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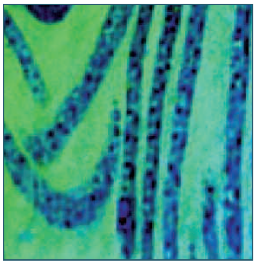
cover picture: The group Physikanten & Co. See the article p. 8



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Friedrich Wagner

THE VALUE OF BASIC RESEARCH

›››EDITORIAL

Between my writing this editorial and you reading it lays December 10th, the day, when the Nobel Prizes were awarded in Stockholm. It was a good year for science in Europe that the Nobel prizes for chemistry and physics went to three European physicists, Gerhard Ertl, Albert Fert and Peter Grünberg. On behalf of EPS, I would like to congratulate the three laureates for their outstanding scientific achievements.

Albert Fert (Université Paris-Sud) and Peter Grünberg (Science Centre Jülich) shared the Nobel Prize in physics for the discovery of "a totally new physical effect – Giant Magnetoresistance or GMR", which led to "the technology that is used to read data on hard disks". The Nobel Prize to Gerhard Ertl (Max-Planck-Society) "is awarded for groundbreaking studies in surface chemistry. This science is important for the chemical industry". In both cases the citation refers to both the results of fundamental research - a new physical effect and groundbreaking studies – and the importance of the discoveries for the development of new technologies in industry. The selection of the prize winners and the citations are in full agreement with the will of the prize founder who intended the prize for those "who shall have made the most important discovery or invention…".

It might be appropriate to use the occasion of these three prizes and the specific citations for some reflections on the value of basic research. I want to look at it from two perspectives – the inherent power of basic research on the one hand and the motivation of a scientist driven by her or his own scientific interests on the other. Grünberg came to his discovery because he was interested in the magnetic coupling of separated layers of transition metals; Fert was interested in spin-dependent transport phenomena.

As we know, basic research advances knowledge and is not primarily oriented to any practical or commercial purpose. It may lead to unpredictable and surprising results with unexpected applications in unrelated areas at any time in the future. Basic research is less driven by the question "what is necessary"; its potential is that it utilises the possibilities nature provides within a strict scientific methodology. Basic research does not stop when the intended goal is reached and the product is there and can be sold. For the Ertl's studies on the catalytic synthesis of ammonia, the technology existed since the beginning of World War I (Haber-Bosch-process). Nowadays, about

150 megatons of NH_3 are produced annually at a price of about 200 $/ton. The method worked and was used but the molecular processes in the presence of the catalyst were not understood and the chain of reaction steps was not sorted out. The energetics of splitting the firmly bound N_2 molecule was specifically unclear and debated. Ertl demonstrated the different reaction steps, and this knowledge may be of inestimable value for more complex reactions when the workhorses in catalysis like platinum run short and have to be replaced by more abundant materials. Black magic as a working principle will not suffice in this case.

Fundamental research operates with models under simplified conditions (*e.g.* Ertl studied single-crystal catalysts) in order to unravel the underlying leading principles and the mathematical description of the observed phenomena is an integral part of the work. Specifically Fert developed the quantum mechanical theory to understand the phenomena behind the GMR effect. Through models and theory, similarities are discovered in the leading principles of largely different systems, which help the process of understanding and directly lead to interdisciplinary approaches. Again, the work of Ertl can serve as proof: The oxidation of CO to CO_2 leads to regular spatial concentration patterns of CO and O at the surface of the catalyst in the form of spirals, concentric rings or waves. Similar spatial structures (and equivalent oscillations) are observed in physics (*e.g.* ionisation waves in plasmas), in chemistry (see above), and in biology (*e.g.* Ca-waves on frog eggs)[1]. The observed dissipative structures are typical for the self-organisation of non-linear, open systems. Basic research builds bridges to other research fields.

Because understanding is the goal and as there is no primary commercial interest, basic research eases the development of personnal contacts between scientists. All laudations on Fert and Grünberg praise the close friendship of the two and the view of A. Fert that personal relations are a necessity for success in research.

A scientist engaged in basic research follows her/his own interests. He has to fight against his own limitations and therefore, failure is rarely an option. This could be different in tasks which are pursued in the interest of an awarding authority. In this case an option is to demonstrate failure on the basis of mission impossible. The working principles of basic research are highly self-motivating and we all know colleagues who even surpass our own devotion and engagement.

I do not intend to construct an artificial discrepancy between basic and applied research. Applied research also progresses only using rigorous scientific principles and methods. My own field – fusion research – is goal oriented research with (still) many basic issues. I am aware of the close link between basic and applied research. In spite of his interests in basic phenomena, Grünberg immediatly realised the practical implications of his discovery. Nevertheless, it was Stuart Parkin from IBM who simplified the film technology and transformed the effect into a commercial product which allowed replacing induction coils in read-out heads. Disks with closely packed binary data can be employed and, owing to miniaturisation, integrated in products for daily use. All three of them, Parkin included, were honoured in 1997 by the EPS Europhysics Prize.

The discrimination between basic and applied research has historical reasons in some countries but it is mostly an aspect for the general public. It is common practice to ask a researcher for the spin-offs of his research and to assess his achievements on the basis of his answer. More critical is the one-sided orientation of research funding to applied problems and the disregard or even rejection of the values of basic research within the public and their political representatives. The reason is obvious because in this sphere, answers are generally more appealing than posing questions and the time scales of basic research do not fit into the world of instant return. There is also gross misunderstanding of curiosity-driven research. Some laymen think that this is a misuse of tax-payer's money; others suspect the freedom of science.

Europe's structures have made an important step to broaden the funding scope with the establishment of the European Research Council (ERC). The spirit of the "terms of reference" is expressed in formulations like "support the best science", "stimulate investigator-initiated frontier research", "focus on excellence", "encourage initiatives", "independence of early-stage investigators", "no predetermined priorities"… The overwhelming response to the first round clearly demonstrated the attraction and the need for such a programme. Close to 9000 proposals were considered which asked for 10 G€ of funding. Only about 300 M€ were available for the first call. The conclusion can only be to strongly increase the funds available to the ERC.

Will this happen? It is an irony that just the science ministers of France and Germany, the countries of the 2007 Nobel Prize winners in physics and chemistry, acknowledged in their meeting November 11^{th} in Berlin, that the Lisbon goals – 3% of the GDP to be spent for science - will not be reached. They concluded that this goal cannot be reached before 2015. One could speculate that the political perception of three Nobel Prizes for Europe is that things are not at all as bad as usually portrayed. This would ignore that the Nobel Prizes today reflect the appreciation of research decades ago. Fert and Grünberg published their ground braking papers in 1988 and got the Nobel Prize 20 years later. In any case, either Europe sets too ambitious and unrealistic goals, whose declarations serve the moment without any real implications for the future or Europe does not have sufficient authority and stamina to realise its plans. Both reasons erode the credibility of European visions. It is specifically for us to deplore this because we always believed in the future of Europe and we work for it in the field of science. ■

Friedrich Wagner,
President of the EPS

NOTE

1. The examples are taken from H-G Purwins, *Physik Journal* **6**, 21 (2007).

2007 EPS HIGH ENERGY PARTICLE PHYSICS »» PRIZE

The 2007 EPS prize for High Energy Particle Physics was awarded to Professors **Makoto Kobayashi** and **Toshihide Maskawa**, for their proposal [1] of a successful mechanism for incorporating CP Violation in the Standard Model (SM) of electroweak and strong interactions. The Kobayashi and Maskawa (KM) mechanism proposed in 1972, predicted the existence of a third family of quarks, much before their experimental discovery.

The phenomenon of CP violation is crucial for the understanding of the fundamental laws of Particle Physics and it has also profound implications for Cosmology. Indeed CP Violation is an essential ingredient [2] for baryogenesis, the generation of the observed matter-antimatter asymmetry in the Universe. The inclusion of CP violation in a realistic unified gauge theory, was a great challenge at the time that the Standard Model (SM) was formulated [3].

The SM is based on the gauge group SU(3) × SU(2) × U(1) with the left-handed fermions transforming as SU(2) doublets while the right-handed counterparts transform as SU(2) singlets. At the time when Kobayashi and Maskawa proposed their mechanism, only two generations of quarks were known: the up and down quarks forming the so called first generation and the strange and charm quarks forming the second generation. Actually, although the charm quark had already been proposed as an elegant solution [4] to the suppression of flavour changing neutral currents, it had not yet been experimentally discovered. So one had only two incomplete generations of quarks.

Quark masses are generated in the SM through Yukawa interactions involving the quark fields and the Higgs scalar which is also responsible for the generation of the masses of the gauge bosons $W^\pm$ and Z. Mixing among the various generations of quarks arises in the SM in a natural way, reflecting the fact that the quark mass matrices for the up (charge 2/3) and down (charge -1/3) quarks are diagonalised by different unitary matrices. If one denotes these matrices by $U^\dagger W$(for the up) and W (for the down), then the physical matrix mixing the quarks in the charged current interanctions, is $V_{CKM} = U^\dagger W$. The matrix V_{CKM} is designated in the literature by Cabibbo-Kobayashi-Maskawa (CKM) matrix and is the generalization to three generations of the Cabibbo mixing [5], proposed in 1963 to account for the relative strength of strange and non strange weak particle decays. This work was an important breakthrough at the time, for which Cabibbo received the 1991 High Energy Particle EPS prize.

The fundamental contribution from Kobayashi and Maskawa was pointing out that in a model with three quark generations one has in V_{CKM} a physical phase which violates CP. One of the special features of the KM mechanism of CP violation is the fact that it makes clear-cut predictions for a large number of physical quantities related to CP violation [6]. The B-meson factories Belle and BaBar at KEK and SLAC provided an impressive set of data, which has played a crucial rôle in the experimental verification of the CKM framework for mixing and CP violation. At the moment, there is a remarkable agreement between experiment and the theory of CP violation proposed by Kobayashi and Maskawa. This provides strong evidence that the CKM matrix with its built-in KM mechanism gives the dominant contribution to quark mixing and CP violation in the processes experimentally studied so far.

In spite of the enormous success of the KM theory, there is a strong motivation to assume that there are additional sources of CP violation beyond the CP violating phase present in the V_{CKM} matrix. One of the motivations stems from the fact that CP violation present in the SM through the KM mechanism is not sufficient to generate the observed Baryon Asymmetry of the Universe (BAU). A very promising framework to generate the observed BAU is leptogenesis [7] where one creates a lepton asymmetry, which is then converted into a baryon asymmetry. In the SM neutrinos are strictly massless. As a result, there is no mixing or CP violation in the leptonic sector of the SM. Therefore, the recent discovery of neutrino oscillations, pointing towards non-vanishing neutrino masses, provides clear evidence for physics beyond the SM. ■

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AURORA BOREALIS BREAKS NEW GROUNDS - AND OLD ICE

>>> ESF CONFERENCE REPORT

It can crush ice sideways and stay precisely on station to an accuracy of a metre. It can drill a hole 1,000 metres deep into the seabed while floating above 5,000 metres of ocean and it can generate 55 megawatts of power. So far, Aurora Borealis is the most unusual ship that has never been built, and it represents a floating laboratory for European science, a breakthrough for polar research and a very big headache for international lawyers.

Aurora Borealis will be the first ever international ship, the brainchild of the European Science Federation, the Alfred Wegener Institute for Polar and Maritime Research in Germany and the Germany Federal Ministry of Research and Education. Russia has announced that it will be a partner in launching this state-of-the-art research vessel, but other European nations may soon join the project. But a European ship represents a metaphorical voyage into unknown waters, the ESF Science Policy Conference learned November 29.

"We do not have a European flag at the moment so one nation has to be responsible. And if it is internationally owned, you can imagine the difficulty," said Nicole Biebow, manager of the project, and a scientist at the Alfred Wegener Institute. "We have to agree where this ship should have its home port. And what happens if there is an accident? Who is responsible if you have an oil spill on the ice, for instance?"

The ice over the polar seas masks millions of years of the planet's history: drilling is difficult in freezing conditions. Aurora Borealis will be the world's first icebreaker that is also a drilling ship. This sets unusual challenges for marine engineers: a vessel poised on top of 5000 metres of drilling rig cannot afford to move very much in any direction. But ice drifts, and currents and winds can alter in moments. So the ship will be designed not just to break the ice as it moves forward and astern, but also to port and starboard.

"We had some early ice tanks tests and they came up with a design that is able to break ice sideways," said Paul Egerton, head of the European Polar Board within the European Science Federation. "As the ice continually presses against the side of the ship, the pieces of ice go underneath the hull and are washed away by the propulsion system. There is also a kind of damping system so the ship can raise itself up and down vertically to break the ice. It has a propeller that can turn 360 degrees, linked to satellite navigation. A lot of the cruise ships now have this so they can navigate in a very small area. But the propeller also has to break ice: it has to be strengthened."

Tony Mayer, European Science Foundation & Conference Co-chair. Photo credit: Luísa Ferreira, ESF

Not only will the diesel-electric ship be the floating equivalent of a 55 MW power station, it will be an intellectual powerhouse as well. It will be probe the role of polar waters in global climate change. Drill cores from the sea floor could answer questions about the geological history of the Arctic Ocean, and other instruments will measure the transport of contaminants through the air, water and ice. The vessel could be home to 120 people, more than half of them scientists who need to go to sea to study the ice, the ocean beneath and the history of the deep sea floor.

It will be equipped with two "moon pools" in the bottom of the hull to give direct access to the open water beneath the ice, so that drillers can work in freezing conditions and biologists can launch underwater vehicles to study the mysterious processes that trigger an explosion of life in the polar seas every spring. The design and preparation of Aurora Borealis will continue until 2011. Builders could start assembling the hull in 2012, it could be cruising the oceans from 2014 – and it could begin answering some of the great questions of ocean science for the next 40 years.

The two-day Science Policy conference (28-29 Nov., 2007) Is ERA, a first step to GLOREA (Global Research Area), provides an occasion for policy makers to interact with the science community, the industry and charities from Asia and North America to discuss topics that are concerning the ERA such as Research Infrastructure, Peer Review: Benchmarking, Strategic Foresight, Young researchers development, Collaborative Research, etc. ■

Website (Conference):
www.esf.org/activities/science-policy/corporate-science-policy-initiatives/esf-science-policy-conference-assembly-2007.html

Photos:
www.esf.org/media-centre/photo-gallery/esf-science-policy-conference.html

Thomas Lau,
European Science Foundation
Email: tlau@esf.org
Website (ESF): www.esf.org

TURBULENCE AND WAVES IN SPACE PLASMAS

>>> CONFERENCE REPORT

On 9-14 September 2007, a course on "Turbulence and Waves in Space Plasmas" was organized by the International School of Space Science – ISSS - www.cifs-isss.org - in cooperation with the Consorzio Area di Ricerca in Astrogeofisica – CARA. The course was held at the Scuola Superiore G. Reiss Romoli (SSGRR), an excellent Hotel/School located in the medieval town of L'Aquila, 100 km east of Rome, Italy, surrounded by the beautiful mountains of the Gran Sasso d'Italia.

The course was the 4th event of the SERSES project (Series of Events on Relations in the Sun-Earth System and Space Weather - www.cifs-isss.org/sersesprogram.asp - aiming to provide a series of events in disciplines related to the Physics of this domain.

The course provided the opportunity for students to learn the main concepts at the basis of propagation of waves and generation/evolution of MHD turbulence in space plasmas and to compare theoretical model predictions with experimental observations. These topics were treated first in interplanetary space and then within the magnetospheric environment. The role played by turbulence in several aspects of solar wind behaviour such as generation, heating, high-energy particles acceleration, cosmic rays propagation and solar wind–magnetosphere coupling was particularly highlighted. The phenomenon of turbulence was also presented within the framework of the dynamics of complex systems. Magnetospheric MHD waves were treated with special attention to: generation and propagation mechanisms, cavity and field line resonances, nonlinear effects, interaction with energetic particles, magnetospheric diagnostic capabilities.

The school was organized in plenary sessions; there were 14 lecturers who gave a 90min lecture each. Twenty-nine students with graduate and undergraduate background from 12 different countries attended the school; they were also given the possibility to present their research activity during special oral sessions dedicated to them throughout the week. The directors of the course were: R. Bruno (IFSI-INAF, Rome, Italy), V. Carbone (University of Calabria, Italy), R.L. Lysak (University of Minnesota, USA), M. Vellante (University of L'Aquila, Italy). ■

Massimo Vellante, (L'Aquila, Italy)

▲ Group picture of the attendees of the Course "Turbulence and Waves in Space Plasmas". Moving from left to right, arrows indicate the directors of the school: R. Bruno, V. Carbone, M. Vellante, R.L. Lysak.

