RESEARCH FOR THE WORLD OF TOMORROW

HZDR

HELMHOLTZ
ZENTRUM DRESDEN
ROSSENDORF

The entrance building at HZDR

Energy. Health. Matter.

In an era of climate change and dwindling mineral resources, how can we use raw materials efficiently, safely and sustainably? For industrialized societies there are few questions more important than this one. On the other hand: how can we recognize cancer at an earlier stage and treat it more effectively? This is one of the greatest challenges facing health research in our times. How do matter and materials react under the influence of high fields and in the tiniest dimensions? This field of research touches on our basic understanding of the world. And it is of practical relevance to the most diverse technologies.

These are the three central questions that drive the ambition of researchers at the Helmholtz-Zentrum Dresden-Rossendorf, and it is only at first glance that they might seem unrelated. Energy, health and matter: research in these three focus areas is closely interconnected in the work of all eight institutes at HZDR.

Together with the other 17 centers in the Helmholtz Association and partners all over the world, the Dresden researchers seek to develop new solutions, processes and products based on the findings of fundamental research.

Innovative solutions are required: the Helmholtz Institute Freiberg for Resource Technology conducts research geared to the material- and energy-efficient handling of mineral- and metal-containing resources.

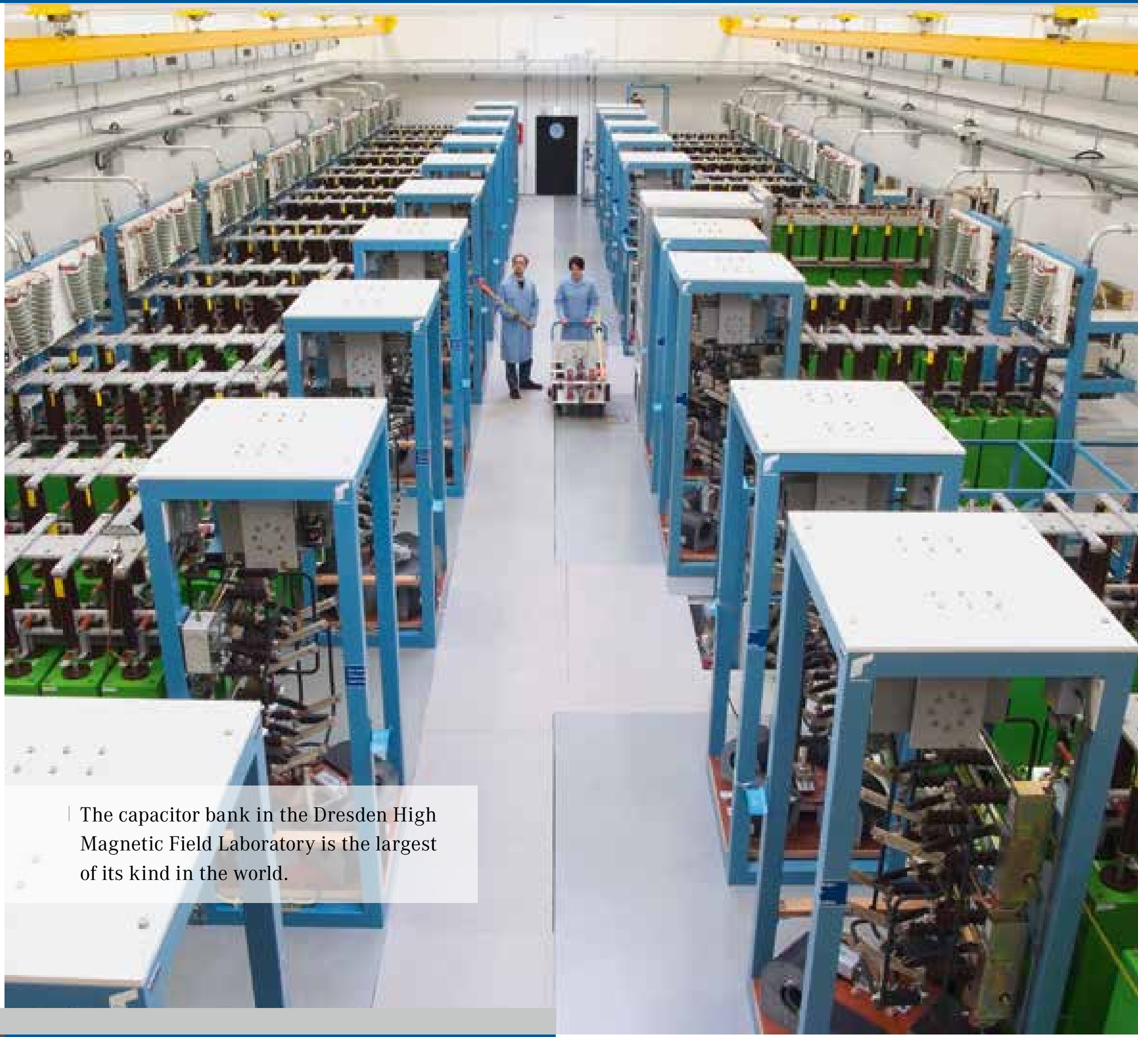
Top-class research thanks to top-class facilities

