by their distribution. On top of such fluorescence light microscopy, which can also be used to study whole cells, the new X-ray method delivers complementary information. The new X-ray microscope exploits the natural contrast between organic material and water to create an image of all cell structures.
The HZB team working with Gerd Schneider of the Institute for Soft Matter and Functional Materials, together with researchers of the National Cancer Institute, were able to produce three-dimensional reconstructions of a deep-frozen mouse adenocarcinoma and to reveal tiny structures down to 36 nanometres wide. By comparison, a human hair measures between 0.04 and 0.1 millimetres on average, so ten nanometres is about one ten-thousandth of the thickness of a hair.

More space for the sample

The imaged ultrastructures were lit with partially coherent light produced by the synchrotron source BESSY II. Tomography with partially coherent light delivers higher image contrast compared to incoherent lighting, even for the smallest of structures. The new X-ray nanotomography method is special for its setup: The object slide for the cell samples can swivel by up to 160 degrees. Together with Californian company XRADIA, a novel lens was developed for the object illumination. This condensing lens illuminates the object directly with monochromatic light and replaces the diaphragm previously used for filtering out the desired X-ray wavelengths, which would sit right up close to the object. The result is more space for the cell sample. “When we began development in 2003, this was a risky issue: nobody had such a condensing lens,” Gerd Schneider explains the initial situation. “Also, there was a dogma about not using a grating monochromator in X-ray microscopy because it intercepts too many photons to produce the necessary narrow spectral bandwidth. But I knew the quantity of X-ray photons from the synchrotron source BESSY II would still be ample for a good image.”
With their combination of high-resolution lens, also produced at HZB using an electron beam lithography system, new X-ray condensing lens and partially coherent light, they were able to reveal tiny details at high contrast – such as the double membrane of the cell nucleus, membrane channels and inclusions such as lysosomes. “We can now find out more precisely how viruses interact with cells and what the viruses do with the nuclear membrane,” says Schneider, who intends to look deeper still into cells in future.

sl



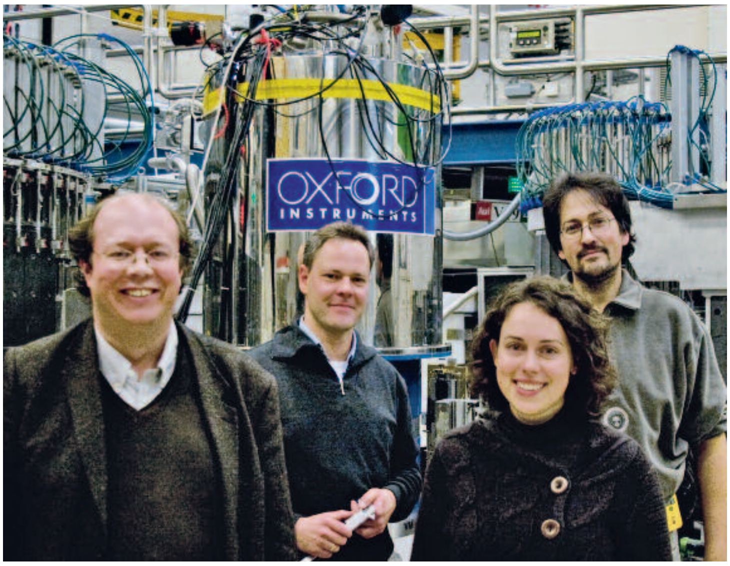
This 3D section through the nucleus of a mouse adenocarcinoma cell shows the nucleolus (Nu) and membrane channels (NMC).

Nature Methods (DOI: 10.1038/nmeth.1533): Three-dimensional cellular ultrastructure resolved by X-ray microscopy, Gerd Schneider et al.

GOLDEN RATIO IN THE QUANTUM WORLD

HZB researchers discovered special symmetry when studying the structure of a **cobalt niobate crystal**.

In art and architecture, the "golden ratio" is a feature of beauty and harmony. It refers to a specific ratio between two quantities calculated from the formula $(1+\sqrt{5})/2$ and is typically given as approximately 1.618. Painters use the golden ratio when composing themes for their paintings, while architects use it in the design of structural components on buildings and facades. This special symmetry is even found in the leaf arrangements of many plants. HZB researchers have now shown that it also resides in the very atoms of solid matter. Researchers led by Prof. Alan Tennant, head of the HZB Institute for Complex Magnetic Materials, discovered indications of the golden ratio in the structure of a crystal of cobalt niobate – a material with unusual magnetic properties. The spin components of the electrons in it string together into threadlike chains. Each of these "spin chains" is as thin as a single atom, and acts like a tiny rod magnet. This makes cobalt niobate an ideal test subject for studying fundamental quantum physical processes.



Prof. Dr. Alan Tennant, Dr. Klaus Habicht, Dr. Elisa Wheeler and Dr. Klaus Kiefer (left to right) researched together on spin chains.

The Berlin scientists worked together on their experiments with colleagues from the British universities of Oxford and Bristol as well as the Rutherford Appleton Laboratory in Didcot near Oxford. The group led by Tennant and Radu Coldea, project head at Oxford University, applied a magnetic field to the cobalt niobate crystal they were investigating. From earlier work, it was already known that the spin chains enter a new physical state if an external magnetic field is applied perpendicularly to their longitudinal axis. Physicists call this "quantum critical" behaviour. The resulting new state resembles a fractal image, composed of many scaled-down copies of its overall shape.

Harmonious quantum systems

The British and German researchers altered the magnetic field in steps, bringing the spin system of the crystal ever closer to the quantum critical point. As they did so, they used neutron scattering to observe how the chains of electron spins responded, with an astounding result: The spin chains behaved like the strings on a guitar. Like plucking a string, the excitation in the magnetic field triggered resonances. Certain "frequencies" were amplified by positive interference. How the atomic string vibrates depends on the forces between neighbouring spin chains. What is exciting about this quantum phenomenon is the ratio of resonance frequencies: It is 1.618, and therefore exactly the golden ratio.

There is a fundamental symmetry behind this resonance effect, which lends quantum systems such as these spin chains a harmonious appearance, the scientists find. Mathematicians name this symmetry, which features prominently in many particle physics theories, simply "E8". The researchers from Berlin and Great Britain are the first to succeed in observing this property of symmetry in a solid. Their results are impressive evidence that in quantum systems – so often described in terms of fuzziness, probability and uncertainty – perfect harmony abides. The character of atomic particles is similar to the aesthetic appeal of paintings and buildings.

Quarks are the components that make up protons and neutrons – and so are elementary components of atomic nuclei. Physicists have never yet caught sight of a solitary quark, since the particles always exist in pairs or in groups of three. They are so strongly interwoven that they cannot be split apart. Try to separate a quark from such a union, and you will merely get a new pair of quarks, which are in turn inseparable. Physicists call this "confinement"; the nuclear components are confined to groups. Responsible for this is the strong interaction – one of the four fundamental forces of nature. It binds the quark groups together. By its peculiar nature, the force becomes stronger the greater the distance over which it acts. It therefore represents an insurmountable hurdle against every attempt to separate two quarks.

Stable spin ladders

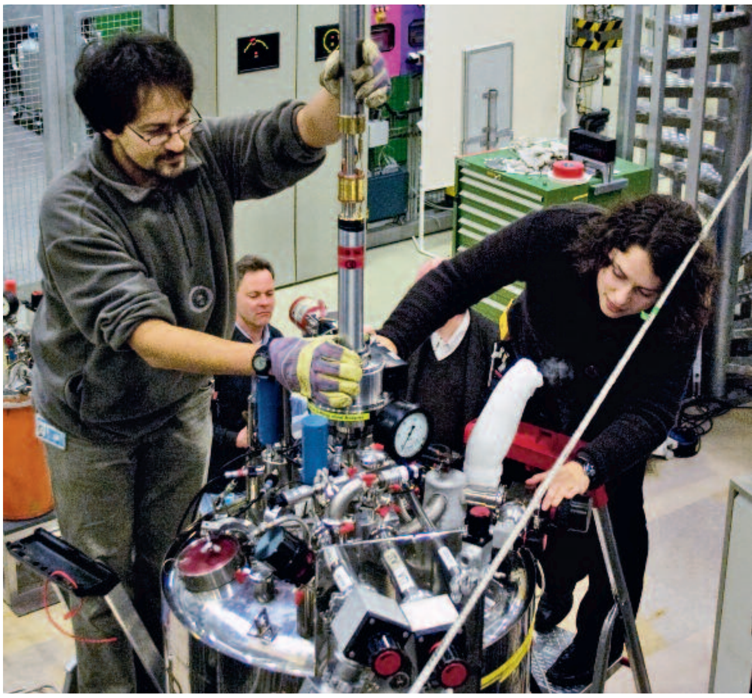
HZB researchers led by Prof. Bella Lake have now delivered proof that this bizarre physical phenomenon occurs in condensed matter systems, too. The team demonstrated the confinement phenomenon in "spin ladders" – systems in which two spin chains arrange to form a ladder-like structure, complete with legs and rungs. The Berlin researchers thus confirmed a theory developed in the 1990s predicting the effect of confinement in condensed matter. Bella Lake and her colleagues studied a crystal in which copper oxide molecules form a spin ladder. In it, two copper chains are held together forming the legs of the molecular ladder. A remarkable feature is that the electrons separate into independent electric charge and spin parts, where the spins exert the constructive force. When the ladder forms, the spin parts recombine in a new way. Similar to quarks, the excited spin parts – called spinons – bind together to form inseparable pairs.

The Berlin researchers observed these processes in neutron scattering experiments. They hope that the analogy between spin systems in condensed matter and quarks in the hearts of atomic nuclei will provide a better understanding of the fundamental mechanisms of confinement – and help quantify the formation processes of the nuclear components protons and neutrons. *rb*

RESOURCEFUL NEUTRONS

In their experiments, the HZB researchers fired neutrons at crystalline samples. Within the crystal, the neutrons interacted with the electrons' magnetic moments associated with their spin. The neutrons thereby altered their direction of motion. They were scattered. From this scattering, the scientists measured the magnetic pattern of the spin chains – and thus discovered the magnetic resonance.

Neutrons are especially suitable for analysing magnetic material properties, since they possess a magnetic moment of their own, but no electric charge that could interfere with the magnetic effects.



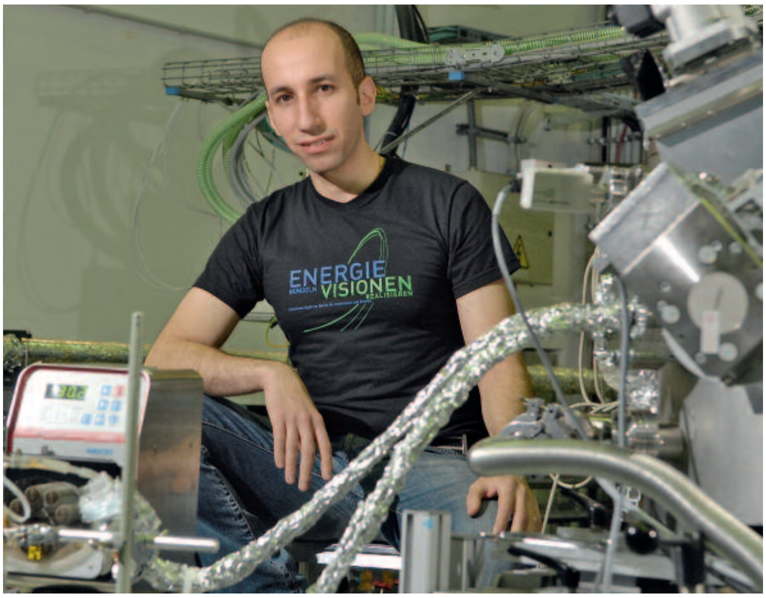
Dr. Klaus Kiefer supports Dr. Elisa Wheeler in the preparation of measurements using neutron scattering under the influence of magnetic fields.

Science (DOI: RE1180085/JEC/PHYSICS): Quantum Criticality in an Ising Chain: Experimental Evidence for Emergent E8 Symmetry, R. Coldea, D. A. Tennant, E. M. Wheeler, E. Wawrzynska, D. Prabhakaran, M. Telling, K. Habicht, P. Smeibidl, K. Kiefer bzw. Nature Physics (DOI: 10.1038/NPHYS1462): Confinement of fractional quantum number particles in a condensed-matter system, B. Lake, A. M. Tsvelik, S. Notbohm, D. A. Tennant, T. G. Perring, M. Reehuis, C. Sekar, G. Krabbes & B. Büchner

DOING 288 THROUGH THE LIXEDROM

The junior research group led by **Prof. Emad Aziz** has developed a measuring chamber for X-ray studies of liquid jets, which will improve future studies of protein structure.

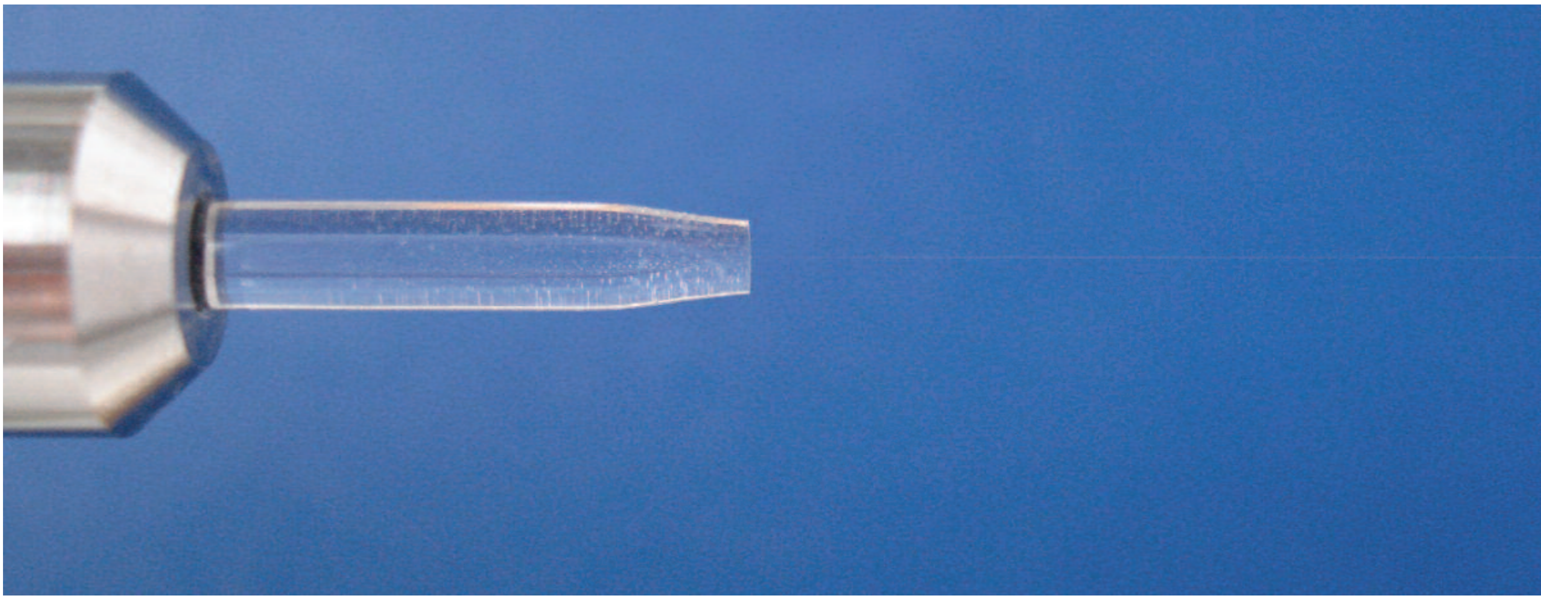
Proteins are vital components in the human body. Being built out of more than 100 amino acids each, proteins can differ extremely in their structure and action. Around 200,000 different proteins make a plethora of biological and chemical processes function in the body. Proteins break down fat, transport oxygen through the blood, act as messengers in the nervous system and, as antibodies, neutralize pathogens. It is little wonder, then, that science has a burning interest in these essential components.
A preferred medium for scientifically studying the structure and thus the properties of a substance is X-rays. When you shine them on a sample, they reveal a great deal of information about its structure. Unfortunately, this mostly applies to solids only, since the sample has to be in a vacuum for the entire time it is being irradiated with soft X-rays. This poses a serious problem when scientists wish to study fluids – they have to remove all water. Frustratingly, biological samples need water as a solvent and as a living environment. Accordingly, it has so far been impossible to analyse proteins in their natural environment using X-rays. A vacuum was needed and the proteins had to be crystallized before they could be X-rayed in such a manner. The results sadly give no indication of their reaction mechanisms and activities in the body, since a protein ordered into a crystal behaves differently from when it is solute.



