Main entrance of the lecture-room of the Hahn-Meitner Institute

News and Events 2003

■ HMI-theorist Martin Falcke receives the 2003 Erwin Schrödinger Prize

Calcium waves participate in almost all processes in living organisms: from fertilization through muscle contraction and secretion to cell death. These waves – areas of increased concentration of calcium ions – travel across any biological cell relaying information that arrives from outside the cell to organelles inside. During their journey across the cell, the waves behave in very characteristic ways: they form typical spiral patterns and avoid certain frequency ranges, i.e., any wave attempting to travel at one of those frequencies is damped immediately.


Photo: Helmholtz-Association

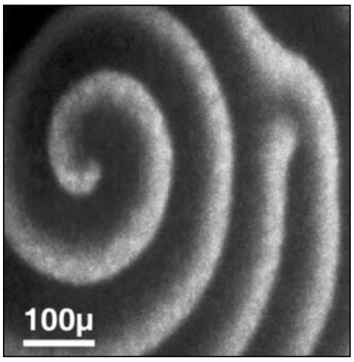
After the ceremony: The Schrödinger laureates with representatives of the prize awarding institutions. From left to right: Prof. Dr. Walter Kröll – President of the Helmholtz Association, Dr. Arend Oetker – President of the Stifterverband, the laurates Prof. Patricia Camacho, Prof. James D. Lechleiter – University of Texas, San Antonio, Dr. Martin Falcke – HMI, Prof. Dr. Karin Mölling – Chairwoman of the Schrödinger-Prize Jury

The surprising properties of calcium communication in living cells is the central topic of the scientific collaboration of the theoretical physicist Martin Falcke (HMI, SF5 – Theoretical Physics) with the experimental biologists Patricia Camacho and James D. Lechleiter (both from the University of Texas in San Antonio). In a common effort, they succeeded in explaining the origin of the calcium waves' behaviour. In particular, Falcke developed a mathematical model showing how the different patterns emerge from the interplay of different organelles releasing and absorbing the calcium in the cell. A brief review of the scientific results behind the prize is given below.
For their groundbreaking results the three scientists received the 2003 Erwin Schrödinger Prize. The prize is awarded annually by the Stifterverband für die deutsche Wissenschaft (Donors' association for the promotion of the sciences and humanities in Germany) and the Helmholtz Association to researchers working at the interface between different fields of science. The interdisciplinary work of this year's laureates fits particularly well into the tradition of Erwin Schrödinger, the theoretical physicist who applied his theoretical approach to the understanding of the genetic code. With his book *What is Life?*, Schrödinger inspired many physicists to look into the fundamental principles of life.

The prize was presented to the laureates on Oct 16 2003 in a ceremony during the annual conference of the Helmholtz Association, which took place in the Hamburg city hall.

Understanding the patterns of life – Research at the interface of physics and biology

Every living organism consists of countless individual cells; every cell consists of many organelles and countless molecules. Only by communicating with each other, the organelles and molecules become a living cell and the cells become a living organism. Within the cells, information is transmitted in form of calcium waves – singular or periodic changes in the calcium concentration. These waves can expand or form characteristic stripes travelling through the cell forming typical patterns. As an example, consider the fertilization of an egg-cell. Here, it is crucially important that only one sperm enters the egg. Therefore, fertilization of the egg-cell must be immediately communicated to its whole surface. This information is transmitted by a calcium wave. Besides fertilization, there are countless further examples of the transmission of information with calcium as a messenger.



A spiral-shaped calcium wave. Calcium waves transmit information between the various organelles in the living cell. The cooperation of the laureates led to a fundamental understanding of calcium communication in cells.

The biologists P. Camacho and J.D. Lechleiter and the physicist M. Falcke had the idea of approaching unsolved problems in cell physiology by studying the behaviour of calcium waves. By thoroughly analyzing the periods, velocities and amplitudes of the waves, they expected to gain insight into the functioning of the different cell components participating in calcium dynamics.
Two kinds of cell organelles – the mitochondria and the endoplasmic reticulum – participate in calcium communication. Both act as reservoirs of calcium ions and are equipped with the ability to both release calcium into the cytosol and to absorb it from there. The amounts of calcium ions absorbed and released depend in a complicated manner on the concentration of calcium ions already present in the cytosol. For example, channels releasing calcium from the endoplasmic reticulum become increasingly permeable when the concentration in the cytosol

slightly increases but close completely as soon as the concentration becomes very high. Thus, the properties of different waves are determined by the interplay between concentration in the cytosol and permeability of the different channels.
Calcium waves form dynamical patterns such as rotating spirals. From their experiments, biologists had already known of the correlation between structure and properties of patterns formed by calcium waves. But an in-depth analysis of this correlation became possible only with the availability of a mathematical description, which combines the numerous factors and identifies the interactions within the system.
Experiments had shown that the spiral patterns disappear as soon as the mitochondria become more active than usual. It became clear that one might obtain important information from understanding the vanishing of the patterns. Calculations made it possible to demonstrate the correlation between the waves' properties – length, period and amplitude – and the calcium exchange. It turned out that calcium uptake and calcium release by the mitochondria prevent particular periods of spiral waves. Thus, mitochondria act as frequency filters. Since the information transmitted by the calcium signal is coded in the frequency, the mitochondria play a crucial role in the calcium communication.
The existence of "forbidden" frequencies had not been known before in the theory of pattern forming systems – the theory, Falcke applied in his work on calcium communication. This shows that both sides profit from the cooperation: on the one hand, the theoretician helped understand the results of biological experiments; the biologists, on the other hand, gave a stimulus for physical research that led to novel results.
Subjects of a further study were the pumps transporting calcium ions back into the endoplasmic reticulum. Surprisingly, an increase in the number of pumps led to an increase in the concentration amplitudes in the cytosol. Calculations suggested that the increase in pump performance together with the calcium transport out of the cell's neighbourhood lead to an increase in the calcium level in the storage. When the channels open, more calcium is released. Measurements confirm these predictions.