In order to address many of the issues of our times, modern science needs large-scale research facilities. Building, operating and using them often means significant financial investments and large numbers of staff. As a member of the Helmholtz Association, HZDR provides a unique infrastructure that attracts visiting researchers from all over the world.

The ELBE Center for High-Power Radiation Sources is a super microscope the size of a football pitch. It generates diverse types of radiation, for example neutrons and positrons as well as variable coherent infrared radiation via the free-electron laser and broadband terahertz radiation. All of these allow researchers to gain unique insights into the states of matter and materials. Two ultra-short pulsed high-power lasers complete the ELBE facility.

The development of new electronic materials and energy-efficient technologies is the focus of the Ion Beam Center, while the Dresden High Magnetic Field Laboratory investigates how magnetic fields impact on the properties of solids. At the European Synchrotron Radiation Facility in Grenoble, France, HZDR operates the Rossendorf Beamline, a radiochemical laboratory of particular relevance to research on the permanent disposal of nuclear waste.

The Center for Positron Emission Tomography (PET), which is operated in cooperation with Carl Gustav Carus University Hospital and TU Dresden, conducts research into molecular imaging to improve cancer diagnosis. In the new Center for Radiopharmaceutical Tumor Research, cancer therapy is also a particular focus area.



The capacitor bank in the Dresden High Magnetic Field Laboratory is the largest of its kind in the world.