Prof. Dr. Emad Flear Aziz Bekhit and his team developed the LiXEdrom.

Studying methaemoglobin and catalase

Prof. Emad Flear Aziz Bekhit, head of the junior research group for Functional Materials in Solution at HZB, has tackled this problem. The research objects of his group were catalase and methaemoglobin, two proteins whose active centres are similarly structured but behave completely differently. Unlike methaemoglobin, the enzyme catalase is extraordinarily efficient at splitting hydrogen peroxide, a degradation product of fatty acid cleavage. In this way, it protects the human organism against attack by oxidants. A catalase molecule can split up to a million hydrogen peroxide molecules in a second; a process in which water and oxygen are produced. Methaemoglobin, by contrast, binds oxygen and transports it through the blood to where it will be used.
In order to study both proteins in their natural environment using X-ray absorption spectroscopy, Emad Aziz has now designed and built a special experimental chamber at the synchrotron storage ring BESSY II. In it, he uses a flow cell with a thin membrane window. The membrane, largely permeable to X-rays, separates the solute protein from the vacuum chamber. This prevents the liquid sample from infiltrating the chamber and destroying the vacuum. By constantly adding fresh samples into the flow cell, radiation damage from the X-ray beams can be avoided. Using this experimental chamber, dubbed the Liquidrom, Emad Aziz performed in 2009 the world's first spectroscopic study using soft X-rays of a protein in its natural environment. In



Close-up of the liquid jet from which the stream of liquid sample shoots in front of X-rays at a speed of 288 kilometres per hour.

doing so, he was able to prove that the active centre of methaemoglobin, the haem group, has a significantly different electronic structure in its natural environment than in crystalline form.

Catalase also has such a haem group acting as its active centre. Emad Aziz and colleague Kathrin Lange discovered in 2010, however, that the electronic structure of the active cells differs between the two enzymes. In methaemoglobin, the central iron ion is in +3 oxidation state, meaning it has a triple positive charge. In catalase, on the other hand, a partially +4 character is observed. That makes the ion much more reactive. “That is the cause for the high enzymatic activity of catalase – and understanding that is enormous progress. It means we will be able to control or mimic such systems in future,” Kathrin Lange explains the significance of the discovery.

From the Liquidrom to the LiXEdrom

As scientists, however, Emad Aziz and his group did not rest on their laurels. Instead, they improved the study method even further. Their aim was to eliminate membranes entirely for studying fluids with soft X-rays. The result of their efforts is called the LiXEdrom, a spectrometer for X-ray absorption (XAS) and emission spectroscopy (XES). It is unique in that the liquid is shot as a jet through the X-ray beam. The jet from the nozzle becomes so thin and, at 80 metres per second, so fast that the vacuum can be maintained without the need of a membrane. This translates to the jet of liquid shooting through the LiXEdrom at a speed of 288 kilometres per hour.

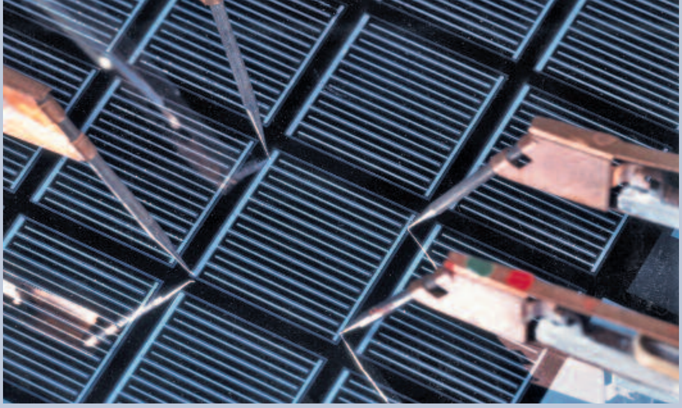
“On our LiXEdrom, we create a vacuum in the liquid chamber of up to 10^{-6} millibar, and can now perform both absorption and emission measurements, giving us even more precise information about the structure of a material,” explains Emad Aziz. It also allows a clear “view” of elements that possess absorption and emission energies in the energy range of membrane materials, and would therefore overlap with the membrane in the spectrum when measured. This concerns above all carbon and nitrogen – precisely those elements of interest in biological samples.

“Another special feature of the LiXEdrom is that the grating holder is based on the revolver principle, where four different gratings in the spectrometer can be moved into the path of the beam, by which an energy range from 20 to 1000 eV can be covered,” explains Dr. René Könnecke, responsible for the design of the LiXEdrom.

In their first measurements, the group demonstrated that they can achieve energy resolutions on their LiXEdrom comparable to those of the latest high-resolution XES spectrometers. For water, they have proven that previous results are not overlapped by disturbing membrane effects. They have also studied the electronic structure of nickel ions, unhampered by a risk of deposits on a membrane wall distorting the results. For many applications such as protein studies, this is a significant step towards obtaining reliable structural information. *cn*

Chem. Phys. (DOI 10.1016/JChemPhys.2010.08.023): High Resolution X-ray Emission Spectroscopy of Water and Aqueous Ions Using the Micro-Jet Technique, K.M. Lange et al.

Physical Chemistry Chemical Physics (DOI: 10.1039/b924245g): On the enzymatic activity of catalase: an iron L-edge X-ray absorption study of the active centre, N. Bergmann, S. Bonhommeau, K. M. Lange, S. M. Greil, S. Eisebitt, F. de Groot, M. Chergui and E. F. Aziz



The electron storage ring at Berlin-Adlershof. Here, users can perform their experiments with the synchrotron radiation source BESSY II – nearly 5000 hours per year.

The research for higher performance solar cells that cost less to produce is one of the focuses of research at HZB. It is also the field in which most cooperatives are formed and numerous patents are held.

FACTS AND FIGURES FROM HZB

Many insightful figures on the work of Helmholtz-Zentrum Berlin researchers have been published in the latest progress report submitted to the Helmholtz Society.

4962

Hours of user operation of the storage ring facility BESSY II in 2009. This breaks down to 7294 eight-hour shifts on 28 insertion-device measuring stations (ID) and 4823 shifts on 16 bending magnet measuring stations (BM). More than 1250 users from about 480 user groups were served in over 800 measuring campaigns.

166

Cooperatives HZB maintained with other scientific establishments at the end of 2009.

102

PhD students supervised by HZB in 2009

473

ISI-cited publications from the scientists at HZB in 2009. Added to these are 107 lectured publications, including the number of books and book contributions mentioned separately in the programmes.

27

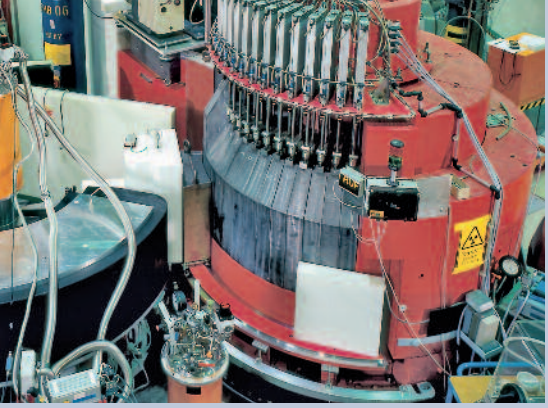
Patents granted to HZB in 2009. HZB's patent portfolio encompassed 348 property rights at the end of 2009, of which 207 were granted patents. 70 property rights, or about one fifth of the intellectual property portfolio, are the subject of current licensing agreements.

18

Percentage of women among 493 scientific employees at HZB. Counting also the 59 administration, technical and other positions, the percentage of female employees is 20 percent.

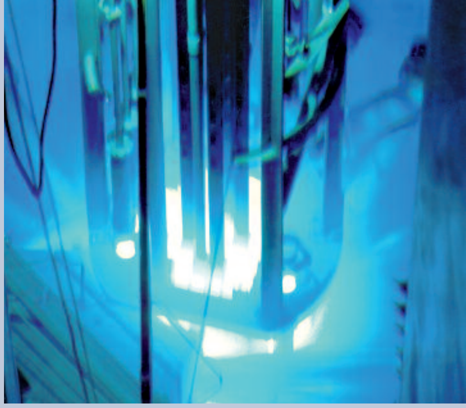
19.271

Million euros of revenue from third-party funds booked by HZB in 2009. Of these, 849,000 euros were for specially financed project funds for BER II and 1.203 million euros for BESSY II.



The two large-scale facilities of HZB – pictured is the experimental hall at the research reactor BER II – entice every year numerous scientists from around the world to Berlin.

Helmholtz-Zentrum Berlin places great value on the education of adolescents and young adults in all fields – in the picture, a component is explained to budding precision engineers.



The research reactor BER II is being renovated since autumn 2010. In 2009, it was available to scientists for 182 days for performing experiments with neutrons.

7.879

Million euros HZB received from technology transfer in 2009. Around 2 million euros came from research and development cooperatives with national and international commercial enterprises, and around 4.45 million euros from other R&D cooperatives. Another 1.39 million euros originate from infrastructure agreements.

59

Cooperatives that HZB newly entered with companies in 2009 alone. This increased the total number of current cooperatives with industry from 112 the previous year to 128. Of these, 9 percent are cooperatives with companies from abroad and roughly 50 percent are cooperatives with small and medium-sized enterprises (SME).

17.5

Percentage of HZB-internal use of radiation time at BESSY II in 2009. Every fifth shift of the insertion-device measuring stations and nearly every tenth hour at the bending magnet measuring stations was used in-house.

182

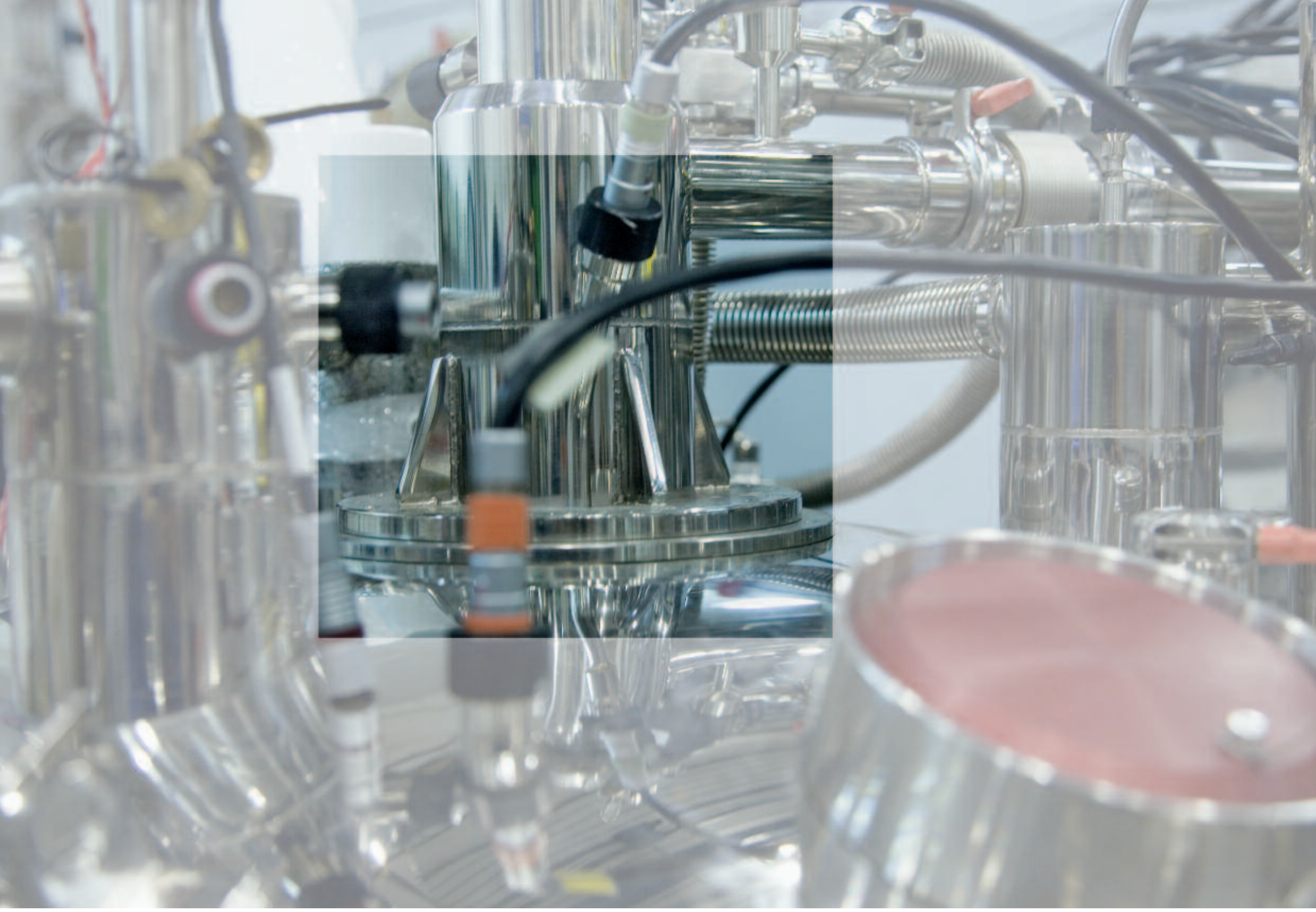
Number of days, with 9 reactor cycles, the research reactor BER II was in powered operation in 2009. 14 instruments equates to 2548 available instrument days for regular user operation. Of these, 303.5 instrument days went into maintenance and 163 days were lost due to the failure of one instrument, meaning a total of 2081.5 instrument days were in fact used. Projected onto the year as a whole, the reactor was available for 50 percent of the year and was used to 41 percent capacity.

