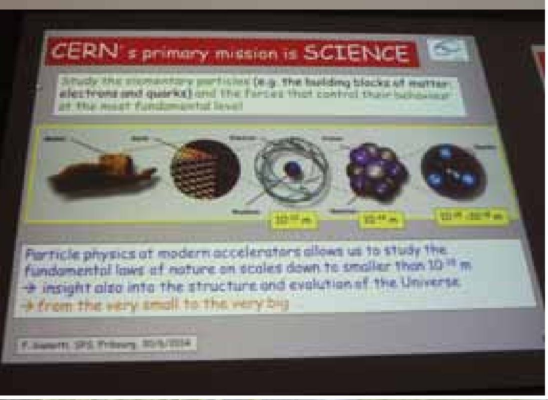
⟨S|P|S⟩ swiss physical society

Nr. 44
September 2014

SPG MITTEILUNGEN
COMMUNICATIONS DE LA SSP



The public lecture "The Higgs Boson and our Life" at the SPS annual meeting in Fribourg was given by Fabiola Giannotti, CERN. See p. 10 for a review.

Politics meets Science: Ambassador Alexandre Fasel and CERN Director General Rolf Heuer "competed" to generate some Higgs particles in the interactive LHC tunnel, a well frequented attraction at the annual meeting in Fribourg. It was part of the events commemorating the 60^{th} anniversary of CERN.

A large group of winners made this year's Award Ceremony extraordinary. Read p. 3 for the winners of the SPS awards, and p. 7 for details on the other prizes.

From left to right: Marco Peruzzi (CHIPP Prize), Simon Gerber, Qianli Chen (both SGN Young Scientist Prize), Jean Fompeyrine as representative of Stefan Abel (SPS Award by OC Oerlikon), Giorgio Signorello (SPS Award by METAS), Florian Koch (IYPT 2013), Philip Moll (SPS Award by ABB), Eric Schertenleib, Laura Guerrini, Patrick Meister (all IYPT 2013) and Andreas Kuhlmann (SPS Award by IBM).

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Impressum:

Die SPG Mitteilungen erscheinen ca. 2-4 mal jährlich und werden an alle Mitglieder abgegeben.

Abonnement für Nichtmitglieder:
CHF 20.- pro Jahrgang (Inland; Ausland auf Anfrage), incl. Lieferung der Hefte sofort nach Erscheinen frei Haus. Bestellungen bzw. Kündigungen jeweils zum Jahresende senden Sie bitte formlos an folgende Adresse:

Verlag und Redaktion:
Schweizerische Physikalische Gesellschaft, Klingelbergstr. 82, CH-4056 Basel, sps@unibas.ch, www.sps.ch

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Druck:
Werner Druck & Medien AG, Kanonengasse 32, 4001 Basel

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Editorial

Pure physics, applied physics,… or simply good physics?

Minh Quang Tran, EPFL-CRPP, SPS President

What is pure research? For me it is the type of research motivated by the fundamental quest to understand. Pure research will always exist, albeit the periodic prediction of the end of science. We see it with the discovery of the Higgs boson. It was not an end but may be the beginning of another quest: the search for new physics, beyond the Standard Model and I am just excited and hoping that the first signals will become available when I shall still be active. Pure physics is the fertile soil on which applied research will grow. It reminds me of the La Fontaine's fable about the old farmer and his sons. He promised that a treasure is hidden in the land and they should plough this piece of land: no treasure was found but the harvest was generous thanks to the care of the land. I would encourage those who urge to reduce the subsidies for Pure Physics to meditate on this fable. As a modern example, let us recall the use of the general relativity for GPS, for the post Newtonian equation for predicting impact of meteorites. And a final example, which is closer to my field: fusion research. In the Euratom Fusion Horizon 2020 Workplan, besides the "mission oriented" research, the Programme has very wisely reserved a space for bottom up research, called *Enabling Research*. This stems out from the consideration that through such Enabling Research some unexpected, highly innovative results may be found.

I was then wondering whether in one's career we are categorized in one or the other category and, as someone marked by fate, always remain in one or the other category. Reflecting on my own career, I found out that I had navigated back and forth between the two. I started out in "basic plasma physics" studying non-linear waves such as ion acoustic or Langmuir waves. But while the spatial evolution of a high frequency wave packet into very narrow structure may appear as a laboratory curiosity, the phenomenon was found to be connected to the generation of electromagnetic waves in the interaction of electron beams emitted by the Sun through the interplanetary plasma. Later on, my boss told me to take care of the development of the gyrotron, a novel type of millimetre high power electron tube in collaboration with industry. Maybe he thought that my (supposed) knowledge of electrodynamics would be sufficient. I then discovered a new fascinating world, where heat exchange, loss tangent, hypervatron structure, interaction of electron and electromagnetic waves are the daily bread and butter of the research. One could have thought that with this type of problems to handle, pure physics fades away and applied physics is dominating. But, physics is full of surprises: the last tube we developed reveals a wealth of "basic non linear dynamics". I do not claim that, through this single example, a physicist career is a continuous exchange between pure physics and applied physics, but how rewarding when it does occur to a physicist.

As a conclusion, I personally feel that this distinction is quite unproductive: it somehow gives the wrong impression, in this utilitarian mood of the society, that there are "useful" physicists and "less useful" physicists. Very likely, many of us in our life have switched or will switch between the two aspects. And I am sure that each time we switched, our preceding life will be beneficial to the new one!

So what is the message our SPS should convey? First of all, we must promote, all together, the notion of good physics, be it pure or applied ones. It is for me the only important criteria. Secondly, that we should explain to our politicians that only good physics can allow the transfer to applications so needed for the wealth of our economy. Good physics will also allow to get not only the low lying fruits of this transfer, but also the high lying ones which can insure benefit in the long term. But this obvious point should be transcribed into actions. Let us start first with the youngest. One of my strong wishes is that our love affair with (beautiful) physics should be shared by the young generation, which is now still at school or in gymnasium. We have to bring to them our enthusiasm and explain to them that a physicist must master the fundamentals of physics, while also recognizing the importance of bringing innovation to the society. The role of the physics teachers (and in general the science teachers) is of utmost importance to fight against the scientific illiteracy. I intend to support the various initiatives that our Society (and other Academies) has started in this frame. As important is also the encouragement that our Society brings to young researchers. I was delighted to see the extremely high quality of the posters I was visiting during our last meeting in Fribourg and how excited their authors were when they shared with me their discovery. How could we develop this encouragement is a good theme for our debate in our Executive Committee.

On a broader scope, promoting good physics leads naturally to the need to participate in the various societal debates, in which Physics has a specific insight. Energy is one field, where I feel that many of us, physicists, can bring a unique perspective thanks to our training. But it is not the only one: climate change, materials for the 21st century are other fields, and I am not comprehensive! A Biophysics section was created, extending our coverage to an expanding field: what could be the impact of this field for society, for the economy are legitimate questions. But how can we have our voices heard? The competencies and network of our Executive Committee are our main assets. We should use our *SPS Communications* as a forum to express ourselves. We should solicit opinions, both internal and external, to be published in it, stimulating exchange of opinions within our community and also outside of it. We also need to establish links with the Learned Societies upstream of any action, so that our specific competencies could be acknowledged.

So let us go over the debate about pure and applied physics to start promoting good physics!

The winners of the SPS Awards 2014

The SPS Award committee, presided by Prof. Louis Schlapbach, had again the great pleasure to select the SPS award winners 2014 from many submitted papers of excellent scientific quality. For the first time we were able to award the new METAS prize.

The winners presented their work at the annual meeting in Fribourg. Please find in the following the laudationes written by L. Schlapbach, and the summaries written by the authors.

SPS Award in General Physics, sponsored by ABB

The SPS 2014 Prize in General Physics is awarded to **Philip Moll** for his excellent PhD- and postdoctoral work in the field of iron based high temperature superconductors entitled "High magnetic-field scales and critical currents in SmFeAs(O,F) crystals", and "Transition from slow Abrikosov to fast moving Josephson vortices in iron pnictide superconductors", both published in *Nature Materials* (2010, 2013).

Based on pioneering use of microfabrication techniques to shape highest quality small samples allowing measurements with unprecedented signal to noise ratios, he discovered surprisingly large intrinsic upper critical magnetic fields exceeding 65 T and isotropic critical current density in iron-based high-temperature superconductor of the LnFeAs(O,F) family. Furthermore, he detected the transition from Abrikosov to Josephson vortices, two different types of magnetic vortices.