■ New Neutron-Guide Hall at HMI

December 9, 2003 marked the starting point of a new era for the Berlin Neutron Scattering Center (BENSC) at the Hahn-Meitner Institute: Representatives from the German Federal Ministry of Education and Research (BMBF) and the local government participated in the ground-breaking ceremony for a second neutron guide hall.
This hall will be erected adjacent to the existing guide hall. It will cover an area of about 1000 square meters and reach a height of 14 meters. An innovative neutron guide system using advanced supermirror optics will deliver a total of two times more neutrons to the instruments in the new hall than are delivered by the three remaining guides in the old hall. Its heart will be a $75\ \mathrm{m}$ long ballistic guide with a multispectral beam-extraction device. Thanks to a front end facing simultaneously the thermal source (reactor core) and the cold source, this ballistic guide will deliver both thermal and cold neutrons under good intensity conditions over an exceptionally broad wavelength range between 0.7 and $20\ \mathrm{Å}$.
This broad wavelength range will be used by a novel time-of-flight diffractometer, the Extreme Sample Environment

Laying of the foundation stone for HMI's new neutron guide hall Prof Michael Steiner, scientific director of the Hahn-Meitner Institute, and the architect Bernd Tibes fill a metal box to be immured in the hall's foundations with artefacts typical for the time of the building's erection.

Diffractometer (EXED), installed at the back end of the ballistic guide. It is the time-of-flight approach in combination with the multi-spectral beam that makes EXED an ideal instrument for neutron scattering experiments at highest magnetic fields. Specifically for use at EXED, HMI, in cooperation with the Forschungszentrum Karlsruhe (FZK), strives to realize a $25\ \mathrm{T}$ superconducting tapered solenoid magnet. This is a further step towards HMI's ultimate goal of reaching $40\ \mathrm{T}$. (For a more extended description of EXED see Highlight report on page 46.)

The blue-gray guide hall II will be attached to the existing guide hall I. The increased height of the building will allow for handling extreme environment facilities in the hall as well as for hosting laboratory and instrument control containers on three levels.

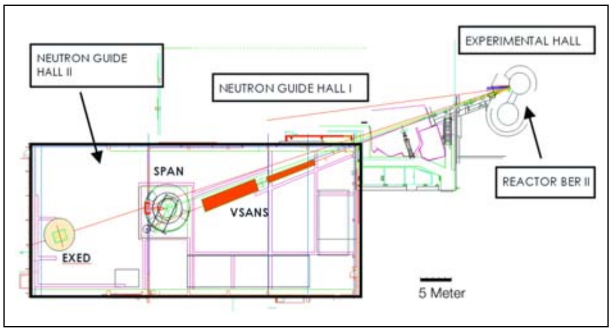
The second new instrument in the new guide hall will be a Very Small Angle Neutron Scattering (VSANS) machine. It is due to the response from an increasing demand from the life sciences user community. Compared to the traditional SANS technique, VSANS will extend the accessible momentum range by an order of magnitude towards smaller values.

The construction of guide hall II is progressing rapidly. Within six months the basement and the large media tunnel for the EXED instrument were completed.

Finally, the existing wide-angle spin-echo spectrometer SPAN will be moved to the new hall. There it will profit from the considerably higher flux provided by the new neutron guides.
As to the planned schedule, the hall itself is expected to be finished by fall 2004. The extraction assemblies for the new guide system will be built into the reactor core during a reactor shut-down from September to December 2004. Both new instruments will become operative by end of 2006 and, finally, the superconducting solenoid magnet allowing for neutron scattering experiments at fields of up to 25 T will become available in 2008.

■ HMI start-up: Sulfurcell wants to manufacture large area solar modules

The HMI start-up Sulfurcell planned to manufacture large area CIS solar modules applying a process developed at the HMI. The first goal of the enterprise is it to transfer the technology which was developed for small modules to the marketable module format 1.2×0.6 m² and to adapt it to the manufacture conditions of an industrial production. This project is designated as up-scaling and Sulfurcell can fall back to established mechanical engineering, whereas the large are processes and individual components of the equipment must be developed by the company itself. The second substantial task consists of guaranteeing the durability of a solar module. The today's manufacturers offer warranties of up to thirty years on the power output of their products. Solar modules must withstand changing and extreme climatic conditions during this period. The layer system of a CIS module reacts with sensitive power losses to dampness influence and therefore it must be encapsulated. The HMI has begun to work on encapsulation techniques and good progress could be obtained. The tasks are still not completely solved, and Sulfurcell reck-on time-intensive series of tests, in order to be able to ensure the stability requirements.
Sulfurcell counts for the development work on the competencies and motivation of the own team and on the experiences of its partners. A network branched out far connects the enterprise with research institutions and industrial enterprises. A license and a co-operation contract was concluded with the HMI. The Institute will continue to carry out research on this type of solar cells and the close co-operation will be maintained.
The manufacturing plant of Sulfurcell is located in the new quarter for science and economics, in Berlin Adlershof. In a 1,200 m² large production hall the first machines started there at the end of the year 2003. Up to twenty employees will work on the development of the production process. By the year 2006 Sulfurcell wants to place CIS modules on the market and expand the production capacities.