69

Adolescents and young adults receiving education at HZB at the end of 2009, of which 17 students aiming for their Bachelor of Science (BA) in Computer Engineering (12), Mechanical Engineering (4) and Safety, specializing in Radiation Protection. HZB also trains young people in ten trained professions far beyond its own needs, including 19 precision mechanics and 5 electronics technicians for industrial engineering. In fiscal year 2009, HZB closed a total of 25 new contracts with trainees and filled a new training position in the scope of a training association with the German Research Centre for Geosciences, Potsdam.

329

Primary and high school pupils plus 57 students and 90 teachers took part in events and full-day project days at the School Lab in 2009. An average of 12 pupils a week deal with natural scientific matters in the working group for pupils. The working group is offered 38 weeks in the year.



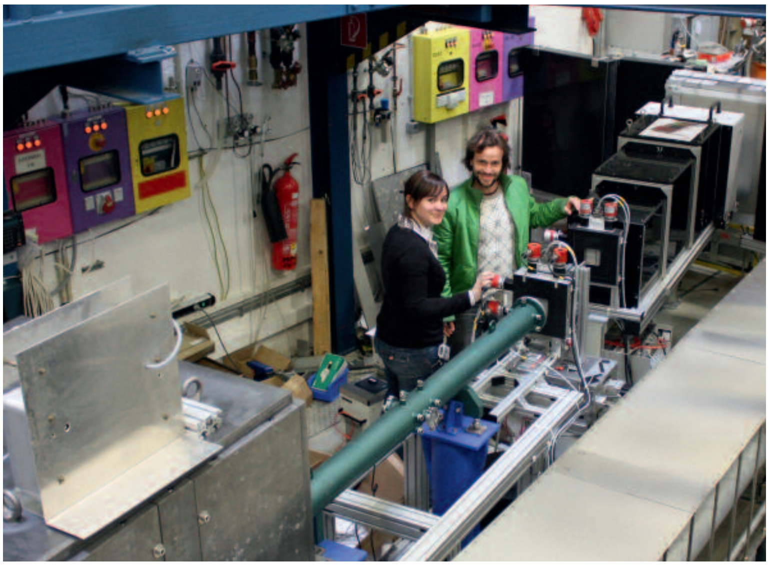
JOINT VENTURES

The Helmholtz-Zentrum Berlin not only works in close cooperation with the universities and colleges in the Berlin-Brandenburg region, but also cooperates on a supra-regional level with some 400 partners at German and international universities, research institutions and companies. Joint research ventures are just one example of the many different forms of cooperation. Together with colleagues from CNRS, the French National Centre for Scientific Research, HZB researchers were thus able to take a big step forward in the development of even more efficient data storage systems. Another form of cooperation is the joint operation of instruments on the large-scale equipment. As a result, the partners are integrated into the user support programme and at the same time receive better access to the large instrumentation and apparatus. Together with four Berlin institutions, HZB has been operating the Laboratory for Macromolecular Crystallography (MX laboratory) at the electron storage ring BESSY II since 2010. This has had the effect that the different Berlin groups currently involved in structure biology research network themselves even more closely and work together on different scientific issues. One of the oldest joint ventures is that with the Charité Berlin. Within the scope of the eye tumour therapy programme using the HZB proton beams, it has been possible to treat over 1600 patients with adjuvant radiotherapy to date. You will find more about HZB cooperations on the following pages.

ONE INSTRUMENT – TWO MEASURING TECHNIQUES

With the **bio-reflectometer**, or BioRef for short, the University of Heidelberg has developed a new instrument at the research reactor BER II.

The biocompatibility of implants such as artificial joints can be improved by covering them with a layer of lipids. Lipids are components of cell membranes, for example. Researchers led by Reiner Dahint and Michael Grunze of the University of Heidelberg are looking at how to make lipids successfully adhere to implants, and how they behave under body-specific temperatures, pressures and chemicals. Studying such soft matter, as it is called, is still a challenge. Given its consistency, it is inaccessible to many conventional methods, such as those requiring vacuum conditions, for example.
Together with Roland Steitz and Matthias Ballauff of the Institute for Soft Matter and Functional Materials at Helmholtz-Zentrum Berlin (HZB) and with funds from the Bundesministerium für Bildung und Forschung, the researchers from Heidelberg University have developed a new, specialized instrument for biological samples. “BioRef” is set up at the Berlin neutron source BER II and combines neutron reflectometry with in-situ infrared spectroscopy. “Both methods complement each other excellently, giving us a more complete picture of the samples,” says Markus Strobl. He largely co-developed the instrument on behalf of Heidelberg University and now manages it in the service of HZB.



Since recently, the new bioreflectometer has been available in regular user service for scientists to perform experiments at HZB.

Combination of two techniques

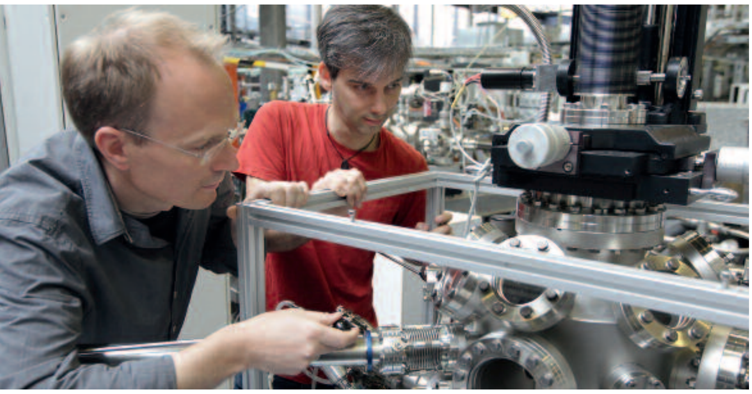
Neutron reflectometry can be used to measure layer thicknesses to great precision. Neutrons are more suitable for soft matter than X-rays, since they are especially sensitive to the light elements, such as hydrogen, that occur in many biological materials. Infrared (IR) spectroscopy uses light at the invisible infrared wavelengths. It lets you determine the inner structure of molecules and recognize how specific molecules bind to surfaces, how proteins unfold or how molecules change as a material transitions from a liquid to a gel-like phase.
Applying both methods to the same sample simultaneously is the actual innovation of BioRef. Since biological samples are often altered or even destroyed by measurements, this has a significant advantage: “The results are much more comparable than successively measuring two similarly prepared samples that are in fact not so identical,” says Strobl. In the measuring cell, neutron and IR radiation are applied perpendicularly to each other. Environmental conditions such as pressure and temperature can be varied. Another decisive advantage is that the resolution of the new instrument, i.e. the precision of the measurement, can be adapted quickly and easily to the respective problem. “If a measurement does not require the highest resolution, then it can be performed considerably faster,” explains Strobl.
The planning and calculation phase of the project began in the summer of 2007. Building commenced the following year in the neutron guide hall in Berlin Wannsee. “Since the summer of 2010, the first research groups we invited to make sample measurements have already tested the system, with very positive feedback,” Strobl emphasizes. Since then, the Heidelberg scientists and HZB have successfully brought BioRef into regular user operation. *ud*

HAND IN HAND
TOWARDS SUPER MEMORY

German and French scientists research together on the **next generation of computer RAM**.

The time of lone wolves in science is over. Most major advancements are now the result of close cooperation between research groups, frequently from different disciplines and across national borders – and where personal relations play no minor role. A good example of this is a joint project between scientists at the Institute for Complex Magnetic Materials of HZB and research colleagues from the French Unité Mixte Physique CNRS/Thales in Palaiseau just outside Paris. The aim of their project was to develop a simple and energy-saving method to control MRAM modules. MRAM stands for magnetoresistive random access memory, which is memory technology based on tunnel magnetoresistance, TMR. This physical effect occurs in certain electronic components. Specifically, it affects those made of two ferromagnetic and metallic material layers acting as electrical contacts separated by an insulator only a few nanometres thick. When an electric potential is applied, the insulator prevents electrons from travelling between the magnetic layers. Yet a quantum mechanical effect – quantum tunnelling – allows a few electrons to overcome the barrier. They "tunnel through" the insulator layer.

Which electrons make it through is decided by the spins – the magnetic moments – of the electrons in the ferromagnetic contacts: The particles only succeed in jumping from one contact to the other if the spins are equally aligned in both layers. If the spins in the two ferromagnetic materials are differently aligned, however, then only a very weak tunnel current flows. The orientation of the spin – the spin polarization – in the ferromagnetic layers can be altered using an external magnetic field, which in turn varies the resistance of the TMR component. This effect is used in the read/write heads of modern hard disks, for example. MRAM is also based on tunnel magnetoresistance. It should serve in future as fast RAM for computers that can store data even after the PC has been switched off. The conditions "spin parallel" and "spin antiparallel" correspond to the binary digits "zero" and "one" to encode the data.

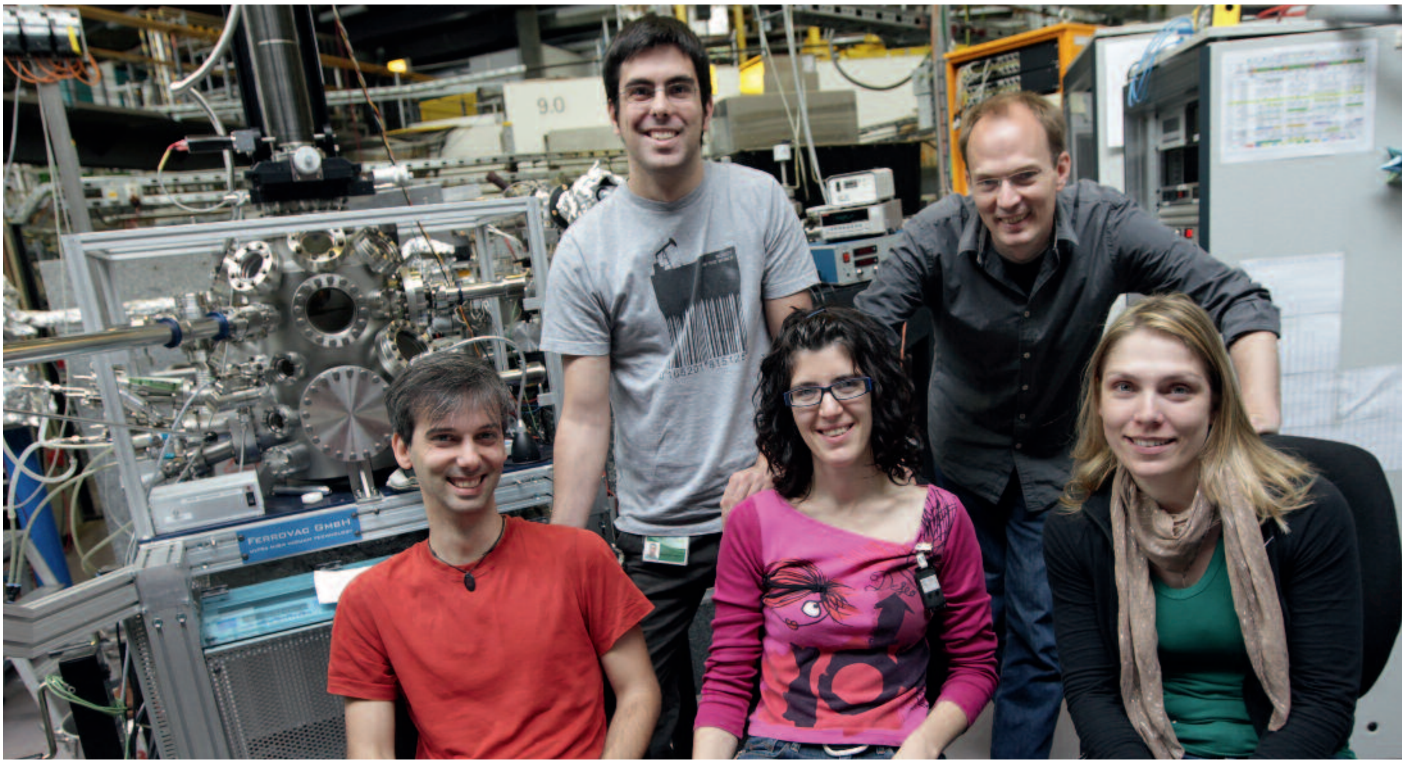


Dr. Florian Kronast (li.) and Dr. Sergio Valencia at the beamline for X-ray absorption spectroscopy.

Switching the tunnel magnetoresistance

There is, however, a certain disadvantage: The spins are reoriented using magnetic fields, which consumes a lot of energy. One possible remedy is to control the tunnel magnetoresistance electrically instead. The two CNRS/Thales researchers Dr. Vincent Garcia and Dr. Manuel Bibes are pursuing exactly this approach. They have replaced the insulator of a TMR element with a crystalline layer of barium titanate – a ferroelectric material that exhibits spontaneous electric polarization as a result of ion shifts within the crystal, which can be influenced by an electric field. This subsequently acts on the orientation of the electron spins in the neighbouring magnetic layers – whereby the tunnel magnetoresistance can be switched.

The barium titanate was produced at Oxford University in England. Using nanostructuring methods, the researchers led by Garcia and Bibes formed a thin layer of this insulator, which they then combined with two magnetic contacts made of iron and a manganese oxide compound. The first task was to analyse the structure and chemical composition of the TMR element – which Dr. Sergio Valencia and Dr. Florian Kronast undertook at HZB. The two Berlin researchers studied the materials by X-ray absorption spectroscopy. Their results have provided valuable insights into boundary layers between the different materials and the



Dr. Sergio Valencia (front left) and Dr. Florian Kronast (back right) with a user group.

processes that take place there – the prerequisite for electrically controlling the TMR effect and producing components that are more efficient.
The collaboration started from the close friendship between Sergio Valencia und Manuel Bibes. "We have known each other for around ten years already, and have become good friends in this time," says the Spaniard Valencia, who came to HZB in 2002. Bibes and he met during their doctorate in Barcelona. "We researched together for some time at the Institute for Material Sciences there before I moved to Berlin," Valencia reports. The Frenchman Bibes left Barcelona later, returning to France. However, the two physicists never lost touch – and kept a lookout for possible cooperatives that would combine their scientific interests. The research project at the Unité Mixte Physique CNRS/Thales presented an ideal opportunity. While the team there are strong on spintronics, the HZB researchers are experts in characterizing complex materials. "We grabbed this opportunity with both hands," says Sergio Valencia with a smile.
There were never any bureaucratic obstacles in the way of the cooperation, the scientist enthuses: "Everything went completely smoothly from the beginning, and the two institutes made every effort to support us." The results of the joint experiments were accordingly positive: With support from Berlin, the researchers working under Garcia and Bibes managed for the first time to switch the spin polarization in an MRAM module using an electric field. The energy requirements are much lower than using a magnetic field to control the tunnel magnetoresistance. "The door to building memory modules based on this effect is thus wide open," Valencia and his colleague Florian Kronast tell with delight.