Conference announcements

EPIOPTICS 10

The 43rd Course of the International School of Solid State Physics, next summer, will be the school "Epioptics-10". It will be held in Erice (Italy), 20-27 June 2008. The school will bring together researchers from universities and research institutes who work in the fields of (semiconductor) surface science, epitaxial growth, materials deposition and optical diagnostics relevant to (semiconductor) materials and structures of interest for present and anticipated (spin) electronic devices.

>>> **Website:** www.ism.cnr.it/epioptics.html

SigmaPhi2008

The International Conference on Statistical Physics (SigmaPhi2008) will be held in Crete, 14-18 July 2008. It will cover all the fields of Statistical Physics.

>>> **Website:** www.polito.it/sigmaphi2008

ESCAMPIG-2008

Granada, Spain, will host the 19th Europhysics Conference on the Atomic and Molecular Physics of Ionized Gases (ESCAMPIG), July 15-19, 2008. The conference will bring together experienced and young researchers working in atomic and molecular processes in plasmas, plasma diagnostics, low and high plasma sources, plasma and discharges theory and simulation, physical basis of plasma chemistry, laser produced plasmas and, among other topics, plasmas and gas flows.

>>> **Website:** www.escampig2008.csic.es

CMD22

The 22nd General Conference of the Condensed Matter Division of the European Physical Society will be held at the University "La Sapienza", Rome, Italy, 25-29 August 2008. The conference will also host the 14th General Conference of the European Physical Society, EPS14, in a special half-day session.

>>> **Website:** www.cmdconf.org

SPREAD OF SHOW PHYSICS IN EUROPE

K. Susman[1], **J. Bajc**[1], **J.J. Renema**[2], **C.T. Herbschleb**[2], **I. Drevensek-Olenik**[3] and **C.H. Voetmann**[4],
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In recent years, physics shows have come to the forefront of attention as a means of bridging the gap between scientists and the general public. Because of their small-scale nature they offer a possibility to establish valuable interactive communication between the scientific community and the general public. The performers of the shows try to gain the attention of the spectators by performing experiments, which demonstrate interesting physical phenomena explained through the adventurous stories, humour and music. EuroPhysicsFun (EPF) was founded in 2004 to stimulate the exchange of ideas and best practices between show groups [1].

EuroPhysicsFun network

The EPF network consists of 28 physics shows from 14 countries (Fig. 1). In total, these groups reach about 250.000 people per year. In 2007 the central organization moved from Aarhus in Denmark to Leiden in the Netherlands. The goal of the network is to stimulate the exchange of ideas and information between the member groups. In this manner the knowledge and experience gained by each particular group are made available to the community.

The main forum where the member groups share their knowledge is the yearly conference *Show Physics*. The most recent of these conferences was held in Leiden in March 2007. Over 15 groups from various European countries, as well as from further abroad, were present.

An important goal of *Show Physics* is to exchange information on demonstration experiments. This is done by means of experimental sessions. For these, the groups bring their equipment to the conference, so that they can demonstrate their experiments to each other. At the end of the conference, the experimental sessions are rounded off with a demonstration in the center of the host city.

The most recent conference was a huge success. A comment which reflects the general atmosphere after the conference was: *"[…] there is a lot we can learn from each other and great things can be done if we work together every once in a while. I've heard all of you speaking enthusiastically about this. I hope that this feeling remains […]"*

The next Show Physics conference will be held in Tartu, Estonia, April 8-12 2008. Registration is still open.

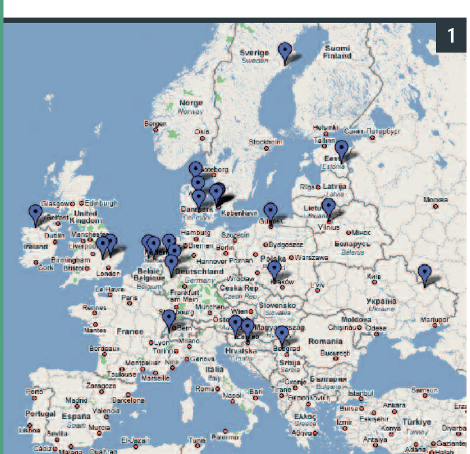
Besides organizing a yearly conference, the network also functions as a repository for knowledge on show physics. Participants, who have experienced many physics shows firsthand, form a community which is ideally suited to set up new physics shows. Furthermore, the network also seeks to stimulate cooperation between physics shows on a national level. This is done by means of regional meetings, in which the physics shows from one area meet to discuss issues, which are especially relevant to their region.

Main aims of the shows

To resolve the composition of show physics groups in Europe and establish what their respective goals are, we have performed a survey among the participants of the EPF network

The primary goal of the physics shows is popularisation of physics. Another common goal is to demonstrate that physics can be a lot of fun. An important goal of the shows is to increase the interest of the youngsters to study physics and to choose natural sciences as a subject in secondary school.

Besides these usual aims, there are many groups which have also other goals, such as: increasing enthusiasm for physics and science in general, demonstrating and explaining everyday phenomena, and demonstration of the importance of physics to modern technology. Other frequently indicated goals are: popularisation of science and research, demonstration and explanation of special physical phenomena



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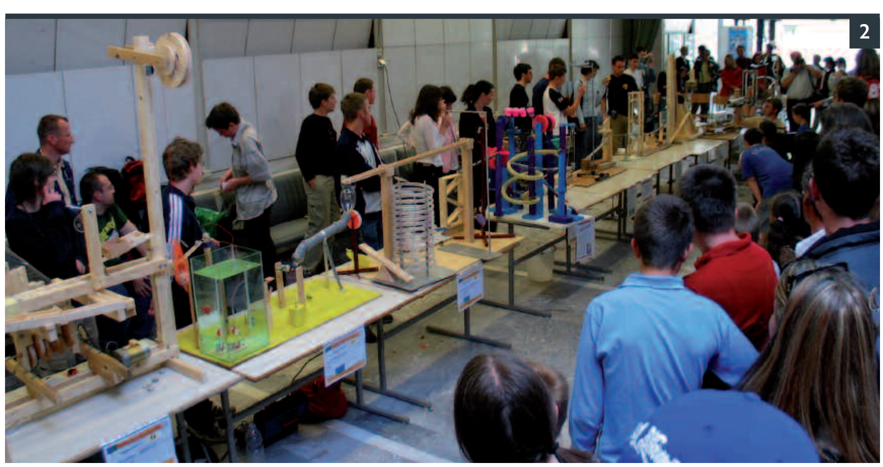

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such as superconductivity and levitation, reducing fear of physics as a difficult school subject, increasing young people's interest to study physics (at university). Surprisingly, only a relatively small percentage (20 %) of the groups aim to demonstrate the methods and principles of scientific research.

From the survey, we have found that the shows are staffed by a very diverse group of people, who mostly have a background in physics (over 80%). This includes everyone from undergraduate students to university staff. Some groups also incorporate amateur enthusiasts for physics, and other groups consist of actors who perform comedy shows and history tales (such as the German group *Physikanten & Co*.

In most cases performances aim at secondary (high) school children, but many of the groups also target both primary school children and students. People of all ages were indicated as a target audience only by 13% of the groups, while pre-school children were claimed to be the target audience solely by one out from the 15 groups.

1. **A map of the participants in the EPF network.**

2. **The Chain experiment group from Slovenia organizes chain experiments, in which connection is made between contraptions constructed by groups of pre-school children, secondary school fellows and students.**

3. **The group Physikanten & Co. from Germany provides shows that are performed by professional actors.**

Almost all groups combine the experimental demonstration and explanation of basic physical phenomena with interactive experiments. About 50% of the shows include hands-on experiments. This way of learning is thought to be much more effective than just observing; it is of course also much more attractive, especially for young spectators.

The Chain experiment group from Slovenia, for example, organizes yearly events for which independent teams construct the experiments entirely by themselves (Fig. 3). A large part of the groups demonstrate experiments with basic emphasis on show and entertainment. Besides this, many groups provide also seminars and lectures.

The majority of the groups present their shows directly at the school buildings. Market stands are also quite common. To achieve the necessary interaction, about 50% of the groups organize workshops and similar events. Some of the groups also organize performances in museums and science centres.

The positive response of society to physics shows confirms its importance as a method of communicating and presenting physics to the general population. The humour, excitement and interesting stories told between the experiments satisfy children as well as students and adults. The success of physics shows is also demonstrated by the increasing visitor numbers.

The participation in the shows provides physics students – the performers of the show – an important opportunity to express their ideas, to improve their knowledge and to acquire the skills needed for public speaking. Therefore both sides, the performers and the spectators, gain a lot of new knowledge and also a lot of fun. ■

Web links:

Physics 2008 conference website: www.fyysika.ee/EPFconference.
EuroPhysicsFun website: www.europhysicsfun.org.

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NOBEL FOR CHEMISTRY 2007 ››› PRIZE

After 19 years, again a German scientist wins the Nobel Prize for chemistry: Gerhard Ertl for his analyses of processes on solid surfaces.

The 2007 Nobel Prize for chemistry honors a personality who has influenced the surface sciences like no-one else. Gerhard Ertl, emeritus scientific member and director at the Fritz-Haber-Institute (FHI) of the Max-Planck-Gesellschaft in Berlin, is also the "scientific great-grandchild" of the institute's founder and eponym. He was informed about this great prize, which he receives undivided, just on his 71st anniversary, October 10th, 2007. Spontaneously, the whole institute, his friends and collaborators, together with a full squadron of journalists celebrated this event with him.

The last Nobel Prize for the FHI, was won by Ernst Ruska in 1986 for his invention of electron microscopy. In its almost 100-year-old history, four more Nobel Prize winners had been working at the institute: Fritz Haber, James Franck, Otto Hahn, and Max von Laue.

Fritz Haber's scientific great-grandchild

Heinz Gerischer, the doctoral advisor of Gerhard Ertl and previous director of the FHI, was the student of Karl Friedrich Bonhoeffer who was the director of our institute after the Second World War and on his part a colleague of Fritz Haber. Here, a scientific circle closes. Between 1905 and 1908 Haber discovered the process of the synthesis of ammonia from the nitrogen of the air, which then Carl Bosch brought to technical maturity at BASF. For this discovery, Haber had won the Nobel Prize in 1918, with the advice that the possibility to produce fertilizer saves Europe from suffering an upcoming famine.

The following fifty years and more were characterized by understanding the mechanism through which the most powerful known bonding between two atoms, in the N_2-molecule, breaks down on the surface of an iron-based catalyst. In 1975 Paul Emmett, an eminent physical chemist, said: *"The experimental work of the last 50 years has taught us that the speed-determining step in ammonia synthesis is the chemisorption of molecular nitrogen. However, the question whether the species on the surface (which then is being hydrogenated) is atomic or molecular has not yet been answered convincingly"*.

Shortly thereafter, Gerhard Ertl and his group showed - by using methods already developed in the new field of surface chemistry - that the step by step hydrogenated species is atomic nitrogen. These achievements clearly revealed Gerhard Ertl's great talent to analyze the essence of a complex process through a simple experiment. The secret of the mechanism had been disclosed about 70 years after its invention by Haber.

Atomic structure and dynamics of solid surfaces

The search for understanding the atomic structure and dynamics of solid surfaces under the influence of adsorbates (frequently molecules from the gas phase) dominated the research of Gerhard Ertl. Again and again he adapted or developed new methods and combined them in an exemplary manner, to extract "physically exact" statements.

One of the intensely studied reactions in Ertl's working group was the oxidation of carbon monoxide to carbon dioxide on interim metal surfaces. Already in 1982 his group reports on kinetic oscillations in the CO_2-production along metallic single-crystal surfaces - a phenomenon that was observed, up to then, only in catalytic reactors.

In a set of pioneering publications, the group showed the connection between the adsorption of carbon monoxide and oxygen that causes a reconstruction of the surface. The reaction and the higher sticking probability of oxygen on the non-reconstructed surface result in a switching between the reconstructed and non-reconstructed arrangements, and consequently to kinetic oscillations. This kind of oscillations can be regular, but can also become irregular or chaotic. These temporal oscillations represent the integral behaviour of the system. But we know from the well-established Belousov - Zhabotinsky reactions, that oscillations lead to topological structures.

▲ Gerhard Ertl receiving his Nobel Prize from his Majesty King Carl XVI Gustaf of Sweden at the Stockholm Concert Hall, 10 December 2007. © Nobel Web AB 2007. Photo Hans Mehlin.

Femtosecond spectroscopy and Raman scattering

To display spatio-temporal structures on surfaces under reaction conditions, the working group developed a new photoelectron emission microscope, with which it was possible for the first time to show the temporally changing topological structures, like helices, chemical waves etc. Together with theorists these non-linear dynamic structures have been successfully modelled. If one is interested in the analysis of chemical processes on solid surfaces at atomic level, which means with the highest spatial resolution, it is obvious to concentrate also on the temporal resolution in the observation of dynamic processes. Gerhard Ertl founded a group within his department in the FHI that studies pump-probe experiments with lasers at a femto-second time resolution. These experiments led to deep insights into the electron dynamics during energy-transfer processes in chemical reactions after photo-excitation. An outstanding example of the new "old" method, besides the comprehensive electrochemical activities that were pushed by Gerhard Ertl, is the tip amplified resonant Raman scattering.

Tragic loss for the Turkish Physics Community

We are deeply sorry to announce that on the 30th of november 2007, six physicists of the turkish physical society, **Engin Arik, F. Senel Boydag, Iskender Hikmet, Mustafa Fidan, Berkol Ozgen Dogan** and **Engin Abat**, died in a plane crash, on their way to a workshop on the turkish accelerator center project.

We have here some first clear indications from his group that the sensitivity can be brought to the single molecule level. From this, further important perspectives in many fields of the recent physical chemistry on surfaces could result.

There are many more aspects to be mentioned, but Gerhard Ertl's oeuvre is too extensive to go into details here: His list of publications contains more than 700 articles. Besides this, he presented hundreds of invited talks. A summary of personal information until 2004, the year when he formally retired, can be found in the Festschrift at the occasion of his 68 birthday. [*cp. Jounal of Physical Chemisty B* ***108****, 14183 (2004)*].

The list of his awards is long: Liebig Medal of the German Chemical Society, Japan Prize, Wolf Prize, Otto-Hahn-Prize, honorary membership in the German Bunsengesellschaft and many more. About 40 memorial lectures and various honorary responsibilities within the scientific community testify the remarkable reputation and reliance that Gerhard Ertl enjoys.

And now the well-deserved coronation!

From Stuttgart via Munich to Berlin

Gerhard Ertl was born in 1936 in Bad Cannstatt and studied physics in Stuttgart where he got his diploma in 1961 and wrote his dissertation with Heinz Gerischer who had been at that time at the Max-Planck-Institute for Metal Research. In 1965 he received his doctor's degree and went, together with his doctoral advisor, to the TU Munich, where he habilitated within only two years. After this, he accepted the call for a professorship for physical chemistry in Hanover. About 5 years later, he accepted a call to the LMU Munich. In 1985 he became successor of his teacher, Heinz Gerischer, as director at the Fritz-Haber-Institute of the Max-Planck-Gesellschaft in Berlin. He held this position until 2004, when he was given the emeritus status.

Gerhard Ertl is a wonderful colleague, friend and – since his retirement – advisor. His participation in the daily institute's life has changed, but only in the way that he retired as director of the institute. We are very pleased to meet him in the institute every day.

It is said that he very often stands in for the pianist during the choir rehearsals of his wife Barbara. He plays wonderfully the piano and the harpsichord. After the recently held Baker-Lecture at Cornell University he is now writing a book. The revised version of the second edition of the Handbook of Heterogeneous Catalysis is possibly almost finished. His activity is unbowed and we are sure that this will continue further on for a long time.

All colleagues, friends, students and collaborators congratulate Gerhard Ertl for winning the Nobel Prize for chemistry 2007 and share his happiness.

Congratulations and all the best wishes. ■

Hans-Joachim Freund,

This laudation has been written by Prof. **Hans-Joachim Freund**, a colleague and close friend of Prof. Gerhard Ertl. It was first published in German in "Nachrichten aus der Chemie" (Nov. 2007, p. 1075). It has been translated for Europhysics News with permission of EuCheMs, the European Chemical and Molecular Sciences.

