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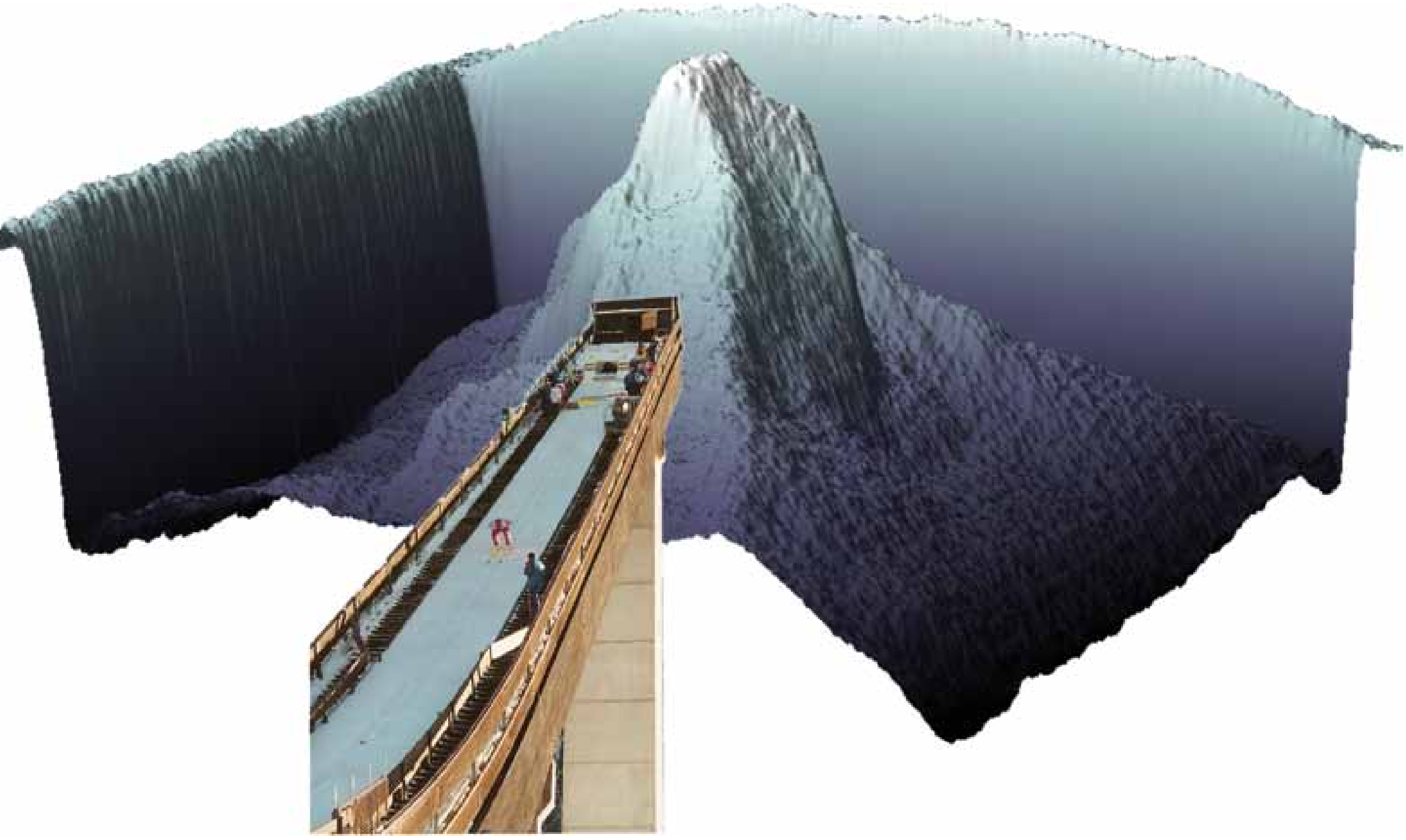

Adapted from D. Pires, J. L. Hedrick, A. De Silva, J. Frommer, B. Gotsmann, H. Wolf, M. Despont, U. Duerig and A. W. Knoll, Science, 328, 732 (2010).

Switzerland is famous for its mountains and its many gold medals in skijumping. Please find on page 14, how the Matterhorn can be shrinked down to the nano-scale size, and on page 21 an article about the construction layout of the giant ski-jumps, based on FIS technical standards.

Die SPG hat fünf neue Ehrenmitglieder !

Am 22. Juni 2010 wurden Hans Beck, Hans-Joachim Güntherodt, Louis Schlapbach, Øystein Fischer (v. l. n. r.) und T. Maurice Rice feierlich zu Ehrenmitgliedern ernannt. (Die Laudationes finden Sie in den SPG-Mitteilungen Nr. 31, S. 10).

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Review of the Annual Meeting 2010 in Basel

This year, the SPS annual meeting was organized at the University of Basel, which is celebrating its 550th anniversary. More than 500 participants came to the Kollegienhaus located in the old town of Basel for the two days conference. About 180 talks and as many posters were presented within the 9 parallel sessions. This large number of contributions is due to the participation of our partners: the national centers of competence in research MaNEP (Materials with Novel Electronic Properties), NANO (Swiss Nanoscience Institute), QP (Quantum Photonics) as well as the CCMX (Material Science and Technology) and the Division of Polymers and Colloids of the Swiss Chemical Society (SCS).

Most striking this year was the presence of a large number of students, the lively poster sessions and coffee breaks and the excellent atmosphere around the 17 stands of the exhibitors. The Kollegienhaus's configuration with its beautiful garden contributed also to the success. At the grill party over 300 persons gathered in the garden, enjoying the excellent and abundant food between sunshine and a light rain shower. A large TV screen for the WM soccer game Chile-Switzerland was also appreciated by many participants who stayed until late in the night.

The plenary sessions were attended by a large audience. The first invited speaker was Prof. Gerd Leuchs (MPI Erlangen) who gave us an overlook of the fascinating developments of the laser in the last 50 years entitled "*50 Jahre Laser: Genauer – Schneller – Kleiner – Heller*". Prof. Felicita Pauss (ETH Zürich & CERN) discussed then the new

Prof. Felicitas Pauss held an interesting talk about the LHC.

era that we enter today in unraveling the mystery of matter, space and time thanks to the Large Hadron Collider at CERN. "*Dirac Fermions in HgTe Quantum Wells*" was the title of the following talk by Prof. Laurens W. Molenkamp (Uni Würzburg) who reported on the quantum spin Hall effect observed in this material. Invited by the SCS Polymers and Colloids division, Prof. Julius Vancso (Uni Twente) reviewed the recent developments in organometallic polymers used for patterning and nanofabrication. On the se-

cond day the new professor Martino Poggio (Uni Basel) shared with us his enthusiasm in describing how to detect single spins (electronic and possibly even nuclear) and do magnetic resonance imaging with nanometer size cantilevers. Prof. Vincenzo Savona (EPFL) concluded this second plenary session with a presentation entitled "*Polaritons: Bose-Einstein condensation and quantum correlations in semiconductors*" expanding on the physics of polaritons and the first observation of polariton-pair entanglement.
The PSI was also present with a model describing the SwissFEL project, i.e., the construction of the hard-x-ray free-electron laser, planned to start its activity in 2016.

The SPS prize ceremony took place on the second day of the meeting. Erik van Heumen (Uni Genève) received the IBM prize 2010 for his work entitled "*Towards a quantitative understanding of the high T_c phenomenon*". The OC Oelikon prize was attributed to Sandra Foletti for her work on "*Universal quantum control of two-electron spin quantum bits using dynamic nuclear polarization*" and the ABB prize to Konstantinos G. Lagoudakis, (EPFL) for his work on the "*Observation of half-quantum vortices in an exciton-polariton condensate*" (see p. 7-9).

The honorary SPS membership was awarded this year to five distinguished members, namely Professors Hans Beck, Øystein Fischer, Hans-Joachim Güntherodt, T. Maurice Rice and Louis Schlapbach for their outstanding contribution to the Swiss physics community and to our Society.

Christophe Rossel, SPS President

Particle, Astro- and Nuclear Physics Session

About 65 contributions were submitted in the area of Particle, Astro- and Nuclear Physics and a very interesting and dense program of high quality talks could be assembled for the TASK sessions. Following feedback and experience from the past few meetings, the topics of the sessions were more mixed up, interleaving theory and experiment, high energy and neutrinos, low energy and nuclear physics.

In the first session on Monday afternoon various recently obtained outstanding results were presented. After the plenary talk by Felicitas Pauss (ETH Zürich and CERN) in the morning about the Large Hadron Collider at CERN, Xin Wu (University of Geneva) and Simon De Visscher (University of Zürich) showed the first results of the LHC detectors ATLAS and CMS, respectively. While the most interesting physics results are still ahead, it was impressive to see the functionality of the machine and the detectors obtained so far.
Dorothee Hildebrand (ETH Zürich) showed a selection of the recent results of the MAGIC imaging atmospheric Cherenkov telescopes, with their impact on particle physics at the highest energies.
Aldo Antognini (MPQ Garching, ETH Zürich) presented a measurement of the Lambshift in muonic hydrogen which has been used to extract a new value for the rms charge radius of the proton. Here a very startling discrepancy to earlier determinations is now a hot topic in the field.
Another outstanding result was reported by Antonio Ereditato (University of Bern): The OPERA experiment in the CERN to Gran Sasso CNGS neutrino beam has seen its first tau event candidate which – with more statistical significance – will eventually directly prove the appearance of tau-neutrinos from an originally muon-neutrino beam.

TASK then continued in two parallel sessions, essentially fully covering the status of the Swiss research in the field. Many interesting discussions also followed during the poster session and, especially, at the barbecue on Monday evening. I would like to thank all contributors, and especially the PhD students and their advisors and group leaders, for excellent talks and continued support of the TASK sessions.

Klaus Kirch, ETHZ & PSI, SPS-TASK

The Materials with Novel Electronic Properties (MaNEP) session

This session, organized by MaNEP, one of the National Centers of Competence in Research (NCCR) of the Swiss National Science Foundation, has been a great success. The different blocks stretched over both days and contained 6

The SV Service did a great job with the organisation and preparation of the coffeebreaks, lunch-buffet and, most important, the grill-party. Even the upcoming rain could not bother them, nor the more than 300 guests. A big "Thank you" to Mr. M. Legio and his team.

invited and 16 contributed talks. These talks were covering fields such as non-conventional and high-T_c superconductivity including the new Fe based materials, progress in the understanding of low dimensional magnetic systems and fundamental aspects of magnetic ground states, electronic condensation of Bose-Einstein type, as well as electronic properties of interfaces. These represented major fields of the activity in NCCR. Whereas the invited talks where all given by internationally well known scientists, the contributed talks were all held by young persons, either post-docs or PhD students. The session was always very well attended, and most of the key members of the NCCR were attending the meeting, leading to lively discussions and questions after the individual talks. A significant component of the success of the session was the strong participation of young scientists and the many contributions of posters, which with its 102 contributions were more than half of all the posters presented at the SPS meeting. The stimulated discussions at the posters strongly contributed to the network character of the NCCR, and were an important and integral part of the session. Additionally included in the session was the opportunity for the IBM award winner (who belongs to a MaNEP group) to present the prize winning study in more detail. The very strong attendance of the NCCR MaNEP participating research groups showed that MaNEP puts high priority in this meeting and shows their strong support for the society and its annual meeting.

Urs Staub, PSI Villigen, SPS-KOND

Nano Session

The session on nanoscience and nanotechnology, organized together with the NCCR Nano and the Swiss Nanoscience Institute Basel, attracted a larger audience than in the years before. Of course, the home field advantage was important. But the fact that 70 posters have been presented and the two days were full of interesting talks might have been even more important. Many young researchers presented their work, among them not only physicists but also chemists, biologists and the first PhD students with a MSc in Nanoscience.

Tibor Gyalog, Uni Basel, SPS Physics Education section

Quantum Photonics Session

The excellent opening plenary lecture (50 Jahre Laser: Genauer – Schneller – Kleiner – Heller) in the field of Quantum Photonics was delivered by Prof. Gerd Leuchs from the Max-Planck-Institut für die Physik des Lichts (Erlangen) in honour of the 50th anniversary of the “invention” of the laser. As usual in even-numbered years the annual SPS meetings are predominantly organized in conjuction with the National Centers of Competence in Research (NCCR). While MaNEP and NANO showed a strong presence with several sessions, the NCCR Quantum Photonics had only a single session with five oral presentations and two poster contributions. A greater effort shall be devoted in future years to attract a stronger participation of contributors from the fields of quantum optics, photonics, and atomic/molecular physics under the common roof of the newly founded SPS-section on Atomic Physics and Quantum Optics (AQUO).