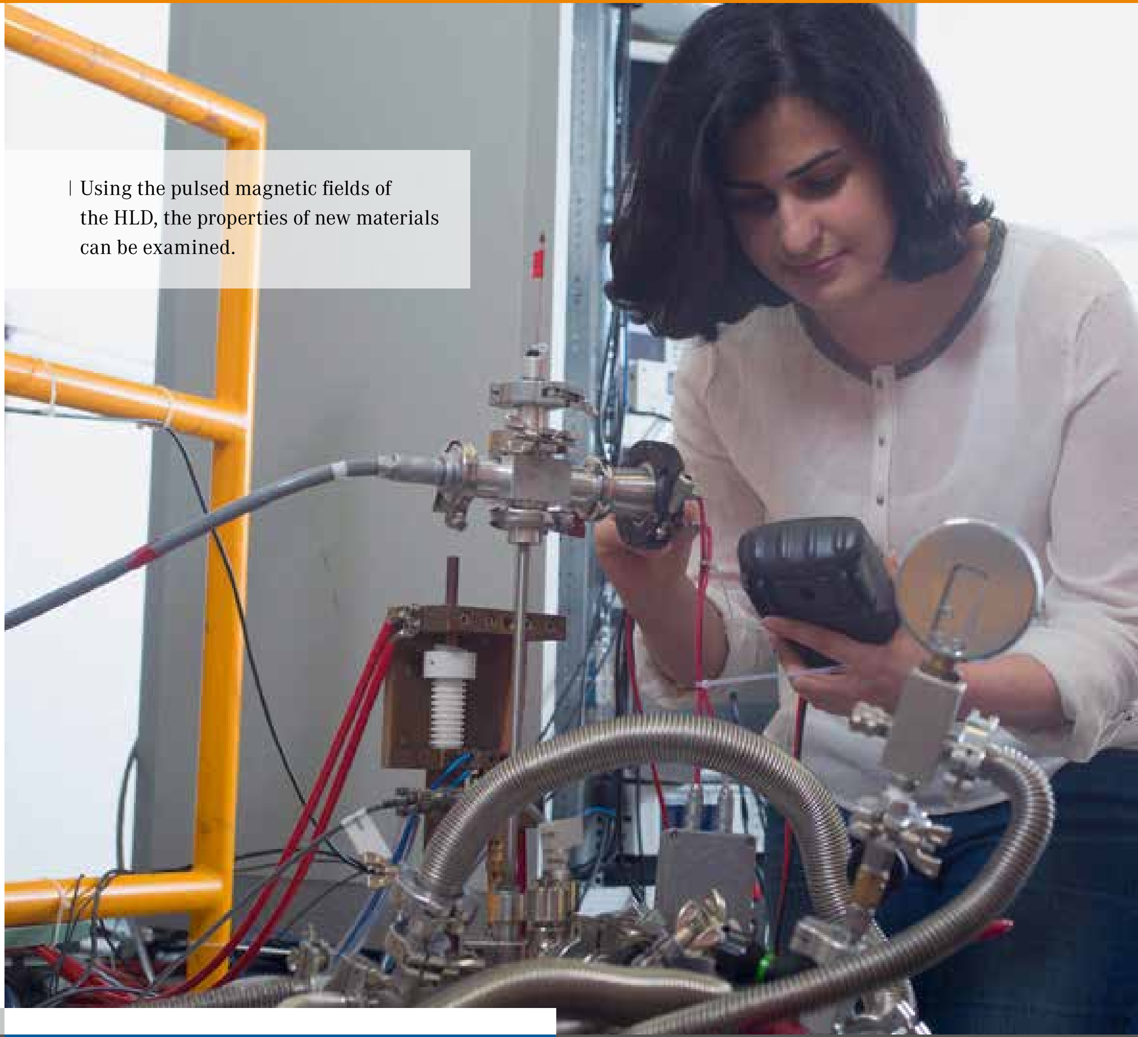
Ion Beam Center

From matter to innovative materials

You can only really make an impact if you get to the very heart of matter. This is why scientists at the Center investigate matter under extreme conditions and in very small dimensions. It enables them to derive fundamental insights: the scale ranges from basic physical phenomena to developing novel materials.

One way of studying the surface of materials, for example, is to apply ion beams. The fast-moving, charged atoms can also trigger targeted changes in surfaces. And this helps to develop storage and computer technologies with new functions. On their search for components with low heat build-up and power consumption, researchers at HZDR's Ion Beam Center (IBC) employ novel physical approaches involving electronics, magnetism and optics. Thus, the IBC is also in great demand among external visiting scientists.

The properties of solids can also be influenced by strong magnetic fields. With its High Magnetic Field Laboratory (HLD), HZDR provides a unique research environment. The outcomes can be utilized for the development of improved materials, such as superconductors and innovative magnets. As a founding member of the European Magnetic Field Laboratory, which connects the three largest, state-of-the-art magnetic field laboratories in Europe, HLD promotes scientific exchange across national borders. Both internal and external users have access to a unique and flexible research infrastructure.



Using the pulsed magnetic fields of the HLD, the properties of new materials can be examined.