CERN'S NEXT DIRECTOR GENERAL »» PHYSICS NEWS

On 14 December, CERN Council appointed Professor **Rolf-Dieter Heuer** to succeed Dr **Robert Aymar** as CERN's Director General. Professor Heuer will serve a five-year term, taking office on 1 January 2009. His mandate will cover the early years of operation and first scientific results from the Laboratory's new flagship research facility, the Large Hadron Collider (LHC). The LHC is scheduled to begin operation in summer 2008.

Currently Research Director for particle and astroparticle physics at Germany's DESY laboratory in Hamburg, a post that he took up in 2004, Professor Heuer is no stranger to CERN. From 1984 to 1998, he was a staff member at the Laboratory, working for the OPAL collaboration at the Large Electron Positron collider (LEP) research facility. From 1994 to 1998, he was the collaboration's spokesman.

"This is a very exciting time for particle physics," said Professor Heuer. "To become CERN's Director General for the early years of LHC operation is a great honour, a great challenge, and probably the best job in physics research today. I'm looking forward to working with CERN's community of personnel and researchers from around the world as we embark on this great adventure."

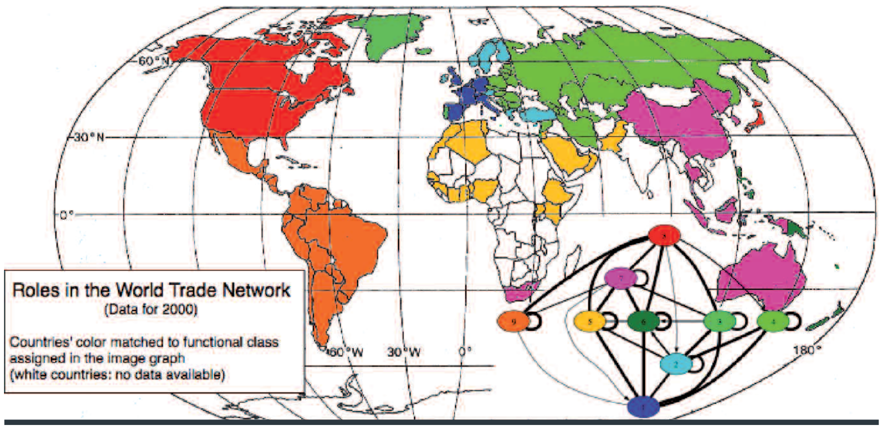
Professor Heuer obtained his doctorate in 1977 from the University of Heidelberg. Much of his career has been involved with the construction and operation of large particle detector systems for studying electron positron collisions. On leaving CERN in 1998, he took up a professorship at the University of Hamburg, where he established a group working on preparations for experiments at a possible future electron-positron collider. On taking up his appointment at DESY in 2004, Professor Heuer was responsible for research at the HERA accelerator, DESY's participation in the LHC and R&D for a future electron-positron collider.

"Rolf Heuer has worked tirelessly for DESY as Germany's main particle physics laboratory, while at the same time strengthening links between DESY, the German University system and CERN," said Professor Torsten Åkesson, President of CERN Council. "This spirit of collaboration will be a valuable asset to CERN as we move into LHC operation, develop strategic options for the long-term scientific programme, and develop collaboration with the European national laboratories and institutes." ■

HIGHLIGHTS FROM EUROPEAN JOURNALS

Representing complex network structure through relational quasi-equivalence classes

The functional roles played by interactive agents lead to specific patterns in the link structure of their interaction network. Understanding complex multi-agent systems from the social life, or biosciences requires understanding of the complex topology of the underlying network. To identify sets of role-equivalent agents we combine ideas from spin glass physics and social network analysis to develop a framework for automatically decomposing (''block-modeling'') the functional classes of agents in a (multi-relational) network. The functional classes and their patterns of connectivity are represented in a resulting image graph, depicting a large network as a small one in a quasi isomorphic way. Our cost function finds the optimal image graph and simultaneously maps agents into functional classes. The method handles directed and undirected two- and one-mode data, weighted networks, finds an optimal number of roles, and is computationally efficient and non-parametric. Applied to the world trade network, countries are grouped into classes with similar commodity bundles of trade relations with others. The image graph shows preferred links where the trade volume exceeds the expectation value given countries' total import and export volume. ■

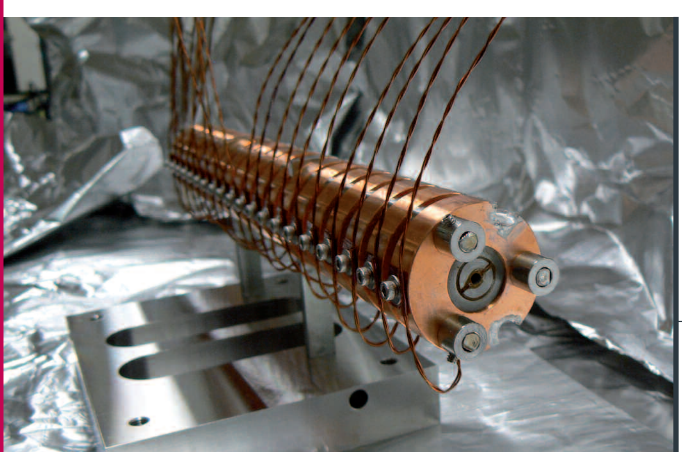


▲ Representation of the world trade network as found by our block-modeling procedure. Countries are grouped into 9 functional classes with two opposing centers (North America/Japan and the European Union), parallel sub-centers in South East Asia and smaller European Countries, and two large peripheries in South America and Eastern Europe. A change in the cost function that regroups the image to include parallel symmetries (regular equivalences) in the graph has the potential to show the three symmetric layers of core, sub-center, and periphery in the image graph that reproduce the three-tiered structure of the world economy (D. Smith and D. White 1992 Structure and Dynamics of the Global Economy: Network Analysis of International Trade 1965-1980. *Social Forces* **70**:857-894).

J. Reichardt and **D.R. White**, "Role Models for Complex Networks" *Eur. Phys. J. B*, **60**, 217 (2007).

Stopping atoms with pulsed magnetic fields

This paper reports the experimental demonstration of a new method to produce cold and trapped atoms, which should be widely applicable to most of the periodic table. While the standard method to control atomic motion has been laser cooling, this approach only works for a small set of atoms in the periodic table that have a closed two-level transition that is accessible with a tunable laser. The starting point for the current work is the supersonic beam of noble-gas atoms, a source that provides a high flux of atoms that is very cold in the co-moving frame but also very fast. These atoms are emitted in bunches as a valve is opened for a short time. Other atoms or molecules can be introduced into the flow by seeding or entrainment near the output of the nozzle. A series of magnetic field coils is timed with the firing of the valve, and slows the atoms by making them climb a magnetic hill and then removing the hill before they have time to roll off. The group will apply these methods to trapping of atomic hydrogen isotopes for precision spectroscopy, and tests of fundamental physics of beta decay of tritium. ■

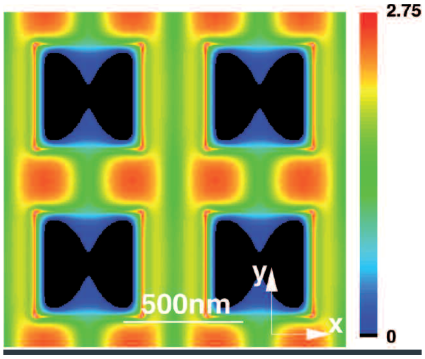


◀ The assembled atomic coil-gun used to slow atoms, before it was put into a vacuum chamber.

E. Narevicius, C.G. Parthey, A. Libson, J. Narevicius, I. Chavez, U. Even and **M.G. Raizen**, "An atomic coil-gun: using pulsed magnetic fields to slow a supersonic beam", *New Journal of Physics*, **9**, 358 (2007)

On the optical properties of gold nano-particle arrays on gold film

Recently, Hohenau *et al.* have demonstrated how far state-of-art nano-fabrication and computer simulations approach to give predictable and defined nano optical functionality. As test system we investigate arrays of gold nano-particles on gold film for their optical far-field (accessed by reflection spectroscopy) and near-field (accessed by two photon luminescence microscopy) properties. These arrays are intended as a simplified model system compared to random arrangements of gold particles on gold film, which show huge surface enhancements for, *e.g.*, Raman scattering of adsorbed molecules, related to the enhanced optical near fields (Figure). By a detailed comparison of the experimental results to finite difference time domain simulations (without free fit-parameters), we can identify the modes responsible for the intensity enhancement on the investigated substrates. We find good agreement between simulations and experiments and are able to identify the parameters responsible for observed differences. They are mainly related to a not yet perfect experimental control and knowledge of the surface structure in the < 10 nm regime and the poor knowledge of the dielectric function of the involved nanostructures. However, the generally well agreement of simulations and experiments demonstrates that macroscopic Maxwell equations as solved by the FDTD code are suitable for a detailed description of the optical properties of this and similar systems. ■

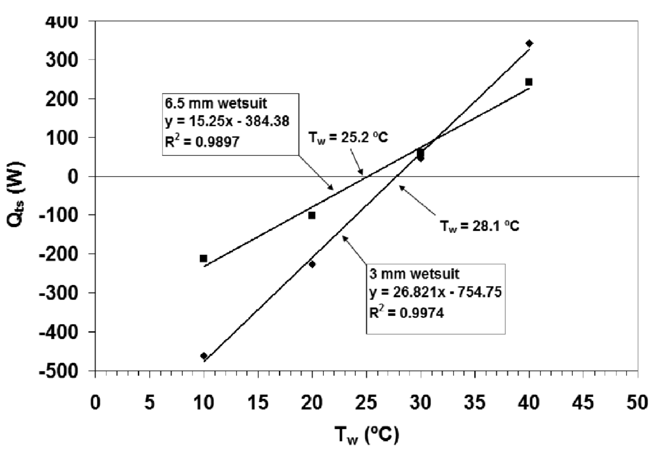


▲ **Simulated optical near field map around square shaped nano-particles in an array on a gold film, if excited at a grating resonance. Plotted quantity: *log* $[|E(r,\lambda)|^2/|E(\lambda)|^2]$, where $E(r,\lambda)$ is the electric field amplitude of the array and $E(\lambda)$ is the electric field amplitude in the top layer of a flat surface. The excitation is polarized parallel to x.**

A. Hohenau, **J.R. Krenn**, **F.J. Garcia-Vidal**, **S.G. Rodrigo**, **L. Martin-Moreno**, **J. Beermann** and **S.I. Bozhevolnyi**, "Comparison of finite-difference time-domain simulations and experiments on the optical properties of gold nano-particle arrays on gold film", *J. Opt. A: Pure Appl. Opt.* **9**, S366 (2007)

Active Heating and Cooling for an Underwater Diver

Passive insulations alone are not sufficient for maintaining underwater SCUBA divers in thermal balance or comfort, therefore an active system is required. The purpose of this study was to experimentally determine the active heating and cooling requirements to keep a resting diver in thermal balance in water temperatures between 10 and 40°C. A diver wearing a prototype tubesuit under a neoprene wetsuit (3 or 6.5mm) was fully submersed in water at a specified temperature (10, 20, 30 and 40°C). During immersion, 30°C water was circulated in the tubesuit at a flow rate of 0.5 L/min to six individual body regions. An attempt was made to keep skin temperatures below 42°C in hot water (> 30°C), and below 32°C in cold water (< 20°C). A skin temperature of 32°C is the threshold for maximal body thermal resistance due to vasoconstriction. Skin temperatures and inner body core temperature were monitored during immersion to ensure they remained within set thermal limits along with skin heat flux, metabolism and the thermal exchange of the tubesuit. In addition to physiological measured responses to changes in water temperature the subject was asked for any subjective comments concerning discomfort. In both wetsuit thicknesses there was a linear correlation between the thermal exchange of the tubesuit and water temperature as shown in Figure 1. Subjectively the subject reported being in "thermal comfort" at all water immersion temperatures and did not report any localized hot or cold spots. It was therefore concluded that a resting prone position diver be kept in thermal balance in 10 – 40°C water with active heating and cooling. ■



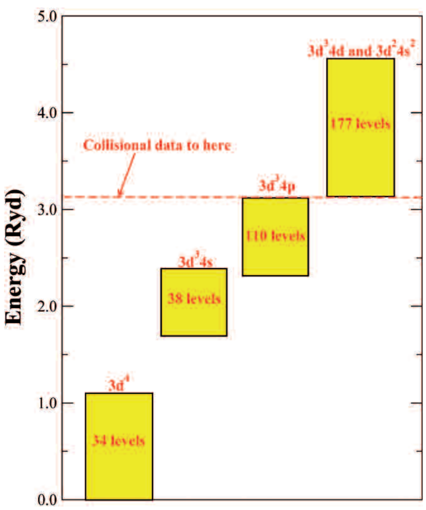
► **Total tubesuit thermal exchange (Q_{ts}) as a function of varying water immersion temperature (T_w) for both wetsuit thicknesses.**

E. Bardy, **J. Mollendorf**, and **D. Pendergast**, "Regional and Total Body Active Heating and Cooling of a Resting Diver in Water of Varied Temperatures", *J.Phys.D Appl.Phys.* **41**, 035501 (2008)

Electron-impact excitation of Fe^{4+}

Electron-impact excitation of complex atoms and ions remains of fundamental importance to atomic physics because it provides a severe test of our understanding of the many-body problem. The incident electron strongly couples the electronic states of low-charge-state ion targets; therefore, in order to obtain accurate theoretical results for such scattering events, one must employ a computational method that includes this coupling. A widely used close-coupling method for such calculations is based on *R*-matrix theory in which configuration space is divided into two regions: an inner region where correlation and electron-exchange are very important and an outer region where electron-exchange is negligible and can therefore be neglected.

There are also many applications of electron-impact excitation to both laboratory plasma physics and astrophysics. For example, since the early nineties, there has been a major effort to calculate electron-impact excitation data for every ion stage of iron. The low ionization stages of iron are of particular importance for the interpretation of such astrophysical events as supernovae and hypernovae explosions. Accessibility to parallel computers and our recent development of a suite of parallel *R*-matrix programs has enabled us overcome the severely truncated scattering calculations of the past. Here, we describe the first calculation of electron-impact excitation of Fe^{4+} that includes relativistic effects and provides data not only within the 34 levels of the $3d^4$ ground configuration, but also the 148 levels of the $3d^34s$ and $3d^34p$ configurations. The close-coupling expansion of the target includes the 359 levels arising from the configurations: $3d^4$, $3d^34s$, $3d^34p$, $3d^34d$, and $3d^24s^2$, as depicted in the energy level diagram shown in the figure. These excitation data have now been made available to the astrophysical and controlled fusion modelling communities on the Oak Ridge National Laboratory Controlled Fusion Atomic Data Center Web site. ■



▲ **Energy diagram of the 359 levels included in the close-coupling (CC) expansion for the present R-matrix calculation of electron-impact excitation in Fe^{4+}.**

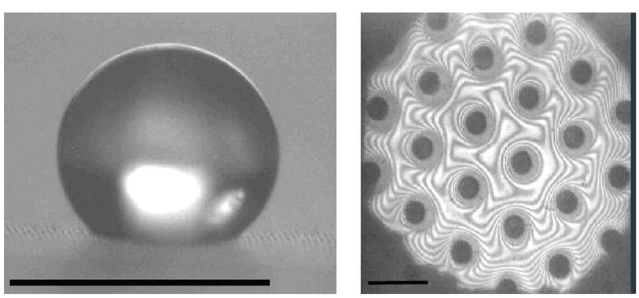
C.P. Ballance, **D.C. Griffin** and **B.M. McLaughlin**, "Electron-impact excitation of Fe^{4+}:an intermediate-coupling R-matrix calculation", *J. Phys. B: At. Mol. Opt. Phys.* **40**, F327 (2007)

The sad fate of a "fakir droplet"

Hydrophobic microstructured surfaces, like the famous sacred lotus leaves, can exhibit extreme water-repellency. On such superhydrophobic surfaces, a gently deposited water droplet sits on top the highest microstructures just like a fakir on a bed of nails. The droplet keeps an almost spherical shape and can roll with as little resistance as a ball on a billiards table, making liquid deposition almost impossible. Potential applications of artificial superhydrophobic surfaces range from self-cleaning coatings for clothes or glass to drop transport on lab-on-a-chip devices.