Antoine Weis, Université de Fribourg, SPS-AQUO

Physics and Sustainable Energy Session

The SPS annual meeting included this year a special session on "*Physics and Sustainable Energy*" covering different aspects of energy production and distribution. It was very well attended, showing that energy is a topic of great interest to many people. Stefan Hirschberg showed that the *sustainability* of the different energy sources relies on a number of economic, environmental and social criteria. A methodology helps to come to decision support tools. Jochen Kreusel from *Desertec* presented how energy production in northern Africa can increase the contribution of sustainable energies to the electricity production for Europe. Mark Zimmermann gave an insight view into *SELF* the self-sufficient home developed by EMPA. Unfortunately the home itself could not be presented in Basel during the conference. Cherry Yuen discussed the challenges and possible solutions that the electrical transmission infrastructure faces due to the introduction of new renewable energy sources. Rakesh Chawla presented the *Swiss Master in Nuclear Engineering*, a master program by the four key players in this area in Switzerland. Finally Edwin Kolbe discussed the sustainability of nuclear energy and what role it could play in the future energy supply of Switzerland.

Kai Hencken, ABB Baden, SPS-INDU

Rapport on the inaugural session of the SPS History of physics (HoP) section

The first session of the History of Physics section of the SPS took place on Monday, June 21st during the annual meeting of the SPS in Basel. Given the relatively short time between the decision of creating the HoP section and the

deadline for submission of papers to the sessions of the Basel meeting, it quickly appeared unfeasible to try building a full fledged HoP session, and doing justice to the wealth of directions of study and styles that pervade current history of physics.
Another decision taken was to open the session to professional historians as well as to "amateurs", namely those physicists willing to bring their testimony on the times of their studies, on their teachers, or wishing to share their retrospective look over their life-time engagement in physics (in what follows, we shall call them "physicists-witnesses"). This decision was conforming to one of the assigned tasks of the HoP section, to establish and possibly tighten the links between the communities of historians and physicists to mutual benefits. The final program of the 2010 inaugural HoP session was thus structured into groups of talks related by their content, with historians starting the session and prominent place given to Paolo Brenni, a world-known historian of scientific instruments, and physicists-witnesses closing the day.
Among the talks that were particularly appreciated, Paolo Brenni's opening feature on instruments for scientific education received a lot of attention. Siegfried Bodenmann's evocation of the 18th century rivalry opposing Euler, d'Alembert and Clairaut over the irregularities of the Moon was another success showing the fascination that physics history can exert on working physicists. Marc Rattcliff's talk proved more challenging to typical members of the SPS since he discussed Abraham Trembley's invention of his "microscope" from the point of view of the sociology of invention, insisting on social and cultural issues rather than physical (optical) ones. Among the short talks, the two interventions of Jean-François Loude and Laurence-Isaline Stahl-Gretsch, in charge of the scientific instruments collections of, respectively, Lausanne's University and Geneva Science Museum, showed the importance of preserving, in our schools and labs, these devices which, although outdated, are important witnesses to the scientific endeavour of past generations and institutions.
Jan Lacki discussed next the short but scientifically dense life of a somewhat forgotten Swiss physicist, Walter Ritz, remembered today only for his line spectra formula which bears his name, but who was in his times one of the most promising young theoreticians recognized by such authorities as Poincaré or Einstein. Finally, the interventions of the physicists-witnesses turned out a bit mixed bag: some talks were genuinely informative (Werner Frank about Johannes de Sacrobosco, Fritz Staudacher about Jost Bürgi, and Bernhard Braunecker about Manfred von Ardenne), while others payed emotional tributes to important physicists as Jakob Jütz to his teacher, the great opticist Max Herzberger, and Klaus Stadler to his ancestor, the Nobel laureate Ferdinand Braun.
To the considerable satisfaction of the organizers, the number of people attending the inaugural HoP session was quite high, certainly above the best expectations, sometimes (first half of the session) towering at almost full room (circa 40 participants). This is even more satisfying as many young people were attending, showing that manifestly the HoP session is not only of interest to historians and retired

scientists, but draws strong interest among young physicists or physics students. It will be one of the challenges of the next months to analyse the reasons of this interest and as much as possible capitalize and rely on it to promote the HoP section.

Jan Lacki, Uni Genève, SPS-HoP

Students Afternoon

We invited 25 students from gymnasiums of the region of Basel to join the meeting for one afternoon. All of them used the opportunity to get insights into their possible career as a physicist. Our committee members Urs Staub, Kai Hencken and Klaus Kirch gave interesting insights into their daily work. They explained their research interests and talked about their professional career. The students' interest was enormous and they asked a lot of questions on physics, on a physics career and on the daily life of a physicist. Between the presentations that have been prepared especially for them, the students joined some of the presentations of the official program and last but not least they joined the poster session and take a breath of their possible future profession.

Tibor Gyalog, Uni Basel, SPS Physics Education section

The Winners of the SPS Awards 2010

The SPS Award Committee, presided by Prof. Hans Beck (Uni Neuchâtel) had this year again the great challenge to choose the three finalists among the 7 candidates nominated for the three renowned awards. Indeed all the proposed candidates had performed excellent work of high scientific quality. In addition to a short presentation at the award ceremony, the three prize winners had the opportunity to give a 15 min talk about their work in other parallel sessions. They are presented in more details below.

(Laudationes written by Hans Beck, abstracts written by the respective authors)

From left to right: Hans Beck (Chair of the award committee), Sandra Foletti (Oerlikon award), Erik van Heumen (IBM award), Christophe Rossel (SPS President), Konstantinos Lagoudakis (ABB award)

SPS Award for General Physics, sponsored by ABB

Konstantinos G. Lagoudakis got a BSc in Physics, with grade A, at the University of Athens in his home country, and a MSc, with distinction, in Optics and Photonics at the Imperial College in London. For his PhD work at the Ecole Polytechnique Fédérale in Lausanne he has studied the fundamental properties of Bose-Einstein condensates of exciton polaritons.

Working on the hot topic of Bose-Einstein condensation of polaritons in microcavity systems, Konstantinos has shown his outstanding capabilities, both in mastering difficult experimental techniques and in developing a deep theoretical understanding. First, he has demonstrated the apparance of vortices in the condensate, which can be detected through a "fork-like dislocation" in the near field interferometry images of the condensate. Their existence proves the superfluid nature of the condensate. He then went one step further and realized the first clear observation of half-quantum vortices in this system with the help of polarization-resolved interferometry, real-space spectroscopy and phase imaging. This particular phenomenon, that had been predicted theoretically, is based on the fact that the polariton superfluid is characterized by a two-component order parameter, due to the spin of the condensing particles.

Attributing the General Physics prize to Konstantinos Lagoudakis the Swiss Physical Society honors an outstanding and brillant young physicist who has produced important new results at the forefront of his research field. His publications have been widely appreciated. He has already new experimental findings to present, namely the ultrafast apparition of vortices and the observation of Josephson oscillations in the polariton condensates.

Observation of half-quantum vortices in an exciton-polariton condensate

The elementary excitations of spinor superfluids are non standard vortical entities that carry fractional vorticity: the commonly known half quantum vortices (HQVs). Contrary to the most usual case of singly quantized vortices where the phase is rotating by 2π around the core, HQVs are characterized by a π rotation of the fluid phase and a π rotation of the fluid spin when circumventing the vortex core. They have been predicted theoretically in the late seventies by the pioneering work of Volovik and Mineev (1976) and Cross and Brinkman (1977) [1]. In the dilute atomic gas Bose Einstein Condensates community, spinor condensates are by now established in several laboratories. They constitute the ideal systems to create and investigate half quantum vortices but the required complexity to excite and capture them has not allowed for their direct observation so far. The only signs of these unconventional vortices have only been reported in high T_c superconductor grain boundaries [2]. Exciton polariton condensates in the solid state are alternative systems in which the observation of half quantum vortices was thought to be possible. The nature of the polariton quantum fluid topology, which depends on the local polarization splitting, can be either that of a scalar or that of a spinor fluid depending on whether the splitting is large or almost zero respectively. In this experimental work we have set out to go beyond the celebrated case of vortices in scalar polariton quantum fluids and we have managed to provide the first experimental evidence of half quantum vortices in a spinor quantum fluid by taking advantage of the spinor nature of polariton condensates.

[1] G. E. Volovik and V. P. Mineev JETP Lett. 24, 561-563 (1976)
[2] J. R. Kirtley et al. Phys. Rev. Lett. 76, 1336 (1996)

SPS Award for Condensed Matter Physics, sponsored by IBM

Erik van Heumen is Dutch. Having obtained his MSc at the University of Leiden he came to the Département de Physique de la Matière Condensée in Geneva for a PhD thesis, dedicated to a better quantitative understanding of high temperature superconductivity. He is now back in his home country, at the University of Amsterdam. Being project leader of a research project entitled "Superconductivity enters the iron age: testing quantitative theories of superconductivity in iron pnictide high T_c superconductors" he fully profits from his new insight into the phenomenon of superconductivity.

High temperature superconductivity is still a major challenge for theoretical physicists. Whereas most specialists in the field believe that the strong electronic correlations necessitate modelling that is different from what has been developed for low temperature materials, Erik has based his considerations on the well established strong coupling formalism that builds a link between the optical conductivity in the normal state, the electronic self-energy, the intensity of the bosonic coupling producing Cooper pairs and the superconducting critical temperature. Using his measured optical data for materials with doping levels spanning the range from underdoped to overdoped, he gets information about the "glue function" that provides the bosonic coupling leading to pairing. He then shows that the resulting critical temperatures follow the dome-shaped dependence on doping with values that are only a factor 2 to 3 above the experimental values.
Given that various other models are not consistent with the relation between optical spectra and transition temperature this is a major step forward in our understanding of high temperature superconductivity. Erik also shows that the frequency dependence of the "glue function" is not compatible with the traditional electron-phonon coupling.

Erik is not only an extremely skilled and powerful experimentalist, but his work also certifies his profound understanding of theoretical analysis and modelling. Let us hope that his deep insight will also lead to an identification of the "glue" that creates electron pairs in the high T_c materials !

Towards a quantitative understanding of the high T_c phenomenon

Conventional wisdom, based on observations in simple metals like lead, is that superconductivity arises from the interaction between electrons mediated by the vibrations of the crystalline lattice. For these materials the theoretical description of the electron-phonon interaction is known as the Migdal-Eliashberg theory. For a number of reasons the pairing mechanism of high T_c superconductors is believed not to be mediated by electron-phonon interaction: (i) The transition temperatures are extremely high. (ii) The electrons in these materials are strongly correlated resulting inter alia in strong magnetic fluctuations and a doping controlled transition into a Mott-Hubbard insulating state. (iii) The condensed pairs have d-wave symmetry. While Migdal- Elaiashberg can in principle be generalized to incorporate interactions mediated by magnetic fluctuations, it can not describe the Mott-Hubbard insulating state and related phenomena. The validity of a generalized Migdal-Eliashberg approach in part of the phase diagram should therefore be tested experimentally. This has been the main objective of this work. We have used a generalized Migdal-Eliashberg approach to analyze the optical spectra of several members of the cuprate family, spanning a range of dopings and critical temperatures [1,2,3]. The overdoped cuprates are thought to be close to Fermi liquids where this formalism should work reasonably well. We found that this is indeed the case, but the same formalism also works surprisingly well for the compounds around optimal doping where the highest critical temperatures are obtained. It works so well that if we analyze the optical spectrum at room temperature, it allows for a quantitative prediction of the optical spectrum at much lower temperatures. At the same time it allows us to extract the energy scales and strength of the interactions felt by the electrons in these materials. Using this information we can calculate the critical temperature expected for such interactions and we find that it is more than strong enough to explain the high T_c of these materials. Although we have not yet pinpointed the exact source of the interactions, our work shows that they originate from the correlated electron motions. Therefore this work puts stringent conditions on possible theoretical frameworks for the high T_c cuprates.

[1] E. van Heumen, "Towards a quantitative understanding of the high T_c phenomenon" Ph D thesis, Université de Genève (2009)
[2] E. van Heumen, E. Muhlethaler, A. B. Kuzmenko, H. Eisaki, W. Meevasana, M. Greven and D. van der Marel, Phys. Rev. B 79, 18451 (2009)
[3] E. van Heumen, W. Meevasana, A. B. Kuzmenko, H. Eisaki and D. van der Marel, New Journal of Physics, 11, 055067 (2009)

SPS Award for Applied Physics, sponsored by OC Oerlikon

Sandra Foletti has studied physics at the two Federal Schools of Technology, two years in Lausanne and up to the MSc degree in Zürich. She did the first part of her experimental PhD work on spin qubits in GaAs double quantum dots at the Weizmann Institute of Science in Israel, before she moved to Harvard University for the second part of her thesis work.