At the ELBE Center for High-Power Radiation Sources the petawatt laser system PENELOPE is being built. The aim is to develop compact laser accelerators for use in proton therapy.

Particle race course

Accelerators are one of the most valuable tools in large-scale research. They accelerate electrically-charged particles almost to the speed of light. Various different research areas are the beneficiaries: from particle physics via material sciences right through to medicine. The electron beam in the Center for High-Power Radiation Sources ELBE at HZDR, for instance, facilitates the development of ultra-precise and ultra-fast detectors which can be used in areas such as cancer treatment to monitor proton beam therapy.

Researchers at HZDR are also working on an extremely compact form of particle acceleration based on high-performance lasers. The Center operates DRACO, which at one petawatt is currently one of the strongest short-pulsed lasers worldwide: when its ultra-short beam encounters matter, acceleration forces are activated that are many thousand times greater than those of established techniques. Multiple award-winning computer simulations help to optimize the complex process of particle acceleration. To cope with the enormous demand for simulation, data modelling and data analysis powerful High Performance Computing Systems are available at HZDR.

High-power lasers will also be used at the Helmholtz International Beamline for Extreme Fields (HIBEF) which is under construction at the European XFEL near Hamburg, coordinated by HZDR. The combination of laser light with X-ray radiation and high magnetic fields allows researchers to gain deeper insights into the structure of materials and fast natural processes.

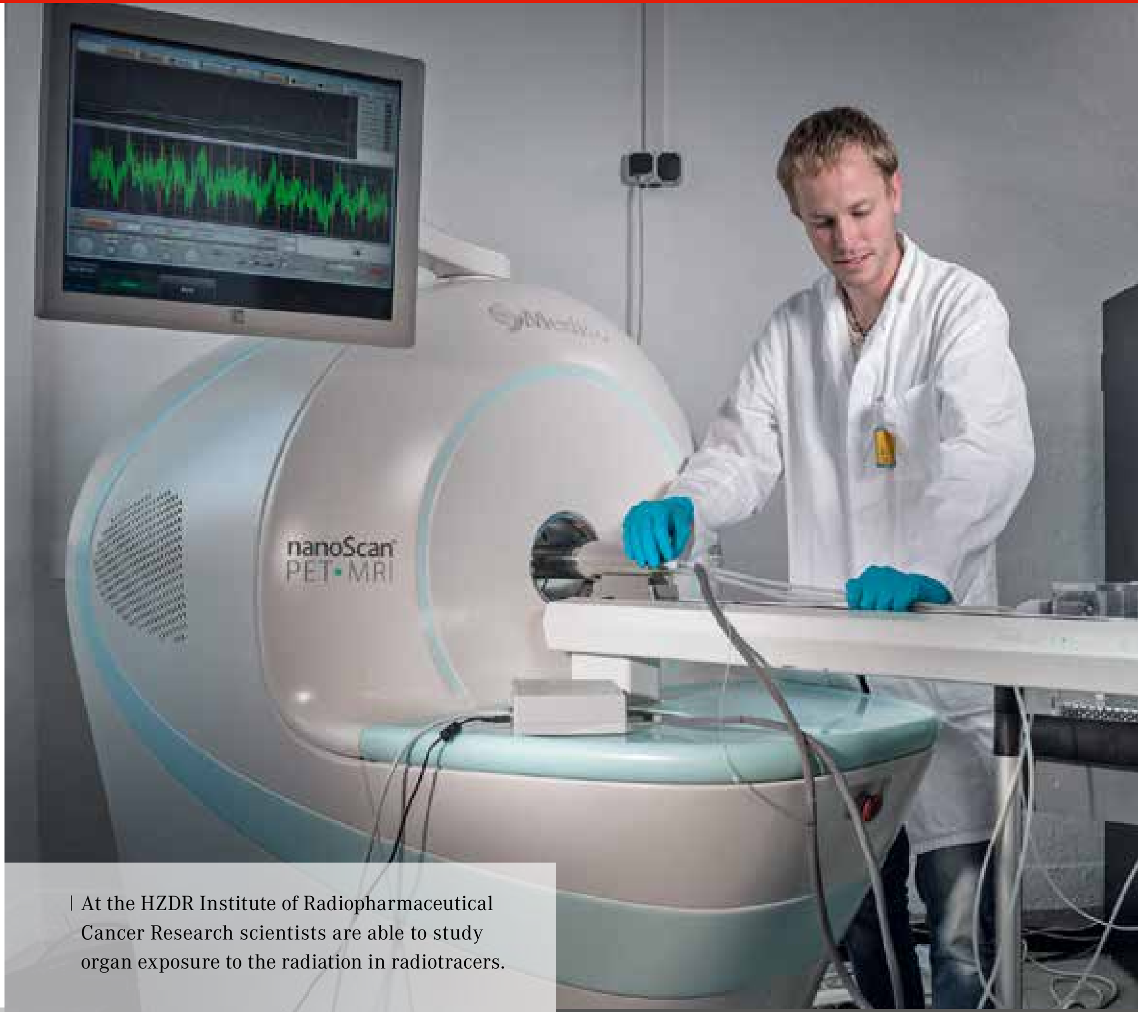
Mechthild Krause, Director of the HZDR Institute of Radiooncology, in front of the proton treatment facility at Dresden University Hospital.