Unfortunately, when the microstructures pierce the drop and the liquid invades the roughness, water repellency is lost. Moreover, the impaled drop then becomes strongly pinned to the solid substrate. This impalement transition is shown to occur during the spontaneous evaporation of a water droplet, which is a major limiting factor for most of the potential applications of superhydrophobicity. The forces dictating the impalement transition were identified by monitoring the evolution of the full 3D shape of the interface below evaporating fakir droplets. This was made using model micropatterned surfaces and interference microscopy. First, it revealed a new stable wetting state halfway between the usual Fakir and impaled states. Second, it led to propose a simple model to account for all the observed impalement scenarios based on the competition between the internal drop pressure (proportional to the inverse drop radius) which pushes the drop downward and the capillary forces applied by the microststructures, which hinder the liquid penetration. Moreover, on top of the quantitative description of the experimental findings this simple picture led an efficient design strategy for "ultra-robust" water repellent coatings which should repel arbitrarily small droplets! ■

S. Moulinet and **B. Bartolo**, "Life and death of a fakir droplet: Impalement transitions on superhydrophobic surfaces", *Eur. Phys. J. E*, **24**, 251 (2007)



◄ **Fakir droplet partly impaled on a microfabricated pillars array. Left: Side view, scale bar 1mm. Right: Same drop viewed from below. The 3D air water interface profiles can be reconstructed from this interference microscopy picture. Scale bar 50µm.**

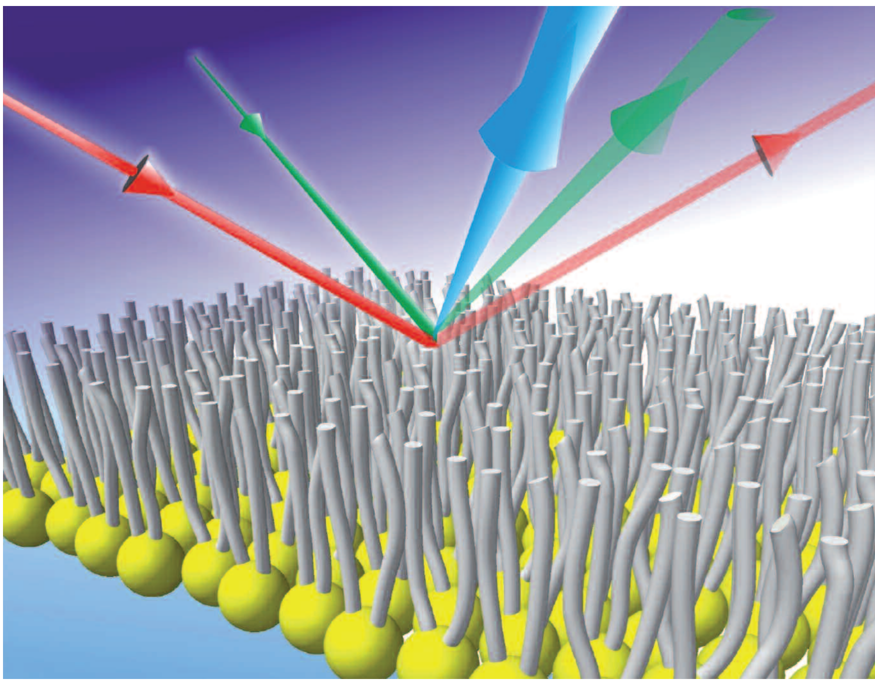
Molecular dynamics in model biological membranes

The cell membrane does more than just separating the inside and outside of the cell. It constitutes a highly active barrier, which controls, for instance, transport in and out of the cell. This is possible through a subtle, dynamic interplay between the key molecular components of the membrane: lipids, membrane proteins and the surrounding water. Experimental information on the biomolecular dynamics in cell membranes has been lagging, despite the evident importance, due to the challenge associated with the specific investigation of interfacial molecules that constitute the membrane, with sufficient time resolution.

Using femtosecond laser spectroscopy direct access to biomolecular dynamics in model membranes is obtained, by investigating the evolution of the biomolecular system in real-time following a laser-pulse induced change (*e.g.* temperature jump or vibrational excitation). The strength of the approach lies in its inherent sensitivity to interfacial phenomena at the level of single molecular layers.

The vibrational energy relaxation and energy transfer in a simplified model system for a biological membrane reveal remarkably fast dynamics: the transfer of heat across half a membrane, for instance, occurs on picosecond timescales. These results demonstrate the potential of using ultrafast surface spectroscopies to elucidate biomolecular dynamics at membrane surfaces. ■

M. Smits, **A. Ghosh**, **J. Bredenbeck**, **S. Yamamoto**, **M. Müller** and **M. Bonn**, "Ultrafast energy flow in model biological membranes", *New J. Phys.* **9**, 390 (2007).



◀ **Schematic of the experiment: A self-assembled monolayer of lipid molecules (with polar headgroups shown in yellow and apolar alkyl chains shown in grey) on water. Laser pulses at different wavelengths are incident on the lipid monolayer. One pulse triggers a temperature jump or vibrational excitation in the monolayer, and a delayed pair of pulses interrogates the transient changes in the monolayer, in a process where the sum-frequency of the incident pair (shown here as red and green) is generated (blue beam). This technique provides surface-specific information on model membrane relaxation processes.**

The reaction $^{48}Ca+^{238}U \rightarrow ^{286}112^*$ studied at GSI-SHIP

The first successful hot-fusion experiment at GSI on the synthesis of a super-heavy element has been carried out by the team lead by S. Hofmann. The GSI team is well known for their cold-fusion reaction experiments in studying the production and decay properties of the heaviest elements up to Z=112.

By bombarding a ^{238}U target with a beam of ^{48}Ca ions they identified the decay of $^{283}112$ nuclide in agreement with two previous studies conducted in Dubna, one employing the gas-filled recoil separator and the other one employing chemical separation. Good agreements on both the alpha-decay energy as well as the half-life were observed in all three experiments. The cross section determined in the GSI experiment is 0.72 (+0.58,-0.35) pbarn which is in reasonable agreement with a slightly higher cross section of 2.5 (+1.8,-1.1) pbarn of the Dubna experiment. However, even with the new result a link via a decay chain to any well-known heavy isotope still remains missing.

The new GSI experiment is an important landmark in paving the way to future experiments on the synthesis of superheavy elements beyond Z=112 and the question of the existence the super-heavy island of stability. The result is of particular importance because it represents the first confirmation experiment conducted outside of Dubna employing hot-fusion reactions in super-heavy element synthesis. Dubna experiments, that have resulted in great amount of data on synthesis and decay properties of superheavy nuclei up to Z=118, are now confirmed for the decay chain of one isotope by this independent experiment which employed the velocity filter SHIP and the UNILAC accelerator. The result obtained will intensify further experimental efforts around hot-fusion experiments. ■

Sigurd Hofmann *et al.* (26 co-authors), "The reaction $^{48}Ca+^{238}U \rightarrow ^{286}112^*$ studied at GSI-SHIP", *Eur. Phys. J. A* **32**, 251 (2007)

EUROPEAN PHYSICAL SOCIETY (1968-2008): THE EARLY YEARS

›››DOI 10.1051/epn:2008001

Henk Kubbinga, University of Groningen, EPS-History of Physics Group.

The European Physical Society is getting ready to celebrate its 40th anniversary as one of oldest pan-European scientific societies based, partly, on individual membership This paper aims to convey an impression of the motivations that guided the founding fathers and of the context in which they succeeded in launching, in less than 30 months, what was to become a stronghold of European science. It is based inter alia on the first issues of Europhysics news, a complete set of which – a rarity, to be sure - is kept in the Archives of EPS, at Mulhouse, where the present author was graciously allowed to consult them.

Pisa, Geneva, London, Prague

If the European Physical Society was founded in 1968, the first initiatives date from November 1965, when Gilberto Bernardini (1906-1995), the distinguished cosmic rays and nuclear physics specialist and then-rector of Pisa's Scuola Normale Superiore, convinced his colleagues, gathered on the occasion of the annual conference of the Italian Physical Society, of its potentialities [1]. A special meeting was convened in Pisa, on 16-17 April 1966, with attendees from all over Europe. There was an enthusiastic key-note address by Sybren de Groot (b.1916; Amsterdam) and the ensuing discussion led to the conclusion that immediate steps should be undertaken. A Steering Committee was nominated, chaired by Bernardini. In November 1966 and May 1967 there followed Committee meetings at CERN, Geneva, and the Institute of Physics, London. Two Working Groups were the result, the one, chaired by Anatole Abragam (b.1914; Paris), aiming at a legal constitution of the new Society, the other, headed by the energetic Bernardini, charged with the planning of its foundation. A Secretariat was set up in Geneva, coordinated by Mrs. Lorette Etienne-Amberg; Switzerland seemed a logical choice of headquarters because of the ease of creating associations there, and because it was the home of many other international organisations. The Working Groups were abolished, but reappeared as Subcommittees, two new Subcommittees being inaugurated with concrete tasks: publications and the organization of the inaugural conference, the first of the Society. From the very beginning, Eastern Europe was given detailed attention: in May 1968 the Steering Committee was warmly received at Prague's Carolus University and elaborated on topics of mutual concern for East and West [2]. That very same year, on 26 September, the brand new European Physical Society was officially registered and its constitution undersigned in CERN's Council Chamber, Geneva. In this way sixty-two individual members and twenty national societies, academies and groups enrolled. The Turkish Physical Society would follow soon.

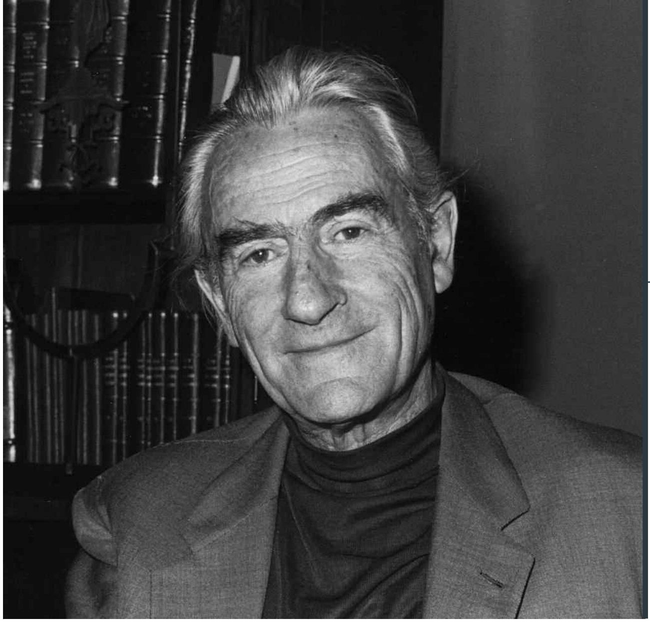
Bernardini: physics as culture. Divisions

The inaugural congress was scheduled for 8-12 April 1969, in Florence, the theme being 'The growth points of physics'. Florence most courteously welcomed its approximately two thousand guests in the magnificent surroundings of two of its Renaissance palaces: the Palazzo Vecchio and the Or' San Michele [3]. Bernardini opened the 'Inaugural Session' wholeheartedly stressing the importance of the Society in making science a ”source of wide-spread, deep-rooted culture, … to serve as a beacon light whenever difficulties beset the path of mutual understanding or human dignity and freedom are threatened” [4]. Subsequently, Victor Weisskopf (1908-2002) [5] presented a survey on 'Physics in Europe in the twentieth century', whilst Patrick M. Blackett (1897-1974) [6], the senior physicist present, brought in a touch of nostalgia by reviving 'The old days at the Cavendish Laboratory'. The actual 'growth points' concerned: 1) astronomy, astrophysics, cosmology and relativity; 2) nuclear and elementary particle physics; 3) physics of condensed matter; 4) atomic, molecular and plasma physics; 5) quantum electronics and optics. Still at Florence, an Executive Committee was elected, chaired by Bernardini, who became in this way EPS's first president, with Erik Rudberg (1903-1980; Stockholm) as vice-chair.

In the slipstream of the news of the Society's envisaged foundation, several specialized branches began developing closer networks. These initiatives were seized upon by the Executive Committee, which had always had in mind a substructure in terms of Specialised Divisions. The first of these were officially recognized in 1969 [7]: Atomic Spectroscopy under Alfred Kastler (1902-1984; Paris), Condensed Matter Physics under Samuel Edwards (b.1928; Manchester), Low-Temperature Physics under Jan de Boer (b.1911; Amsterdam), Plasma Physics under Bo Lehnert (b.1926; Stockholm), and Quantum Electronics under Klaus Peter Meyer (b.1911; Berne).

A place of its own

The new Society had to establish its credibility as there were already several more or less formalised networks in existence, among which the distinguished Summer Schools of Les Houches and of Uppsala-Beitosølen, the first devoted to Theoretical Physics (Grenoble; since 1951), the second to Quantum Theory in Chemistry, Physics and Biology (Uppsala, Beitosølen). In France, the Groupement Ampère [8], mainly consisting of research scientists, but allowing postgraduate students among its members, had been active since 1952 and had acquired a European dimension. The idea behind these summer schools had been, on the one hand, to push Europe forwards in the post-war world of science as dominated by Russia and the United States, and, on the other, to bridge the gap between the university curricula of the various academic traditions and the cutting-edge research science of the time. That idea had met with such success that, as Bernardini put it once [9], ”every European country which had some villa or castle to offer with a nice view on some mountain or lake” featured a summer school or was hard trying to acquire one. Already in the autumn of 1970 the 1000th individual member joined the



◀ Gilberto Bernardini, the 1st EPS president

Society. It was the time that the first 12 issues of *Europhysics news*, together with the pilot issue and two 'Meetings issues', were provided with a 'General index'.

Publications

The Committee on Publications, directed by Jan de Boer, decided not to aim at independent European journals as counterweights of AIP's *Physical Review* and its derivatives [10]. Instead it opted, given the particularities of the Old Continent, for the upgrade of existing journals by setting appropriate standards: the languages should be three or four out of English, French, German and Russian; the editorial committee had to feature eminent scientists from other European countries; the choice of the editor-in-chief and the composition of the editorial board should be subject to approval by the EPS; an effective refereeing system should be put in place in order to guarantee a high scientific standard and, of course, to avoid national bias; there should not be page charges and some uniformity rules ought to be agreed upon (size; front page make-up; preparations of manuscripts). In March 1970, the first journals were accepted and granted the right to use the EPS logo and the distinction *Recognized by the European Physical Society* on their cover. It concerned the *Czechoslovak Journal of Physics, Fizika, Il Nuovo Cimento, Journal de Physique, Journal of Physics Section A, B and C, Physica, The Philosophical Magazine* and the *Zeitschrift fuer Naturforschung*. For direct communication with the membership *Europhysics news* rapidly imposed itself, though inadvertently [11]. It concerned a most gratifying co-operative effort of CERN, the Institut Battelle [12], the University of Geneva and the Main Secretariat. Initially, it was meant to be temporary, in the wake of a full-size periodical in the spirit of *Physics Today*, but rapidly became indispensable. The dust-dry first issues, full of constitutional and financial details, indeed almost spontaneously turned into a more lively journal: the editors, guided by Lorette Etienne — and, later, Peter Boswell —, could not help reporting great events, *e.g.* the deaths of Amos de-Shalit (2 September 1969) and Max Born (5 January 1970) and the Nobel Prizes for Murray Gell-Mann (1969) and Louis Néel and Hannes Alfvén (1970), and soon included 'classified advertisements' for vacancies at the professorial level. In parallel, a 'Letters to the Editor' section emerged out of the blue, reflecting the societal and educational preoccupations of the time; it bore testimony of a keen interest of the readership in what was going on. Authorities introduced the various 'blood groups' of the new Society in a loose, 'getting together party' style: so M. Lebedenko described the Joint Institute for Nuclear Research at Dubna, the Editors successively analyzed the functioning of the German, the Hungarian and the French Physical Societies, while Andrew V. Borovsky and Louis Cohen (1925; Institute of Physics) assessed the organizational structure of the Russian Academy of Sciences and the Institute of Physics (and the Physical Society), respectively. Twice a year an issue featured the conferences of the near future, classified in the strict terms of the Conference Committee. This Committee was composed of Werner Buckel (1920-2003; Karlsruhe), Jacques Friedel (b.1921; Orsay) and Nicholas Kurti (1908-1998; Oxford). It had proposed two types of conferences: General Conferences on the lines of the Inaugural Conference of Florence, and Europhysics Conferences, the latter modelled on the Gordon Conferences in the US [13]. These 'Europhysics Conferences' would be state of the art 'study conferences', essentially different from the summer schools both in venue, duration and attendance. The attendance would be only on invitation (after application), the conference being held preferably for about 4-5 days and so in a truly Spartan environment "away from the distractions of large towns, …with facilities for outdoor recreation", thus not so much in villas or castles, but *e.g.* in holiday and sporting resorts out of season. Apart from these, there would be 'topical conferences' under the responsibility of the Divisions. Any conference held in Europe could be sponsored by EPS when it satisfied well-defined criteria as to scientific value, international character and organization.