SPS (now Vice-) President Andreas Schopper and Philip Moll

High magnetic-field scales and critical currents in SmFeAs(O,F) crystals

Transition from slow Abrikosov to fast moving Josephson vortices in iron pnictide superconductors

Materials of interest in modern condensed matter physics are often challenging to characterize electrically due to the small size, unfavorable shape and overall homogeneity of available samples. We use Focused Ion Beam (FIB) based techniques to shape, manipulate and electrically contact even smallest crystallites, to address a wide range of questions in high-temperature superconductivity, heavy fermions and charge-order compounds. These samples perform well even under the most extreme experimental conditions, from high pressures (> 40 kBar) and the most powerful pulsed magnetic fields in excess of 100 T. Using these FIB techniques on microcrystals, we have investigated the interplay of strong magnetic fields with the unconventional superconductivity in the iron-pnictide SmFeAs(O,F) (T_c ~ 50 K). The superconducting properties, such as upper critical fields and critical currents, show a tendency towards isotropic behavior at low temperatures. While this behavior is favorable for applications, it comes as a surprise: The low dimensional character of these layered compounds is believed to be essential for high T_c and is reflected by the strongly two-dimensional character of the electronic band structure [1]. This peculiar dichotomy of isotropic and anisotropic characters lead to new phenomena in the vortex matter arising from the competition of two important length scales: The interlayer coherence length $\xi_c(T)$ and the distance d_c between adjacent FeAs-layers. $\xi_c(T)$ crosses d_c at a temperature $T^* \sim 0.8\, T_c$, separating two regimes well pinned Abrikosov-like vortices at high temperature ($\xi_c(T) > d_c$) and highly mobile Josephson-like vortices at low temperature ($\xi_c(T) < d_c$). The transition is evidenced by a sudden jump in flux flow voltage over many orders of magnitude [2].

[1] Philip J. W. Moll, Roman Puzniak, Fedor Balakirev, Krzysztof Rogacki, Janusz Karpinski, Nikolai D. Zhigadlo, Bertram Batlogg. Nature Materials 9, 628-633 (2010)
[2] Philip J. W. Moll, Luis Balicas, Vadim Geshkenbein, Gianni Blatter, Janusz Karpinski, Nikolai D. Zhigadlo, Bertram Batlogg. Nature Materials 12, 134-138 (2013)

SPS Award in Applied Physics, sponsored by OC Oerlikon

Stefan Abel is awarded with the SPS 2014 Prize in Applied Physics for his excellent contribution to the advancement of silicon photonics reported in "A strong electro-optically active lead-free ferroelectric integrated on silicon" published in *Nature Communications*.

Silicon microfabrication technologies are advanced, however, silicon does not exhibit an electro-optic effect. Stefan Abel has grown a thin film layer of ferroelectric barium titanate directly onto silicon. Because of the high structural quality of the material, an electro-optic coefficient five times as large as the one in the current material of choice for electro-optic devices (lithium niobate) was reached in these layers. Silicon photonics is becoming a base technology for data communication and quantum technology. This result is therefore a key to many important quantum electronic devices such as modulators, phase-shifters, frequency shifters etc., that are the building blocks of this emerging areas of applied physics.

A strong electro-optically active lead-free ferroelectric integrated on silicon

Silicon photonics is an emerging area of applied physics. This new technology of integrated photonics is to be intimately integrated with future generations of high-performance microprocessors, overcoming current bottlenecks related to the excessive power consumption of the computing devices. The use of silicon micro-fabrication technologies will allow high volume and low cost production, thus ensuring ubiquity of this novel technology. But silicon itself cannot deliver all necessary optical functions, and these limitations are purely physical. One of missing functions is an efficient electro-optic effect necessary to modulate and route light through complex optical circuitry. The heart of our work is to introduce ferroelectric oxides such as $BaTiO_3$ (BTO) into silicon photonic processes, and to take advantage of the known large Pockels coefficient of BTO. Because of the lower refractive index of BTO with respect to silicon, slot waveguides were proposed where a thin BTO film is sandwiched between a lower and upper Si slab. This approach results in the enhancement of the optical field in BTO, where the Pockels effect is present. It requires however controlling the deposition of thin, high-quality, well oriented films to exploit the effect associated with the largest element in the electro-optic tensor. In a first step, new growth methodologies have been studied to obtain single crystalline BTO films in a slot waveguide configuration [1]. After having developed a specific characterization technique to measure polarization rotation down to 10^{-5} degrees, the Pockels effect in epitaxial BTO films grown on silicon could be evidenced [2]. In a second step, BTO stacks were used to fabricate different optical devices, in particular racetrack ring resonators. When applying a DC field across the waveguide, a clear shift in wavelength in the optical resonance could be measured [3]. The magnitude of this shift, depending on the orientation of the electrodes with respect to the crystalline axis of the BTO films, underpins that the true Pockels effect is indeed exploited in his structures. This work clearly paves the way for the fabrication of new type of devices, such as low power modulators that could replace Si-based modulators using the plasma dispersion effect. Low power devices can be envisioned to compensate for the variability in the fabrication process or to compensate for temperature fluctuations. Other device concepts could be proposed such as modulators working at cryogenic temperatures, optical memories and sensors, optical diodes, etc.

[1] S. Abel, M. Sousa, C. Rossel, D. Caimi, M. D. Rossell, R. Erni, J. Fompeyrine, C. Marchiori; Nanotechnology 24(28), 285701 (2013)
[2] S. Abel, T. Stöferle, C. Marchiori, C. Rossel, M. D. Rossell, R. Erni, D. Caimi, M. Sousa, A. Chelnokov, B. Offrein, J. Fompeyrine; Nature Communications 4, 1671 (2013)
[3] S. Abel, T. Stöferle, C. Marchiori, D. Caimi, L. Czornomaz, C. Rossel, M. Rossell, R. Erni, M. Sousa, H. Siegwart, J. Hofrichter, M. Stuckelberger, A. Chelnokov, B. J. Offrein, J. Fompeyrine; Integrated Photonics Research "IPR," Silicon and Nanophotonics, Rio Grande, Puerto Rico (OSA, July 2013), 10.1364/IPRSN.2013.IW4A.5

SPS Award in Condensed Matter Physics, sponsored by IBM

The SPS 2014 Prize in Condensed Matter Physics is awarded to **Andreas Kuhlmann** for his excellent PhD-work in the field of semiconductor quantum dots. He developed a new dark-field microscope for the detection of resonance fluorescence from single semiconductor quantum dots (*Review of Scientific Instruments* 2013, *Phys. Rev. Lett.* 2012) and discovered a spectroscopic technique to distinguish between the two noise sources in semiconductor quantum dots, charge noise and spin noise, published in *Nature Physics* (2013) under the title "Charge noise and spin noise in a semiconductor quantum device". Based on this new understanding, he went on to develop a frequency-stabilized source of single photons using a single quantum dot as emitter (*Phys. Rev. X* 2013).

Noise is a central theme in solid-state qubits such as single quantum dots as it limits their performance. Qubits need to be robust against noise; on the other hand, much of the interesting physics lies in the noise and by operating at the single electron - single photon level with contemporary experimental techniques, powerful new insights can be gleaned into core themes: electron localization, the central spin problem and electron-electron interactions, etc. Andreas Kuhlmann has made a very significant contribution to the understanding of noise in a semiconductor device and ways to circumvent it.

Charge noise and spin noise in a self-assembled semiconductor quantum dot

Self-assembled quantum dots are potentially excellent single-photon sources. A single quantum dot is a robust, fast, bright and narrow-linewidth emitter of single photons. A coherent spin qubit in the solid state is realized by a single hole spin confined to a quantum dot. Both optical ("exciton") and spin qubit coherence are limited by intrinsic sources of noise. Optimizing performance demands an understanding of noise and a strategy to circumvent its deleterious effects.

There are two main sources of noise inherent to the semiconductor: charge noise and spin noise [1]. Charge noise arises from occupation fluctuations of the available states in the semiconductor and leads to fluctuations in the local electric field [1, 2]. Spin noise arises from fluctuations in the nuclear spins of the host material and, on account of the hyperfine interaction, results in a fluctuating magnetic field (the Overhauser field) experienced by an electron spin.