From diagnosis to therapy

Imaging now enables us to understand ever more about cancer – the basic precondition for effective therapies. HZDR has specialized in positron-emission tomography (PET). At the Center, radioactive drugs for PET imaging that can adhere to specific tissue structures are developed and manufactured. The radiation they produce can be captured externally on a PET camera which enables scientists to determine the location and behavior of the tumor or investigate the efficacy of therapies.

In future, radioactive drugs could also be used in cancer therapy to irradiate tumor tissue within the body. In the case of endoradionuclide therapy, chemical compounds trace the diseased cells in order to transport radioactive atoms directly into the tumor. Synthetic peptides and antibodies play an important role in this process. The human body produces similar substances for signal transduction and for fighting viruses and bacteria.

But the body's own immune system could do more to fight cancer. Dresden scientists are working on antibodies which aim to specifically link special immune cells with tumors. This activates the immune system that destroys the cancer cells.



At the HZDR Institute of Radiopharmaceutical Cancer Research scientists are able to study organ exposure to the radiation in radiotracers.

HZDR is developing compact accelerators for proton therapy as well as systems to monitor tumor therapy in real time.

Proton beams

A novel method of cancer treatment is proton therapy. The tumor is irradiated with charged particles which cause less harm to the healthy tissue while damaging the diseased cells more effectively. Since the end of 2014, patients have been treated using this procedure at Universitäts Protonen Therapie Dresden (UPTD), in which the Center is also a partner.

Because the position of the beam relative to the tumor cannot be visualized directly, researchers at the HZDR Institute of Radiooncology and the OncoRay Center are investigating how to monitor the proton beams precisely. In the world's first patient studies, they use innovative camera systems which utilize the gamma radiation generated, allowing the treatment to be controlled in real time.

Up to now, large-scale accelerators have been required to produce protons. This is why researchers are now engaged in finding ways of making the technology more compact. HZDR's approach is to accelerate the particles with the help of laser light. The equipment could thus become much smaller and more economical, making it easier for other hospitals to acquire it.

In order to enhance its specific expertise in cancer research, HZDR is collaborating with University Hospital Carl Gustav Carus, TU Dresden and the German Cancer Research Center to develop the National Center for Tumor Diseases (NCT) in Dresden. It will be the partner location of Heidelberg NCT. The common goal is to conduct cross-disciplinary research, therapy and prevention for the benefit of patients – and to do so at top international level.

| ESRF Grenoble: where HZDR operates its own beamline.