Layout of Neutron Guide Hall II

The HMI holds the top position in the international research on Copper Indium Sulfide (CIS): The material for photovoltaic is for more than ten years under research. Already seven years ago the transition took place to industrial typical coating techniques, in order to ensure the applicability of the results. By the continuous research work it was succeeded to establish a standard technique, which supplies regularly solar cells with a mean efficiency of 11 %. In the meantime the HMI holds the world record for the best CIS solar cell (0.5 cm², efficiency 12.7 %) and the best small module (5×5 cm², efficiency 9.7 %). Research successes of the HMI suggest further progress for the coming years with the increase of the efficiency. The innovation potential of the technology is today already so interesting that the recently founded enterprise Sulfurcell concluded a license agreement with the HMI in order to use the technology in an industrial pilot production. The reasons are first of all the cost reduction potential of the technology, secondly the high energy yield of the CIS modules and thirdly their favorable environmental balance:

1. The cost analysis for a potential production showed that CIS modules can be manufactured at least 50 % more cost effective than the solar modules from crystalline sili-

The manufacturing plant of Sulfurcell in Berlin Adlershof

con dominating the market today. The utilisation of small amounts of semiconductor material as well as the favorable manufacturing methods contributes to the cost reduction. The employment of a thin film system in place of a crystal wafer from electronic-grade silicon reduces materials requirements to a hundredth and makes it possible to use simple glass as substrate for the photovoltaic active layers. The thin films of a CIS module can be manufactured using the large area coating methods of the glass industry and do not require the batch processing of small wafers, which is necessary with crystalline silicon modules.

2. CIS modules are placed with almost 10 %-efficiency in the mid range, concerning the energy yield per efficiency per cent they are at a top position. The energy yield of a solar module is determined only insufficiently by the frequently discussed efficiency. The (standard) efficiency is the relationship of the produced electricity to the irradiated light energy measured in the laboratory (noontime sun exposure, 25°C module temperature). Under real environmental condition solar plants work frequently at higher temperatures and under smaller incident light radiation than under laboratory conditions. Under these conditions CIS modules supply a substantially higher energy yield than silicon or CISe modules. Thus Fraunhofer Institute for Solar Energy Systems computed for the location Florida that a CIS solar cell achieves with 10,4 %-efficiency the same energy yield as a CISe solar cell with 12,8 %. Besides, the energy yield of a CIS module is little affected if parts of the module are shaded. Hard shadows of masts, trees or house walls impair their efficiency substantially less, than it is to be observed with silicon modules.

3. The CIS technology is frequently referred to as "CIS of the 2. Generation" and it can count on very good market chances. A substantial reason is the outstanding environmental balance of the CIS technology. The Technical University of Berlin evaluated the environment-friendliness of a potential CIS production and provided an environmental balance. CIS modules need only one year in order to return the energy needed for their production. Causes are the absence of high temperature steps and the use of the highly reactive sulphur. In addition, due to the avoidance of selenium and the small heavy metal content in the CIS modules, their toxicity is on the low level of crystalline silicon modules.

The success of Sulfurcell is now to be measured at the results of the development and success at the market. The crucial steps of the transfer of technology are still in store for the enterprise: Up-scaling of the technology and set up of a stable production and product development. We dependent on partnerships – Hahn-Meitner Institute is the most important and will be in the future, on its research work and support we build. For all aids and fellow combatants applies our cordial thanks.

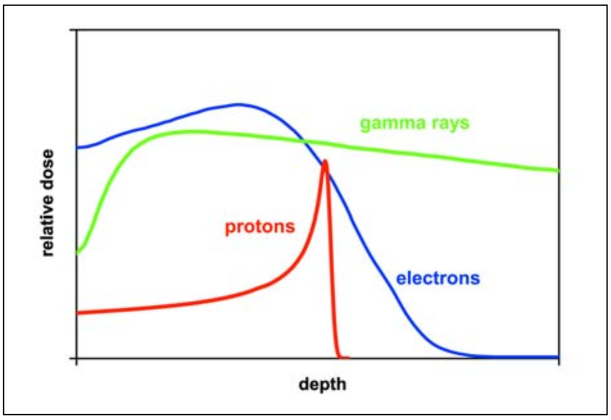
Nikolaus Meyer, Sulfurcell

5 Years of Experience in Proton Therapy for Ocular Tumours in Germany

In June 1998 proton beam therapy of ocular tumours was introduced at the Hahn-Meitner Institute. Thus, this very efficient method of treating cancer of the eye became available in Germany for the first time. Since then, more than 400 patients have been treated successfully. From its beginning, the treatment was conducted in cooperation with the University Hospital Benjamin Franklin (now Charité – Campus Benjamin Franklin). In late 2002 the University Hospital Essen became the second cooperating hospital.