Quantum computation and information processing – Sandra's research field – is a challenging application of the basic laws of quantum mechanics. It aims at implementing secure information transfer and at providing methods for solving complex computational problems. It is well known that the solid state environment limits the necessary coherence time of the quantum bits that should do the work for the user. Sandra has shown that even in GaAs, where each atom bears a nuclear spin, this problem can be overcome. Her work focuses on the dynamic coupling and decoupling between the coupled spins of two electrons in a double quantum dot structure and the surrounding bath of nuclear spins. Her work has literally revolutionized the field ! By decoupling the qubit spin from its environment she has succeeded in extending the coherence time by 3 orders of magnitude, reaching several hundreds of microseconds. Taking advantage of the hyperfine interaction between electrons and nuclei she has generated a magnetic field gradient which is needed to achieve full control over the individual two-electron spin qubit.This was a non-trivial experimental task that Sandra has mastered beautifully.

Therefore, Sandra's work, although in principal being done in the framework of basic quantum physics, represents a striking breakthrough in the worldwide effort to use spin qubits in solid state systems with sufficiently long coherence time. This is an important step forward towards the application of fundamental physics to quantum computing, which is a promising future tool for the community of computer users. Sandra therefore fully merits the Swiss Physical Society prize for applied physics.

Universal quantum control of two-electron spin quantum bits using dynamic nuclear polarization

Spin based quantum bits have been considered as promising candidates for quantum computation due to their potential for scalability, miniaturization and control. In this work [1] we utilize a logical spin-based quantum bit where the two-level system is provided by the $m_z = 0$ singlet and triplet states of two electrons confined to a double quantum-dot structure. In comparison with the single electron spin qubit, this approach has the advantage that it is protected against uniform magnetic field fluctuations and more importantly, that all manipulations can be done electrostatically.
Universal control of the quantum bit requires arbitrary rotations around two axes of the Bloch sphere: one axis, demonstrated in earlier work, corresponds to rapid exchange of the two electrons. Here we demonstrate control over the second rotation axis whose physical implementation is a magnetic field gradient across the two dots. We take advantage of the hyperfine interaction that couples the electrons to approximately a million nuclei of the host GaAs lattice to create such a gradient.
To operate our two-electron spin qubit, we first generate a field gradient by dynamical nuclear polarization of the underlying lattice, employing pulse schemes that transfer angular momentum and thus magnetic moment to the nuclei. With such pumping sequences, we can achieve gradients in excess of 200 mT, that can be sustained for 30 min and beyond.
Once a nuclear gradient of the appropriate magnitude is created, the qubit can be manipulated. We demonstrate full quantum control of our qubit by reconstructing the evolution of the state of the qubit within the Bloch sphere through quantum state tomography. The typical manipulation times of our qubit are in the nanosecond range. In combination with coherence times of ≈ 100 μs [2], this allows for at least 10^4 quantum operations which are required for fault tolerant error correction schemes.
Our gradient generation through the hyperfine interaction demonstrates that the nuclear spin environment may actually serve as a valuable resource for spin qubits. Moreover, it lays the foundation for future development of additional control schemes that are needed in order to prolong the inhomogeneous decoherence time T^*_2 which ultimately limits the qubit fidelity [3].

[1] S. Foletti, H. Bluhm et al., Nature Physics 5, 903 (2009)
[2] H. Bluhm, S. Foletti et al., arXiv:1005.2995
[3] H. Bluhm, S. Foletti et al., arXiv:1003.4031

Notes from the General Assembly

At the general assembly several important points were addressed. In particular changes in the bylaws were needed to adapt to the new membership fees and new categories of members. All the proposed modifications (cf. SPG Mitteilungen Nr. 31) were accepted and will become effective by January 2011. The creation of the new section "History of Physics" was approved unanimously.
Reelected for a new term are the following committee members: Christophe Rossel (President for one more year), Pierangelo Gröning (Treasurer) and Urs Staub (Condensed Matter Physics).
Antoine Pochelon, past revisor, was elected new secretary in replacement of Bernhard Braunecker, who was warmly thanked for his long and efficient commitment as secretary and who shall occupy the new position of scientific editor.
Jan Lacki has also been unanimously elected as head of the new section "History of Physics". More details on the general assembly will be found in the minutes.

Christophe Rossel, SPS President

New SPS Committee Member

Prof. Jan Lacki (History of Physics)

After studying physics at the University of Geneva, Jan Lacki obtained his Ph. D. in theoretical physics in 1989 with a thesis in the field of mathematical methods in high energy physics. During the next years, he continued research with publications in string theory, conformal field theory, and later in numerical simulations of the behaviour of statistical mechanics models. In parallel with his interest in theoretical physics, Jan Lacki went in these years increasingly involved in activities related to history and philosophy of physics, a field which since his student years was attracting him. In 1990, Jan Lacki went as a post-doc to the Institute for Advanced Study at Princeton where he pursued his interests in theoretical physics as well as in history and philosophy of physics. Back to Switzerland in 1993, he joined the team of the History and Philosophy of Science (HPS) Unit of the University of Geneva with which he had already working contacts before leaving for United States. After the retirement of the head of the HPS unit in 2005, Jan Lacki took over its direction as professor "titulaire", taking advantage of his international contacts to further promote his Unit within Geneva and Switzerland as well as abroad. Member at large of the French CNRS, Jan Lacki is among others currently working on a project of a convention linking the philosophers and historians of the Paris 7 – Denis Diderot University with those of Geneva.

Current research interests of Jan Lacki are history of quantum theory, especially in the founding years 1925-27 of quantum mechanics and then of quantum field theory, relativity theory, and, also on the philosophical side, the study of the historical and epistemological aspects of approximation methods in physics, with special emphasis put on perturbation theory. Within a recent grant from the SNF, Jan Lacki and members of his team are involved in a broad study of the history of theoretical physics in Switzerland, especially in its French speaking part. He also currently supervises a thesis on recent history of CERN (history of LEP), and another one devoted to the “Wigner problem” of the effectiveness of mathematics in natural sciences.

The opportunity of developing a new SPS section devoted to the history of physics is a challenge that suits perfectly Jan Lacki’s long term engagement both in promoting interest in history of physics within the community of physicists, and in working to maintain close links of historians of science with the scientists themselves. Indeed, beyond the sheer intellectual and cultural importance of history of science, physicists can benefit from the knowledge of the history of their field, if only because the wealth of models and theories it displays can sometimes inspire them in their current practice. Reciprocally, believes Jan Lacki, historians of science, much involved currently in examining the sociological aspects of science where its cultural, institutional and political aspects are mainly considered, should never loose sight of, and rather keep close to the very core of scientific activity, theory building and experimentation, which underlie the scientists’ identity and that distinguish their practice from other forms of knowledge.

Ausschreibung der SPG Preise für 2011
Annonce des prix de la SSP pour 2011

Auch im Jahr 2011 sollen wieder SPG Preise, die mit je CHF 5000.- dotiert sind, vergeben werden.

- SPG Preis gestiftet vom Forschungszentrum ABB Schweiz AG für eine hervorragende Forschungsarbeit auf allen Gebieten der Physik
- SPG Preis gestiftet von der Firma IBM für eine hervorragende Forschungsarbeit auf dem Gebiet der Kondensierten Materie
- SPG Preis gestiftet von der Firma OC Oerlikon für eine hervorragende Forschungsarbeit auf dem Gebiet der Angewandten Physik

Die SPG möchte mit diesen Preisen junge PhysikerInnen für hervorragende wissenschaftliche Arbeiten auszeichnen. Die eingereichten Arbeiten müssen entweder in der Schweiz oder von SchweizerInnen im Ausland ausgeführt worden sein. Die Beurteilung der Arbeiten erfolgt auf Grund ihrer Bedeutung, Qualität und Originalität.
Der Antrag für die Prämierung einer Arbeit muss schriftlich begründet werden. Die Arbeit muss in einer renommierten Zeitschrift publiziert oder zur Publikation angenommen sein. Wenn mehrere Publikationen eingereicht werden, um die Leistungen des Kandidaten umfassender darzustellen, muss genau gesagt werden, welche Publikation für die Preisvergabe in Betracht gezogen werden soll.
Der Antrag muss die folgenden Unterlagen enthalten:

Begleitbrief mit Begründung, Lebenslauf des Kandidaten mit Publikationsliste, die zu prämierende Arbeit und ein Gutachten.

Diese Unterlagen werden elektronisch im "pdf"-Format direkt an das Preiskomitee eingereicht (große Dateien bitte komprimieren (zip oder sit)):

En 2011, la SSP attribuera à nouveau des prix de CHF 5000.- chacun, à savoir:

- Le prix SSP offert par le centre de recherche ABB Schweiz AG pour un travail de recherche d'une qualité exceptionnelle dans tout domaine de la physique
- Le prix SSP offert par l'entreprise IBM pour un travail de recherche d'une qualité exceptionnelle en physique de la matière condensée
- Le prix SSP offert par l'entreprise OC Oerlikon pour un travail de recherche d'une qualité exceptionnelle dans le domaine de la physique appliquée

La SSP aimerait saluer l'excellence d'un travail scientifique effectué par de jeunes physiciens ou physiciennes. Les travaux soumis à candidature doivent avoir été effectués en Suisse ou par des Suisses à l'étranger. L'évaluation portera sur l'originalité, l'importance et la qualité des travaux.
La candidature soumise à nomination doit être justifiée par écrit. Le travail doit avoir été publié dans une revue renommée ou être accepté pour publication. Si plusieurs publications sont présentées, dans le but de mieux décrire la performance du candidat, il faut préciser laquelle est à prendre en considération pour l'attribution d'un prix.
Le dossier de candidature doit comporter les documents suivants:

une lettre de motivation, le curriculum vitae des auteurs, une liste de publications, le travail proposé et une lettre de recommandation.

Ces documents seront envoyés électroniquement en format "pdf" directement au comité de prix (svp. comprimez des fichiers très grands (zip ou sit):

awards@sps.ch

Einsendeschluss: 28. Februar 2011
Délai: 28 février 2011

Die Preise werden an der Jahrestagung 2011 der SPG in Lausanne überreicht.

Das Preisreglement befindet sich auf den Webseiten der SPG: *www.sps.ch*

Les prix seront attribués à la réunion annuelle de la SSP qui se tiendra en 2011 à Lausanne.

Le règlement des prix se trouve sur les pages Web de la SSP: *www.sps.ch*

Ein "Smart Grid" dank intensivierter Zusammenarbeit von SATW und SPG

Bernhard Braunecker, SPG; Rolf Hügli, Geschäftsführer SATW

Industriephysiker als Potential

Die SPG ist gemäss ihren Statuten (Art. 11-13) Mitgliedsgesellschaft der beiden Schweizerischen Akademien SCNAT und SATW. Dabei deckt die SCNAT mehr die Belange der an den Hochschulen tätigen Wissenschafter ab, während die SATW mehr die Industriephysiker anspricht, die immerhin 10-20% der knapp 1200 SPG-Mitglieder ausmachen.

Eine der Hauptaktivitäten der SPG ist ihre Jahrestagung, die durch neue Ansätze – wie die alle zwei Jahre praktizierte Hinzunahme der NCCR-Cluster – unter den akademischen Mitgliedern stark an Attraktivität gewonnen hat. Die SPG stellt aber fest, dass die Industriephysiker weiterhin leider nur marginal an der Tagung vertreten sind und als Gruppe auch sonst relativ schwer erreicht werden können. Diese Asymmetrie liegt zum Grossteil in der Industriekultur und ihren wirtschaftlichen Zwängen begründet, wobei man sich generell schwerer tut, zu publizieren, wo aber vielfach auch die Zeit, die Musse und das Basiswissen nicht zur Verfügung steht, um sich in Details der vorgetragenen Forschungsarbeiten zu vertiefen.
Was ist also zu tun, um auch diese Gruppe stärker einzubinden?

Passender Leistungsauftrag der SATW

Eine interessante Möglichkeit der besseren Unterstützung von Industriephysikern eröffnet jetzt eine verstärkte Zusammenarbeit mit der Schweizerischen Akademie der Technischen Wissenschaften (SATW), pflegen beide Organisationen doch bereits heute einen begrenzten regelmässigen Informationsaustausch. Mitglieder der SPG sind beispielsweise höchst willkommene Referenten an den TecDays der SATW. Betrachten wir aber die Zusammenarbeit in praxisrelevanten Fragen, so gäbe es aus Sicht der SATW noch ein erhebliches, bis anhin ungenutztes Potential.

In der Leistungsvereinbarung mit dem Staatssekretariat für Bildung und Forschung (SBF) wird der SATW unter anderem der Auftrag erteilt: "Experten und Expertinnen zusammenführen". Die SATW geht noch einen Schritt weiter. In ihrem eigenen Mission-Statement steht: "Die SATW engagiert sich für die Umsetzung wissenschaftlicher Erkenntnisse in volkswirtschaftlich wertvolle Leistungen". Die SATW versteht sich also als "Akademie mit praktischer Wirkung". Nebst der Pflege der Wissenschaft sieht sie auch die Umsetzung von Erkenntnissen in der Praxis (Industrie) als Aufgabe: Wissenschaft und Technik zum Wohle der Gesellschaft.
Dazu nehmen zum einen die Kommissionen der SATW Stellung zu volkswirtschaftlich wichtigen Fragen aus den Bereichen Energie, Informationsverarbeitung, Nanotechnologie und anderen mehr. Zum anderen befassen sich die öffentlichen SATW - Jahreskongresse mit Themen wie Energie, Mobilität, Klima, industrielles Krisenmanagement und – dieses Jahr – mit der Luft- und Raumfahrt, womit sie insgesamt einen breiten Technologiebereich abdecken. Zusätzlich organisiert die SATW Besuche bei Firmen und Instituten sowie z.B. von Grossbaustellen.