We have investigated noise in an ultra-clean semiconductor quantum device at low temperature using a minimally-invasive, ultra-sensitive, local probe: resonance fluorescence from a single quantum dot [3]. This yields noise spectra with 6 decades of resolution in the noise power over 6 decades of frequency, from 0.1 Hz to 100 kHz [1]. Significantly, we have discovered a spectroscopic way to distinguish charge noise from spin noise. We find that the charge noise is concentrated at low frequencies and gives a large noise power but only in a small bandwidth. The spin noise lies at higher frequencies and gives much weaker noise powers but over a much larger bandwidth. We present a dynamic feedback technique to remove charge noise from the device [2]. We show that nuclear spin noise is the dominant dephasing mechanism that limits performance as a single-photon source.

For the neutral exciton, we demonstrate an increase in the spin noise with increasing resonant laser power. Conversely for the charged exciton, we demonstrate a significant decrease in the spin noise with resonant laser excitation. This noise reduction for the charged exciton is exploited to demonstrate transform-limited optical linewidths even when the measurement is performed very slowly [4].

[1] A. V. Kuhlmann et al., Nature Phys. 9, 570 (2013).
[2] J. H. Prechtel et al., Phys. Rev. X 3, 041006 (2013).
[3] A. V. Kuhlmann et al., Rev. Sci. Instrum. 84, 073905 (2013).
[4] A. V. Kuhlmann et al., arXiv:1307.7109 (2013).

SPS Award related to Metrology, sponsored by METAS

The SPS 2014 Prize related to Metrology is awarded to **Giorgio Signorello** for his excellent PhD-work entitled "Uniaxial Stress Effects in Zincblende and Wurtzite GaAs Nanowires: an Optical Spectroscopy Study" and his follow-up publications "Tuning the Light Emission from GaAs Nanowires over 290 meV with Uniaxial Strain" in *Nano Letters (2013)*, and "Inducing a Direct-to-Pseudodirect Bandgap Transition in Wurtzite GaAs Nanowires with Uniaxial Stress" (*Nature Communications 2014*).

Giorgio Signorello successfully demonstrated that the intensity as well as the colour of the emitted light by GaAs nanowires of the Wurtzite structure (not obtainable in bulk or thin film form) can be varied over a broad range by applying strain. Combining experimental with theoretical skills, he showed that this remarkable finding results from a novel bandstructure transition that has never been observed before in a one-dimensional semiconductor structure, and has a high potential for future applications in the field of electronic and optoelectronic devices, including measurement tools.

Louis Schlapbach, President of the Award Committee, Andreas Schopper, Giorgio Signorello and Philippe Richard, Vice-Director of METAS, which sponsors the new award for the first time.

Uniaxial Stress Effects in Zincblende and Wurtzite GaAs Nanowires: an Optical Spectroscopy Study

Inspired by possibility to boost the performance of future transistors and optoelectronic devices, we have explored the effect of strain in III-V nanowires. GaAs nanowires are characterized by large yield strength and the exceptional mechanics, which makes them an attractive system to study the enhancement of strain effects. At nanoscale dimensions it is possible to achieve controllable growth of different crystal structures like Zincblende or Wurtzite, enabling new degrees of freedom to tailor electronic and optoelectonic properties.

We show that the photoluminescence (PL) of Zincblende GaAs nanowires can be red-shifted by 290 meV by axially elongating Zincblende GaAs nanowires by up to 3.5%, from tension to compression. Fingerprints of symmetry breaking due to the anisotropic nature of the nanowire deformation are found in the Raman spectra, where the phonon-lifted degeneracy is resolved, and in the PL, which undergoes a more pronounced shift in tension than in compression because of the different symmetry character (heavy or light hole) of the top valence band [1].

In Wurtzite GaAs nanowires, we demonstrate a remarkable energy shift of the PL up to 345 meV by varying the axial strain over a range of 2%, in tension and compression. For the first time, we show spectroscopic evidence of a direct-to-pseudo-direct bandgap transition and demonstrate that light emission can be suppressed by more than three orders of magnitude. Using the Raman scattering spectra as relative strain gauge and fitting the optical transition energies to a k·p model, we determine all band-structure parameters of Wurtzite GaAs in unstrained conditions, clarifying once and for all its band structure. Quantities like the Poisson ratio along the c-axis and the phonon deformation potentials of the GaAs and AlGaAs optical phonons have also been determined [2].

This body of results constitutes a solid foundation for understanding strain effects on the optical and electronic properties of III-V nanowires.

[1] Signorello, G., Karg, S., Björk, M. T., Gotsmann, B. & Riel, H. Tuning the light emission from GaAs nanowires over 290 meV with uniaxial strain. Nano Lett. 13, 917–24 (2013).
[2] Signorello, G. et al. Inducing a direct-to-pseudodirect bandgap transition in wurtzite GaAs nanowires with uniaxial stress. Nat. Commun. 5, article 3655 (2014).

Review of SPS Annual Meeting 2014 in Fribourg

This year's SPS Annual Meeting took place in Fribourg during three days from 30 June to 2 July. It was also hosting the CHIPP meeting and SGN sessions and was the place that CERN chose to celebrate the 60 years of CERN in Switzerland. All these joint events contributed to give a high level and large resonance to this meeting, with a scope extending from plenary talks and specialized sessions to an evening outreach public lecture and even, in a large panel discussion with eminent guests from the field of academy and diplomacy, to political and societal implications of research.

We received a lot of praise for this interesting program that has also been put together thanks to all of you, conference contributors! We also got very positive feedback on the well-organised poster session, the various award sessions, as well as for the special event for the industrial exhibitors. The

More than 200 conference participants enjoyed the dinner on Tuesday evening in the nice EIAF mensa.

The apéro during the poster session was an excellent opportunity for discussions.

overall organisation of the meeting by Stefan Albietz, Antoine Weis and their supporting team was impressive and very much appreciated. The additional burden due to the organisation of the CERN60 event was certainly a significant load for Andreas Schopper and Hans Peter Beck who made this a memorable success. It is thus certainly a good place to thank sincerely our outgoing president Andreas Schopper for this achievement and the impulse he gave to the SPS during these two last years. Nearly 500 participants came to the meeting, with about 200 talks and 120 posters presented, showing that the Swiss physics community values its SPS annual meeting.

The catering by the UNIFR (coffee breaks, lunch buffet, exhibitor event, CERN event) and EIAF (conference reception, conference dinner) mensa chefs was organized to perfection, reflecting the culinary hospitality of the Fribourg region.

Antoine Pochelon

Below we present a selection of reports on the various sessions and special events which made our annual meeting once more successful.

Award ceremonies

This year's award ceremony, held on July 1, was not only the regular SPS ceremony (see p. 4 for the winners), but the two co-organising entities CHIPP (Swiss Institute for Particle Physics) and SGN (Schweizerische Gesellschaft für Neutronenstreuung) took the opportunity to award their own prizes (see further below). Also the SPS recognized and congratulated the Swiss team of the IYPT 2013 for their gold medals and excellent performances.

The 26th International Young Physicists Tournament took place in Taiwan end of July 2013. Around 130 students from all over the world attended this school tournament. The Swiss team reached the Final for the first time after a total of 12 appearances in this international student competition and thus won a gold medal.
The task of the students was to find solutions to complex technical and physical present problems in so-called Physics Fights in English language and defend against other teams in front of a professional jury. The previously released tasks correspond to small research projects comparable in difficulty to complex Maturity work.
The five winners are from MNG Rämibühl and from the Zurich International School and have first qualified in a national competition, the Swiss Young Physicists Tournament SYPT. They were accompanied by the two physics teachers Samuel Byland and Daniel Keller, and by Prof Andreas Vaterlaus from ETHZ.

On July 2, we could, already for the third time, award 3 prizes for the best posters displayed during the conference.These prizes are sponsored by the European Journal EPL whose representative Emma Watkins congratulated the winners:

The winners of the Best Poster Prizes: Antoine Pochelon, Chair of the jury, Emma Watkins, representative of EPL, Francesco Simone Ruggeri, Sarah B. Etter, Saumya Mukherjee, Andreas Schopper, SPS President (now Vice-President).

- **Sarah B. Etter**, ETHZ, on *New limiting mechanism for topologically frustrated Josephson junctions in* Sr_2RuO_4
- **Saumya Mukherjee**, PSI, on *Strain induced coupling between ferromagnetism and ferroelectricity in o-*$LuMnO_3$ *thin films*
- **Francesco Simone Ruggeri**, EPFL, on *AFM Nanoscale Infrared Spectroscopy: Chemical characterization at Single Amyloid Molecule Scale.*

The prizes are doted with 200.- CHF each. The jury was formed of A. Pochelon, T. Fennell, S. Goyette, G. M. Graf, M. Mansson and M. Q. Tran.