Background

Most patients treated for eye cancer at HMI suffer from a choroidal melanoma – a malignant tumour of the choroid (the middle layer of the eye-ball composed of layers of blood vessels that nourish the back of the eye. The choroid, along with the iris and ciliary body, are also referred to as the uvea.). Between 500 and 600 new cases are notified in Germany each year. The tumour does not only endanger the eye's vision, but can be lethal due to the risk of



Dose distribution versus depth for different types of radiation. In contrast to electrons and gamma-radiation, protons deposit their energy in a very narrow area – the so-called Bragg peak. This property makes proton beams particularly suited for the treatment of eye-tumours: they destroy the tumour leaving surrounding healthy tissue virtually unharmed.

metastasis. Therefore, the removal or destruction of the tumour is of essential importance for the patient's survival. But, in addition to local tumour control as a primary goal, the objective of a curative therapy is the retention of the patient's vision.
Therefore, enucleation – the complete removal of the eyeball – is increasingly replaced by a variety of surgical, laser or radiation therapies.

Proton therapy

At HMI ocular tumours are treated with high-energy protons (68 MeV) provided by the accelerators of the Ion-Beam Lab ISL. In contrast to other kinds of radiation applied in tumour therapy, high energy protons deposit almost the whole dose in a rather small well-defined region – a fact reflected in the Bragg peak in the dose distribution (Fig. 1). This makes proton therapy particularly suitable for those cases where the tumour is located in the vicinity of critical structures like the optical nerve, the optic disc or the macula that would be damaged in other forms of radiotherapy. By exactly forming the proton beam's cross section and adjusting its energy, it often becomes possible to avoid these critical structures during the irradiation.

Study shows high quality of treatment at HMI

In a recent study, the treatment outcome for patients with uveal melanomas has been evaluated.

Material and Methods

245 consecutive patients with primary mela-noma of the uvea have been treated from June 1998 to April 2003 at HMI. In 96.2 % of all patients a uniform fractionation scheme was applied. It consisted of single doses of 15 CGE (Cobalt Gray Equivalent), and a total dose of 60 CGE applied on 4 consecutive days. Follow-up is available for 229 patients. Since May 2000, 45 of the patients with large tumours of at least 5 mm prominence have been treated with an endoresection – the surgical removal of the irradiated tumour – following proton beam treatment.

Results

The study population in general and the subset of those treated with an endoresection were comparable in terms of age (median 60.9 years vs. 58.7 years) and visual decimal acuity (0.5 vs. 0.5). As expected, tumours treated by additional endoresection were larger (median prominence 8.8 mm vs. 3.5 mm, median base of the tumour 15.4 vs. 10.3 mm) and were not in direct proximity to critical structures as optic disc (median 2.3 mm vs. 1.5 mm) and fovea centralis (median 3.4 mm vs. 0.6 mm). At the time of median follow up (18.4 months) local control is 96.4 % and 95.5 % at 3 years. Eye retention rate is 92.6 % at 20 months (median follow-up) and 87.5 % at 3 years. The subset of patients treated with an endoresection did fairly well: Although those tumours were larger in volume, their outcome does compare favourably with the others. Local control is 98 % at 18 months (the time of median follow-up for this parameter is 18.1 months) and eye-retention rate is 88.6 % after 2 years.

Positioning of the patient during eye-tumour therapy
The patient's head is immobilized by means of a mask and a bite block, both custom made.

Conclusions

Proton beam irradiation of uveal melanomas at the Hahn-Meitner Institute after the first 5 years of its initiation reveals local tumour control- and eye-retention rates in the range of other centres with larger experience. Delivering high treatment quality in hadron therapy from the beginning has been achieved. As there will be a learning curve as documented in other centres, there is hope for a further rise in results with increasing experience and a longer follow-up period. The concept of endoresection after proton beam irradiation seems promising but will need further evaluation with more patients and a longer follow-up period.

Outlook

The promising results achieved in the treatment of ocular tumours and the growing knowledge gathered over the years would seem a reasonable basis for a large scale proton therapy centre jointly run by HMI and Charité medical school.

Authors of the study:
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■ Trace element research: Towards New Frontiers and Good-bye to an Old Campaigner

(Workshop on *Metalloproteins and Metalloidproteins* and colloquium in honour of Prof. Dietrich Behne on his retirement from the HMI)

It is a well-known fact that several elements, although they are present in the organism at only very low concentrations, are none-the-less indispensable for maintaining human and animal health. Recent research has indicated that most of these essential trace elements are bound to

proteins and that their biological effects are thus due to the functions of a multitude of specific trace element-protein-complexes. With the recent advances in biochemical and molecular biological methods and in the physical and chemical analytical techniques, we now have the tools to study these compounds, especially with regard to their biological roles and to their applicability in the diagnosis and therapy of diseases. At our department Molecular Trace Element Research in the Life Sciences we are mainly concerned with the identification and investigation of novel metallo- and metalloidproteins and, with the multidisciplinary know-how available in our group and the possibility of combining modern methods from both the life sciences and trace element analysis, are at the cutting edge in this field.
Our involvement in this area triggered the idea to initiate a workshop series on Metalloproteins and Metalloid-proteins and in this way to bring together the German research groups from the different scientific disciplines which are concerned with metalloprotein research, establish contacts between these groups and encourage or intensify interdisciplinary collaboration.