Education

One of the major topics discussed was, naturally, education. Edoardo Amaldi (1908-1989) the visionary initiator of CERN and by now dean of the Physics Department of Rome University, addressed the matter in a plenary talk at the Inaugural Conference [14]. Amongst the new aspects of the problematic he mentioned the enormous growth of the student population at all levels (the birth-wave of the late 1940's) and the existing gap between education (secondary school, university) and society as to the latter's technological complexity and scientific refinement. Culture was indeed increasingly permeated by science, though the acceptance of science as an integral part of that culture had not evolved correspondingly. To cope with this odd situation - a real menace for the future, in Amaldi's opinion - the educational methods had to be modernized, whilst more time and attention should be devoted to the teaching of mathematics and the natural sciences from new points of view. IUPAP's Committee on Physics Education (1960) had indicated the way to forward; UNESCO and OECD contributed in their own way. Several projects had been launched in the mean time by the Physical Science Study Committee and Harvard Project Physics was well underway; UK's Nuffield Foundation concentrated on the guidance to teachers. By and large an increase in the role of the humanities and social sciences was inescapable. An important suggestion came from Russia, namely, to link secondary schools with neighbouring institutions of higher education and/or industrial companies; the important thing was to give students easy access to research laboratories at the forefront of science. Amaldi otherwise referred to the contemporary unrest and movements among students. The immediate reasons were evident, in his eyes: the archaic structure of many universities, on the one hand, and the inadequacy of the staff and of the facilities, on the other. The profound dissatisfaction of the young generation with the present state of affairs prevailing in the world should be acknowledged.

Pure and Applied Physics, Science and Industry

Another - more traditional – 'hot' subject was the relation between pure and applied physics. In the German system that relation was embodied in the presidency of its Society, where captains of industry alternated with university professors. It was a favourite theme of Hendrik Casimir (1909-2000; director research and development at Royal Philips Incandescent Lamps Factories, Eindhoven), who had been asked to assess it at the Inaugural Conference in Florence [15]. In most of the older industries empiricism and the results of past generations dominated perhaps, Casimir argued, but even there systematic research became necessary. New branches, though, tended to be based entirely on fairly recent scientific research. Electronics was a case in point: Casimir discussed in some detail the progress of the loudspeaker and the magnetic tape of the tape recorder, showing how a great variety of fundamental physical notions were involved in these comparatively simple products. Casimir's plea was not in vain. There would indeed be an Advisory Committee on Applied Physics and Physics in Industry, a committee chaired by Otto Gert Folberth (b.1924; IBM, Boeblingen).

Those were the days

Those were simple days, at least in hindsight. Laurens Jansen (Geneva), the first Secretary of the Executive Committee, called it, on the fifth anniversary, the 'romantic period' [16]. The root-mean-square physicist still resembled the 'good savage' of Jean-Jacques Rousseau, one might say, fully enjoying their research and almost unconscious of the bad things in the outer world. The word 'gender' had not yet invaded our root-mean-square's vocabulary. The lady physicists, that had always been there, just did what a good physicist ought to do, that is, science. That France featured the largest fraction — doubtless due to Marie Curie, her daughter Irène and granddaughter Hélène — was broadly appreciated in the community. It was in fact considered one of its charms. To conclude with just a fact: anno 1970, the Institute of Physics (and the Physical Society) was numerically by far the largest Society; it was followed by the Societies of Germany, France and the Netherlands, and the USSR's Academy, in that order [17].

Erik Rudberg succeeded Gilberto Bernardini, Casimir succeeded Rudberg, … Martin Huber (Zurich) left, Ove Poulsen (Aarhus) came, to be succeeded by Friedrich Wagner (Greifswald). Those forty years knew three General Secretaries who guaranteed the continuity: Lorette Etienne-Amberg, Gerald Thomas (1974-1997), and, since, David Lee. In 1997, the Society moved from CH-1213 Petit-Lancy 2, Geneva, to F-68060 Mulhouse Cedex, where it finally received indeed stylish premises, under the wings of the University. ■

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About the author

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References

[1] The event was summarized in a 'special issue', of *Europhysics news, Bulletin of the European Physical Society*, number 0 (November 1968).

[2] The still current EPS logo was proposed on this occasion by the Czechoslovak Physical Society.

[3] The *Proceedings of the Florence Inaugural Conference* appeared as a special issue of *Rivista del Nuovo Cimento* (1969); we refer to it in the following.

[4] Above, reference 3, p.XI-XII.

[5] Above, reference 3, p.XIII-XXXI.

[6] Above, reference 3, p.XXXII-XXXIX.

[7] *Europhysics news* **1** (5) p.1-2 (September 1969).

[8] An acronym ... for Atomes et Molécules Par Etudes Radioélectriques. The XVIth colloquium was scheduled for 1-5 September 1970 in Bucharest.

[9] *Europhysics news* **1** (6) p.1-3 (November 1969).

[10] *Europhysics news* **1** (2), p.1-2 (March 1969).

[11] *Europhysics news* **1** (12) p.1-3 (November 1970).

[12] The Institut Battelle was the Geneva branch of the Battelle Memorial Institute of Columbus (Ohio), a not-for-profit organisation created in 1929, by the will of Gordon Battelle (1883-1923), ''for the encouragement of creative and research work and the making of discoveries and inventions".

[13]*Europhysics news* **1** (12M) p.1-2 (Autumn 1970). *The Gordon Research Conferences* had been installed by Neil Elbridge Gordon (1886-1949) of Johns Hopkins University to stimulate unfettered scientific discussions; the first was organized in 1931. Guests were not admitted in the conference room; recording of lectures and photography of slides or posters were strictly forbidden; it was not allowed to refer in print to papers or discussions; there were no proceedings.

[14] Above, reference 3, p.1-16.

[15] Above, reference 3, p.17-29.

[16] *Europhysics news* **4** (11) p.6 (November 1973).

[17] *Europhysics news* **1** (10) p.5 (July 1970).

THE SWISS PHYSICAL SOCIETY CELEBRATES ITS 100TH ANNIVERSARY

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This year 2008 the Swiss Physical Society (SPS) celebrates its Centennial. Over its 100 years of existence the SPS has grown up to a society with more than 1200 members, university professors, teachers, PhD students and other professionals from research laboratories and industry, all linked by their interest for physics. Famous members of the Society are Nobel laureates such as Charles-Edouard Guillaume, Albert Einstein, Wolfgang Pauli, Felix Bloch, Karl-Alex Müller and Heinrich Rohrer.

The SPS is a collective member of the Swiss Academy of Sciences (SCNAT), the Swiss Academy of Technical Sciences (SATW) and the European Physical Society (EPS). Organized like other learned societies, the SPS has representatives from condensed matter physics, astrophysics, nuclear and particles physics, theoretical, applied, and industrial physics. The SPS has also special joint membership agreements with the German Physical Society (DPG), the Austrian Physical Society (ÖPG) and the American Physical Society (APS). Every year it distributes awards to recognize outstanding young physicists in General Physics, Condensed Matter Physics and Applied Physics. In recognition of outstanding contributions in physics and for the advancement of science and technology, the SPS awards also fellowships. The journal of the Swiss Physical Society was the famous *Helvetica Physica Acta*, which has been published since 1928 by Birkhäuser Verlag. In 2000 it was merged with the *Annales de l'Institut Henri Poincaré* to become the *Annales Henri Poincaré*, a Journal of Theoretical and Mathematical Physics.

The annual meeting of the Society will take place this year on March 26-27th in Geneva. It is organized jointly with the three Swiss National Centers of Competence in Research (NCCR): Nanoscale Science (NANO), Materials with Novel Electronic Properties (MaNEP) and Quantum Photonics (QP). A special Centenary celebration event will be organized on June 27th in Bern at the Kultur Casino, in the presence of the political authorities, many honorable members of the Society and students. The special ceremony will include a round-table discussion on "*Research in Physics a hundred years ago and today*" and a plenary talk by Theodor Hänsch - Nobel Laureate 2005 - on the "*Visions for Physics*". During the afternoon outreach activities and exhibits will be proposed to the public.

◀ **Meeting of the Swiss Natural Science Society 1908 in Glarus. Source: Burgerbibliothek Bern.**

From the Natural Science Society to specialized societies

The Swiss Physical Society was founded in 1908 as part of a wave of new, independent scientific societies, which included the Chemical Society and the Mathematical Society (founded in 1901 and 1910, respectively). All of these newly established societies were offshoots of the Swiss Natural Science Society, which had existed since 1815. On the occasion of its 100th anniversary, the Swiss Physical Society can look back on a remarkable history. Nearly all important Swiss physicists of the last 100 years were members. As early as in 1908, the year of its founding, the society's roster included such famous names as Marcel Großmann, Walter Ritz, and Albert Einstein.

The SPS's parent society, the Swiss Natural Science Society (SNG), was formed in the early 19th century, at a time when academic societies were gaining ground as centres of independent research. The academic societies were competing effectively with the more established university system, and were seen by many as more important to scientific innovation. In the middle of the 18th century, the Swiss physician, scientist and polymath Albrecht von Haller noted that universities were "instructing academies", whereas academic societies were the actual "inventing academies".

The SNG was not, however, officially an "academy".[1] Academies usually consisted of professional scientists, whereas the SNG was a union of interested laymen who did their research, for the most part, as a hobby – their actual occupations were as teachers, ministers, bailiffs ("Landvögte") and the like.

Beginning in the 19th century, specialized societies were founded all over Europe. The reasons for their emergence were various: The German Physical Society, for example, which was founded in 1850, wanted to create "an association open to everyone" that would "search for the relationship among many natural sciences and wider scopes connected with physics."

The Swiss Physical Society was created in May of 1908, during the annual meeting of the SNG in Glarus. It had already existed informally for several decades as a section of the SNG, and had held separate meetings on mathematical and physical topics. In many regards, the SPS was a substantially more professional organization than the SNG, consisting almost exclusively of professional physicists. Most of them worked at universities, while others were Gymnasium teachers who often held an adjunct professorship ("Titularprofessur") at a university. Among the non-physicists, there were some chemists, mathematicians, astronomers and also engineers who were directly involved with the physical research, either as collaborators of the physicists or as private researchers.

The founders

Pierre Eugène Chappuis-Sarasin (1855 – 1916) from Basel was the founding president of the SPS and remained president until 1910. He had already been active as secretary of the SNG, president of the Bernouillanum commission in Basel as well as president of the Natural Science Society of Basel from 1904 to 1906. In addition, he was active in numerous non-profit organisations, among other things for the support of the victims of the First World War. Thus, given his manifest organizational talent, it may not surprise that Chappuis also participated actively in the founding of the SPS.

Beside Chappuis there were two more people in the board of directors of the SPS: Alfred Kleiner (1849 – 1916) from the University of Zurich served as vice president. Kleiner is remembered today largely because he examined Albert Einstein's thesis of 1905 and in 1909 was responsible for hiring Einstein at the University of Zurich. Since 1879 he had been associate professor for physics, and from 1908 to 1910 he was director of the university. Second, as secretary there was the young Emile Alfred Rosselet (1887 – 1950). Rosselet had studied physics at the University of Lausanne and earned a doctorate in 1909.

At that time many members came from the famous "Polytechnikum" in Zurich - the later Swiss Federal Institute of Technology. Among them, Professor Pierre Weiss (1845 – 1940), who served as secretary of the SPS in 1909, as vice president in 1910 and as president in 1912, as well as the Professors Alfred Fritz Schweitzer (1875 – 1963), Heinrich Friedrich Weber (1843 – 1912), Marcel Großmann (1878 – 1936) and Walter Kummer (1875 – 1962).

From the University of Zurich – besides Alfred Kleiner – there was Albert Einstein[2], as well as the doctors Edgar Meyer – the later successor of Kleiner – and Friedrich Adler.

▼Postcard showing the Polytechnikum in Zurich in 1908. Source: Image Archive ETH-Bibliothek Zurich.

Einstein and Adler

Adler had studied physics, chemistry and mathematics at the University of Zurich from 1897 to 1903. After employment at the Deutsches Museum in Munich he worked from 1907 onward as a private lecturer at the University of Zurich. Alfred Kleiner who was director of the university at the time, offered Adler a newly opened position in theoretical physics. Adler refused it, arguing that "if our university can get a man like Einstein, then it would be unreasonable to appoint me. My abilities as a researcher can in no way be compared with those of Einstein. Such an opportunity to win a man who can effect an elevation of the whole field, one should not lose because of political sympathies."[3] If it had not been for Adler's support, Einstein – a mere civil servant and unpaid private lecturer at the University of Berne – would hardly have been a viable candidate. Einstein would never forget this nobility on Adler's part. Adler's act of selflessness was even more amazing in light of the fact that although he did indeed admire Einstein's abilities, he doubted his results.

When Einstein moved to the University of Prague in 1911, he recommended Adler as his successor. Adler, however, decided to go into politics and took a position as party secretary of the Austrian social-democratic party in Vienna. Since the beginning of the First World War, Prime Minister Karl Freiherr von Stuergkh (1859 – 1916) had ruled under the so-called "Notstandsparagraphen" without a parliament. In 1916 Adler organized a demonstration demanding the re-instatement of the parliament, but Stuergkh prevented this by forbidding any demonstrations. In a violent reaction, Adler shot the Prime Minister in public. When Einstein heard of the arrest of his former colleague, he organized – together with other Swiss physicists – a personal appeal to the emperor requesting mercy on Adler.[4] Adler, however, rejected Einstein's offer. In 1917, Adler was sentenced to death, but the verdict was first converted to 18 years' detention and then a year later – as a result of the dissolution of the Austro-Hungarian Empire – he received full amnesty. During his time in prison he kept working on physics, exchanged letters with Einstein, and wrote a treatise about the refutation of relativity theory – he remained at odds with Einstein on that subject.[5] In the following years, Adler continued to pursue his political career, becoming General Secretary of the reformed Socialist International in 1919. At the end of the Second World War he retired from politics and returned to Zurich.

This episode shows that the contact between the physicists had not broken off – and the connecting link between them was among other things the SPS, whose annual meetings provided the framework for both scientific and personal exchanges.

World War II and beyond: Debye, Scherrer, Pauli

Swiss physicists were not affected by National Socialism nearly as much as their German colleagues. Nevertheless, the political climate in the neighbouring country was distinctly felt by the Swiss scientific community, in part because one of its most famous members was a dedicated opponent of Nazism: Paul Scherrer (1890 – 1969). Among Scherrer's many accomplishments is his involvement in the founding of two of the most important research institutions in Switzerland: the CERN in Geneva and what is now known as the Paul Scherrer Institute near Zurich.

Beginning in 1954, Scherrer contributed to the development of the CERN (Conseil Européen pour la Recherche Nucléaire). Twelve European Nations were the original signatories of the convention establishing the CERN, and nine more nations have joined since. The CERN remains the preeminent international center for research in particle physics. Even more important was Scherrer's part in the founding in 1955 of Reaktor AG, which has since then been renamed the Paul Scherrer Institute in recognition of Scherrer's contributions. Today, the Paul Scherrer Institute is best known for its facilities for treating tumors by proton irradiation and for its most advanced synchrotron light source (SLS).

Scherrer studied physics in Zurich, Königsberg and Göttingen before working as a Privatdozent (University lecturer) in Göttingen. Together with his advisor Peter Debye, with whom he had developed the Debye-Scherrer-method for measuring the atomic structure of crystals, he moved to the Polytechnikum in Zurich in 1920, taking a position as professor. In 1927, after Debye's departure from Zurich, Scherrer assumed Debye's chair in experimental physics. During his short stay in Switzerland, Debye (1884 –1966) had been active in the SPS: he served as vice president from 1923 to 1925 and as president from 1925 to 1927. In Germany, he became the president of the German Physical Society in 1937.