MRAM modules do not work at room temperature

It will still be some time, however, before electrically controlled MRAM modules find their way into PCs. "The problem is that the manganite layer used so far loses its magnetic properties at room temperature," says Sergio Valencia. The experiments have namely been conducted at low temperatures of a few degrees above absolute zero. In order to prepare the components for use at normal environmental temperatures, Valencia and Manuel Bibes intend to continue and intensify the cooperation. For this, the researchers from France and Berlin have applied for further funding of their project. This should lead to novel, electrically controlled memory modules that can store non-volatile data at high speed, low energy and high density, thereby unifying the advantages of conventional RAM and hard disks – the best of both worlds. *rb*

Science, DOI: 10.1126/science.1184028: Ferroelectric control of spin polarization, V. Garcia, M. Bibes, L. Bocher, S. Valencia, F. Kronast, A. Crassous, X. Moya, S. Enouz-Vedrenne, A. Gloter, D. Imhoff, C. Deranlot, N. D. Mathur, S. Fusil, K. Bouzehouane and A. Barthélémy

MX LABORATORY – TWO BEAMLINES FOR FIVE PARTNERS

Five partner institutes have been working together for a year on the electron storage ring BESSY II in the **Joint Berlin MX Laboratory**, the laboratory for macromolecular crystallography.

Cooperatives are commonplace in science these days, but five partners working together is still an exception. Accordingly, Helmholtz-Zentrum Berlin hosted a special ceremony on 1 March 2010 to officially celebrate the inauguration of the joint MX Laboratory with the four partner institutes Freie Universität Berlin, Humboldt-Universität Berlin, Max-Delbrück Centrum in Berlin-Buch and the Research Institute for Molecular Pharmacology in Berlin-Buch. During the opening event, Israeli Nobel Laureate for Chemistry of 2009, Prof. Dr. Ada Yonath of the prestigious Weizman Institute of Science in Rehovot, gave a speech on “The Stunning Ribosome Architecture and Hints about its Origin”.

Prof. Dr. Ada Yonath

The MX Laboratory, set up on the electron storage ring BESSY II, shall deliver insights into extraordinary phenomena of structural biology and, above all the structure of proteins. Three experimental stations have been set up and optimized specifically for investigating macromolecular biological samples. HZB has provided the cooperative with two of its three crystallography measuring stations for extensive use by the partner institutes. “Beamlines 14.2 and 14.3 are also ready for experiments at short notice,” explains Dr. Uwe Müller, head of the Workgroup for Macromolecular Crystallography at HZB. Furthermore, the partners can also work on expanding and enhancing the beamlines in future. A dehydrogenation machine for crystals was purchased for Beamline 14.3 in 2010, for instance. The advantage of the cooperative for HZB is that different scientific questions can be tackled using the in-house measuring stations. “The partner institutes are sending capable workers to do some of their work at HZB, where they will support the scientists there in joint projects,” Uwe Müller reports.

The managing directors of the five partner institutes and guest lecturer Prof. Dr. Ada Yonath give the start signal for the new MX Lab in Berlin.

Gaining insights into protein structures

Every person has around 200,000 different proteins in their body, without which the many vital biological and chemical processes could not take place: proteins transport oxygen through the blood, act as messengers to activate processes in the nervous system and, as antibodies, are essential parts of the immune system. Proteins are built out of more than 100 amino acids, and the scientists’ first job is to elucidate their spatial arrangement. Then, to figure out the protein’s function from this, the researchers study the proteins at an atomic level. The intense X-ray light from the synchrotron radiation source BESSY II is ideal for this purpose, since the scientists can use it to measure the molecules from atom to atom. This method is called crystallography. The researchers first cultivate symmetrical crystals of billions of identical protein molecules and then fire the BESSY II synchrotron beam at them. This yields a so-called scattering pattern on detectors. These comprise a multitude of points from which the protein structure can be reconstructed using a mathematical operation.

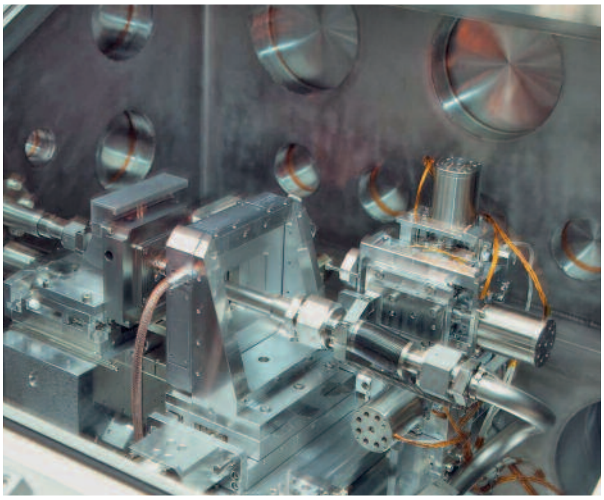
Using this technique, the researchers and scientists from FU Berlin determined the first protein structure on the beamlines of BESSY II in January 2003. 2011 already saw the 500th decoded structure deposited into the international "Protein Database". In order to reconstruct even more proteins and gain further insights into structural biology, the MX Laboratory in Berlin shall pool the existing competence in the field of macromolecular crystallography and initiate and intensify scientific cooperatives. There are by now a dozen groups doing protein structure research in the Greater Berlin area alone. On the first Joint Berlin MX Day, which took place on 23 August 2010 and will take place every year from now on, 78 participants talked about their first cooperatively gathered experience and had the chance to inform other teams about their projects. *cn*

MAXYMUS – NEW INSIGHTS FROM X-RAY FLASHES

Since October 2010, the Max Planck Institute for Metal Research, Stuttgart, has been operating a modern **scanning transmission X-ray microspectroscope** at HZB.

On 10 and 11 November 2009, at the International workshop "New Frontiers in Soft X-Ray Microscopy", the Max-Planck-Institut für Metallforschung (MPI-MF), Stuttgart, inaugurated its new scanning transmission X-ray microspectroscope MAXYMUS at the Berlin synchrotron radiation source BESSY II. MAXYMUS stands for "MAgnetic X-raY Micro- and UHV Spectroscope". What is special about this novel machine is its sample environment and its broad range of applications, for MAXYMUS is suitable for biological, soft and hard materials and is one of the world's best X-ray microscopes. You can work with it in an ultra-high vacuum, apply magnetic fields of different strengths and watch ultra-fast processes. "For the first time, we can use a scanning X-ray microscope to study even samples that are opaque to X-rays, which gives us new and exciting possibilities," explains Prof. Gisela Schütz, director of the "Modern Magnetic Materials" department at MPI-MF. MAXYMUS can be used, for example, to observe structural, chemical and magnetic changes in the tiniest of structures at a spatial resolution of less than 25 nanometres and a temporal resolution of less than 10 picoseconds.

After the official inauguration of the machine, the scientists began the usual preparations for using the equipment. Specifications were taken and test runs performed in the first half of 2010. "We have developed an entirely novel set-up that allows us to perform dynamic investigations in the gigahertz range. That is why the first user operation only began in October 2010," says Dr. Eberhard Goering, who is responsible for the machine on behalf of MPI-MF.

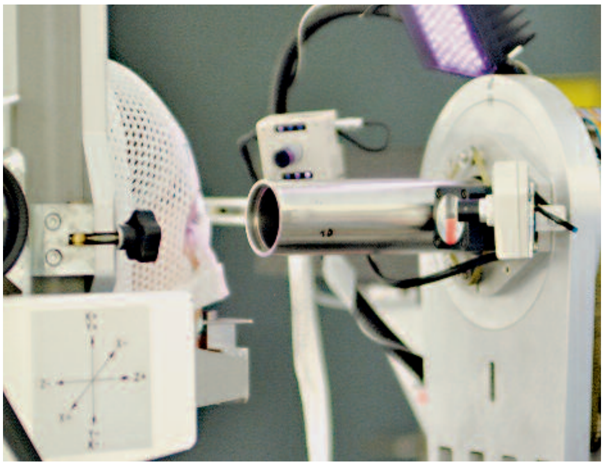


The new scanning X-ray microspectroscope, since recently in user operation.

In the scope of their cooperative, HZB and MPI-MF share their tasks on the new machine: care and maintenance of MAXYMUS are done in close cooperation. "As for other equipment, HZB allocates beam time after evaluating applications. Because we have considerable financial means, however, the Max Planck Society is entitled to 70 percent of the measurement times, which are also awarded by applications," explains Goering. "As it is, almost twice as many beam time applications are submitted as can be awarded," Goering adds. *cn*

MORE THAN 1600 PATIENTS TREATED

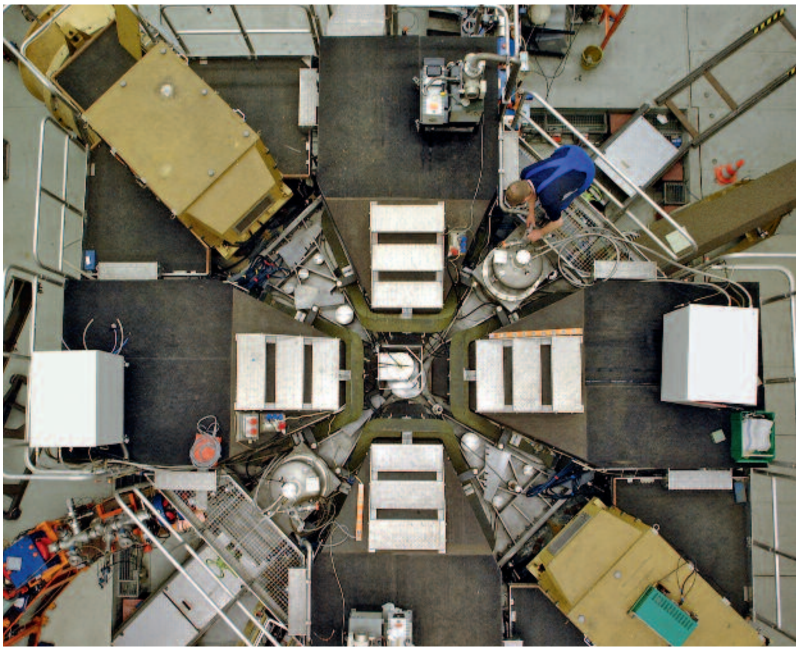
HZB has been cooperating with Charité Berlin since 1998, delivering the **proton beam used in eye tumour therapy**. One patient in 2009 was an infant with a retinoblastoma on the left eye.



Patient in position for treatment.

It was a heart-rending sight: Under general anaesthetic, a suction cup applied to the eye by which the line of sight could be manually directed by a rod, a nine-month-old baby boy sat in the specially built chair in front of the beam tube in the treatment room of HZB. It took four hours of preparation and follow-up for an irradiation of just a few seconds. “We had goose bumps when we realized it had worked,” reports Dr. Andreas Weber, medical physicist of Charité Berlin. The treatment of by far the youngest patient was the most extraordinary of more than 1600 cases so far in the long cooperation between HZB and the Eye Clinic and the Clinic for Radiotherapy of Charité on the Benjamin Franklin campus.

The hopes of many of the 500 to 600 German people each year who develop choroidal melanoma, a malignant eye tumour, rest on Berlin. The ion-accelerator at HZB is used jointly by Charité Berlin to treat such eye tumours using proton beams. Protons are the nuclei of hydrogen atoms and can destroy tumours inside the eyeball without significant damage to the surrounding, healthy tissue. This special type of eye tumour irradiation is to date a unique therapy option in Germany, but is also practiced at other centres around the world with great success.



The Cyclotron of Helmholtz-Zentrum Berlin is part of the particle accelerator that delivers the proton beam for eye tumour therapy.

Four days – thirty seconds

Proton treatment, which has been performed at HZB since 2007 under the responsibility of Charité Berlin, requires precision work from the doctors and medical physicists. To ensure the particle beam strikes the tumour accurately, it must be clearly delimited from the immediately surrounding healthy tissue. The ophthalmologist therefore determines the location, extent and shape of the tumour first using photographs of the ocular fundus, the background of the eye. During treatment with the proton beam, the patient sits in a special treatment chair. Elaborate technology and the physical properties of protons ensure the proton beam unfolds its action almost exclusively inside the tumour. The actual irradiation is generally performed on four successive days and lasts about thirty seconds each time.

Ample capacity

In most cases, the eye tumour therapy at HZB saves the patient's eye – a decisive advantage compared to other therapies. More than 1660 patients have been treated in Berlin so far, and the success speaks for itself: In more than 97 percent of cases, the tumour can be fully destroyed. Most of the time, not only the eye can be saved but also a satisfactory degree of sight; even if the tumour is located close to a sensitive organ, such as the area of sharpest vision. Prof. Michael Foerster, who introduced medical eye tumour proton therapy to Berlin and successfully oversaw it for many years, retired in March 2010. His successor is Prof. Antonia Joussen, director of the eye clinics of all Charité campuses, who is anxious to increase pure research into this therapy. The capacity of the accelerator at HZB is at any rate sufficient for all patients in Germany for whom proton therapy is the better solution above other forms of treatment. *cn*

MAKING PROGRESS HAND IN HAND

Seven joint research groups reinforce HZB's cooperation with various universities. The aim is to speed up the advancement of instruments and methods on the large-scale equipment.

Following the fusion of the former Hahn-Meitner Institute (HMI) and Berlin Elektronenspeicherring – Gesellschaft für Synchrotronstrahlung (BESSY) into Helmholtz Zentrum Berlin für Materialien und Energie at the beginning of 2009, the concept of joint research groups at HZB was soon realized. These are a special kind of cooperation between HZB and the universities involved. The joint research groups aim at making the universities' knowledge more accessible to the Helmholtz-Zentrum Berlin. The universities introduce their competence in the use of large-scale equipment and the supervision of individual instruments while HZB provides the necessary technology and helps finance young scientists. Through the work of the joint research groups, the large-scale facilities can be used more efficiently and new instruments and methods developed.