Prof. Dietrich Behne welcoming the participants of the Workshop on *Metalloproteins and Metalloidproteins*

The second annual meeting of this series, organized together with the Gesellschaft für Mineralstoffe und Spurenelemente (GMS) was held at the HMI from Nov. 6–8, 2003, Its multidisciplinary character was underlined by the fact that amongst the 150 participants there were physicists, crystallographers, mathematicians, chemists, biochemists, molecular biologists, pharmacologists, nutritional scientists, dieticians, and physicians. 34 lectures and 18 poster presentations dealt with analytical aspects, redox processes, antioxidative systems, interactions between metals and proteins, and pathobiochemistry. The studies showed that with the advances in the development of specific chemical, physical, analytical, crystallographic, mathematical, biochemical and molecular biological methods and their appropriate combination, trace element research is being pushed towards new frontiers. The contributions from out department included a plenary lecture, two lectures and 9 poster presentations. One of them by K. Bukalis et al. on trace-element containing proteins in the lungs received the first prize of the poster awards, and the Heinz-Zumkley Prize, donated by the GMS, was awarded to Dr. Andrea-Nicole Richarz from our department for her PhD thesis on the analysis of metal-containing proteins.

Colloquium in honour of Prof. Dietrich Behne

A colloquium in honour of Prof. Dietrich Behne, the head of our department and an old campaigner in this field of research, on his retirement from the HMI was incorporated into the conference. Prof. Behne has had a long-standing relationship with the HMI, having started here as a chemistry student in autumn 1962 with his diploma thesis, followed by his dissertation, both with Prof. Zimen in nuclear chemistry on the separation of isotopes. After his PhD he moved to analytical chemistry and radiochemistry and began studies on the determination of trace elements by means of neutron activation analysis and radiochemical methods. From 1968 to 1970 he worked in England at Reading University and at the nuclear centres in Harwell and Aldermaston to deepen his knowledge of neutron activation analysis of biological materials. After his return to Berlin he introduced these methods and their application in the life sciences as a novel area of research at the new nuclear reactor BER II and also taught analytical chemistry and radio-chemistry at the Freie Universität Berlin. He did not content himself, however, with purely analytical tasks, but extended his studies in trace element research more and more into the biochemical and medical fields. Over the years this resulted in the development of a unique multidisciplinary research group in which, in addition to neutron activation analysis, synchrotron radiation X-ray fluorescence and other analytical methods, radiotracer techniques, nutritional studies on laboratory animals, cell culture experiments and various biochemical and molecular biological procedures are being combined in order to investigate the biological functions of the trace elements and their role in health and disease. In his laudatio, Prof. Köhrle from the Institute of Experimental Endocrinology at the Charité emphasized Prof. Behne's scientific versatility and his expertise in several different disciplines as one of the outstanding characteristics of his scientific career and thebasis for his achievements and success. Accordingly his publications cover a wide range of themes including methodological studies on the development and use of element analytical methods and radiotracer techniques in the life sciences, the combination of these procedures with biochemical and molecular biological methods, studies on trace element biochemistry and trace element metabolism, medical studies on the role of trace elements in health and disease and metalloprotein research. The most important contributions have, however, been his studies in selenium research where he detected that this trace element is present in the body in the form of numerous selenoproteins with key functions in the mammalian organism and that an insufficient selenium supply may lead to serious diseases. His discovery that a selenoenzyme is responsible for the production of the thyroid hormone T3 and that thus not only iodine but also selenium is needed for a normal thyroid hormone metabolism, has

had a great impact in thyroid endocrinology, and due to this finding the selenium status of patients is now taken into consideration in hospitals in the diagnosis and treatment of thyroid hormone-related diseases. In recognition of this work Prof. Behne was awarded the Klaus-Schwarz Commemorative Medal in 1991 for the identification of the type I deiodinase as a selenoenzyme and the elucidation of the role of selenium in thyroid hormone metabolism. His recent finding that another selenoenzyme is necessary for the normal development of the sperm and thus for male fertility may gain similar importance in the diagnosis and treatment of human male infertility.
Although considerable progress has been made in research on trace elements and trace element containing proteins since Prof. Behne first began his studies, many questions still remain to be answered and, with the research project Selenoproteins and Metalloproteins as part of the programme Environmental Health within the Helmholtz Association, the department will continue this work.

Antonios Kyriakopoulos, SF6

■ Outstanding, rapidly done with open mind

Adlershof thesis award for physicist of the Hahn-Meitner Institute

The city for science, economics and media assigned for the second time the Adlershof thesis award for outstanding work of its scientific new generation. The 32 years old physicist Dr. Christoph Böhme received the award endowed with 3.000 Euro in the context of the Adlershofer Campus week on December, 3rd, 2003. Founders of the award are in equal parts the Joint Initiative of Non-University Research Institutions in Adlershof (IGAFA), the Humboldt University Berlin (HU) and the WISTA MANAGEMENT Ltd.
The awarded thesis of Christoph Böhme "Dynamics of charge carrier recombination" was prepared under the supervision of Prof. Dr. Walther Fuhs at the Silicon Photovoltaic Department of the Hahn-Meitner-Institute located in Adlershof in only 27 months and was accepted in January 2003 at the Physics Faculty of the University of Marburg with "summa cum laude".
Christoph Böhme developed in his work the theoretical and the experimental basis for a new measuring method (pulsed electrical detected magnetic resonance, pEDMR) for the analysis of defects in semiconductor layers and devices. The analysis of defects is a pre-condition for the increase of the capability of semiconductor components, particularly regarding their miniaturization. With his measuring method the laureate enters not only new ground in the material sciences, but gives also a substantial new stimulus for the spin-based quantum computing. Böhme's work was already published in twelve renowned technical periodicals, presented at international conferences; a patent request for the measuring method is posed. The laureate studied in Heidelberg and at the North Carolina State University (the USA) and acquired in parallel the German Diploma in Physics and the Master of Science.
Since 2002 he works as a scientist at the Hahn-Meitner-Institut in Adlershof.
The Adlershof thesis price is to document the quality of the research and the co-operation of science and economics in the biggest German science and technology park. Decisive for the award is scientific excellence (mark, number of the publications and patents, appraisals) and graduation duration.