Energy efficiency – which also means resource efficiency

A location like Germany with an economy based on advanced technology has to pull out all the stops when it comes to energy issues if it wants to avoid dependency on third countries. The Center addresses three important aspects of this challenge: the first is developing energy-efficient technologies, the second is finding solutions for the problem of permanently disposing of nuclear waste.

The third aspect deals with the shortage of resources themselves. On world markets, strategically important raw materials, without which computers and even wind turbines would be unthinkable, are becoming ever more scarce and expensive. What are needed are methods for tapping these resources from every conceivable source and providing sustainable solutions in the sense of a recycling economy. In response, the Federal Government launched the Helmholtz Institute Freiberg for Resource Technology (HIF) at HZDR in 2011. It develops innovative procedures for exploring, extracting, processing, refining and recycling raw materials. It cooperates closely with TU Bergakademie Freiberg.

The issue of sustainable raw materials production does not, however, stop at the German border. HZDR consequently coordinated the successful establishment of the Knowledge and Innovation Community, EIT RawMaterials, the largest resource consortium in Europe. The virtual institute GERRI aims to bundle national expertise, infrastructures and strategies in the raw materials sector.

The researchers in the NetFlot project want to establish a European network for flotation treatment processes.

Let it flow – as energy efficiently as possible

In order to make many industrial processes more energy efficient, knowledge of multi-phase flows is required. Flows of this kind, in which at least two gases, liquids or solid components circulate, play a particular role in the energy-intensive processes used in metallurgy and the chemical industry – sectors in which the production conditions are disadvantageous for investigating flow behavior.

For this reason, HZDR is developing practice-related, three-dimensional computer models to simulate flows as a basis for optimizing processes. Scientists test their assumptions using the thermohydraulic test facility, TOPFLOW, and sophisticated measuring techniques. LIMMCAST, the liquid metal model for continuous casting employs a special alloy to simulate the processes taking place during metal casting. Given the high temperatures, improving the quality is a further aspect of energy efficiency. Researchers are trying to discover whether externally applied magnetic fields can influence the molten steel so that the structural composition of the steel is improved and wastage avoided.

DRESDYN is a facility for experiments involving liquid sodium. Researchers want to use the large experimental dynamo that revoles at high speed around two axes to discover the answers to fundamental questions: How did planetary magnetic fields and especially the magnetic field of the Earth evolve, and how do they behave? DRESDYN experiments are, however, also expected to help develop liquid metal batteries and thus deliver solutions for optimum energy storage.

| The LIMMCAST experimental facility: where the real events taking place at 1,500 degrees Celsius can be investigated at just 300 degrees Celsius.

Maintaining expert knowledge despite the German energy revolution

We still have no answer to the question of how to dispose of high-level radioactive waste from nuclear power plants. Various rock formations could provide suitable storage sites – provided that the radioactive waste can be securely encased. For this purpose, it is however important to know exactly how radioactive substances behave in the biosphere and geosphere. HZDR scientists are addressing this question. Their findings are fed directly into international databases and codes, because nuclear waste disposal is a challenge that transcends national boundaries. The radiochemical laboratory at the Rossendorf Beamline, located at the European Synchrotron Radiation Facility in Grenoble, makes a valuable contribution.

Although Germany is committed to gradually phasing out nuclear power, reactor safety is still an important issue. In Europe, in particular, many nuclear power plants of the older and new generations are being built. If Germany wants to be part of this discussion, it must maintain and extend its expertise. In order to simulate hazardous incidents, the Center is developing thermohydraulic and reactor-related physical calculation procedures as well as material models for experimental testing. The European Union's nuclear research programs use this knowledge in their work.

| HZDR is one of the few research institutions in Europe able to work with highly radiotoxic materials.