While Debye was rather indifferent in regard to Nazism and avoided any confrontation, Scherrer was actively involved in mounting opposition against National Socialism. Partly through his membership of the German Physical Society, Scherrer maintained close contact with his German colleagues even during the Second World War, among others with Werner Heisenberg. Scherrer kept his eyes and ears open and forwarded what he learned about German research to the Office of Strategic Research (OSS) – the predecessor of today's CIA.

During the war, Scherrer sheltered two Jewish physicists at his institute, Corudis Gugelot and Hans-Gerhard Heine – and he worked toward the emigration of Lise Meitner from Germany. Meitner hesitated to leave the Kaiser Wilhelm Institute, since she identified herself as German. Scherrer's view was probably more realistic. In July of 1938 he urged her on: "Pull yourself together and come here this week, it is but a short hop by plane. You may give your lecture on Wednesdays or Fridays from five to seven."

Denied to leave the country by the German authorities, Lise Meitner was helped by several European scientists and finally moved to the Netherlands with the support of the Dutch physicist Dirk Coster.

Scherrer also supported Wolfang Pauli (1900 –1958), who decided even in 1928 that he no longer wanted to live in Germany. Scherrer immediately procured a position for Pauli at the Polytechnikum. In 1938, when the situation in Switzerland became too precarious for Pauli, Scherrer helped him obtain a visa to the USA – with a heavy heart, for the two men had since become close friends. When Pauli left Zurich in 1940 to assume a position at Princeton, Scherrer refused to take back Pauli's key to the institute. Indeed, Pauli would return to the ETH in 1946 – his position had been kept on hold for him through all these years. Pauli again became active in the Swiss scientific community and served as vice president (from 1952 to 1954) and then as president (from 1954 to 1956) of the SPS.

▲ Paul Scherrer and Wolfgang Pauli in Zurich in the late 1940s. Source: CERN.

A common watering hole

These were just a few episodes in the history of the Swiss Physical Society. Outside of Zurich, we find he same picture; the SPS brought all Swiss physicists together. Not only established scientists were member of the SPS: young talents were also accepted. It is noteworthy that the SPS had few members without an academic title – and that those who were part of it nearly without exception had an extraordinary academic career.

At the time the vast majority of Swiss physicists participated in the Swiss Physical Society. Of course the SPS was not the only bond that held the scientists together, but nevertheless it was a strong link – a Society that carried scientific and private exchange. Today, in spite of many changes in the communication means, the SPS is still a kind of "common watering hole" for physicists all over Switzerland. Its role is not only to defend the interest of the physics community at large, but also to promote the awareness of the public on the importance of physics in our everyday life and to develop the interest for physics among youngsters, boys and girls alike. The participation of the SPS in the World Year of Physics 2005 and in the different events that took place in Bern to celebrate Einstein's seminal papers of 1905 is a good example of its engagement. ■

NOTES

1. The society was renamed to include the word "academy" only in 1988, almost two centuries after its founding.
2. Einstein didn't join in 1908 but in 1909 when he got the chair in physics.
3. Adler wrote to his father that Kleiner would definitely prefer Einstein and he anyway wouldn't get the job. It remains open if that was false dignity; Einstein saw it the other way.
4. They wrote a letter in the name of the Physical Society Zurich.
5. Ortszeit, Systemzeit, Zonenzeit und das ausgezeichnete Bezugssystem der Elektro- dynamik. Eine Untersuchung über die Lorentzsche und die Einsteinsche Kinematik. Verlag der Wiener Volksbuchhandlung, 1920.

PTYCHOGRAPHY & LENSLESS X-RAY IMAGING

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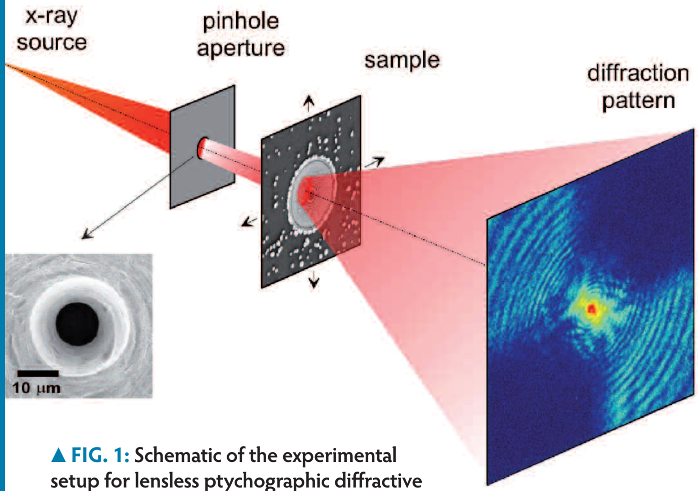
If an object is illuminated with coherent electromagnetic radiation, *e.g.*, by visible laser light or highly brilliant x-rays, a diffraction pattern is formed in the Fraunhofer far field that is related via a Fourier transform to the optical transmission function of the object. The aim of *coherent diffractive imaging* (CDI), or so-called *lensless imaging*, is to directly reconstruct the original optical transmission function of the specimen from its measured diffraction pattern. In principle, CDI allows one to obtain a resolution that is ultimately limited only by the wavelength of the radiation used and not by the quality of optical lenses. In x-ray microscopy, for instance, the resolution is presently limited to several tens of nanometres because of difficulties in manufacturing efficient high-quality nano-structured x-ray optical elements. Since CDI schemes allow the resolution to be increased beyond these limits they are among the most promising techniques for x-ray imaging applications in life and materials sciences on the nanometre scale.

Solution of the phase problem with iterative algorithms

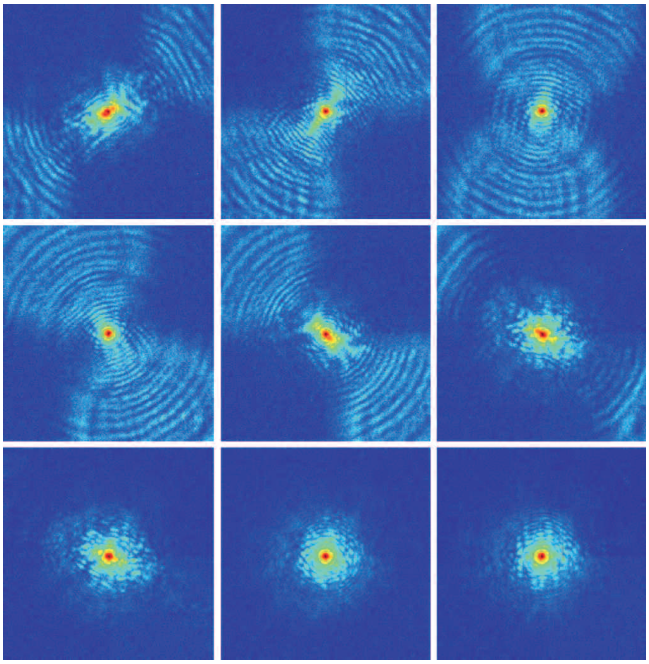
A fundamental drawback of any coherent diffractive imaging method, however, is the phase problem: the measurable real-valued intensity diffraction data contain only amplitude information while the equally important phase distribution is not recorded. Fortunately, with the advent of modern computers the solution of the phase problem became feasible via certain iterative phase retrieval methods. These are algorithms alternating between real and Fourier space while imposing certain boundary constraints on both [3,4]. They have proven useful in fields like astronomy, digital signal processing, and coherent imaging. Especially in the field of CDI, impressive results have been reported meanwhile, such as, for example, the imaging of a freeze-dried yeast cell [5], lead nanocrystals [6] and gold nano-structures [7]. Despite these promising results there are some severe principal limitations. To retrieve a unique set of phases most algorithms require the object to be very small and of a finite extent so that the corresponding highly detailed coherent diffraction pattern can be adequately sampled by the detector [3-7]. Therefore, obtaining a low-resolution overview of a comparably large area and then zooming into a region of interest - a standard procedure in microscopy - is not feasible.

Ptychography & Coherent Diffractive Imaging

Ptychographical coherent diffractive imaging (pCDI) is an extension of the above mentioned iterative phase retrieval methods and relies on collecting a number of Fraunhofer diffraction patterns (Fig. 1 and Fig. 2). Each of these patterns originates from a different but overlapping region of the specimen, which is moved laterally across the illuminating beam (Fig. 3a). The solution strategy is to iteratively reconstruct and refine a single projection image of the sample, which is consistent with all the recorded diffraction patterns. The method is related to a direct, non-iterative solution of the crystallographic phase problem



▲ **FIG. 1: Schematic of the experimental setup for lensless ptychographic diffractive imaging. The sample is scanned across the x-ray beam defined by a pinhole aperture and for each sample position a diffraction pattern is recorded by a two-dimensional detector.**



► **FIG. 2: Nine (out of 225) coherent x-ray diffraction patterns (displayed on logarithmic colorscale) recorded for a micro-structured test sample displayed in Fig. 3a.**

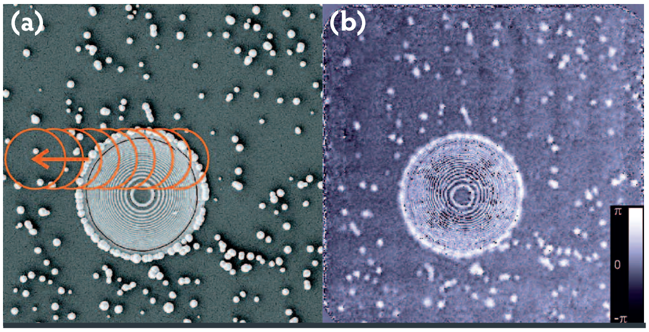
called *ptychography* (from the Greek "πτνξ" meaning "fold" [8]) and was first proposed by Hoppe and Hegerl more than 30 years ago [8,9]. In his pioneering work Hoppe describes how finite coherent illumination can be used to restore the phase information from the interference pattern recorded between the Bragg peaks of a crystalline specimen. The method was further developed for non-periodic objects [10-12], combined with iterative phase retrieval algorithms [13,14] and finally demonstrated with visible light and x-rays [1,2,15]. In the following, we briefly review the basic principles of the method and present some recent results obtained with x-rays and visible laser light.

Prerequisite for pCDI is a well-known, substantially localized and mainly coherent illumination. In the case of x-rays, this can be achieved by placing a small pinhole aperture into a highly brilliant x-ray beam from a third-generation synchrotron source, see Fig. 1. The resulting illumination function, described by the complex-valued probe $P(r)$, is then incident on the object, which is characterized by the function $O(r)$. For a relative shift, r_i, between the sample and the illumination function, the resulting exit wave, $\Psi_i(r) = P(r)O(r-r_i)$, is propagated onto the Fraunhofer plane (blue arrows in Fig. 4), where the modulus is replaced by the recorded data and the phase is preserved, as is usual in iterative methods. Upon backpropagation (red arrows in Fig. 4), the so-obtained new exit wave $\Psi_{i,new}(r)$ differs from the initial exit wave estimate $\Psi_i(r)$. The difference between these is used to correct the object function $O(r-r_i)$ in regions where the probe amplitude has a significant, non-zero value. A cycle over all diffraction patterns corresponds to one iteration step that brings us from the current object estimate, $O_n(r-r_i)$, to the input for the next iteration: $O_{n+1}(r-r_i)$, where n labels the number of iteration. The cycle is initiated with a random set of amplitudes and phases in the object function. Convergence of the algorithm is typically obtained after a few tens of iterations and can be monitored by the deviation between measured and calculated intensities via a normalized sum of squared errors.

Experimental Results

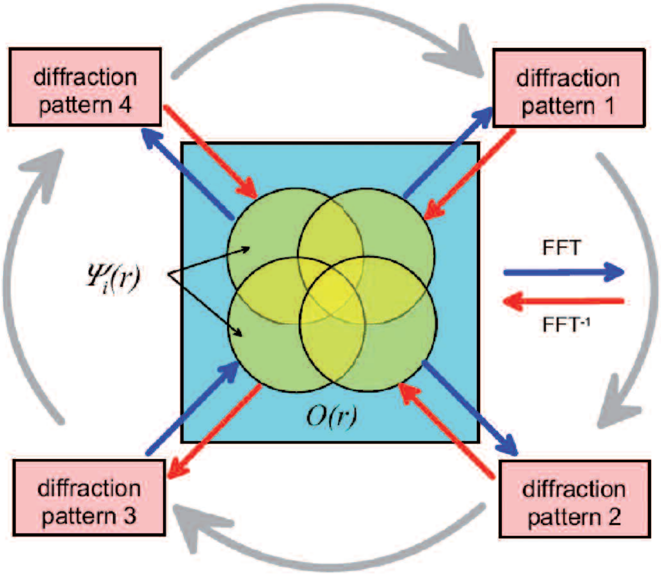
The results shown in Fig. 2 and Fig. 3 where obtained at the Swiss Light Source with monochromatic x-rays with an energy of 6.0 keV (λ = 0.21 nm). The beam-defining pinhole aperture of 10 µm diameter (see Fig. 1) was placed at a distance of 35 m from the source. A nano-structured object, a gold Fresnel zone plate, was used as specimen and illuminated at 15 × 15 overlapping positions that were spaced by 3 µm, nine of which are shown in Fig. 3a. The corresponding diffraction patterns (shown in Fig. 2) were recorded with a fibre-coupled CCD detector (Photonic Science Hystar, effective pixel size 4.5 µm) located 2.25 m downstream from the sample, using an exposure time of 1 sec per position.

The phase of the complex object transmission function that was reconstructed from the 225 diffraction patterns after 20 iterations is shown in Fig. 3b. On the outskirts of the zone plate, *i.e.*, the alternating attenuating and phase shifting concentric rings in the centre of the image, is a random distribution of gold balls ranging from 250 to 1500 nm in diameter. Both the inner ring structure, with periods in the few hundred nanometre range, and the outlying gold balls are clearly visible in the reconstruction.



▲ **FIG. 3:** Results with X-rays. **(a)** Scanning electron micrograph of the test sample with gold nanostructures. The circles indicate nine of the 225 pinhole positions for which diffraction patterns were recorded (Fig. 2). **(b)** Phase of the reconstructed complex-valued exit wave of the specimen (linear colour scale). The images represent a field of view of 52 x 52 µm².

▼ **FIG. 4:** Schematic of the iterative phase-retrieval algorithm for ptychographical coherent diffractive imaging. The gray circular arrows indicate the iterative loop according to which the diffraction patterns are used to update the object. The blue and red arrows within represent the forward and backward Fourier transforms that link the diffraction patterns with the object.



Importantly, these features are significantly smaller than the diameter of the illumination function (~ 10 μm) that was used to scan the sample. The image resolution in this reconstruction of about 200 nm was mainly limited by the dynamic range and signal-to-noise ratio of the CCD detector. We believe that in the near future this resolution can be pushed into the several nanometre range by using improved x-ray detectors as, *e.g.*, noiseless, direct-detection x-ray pixel detectors with high dynamic range.

The potential of the method in indeed yielding almost diffraction-limited resolution without using lenses or other optical components was furthermore confirmed by recent experiments with visible laser light [2,15]. Additional results, shown here in Fig. 5, were obtained with a 15 mW HeNe laser, a 200 micron pinhole aperture and a standard cooled 1 Megapixel CCD detector without a single lens in the optical path. 11 × 11 diffraction patterns (with 50 μm stepsize) were recorded at a distance of 200 mm behind the sample. The reconstructed combined amplitude and phase image of the object is shown in Fig. 5 together with a conventional visible-light micrograph. These results clearly demonstrate both that this method has the potential to yield wavelength limited resolution without relying on the use of an objective and that complex amplitude and phase objects can be reconstructed without significant artefacts or the usual non-uniqueness problems associated with the reconstruction of complex-valued objects. ■

▼ FIG. 5: Results with visible laser light. (a) Visible-light micrograph of the stem tip of a hydrilla verticillata. (b) Reconstructed phase and amplitude image from 121 diffraction patterns taken within the area indicated by the dashed square in (a). For the color representation in (b), the amplitude of the reconstructed exit wave of the specimen was assigned to the brightness and the complex phase to the hue in the image. The white scale bar represents 250 μm.

Acknowledgements:

We gratefully acknowledge J. M. Rodenburg, A. C. Hurst, and A. G. Cullis for many fruitful discussions.