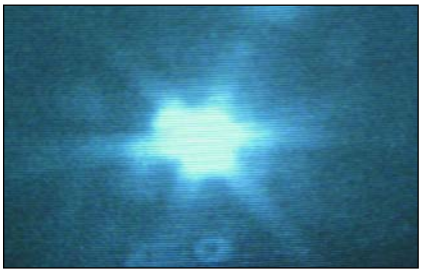
Source: IGAFA, science office

■ First light from the 7-Tesla Wiggler

Almost as an early Christmas gift to themselves, on December 11 2003 HMI scientists working at the Berlin electron storage ring BESSY in Berlin-Adlershof for the first time opened the beam shutters to allow x-rays produced by the 7-Tesla wiggler to enter their beamlines. On a fluorescence screen, this radiation was registered as "first light" (see picture). The wiggler belongs to the class of insertion devices – special magnetic structures built to create extremely intense x-rays. No other insertion device world-wide has as many poles with such a high magnetic field in a comparatively small space. Thus, it is the strongest source of hard, penetrating x-rays at BESSY. In the five years preceding the first light, this unique device was planned and developed in close collaboration between HMI and BESSY and, finally, built by the Budker Institute in Novosibirsk (Russian Federation). As the machine reaches the frontiers of what is feasible today in this field, a number of technical problems had to be overcome before the first successful tests. Now the radiation from the wiggler is available to supply the beamlines and experimental stations built up by HMI's scientists.

HMI's 7-Tesla wiggler at BESSY

The radiation produced by the wiggler will be used in materials research, magnetism and other fields of structural research. As part of the BENSC user-service, the experimental facilities at the wiggler beamlines will be available to external researchers from universities and other scientific institutes. The new facilities complete the suite of experimental opportunities available at BESSY. Several of the more than 40 experimental stations operated at BESSY



First light from HMI's 7-Tesla wiggler visible on a fluorescence screen. December 11 2003, 12:00 Noon

are run or used by HMI. Among these is an experimental station for the investigation of magnetic nanostructures and thin magnetic films (cf. Highlight Report page 32) installed at an undulator – another insertion device built in close HMI-BESSY collaboration. With the inauguration of the wiggler, synchrotron radiation becomes – in addition to neutrons and fast ions available in Berlin-Wannsee – the third main pillar of structural research at HMI.

Ralf Feyerherm, SF2

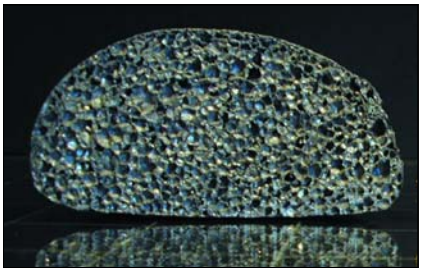
■ Materials department inaugurates new metal foam lab at TU-Berlin

Aqueous solutions, polymers and glass can be foamed. For a long time scientists have had the ambition to foam metals in order to create novel materials combining the advantages of the unique foam morphology with the known properties of metals. In the past 10 years, many new processes for making metal foams – mostly from aluminium or aluminium alloys – have been developed to such a level of sophistication that more and more industrial applications are emerging. There are two main ways of producing metal foams: the powder metallurgical foam production route and the gas injection route. In the former case, metal powder is mixed with a powdered blowing agent and subsequently condensed. When heated, the metal melts and the blowing agent produces a gas that creates the bubbles in the foam. In the latter case, a gas is injected into the molten metal creating the foam structure. Although metal foaming technology is quite advanced now, the properties of metal foams and the physics of metal foam generation and evolution are only starting to be explored.

The metal-foam group formed around Prof. John Banhart (HMI, SF3 – Materials) is working on the characterisation of the foaming process of metals and metal alloys. The group is looking for ways to improve current manufacturing processes and to develop new ones. Since late 2003, this work has been done at the Technische Universität Berlin, in cooperation with the Hahn-Meitner Institute. Two main labs are available: the x-ray-lab, where both foaming methods are investigated, and the main lab dedicated to research on the powder metallurgical route. Here, powder mixing and milling machines, metallic sieves, a 100 tons hot press and several foaming furnaces are available. With this equipment, the whole process from the precursor material production to the foaming itself can be performed and all production parameters can be adjusted for the investigation.

For the real time in situ analysis of the foaming process, a microfocus x-ray measurement place was designed and built. X-ray radioscopy is used to resolve the internal pore structure during foaming and observe the foaming dynamic. The measurement place is supported by a picture-analysis software that allows calculating the foam expansion, find the critical cell-wall thickness and measure coalescence rates.