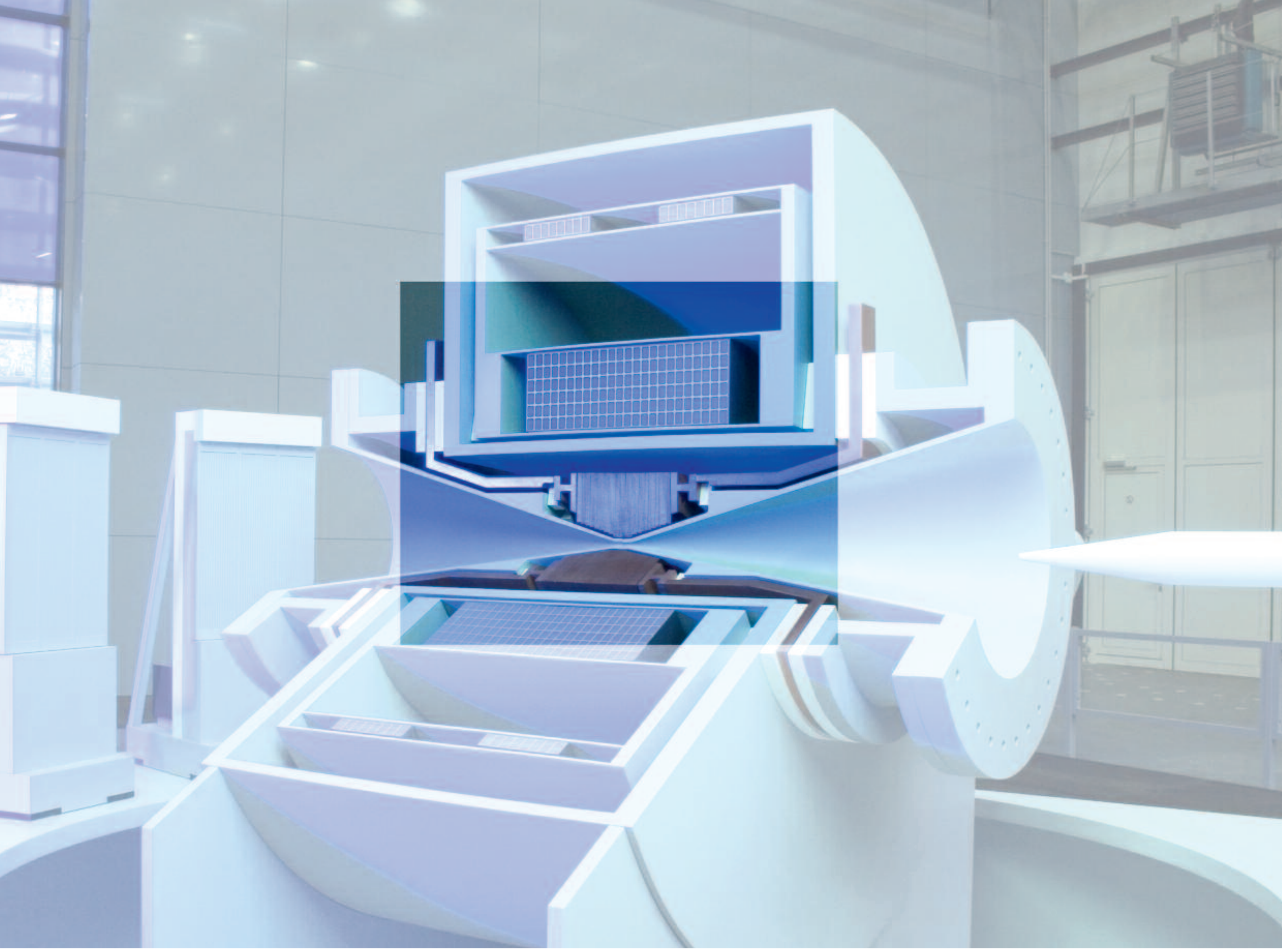
Cooperative agreements

The seven joint research groups so far (see table) are each based on a cooperative agreement between HZB and the respective university. Each group is initially installed for five years. Rather than selecting a manager in a joint appointment procedure, the position is given to a professor from the university instead. Alongside his duties at the university, the university professor supports the HZB research programme with a small group funded by HZB. The joint professorships work the other way round.

Of the seven current joint research groups, two are working at the neutron source BER II, four at the synchrotron radiation source BESSY II and one at the neutron source FRM II of TU München, where it oversees the HZB instrument PANDA. The pilot phase for the joint research groups will serve to assess the efficiency of this newly developed type of cooperation before the end of the current funding period and to reach a decision as to its continuation in the future.

The joint research groups at Helmholtz-Zentrum Berlin

Research Group	Head	University
Molecular Systems (E-G1)	Prof. Dr. N. Koch	FU Berlin
Energy Catalysis (E-G2)	Prof. R. Schlögl	FUB / FHI
Neutron Tomography (G-G1)	Prof. Dr. W. Treimer	TFH Berlin
PANDA (M-G1)	Prof. Dr. M. Loewenhaupt	TU Dresden
Functional Nanomaterials (F-G2)	Prof. Dr. S. Eisebitt	TU Berlin
Microstructure Analysis (F-G3)	Prof. Dr. W. Theisen	Uni Bochum
Ultrafast Dynamics (F-G4)	Prof. Dr. M. Bargheer	Uni Potsdam



FUTURE PROJECTS

The Helmholtz-Zentrum Berlin operates the research reactor BER II and the electron storage ring BESSY II. Used by researchers from all over the world for experiments, one of the central tasks of the HZB scientists is to continuously improve and refine these facilities and the associated instruments. It is only in this way that it will be possible for HZB to continue offering attractive research facilities in the future. There are consequently a number of projects currently in the throes of being realised: in Berlin-Wannsee, a new magnet will soon be ready for neutron scattering experiments that has a magnetic field strength of up to 30 Tesla, thus making it the strongest magnet in the world. Also at the realisation stage are technical milestones which lend additional drive to the research at HZB, e.g. the cold neutron source and the NEAT time-of-flight spectrometer. And at the research facility in Berlin-Adlershof, it is planned within the framework of the B*ERL*inPro project to develop a superconductive linear accelerator (Linac) over the next five years which will push open the door to new application areas. The “PV-ComB Competence Centre Thin-Film and Nanotechnology for Photovoltaics Berlin” is also an important HZB project and is intended to bridge the gap between basic research ideas in the field of solar cell development and industrial applications. Browse through the following pages for more details of our future projects.

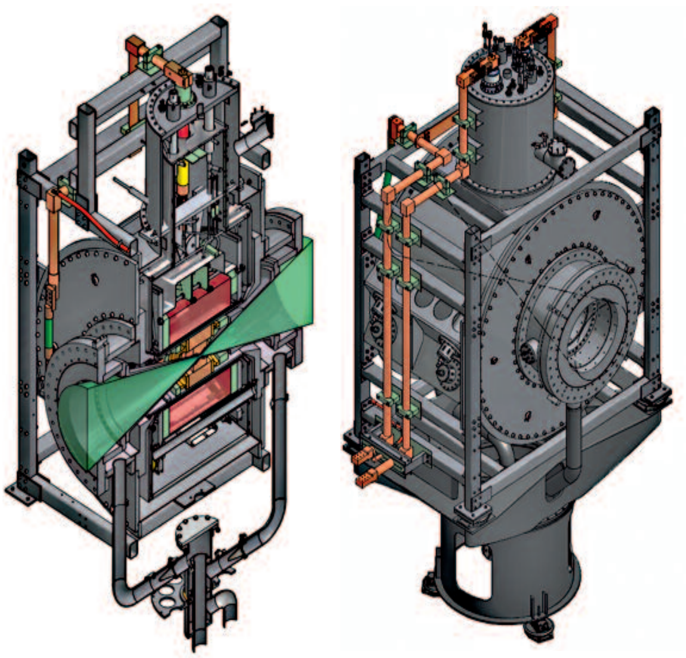
ADVANCING INTO NEW TESLA DIMENSIONS

The **new high-field magnet** to be commissioned at HZB in 2013 will allow experiments with field strengths of 25 to 30 Tesla.

Experiments involving neutron scattering combined with strong magnetic fields and low temperatures are a particular strength of Helmholtz-Zentrum Berlin. Nowhere else will you find more expertise in bombarding samples with neutrons inside extremely strong magnetic fields to pursue the latest questions from science. Researchers are therefore eagerly awaiting the completion of the world's strongest high-field magnets to perform such experiments for their structural research. They will be able to produce magnetic fields at HZB that are about a million times stronger than the earth's magnetic field.
The project was approved at the beginning of 2007 by the Bundesministerium für Bildung und Forschung and received investments of around 20 million euros. "The new infrastructure building for the energy supply, helium cooling and water cooling of the test centre was already completed in November 2010," says technical project head Dr. Peter Smeibidl. "Delivery and testing of the three components should be concluded by the end of 2011. Integration of the high-field magnets into the neighbouring neutron guide hall should be finished by March 2013, meaning the first experiments will be able to be performed at the end of that year."
The core of the project is the hybrid magnet. It is being developed in cooperation with the National High Magnetic Field Laboratory in Tallahassee, Florida. The project is being implemented in multiple stages. Combined with a superconducting outer coil, a magnet system will first be installed with a resistive 4-megawatt inner coil, allowing fields of 25 to 26 Tesla. By changing the inner coil and expanding the necessary cooling system and with a connected power of 8 megawatts, it will later achieve magnetic fields of 31 to 32 Tesla.

Strong magnetic fields for neutron experiments

Producing extremely strong magnetic fields will open the door to new insights, the scientists hope. All materials, even apparently nonmagnetic ones, react to magnetism. Accordingly, alongside temperature and pressure, magnetic fields are key parameters for experiments – although only if the magnetic field is strong enough to produce an



Cross-section of the high field magnets: The neutron experiments take place inside the magnetic cone.

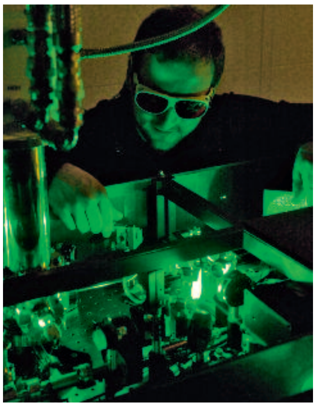
effect. Experiments using neutrons and neutron scattering are in turn ideal for studying these magnetic material structures, since neutrons also possess a magnetic moment. This aligns to a magnetic field like the needle of a compass. Combining neutrons with strong magnetic fields in experiments is enormously useful for pure physics research and materials science.
So far, no research establishment has been able to offer neutron experiments above a magnetic field of 17 Tesla. That means access to many interesting phenomena that only occur at higher fields has so far been denied. "45 Tesla is the highest magnetic field strength ever to be technically produced, albeit in very small volumes. Given the geometric requirements for performing experiments with neutrons, we will achieve something just above 30 Tesla in the last expansion stage," says Peter Smeibidl. That will push HZB far into new dimensions of magnetism for structural research.

cn

COMPACT ELECTRON PACKETS FOR BRILLIANT LIGHT

With the **project B*ERL*inPro**, under the responsibility of HZB, a novel accelerator technology shall be enhanced over the next five years.

The consultation ended with unanimous agreement: The Helmholtz senate, the highest decision-making body of the Helmholtz Society, voted unanimously in favour of implementing the strategic expansion investment B*ERL*inPro. Funding for the 25-million-euro project, in which the Helmholtz Society, the State of Berlin and HZB are involved, is thus assured until the end of 2015. With the B*ERL*inPro project, HZB and its partners in the Helmholtz Society and from all around the world are aiming at enhancing a novel accelerator technology and to put the principle of "energy recovery linac" (ERL) on a new technological basis.
In the energy recovery linac prototype, electron packets are generated in an injector and accelerated in a long, straight and superconducting linear accelerator (linac). The electrons are then guided by magnets, called undulators, where they produce X-rays as in a synchrotron radiation source, but at higher brilliance, since the electron packets in the linac remain more compact than in a circular accelerator. The electron packets are continuously injected and, after their circuit, return into the linac, where they are braked. This means practically all the energy is recovered, which allows the acceleration of high currents.



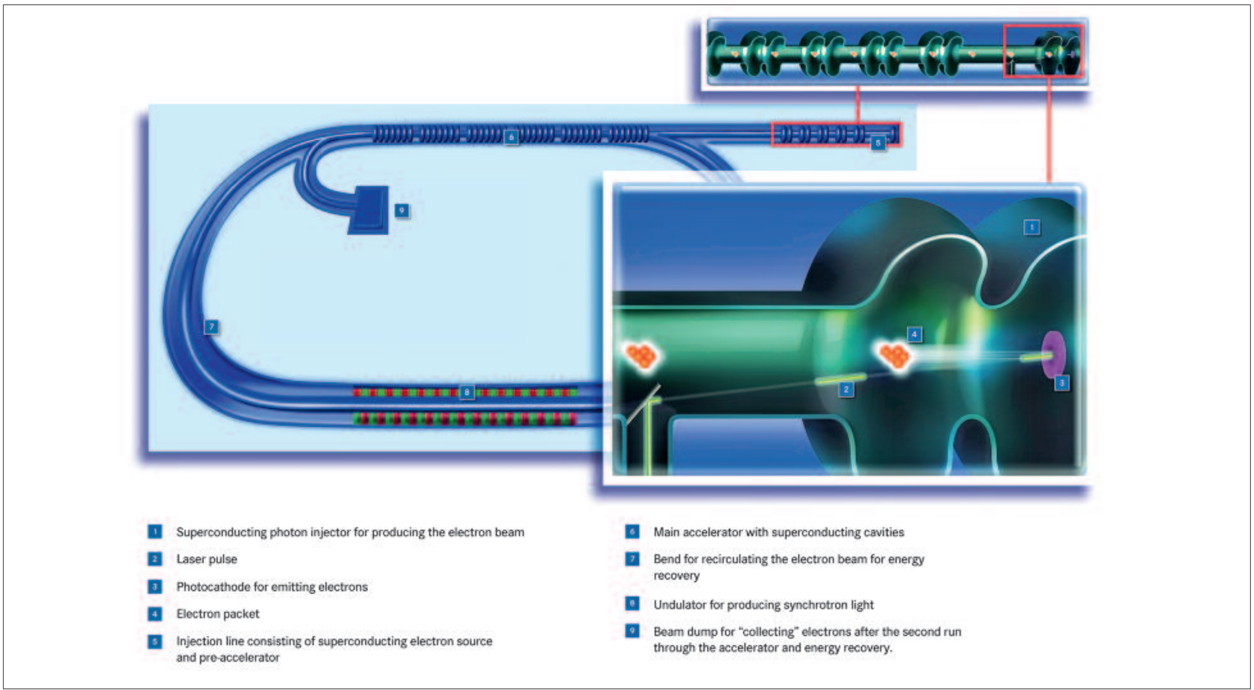
Precision work – B*ERL*inPro allows the energy in electron packets to be recovered.