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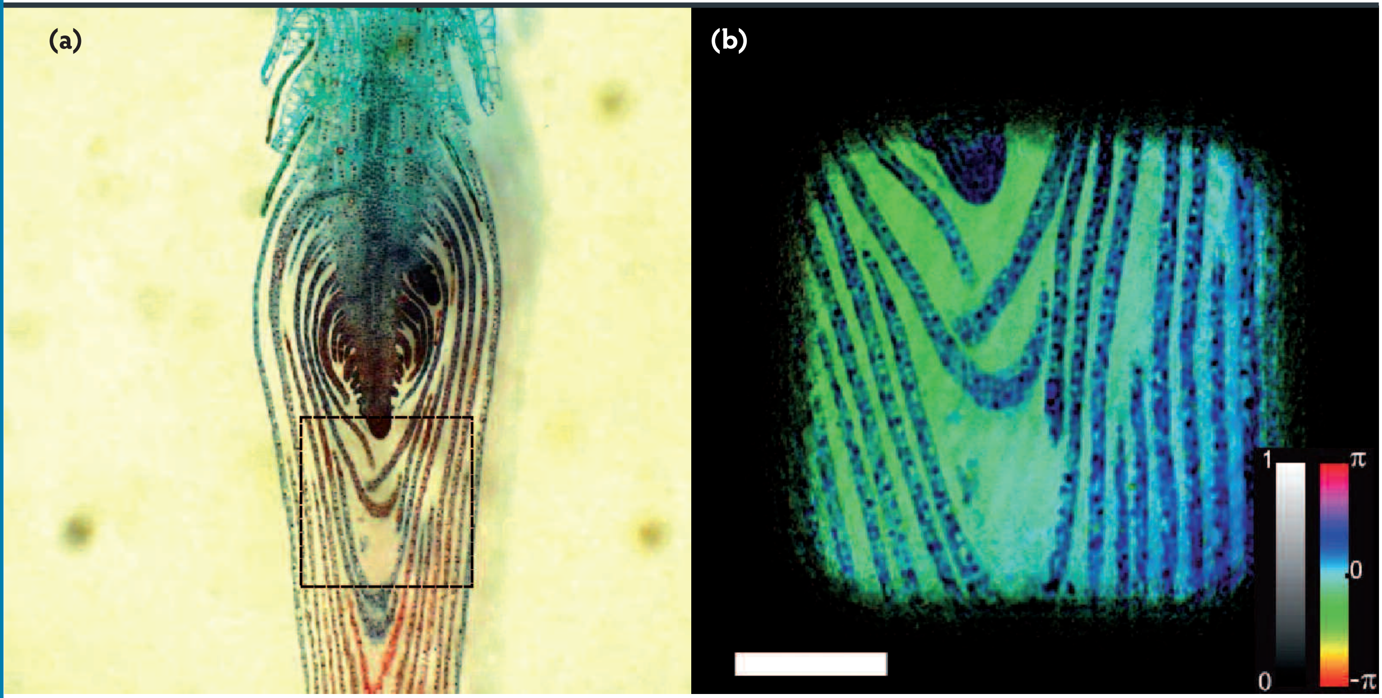

QUANTUM ATOM OPTICS WITH BOSONS AND FERMIONS

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Most of the time, experimental physicists fight to eliminate noise. But the history of physics is full of examples in which the study of noise, or more precisely fluctuation phenomena has led to significant discoveries. A famous example is Einstein's analysis of Brownian motion in 1905 which played a crucial role in the development of the atomic theory of matter. And several times in his later career, Einstein returned to the study of fluctuations. In the famous 1925 article in which he described what we now know as Bose-Einstein condensation [1], Einstein considered the fluctuation in the number of particles N in a small volume within a larger volume of an ideal gas at a given temperature. Using thermodynamic arguments, he found a formula for the variance of N:

$$\delta N^2 = \langle N \rangle + \langle N^2 \rangle / g \qquad (1)$$

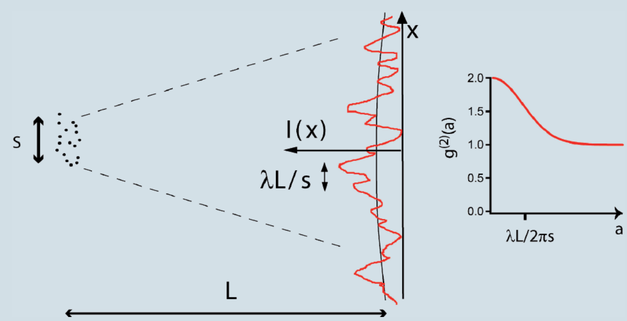
Recall that the variance is the mean squared deviation from the mean of N: $\delta N^2 = \langle (N - \langle N \rangle)^2 \rangle$. In Eq. (1) the quantity g is the number of phase space cells occupied by the gas, that is the phase space volume divided by Planck's constant cubed: $g = (\Delta x \Delta p / h)^3$.

In reading the paper, one can sense his fascination with this formula: he identifies the linear term with the fluctuations of independent particles, what we often call shot noise today. Einstein recognizes the quadratic term as being due to an interference effect. Indeed he had already made a similar analysis in the case of radiation [2], in which case the quadratically increasing variance can be interpereted as "speckle" (see Box 1). Here however, the formula applies to matter and he remarks on the "mutual influence between the particles of an altogether puzzling nature". With the formulation of the quantum theory in the ensuing few years, it became clear that he had put his finger once again on the wave-particle duality.

This formula became standard fare in textbooks on quantum statistical mechanics [3], but like many calculations in textbooks it applied to a *Gedankenexperiment*. The quadratic term is usually extremely small compared to the linear term, which itself is often difficult to observe. For example at atmospheric temperature and pressure, 1 mm^3 of air contains about 2 10^{16} molecules. According to (1), the shot noise is of order 10^{-8} and the interference term is another 10^6 times smaller. In other words the spatial and temporal coherence of a typical gas of atoms or photons is extremely small. To our knowledge the first observation of these interference fluctuations was made using light, in the famous experiments of Robert Hanbury Brown and Richard Twiss (HBT), which we shall describe below (see Fig. 1). The HBT experiment stimulated deep questions about the quantum description of light and gave rise to the birth of modern quantum optics. This line of research was recently recognized in the attribution of part of the Nobel prize for physics to Roy Glauber for his "contributions to the quantum theory of optical coherence".

Since the appearance of the first atom interferometers in the 1990's the field of atom optics has made tremendous progress, often inspired by traditional optics. Recently it has become possible to realize fluctuation experiments analogous to the HBT experiment. In the following we will describe some of these experiments. The first ones, carried out with bosons, give results highly analogous to those with photons. The results are of course unsurprising since photons are also bosons. Still, they nicely demonstrate this puzzling "mutual influence between particles", an influence which we have now learned to interpret as two particle quantum interference. In atom optics, one can also use fermions. The quadratic term in Eq. 1 appears with a minus

Box 1



Intensity correlations can be interpreted in terms of speckle. A source region of diameter s contains a large number of independent (randomly phased) point sources. On a screen at a distance L, there appears a random interference pattern known as speckle. For two points x and $x+a$ with a sufficient spatial separation, the intensities at a given time t are not correlated and $\langle I(t,x)\, I(t,x+a)\rangle = \langle I \rangle^2$. For zero separation the intensities are correlated and therefore $\langle I^2 \rangle \geq \langle I \rangle^2$. For thermal radiation, and neglecting shot noise, Einstein's formula reads: $\langle I^2 \rangle = 2\langle I \rangle^2$, if we identify I with the number of photons. The averages $\langle . \rangle$ can be thought of either as ensemble averages over a large number of equivalent realizations, or as time averages if one supposes that the relative phases of the source points are time dependent (for example because of atomic motion or collisions in a discharge lamp). One defines a correlation function $g^{(2)}(a) = \langle I(t,x)\, I(t,x+a)\rangle / \langle I(t,x)\rangle \langle I(t,x+a)\rangle$. The width of this function corresponds to the typical width of the speckles and represents the distance over which the relative phases associated with the optical paths between the source points and the observation points vary by less than 1 radian. The width is $\lambda L / 2\pi s$, and thus a measurement of this width leads to the angular size of the source s / L.

sign, a manifestation of the exclusion principle, and it gives rise to an effect which has no optical or classical wave analog.

We will begin with a discussion of the Hanbury Brown – Twiss experiments using light. This discussion will allow us to introduce practically all the necessary concepts to understand the second part in which we discuss the case of atoms.

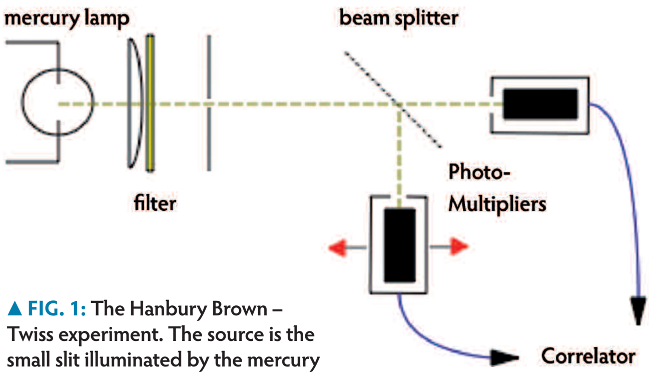
The Hanbury Brown – Twiss Experiment

First, a bit of the history of photon correlations. After his experience in the development of radar in the second world war, Hanbury Brown turned to radio astronomy. He proposed a new method to measure the angular diameter of a star by studying correlations in the fluctations in two radio telescopes as a function of their separation. The method depends on a generalization of Eq. 1 to fluctuations at two separate points in space (see Box.1). If two telescopes are close together, their fluctuations are correlated and the quadratic term in Eq. 1 is present. A measurement of the distance over which this correlation persists is related to the angular diameter of the star (see Box 1).

After demonstrating the method in the radio frequency domain, Hanbury Brown proposed an extension to the visible. The proposal was greeted with great skepticism. Perhaps with the recent introduction of photomultiplier tubes, based on the photoelectric effect, physicists had become accustomed to thinking of light in terms of photons. But the photon description of Hanbury Brown's method is to say the least, surprising. A correlation between the detection probabilities of different photons seemed to imply that the photons "know" that they should arrive together, even if they were emitted by two well separated points on a distant star. Box 2 gives a quantum explication of how this is possible. But in 1955 Hanbury Brown could not convince his colleagues nor funding agents of the validity of his idea.

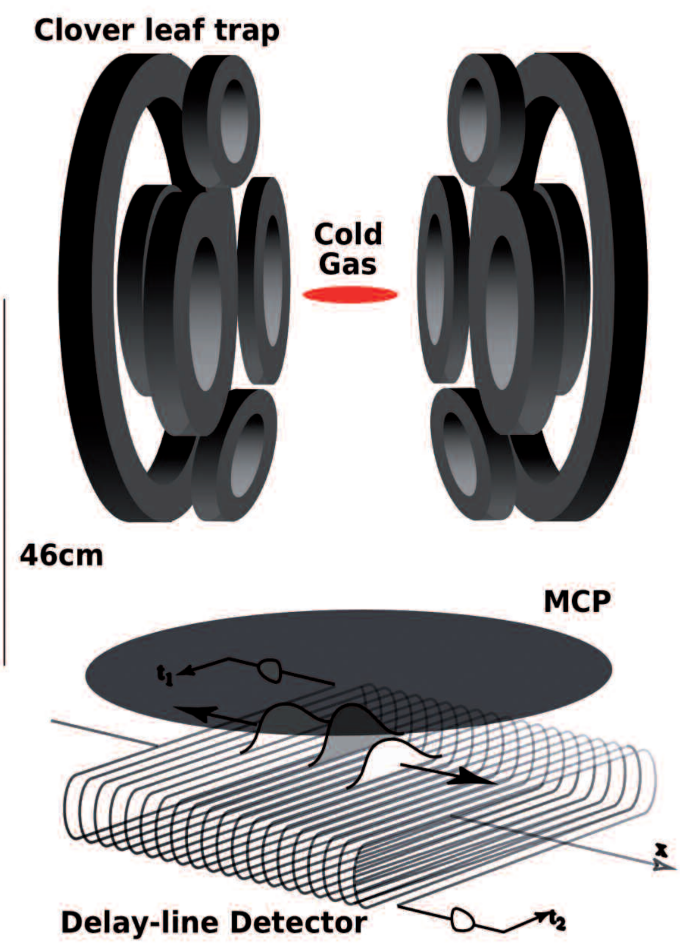
To convince the skeptics Hanbury Brown began a collaboration with Twiss to perform a laboratory demonstration of the method [4] (see Fig. 1). Their system of two detectors observing the same source through a beam splitter is now a standard quantum optics tool. The results confirmed Hanbury Brown's idea and the two scientists made their first astronomical observation on the star Sirius, whose high brightness facilitated the observation. In subsequent work done in Australia, they measured the angular diameter of several other stars.

Despite the experiments, controversies continued. The invention of the laser in 1960 posed new questions. Debates raged about the highly coherent laser light: would it, exhibit HBT correlations? Glauber gave a clear answer in 1963 using quantized fields and a careful examination of what constitutes photon detection [5]. The result was that unlike "normal light", the photons emitted by a laser are in general *not* correlated (see Box 2). By 1965 experiments had confirmed Glauber's analysis. The quantum theory of optical coherence led experimenters to investigate situations in which photon correlations cannot be understood in terms of classical waves, unlike the HBT experiment. The development of methods to create and use new states of light (single photons, squeezed states and entangled states), not described by classical electromagnetism has been an essential occupation of the field of quantum optics since then.



▲ **FIG. 1:** The Hanbury Brown – Twiss experiment. The source is the small slit illuminated by the mercury lamp. A filter selects a single emission line in order to lower the time scale of the fluctuations which are much faster than those of the detectors. The correlator multiplies the photo currents and averages them over time. If the image of one detector in the beam splitter is superposed with the other one, the photocurrents are correlated. A displacement of one of the detectors (indicated by the red arrows), corresponds to changing the distance a in Box 1. The correlation disappears when the detectors are separated by more than a correlation length. In terms of photons it means that they tend to be detected together or "bunched", a surprising effect for 2 photons emitted from two points on the surface of a star.

▼ **FIG. 2:** Experimental setup at the Institut d'Optique. The atoms are held in a magnetic trap where laser and evaporative cooling produce a cloud of 10^5 atoms at a temperature of order one microKelvin. The detector is 80 mm in diameter and uses a system of delay line anodes to achieve a spatial resolution of about 0.5 mm.



The atomic Hanbury Brown - Twiss effect

The possibility of demonstrating an analogous effect with atoms has fascinated researchers at least since the emergence of atom optics in the 1990's, if not much earlier. Although one can easily generalize Glauber's formalism to atoms, one must remember that the HBT effect is particularly surprising when one interprets it in terms of particles, something which is not really necessary for light. Atoms on the other hand really seem like particles to us, and if they exhibit bunching, one can still, like Einstein, be troubled by the "mutual influence" between particles which arises without any force.

In addition atom optics permits one to ask new questions. What happens with fermions? The theoretical answer is unambiguous: the two amplitudes which interfere constructively for bosons must interfere destructively for fermions, and joint detection of indistinguishable fermions is less probable than that of independent particles – this effect is called anti-bunching and can be viewed as a manifestation of the exclusion principle. An interesting point is that no classical interpretation exists for anti-bunching, and as such one can say that fermions are "more" quantum mechanical than bosons, many of whose properties do have classical interpretations.

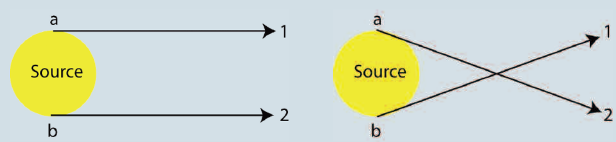
In practice, observing bunching or anti-bunching with atoms is difficult, in part because the probability of finding two particles in the same elementary phase space cell is very small. Only the advances in cooling atoms with lasers and by evaporation over the past two decades have rendered the enterprise feasible. Lowering the temperature reduces the occupied volume in momentum space $(\Delta p)^3$. In addition, if the confining potential is curved (*e.g.* harmonic) rather than a box, lower temperature also corresponds to a smaller volume in real space $(\Delta x)^3$. Indeed, as one approaches the threshold for Bose-Einstein condensation, the average number of particles per phase space cell approaches unity and the signal to noise can be high. Unfortunately the real space volume over which the correlation is strong is quite small despite the low temperature, and it is difficult to achieve a resolution corresponding to a single phase space cell. The factor g is therefore greater that unity, decreasing the contribution of the second term in Eq. 1. In our experiment described below, g is of order 15. The contrast of the signal is diminished by a factor of this order.