Konkrete Zusammenarbeit für die Technologie-Früherkennung

Die Frage stellt sich, inwieweit die genannten SATW-Aktivitäten auch für die Industriemitglieder der SPG interessant sein könnten? Industriephysiker sind in der Regel *Vorentwickler*, also im Bereich zwischen Forschung und Entwicklung angesiedelt, und somit gehalten, neue Technologieansätze zu verfolgen. Dabei ist es durchaus erwünscht und üblich, diese Ansätze, - solange sie noch produkt- und marktfern sind -, innerhalb einer ‚Community', also auch mit Kollegen anderer Firmen, zu diskutieren, um Risiken und Chancen für die eigene, geplante Produktreihe abwägen zu können. Dieser frühzeitige Informationsaustausch kann sogar die Grundlage einer erfolgreichen Strategie darstellen: So verfährt das staatliche MITI in Japan, wenn es Technologietrends erstmals *gemeinsam* von Grossfirmen hinterfragen und bewerten lässt, obwohl sich diese auf dem Markt später heftig konkurrenzieren können.

Im soeben verabschiedeten Mehrjahresprogramm (2012-2016) hat sich die SATW vorgenommen, für die Schweiz eine Technologie-Strategie in Form einer Technologie-Roadmap zu formulieren. In diesem Dokument sollen aus neutraler Perspektive all diejenigen Schlüsseltechnologien identifiziert werden, die für die Volkswirtschaft der Schweiz während eines Zeitraumes von mehreren Jahren eine hohe Bedeutung erlangen könnten. Angesichts dieses Zeithorizontes sollen vor allem möglichst konkrete und belegbare Aussagen über bereits klar erkennbare Trends in der angewandten Forschung diskutiert und ins Bewusstsein der Entscheidungsträger gebracht werden. Natürlich ist auch vorgesehen, die Schweiz betreffende Themen der Grundlagenforschung in Gebieten hoher technischer und gesellschaftlicher Relevanz zu identifizieren.

Damit diese Studie fundierte und nachvollziehbare Empfehlungen liefern kann, ist die SATW auf die Mitarbeit von möglichst vielen Know-How-Trägern in der Praxis angewiesen, wobei diejenigen Mitglieder der SPG, die in der Industrie in der Forschung und Entwicklung arbeiten und sich zwangsläufig mit diesen Fragestellungen auseinandersetzen, ideal geeignet wären. Natürlich geht es dabei nicht um vertrauliche firmenspezifische Prozesse, sondern um die globalere Beobachtung der Trends in einem bestimmten Industriesektor.

Die SATW wird ihre Projektorganisation für diese Aktivität in der zweiten Jahreshälfte formieren und sie anschliessend der SPG präsentieren. Die SATW ist zudem daran, ihre Strukturen und Abläufe zu modernisieren. Ziel dieser

Reorganisation ist die Fähigkeit/Kompetenz, Aktivitäten in thematisch breiten Feldern schnell und einfach lancieren zu können. Um die thematische Breite erweitern zu können, muss konsequenterweise auch das Expertennetzwerk der SATW mit Spitzenleuten aus allen wichtigen Technologiebereichen erweitert werden. Auch hier ist die Mitarbeit von Mitgliedern der SPG als Experten sehr willkommen.

Simultane Nachwuchsförderung

Ein weiteres wichtiges Gebiet, in dem SPG und SATW den Schulterschluss praktizieren könnten, ist die *Nachwuchsförderung*. Im Verbund mit anderen Organisationen engagiert sich die SATW für die Erhöhung des Stellenwertes der Naturwissenschaften und der Technik in der Öffentlichkeit und im Erziehungssystem. Die für den Ingenieurberuf dabei bereits erarbeiteten Lösungsansätze sind voll übertragbar auf die Belange der Physikerziehung im vor-universitären Bereich. Umgekehrt kann die Physik mit ihren modernen Ansätzen, z.B. einer zeitgemässen Gestaltung der Maturaarbeiten, vorbildhaft für die anderen Organisationen im Verbund wirken.

Fazit: Machen Sie mit!

Der SATW verfügt über eine leistungsstarke und gut vernetzte Infrastruktur zur Lösung volkswirtschaftsbezogener Fragestellungen. In dieses Netzwerk kann sich die SPG mit dem Fachwissen ihrer Mitglieder – und darunter besonders der an der Technologiefront tätigen Industriephysiker –, in effektiver und effizienter Weise einbringen. Beide Partnergesellschaften können sich in dieser für die Schweiz wichtigen Aufgabe in idealer Weise ergänzen. Machen wir also das heutige lose Netzwerk zu einem ‚Nutzwerk' – zu einem "Smart Grid" – und sorgen wir gemeinsam dafür, dass darin tatsächlich auch „Wirkleistung" transportiert wird.

Sie sind herzlich eingeladen.

Universität Zürich

Physik-Institut - Institut für Theoretische Physik

«Science Alumni UZH»

Die Ehemaligen-Vereinigung der Mathematisch-naturwissenschaftlichen Fakultät der Universität Zürich «Science Alumni UZH» und die beiden Physik-Institute laden ihre ehemaligen Mitarbeiter und Studierenden zu einem Treffen ein, das im Anschluss an das gemeinsame Symposium von PGZ und SPG am Nachmittag des Samstags, 2. Oktober 2010, an der Universität Zürich Irchel stattfinden soll.

Vor 27 Jahren fand das letzte Treffen anlässlich des 150-jährigen Jubiläums der Universität Zürich statt, als Prof. Verena Meyer Rektorin war. Die Zeit ist daher reif für eine Wiederholung dieses erfolgreichen Anlasses, an dem alte Kontakte wieder aufgefrischt und neue geschaffen werden können, aber auch die bemerkenswerte Entwicklung der beiden Institute mit ihrem heutigen Forschungsspektrum vorgestellt wird. Das folgende Programm ist vorgesehen:

Ehemaligen-Treffen

Datum: 2. Oktober 2010
Zeit und Ort: 14:00 - ca. 20:30
Universität Zürich Irchel,
Winterthurerstrasse 190,
8057 Zürich,
Treffpunkt Eingang Gebäude 36

ÖV - Tram 9/10 bis Haltestelle Irchel,
Parkmöglichkeit im Parkhaus Irchel,
beides in ca. 5 Minuten zu Fuss erreichbar

Programm:

- ab 14:00 Begrüssungskaffee
- 14:30 - 16:00 Vorstellung der Aktivitäten in Forschung und Lehre der beiden Physik-Institute durch die Professoren Hugo Keller, Ulrich Straumann und Daniel Wyler
- ab 16:00 Rundgang mit Führungen durch die beiden Institute
- ab 17:30 Apéro
- 18:00 Gemeinsames Abendessen in der Cafeteria «Atrium» am Irchel

Anmeldung via http://www.sciencealumni.uzh.ch/Agenda.html

Progress in Physics (19)

3D Nanofabrication using heated probes

Armin W. Knoll (ark@zurich.ibm.com) and Urs Duerig
IBM Research - Zurich, IBM Research GmbH, Säumerstr. 4, 8803 Rüschlikon

Introduction

Structuring of surfaces is at the heart of nano-technology and CMOS-electronics. For future CMOS technology, the quest to continue with Moore's scaling is driven by the economic advantages of integrating more functionality on a given Si footprint and the performance gain that can be achieved by using overall smaller devices. According to the roadmap, high throughput lithography will have to cope with a 20 nm feature size in 2017 [1]. It is not clear at all, whether optical lithography can be extended towards this scale.

At the same time prototyping tools are required to help develop the next generation CMOS devices. Today, electron beam lithography (EBL) is a well established high-resolution technology used in many fields ranging from prototyping nanoscale devices in research to the fabrication of optical masks for CMOS fabrication. However, at scales of some tens of nanometers, EBL is difficult to control because of the proximity effect, i.e., the unwanted exposure of nearby areas by secondary electrons. Therefore, new beam methods are currently investigated, e.g. He^+ beam lithography with strongly reduced proximity effects [2].
Alternatively scanning probe methods have shown that surface modifications can be achieved down to the atomic level [3] and have been used to fabricate nanoscale structures [4] and devices [5] of exceptional quality. In real-world applications, the production of nanoscale patterns and devices requires substantial throughput capabilities in combination with sufficient tip endurance to address areas on the order of $(0.1\text{-}1\ mm)^2$ at high resolution. At a typical pixel pitch of 10 nm, this translates to 10^8 - 10^{10} pixels to be written with a single tip. Therefore a highly sensitive patterning approach that is gentle to the tip is indispensable.

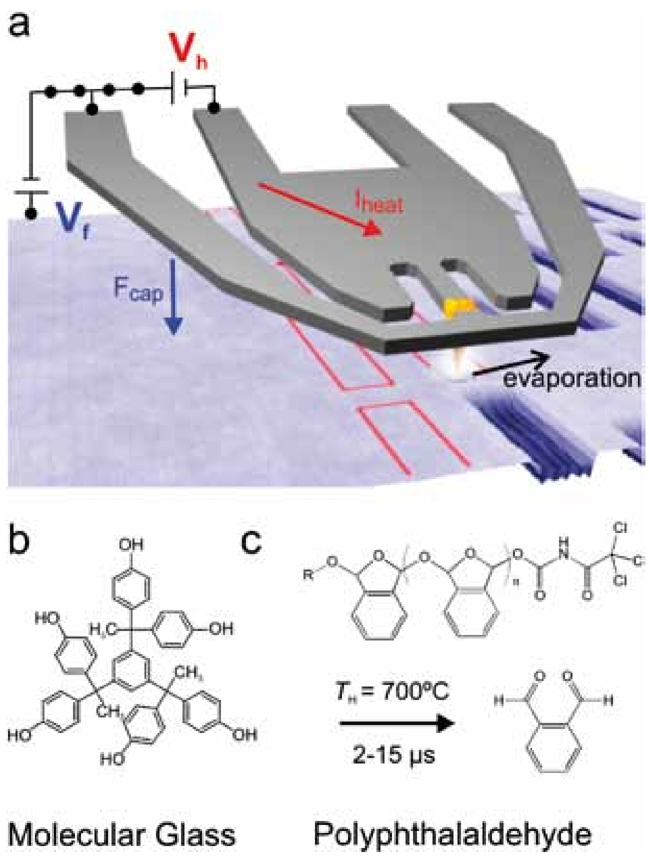


Figure 1: Patterning principle and materials.
a) The silicon cantilever has an embedded heater to locally heat the tip and thereby the resist in contact with the tip. The cantilever is pulled into contact on the timescale of one microsecond by applying an electrostatic force F_{cap}.
b) Chemical structure of the molecular glass and
c) the polymer used as resist materials, which are sensitive to the heat stimulus and react by spontaneous desorption of material.

Patterning of resist by heated probes

Our preferred strategy is to use a polymer medium that fully volatilizes upon contact with a hot atomic force microscope (AFM) tip [7-9]. This enables a solvent-free, i.e. dry patterning approach without the need to expose the substrate and the resist to solvents, thus avoiding swelling induced distortions and cross-contamination of the sample. As schematically shown in Figure 1a our cantilever-style probe sensor is made from silicon and comprises a capacitive platform for exerting a loading force by electrostatic means and a resistive heater for heating the tip, which is integrated on top of the heater. A capacitive force pulse brings the tip into contact with the resist surface and the hot tip locally triggers the evaporation reaction. Two materials that react in the desired manner have been identified. Shown in Figure 1b is a phenolic molecule [6], which forms a molecular glass in the bulk of the material [7]. Six hydroxy groups are located at the periphery of the molecule and give rise to numerous hydrogen-bonding interactions in the bulk of the material, as inferred from the high glass transition temperature T_g of 126°C. The second material is a polyphthtalaldehyde (PPA) polymer [8, 9], which exhibits a low ceiling- (or decomposition-) temperature of ~ 150°C. In such a polymer, the breaking of a single bond induces the spontaneous depolymerization of the entire polymer chain [10, 11], a concept that was first demonstrated as a dry lithography approach in the early 80's. Both materials provide the necessary stability at room temperature so that they can be imaged by the scanning probe and serve as etch masks for transferring the written patterns into the substrate of choice.