Treffen mit Industrieausstellern

Die SPG hat zum ersten Mal zu einem speziellen Ausstellerevent eingeladen. In zwangloser Atmosphäre trafen sich die Industrievertreter mit Mitgliedern des SPG-Vorstands im Rahmen eines Apéros mit Fribourger Wein. Der bis zur Tagung amtierende SPG-Präsident Andreas Schopper erläuterte in seinen Begrüssungsworten den Wunsch der SPG, den Kontakt zwischen den Tagungsbesuchern, die meist aus der Forschung kommen, und der Industrie zu vertiefen. Für die Aussteller sind nicht nur die Kontakte zu potentiellen Kunden oder - im Falle von Studenten- zukünftigen Kunden wichtig, sondern auch das Wissen, in welcher Richtung sich die Forschung bewegen wird und welches Instrumentarium in Zukunft dazu benötigt werden wird. Auch

ist es für sie interessant zu erfahren, welche Technologien sich bei grossen Forschungseinrichtungen wie z.B. CERN oder PSI in der Entwicklung befinden und in absehbarer Zeit vermarktet werden können.

Kai Hencken, Leiter der SPG-Sektion "Physik in der Industrie", stellte dazu in seinem Kurzvortrag das Technologie-Transferprogramm von CERN vor, bei dem diverse Aspekte moderner Vakuum-, Mess- und Informationstechnik abgedeckt werden.
In der anschließenden Diskussion wurden viele Sachfragen erörtert, aber auch Anregungen diskutiert, wie sich in Zukunft die Wechselwirkung zwischen den Tagungsteilnehmern und den Ausstellern verbessern liesse.
Die Vortragsfolien können vom CERN Knowledge Transfer Office herunter geladen werden:
http://cern.ch/knowledgetransfer

Bernhard Braunecker, Kai Hencken

Atomic Physics and Quantum Optics

The Plenary Lecture of the APQO section was given by Thomas Udem (MPQ, Garching) who presented an overview of the spectacularly high precision of laser spectroscopy experiments in atomic hydrogen that have led to the Rydberg constant becoming the experimentally best known fundamental constant. He also addressed the "proton radius puzzle" that arose from Lamb shift measurements in muonic hydrogen, and the solution of which may come from further precision measurements in atomic hydrogen.
The APQO section held two sessions with a total of 16 oral presentations and 9 contributed posters. As a novum,

this year's conference was enriched by a session that was jointly organized by APQO and TASK. The session was devoted to the ongoing international collaborative effort aimed a searching for a permanent electric dipole moment of the neutron (nEDM) at PSI. The opening lecture by P. Pataguppi gave an overview of the experiment's status, illustrating the need for the precise and high sensitivity control of magnetic fields. The five follow-up talks by speakers from PSI and Uni Fribourg described in detail the experimental progress of the various complementary atomic magnetometry approaches deployed at PSI. The second APQO session covered a range of atomic physics topics ranging x-ray spectroscopy, the imaging of plasmons and (microwave or DC) magnetic fields, to more "quantum" topics such as Fock states and quantized conductance.

Antoine Weis

Condensed Matter (KOND)

The KOND section organized jointly with the Swiss Neutron Scattering Society SGN and the MaNEP Switzerland Network 10 parallel sessions and contributed a large number of poster presentations to the SPS Annual Meeting in Fribourg.

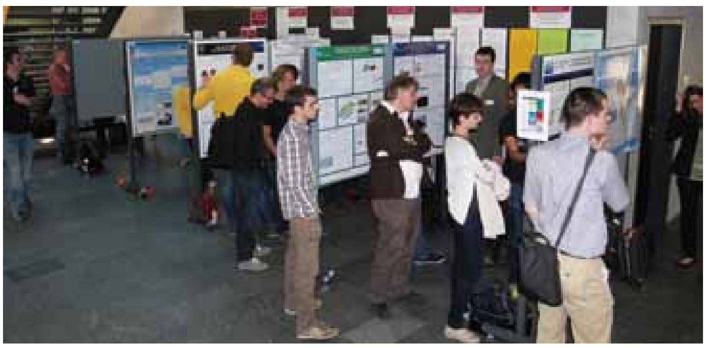
Gabriel Aeppli from the Paul Scherrer Institute, ETH Zürich and EPF Lausanne gave the plenary talk of the section on Tue morning. In his talk he motivated science by demonstrating its impact on e.g. information technology and predicted a (second) Golden Age of silicon. The advantages of the material are combined with dopants forming Rydberg states that can then be controlled elegantly in future devices.

Lukas Gallmann (University of Bern and ETH Zürich) introduced the fascinating physics and especially photoemission processes of solids and solid interfaces at the attosecond timescale in a second plenary talk on Wed.

The Swiss Neutron Scattering Society SGN organized for the first time sessions at the SPS Annual Meeting. The program chairs Martin Mansson and Tom Fennell, both from PSI, arranged four parallel sessions focusing on soft matter, energy research, instrumentation, and condensed matter physics with many exciting presentations by young scientists. They were very well attended and demonstrated the wide application of neutrons in science. In an invited talk Ken Andersen presented the status of the new European Spallation Source ESS, which is currently being built in Lund, Sweden, with Switzerland as a strong partner. The SGN also awarded its Young Scientist Prize in Fribourg to Simon Gerber (PSI) and Qianli Chen (EMPA) for their thesis projects on unconventional superconductivity and ceramic proton conductors, respectively.

Qianly Chen, Henrik Rønnow (SGN President) and Simon Gerber.

The Association MaNEP Switzerland Network continues activities of the former NCCR MaNEP e.g. its Winter School and Swiss Workshop on Materials with Novel Electronic Properties meeting series, as well as other important community activities. For the SPS Annual Meeting in Fribourg, its program committee chaired by Felix Baumberger (University of Geneva) organized two parallel sessions on Monday afternoon with invited talks by Pietro Gambardella and Werner Wegscheider (both from ETH Zürich) and many contributed talks by PhD students from a large number of groups in Switzerland.
On Tue afternoon focused programs on electronic properties at surfaces and interfaces were organized by Thorsten Schmitt and Ming Shi (PSI) and on functional magnetics: from nanomagnets to multiferroic materials by Cinthia Piamontese and Carlos Vaz (PSI). Invited talks by Fabio Miletto (CNR-SPIN Institute Naples), Milan Radovic (PSI), Harald Brune (EPF Lausanne) and Manfred Fiebig (ETH Zürich) on understanding and controlling electronic and magnetic states in functional hetero- and nanostructures demonstrated the current frontiers in these areas of research.
Semiconductor physics and the emerging field of ultra-fast dynamics were slightly underrepresented at the meeting. Contributions from these communities and suggestions for



sessions at future SPS meetings are especially encouraged. I thank all organizers and participants of the various sessions for their contributions to a very successful program.

Christian Rüegg

TASK

This year, the TASK and CHIPP sessions were combined (see separate report further below). In addition, there was an evening public lecture by Fabiola Gianotti and a plenary talk by Teresa Montaruli.

On Monday evening at the opening day of the meeting, a special event was organized with a public lecture on *The Higgs boson and our life* by Fabiola Gianotti, former spokesperson of the ATLAS experiment. It took 50 years from the original works of Brout, Englert and Higgs, until the discovery of the Higgs boson in 2012 and the subsequent Nobel Prize being awarded to Englert and Higgs. Gianotti gave an overview on the tremendous task it was by a world-spanning effort involving 10'000 physicists and an experimental infrastructure that could only be at a place like CERN. With the Higgs boson confirmed a century long quest in the understanding of matter and the working of the universe made a big leap forward and new questions come now to central focus as e.g. the understanding of the nature of Dark Matter. On three commonly asked questions, whether the new found particle is indeed the long sought of Higgs boson, on whether the task of the LHC is now over, and on whether the Higgs boson will change our life, Gianotti answered: that the new found particle looks like the Higgs boson, but more careful study is needed to assure whether this particle is just the Standard Model Higgs or a more exotic object of a more general theory; that therefore the task of the LHC is far from being completed yet, and that the Higgs is not the only task of the LHC, but searches of new phenomena for a more general theory will be made in the coming years and decades. Finally, Gianotti concluded that the Higgs particle already did change our life.