B*ERL*inPro – high currents and small emittances

In all the world, the ERL principle has only been demonstrated at currents up to 10 mA so far. In B*ERL*inPro, a compact facility will now be built, containing all key elements for a high current source. The building phase, commencing in 2011, will see all critical components developed and tested – for example the high-brilliancy electron source, superconducting accelerator sections and magnetic systems for injection and beam return without

A model of the linear accelerator (linac) with superconducting cavities.

beam quality loss. The ERL principle shall be demonstrated at hitherto unattained beam power and brilliance and the aspects of beam stability, control of beam loss and flexibility of the beam parameters studied.
In B*ERL*inPro, a superconducting linear accelerator will produce an electron beam, which will be accelerated in so-called cavities – niobium metal tubes cooled with liquid helium to a temperature of two Kelvin (−271 degrees Celsius), just above absolute zero. The low temperatures are essential for operating the superconducting accelerator, which produces the electron packets at a rate of 1.3 gigahertz – steadily. The energy achieved by acceleration equates to passing through a voltage of 100 million volts.
At this energy, the electrons fly through the beam guidance system, which forces them onto a "racetrack". From there, they are injected a second time into the linac to be braked. Undulators can be incorporated along this stretch, in which synchrotron light is produced. The biggest problem is repulsion between the electron packets, due to their like charge, which causes them to spread out. An electron lens built into the system must ensure the quality of the electron packets does not change during their circuit. At the same time, the magnetic components of the system make sure



In the energy recovery linac prototype (B*ERL*inPro), electron packets are generated in the injector and accelerated in a long, straight and superconducting linear accelerator (linac) before being guided through magnets where they produce X-rays as in a synchrotron radiation source.

the circuiting packets fit precisely between two packets to be accelerated in the linac – like in a zip.

B*ERL*inPro will ultimately demonstrate the ability to guide an electron beam of highest intensity and density through the beam guidance system and then transport it back to the linear accelerator where the electrons will be braked in the electromagnetic field there and their energy returned to the field. The recovered energy from the beam is then available to accelerate a freshly generated electron beam – which in turn possesses the same excellent parameters as the returning beam before it.

Basis for new applications

If B*ERL*inPro is a success, then the performance parameters of ERLs will be boosted by orders of magnitude. Most of all, scientists want ERL technology to generate brief, highly brilliant light pulses at very high currents in their synchrotron sources. This would allow many new applications in future. For instance, such technologies could be used as so-called "inverse Compton scattering radiation sources" in medical therapy and diagnostics. For particle physicists, new electron coolers could be developed that overcome the limits of conventionally employed electrostatic coolers. Furthermore, the technology could be used to determine with certainty the isotope composition of radioactive fallout in its containment before storage or further processing.

"The development of ERL technology might even push a window wide open to new applications we know nothing about yet," considers Professor Jens Knobloch, director of the Institute SRF – Science and Technology. After all, the way we use X-rays in science these days has nothing to do with the development of the first light sources in the 1950s. The development of B*ERL*inPro will certainly break new ground. *cn*

HOBICAT

HoBiCaT is the acronym for the test facility for superconducting cavities: Horizontal Bi-cavity Test facility. Cavity resonators form the heart of linear accelerators (linac). They are "metal tubes" with bulbous hollow cavities in which strong electric fields are generated. For the most part, copper cavities have been used so far, which do not allow very strong fields to be generated due to energy losses during continuous wave operation. Therefore, in future, superconducting niobium shall be used, which can achieve a thousand times higher power. Unfortunately, this requires the niobium cavities to be cooled to temperatures down to two Kelvin (-271.15 degrees Celsius) and protected against external heat.

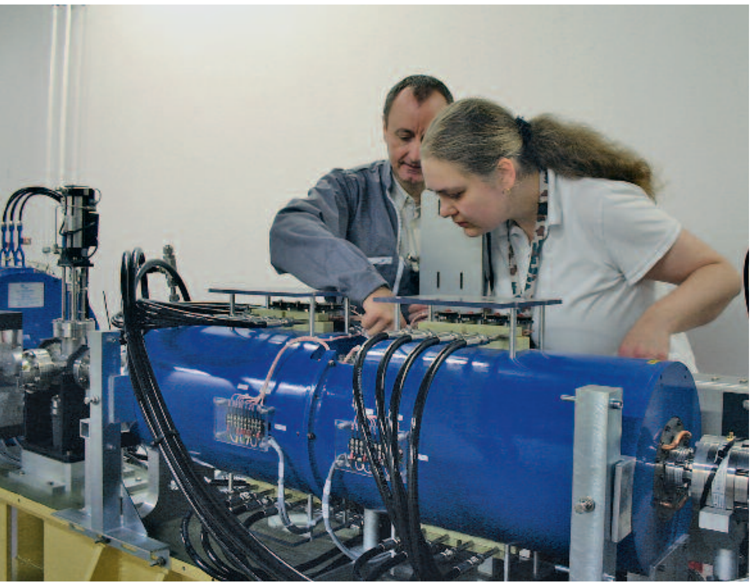
HoBiCaT is an essential component of the future project B*ERL*inPro. The new electron source of the ERL accelerator, a photoinjector, is also based on a superconducting cavity. The first prototype was commissioned in HoBiCaT in 2011.

NEW PRE-ACCELERATOR FOR BESSY II

In mid 2011, the **LINAC** will replace the microtron as a pre-accelerator for BESSY II. This will enable the electron storage ring to deliver synchrotron light with even more flexible pulse forms.

Luckily, the users didn't notice the incident at all," says Dr. Ernst Weihreter, who is heading the rebuilding process at the electron storage ring. The physicist is referring to November 2010, when a leak in the soldering of a central component was discovered in the new linear accelerator. The LINAC had been installed only two months before during a shutdown of the storage ring and was in the middle of the run-in phase. After several months of deliberation and discussion with the manufacturer, it was decided it would be repaired on the spot, and not without settling an unusually long warranty period of twelve years. "We assume the repair was successful and that the LINAC can now be brought into operation," emphasizes Ernst Weihreter.

A detailed concept for the new injector was already developed more than three years earlier for shutting down and dismantling the microtron in the long term. The task of the pre-accelerator is to produce an electron beam and fire it into the synchrotron. There, the electrons are accelerated to 1,700 mega electron volts, their ultimate energy, and then released into the actual storage ring. An investment of around 3.7 million euros in total makes this improvement in the beam properties of the BESSY light possible. Electron losses can be balanced out around every one to two minutes during operation in so-called "top-up" mode, by reinjecting subsequent electron packets. That ensures a practically constant light intensity reaching the experiment – a major advantage for the stability of highly sensitive X-ray optics. By contrast, electron losses were previously equalized by reinjection only once every eight hours during normal operation.



The new injector was carefully tested and installed into the electron storage ring in Berlin. After the run-in phase, users will benefit from the improved beam properties in their experiments.

Parallel operation until the summer of 2011

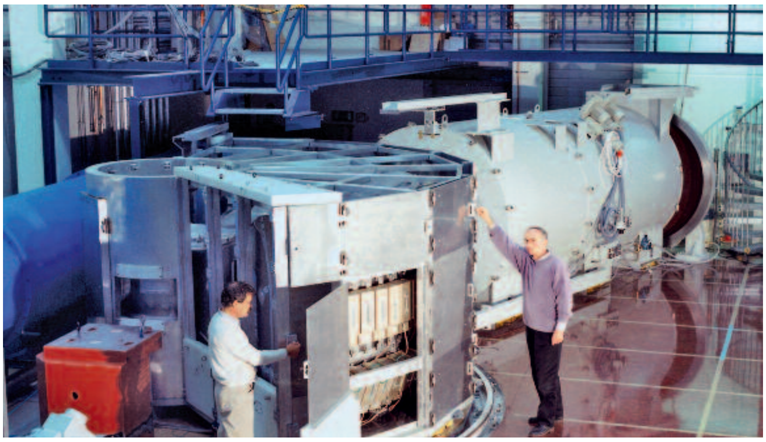
Technologically, the microtron could also have been run in "top-up" mode, as the BESSY accelerator group demonstrated in a test week at the beginning of 2008. Yet, for continuous operation in this mode, the LINAC is needed since it can deliver flexible electron pulses for the respective synchrotron filling pattern. Users performing time-resolved experiments will benefit most from installation of the LINAC. Femtoslicing experiments, for example, will be able to be performed at higher count rates.

Once the LINAC was repaired, the last run-in stage of the project began. Users will experience no restrictions whatsoever, since the new LINAC is being run in while the microtron continues to perform its duties. Until the summer of 2011, both pre-accelerators will run in parallel operation for at least a quarter of a year. Only when the LINAC is up and running at full capacity will it be decided whether and when to shut down and dismantle the microtron. Running a second pre-accelerator is namely a question of cost since, as with all technical equipment, it needs service and maintenance to remain functional. Still, it will be of great advantage to HZB as a reliable backup during the trial period. "After the delay in the run-in phase, users will only get to fully appreciate the advantages of the LINAC sometime later," says Ernst Weihreter, who went into "active" retirement at the end of May 2011. c*n*

RETROFITTED FOR THE FUTURE

HZB is **rebuilding the cold source** of its research reactor BER II, updating the large facility to the state of the art by summer 2011. Furthermore, a new **time-of-flight spectrometer** is being built, to be ready in 2014.

Since October 2010, experiments at BER II have been idle, but this does not mean the scientists have to sit and twiddle their thumbs. On the contrary, with the upgrading of the cold source (see box), the reactor is being extensively "beefed up". The aim is to improve the quality of the facility to keep it globally competitive.
To achieve this, four coordinated measures are being undertaken: The cold source will have a new geometry and a new conical beam tube, one of the most important components of the reactor. "With this, we will achieve a neutron flux increase of 60 percent," says acting senior head of department Dr. Norbert Stüßer. The second measure is to renew the neutron guide, through which the neutrons zoom from the reactor to the experimental stations. "With its larger diameter and new surface coating, we can increase the neutron flux up to five times," Stüßer explains the benefit. Also, a number of instruments such as the tomography station (Conrad) and the three-axis spectrometer (FLEX) are being remodelled to be put to better use. FLEX is now being given an attractive conductor end position as well as a new primary spectrometer. The reactor should be back in operation in the summer of 2011. The measures on the instruments will be finished in autumn.



The time-of-flight spectrometer is being rebuilt and housed in an extension.

The new time-of-flight spectrometer NEAT

The fourth measure is the building of a new time-of-flight spectrometer NEAT, which will be forty times more powerful than the old instrument, and will thus open up new research areas in the fields of magnetism, materials sciences and soft matter. Essential elements of the renovation are the use of modern supermirror guides and increasing the beam cross section. The range of the detector angle will also be increased by position resolving detectors. These allow studies of monocrystals, and offer optimal possibilities for extreme sample environments. An extension to the neutron guide hall will guarantee optimal sample connection for the modernized instrument, which is planned to go into user operation in 2014. *cn*

BER II AND THE "COLD SOURCE"

Research reactors stand out for a very compact reactor core for achieving as large a neutron flux as possible from a small volume of fissile material. BER II, for example, consumes only 2.5 kilograms of fissile Uranium 235 per year. The reactor core of BER II consists of 30 to 40 fuel elements surrounded by water. The water serves not only for cooling, but also as a moderator for the neutrons, i.e. the water slows them down, making them useful for experiments. While research is being done in the experimental hall using such thermal neutrons, as they are called, they are slowed further still for experiments in the neutron guide hall. This is done in the moderator cell, dubbed the "cold source" – a layer of gaseous hydrogen about ten centimetres thick that is cooled to -245°C and kept under a pressure of 13 bar. The "cold" neutrons thus produced are suitable for special scientific experiments and can also be guided to distant experimental workstations using neutron guides.

A SUCCESSFUL START FOR PVCOMB

The **Competence Centre Thin-Film- and Nanotechnology for Photovoltaics Berlin** (PVcomB) is an interface between research and industry that facilitates the introduction of new ideas into industrial applications.

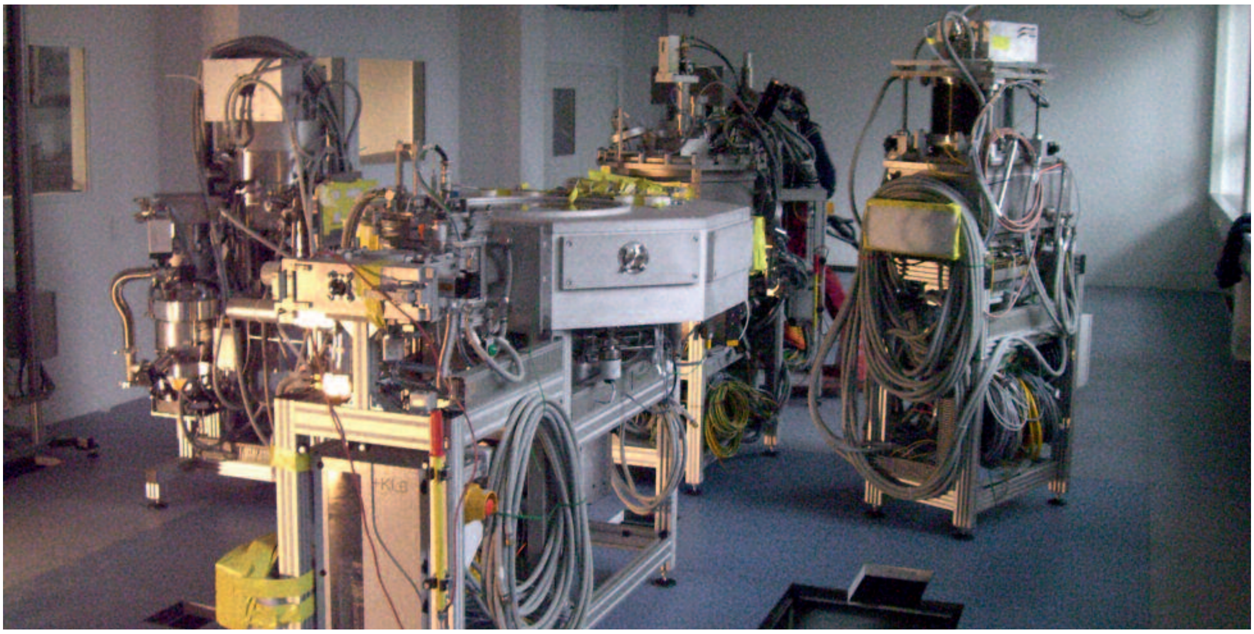
Helmholtz-Zentrum Berlin and the Technische Universität Berlin (TUB) jointly established PVcomB in 2007. Its aim is to ensure the rapid introduction of thin-film solar cells into industrial application by improving the transfer of knowledge and technology. PVcomB develops and studies production methods for manufacturing thin-film modules out of silicon and CIGS (copper indium gallium sulphide/selenide). Low energy and material consumption and large-surface production are but two of the advantages of thin-film photovoltaics, which experts believe will lower the overall cost of solar electricity. It is expected that thin-film technology will represent a rapidly growing percentage of the global PV market in the coming years. “At PVcomB, we are working with partners and companies on significantly increasing the market share of thin-film photovoltaics. In our research at HZB, we are already working on the next-but-one generation of solar cells, which we will later bring out on the market through PVcomB,” states Prof. Wolfgang Eberhardt, Scientific Director for Energy Research of HZB and professor at TUB. Technology and knowledge are transferred in joint research projects with industrial partners and by advanced education of highly qualified specialists.