Experiment with metastable helium

With these ideas in mind our group at the Institut d'Optique has developed a detector capable of measuring spatio-temporal correlations between atoms by taking advantage of the properties of metastable helium. The metastable state 2^3S_1 is 20 eV above the ground state and although its lifetime is 9000 s in vacuum, it rapidly deexcites when in contact with a metal surface (such as that of a microchannel plate) thus liberating 20 eV in the form of a free electron. The microchannel plate can thus provide an electrical pulse for a single atom. A position sensitive anode makes the plate the equivalent of an array of about 10^4 separate detectors, capable of recording the arrival times and positions of a large number of atoms. The experimental set up is shown in Fig. 2. A cloud of cold, but not Bose condensed atoms falls, accelerated by gravity, onto the detector. With the three dimensional arrival information of each atom, one can construct the correlation function by histogramming the number of detected atom pairs as a function of their separation. Typical data are shown in Fig. 3. Since all atoms arrive at the detector with essentially the same velocity, it is convenient to convert arrival times to vertical positions.

In 2005 we used helium 4 (a boson) to observe the atomic HBT effect with good signal to noise. In addition, by cooling the sample to below the Bose-Einstein condensation threshold, we were able to observe the absence of correlations in a BEC, illustrating the profound analogy between this state of matter and the light from a laser. More recently, in collaboration with a group in Amsterdam, we have also made the same measurement for helium 3, a fermion [6]. Indeed in that experiment we were able to study helium-3 and helium 4 clouds under nearly identical conditions in the same apparatus. The clouds were of sufficiently low density that the comparison of the two isotopes in Fig. 3 shows a purely quantum statistical effect. For thermal bosons the probability to detect two particles is increased while

Box 2



Amplitude: ⟨a|1⟩⟨b|2⟩ ⟨a|2⟩⟨b|1⟩

Quantum interpretation of intensity correlations. Two photons from two source points, a and b are detected at points 1 and 2 following the two possible pairs of paths shown above. Each pair of paths corresponds to a quantum amplitude, and these amplitudes are added to find the probability to detect 2 photons:

$$P = |\langle a|1\rangle\langle b|2\rangle + \langle a|2\rangle\langle b|1\rangle|^2.$$

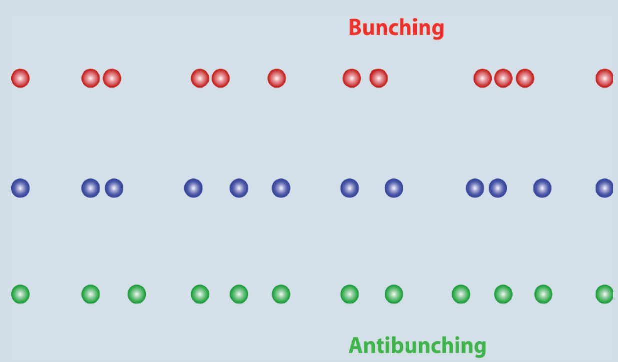
The interference term between thes two amplitudes is washed out by the average over all the points in the source unless the distance between 1 and 2 is sufficiently small. This distance is the diffraction spot of the source. It is important to note that at the quantum level, the interference takes place in an abstract space in which the two photons are described as a single system. This explains the conceptual difficulty of the quantum interpretation. It is an example in which a simple classical effect obscures a rather subtle quantum effect. In a laser all the photons are in the same field mode: the points a and b are thus one and the same and there is no interference term.

In the case of fermions, the antisymmetrization under exchange of the particles leads to a minus sign between the two amplitudes. Thus the probability of detecting two fermions at the same point at the same time is zero. Such anti-correlated fluctuations have no explanation in terms of speckle nor any other classical interpretation, be it wave-like or particle-like.

for fermions it is decreased. The spatial scale of the correlation can be understood with a calculation similar to that in the case of light (see Box 1); after a time of flight t, the correlation length is $ht / 2\pi ms$, where m is the atomic mass, h is Planck's constant and s is the source size. The correlation length for light, $\lambda L / 2\pi s$ can be recovered by identifying h / mv with the de Broglie wavelength of an atom moving at speed $v = L / t$. If the detector has arbitrarily good resolution one expects a value 0 for fermions and 2 for bosons at zero separation. In the experiment the amplitude of the signal is limited by the detector resolution resulting in a factor g is of order 15 as mentioned above.

We have given a discription of our experiments at the Institut d'Optique, but many other groups have performed related experiments in recent years. In the references below we cite some of these experiments [7].

Box 3



The figure above illustrates the meaning of the terms bunching and antibunching. Suppose the spheres in each row represent the positions of a group of particles along a line. (They could also represent the arrival times at a detector.)

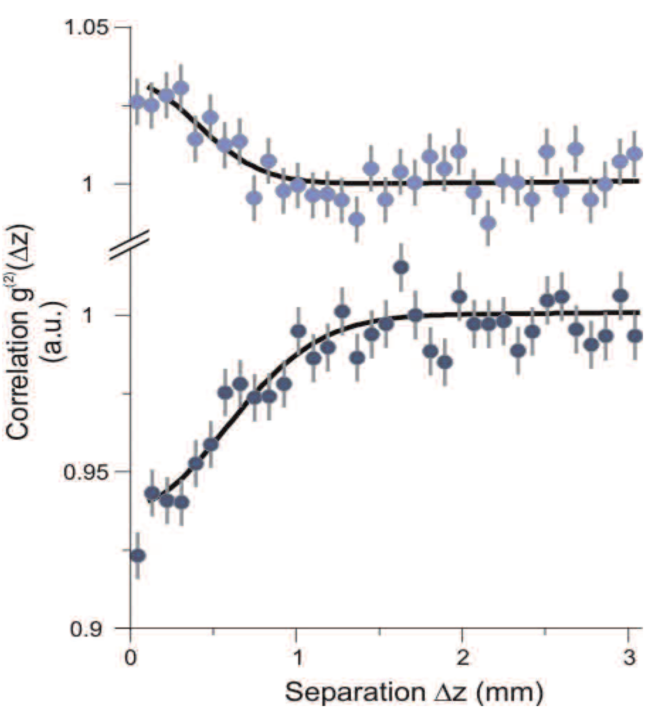
- The middle row of spheres **(blue)** corresponds to normal, everyday, *independent* particles. The spheres were placed at random positions on a line and the position of each sphere is independent of all the others. Sometimes they are close together sometimes they are far apart.
- The upper row **(red)** corresponds to particles exhibiting *bunching*. Note that compared to the independent particles, the particles tend to clump together. They are more often found together than independent particles.
- The lower row **(green)** represents *antibunched* particles. In this case they are more evenly spaced than independent particles. Indeed, they are never found close together.

Bunching or antibunching can have any of several physical origins. An obvious cause is interactions between the particles: if the particles attract each other they will clump together (bunching), if they repel each other they will spread out (antibunching) It is important to realize however, that in the experiments we have carried out on helium atoms, such interactions are completely negligible and that the origin of (anti-) bunching is a rather more mysterious interference effect.

Prospects

In a sense, the correlations between atoms that we have observed are a consequence of elementary quantum theory, and one might ask why we and other researchers have gone to such efforts to observe them. One answer is that the experimental demonstration of non-trivial quantum phenomena, even elementary ones, often stimulates fruitful new ideas. But we also know that the demonstration of these correlations is only the beginning. The interaction between atoms, which we entirely neglect here, the possible formation of molecular dimers or the use of more complex configurations – such as putting the atoms in optical lattices – should lead to a rich variety of phenomena. Experiments similar to ours have been done on both bosons and fermions in optical lattices [8]. We know that in such structures, confined in one or two dimensions or in rotating traps, ultra cold atoms constitute important testing grounds for models from condensed matter physics. Some even hope to shed light on phenomena which are still poorly understood such as high temperature superconductivity.

Hanbury Brown - Twiss experiments have also been performed on other types of particles. In nuclear physics, correlations between pions give information about collision volumes in heavy ion collisions, thus realizing at the scale of femtometers a measurement analogous to HBT's measurements of stellar diameters [9]. In a solid, conduction electrons form an essentially ideal Fermi gas and HBT type anti-correlations have been observed [10]. As in the case of atoms, these experiments are open-



▲ **FIG. 3: Correlation function for helium-4 (bosons, upper curve) and helium-3 (fermions, lower curve). The bosons exhibit bunching, the fermions anti-bunching. Since the detector resolution is somewhat larger than the correlation length, the signal is spread out and the amplitude is reduced by a factor $g \approx 15$.**

ing interesting paths towards the study of electron correlations in more exotic situations such as the fractional quantum Hall effect. ■

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REFUELING

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We don't usually think about it when driving down the highway, but what will traffic look like after the fossil-fuel age? How will our grand-grand-children move 'in the fast lane'? No longer in a gasoline-powered car, probably. An all-electric car perhaps? Or a hydrogen car powered by fuel cells? Or will they use some synthetic liquid fuel to power their engine? Things don't seem very clear yet.

Let us assume for a moment that it will be an all-electric car. Sure, there is a problem with the weight of the batteries: Even with the best battery type now available, the weight of our car would roughly double if we want to carry batteries with the equivalent of 50 or so litres of gasoline. But let us be optimistic: let us assume that we are able to improve the energy density of batteries by another order of magnitude. That would make the extra weight quite acceptable. Problem solved, one would think. But now another interesting aspect comes up. How about refueling? When driving long stretches on vacation in our present cars, refueling is a piece of cake. We can do it during the coffee break, for example. Now let us consider the electric car. Suppose our batteries are running low, and it is late afternoon. Fortunately, our hotel is near. No need for a gasoline station: there are power outlets in the hotel, and we will nicely reimburse the hotel owner. But how long will the charging procedure last, if we want to drive another 700 km the next day?

Let us do a back-of-an-envelope calculation. A standard power outlet can draw 16 A at most if we don't want to blow the fuse. At 220/230 V this yields a power of, say, 3,5 kW.

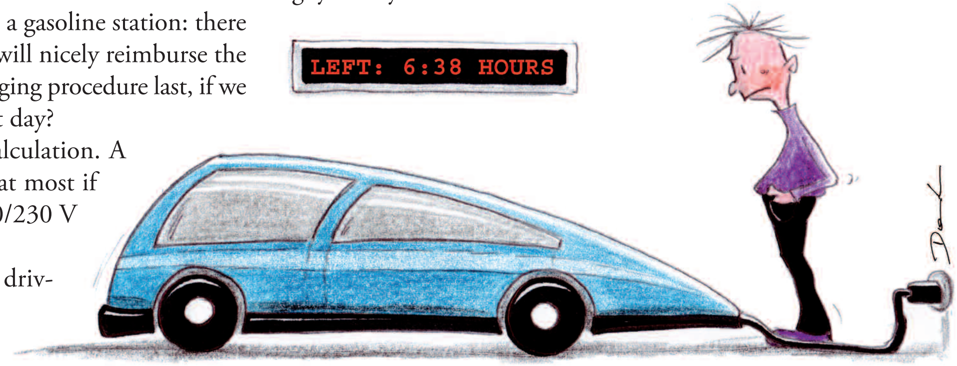
Compare this with the average car driving on the highway: it uses about 15 kW, which is higher by a factor of 4.

The conclusion is that we need to charge the batteries for roughly 4 hours for every hour of driving. Since we want to drive for about 7 hours the next day, we need to charge for about 28 hours.

So if our grand-grand-child will be driving an electric car, he had better pick a hotel that is especially equipped for fast overnight charging. And become very good friends with the hotel owner. Otherwise: forget about an early start the next morning.

Given the above result, it is interesting to calculate the energy flow into our present car when we fill our tank with gasoline. It turns out that we pump about 0,6 litres of gasoline each second. With the heat of combustion being about 35 MJ per litre, this translates into 21 MJ/s = 21 MW (!). In terms of electric power, given a conversion efficiency of ⅓, this is some 7 MW. That is 2000 times as fast as charging batteries from a standard electric outlet, see above.

Should our grand-grand-children muse about such numbers when driving down the highway, chances are that they'll look back at us and our petroleum age, and think: gee, weren't *those* guys lucky… ■



LAUNCHPAD GALLERY, SCIENCE MUSEUM, LONDON

I remember visiting museums as a child - they were full of dusty old artefacts behind faded velvet ropes with signs saying 'Do not touch' everywhere I looked. But things are very different at London's Science Museum, as I found out on a visit to their revamped Launchpad gallery.

The new Launchpad gallery aims to bring physics to life for eight to 14 year olds by encouraging them to play and interact with over 50 'hands-on' exhibits. The original Launchpad opened in 1986 and since then has seen around one million visitors a year making it the museum's most popular gallery. But this vast number of visitors had taken its toll on the exhibits, and when the opportunity for major sponsorship came along, it gave the Science Museum the chance to relocate and revamp the gallery introducing some new exhibits, and giving the old favourites a new lease of life.

The new exhibition space is divided into two main sections, dark and light, with further zoning of exhibits under physics topics such as light, materials, sound and energy transfer. On entering the gallery the first exhibit I came across was called 'Icy Bodies'. Here pellets of dry ice were being dropped onto a shallow dish of blue water. As they turned to gas they moved across the water, sometimes spinning around looking like images of spiral galaxies.

The next exhibit that caught my eye was a classic hands-on exhibit, 'The Hydrogen Rocket'. Visitors use electrolysis to separate water into oxygen and hydrogen only to ignite the hydrogen to launch a small rocket into the air.

An exhibit nearby showed water freezing on a refrigerated light box and the member of staff here showed me how I could view the ice crystals form through polarised sheets making them more defined and colourful.

As I watched the ice crystals form I realised that I had already learnt some physics, but without reading one of the short text panels that accompany each exhibit. Emily Scott-Dearing, Project Leader for Launchpad told me that this sort of learning was intentional in the exhibit design. 'The exhibits are left deliberately open ended to encourage the children to ask questions, rather than give them lots of information' she explained as we played with shining a beam of light through a prism.

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Emily went on to describe how the exhibition space had been designed with various audiences in mind. Some exhibits encourage family groups to work together and the zoning of the exhibits under different physics topics helps teachers when they come in with a class, but the overall look of the gallery is made to feel quite sophisticated so to encourage older children to visit. The £4m Launchpad project also includes hourly science shows at the gallery and a three year schools outreach programme to help reach a national audience.

As we stepped through to the light section of the gallery we faced the 4 metre tall exhibit 'Big Machine'. Groups of children were busy pumping levers, pulling on pulleys and turning Archimedes screws in order to get small plastic pellets up to the top of the exhibit, only to see them tumble back down into the troughs. Whilst I watched a water rocket was blasted over my head on a 30m long track much to the delight of the gathered crowd.

Although Launchpad is designed with eight to 14 year olds in mind, it would be impossible not to find something to amaze visitors of any age here. Launchpad allows its visitors to play and to discover physics through engaging and fascinating interactive exhibits. This helps them make positive connections with physics, hopefully inspiring them to find out more once their visit is over… and all this with not a velvet rope, or 'Do not touch' sign in sight.

London's Science Museum was established with the profits from The Great Exhibition of 1851 and is now home to more than 12,000 objects. The Science Museum is free of charge to all visitors and is open daily from 10am - 6pm. The nearest tube is South Kensington. For more information visit www.sciencemuseum.org.uk

Elizabeth Jeavans,
Outreach Officer for the
Institute of Physics (IOP), UK

1. Making Magnetic Sculptures

2. Looking at Sticky Liquids

3. Making bubbles at the Bubble Pools

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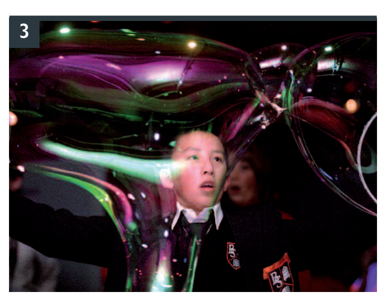

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ANNUAL INDEX - VOLUME 38 - 2007

After many years of interruption, Europhysics News resumes its annual index. The present one covers the 6 issues of 2007. It has two entries: the alphabetical author index and the subject index. The latter is divided into several sections, which are presented in alphabetical order.

AUTHOR INDEX

MATTER INDEX

The EPS directory will be published in the next issue (39/2).