Teresa Montaruli of Uni Geneva presented an overview of the TeV scale Universe in a plenary talk on *Neutrino astronomy at its sunrise*. Using the km^3 scale IceCube detector at the South Pole, high energetic cosmic neutrinos can be measured and used to gain deeper understanding of cosmic particle acceleration. Neutrinos, as being neutral and only weakly interacting, traverse long distances through intergalactic space without being disturbed and carrying information from the deepest parts of the Universe. Fundamental questions like what is the nature of Dark Matter, or is the speed of high-energy neutrinos constant and at the speed of light, are being addressed. Point sources for the highest energetic neutrinos are being looked for. However, no significant clustering of neutrino sources has been found in three years of data of multi-TeV scale neutrinos and no direct evidence of Dark Matter annihilation expected to happen in the core of the sun has been found. With the three highest energetic neutrino events named Ernie, Bird, and Big Bird, the door to PeV scale physics has been opened. More data at the highest energies and higher precision to be expected from PINGU, a deep core upgrade of IceCube, will give more insight in the future. A substantial increase of the measured rate is being investigated with DecaCube, a proposal where the effective volume of IceCube would be doubled, tripled, or even increased 10-fold. However, this may still lie in the far future.

Hans Peter Beck

Applied Physics & Earth, Atmosphere and Environmental Physics

This year, orals and posters, gathered into a combined session organised under the name of "Applied, Physics & Earth, Atmosphere and Environmental Physics", was chaired by Stéphane Goyette on Monday, June 30. Prior to that session, the opening conference by Martin Beniston addressed a topic that is often in the headlines: climatic change and mountain water resources. He reminded quite convincingly that mountain regions are recognized as particularly sensitive physical environments where the impacts of a changing climate may be large with respect to the quantity and quality of water originating in mountains, particularly where snow- and ice melt represent a large, sometimes the largest, streamflow component. The oral session then continued with a talk discussing the similarity between electromagnetic and mechanical wave behaviour to the development of non-linear fast growth of surface gravity wave over the ocean.

Then, a talk about the application and refinement of a wind gust parameterization to be used in climate and numerical weather prediction models. Next, a series of talk about miniature systems for sensitive in situ measurements on solar system objects, on the implementation of a spin rotator in a electron microscope, the characterization of an electron cyclotron Maser for NMR spectroscopy, an overview of the research activities at the new Bern PET cyclotron, and on the investigation of charge separation dynamics in Perovskite solar cells. Finally a poster on the development of a single column climate model with an application to Lake Geneva came to close this session. This session demonstrated that Physics is at the basis of many research activities, including, oceanography, astronomy, climatology, and can also be applied to biology or medical science.

Stéphane Goyette

Plasma Physics

A delegation of speakers from the CRPP, EPFL, as well as the University of Basel presented a series of very interesting talks, reporting on the latest progress made on various research topics addressing both physical and technical issues in both the core and edge of tokamak plasmas. Among others, experimental studies of toroidal momentum transport on the TCV tokamak, work on simulating turbulent transport both in core and edge plasmas, as well as on the control of MHD activity with currents tailored by ion cyclotron resonant heating, were presented.
Some highlights of experimental results on the TCV tokamak, in particular first diverted snowflake configurations ever achieved, have been presented in an overview talk by Yves Martin. The current installation of a 1 MW neutral beam injection system in the frame of the current upgrade of TCV was also reported on.
In the field of plasma processing, a presentation was given by R. Jacquier, CRPP, on resonant RF network antennas as a promising alternative to conventional capacity and inductively coupled plasma source devices.

Stephan Brunner

Theoretical Physics

Matthias Troyer gave a presentation of quantum annealing in connection with the recent announcement by D-Wave systems, a Canadian company, of a commercial quantum computer. Troyer explained the use of quantum annealing as a technique to solve hard optimization problems, like finding the ground state of a spin glass Hamiltonian, based on quantum tunnelling. He then presented the architecture of the machine and a number of tests made on it in order to compare its performance with that of classical computers and that of a simulated quantum annealer. While evidence was found that quantum annealing is indeed taking place in the device, no significant quantum speed-up in solving generic optimization problems could be seen so far.

The session in Theoretical Physics took place on the afternoons of July 1st and 2nd with invited and contributed talks enjoying a reasonably good attendance. We report here on a small selection of them.
Dionys Baeriswyl (Fribourg) discussed the BCS-Hamiltonian of superconductivity and the related Richardson model. Contrary to accepted belief, the mean-field approximation does not become exact in the thermodynamic limit, or at least not in all respects. Christian Flindt (Geneva) presented theoretical results on waiting times distributions, as they occur in mesoscopic, single-electron transport experiments with quantum dots. Fabio Pedrocchi (Aachen, formerly Basel) discussed lattice models based on parafermions (including Majoranas) in relation with reflection positivity and topological order. Uwe-Jens Wiese (Bern) presented abelian and non-abelian lattice gauge models, which may be tested on quantum simulators.

Gian Michele Graf

History of Physics

The 2014 History of Physics session gathered professional historians together with young scholars initiating their first steps in research. As there was no underlying theme, the talks span over a broad range of topics from history of relativity (Christian Bracco from Montpellier on Poincaré's contributions) to specifically Swiss issues of its nuclear research project in the aftermath of the WWII (Jean-Pierre Hurni, Geneva). History of science was often used for making broader cases on the nature of physical knowledge and of its community of scholars. Many talks had hence definite philosophical overtones: Adrien Vila Vals (Lyon) discussed the ontologies underlying the work of some of the most renowned quantum physicists, Thomas Mueller (Lausanne) discussed the implication of the French Boussinesq in the then fierce debate over free will, while Jan Lacki (Geneva) used the case of the combination of data in history to share his thoughts on the subtle relationship between data and "exact" values. Tibor Gyalog used Euler's popular science writing to ponder on the art of efficient science communication while Jean-François Loude, faithful to his lasting interest in the history of instrumentation, presented a fascinating story of the attempts at measuring force.

Jan Lacki

Biophysics, Soft Matter and Medical Physics

Following the successful Linz first Biophysics, Soft Matter and Medical Physics session, also in Fribourg the meeting has collected a number of excellent talks. First of all, the plenary lecture of Erwin Frey of the Ludwig Maximilians University in Munich has drawn a large crowd of people in the nice lecture hall of the University of Fribourg. Frey's lecture was centred on two fundamental function of living matter, length control and regulation of processes. Frey has clearly shown how physical insight can unravel new mechanisms used by the living matter to perform vital function. Despite the complexity of living matter, physicists are able to extract the building blocks of the biological machine, which are based on statistical physics models. The lecture was superbly didactical and clear. In the session talks, the invited talk by Joseph Brader, Uni Fribourg, has treated the question of complex fluids and their implications for many important everyday applications. The rest of the session was dedicated to the chosen talks from the submitted abstracts and was a cross-section through the different domains concerned by this section.

Giovanni Dietler

TASK and CHIPP Plenary meeting

The Swiss Institute for Particle Physics, also known as CHIPP, held its 2014 annual plenary meeting during the SPS annual meeting in Fribourg. Why ?

CHIPP (www.chipp.ch) was founded in 2003 and became an official association in 2011. It aims at strengthening particle, astroparticle and nuclear physics in Switzerland. It currently has 480 members, who are all the particle, astroparticle and nuclear scientists holding a Master in physics and working for a Swiss institution, as well as the Swiss PhD nationals working for CERN. In January 2013, the CHIPP Board decided that the association will organize its PhD/postdoc days every other year in connection with the annual SPS meeting, starting in 2014. A desired effect of such decision was to enhance the participation of CHIPP members in the SPS annual meeting and revitalize its well established TASK sessions. As a result, for the first time this year in Fribourg, the TASK sessions have also been at the same time the "CHIPP PhD and postdoc days".

The scientific programme of these sessions has been defined in collaboration between the CHIPP and SPS persons in charge, based on the abstracts submitted by CHIPP PhD students and postdocs. In order to give everyone a chance to speak about their research work, some TASK sessions had to be split and run in parallel. In total, CHIPP PhD students and postdocs contributed 49 talks and 8 posters to this event, while 113 CHIPP members registered to the SPS meeting, a clear success for this new format of the PhD/postdoc days !