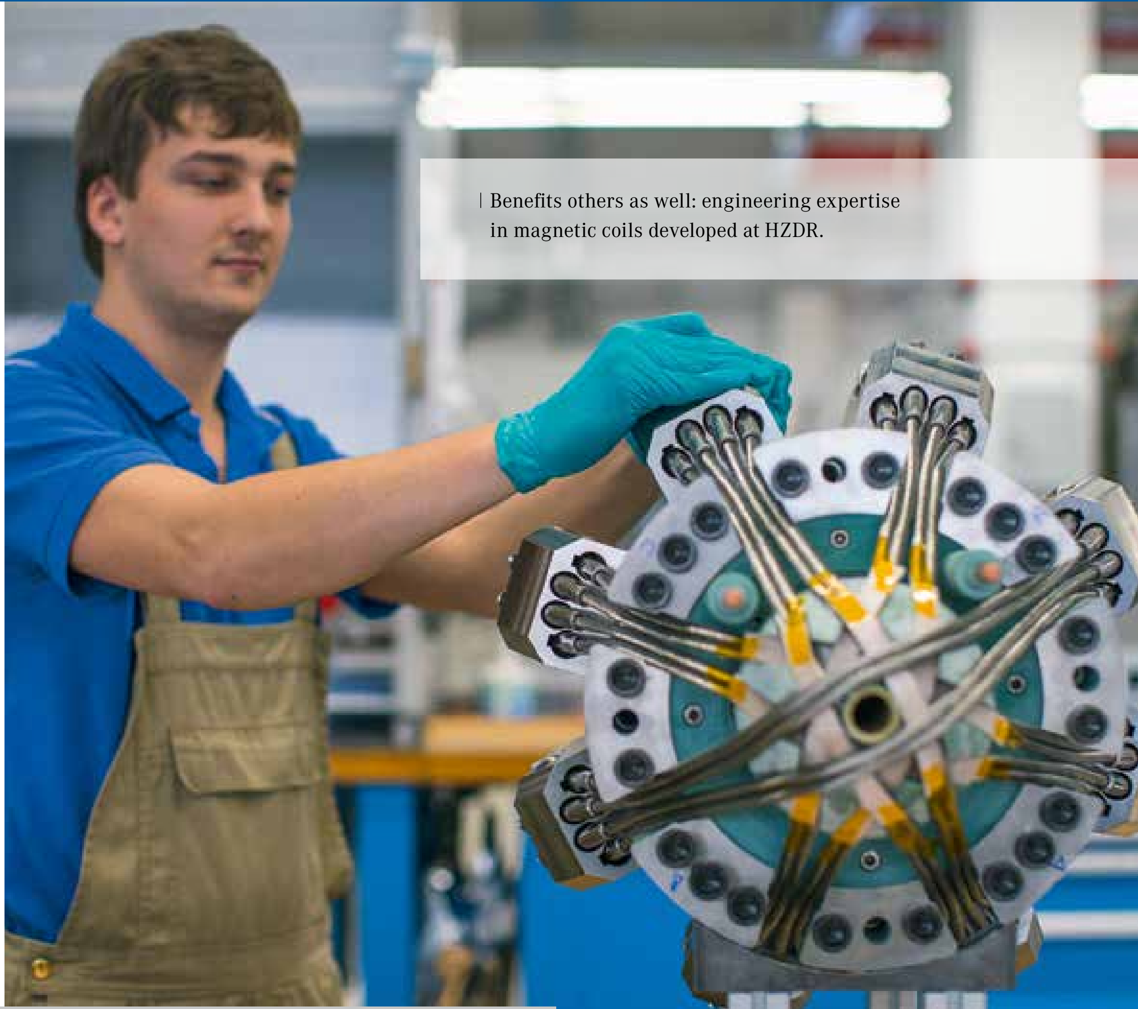
High energy implantation at the Ion Beam Center

From lab to society

HZDR aims to transfer research results to society and industry as quickly as possible. Its leading scientists are thus actively involved in scientific academies and special commissions at home and abroad. The Center also provides independent advice for policy-makers, informs the general public on specific issues and offers subject-related training courses, not least in the socially-relevant field of nuclear safety. Moreover, it ensures the safety of European nuclear power plants by producing computer programs which help authorities, operators and research institutions to draw up reliable safety strategies.