In the near future, the acquisition of a specially designed dilatometer is planed. This facility will allow analysing the formation and decay of metal foams in a form applying various in-situ-foaming techniques. This way, time-dependent volume expansion can be easily monitored.



A zinc foam

The scientists of the metal-foam group are interested in the phenomena and mechanisms responsible for the formation and stabilization of pores in the metal foaming process. If one wants to study the very early stages of foaming, i.e., stages in which the pores are just being formed, one has to apply methods that act on the appropriate length scales which range from some tens of nanometres to several micrometers. Optical or electron microscopy is suitable for investigations whenever two-dimensional information is sufficient. High-resolution x-ray tomography allows for a precise determination of three-dimensional features. Often, however, one is less interested in mapping individual pores, but wants to obtain a three-dimensional average of a pore size distribution. Such distributions can

An x-ray radiograph of a 10 mm slice of aluminium foam be useful, for example, as input data for model calculations of the foam generation process. Ultra small-angle neutron scattering (USANS) is a promising method for obtaining this information because scattering of cold neutrons at very small wave vectors provides data in exactly the size range required.

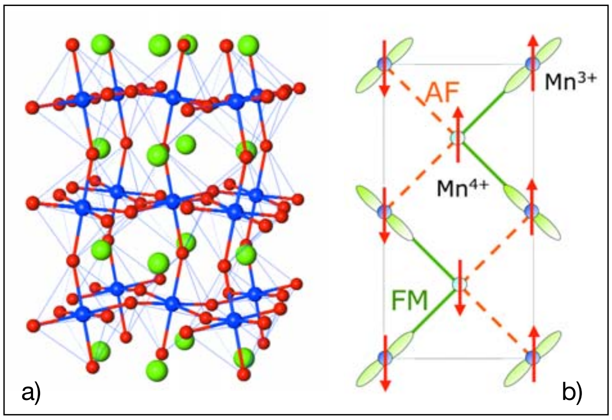
Francisco Garcia-Moreno, SF3

HMI hosts Workshop on Orbital Physics and Novel Phenomena in Transition Metal Oxides.

The physical properties of complex transition metal oxides (TMO) are driven by a rich interplay between charge, spin, and lattice interactions. Nature has already shown how powerful this interplay is in these materials: superconductivity with the highest critical temperatures, ferroelectricity with exceptional dielectric response, colossal magnetoresistance, and negative thermal expansion from 2 to 1400 K. TMOs are an exceptional laboratory for studying a variety of interactions on the nanoscale lengths where they compete.

Participants of the HMI Workshop on Orbital Physics and Novel Phenomena in Transition Metal Oxides

An example of the competition between charge, lattice and spin degrees of freedom is in the doped manganites perovskites. Here a magnetic interaction propagated by a hopping charge (double-exchange) competes with an enhanced electron-phonon coupling via the Jahn-Teller active Mn^{3+} ion. At the right electronic doping this competition produces a transition from the ferromagnetic-metallic ground state to an insulating state at elevated temperatures, with a change of resistivity of several orders of magnitude. The orbital configuration of the Mn^{3+} is important in these materials as the sign of the exchange (antiferromagnetic or ferromagnetic) is controlled by the polarization of the e_g orbitals (see figure).
A workshop on Orbital Physics and Novel Phenomena in Transition Metal Oxides was hosted at the Hahn-Meitner Institute on the 24th and 25th of September 2003 to discuss the latest developments in this exciting area of research. The meeting was attended by about 50 participants from Germany and greater Europe, twice as many as last year's workshop. Talks focused on both recent experiments and new developments in theory. For example Orbital Ordering and the role of orbitons in $LaMnO_3$ was discussed by Rilana Krüger (University of Hamburg) while Sylvie Hébert (CRISMAT, Caen) presented recent developments in the field of cobalt oxide thermoelectric materials. Theoretical work on charge ordering in manganites was presented by Daniel Komskii (University of Cologne) with significant contributions from Peter Horsch and Giniyat Khaliullin (Max Planck Institute for Solid State Research, Stuttgart) on frustration and orbital ordering in manganites and titanates.
Participants from the Hahn-Meitner-Institut presented work on the lattice dynamics (Heloisa N. Bordallo, HMI, SF1 – Methods and Instruments), and magnetic short range ordering in CMR manganites (Jens-Uwe Hoffman, HMI, SF2 – Magnetism), while Christopher J. Milne (HMI, SF2) presented recent work on the synthesis and structure of a newly discovered novel superconductor $Na_xCoO_2 \cdot yH_2O$. The synthesis of nano-clusters of transition metal oxides was discussed by Abdelkrim Chemseddine (HMI, SE4 – Dynamics of Interfacial Reactions). This workshop so far has stimulated significant interest in transition metal oxides both within HMI and in the wider community. Currently partly due to this workshop efforts are underway to seek funding from the German Research Foundation (DFG) for such work under a Priority Programme (Schwerpunktprogramm). In addition collaborations between HMI and other groups are beginning. Currently there is a samples synthesis effort in the department SF2 for the fabrication of powder and single crystals samples of various interesting TMOs such as manganites and superconducting $Na_xCoO_2 \cdot yH_2O$, while the BENSC



a) Crystal structure of a typical manganite perovskite. Mn atoms bond to O-atoms (red) to form MnO_6 octahedra (shown in transparent blue). The darker blue spheres are typically trivalent or divalent rare earths. A mixture of 3+ and 2+ rare earth elements is used to electronically dope these materials.
b) Focusing only on the electronic configuration of the Mn atom we illustrate the importance of orbital degrees of freedom for an ordered arrangement of Mn^{3+} and Mn^{4+} ions in a perovskite. The interaction shown as a solid line is ferromagnetic (parallel spins) as a filled Mn^{3+} e_g orbital points towards a Mn^{4+} ion (which has a vacant e_g orbitals). Interactions between vacant e_g orbitals lead to antiferromagnetic superexchange (dashed line).