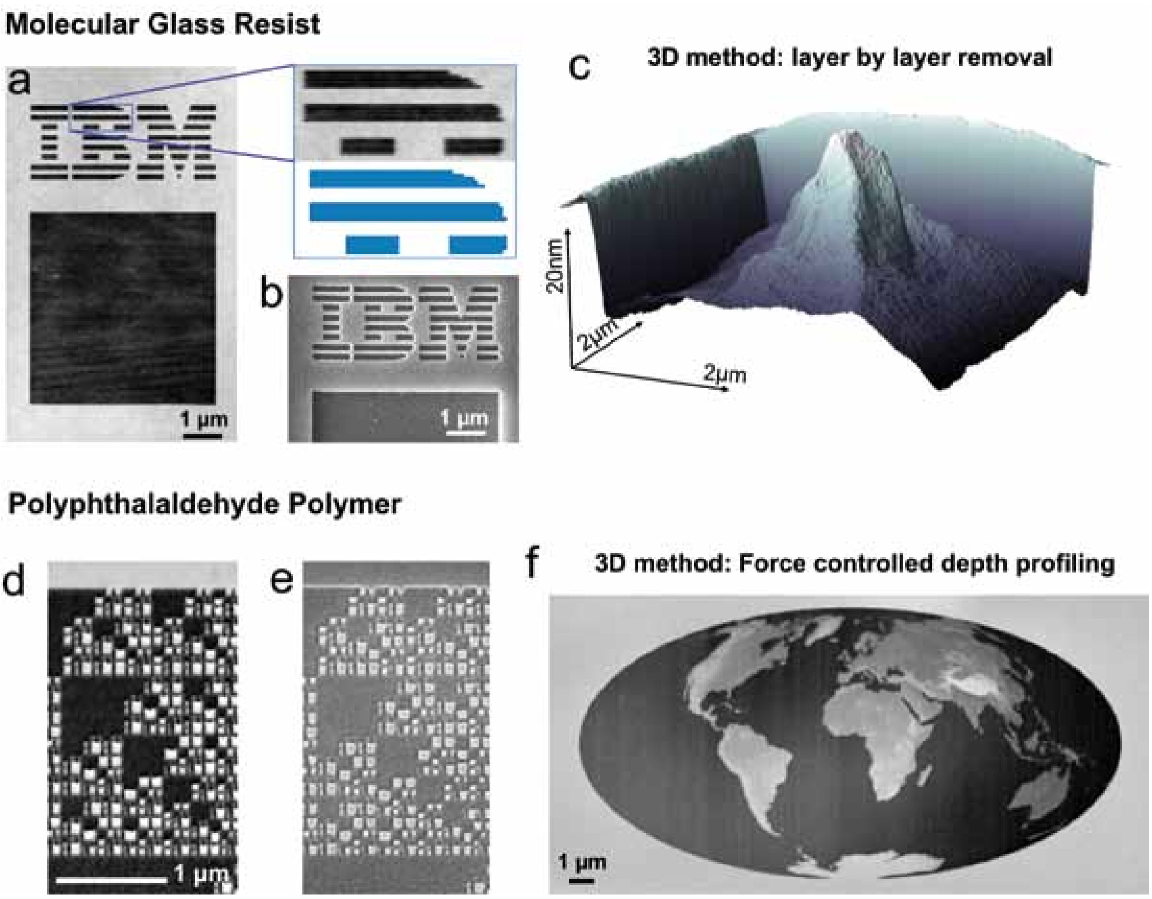


Figure 2: Patterning results and transfer into silicon substrates. a) Pattern written 8-10 nm deep into an 18 nm thick molecular glass resist. Also shown are a comparison with the programmed pattern and (b) the same pattern transferred 400 nm deep into silicon. c) 25 nm tall and 4 µm wide nanoscale replica of the Matterhorn. d) AFM image of a fractal carpet pattern written 16 nm deep into a 50 nm thick polyphthalaldehyde film. e) SEM images of the pattern after transfer into silicon. The final silicon structures are 90 nm tall. f) 3D world map written into a 60 nm thick polyphthalaldehyde film. a), b), and c) adapted from [7]; d) and e) reprinted from [9]

Examples of patterns written using the two materials are shown in Figure 2 for the molecular glass and the PPA polymer resist in the top and bottom row, respectively. The AFM images in Figure 2a and 2d exemplify the quality of conventional 2D resist patterning. Patterning is uniform, resulting from well-controlled and reproducible single-pixel-writing events. Although a substantial volume of resist material has been removed from the surface, no pile-up or redeposition of material can be detected. The patterns were transferred into silicon substrates as demonstrated by the SEM micrographs shown in Figure 2b and 2e, using reactive ion etch methods described in detail in [7] and [9]. Using these transfer steps vertical depth amplifications factors of 50 and 6 (in 2b and 2e, respectively) have been achieved by exploiting the etch selectivity of the different materials. Furthermore, the well controlled single patterning events enable the fabrication of 3D structures. A replica of the Matterhorn created in a molecular glass film is shown in Figure 2c. It was made by consecutive removal of 120 molecular glass layers with defined thickness. Fine details of the original are reproduced in the nanometer-scale replica. The conformal reproduction proves that the final structure is a linear superposition of well-defined single patterning steps. For the PPA polymer, a linear force-depth relation in combination with a high writing efficiency render the material an ideal candidate for direct three-dimensional patterning. The world map shown in Figure 2e has been written in a single patterning step encoding the depth by a linear transformation of the world's elevation data to a force map. The image comprises 5×10^5 pixels written at a pitch of 20 nm, and the writing of the entire relief was accomplished in 143 s.

The unique capability to create nanometer precise 3D structures makes the method a perfect technique for generating templates that can then be multiplied and printed by the technologies developed for nano-imprint lithography [12, 13]. We see potential applications in printing optics on chips [13], fabricating 3D nanomedical particles [14], or the creation of nanoscale 3D templates for shape matching self-assembly of objects such as nano rods or cubes [15].

References:

[1] International Technology Roadmap for Semiconductors, 2008 Update (www.itrs.net/Links/2008ITRS/Update/2008Tables_FOCUS_B.xls).
[2] J. Morgan, J. Notte, R. Hill and B. Ward, Microscopy Today, **14**, 24 (2006).
[3] D. M. Eigler, E. K. Schweizer, Nature **344** , 524 (1990).
[4] see e.g. R. Garcia, R. V. Martinez, J. Martinez, Chem. Soc. Rev., **35**, 29 (2006).
[5] A. Fuhrer, S. Lüscher, T. Ihn, T. Heinzel, K. Ensslin, W. Wegscheider and M. Bichler , Nature, **413**, 822 (2001).
[6] A. De Silva, J. K. Lee, X. André, N. M. Felix, H. B. Cao, H. Deng and C. K. Ober, Chem. Mater., **20**, 1606 (2008).
[7] D. Pires, J. Hedrick, A. De Silva, J. Frommer, B. Gotsmann, H. Wolf, M. Despont, U. Duerig and A. Knoll , Science, **328**, 732 (2010).
[8] O. Coulembier, A. Knoll, D. Pires, B. Gotsmann, U. Duerig, J. Frommer, R. Miller, P. Dubois and J. Hedrick , Macromolecules, **43**, 572 (2010).

[9] A. Knoll, D. Pires, O. Coulembier, P. Dubois, J. L. Hedrick, J. Frommer, and U. Duerig, Adv. Mater., **22**, 3361 (2010)
[10] H. Ito and C. G. Willson, Polym. Eng. Sci **1983**, 23, 331.
[11] H. Ito and C. G. Willson, Polym. Eng. Sci **1983**, 23, 1018.
[12] M. Li, L. Chen and S. Chou, Appl. Phys. Lett. 2001, **78**, 3322.
[13] K. Watanabe, T. Morita, R. Kometani, T. Hoshino, K. Kondo, K. Kanda, Y. Haruyama, T. Kaito, J. Fujita, M. Ishida, Y. Ochiai, T. Tajima, and S. Matsui, J. Vac. Sci. Technol. B **2004**, 22, 22.
[14] J. P. Rolland, B. W. Maynor, L. E. Euliss, A. E. Exner, G. M. Denison, and J. M. DeSimone, J. Am. Chem. Soc **2005**, 127, 10096.
[15] T. Kraus, L. Malaquin, H. Schmid, W. Riess, N. Spencer, and H. Wolf , Nature Nanotech. **2007**, 2, 570.

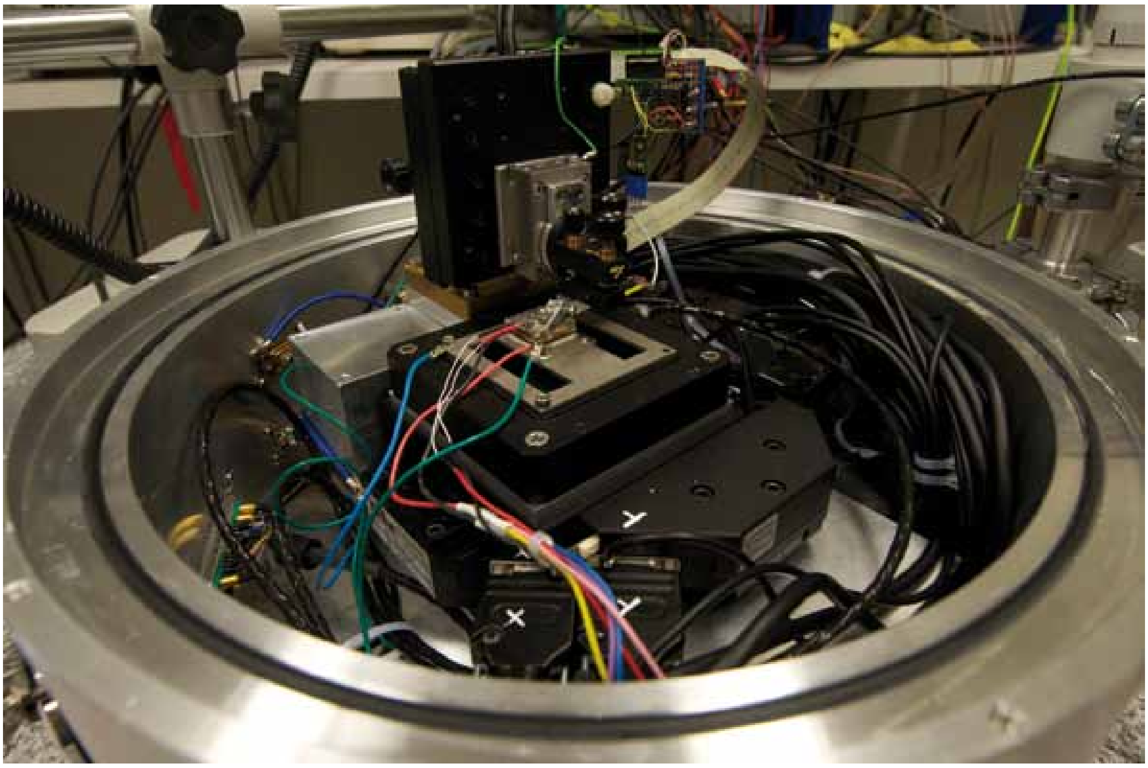


Figure 3: The new nanopatterning tool, which can fit on a desktop, at IBM Research - Zurich. At the heart of the new tool, it uses a nanoscale tip, 10,000 times smaller than an ant, to create patterns and structures as small as 15 nanometers. The photo shows a close-up of the core mechanical system of the tool, which controls the tip.

Announcement: Joint Annual Meeting of SPS and ÖPG in 2011

After the great success of the joint meeting 2009 in Innsbruck organized wit the Austrian Physical Society (ÖPG), it has been decided to repeat the experiment in 2011. This time the joint meeting will be held in Switzerland and we shall welcome our Austrian colleagues at the EPFL in Lausanne for three days on 15-17 June 2011.
Based on the positive feedback received after the Innsbruck conference, the format of the meeting will be the same with plenary talks, invited and contributed presentations in parallel topical sessions, poster sessions and a scientific exhibition.

A joint award ceremony is also planned as well as separated general assemblies for both societies. If you wish to contribute in the organization of a session or suggest the name of potential plenary speakers, feel free to contact the SPS committee.

More detailed information will be provided in the next issue of the SPS Communications, to be released in January 2011. All details will also be available on our website *www.sps.ch* .