The first fruits of funding are borne

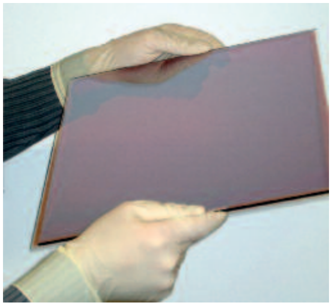
The wheels are already in motion for expanding the research centre. On 18 May 2009, PVcomB was granted funding as part of the program “Spitzenforschung und Innovationen in den neuen Ländern” (cutting-edge research and innovation in the new German Länder). The German Federal Ministry for Education and Research (BMBF) has funded the program with 12 million euros, with the Senat Berlin adding 25 percent of the funding total. “With BMBF’s funding, we and our partners can expand PVcomB very rapidly. We had already received millions of euros in industrial contracts and pledges, but there was still a gap in the start-up financing – now we can really step on the gas,” Director of PVcomB Dr. Rutger Schlatmann said upon announcement from the Federal Ministry. One of the acquisitions financed with BMBF’s funding in summer 2010 is the “Super Solar Simulator” from Wacom. Its xenon and halogen lamps deliver light very close to the solar spectrum. Thus it can be used to determine the efficiency of a solar cell under standardized conditions with greatest precision.

The first successes were not long in the waiting: On 15 November 2010, the colleagues coated the first 30 x 30-centimetre glass modules with amorphous silicon. This was deposited using a PECVD cluster tool from Applied Materials. PECVD stands for plasma enhanced chemical vapour deposition. For industrial silicon applications, this cluster tool is currently the technology of choice. It forms the heart of the research production line for thinfilm silicon currently being built at PVcomB. In the cluster tool, ultra-thin amorphous and microcrystalline silicon layers

Dr. Rutger Schlatmann, Director of PVcomB, explains the advantages of the new centre in a lecture at the April 2010 “Photovoltaics Thin-Film Week” held in Berlin.



The new cluster tool of PVcomB is now in operation. HZB scientists have already produced the first large-format photovoltaic modules on this research line.



The 30 x 30-centimetre modules are an important step on the path from the laboratory cell to the industrial module.

(a-Si/µc-Si) are deposited onto substrates such as glass. This material combination has many advantages over "classic" wafer-based silicon technology, such as significantly lower material and energy consumption. Nevertheless, the developers still intend to achieve higher degrees of efficiency with this kind of photovoltaic module. PVcomB has therefore set its efficiency sights to world record level. The path from laboratory scale to mass production is better understood and controlled for thin-film silicon technology than for the other thin-film technologies.

Greater process stability is the goal

CIGS cells, which HZB and PVcomB are also investigating, reach significantly higher degrees of efficiency than thin-film silicon cells so far. The industrial application of this technology, however, has not come as far in terms of homogeneity and process stability. PVcomB plans to make an important contribution to this field as well. The close connection to on-going pure research at HZB will be vital to their success.

PVcomB operates a research production line to emulate industrial production of photovoltaic modules. The modules measure 30 x 30 centimetres. They close a gap between the small, often only millimetre-sized cells created in the laboratory and large industrial models several square metres in size. "With the two research lines, we work at PVcomB under similar conditions to those in industry. That means we are a direct bridge between pure research and industry, and can support companies with both research results and scientists with practical expertise," explains Rutger Schlatmann. *cn*

PHOTOVOLTAICS THIN-FILM WEEK ESTABLISHED

In April 2009, the first Photovoltaics Thin-Film Week took place in Berlin-Adlershof. It was jointly hosted by PVcomB and Solarpraxis AG. PVcomB offered workshops specifically aimed at technologists and scientists in the field of photovoltaics, while Solarpraxis AG organized a practical industrial forum. Scientists, managers and investors from the solar industry got together there to exchange information about future developments. With around 450 participants, the first PV Thin-Film Week was a complete success, and a continuation was planned. While as well visited as 2009, the second PV Thin-Film Week in April 2010 was, in the truest sense of the word, overshadowed by the eruption of the Icelandic volcano Eyjafjallajökull. A number of speakers from Asia and the USA had to cancel their participation at short notice. Nevertheless, the 1st International Workshop on CIGS Solar Cell Technology took place as planned. From 19 to 21 April, speakers presented the latest insights and developments from research and industry in the field of chalcopyrite-based solar cells (copper indium gallium sulphide/selenide – CIGS).

THE YEAR OF ENERGY – INFORMATIVE AND ENTERTAINING

THE MOTTO OF THE SCIENCE YEAR 2010 WAS **"THE FUTURE OF ENERGY"**, AND THE HELMHOLTZ-ZENTRUM BERLIN STAGED NUMEROUS EVENTS.

The sponsors of the Year of Science dedicated to energy were the Federal Ministry of Education and Research, the Wissenschaft im Dialog (Science in Dialogue) initiative and the Helmholtz-Gemeinschaft Deutscher Forschungszentren (Helmholtz Association of German Research Centres). To start off the science year, four so-called Sunday lectures were organised jointly by the HU Berlin and HZB. The third lecture was held on 28th March by Prof. Dr. Bern Rech, head of the HZB Institute for Silicon Photovoltaics, together with Prof. Dr. Norbert Koch from the Institute for Physics at the Humboldt University Berlin. The topic was "Energy of the future: the new thin-film solar cells". They presented the current state of the art in photovoltaics and also gave a preview of tomorrow's solar cells, which instead of silicon might possibly be manufactured on the basis of organic molecules and polymers.

"Weigh anchor" was the command given on 18 May 2010 for the exhibition ship "MS Wissenschaft" as it set sail on its tour starting in Berlin and finishing in Würzburg on 7 October. Mounted on the roof of the ship was a photovoltaic solar power plant which demonstrated this form of renewable energy production quite impressively. The power plant comprised 32 black solar modules made by Sulfurcell Ltd., a spin-off of HZB, and had a capacity of 1700 kWh per year – about as much electric energy as one person in Germany consumes in a household per year. The main attraction on board were four storage batteries in which the generated energy could be stored and a vacuum cleaner operated from a power socket supplied with solar electricity.

The highlight of the Science Year 2010 was the "Day of Energy", for which numerous companies, universities, research institutes, museums, public utility companies and energy agencies opened their doors on 25 September, providing a glimpse behind the scenes and an insight into

A solar beetle shows children how light is converted to electricity at the "Day of Energy".

new developments, research projects and production processes. The HZB participated at its research location Berlin-Adlershof with the topic "Light is energy", and not only offered guided tours, talks and exhibits but also opened its school lab. Erik Zürn set the tone with his lecture on "Photovoltaics – technology of the future", followed by guided tours throughout the day through the electron storage ring BESSY II and the Institute for Silicon Photovoltaics, where the visitors were able to gather first-hand experience of the research on thin-film solar cells. In the afternoon, Prof. Dr. Wolfgang Eberhardt threw light on the current "research into a safe and environmentally compatible energy supply of the future". In the school lab "Light is energy", visitors both big and small were given the opportunity of assuming the role of researchers themselves in various join-in experiments.

Energy was also the main emphasis at the "Research Days" held on the two days before, which also took place at Berlin-Adlershof. For the 17th time, around 1000 schoolgirls and schoolboys streamed into the institutes, laboratories and auditoriums of the companies and institutions resident in the technology park. On the 23rd September, Tobias Sontheimer and Mark Wimmer showed 20 pupils through the Institute for Silicon Photovoltaics and explained to them how electric power is generated from sunlight. The day after, Johannes Wolf offered a laboratory workshop with BESSY II, in which the pupils were able to experiment with lithographic processes as a means of manufacturing micro components from light.

The fact that the topic of energy can be presented not only informatively but also in an amusing and entertaining manner was demonstrated by the participants of the "Energy Slam", supported by HZB as a partner. Numerous young scientists each had 10 minutes on stage to present their research topics in an exciting, witty and above all comprehensible manner. The audience then awarded points for the presentations and thus chose the Slam Champion of the evening. With his talk: "Energy – how can you waste something that cannot decrease", Martin Buchholz was able to sway the final decision in Berlin on December 9th 2010 in his favour.

GAINING INSIGHTS INTO THE WORLD OF RESEARCH

WITH A **SECOND SCHOOL LAB**, **THE GIRLS' DAY** AND THE **SUMMER STUDENT PROGRAMME**, THE HELMHOLTZ- ZENTRUM BERLIN WANTS TO INSPIRE YOUNG PEOPLE TO TAKE AN INTEREST IN THE WORLD OF SCIENCE.

The current-affairs television programme “Heute Journal” televised on 7th September 2010 by ZDF (the German television channel 2), was dedicated to the politically charged topic “The lack of skilled personnel in Germany”. The young doctoral student Kathrin Lange – who is currently working in the young investigator group for functional materials in solution at HZB – was able to have her say during the programme. She belongs to the mere 24 percent of all 25- to 34-year-olds in Germany, who according to the OECD (Organisation for Economic Cooperation and Development) have completed a university course of study. This figure leaves Germany not only far behind the leader South Korea, where 60 percent of this age group complete a university course, but also noticeably under the 41 percent average of all 34 OECD countries.
HZB recognised the necessity of fuelling the interest of schoolchildren for academic studies or a career in the field of natural science or technology many years ago: a school lab has been in operation in Berlin-Wannsee since 2004 that has already been visited by over 5000 children and young adults. On 28th October 2010, HZB opened a second school lab at its research location in Berlin-Adlershof. Schoolchildren can now experience the fascination of physics in the school lab Looking into Matter in the direct environment of the electron storage ring BESSY II. The experiments offered revolve around the topic “Light and colour”, and are directed at children and young adults in primary schools and secondary schools. Planned for the near future are project days for more senior grades. “Here at Berlin-Adlershof, we are hoping that we can build on the excellent experience gathered in Berlin-Wannsee”, says

Whether in the school lab (top) or at the Girls' Day – the kids and teens can experiment to their heart's delight at HZB. The objective is to spark their interest for the natural sciences.

Kerstin Berthold, who heads up the HZB school lab.
To open the door to the natural sciences – above all for girls – the nationwide Girls‘ Day was started in 2001, and HZB participated again in 2010 with great success. Some 70 girls from school grades 5 to 10 visited both research locations on 22nd April in order to get an idea of the careers and jobs that are usually considered more typical for men: while 50 girls investigated solar cells, prepared crystals on their own or checked out the innards of a computer at Berlin-Wannsee, another 20 girls discovered what the naked eye cannot see with terahertz radiation and made themselves conversant with the challenges of solar energy research as well as research methods with light at the Berlin-Adlershof location.
Young students from all over the world who have already ventured into science were invited to the 22nd international summer student programme organised by HZB from 2nd August to 24th September 2010. This eight-week programme gave 27 young researchers from 14 nations the opportunity of working together with HZB researchers on their projects. A series of seminars introduced the students to selected fields of activity at HZB. They were also able to get a good look at the two large-scale research facilities as well as the laboratories for solar energy research.

FEDERAL ORDERS OF MERIT FOR PROFESSOR STEINER AND PROFESSOR JAESCHKE

IN THE SPRING OF 2010, THE FORMER MANAGING DIRECTORS OF HMI AND BESSY EACH RECEIVED A **HIGH DISTINCTION** FOR THEIR CONTRIBUTIONS TO SCIENCE IN GERMANY.

The Helmholtz-Zentrum Berlin, which was formed from the merger of the former Hahn-Meitner Institute (HMI) and the Berlin Electron Storage Ring Society for Synchrotron Radiation (BESSY), had two very good reasons to celebrate in March and April 2010: Prof. Dr. Michael Steiner and Prof. Dr. Eberhard Jaeschke – the former managing directors of HMI and BESSY – who at the end of their respective functions as heads of the above institutes had channelled their efforts into setting up HZB, were honoured.

Prof. Dr. Michael Steiner was head of the Hahn-Meitner Institute in Berlin-Wannsee for 11 years.

Prof. Dr. Eberhard Jaeschke was technical director of BESSY for 17 years.

Prof. Dr. Michael Steiner, who was scientific director, CEO, of the Hahn-Meitner Institute from 1998 to 2008, was awarded the Officer's Cross of the Order of Merit of the Federal Republic of Germany on 18 March 2010. With this award, the federal president of Germany honoured above all Steiner's contributions “towards advancing the German scientific system over and beyond its prevailing limits”. The laudation went on to say that Steiner had displayed tireless engagement in his efforts to strengthen the European scientific infrastructure and had succeeded in closely meshing the development of both science and technology at the same time. Highlighted was also the fact that Steiner created new structures for the solar energy research established at HMI which make it easier to implement scientific results in the development of new technology. Under Prof. Steiner, who had been in charge of user access to the research reactor since 1994, the user service achieved its reputation that is still valid today of being able to offer highly sophisticated technical conditions such as high magnetic fields and cryogenic temperatures in an everyday experimental environment. This succeeded in luring many international groups of scientists to Berlin, and in 2007, HMI was finally awarded the contract of building the world's strongest magnet for neutron research. Since October 2009, Professor Steiner has been official speaker of the European Neutron Scattering Association, a union of some 4500 researchers who use the European neutron sources for their experiments.

Prof. Dr. Eberhard Jaeschke, who was technical director of the Berlin Electron Storage Ring Society for Synchrotron Radiation (BESSY) from 1991 to 2008, was also awarded the Officer's Cross of the Order of Merit of the Federal Republic of Germany on 21 April 2010. With this award, the federal president of Germany honoured Jaeschke's “outstanding contributions to physics and the technology of particle accelerators and his services rendered in the field of national and global research on synchrotron radiation”. It is also thanks to him in no small measure that construction of BESSY II began in 1994 and ultimately found its home in the research location Berlin-Adlershof. He was previously head of other accelerator projects, e.g. at the Max-Planck Institute for Nuclear Physics in Heidelberg. This is where he designed a heavy-ion linear accelerator, and between 1986 and 1988, he set up the first heavy-ion cooler ring with laser and electron cooling in the world. Even after his withdrawal from office as managing director, Professor Jaeschke is still active in numerous committees and is very much in demand as a consultant when it comes to designing next-generation radiation sources. At the Helmholtz-Zentrum Berlin, this source has been dubbed Energy Recovery Linac (ERL), a combination of a linear accelerator and a storage ring. While still managing director at BESSY, Eberhard Jaeschke pushed work on the prototype B*ERL*inPro ahead to such an extent that the project received top marks from all scientific appraisal committees and will now be realised.

EU COMMISSION HONOURS PROFESSOR SCHOCK

THE HZB SCIENTIST WAS AWARDED THE PRESTIGIOUS **BECQUEREL PRIZE** FOR HIS SUCCESSFUL RESEARCH IN THE FIELD OF PHOTOVOLTAICS.