In addition to the TASK sessions, CHIPP organized two specific meetings on the first day of the SPS annual gathering. In the morning, the CHIPP Board held its second regular meeting of the year (out of three), while the annual plenary meeting of the association took place in the afternoon, already embedded in the SPS programme and open to any SPS member. The plenary meeting was the occasion to hear several reports from CHIPP bodies (such as the Board, the Computing group, the Outreach group) as well as from Swiss representatives in various international bodies dealing with particle, astroparticle and nuclear physics (such as the CERN Council, the European Committee for Future Accelerators – ECFA, the Nuclear Physics European Collaboration Committee – NuPECC, and the Astroparticle Physics European Consortium – ApPEC). The election of Prof. Adrian Signer (Univ. Zürich & PSI) as new CHIPP Executive Board member starting in January 2015 in replacement of Prof. Gilberto Colangelo (Univ. Berne), the re-election of Prof. Teresa Montaruli (Univ. Geneva) for a second two-year mandate in the CHIPP Executive Board, and the organisation of the 2015 CHIPP Winter School (January 18-

Olivier Schneider, CHIPP Chair; Marco Peruzzi, Winner of the CHIPP Prize 2014; Gilberto Colangelo, chair of the CHIPP prize selection commitee.

23, 2015, Grindelwald) were announced. The plenary also elected Dr Michael Dittmar (ETHZ) to succeed Prof. Michele Weber (Univ. Berne) as the Swiss representative in ACCU, the Advisory Committee of CERN users.

However, contrary to the tradition since 2008, the announcement of the yearly CHIPP prize for the best PhD student in experimental or theoretical particle physics did not take place in the plenary meeting. Instead this was integrated this year with the SPS prize ceremony on Tuesday morning. Only PhD students who have not yet completed their thesis may run for the prize. The 2014 CHIPP prize was awarded to Marco Peruzzi (ETHZ) with the following laudatio: "For his original contribution to the development of novel topological algorithms to identify single photons in the electromagnetic calorimeter of the CMS experiment at the LHC and discriminate them against abundant background from neutral pions". This was all well explained in detail by the recipient, during the CHIPP prize talk opening the afternoon TASK session.

This year is special because of the 60th anniversary of CERN. The joint CHIPP/SPS gathering in Fribourg was therefore the natural and ideal occasion to be the "Swiss national event" to commemorate this anniversary. Throughout the three-day meeting, several activities were offered to the participants: a public conference on "The Higgs boson and our life" by Dr Fabiola Gianotti (CERN), a display of a set of 15 historical posters prepared by CHIPP members on the scientific

contributions of Swiss institutes and groups to the CERN research programme, the exhibition of the interactive LHC tunnel, as well as further posters about CERN. The celebration culminated in a well attended ceremony on the last day, featuring a speech from the CERN Director General Rolf

Andreas Schopper being interviewed by a local TV station during the celebration of the 60th anniversary of CERN.

Heuer on "60 years of Science for Peace", followed by an interesting and lively panel discussion with several special guests on CERN's impact on Switzerland and its society (see the dedicated report from Benedikt Vogel on page 15).

Overall, the Fribourg gathering will be remembered as three very intense days, which have brought the CHIPP community closer to SPS, in a very well organized set-up. There are now good objective reasons to look forward to the next edition of the CHIPP PhD/postdoc days at the SPS annual meeting in 2016 !

Olivier Schneider, CHIPP chair

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A special lunch buffet for the guests of the CERN60 event.

News from SPS Committee meetings (May 2014)

Good news and congratulations: our former SPS president Christophe Rossel (2008-2012) was elected as president of the European Physical Society for the period 2015-2016.

A substantial effort was dedicated to the organization of the Annual Meeting in Fribourg and its different joint and satellite events (plenary and parallel sessions, public lecture, CHIPP meeting, CERN event: "60 years of science for peace", exhibitors' event, various awards, poster award, recognition of IYPT2013).

The Young Physics Forum (YPF) was completing the speakers' list for its workshop on energy technology at the Technorama Winterthur (see report on p. 42).

Subjects of common interest are reviewed for cooperation with SCNAT and in particular with SATW (importance of physics in economy in Switzerland, common energy section with academic and technical share, MINT). Important to note, SATW has thematic platforms where physicists' input is welcome. A Technology Outlook report (see SPS-Communications Nr. 43, p.45), including a first selection of technology fields with importance for Swiss industries will be distributed to politicians at the end of this year. This report could be of special interest for physicists in industry. The question was put, if SPS could also join in the future the two other academies SAGM (Swiss Academy of Medical Sciences) and SAGW (Swiss Academy of Humanities and Social Sciences). Perhaps we physicists can help to answer questions of central importance of our colleagues.

For 2015, the SPS is organizing the event International Year of Light (IYL 2015) in Switzerland with Antoine Weis coordinating the activities. A platform will be set up to group all the activities and yield links to local webpages. You are welcome to contact antoine.weis@unifr.ch.

The SCNAT bicentennial 2015 has a new project organizer, Marcel Falk. The project has been downscaled significantly and an updated proposal will be published after the summer.

Antoine Pochelon, SPS Secretary

News from the General Assembly

The number of participants to the General Assembly was very encouraging with 72 persons present. Let us mention just a few points beyond the "usual business":
The new section "Biophysics, Soft Matter and Medical Physics has been sucessfully created. Prof. Giovanni Dietler has been elected as its chair, see below. Other changes in the committee are as follows: New president is Minh Quang Tran, while Andreas Schopper becomes vice-president for another year. Martin Pohl stepped down from his position as chair of the TASK section. Hans Peter Beck, already co-chair of the "Education" section, took over his duties.

Prof. Emeritus Francis Troyon received the title "Honorary member". After recalling his extremely rich career and his outstanding scientific achievements (see *SPS Communications* No. 43, page 10, http://www.sps.ch/uploads/media/Mitteilungen.43.pdf), the President read the laudatio:

"*Le titre de Membre Honoraire de la Société Suisse de Physique est attribué à Francis Troyon pour ses contributions majeures pour le développement de la physique des plasmas et de la fusion en Suisse et dans le monde.*"

Minh Quang Tran gave a few words of apologies from Prof. Emeritus F. Troyon, who could not attend the ceremony for personal reasons and expressed on his behalf his deepest gratitude to the SPS for the honour the Society has given to him. The diploma was received by Mr Tran from the hands of the President.

New SPS Committee member

Prof. Giovanni Dietler (Chair of the Section "Biophysics, Soft Matter and Medical Physics")

Giovanni Dietler studied physics at the ETHZ and received his diploma in 1981. He then continued at ETHZ with a PhD in Biophysics studying phase transitions especially in the case of blood coagulation. Thereafter, he spent 3 years at the University of California at Santa Barbara where his main research focus was on the statistical properties of polymers, the structure of disordered systems like gels, and phase transitions in binary solution. Back in Switzerland at the University of Fribourg, he changed his research interests to local probe microscopy, especially for the study of polymer surfaces. In 1996, he was nominated professor at the University of Lausanne and developed local probe microscopy to study mainly DNA topology, protein and cell mechanics. Since 2003, he is professor at the EPFL. In 2009 an Institut de Physique des Systèmes Biologiques was created within the EPFL physics section and he is the actual director. He is convinced that physics can make important contributions to biology from many points of view. From the development of instrumentation for investigating the biological matter to conceptual contribution in order to understand complex systems as they are found in biological matter, both from the theoretical side as well as from the experimental side. The creation of a "Biophysics, Soft Matter and Medical Physics" section within the Swiss Physical Society is an important step to foster interdisciplinary research aiming at understanding the complexity of the biological matter.

Großer Nutzen, verpasste Chancen

Benedikt Vogel, Berlin

Während der gemeinsamen Jahrestagung der Physikorganisationen CHIPP und SPG hat am 2. Juli an der Universität Fribourg ein prominent besetztes Podium über den 'Einfluss des CERN auf die Schweiz und ihre Gesellschaft' diskutiert. Die Debatte anlässlich des 60-Jahr-Jubiläums des Europäischen Labors für Teilchenphysik (CERN) handelte von grossem Nutzen, aber auch von verpassten Chancen.

Vor 60 Jahren riefen zwölf europäische Länder in Genf das Teilchenphysiklabor CERN ins Leben. Mit von der Partei bei der Gründung: die Schweiz, die die Forschungsorganisation bis heute zusammen mit Frankreich beherbergt. Seit 1954 sind die am CERN verwendeten Teilchenbeschleuniger immer grösser geworden. Grösser geworden ist auch die Familie der CERN-Mitglieder. Dieser umfasst heute 21 Staaten, und mit Israel gehört seit diesem Jahr auch ein Land dazu, das geografisch nicht zu Europa zählt. Und mit Rumänien und Serbien stehen bereits zwei weitere Neumitglieder vor der Tür.