user program routinely provides beam time to investigate these materials from groups throughout Germany and Europe.
This meeting was sponsored by both the HMI and the University of Hamburg (Michael Rübhausen). The organizers are grateful for the participation of Marie Haltod.

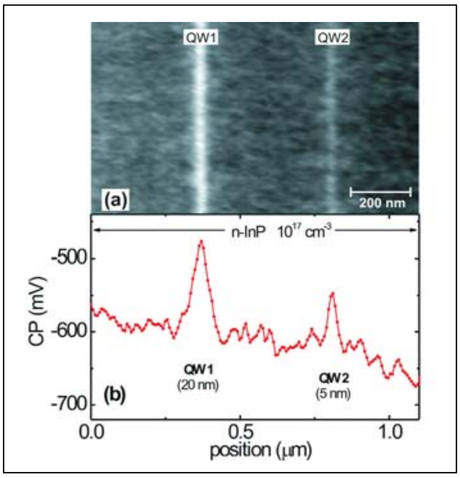
Dimitri N. Argyriou, SF2

■ Development of a new Kelvin-Electronic for Omicron GmbH

For the measurement of the absolute work function on nanometer scale and meV sensitivity with Kelvin probe force microscopy (KPFM) a second feedback circuit in standard non-contact atomic force microscopy (NC-AFM) is needed. To separate the information of the tip-sample interaction induced by the Van der Waals forces (used for the topography measurement) and the electrostatic forces, which is induced by the contact potential (CP) between tip and sample, an additional ac-voltage is applied between tip and sample. With lock-in technique the oscillation amplitude of the electrostatic force induced by the ac-voltage can be determined and minimized by a compensating dc-voltage which is applied to the sample. This compensation voltage corresponds to the CP and can be used to calculate the work function of the sample when knowing the work function of the tip. For NC-AFM in ultrahigh vacuum (UHV) the first resonance frequency of the cantilever (~70 kHz) is used for the detection of the topography. A resonant and therefore very sensitive way of detecting the electrostatic force separately but simultaneously to the topography is the use of the second resonance frequency of the cantilever (~420 kHz) for the ac-voltage. In this setup ac-amplitudes as small as 100 mVpp can be used, which is especially important for measurements on semiconducting samples to avoid a tip induced surface band bending.
Omicron nanotechnology is one of the world's leading supplier of solutions for analytic requirements under UHV-conditions in the fields of surface science and nanotechnology especially regarding scanning probe microscopy. Ch. Sommerhalter started in 1998 at the HMI to implement the Kelvin-mode for measuring the work function simultaneously to the topography in a UHV-AFM manufactured by Omicron. After 4 years development and successful utilization of this novel technique in the scanning probe group of SE2 we started a cooperation with Omicron to develop a complete electronic setup for commercialisation. This setup consists of specially designed high and low pass filters to separate the signals of the first and second resonance frequency of the cantilever, a PI-controller to minimize the lock-in signal by applying an adequate compensation voltage and an adder to combine the ac- and dc-signal which are applied to the sample. Very high requirements are imposed on all parts regarding the frequency and phase stability, exact determination of the time constant and proportional gain and the noise level which is the lower mV range. The HMI department of electronic development (DH), especially B. Namaschk, was deeply involved in the fast and successful realization of this project. Omicron successfully launched the Kelvin-electronics as a product in the fall 2003.

Thilo Glatzel, SE2

■ Quantum Well structures measured by UHV-Kelvin Probe Force Microscopy in cooperation with KTH – Stockholm



KPFM measurement on the InGaAs/InP quantum well structure showing two quantum wells. a) Contact potential (CP) image (contrast ΔCP = 230 mV). b) Typical single line scan showing the quantum wells.

Within the HERCULAS project a student (Olivier Douheret) from the Royal Institute of Technology (KTH) in Stockholm joined the KPFM group of SE2 in the summer 2003. The EU-project is focused on the qualitative and quantitative determination of the doping concentration with scanning probe techniques, e.g. SSRM, SCM and KPFM. Within this cooperation we succeeded to characterize the electronic structure of InGaAs/InP quantum well by cross-sectional Kelvin Probe Force Microscopy (KPFM) measurements in ultrahigh vacuum. The KPFM signal, as presented in the figure, have clear peaks at the position of the quantum wells, showing a systematic trend for different wells. It was demonstrated for the first time that UHV-KPFM is capable of detecting quantum wells as narrow as 5 nm. The results lead to a clear evidence for charge carrier accumulation in the quantum wells. Complete quantitative analysis of quantum well properties is impeded by a tip averaging effect and due to surface and oxide interface states. In the future complete 3D-Poisson/Schrödinger simulation including these effects will be used to extract the charge carrier concentration accumulated in the quantum wells.

Thilo Glatzel, SE2