Prof. Dr. Hans-Werner Schock, institute head and spokesman for the Solar Energy Research Division at HZB, was awarded the Becquerel Prize at the 25th European Photovoltaic Solar Energy Conference and Exhibition in Valencia on 9th September 2010. With this prize, the EU commission paid tribute to the HZB scientist for his life's work in the field of photovoltaics and for his outstanding achievements in the field of solar energy technology and the development of thin-film solar cells.
This award – which counts among the most highly respected solar awards – is named after the French scientist Alexandre Edmond Becquerel (1820-1891), who discovered the photovoltaic effect in 1839. The Becquerel Prize was awarded by the EU commission for the first time in 1989 to mark the 150th anniversary of this discovery. The presentation took place following Professor Schock's plenary presentation on the subject "The status and further potential of CIS and related solar cells".
Under Professor Schock's direction, the first pioneering experiments on chalcopyrite-based solar cells were carried out in the 1980s, and succeeded in making solar energy more efficient and less expensive. His research group is currently working on new material combinations made up of frequently occurring and eco-friendly chemical elements, and on refining the solar cells. According to Schock, the aim is that "solar cells no longer count as main investment goods but are rather naturally integrated into buildings, for example, right from the word go".

Prof. Dr. Hans-Werner Schock

IMPORTANT APPOINTMENTS

IN THE LAST TWO YEARS, A HOST OF HZB SCIENTISTS HAVE RECEIVED PROFESSORSHIP APPOINTMENTS IN BERLIN AND OTHER LOCATIONS.

Since September 2010, **Prof. Dr. Jens Knobloch** has held the chair for "Acceleration physics" at the University of Siegen. Professor Knobloch's research focus is the development of superconducting high-frequency systems for new light sources and future accelerators, or "superconducting radio-frequency (SRF) technology" for short. He has been head of the HZB institute "SRF Science and Technology" since 2009.

Prof. Dr. Emad Aziz received a junior professorship at the Freie Universität Berlin in April 2010. The research focus of the HZB scientist is functional materials in solution and at interfaces.

Prof. Dr. Roland Scheer, formerly deputy institute head at HZB, took over the endowed chair of the photovoltaics company "Q-Cells" at the Martin-Luther University (MLU) in Halle-Wittenberg on 1st June 2010.

Prof. Dr. Bert Stegemann from PVcomB has been a professor for photovoltaics at the HTW Berlin (university of applied sciences) since May 2009.

The photovoltaics researcher, **Prof. Dr. Christian-Herbert Fischer** from the HZB Institute for Heterogeneous Material Systems, was appointed honorary professor at the Freie Universität Berlin (FUB) on 11th January 2010.

In September 2010, **Prof. Dr. Marcus Bär** was appointed adjunct assistant professor of the department of chemistry at the College of Science at the Nevada University in Las Vegas.

Prof. Dr. Sebastian Fiechter, provisional head of the Institute for Solar Fuels and Energy Storage Materials at HZB, received a supernumerary professorship at the TU Berlin in December 2009.

Prof. Dr. Norbert Nickel, deputy head of the Institute for Silicon Photovoltaics at HZB, received a supernumerary professorship at the TU Berlin in October 2009.

THREE NEW INSTITUTE DIRECTORS AT HZB

WITH **PROF. BALLAUFF, PROF. FÖHLISCH AND PROF. JANKOWIAK**, VACANT POSITIONS AT THREE HZB INSTITUTES WERE FILLED IN 2009 AND 2010.

Prof. Dr. Matthias Ballauff

Prof. Dr. Alexander Föhlisch

Prof. Dr. Andreas Jankowiak

In March 2009, **Prof. Dr. Matthias Ballauff** was offered a professorship at the Humboldt University in Berlin and the position of executive scientist at HZB. Since mid-July 2009, he has headed up the Institute for Soft Matter and Functional Materials and has thus assumed responsibility for a core field in operation of the research reactor BER II as well as the synchrotron radiation source BESSY II. Before 2009, the graduate chemist was employed at Karlsruhe University, the Max-Planck Institute for polymer research in Mainz and Stanford University. His last station before coming to HZB was as a professor for physical chemistry at the University of Bayreuth. The deciding factor for his move were the vast research possibilities for experiments with neutrons and synchrotron radiation available at HZB. He sees his commitment to teaching as being extremely important, and he wants to introduce as many young people as possible to the world of research with large-scale facilities. His research interests include the analysis of colloid structures that base on polymer materials. Professor Ballauff also chairs the Topics Committee of the German Bunsen Society for Physical Chemistry and has been a member of their standing committee since 2011.

Prof. Dr. Alexander Föhlisch has headed up the Institute of Methods and Instrumentation for Research with Synchrotron Radiation at HZB since 1st October 2009. On 22nd July, he accepted a joint appointment as professor at the University of Potsdam and institute director at HZB. Professor Föhlisch studied physics in Tübingen, Stony Brook and Hamburg and did his doctoral research at the Advanced Light Source in Berkeley (USA), which led to a PhD at Uppsala University. Prior to his move to Berlin, he worked as a university lecturer at the Institute for Experimental Physics at Hamburg University and also at the Centre for Free-Electron Laser Science (DESY). The focus of his scientific interest is the refinement of innovative X-ray methods in order to see how electronic structure and ultrafast dynamics on the atomic scale interplay. The resultant knowledge of relevant physical and chemical processes provides a better understanding of functional materials for ultrafast switching in condensed matter, of photovoltaics and molecular dynamics and also of heterogeneous catalysis.

Prof. Dr. Andreas Jankowiak took over the Institute for Accelerator Physics and the Accelerator Operation Department at HZB at the beginning of March 2010. Prior to this, in February, he accepted a chair as professor of experimental physics/accelerator physics at the Institute for Physics of the Humboldt University in Berlin. As head of the working group for accelerator operation and development, the graduate physicist previously worked with the Mainz Microtron operated by the University of Mainz. Before his engagement in Mainz, Professor Jankowiak was head of the working group for high-frequency systems of the synchrotron radiation source DELTA at Dortmund University. Born and bred in Recklinghausen in the north-west of Germany, Professor Jankowiak is instrumental at HZB in the operation and further development of the synchrotron radiation source BESSY II and is also involved in the Metrology Light Source (MLS). An important project that was taken over by Professor Jankowiak and where he works in close cooperation with the deputy project manager Professor Jens Knobloch from the newly formed institute SRF– Science and Technology at HZB, is the BERLinPro – the prototype of the Energy Recovery Linac (ERL).

NO END OF VISITORS CAME TO THE "BRIGHTEST NIGHT OF THE YEAR"

IN SUMMER 2010, HZB PARTICIPATED IN THE 10TH "**LONG NIGHT OF SCIENCE**".

How do you communicate complex scientific topics in a comprehensible manner to members of an interested but lay audience? By inviting them to research institutes and showing them what goes on there. This idea was realised for the first time in the summer of 2001 in Berlin in the form of a "Long Night of Science". And the format proved to be successful: on 5 June 2010, the "Long Night of Science" was held for the tenth time – with over 2,000 events at 70 institutes in Berlin, Potsdam and Wildau. HZB naturally also took part at its two research locations with an extensive programme. The beautiful weather enticed some 4,600 visitors to flock around the experimental workstations of the large-scale facilities as well as into the solar energy research laboratories at Berlin-Wannsee and Berlin-Adlershof, where they listened eagerly to the explanations offered by the numerous scientists present. In the school lab, young people were able to experiment to their heart's delight – because arousing and satisfying curiosity, explaining complicated relationships in an understandable manner, posing popular questions and addressing senses and feelings is something that the researchers achieve every year with the Long Night of Science.

HZB ORGANISED THE SNI 2010

OVER **700 SCIENTISTS** WHOSE RESEARCH FOCUS IS SYNCHROTRON, NEUTRON AND ION BEAMS CAME TO BERLIN IN FEBRUARY 2010.

The research on synchrotron, neutron and ion beams (SNI) permits insights into the tiniest structures that go to make up matter. Scientists who work with such methods find not only the corresponding large-scale facilities at HZB, but they are also able to compare notes and exchange views. Around 700 researchers – not only physical scientists, but also doctors of medicine and even humanists – came together from 24 to 26 February 2010 to attend the SNI 2010 conference. The conference was organised by HZB in close cooperation with the Berlin universities and the Potsdam university. After the first SNI in 2006, this was only the second SNI conference in this series to be organised. Besides a trade show, some 80 scientific lectures were held and 560 poster contributions were shown, with which above all doctoral students and young scientists wanted to present their work. Two of the highlights constituted the public evening lectures given by Prof. Dr. Michael H. Foerster from the eye clinic at the Charité on "Twelve years of proton therapy in Berlin", and by Dr. Ina Reiche from CNRS Louvre, Paris, on "Cultural treasures in the focus of scientific large-scale facilities".

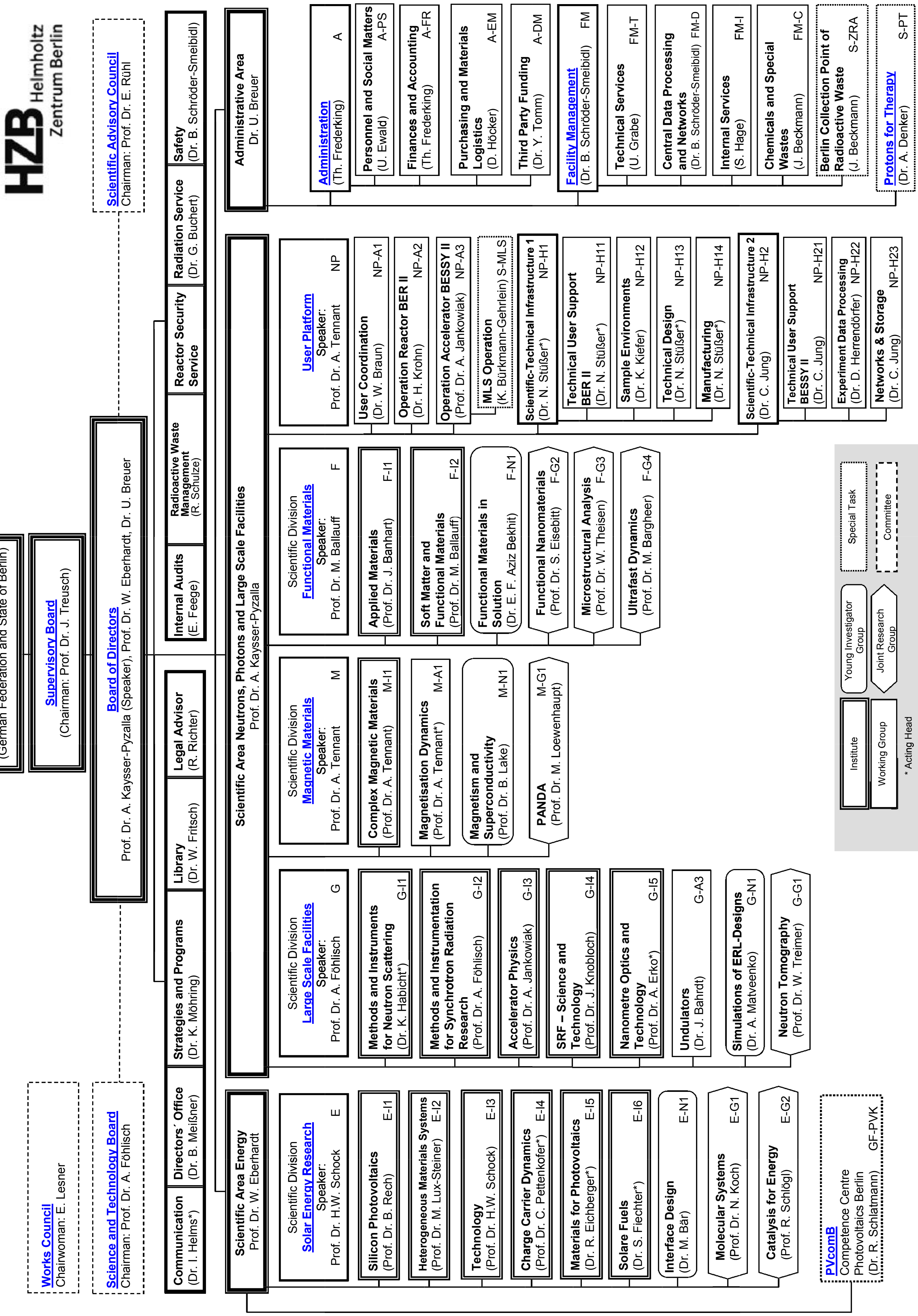
NEWSFLASH

The annual convention of the ForschungsVerbund Erneuerbare Energien (FVEE – Renewable Energy Research Association), to which HZB also belongs, took place in Berlin on 11 and 12 October 2010. The managing director of HZB, Prof. Dr. Wolfgang Eberhardt, ran the annual convention at which the 20th anniversary of the umbrella organisation was also celebrated. The objective of the FVEE members is to develop the technologies necessary to ensure a complete energy supply using renewable energy.

Within the framework of the scientific conference "Falling Walls Conference 2010" held in Berlin, a group of young scientists visited HZB's research location in Berlin-Adlershof on 7 November 2010. The Falling Walls Conference was held for the first time in 2009 on the occasion of the 20th anniversary of the fall of the Berlin wall, and is supported by a battery of reputable scientific institutions, among them the Helmholtz Association.

Within the scope of the conference "Materials Science and Engineering 2010" held by the DGM (German Society for Materials Science) in Darmstadt from 24 to 26 August 2010, Prof. Dr. Anke-Rita Kaysser-Pyzalla – HZB's management spokeswoman – was responsible for the topic of main emphasis "Characterization".

Organisation Chart HZB



Site map
The Lise-Meitner Campus with the BER II research reactor is located at the HZB Berlin-Wannsee site, whereas the Conrad-Röntgen Campus with the electron storage ring BESSY II is located at the HZB Berlin-Adlershof site.

IMPRINT

HZB Highlight Report 2009/2010 of the Helmholtz-Zentrum Berlin für Materialien und Energie GmbH. Reprint only with the express permission of the publisher.
Press date: June 2011

Publisher:
Helmholtz-Zentrum Berlin, Hahn-Meitner-Platz 1, 14109 Berlin, Fon: +49 (0)30 80 62-420 34.

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Publishing services & support:
n.k mediaconcept GbR, Obere Lagerstraße 38b,
82178 Puchheim bei München, Fon: +49 (0)89 89 02 20-10
Managing directors: Klaus Dieter Krön, Christoph Neuschäffer

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Translation: Peter Gregg, Gill Elaine Schneider

Design & layout: Klaus Dieter Krön

Picture editor: Christoph Neuschäffer

Picture editing: Lothar Trutter

Proofs: Trumedia Gmbh, Tattenbachstraße 19, 86179 Augsburg

Print: Feller, Rheinstraße 15 b, 14513 Berlin

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