SPG Präsident Andreas Schopper (r.) und CHIPP-Vorsitzender Olivier Schneider. Foto: SPG

Das CERN hat also seit seiner Gründung keineswegs an Attraktivität verloren. Die Forschungsinstitution zieht bei ihrem 60. Geburtstag nicht nur die Aufmerksamkeit von über 10000 Wissenschaftlern auf sich, die hier Elementarteilchen erforschen, sondern sie fasziniert auch die breite Öffentlichkeit. Weltweit ebenso wie in der Schweiz. Diese Faszination ist gewiss die naheliegendste Antwort, wenn man – wie CHIPP und SPG bei ihrer Jubiläumsveranstaltung in Fribourg – nach dem 'Einfluss des CERN auf die Schweiz und ihre Gesellschaft' fragt. Die Schweizerische Physikalische Gesellschaft (SPG) und das Swiss Institute of Particle Physics (CHIPP) sind zwei wichtige Physikorganisationen der Schweiz.

"Trainingslager für Ingenieure und Wissenschaftler"

SPG Präsident Andreas Schopper und CHIPP-Vorsitzender Olivier Schneider konnten an der Saane CERN-Generaldirektor Rolf Heuer als Keynote-Speaker begrüssen. Dieser stellte die von ihm geleitete Organisation mit ihren 2300 Angestellten als ein "phantastisches Trainingslager für Ingenieure und Wissenschaftler" vor. Das CERN als Nachwuchsschmiede – das konnte Heuer auch mit einer prägnanten Zahl belegen: unter den am CERN tätigen Wissenschaftlerinnen und Wissenschaftlern ist kein Jahrgang stärker vertreten als die 26jährigen. "Wir sind europäisch gestartet, heute aber sind wir global", führte Heuer aus und warf einen Blick zurück in die Geschichte. Zu den Gründern des CERN gehörte der französische Diplomat François de Rose. Dieser stattete dem CERN im Jahr 2012, nachdem dort das Higgs-Teilchen entdeckt worden war, einen Besuch ab. Dort wurde der 102 Jahre alte CERN Gründer von CERN-Direktor Heuer empfangen. In seinen Augen habe noch immer die Vision des CERN einer multinationalen Forschungsorganisation geleuchtet, sagte Heuer in Fribourg über de Rose. Und Heuer erzählte, welchen Wunsch ihm der 102jährige damals aufgetragen habe: "Geben Sie mir bitte Bescheid, wenn Sie die nächste Entdeckung gemacht haben." Dafür kam die nächste Entdeckung des CERN leider nicht schnell genug – de Rose ist im März 2014 verstorben. Heuer blickte auch in die Zukunft. Er stellte die verschiedenen neuen Projekte für Ringbeschleuniger (Genf), Linearbeschleuniger (Genf, Japan) und eine Neutrino-Grossforschungseinrichtung (USA) vor. Im Moment aber richtet sich das Hauptinteresse auf die Ergebnisse, welche vom Teilchenbeschleuniger LHC weiter zu erwarten sind. Denn auch wenn der LHC bereits drei Jahre Laufzeit (2010-2012) hinter sich hat und zur Entdeckung des Higgs-Bosons führte, steht er noch ganz am Anfang. Der Beschleuniger habe erst zehn Prozent seiner Lebenszeit hinter sich und erst ein Prozent der erwarteten Teilchenkollisionen produziert, sagte Heuer. Während der Betriebszeit, die über das Jahr 2030 hinaus gehen wird, seien noch viele neue Erkenntnisse möglich, meinte Heuer. Etwa Antworten auf die Frage, ob es sich beim entdeckten Higgs-Teilchen um das Higgs-Teilchen des Standardmodells handelt oder einfach um ein Higgs-Teilchen von vielen. Heuer zeigte sich auch zuversichtlich, die Higgs-Forschung könnte dereinst Hinweise geben auf Dunkle Materie und Dunkle Energie.

Politische Störmanöver

Das CERN bringt Protonen, Ionen, Neutronen, Antiprotonen, Elektronen und Neutrinos in Bewegung. Was aber bewegt das CERN in seinem Gastland Schweiz? Diese Frage stand in Fribourg im Zentrum eines vom Wissenschaftsjournalisten Olivier Dessibourg ('Le Temps') moderierten Podiums. "Das CERN zeigt, was man mit erstklassiger Ingenieurwissenschaft leisten kann", sagte Ulrich W. Suter, Präsident der Schweizerische Akademie der Technischen Wissenschaften (SATW) in der Diskussion. Auf den grossen wirtschaftlichen Einfluss gerade auch in der Schweiz verwies Friedrich K. Thielemann, Präsident der Plattform Mathematik, Astronomie, Physik (MAP) bei der Akademie der Naturwissenschaften (SCNAT). Thielemann erwähnte zugleich aber auch den grossen Beitrag des CERN im Bildungsbereich.

Das Podium anlässlich 60 Jahre CERN diskutierte in Fribourg den Impact des CERN auf die Schweiz. V.l.n.r: Olivier Dessibourg (stehend, Moderation), Maurice Bourquin, Ralph Eichler, Alexandre Fasel, Rolf Heuer, Ulrich W. Suter, Friedrich Karl Thielemann, Martin Vetterli. Foto: SPG

Ganz von allein kam die Diskussion auf die schweren Irritationen in der Forschungszusammenarbeit mit der EU, welche sich nach der Volksabstimmung über die Masseneinwanderungsinitiative im Februar 2014 eingestellt hatten und zur Rückstufung der Schweiz zu einem 'Drittland' geführt hatten. Das CERN sei von dieser Entwicklung nicht betroffen, hielt Heuer fest, und mit einer gekonnten Anspielung auf den unterirdischen Teilchenbeschleuniger LHC stellte er fest: "Es gibt keinen Grund, dass das CERN von Genf weggeht – wir sind sehr gut im Untergrund verankert." Weniger unbekümmert nahm ETH-Präsident Ralph Eichler die politische Entwicklung zur Kenntnis: "Das Schlimmste ist, dass wir vom wissenschaftlichen Wettbewerb ausgeschlossenen sind. Das ist, wie wenn der FC Basel nur innerhalb der Schweiz spielen könnte und sich nicht mehr mit internationalen Vereinen messen könnte".

Ungenutztes Potenzial beim Technologietransfer

Kritisch äusserten sich die Diskussionsteilnehmer zum Beitrag der CERN Grundlagenforschung auf Industrie und kommerzielle Anwendungen. Die Schweiz und die europäische Gesellschaft seien nicht in der Lage gewesen, von technologischen Innovation des CERN wie der Entdeckung des World Wide Web angemessen zu profitieren, meinte Martin Vetterli, Präsident des Forschungsrats des Schweizerischen Nationalfonds. Die USA hätten es besser verstanden, neue innovative Techniken aus der teilchenphysikalischen Grundlagenforschung gewinnbringend umzusetzen, nicht zuletzt deshalb, weil sie eine andere Unternehmenskultur hätten, wurde auf dem Podium geltend gemacht. In diese Richtung äußerte sich auch ETH-Präsident Eichler: "Das CERN hätte noch mehr für den Technologietransfer tun können." Ein Grund für diese ungenutzte Chance sei, dass das CERN von verschiedenen Ländern getragen werde und unklar sei, wer dessen Fruchte ernten durfte. Auf dem Podium war neben Maurice Bourquin, ehemaliger Präsident des CERN Council, auch Botschafter Alexandre Fasel, ständiger Vertreter der Schweiz bei der UNO und den internationalen Organisationen in Genf, vertreten. Fasel betonte, durch den Standort Genf sei das CERN nahe an den Vereinten Nationen und könne dort die Anliegen der Wissenschaft einbringen. Das CERN helfe auch der Schweiz im Bereich der Wissenschafts-Diplomatie, meinte er, räumte aber ein, dass die Schweiz in diesem Bereich "nicht zu den early movern zählt".

SPG - Lehrerfortbildung: Moderne Aspekte der Physik kondensierter Materie

Paul Scherrer Institut, 28. & 29. November 2014

Programmübersicht:

- Vorträge zu aktuellen Themen der Forschung:
  Magnetismus und Supraleitung
  Röntgen-Phasenkontrast Imaging
  Selbstorganisierende supramolekulare Architekturen
  Nanomagnete als Modellsysteme
  Protonenbeschleuniger
- Besuch der Grossforschungsanlagen und des Schülerlabors iLab
- Diskussion über Entwicklungen in der Physikdidaktik

Organisation: Dr. Thomas Geue (thomas.geue@psi.ch), Prof. Dr. Christian Rüegg (christian.rueegg@psi.ch)

Anmeldung bis spätestens 30. Oktober 2014: Frau Pamela Knupp, pamela.knupp@psi.ch

Weitere Informationen sind in Kürze auf www.sps.ch verfügbar.