In order to transfer concrete technologies or procedures to industry the HZDR chooses a number of routes – for example, contract and collaborative research, licensing, spin-offs, transfer of staff or the shared use of infrastructure. This also benefits medium-sized businesses in the region. In addition to this, technology transfer depends on collaboration with special service providers. Important partners include the spin-off "Dresden exists" and the company Ascenion, which focuses on the exploitation of knowledge derived from the life sciences.

Together with the GWT GmbH (Knowledge and Technology Transfer Ltd) of TU Dresden, Helmholtz-Zentrum Dresden-Rossendorf founded HZDR INNOVATION GmbH – a subsidiary company that opens up the Center’s unique infrastructure to industry. The microelectronics and automotive sectors in particular take advantage of this opportunity.



| Benefits others as well: engineering expertise in magnetic coils developed at HZDR.

Sparking enthusiasm together

As part of DRESDEN-concept, a research alliance of 22 partners with the excellence university TU Dresden at its heart, the Center is committed to outstanding research, teaching and infrastructure. The universities in Saxony are important partners in promoting highly-qualified junior researchers. The directors of HZDR's institutes and other experienced scientists also hold professorships at these universities.

A number of junior research groups act as a springboard for young researchers' careers. No fewer than two teams of scientists at the Center benefit from the European Research Council's coveted "Starting Grants". The Helmholtz Research School NanoNet promotes junior researchers in molecular electronics, and an international summer program attracts talented students to Dresden every year. But opportunities to continue training and expand one's horizons are also important for technical staff at a research facility. HZDR has consequently established its own "Technical Staff Academy".

Enthusiasm for science can already be sparked in childhood: in HZDR's DeltaX school lab, children and young people from elementary school to college can try out their skills as potential researchers in a genuine research environment – including in-service training opportunities for teachers. The "Smart Kids" program even whisks away pre-school children to the exciting world of natural science with play-based experiments.

Investigating an oscillating circuit in the school lab at HZDR

ENERGY HEALTH MATTER

Cooperation is the key to success

Institute of Fluid Dynamics

// Helmholtz Alliance Liquid Metal Technologies LIMTECH
// AREVA Endowed Chair of Imaging Techniques in Energy and Process Engineering

Institute of Ion Beam Physics and Materials Research

// Shanghai Institute of Microsystem and Information Technology SIMIT
// Helmholtz Energy Materials Characterization Platform HEMCP & Helmholtz Energy Materials Foundry HEMF

Institute of Radiooncology

// National Center for Tumor Diseases NCT Dresden
// Dresden University Medical Faculty and Hospital – OncoRay

Institute of Radiopharmaceutical Cancer Research

// Turku PET Center, Finland
// Helmholtz cross-program activity Technology and Medicine

Institute of Resource Ecology

// Rossendorf Beamline ROBL at the European Synchrotron ESRF
// German Association for Repository Research DAEF

Institute of Radiation Physics

// Helmholtz International Beamline for Extreme Fields HIBEF at the European XFEL
// Stanford Linear Accelerator Center SLAC, USA

Dresden High Magnetic Field Laboratory

// European Magnetic Field Laboratory EMFL
// Collaborative Research Center SFB 1143 Correlated Magnetism: From Frustration to Topology

Helmholtz Institute Freiberg for Resource Technology

// Knowledge and Innovation Community EIT RawMaterials
// German Resource Research Institute GERRI

Research at five locations

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_LEIPZIG
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for Interdisciplinary Isotope Research
Permoserstrasse 15
04318 Leipzig, Germany

_SCHENEFELD
HIBEF at European XFEL GmbH
22869 Schenefeld, Germany

_GRENOBLE
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CRG – ROBL
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