Progress in Physics (20)

Muonic hydrogen and the proton radius puzzle

A. Antognini [1,2] (aldo@phys.ethz.ch) and F. Kottmann [1,2] on behalf of the CREMA collaboration
[1] Institut für Teilchenphysik, ETH Zürich, 8093 Zürich
[2] Paul Scherrer Institute, 5232 Villigen PSI

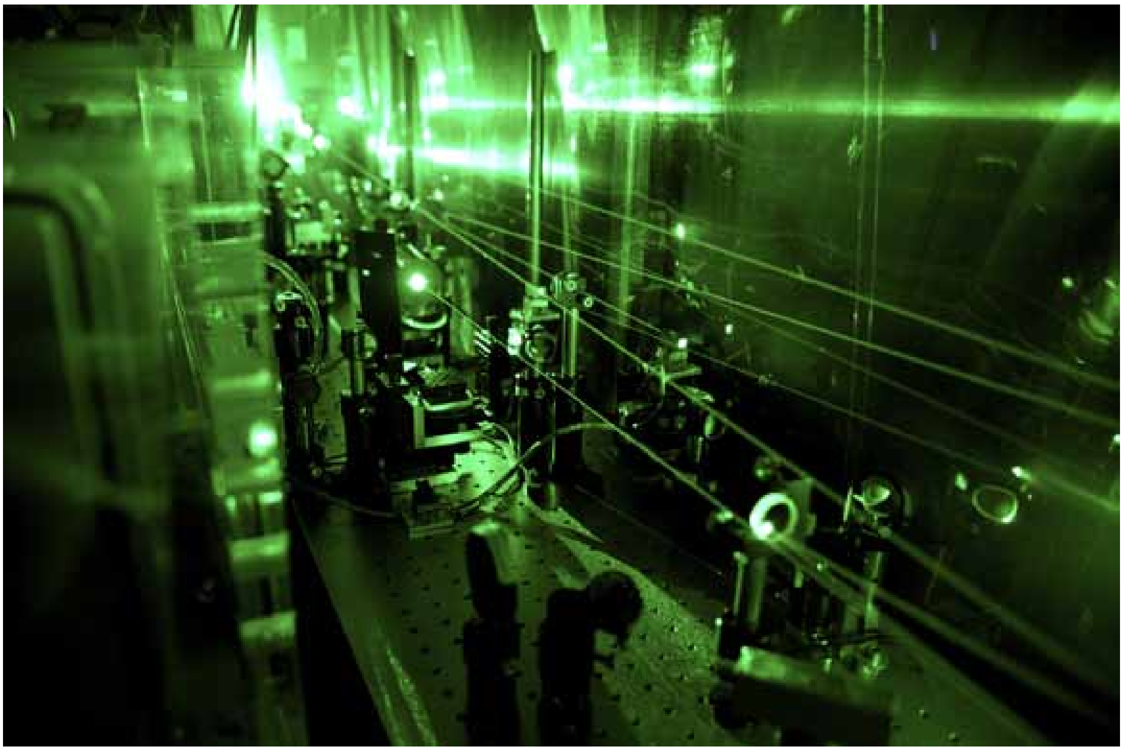


Figure 1: Part of the laser system used to measure the muonic hydrogen 2S-2P splitting.

Introduction

The hydrogen atom is unique since physical theories can be applied to it "without" approximations. Any discrepancy between theoretical prediction and experimental measurement which may be unveiled at any increase of theoretical and experimental accuracy thus holds the potential for new fundamental insights.

Nothing can hide in hydrogen, not even the proton at its center. In fact, measurements with hydrogen beams by Stern in 1933 revealed that the magnetic moment of the proton deviated from the prediction of the Dirac relativistic theory. This was the first indication that the proton - contrary to the electron - has a structure. In 1947 measurements of the 2S-2P (Lamb shift) and 1S-hyperfine splitting in hydrogen deviated from those predicted by the Dirac equation. This was the initiation for the development of quantum electrodynamics (QED). In the last four decades, the goal to measure hydrogen energy levels with greater accuracy has lead to advances in high resolution spectroscopy and metrology. This peaked with the invention of the frequency comb laser by Hänsch in the late 90ies. The high accuracy obtained with such techniques provided cornerstones to test bound-state QED, to determine the Rydberg constant and the proton radius (assuming the correctness of the theory), and to search for slow time variations of fundamental constants.

Hydrogen energy levels are slightly modified by the fact that in contrast to the electron the proton has a size. Hence, to precisely predict these energy levels an accurate knowledge of the root-mean-square charge radius of the proton is necessary. The historical method of determining the proton radius was based upon scattering electrons on protons, in effect by scattering an electron beam on a liquid hydrogen target. The uncertainty related to the knowledge of the proton radius extracted from electron-proton scattering limited the prediction accuracy of the hydrogen energy levels, and consequently it was limiting the comparison between theory and measurements. Therefore to advance the check (comparison between prediction and measurement) of bound-state QED describing the hydrogen energy levels it was necessary to have a more precise determination of the proton radius. This was one of the main motivations for our experiment: to measure the 2S-2P energy difference in muonic hydrogen (μp), an exotic atom composed by a negative muon and a proton. The single electron of a hydrogen atom is replaced by a negative muon which has a lifetime of only 2 microseconds and is 200 times heavier than the electron. According to the laws of quantum mechanics the muon wave functions in S-states overlap therefore more with the proton and the corresponding µp energy levels are sensitive to the proton size. By measuring the 2S-2P transition frequency in muonic hydrogen it is thus possible to extract with great accuracy the proton radius, assuming that the main QED contributions to the 2S-2P splitting are correctly predicted by theory.

Method and measurements

Our experiment is based upon laser spectroscopy of muonic hydrogen. The main components which had to be developed for this experiment are a low energy muon beam, an infrared laser system used to drive 2S-2P transitions in µp, and detectors for 2 keV X-rays emitted from 2P-1S transitions. More details are given in Ref. [1]. Muonic hydrogen is produced by stopping negative muons in hydrogen gas. Only at the Paul Scherrer Institut (PSI), Switzerland, is there a suffciently strong low energy muon beam suited for such an experiment. The µp atoms are produced at highly excited states (around n=14). Most of these de-excite quickly to the 1S-ground state, but ~1% populate the long-lived 2S-state (Fig. 2 (a)). A short laser pulse tunable to a wavelength around $\lambda \approx 6$ µm (corresponding to the 2S-2P energy splitting) illuminates the muonic atom. 2S → 2P transitions are induced by the laser light (Fig. 2 (b)), immediately followed by 2P → 1S de-excitation via emission of a 2 keV X-ray (lifetime τ_{2P} = 8.5 ps). The transition from the 2S to the 2P state and the subsequent emission of X-ray only occurs if the laser frequency corresponds to the energy difference between 2S and 2P levels.

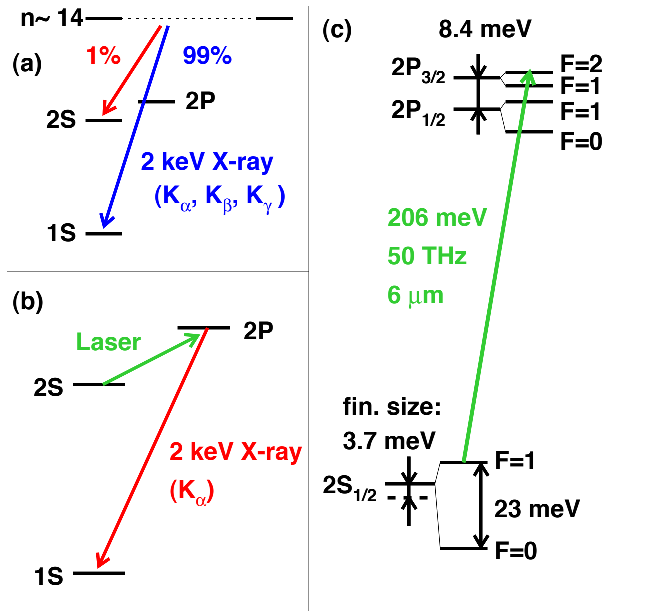


Figure 2: Energy levels, cascade and experimental principle in muonic hydrogen.
(a) About 99% of the muons stopped in H_2 proceed directly to the 1S ground state during the muonic cascade, emitting X-rays of the Lyman series at around 2 keV. 1% of the muons form long-lived metastable 2S states with a lifetime τ_{2S} = 1 µs at 1 hPa (1 mbar) hydrogen gas.
(b) The muonic hydrogen atoms are illuminated by a short laser pulse 1 µs after their formation. If the laser frequency is on resonance, 2 keV X-rays from 2P-1S transitions in time coincidence with the laser light are observed.
(c) Muonic hydrogen energy levels with details of the fine- and hyperfine-splittings of the n = 2 states. The proton finite size effect accounts for 2% of the total splitting which is dominated by vacuum polarization.

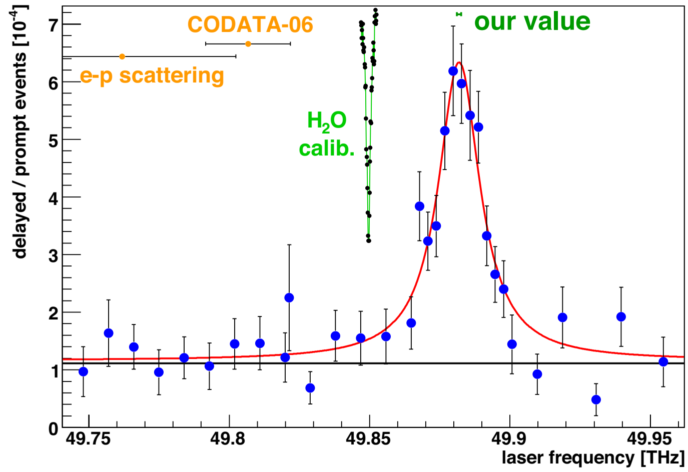


Figure 3: 2S - 2P resonance in muonic hydrogen. The number of 2 keV X-rays in coincidence with the laser pulse, normalized to the number of 'prompt' events, is plotted as a function of the laser frequency. On resonance we have six events per hour. The predictions (orange points) for the line position assume the proton radius from the CODATA group [2] and from world average electron scattering data [3]. One of the frequency calibration measurements using water absorption is also shown (in green).

Fig. 3 shows the resulting resonance curve obtained by plotting the number of 2 keV X-rays at different laser wavelengths that occur in time-coincidence with the laser pulse. The centroid position is determined with a statistical uncertainty of 700 MHz. The linewidth is in good agreement with the theoretical prediction. The laser frequency is known over the whole region with 300 MHz accuracy and was determined with two independent methods. The systematics are completely dominated by the laser frequency calibration. Effects like Zeeman shift, Doppler shift, AC- and DC-Stark shifts and pressure shift are smaller than 50 MHz.

In summary, we have measured the muonic hydrogen $2S^{F=1}_{1/2} - 2P^{F=2}_{3/2}$ transition at a frequency of 49881.88(76) GHz which corresponds to an energy of 206.2949(32) meV [1]. The position of this line strongly disagrees with predictions (shown by the orange points in Fig. 3) which have been computed assuming the proton radius extracted from hydrogen spectroscopy and theory, and the proton radius from electron-proton scattering experiments.

Interpretation of the measured transition

Comparison of the measured transition energy, ΔE^{exp}=206.2949(32)meV, with calculations of the corresponding µp 2S-2P energy difference, ΔE^{theo}=209.9779(49) − $5.2262 r_p^2 + 0.0347 r_p^3$ meV (where r_p is given in fm) results in a determination of the only parameter which is not well known: the root-mean-square proton charge radius $r_p = \sqrt{< r_p^2 >}$. The resulting value r_p=0.84184(36)^{exp}(56)^{theo} fm = 0.84184(67) fm is 10 times more precise but 5σ smaller than the previous CODATA value [2] which is essentially based on hydrogen spectroscopy. It is also 3σ smaller than the electron-proton world average scattering result [3].

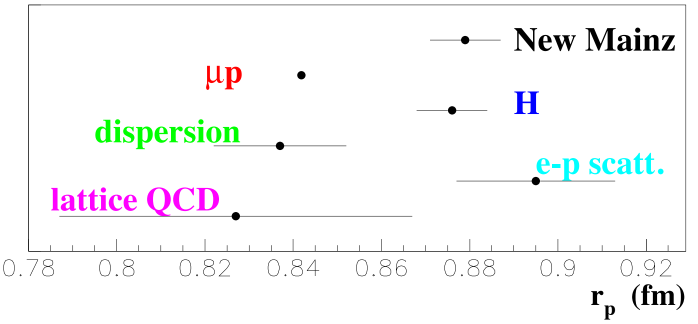


Figure 4: Our new proton radius value from muonic hydrogen spectroscopy (μp) is in strong disagreement with the values extracted from hydrogen spectroscopy (H) [2], with the value from the world average electron scattering (e-p scatt.) data [3], and with the new electron scattering value from Mainz [4]. Values from "lattice QCD" calculations [5] and a "dispersion" fit of scattering data [6] are model dependent.

Fig. 4 shows the several proton radius values from various experiments and calculations. It includes a very recent result from electron-proton scattering data obtained at Mainz [4] which also deviates by 5σ from the μp value. The origin of the discrepancies is not yet known. It may come from theory of the muonic hydrogen energy levels (used to deduce our new value), from problems in hydrogen spectroscopy experiments or hydrogen energy level theory (both used to deduce the "H" value by CODATA), from inconsistent definitions of the proton radius in the various systems, or it occurs from uncalculated or new effects.

Conclusions

First of all we need to understand the origin of the observed discrepancy. It may be a computational mistake of the energy levels in muonic hydrogen or hydrogen, a fundamental error in bound-state QED, an unknown effect related to the proton or the muon, or a contribution which has been neglected. In addition it may be that the Rydberg constant, the most precise constant in physics, has to be slightly corrected.

As soon as the discrepancy is solved the new precise proton radius value will pave the way to check hydrogen energy level theory to an unprecedented level of accuracy. Hydrogen theory is intriguing, since bound-state QED is challenging both from mathematical and from fundamental (binding effects, relativistic two-body system) points of view. Bound-state QED in hydrogen has to deal with several expansion parameters which account for radiative, recoil, relativistic, binding, and nuclear structure effects. Calculation of the one-loop radiative contributions has taken more than five decades because of the complexity of the binding properties. Several groups are presently working on the two-loop contributions. Two different approaches to the binding effects have been developed: one perturbative and one all-order / non-perturbative. Our experiment has opened the way for checking these problematic terms and the various approaches.

Hydrogen may therefore be considered as a platform for developing tools for even stronger bound systems. In addition our measurement will improve on the determination of the Rydberg constant by a factor of 5 to a level of 1×10^{-12}. The Rydberg constant is the best know physical constant and plays a very important role because it connects fundamental constants like the fine-structure constant α, the Planck constant and the electron mass. Also, the proton radius itself is an interesting benchmark for lattice quantum chromodynamics (QCD), aiming to model the proton from its constituents: the quarks and gluons.

Spectroscopy in hydrogen-like atoms continues to challenge our understanding of physics. We have also measured other 2S-2P transitions in muonic hydrogen and deuterium which are presently being analyzed, and a similar measurement of the Lamb shift in muonic helium ions is being prepared at PSI. A combined analysis of these experiments will help to clarify whether the problem arises in the muonic sector or if it is related to the proton, or the Rydberg constant, or if it originates from bound-state QED.

[1] R. Pohl, A. Antognini, F. Nez, et al., Nature **466**, 213 (2010).
[2] CODATA-06: P. J. Mohr, B. N. Taylor and D. B. Newell, Rev. Mod. Phys. **80**, 633 (2008).
[3] I. Sick, Phys. Lett. B **576**, 62 (2003); P. G. Blunden and I. Sick, Phys. Rev. C **72**, 057601 (2005).
[4] J. C. Bernauer et al., arXiv nucl-ex, 1007.5076 (2010).
[5] P. Wang et al., Phys. Rev. D **79**, 094001 (2009).
[6] M. A. Belushkin, H. W. Hammer, and U. G. Meissner, Phys. Rev. C **75**, 035202 (2007).

An animation of our experiment is found in:
https://muhy.web.psi.ch/wiki/index.php/Main/Movie

Negative pions are injected into a magnetic trap where they decay into muons of MeV energy. The muon is slowed down and when its momentum is sufficiently low it escapes from the magnetic trap and goes through a toroidal assembly of coils which act as momentum filter. Then the muon enters a 5 Tesla solenoid containing the hydrogen target and a muon detector based on stacks of carbon foils. When a muon crosses these foils electrons are released. The successive E×B field separates electrons from the muons. The muon continues and reaches a second stack of carbon foil before it stops in hydrogen. The electrons released by the foils are detected and serve as a trigger for the laser system. The muon stopped in hydrogen forms muonic hydrogen. The laser system delivers a laser pulse which illuminates the muon stopping volume. The laser-induced 2 keV X-ray is detected with large-area avalanche photodiodes (LAAPD).

Physik Anekdoten (9)

A portrait of Stueckelberg as a young man

Gérard Wanders, Lausanne

E. C. G. Stueckelberg was a Swiss physicist of the twentieth century, famous for his contributions to the theory of elementary particles. The early part of his career, which ended dramatically in 1932, is not well known, but the facts below help to shed some light on Stueckelberg during this period.

E. C. G. Stueckelberg was born in Basel in 1905. His full name was Johann Melchior Ernst Karl Gerlach Stueckelberg, Freiherr von Breidenbach zu Breidenstein und Melsbach. He inherited his German aristocratic title from his mother's side. His father was a lawyer and his paternal grandfather a Swiss painter renowned for his frescoes of the 'Tellskapelle' on the 'Vierwaldstättersee'.

Stueckelberg started to study physics at the University of Basel in 1923 and became President of the Students' Union within his first year. In this capacity, he invited Arnold Sommerfeld, a renowned leader in theoretical physics, to give a lecture in Basel. Surprisingly, this invitation was accepted. Impressed by Stueckelberg's intelligence and good manners, Sommerfeld invited him to spend the academic year 1924-25 in his institute in Munich.

This episode was the making of the young Stueckelberg, a brilliant freshman who was already aware of what was happening at the forefront of theoretical physics and knew that Sommerfeld was a master in this field. Instead of travelling to Munich in an attempt to be introduced to the master, he took the initiative, as President of the Students' Union, to invite him, and succeeded. Stueckelberg gave a brilliant introduction to Sommerfeld's lecture, which took place in the Bernoullianum in Basel. His reward was a one-year stay in Munich. Stueckelberg is thus portrayed as a smart, self-confident and determined young man.

The Munich experience was a critical period in Stueckelberg's education in theoretical physics. He was given the opportunity to learn quantum mechanics in a fundamental research environment. He was able to meet Werner Heisenberg and could attend Sommerfeld's famous lectures, which became a model for his own teaching. Back at Basel University, he undertook a Ph.D. thesis on cathode temperatures and got his degree in 1927, at the age of 22. He also became an officer in the Swiss Army.

Stueckelberg's father offered his son a trip to the United States of America as a reward for his Ph.D. Stueckelberg did not actually travel in the USA as a tourist, his goal being to find a job. This is another striking episode in Stueckelberg's life. He obviously wanted to start his career in the USA right away, without first looking for an opportunity in Europe. What is amazing is that he was very quickly successful and was offered a post in one of the most prestigious universities in the USA, Princeton University. At the end of 1927, he became Research Associate at the Palmer Physical Laboratory, a highly renowned research institution. Stueckelberg thus proved that the USA is a country where everything is possible. Sommerfeld's recommendation clearly played a role in Stueckelberg's appointment. It would be interesting to know if there were other Swiss scientists holding postdoctoral posts in the USA in 1927 or if Stueckelberg was the only one in his field.

As the quantum theory of atoms was already well understood when Stueckelberg arrived in Princeton, the next challenge was the quantum theory of molecules. It was one of the main topics of research at the Palmer Physical Laboratory. New tools had to be devised for the computation of the spectra of molecules and for the description of their interactions. This required new reliable approximation methods for the solution of quantum mechanical problems.

Dealing with applications of quantum mechanics could still be quite an adventure in the late 1920s (Dirac's *Quantum Mechanics* appeared in 1930). Various approaches coexisted and were vividly argued and discussed. A funny story occurred while Stueckelberg was attending the 1928 Michigan summer physics programme where H. A. Kramers, a prominent theoretician was giving lectures. Stueckelberg asked Kramers to give him his view of quantum mechanics, but Kramers did not have time for that, as he was leaving and had to pack. Stueckelberg insisted and offered to pack Kramers's bags himself; as a Swiss army officer, he was expert in packing. This suggests a picturesque scene: Stueckelberg packing bags while carefully listening to Kramers, his senior by eleven years, explaining quantum mechanics.

The Princeton stay was quite a productive period. Stueckelberg was in close contact with colleagues at the Palmer Physical Laboratory, P. M. Morse among others. He was working on molecular spectra, explaining for instance the continuous spectrum of the hydrogen molecule with J. G. Winans. His main efforts were focused on the description of collisions (ion-molecule, atom-molecule, molecule-molecule, electron-molecule), and this was done in part with P. M. Morse. Stueckelberg developed a theory of non-adiabatic effects in the collisions of two atomic systems. Nowadays, this theory is known as the Landau-Zener-Stueckelberg formalism, actually produced separately and simultaneously by the three authors.

Stueckelberg published eighteen papers between 1928 and 1932, and was promoted to Assistant Professor in 1930, at the age of 25. He was affected by the 1929 financial crash. His salary was reduced and he improved his income by giving occasional riding instruction.

His life changed suddenly in January 1932, when Stueckelberg was afflicted by the first attack of a terrible mental disease, manic-depressive psychosis. His illness cast a dark shadow on the rest of his life. He decided that his mental state would not allow him to pursue his career in the USA. He resigned from his position at the Palmer Physical Laboratory and came back to Basel.

The University of Basel did not really welcome Stueckelberg on his return. His Princeton experience was not recognised and all he was offered was a junior assistant's post. He could not apply for an academic position in the German-speaking part of Switzerland because he had no *Habilitationsschrift*. He therefore produced such a thesis, with a detailed account of his version of the Landau-Zener-Stueckelberg formalism, but it was not accepted. At that time, the only positive event was his nomination as *Privatdozent* at the University of Zürich in 1933. His financial and scientific situation became stable in 1934 when he was appointed Professor of Theoretical Physics at the University of Geneva.

E. C. G. Stueckelberg, third from left, with colleagues in Princeton

Stueckelberg completely abandoned molecular physics after writing his *Habilitationsschrift* and became a pioneer of elementary particle physics, but that is another story.

For further information on Stueckelberg's life and work:
- Jan Lacki, Henri Ruegg, Gérard Wanders (eds), *E. C. G. Stueckelberg, An Unconventional Figure of Twentieth Century Physics*, Birkhäuser Verlag, 2009.
- Ruth Wenger, *Ernest C. G. Stueckelberg von Breidenbach – étude biographique*. Genève: Université de Genève, Bibliothèque de l'Ecole de Physique, 1986.
- R. P. Crease and Ch. C. Mann, *The physicist that physics forgot: Baron Stueckelberg's brilliantly obscure career*, in The Science, July-Aug. 1985, vol. 25, p. 18.
- J. J. O'Connor, E. F. Robertson, *Ernst Carl Gerlach Stueckelberg*, The MacTutor History of Mathematics archive, 2008, available online at: *http://www-history.mcs.st-andrews.ac.uk/Biographies/Stueckelberg.html*.

Gérard Wanders a été assistant de E. C. G. Stueckelberg (1953 - 1957). Nommé professeur en 1961, enseignement de la physique théorique à l'Université de Lausanne et à l'Ecole Polytechnique de Lausanne jusqu'en 1997. Recherches en théorie des champs quantifiés appliquée à la physique des particules élémentaires. Rédacteur des Helvetica Physica Acta (1965 - 1982). Membre du Conseil National de la Recherche du Fond National de la Recherche Scientifique, Division des mathématiques, sciences naturelles et sciences de l'ingénieur (1987 - 1996).

Physik und Gesellschaft

Physikalische Ansätze im Leistungssport

Die Rolle des Leistungssports in der Gesellschaft

Bernhard Braunecker

Nahezu alle Hochleistungssportarten verzeichneten in den letzten Dekaden enorme Leistungssteigerungen, die zum Grossteil durch die Verwendung neuer Materialien und Anlagen ermöglicht wurden. Allerdings erhöhen leistungsstärkere Anlagen oft auch die Sicherheitsrisiken, so dass der Anlagenbauer sowohl der Leistungssteigerung als auch den Sicherheitsaspekten Rechnung tragen muss. Ein gutes Beispiel für das nicht-triviale Gelingen sind die Sportarten Skispringen und Skifliegen, bei denen durch Neugestaltung der Sprunganlagen immer grössere Sprungweiten erzielbar wurden, ohne dass dabei die Sicherheit der Athleten gelitten hätte.

Eine weitere Herausforderung für den Anlagenbauer ist durch die Tatsache gegeben, dass in vielen medienattraktiven Disziplinen des Hochleistungssports das Interesse der Öffentlichkeit nur dem Sieger gilt, nicht dem Zweiten und Dritten. Da jedoch die Erfolgskriterien aus Gründen der Verständlichkeit einfacher Natur wie "schneller, höher oder weiter" sein müssen, sind mittlerweile die Unterschiede in den Rängen oft geringer als stochastische und systematische Wettbewerbsfehler. Der Anlagenbauer ist daher zusätzlich gefordert, den Wettbewerbsablauf so zu konzipieren, dass der Einfluss kurzfristig sich ändernder Umweltparameter wie Wind und Niederschläge weitgehend eliminiert, und der Einfluss quasi-systematischer Fehler wie Änderungen der Temperatur zumindest nachträglich kompensiert werden kann. Es gilt die Wirkung der Fehlereinflüsse kleiner zu halten als die zu erwartenden Unterschiede in den vorderen Rängen. Diese so genannten "Kompensationsmassnahmen", mit denen während des Wettkampfes aufgrund neuer Umweltsituationen die bisherigen Ergebnisse korrigiert werden können, müssen einfach verständlichen Regeln genügen, um nicht als undurchschaubare Manipulation diskreditiert zu werden. Bei diesem Bemühen, eine Balance zwischen physikalisch basierter Genauigkeit und einfacher Nachvollziehbarkeit zu finden, hat der moderne Skisprungsport ebenfalls eine Vorreiterrolle übernommen.

Skispringen und Skisprung-Schanzen

Hans-Heini Gasser

Für den Schanzenbauer stellt sich die Aufgabe, das Anlaufprofil unter Einhaltung einer Reihe von Nebenbedingungen hinsichtlich Länge zu optimieren. Die maximale Neigung soll aus Gründen der Präparierbarkeit 37 Grad nicht übersteigen. Die Tischneigung ist in jahrelanger Erfahrung auf 8 bis 11 Grad optimiert worden. Der Absprungtisch ist eine Ebene, deren Länge den Absprung gewährleisten soll. Die Übergangskurve soll den Zentrifugaldruck von Null an aufbauen und in gegebenen Grenzen halten. Das Aufsprungprofil soll Landebedingungen bieten, die innerhalb einer kritischen Weite sicher zu stehen sind. Der maximale Landedruck, der bei der kritischen Weite auftritt, richtet sich nach dem athletischen Niveau der Springer und ist aus Erfahrung bekannt. Schliesslich ist noch ein Übergangsbogen von der Landefläche in die Auslaufebene zu entwerfen, der vorzugsweise mit zunehmender Krümmung versehen wird und eine bestimmte Zentrifugalkraft nicht überschreiten lässt.

Es ist offensichtlich, dass der anspruchsvollste Teil des Schanzenprofils das Aufsprungprofil ist. Es soll nicht nur den gesetzten Grenzwert des Landedruckes gewährleisten, sondern es soll aus Sicherheitsgründen die Flughöhen minimieren, oder einfach gesagt, es soll sich möglichst gut der Flugbahn anpassen. Die Kenntnis der Flugbahn ist also erste Voraussetzung. Man erhält sie durch Integration des Differentialgleichungssystems, das die Flugphase bestimmt. Es sind vier nichtlineare Differentialgleichungen erster Ordnung mit den Koeffizienten Erdbeschleunigung und den während des Fluges variierenden Luftwiderstands- und Luftauftriebskräften. Im Informationskasten findet sich ein Link zur Beschreibung der mathematischen Modellierung.

Die Luftkraftbeiwerte können im Windkanal gemessen werden. Dazu ist aber ein ganzer Katalog von Springer-Ski-Konfigurationen mit zugehöriger Anströmrichtung der Luft erforderlich, die kurzen Abschnitten der Flugbahn zugeordnet sind. Dieser Katalog kann aus Filmaufnahmen von Sprüngen entnommen werden. Einfacher ist die Ermittlung der Beiwerte direkt aus den Raum-Zeit-Koordinaten einer mit "High-Speed"-Kameras gefilmten Flugbahn. Wenn es gelingt, den Schwerpunkt des Systems Springer-Ski und auch den zugehörigen Zeitpunkt in jeder Phase genau zu bestimmen, so können durch Differenzieren die Kraftbeiwerte berechnet werden.

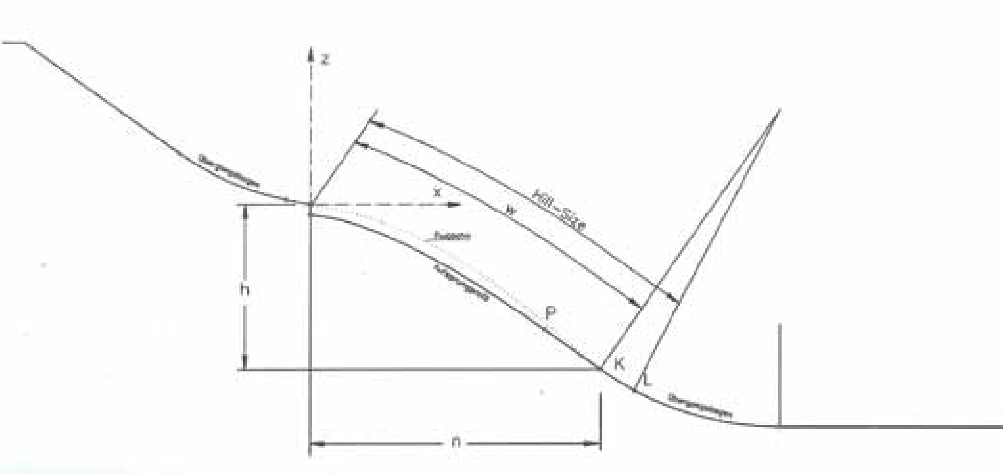
Mit der beschriebenen Methode sind in Zeitabschnitten von rund zehn Jahren seit der erstmaligen Flugbahnvermessung 1976 drei weitere erfolgt, zuletzt 2006. Wir kennen also die aktuellen Luftkraftbeiwerte der weltbesten Springer. Nun gibt es ja grosse und kleinere, steile und flachere Schanzen. Die wünschbare Flugbahn kann durch Variieren der Anfangsbedingungen Absprunggeschwindigkeit und Absprungwinkel gefunden werden. Mit diesem Hilfsmittel sind verschiedene Kurventypen für die Beschreibung des Aufsprungprofils getestet worden. Es hat sich gezeigt, dass ein Polynom dritten Grades, fortgesetzt mit einem nach oben geöffneten Kreisbogen mit grossem Radius im Landebereich, gute Ergebnisse liefert. Die Abhängigkeiten der Polynomkoeffizienten und des Kreisradius ist in den Baunormen festgelegt (siehe zweiter Link im Informationskasten).

Die Schanze in Sapporo (Japan) während der Winterspiele 1988. Der Autor (Mitte) wirkte als Technischer Delegierter der FIS, mit zwei lokalen FIS Komitee - Mitgliedern.

Der Wettkampf Skispringen

Im vergangenen Winter hat die FIS versuchsweise Kompensationspunkte eingeführt, die bei einem Startlukenwechsel während eines Durchganges die Chancenveränderung durch den Wechsel möglichst gerecht ausgleicht. Auch dem Umstand, dass ein Springer bei Gegenwind weiter und umgekehrt bei Rückenwind kürzer springt, wird mit auf Grund der während des Sprunges gemessenen Windgeschwindigkeit berechneten Kompensationspunkten ausgeglichen. Im Fall der Lukenänderung bewirkt die Kompensation eine Erhöhung der Sicherheit, weil mit ihr nicht mehr abgewogen werden muss, ob gegen Ende eines Durchganges trotz aufkommenden Gegenwindes die Fortsetzung des Durchganges riskiert werden kann, oder ob der Anlauf verkürzt und damit der Wettkampf verlängert werden soll. Zudem kann jetzt auch bei Windgeschwindigkeiten noch gesprungen werden, die ohne Kompensation zu Verzerrungen führen, die das zumutbare Mass an Irregularität überschreiten würden. Beiden gemeinsam ist die Verkürzung eines Wettkampfes, die in den meisten Fällen erzielt wird.

Die Einführung dieser Regelergänzung war nicht einfach. Der Argwohn, dass die für Nichtmathematiker komplizierten Kompensationsformeln nicht nachvollziehbar sind und deshalb dazu missbraucht werden könnten, einzelne Springer zu bevorzugen, war anfänglich gross. Man musste auch einräumen, dass eine mathematische Exaktheit nicht möglich ist. Die absolut gerechte Startlukenkompensation würde voraussetzen, dass der Gleitreibungskoeffizient während eines Durchganges unverändert bliebe und dass Windstille herrsche. Bei den heute meist gekühlten Eisspuren sind die



Geometrische Beschreibung des Schanzenprofils

Reibungswerte zwar nur mehr wenig variabel und Winde in der Anlaufspur haben auf die Absprunggeschwindigkeit eine untergeordnete Auswirkung. Aber problematischer ist die Berechnung der Windkompensation. Man trifft oft auf recht stark wechselnde Windverhältnisse, selbst während der Dauer eines Sprunges. Dabei ändert nicht nur die Windstärke, sondern meist auch die Windrichtung. Eine gut zutreffende Simulation einer Flugbahn wäre möglich, wenn man die Tangentialkomponente der Windgeschwindigkeit längs der Flugbahn kennen würde. Messbar sind aber nur die herrschenden Windkomponenten am Pistenrand. Das bewirkt bei gewissen Bedingungen, wenn auch selten eintreffend, unvermeidliche Ungenauigkeiten bei der Datenerhebung. Es sind aber dabei vornehmlich Unsicherheiten im Betrag des Windeinflusses, nicht aber im Vorzeichen. D.h. die Kompensation geht in die richtige Richtung, ist aber betragsmässig nicht exakt richtig. Rückenwind erzeugt eine Gutschrift, und Gegenwind erzeugt einen Abzug, vielleicht dem Betrag nach etwas zu gering, aber so immer noch besser, als die bisherige Bewertung.

Die praktische Ausgestaltung der Kompensationsformeln

Es ist natürlich wünschenswert, die Kompensation möglichst genau zu ermitteln, selbst wenn es mathematisch aufwendig ist. Andererseits sollen die Trainer, die Medienleute und die Zuschauer nicht unnötig überfordert werden. Dazu kommt, dass komplizierte Formeln eine Genauigkeit vortäuschen können, die, wie beschrieben, ja gar nicht gerechtfertigt ist. Wir haben uns daher dafür entschieden, dass die Kompensationen auf den Ansatz einer linearen Abhängigkeit von der Anlauflängenänderung bzw. von der herrschenden Windgeschwindigkeit reduziert werden soll. So lässt sich die Resultatliste für einen Interessierten mit einem Taschenrechner nachvollziehen. Ferner beschränkt man sich auf die zwei Faktoren Weitenänderung pro Meter Anlaufänderung und Weitenänderung pro m/s Wind. Diese beiden Faktoren sind aber für jede Schanze zu berechnen, denn sowohl Anlauf wie vor allem das Aufsprungprofil ist von Schanze zu Schanze verschieden. Es ist zu erwarten, dass Anlaufänderung und Wind bei kurzen Sprüngen eine andere Weitenkompensation ergeben würde als bei weiten Sprüngen. Ebenso dürften die "gerechten" Kompensationen vom technischen Können der Springer abhängen. Nun geht es ja in der Praxis um die ersten Ränge. Man vereinbarte daher, dass die Faktoren auf eine Weite optimiert werden, die der Siegspringer hinlegt. Damit ist auch ausgesagt, dass wir für die Flugbahnsimulation die Flugcharakteristiken der besten Weltcupspringer einsetzen.

Unser Autor Hans-Heini Gasser hat für den Internationalen Skiverband FIS Normen für den Bau von Sprungschanzen erstellt, die heute weltweit gelten, und die die Sicherheit der Sportler massgeblich verbessert haben. Herr Gasser hat an der ETH Bauingenieurswesen studiert und promoviert, führte von 1965 seine eigene Firma, war von 1973 - 1986 Regierungsrat des Kantons Obwalden, präsidierte von 1991 - 1996 den Schweizerischen Ingenieur- und Architektenverein SIA und ist seit 1996 Einzelmitglied der Schweizerischen Akademie der Technischen Wissenschaften SATW. Seit 1973 ist er für die FIS in diversen Gremien tätig. Sein Bericht zeigt die wichtige Bedeutung der physikalischen Modellierung bei der Konzipierung von Sportanlagen, und hier speziell bei der Optimierung der Ablaufvorgänge beim Skisprung.
Die zugrunde liegenden mathematisch-physikalischen Ansätze sind dem Dokument *http://www.fis-ski.com/data/document/grundlagen-fur-die-auslegung.pdf* zu entnehmen, und die daraus abgeleiteten Baunormen finden sich abgelegt in *http://www.fis-ski.com/data/document/skisprungschanzen_bau-normen2008.pdf* .

Die Wissensexplosion

Chancen und Risiken

Wissenschaftskommunikation im Zeitalter elektronischer Medien

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Symposium am 2. Oktober 2010
Universität Zürich Zentrum
Rämistrasse 71, Zürich

09:00 bis 13:00
Hörsaal KOL-F-118
Eintritt frei

Referate:

Jürgen Galler	Director Product Management EMEA, Google
Ursula Renold	Direktorin Bundesamt für Berufsbildung und Technologie, BBT
Christian Speicher	Redaktionsleiter Wissenschaft, NZZ
Heinz Bonfadelli	Professor für Kommunikationswissenschaften, Universität Zürich

Anschliessend
Podiumsdiskussion unter der Leitung von **Nicole Ulrich**, Moderatorin "Einstein", SF DRS

Was ist das Chancenpotential neuer Kommunikationsmittel für die Wissenschaft? Mobile Kommunikation sowie neue Plattformen und Medien verändern den Informationsfluss in Wissenschaft und Gesellschaft. Was sind die Risiken dabei? Und wie beeinflussen diese neuen Kommunikationsmedien die Wahrnehmung der Naturwissenschaften und der Technik in der Öffentlichkeit?

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