Ausschreibung der SPG Preise für 2015
Annonce des prix de la SSP pour 2015

Auch im Jahr 2015 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
- SPG Preis gestiftet vom METAS für eine hervorragende Forschungsarbeit mit Bezug zur Metrologie

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)):

En 2015, 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
- Le prix SSP offert par le METAS pour un travail de recherche d'une qualité exceptionnelle faisant référence au domaine de la métrologie

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):

awards@sps.ch

Einsendeschluss: 28. Februar 2015

Délai: 28 février 2015

Die Preise werden an der gemeinsamen Jahrestagung 2015 in Wien überreicht.

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

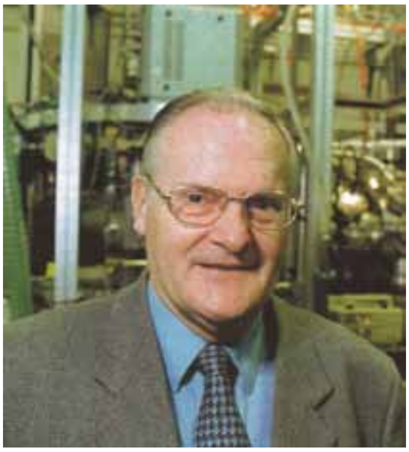
Les prix seront attribués à la réunion annuelle commune qui se tiendra en 2015 à Vienne.

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

Nachruf für SPG Ehrenmitglied Hans-Joachim Güntherodt

Am 6. Juli 2014 ist Prof. Dr. Hans-Joachim Güntherodt, emeritierter Ordinarius für Experimentalphysik am Departement Physik der Universität Basel, in Basel verstorben.

Hans-Joachim Güntherodt wurde 1939 in Thüringen geboren. Er studierte Physik an der ETH in Zürich, wo er 1967 promovierte. 1973 wurde er zum Ordinarius für Experimentalphysik an der Philosophisch-Naturwissenschaftlichen Fakultät gewählt und setzte sich in den folgenden Jahrzenten erfolgreich für die Belange der Universität Basel ein. Im akademischen Jahr 1986/87 stand er der Fakultät als Dekan vor. Von 1994 bis 1996 leitete er die Universität als Rektor. Im Jahre 2009 trat er in den Ruhestand.



Professor Güntherodt begründete seinen wissenschaftlichen Ruf mit weltweit beachteten Arbeiten zu metallischen Gläsern und flüssigen Metallen. Anschliessend wandte er sich der Untersuchung der Kondensierten Materie auf atomarer Ebene zu und prägte in der Folge die Entwicklung der Physik in Basel wie wohl kein anderer. Es gelang ihm ausserdem, die Nanowissenschaften erfolgreich als Nationales Kompetenzzentrum an der Universität Basel zu etablieren. Er leitete dieses Zentrum von 2001 bis 2006 als Direktor und war im Jahre 2008 Mitbegründer des Swiss Nanoscience Institute.

Es war Professor Güntherodt ein stetes Anliegen, die in der Grundlagenforschung erzielten Resultate in konkrete Anwendungen zu überführen und die Entwicklung der Schnittstelle zwischen Universität und Industrie zu fördern. Viele seiner jungen Kollegen inspirierte er für Industriekarrieren und zeigte ihnen die vielfältigen Möglichkeiten der Nanowissenschaften auch ausserhalb der Universität auf.

In seinen Vorlesungen konnte er Studierende und Doktorierende begeistern und inspirierte Generationen von jungen Forschern. Er trug wesentlich zur Einrichtung eines erfolgreichen Studiengangs in Nanowissenschaften an der Universität Basel bei. In seinen zahlreichen allgemeinen Vorträgen gab er seine Begeisterung für die Nanowissenschaften auch an die breite Öffentlichkeit weiter.

Mit Umsicht leitete Hans-Joachim Güntherodt als Rektor die Universität in einer Phase des Umbruchs und erwarb sich damit bei ihrer Überführung in die Autonomie im Jahre 1996 grosse Verdienste.

Die SPG ernannte Prof. Güntherodt für seine wissenschaftlichen Leistungen sowie seine nachhaltigen Beiträge für die Schweiz als Bildungsstätte und Wirtschaftsraum im Jahr 2010 zum Ehrenmitglied.

Mit Hans-Joachim Güntherodt verlieren wir eine charismatische Persönlichkeit und einen guten Kollegen, der sich in ausserordentlicher Weise für die Belange der Physik und der Wissenschaft eingesetzt hat. Wir werden ihm ein ehrendes Andenken bewahren.

Ernst Meyer, Uni Basel

Martin C. Gutzwiller (1925 - 2014)

Einer der wichtigsten Schweizer Physiker unserer Zeit war Martin Gutzwiller, der dieses Jahr am 3. März im Alter von 89 Jahren in Albuquerque, New Mexico / USA, dort die letzten Jahre bei seiner Tochter lebend, verstorben ist. Unser SPG-Kollege Dionys Baeriswyl verfasste einen ausführlichen Nachruf in *Physics Today*, *June 2014, p. 60*, der im Wesentlichen den Werdegang und die aussergewöhnlichen Leistungen Gutzwillers schildert, die auch vor geraumer Zeit in den *SPG Mitteilungen* (http://www.sps.ch/artikel/diverse_artikel/the_legacy_of_martin_gutzwiller/) gewürdigt wurden. Mit Martin Gutzwiller verliert die Schweiz eine ihrer bedeutendsten Persönlichkeiten, die sich um die Physik in ausserordentlicher Weise verdient gemacht hat.

Bernhard Braunecker

Gerald Stanford Guralnik (1936 - 2014)

Mit grosser Bestürzung ist auch der Tod von Gerald S. Guralnik zu vermelden. Gerry starb nach einem Vortrag an der Brown University / Rhode Island am 26. April dieses Jahres. Ein ausführlicher und persönlich gehaltener Nachruf wurde von seinem Mitstreiter aus jungen Jahren Carl R. Hagen in *Physics Today, August 2014, p. 57-58* verfasst. Wir konnten Gerry letztes Jahr für den Inauguralartikel unserer Serie *Meilensteine der Physik* gewinnen (http://www.sps.ch/artikel/meilensteine_der_physik/heretical_ideas_that_provided_the_cornerstone_for_the_standard_model_of_particle_physics_1/), worin er seine Arbeiten aus dem Wunderjahr 1964 schilderte. Es war ein Vergnügen, mit ihm zu korrespondieren und ihn zu bewegen, auch Persönliches in den Artikel mit einzuflechten. Schade, dass es die veralteten Bestimmungen der Nobelpreisstiftung nicht erlaubten, ihn für seine Beiträge zur modernen Physik in der ihm gebührenden Weise zu berücksichtigen.

Bernhard Braunecker

47th International Physics Olympiad 2016 in Zurich

The year 2016 will present a key year in Physics for Switzerland, as the 47th International Physics Olympiad (IPhO) 2016 will be hosted by Switzerland and Liechtenstein and take place in Zurich from July 10 to 18, 2016. About 450 of the best high school students in physics from all over the world will participate in this challenging competition.

The International Physics Olympiad (IPhO) poses a big challenge for all involved people. During the IPhO, the students will complete demanding experimental and theoretical tasks (difficulty level of first year bachelor studies) and get the opportunity to form friendships. All these youngsters have been selected during the national Olympiads and are the best of their countries. They will meet in Zurich with peers from about 90 countries and hopefully enjoy an unforgettable week.

More than Physics

The exams are prepared by the host countries and accepted by the board of leaders, mostly people involved in physics education or country representatives that accompany the youngsters. The leaders will also translate the exams into their students' mother tongue, a huge task, and oversee the corrections. The IPhO is committed to promote the new scientists' generation, but not only that. Another objective is to provide the youngsters with as many opportunities as possible to interact, to network and to encourage intercultural exchange. Besides, the IPhO offers a great opportunity to present Switzerland and Liechtenstein through excursions and provide a small overview of their scientific achievements.

A challenging project

2016 is the first time that two countries, Switzerland and the Principality of Liechtenstein, host the IPhO. The IPhO 2016 is co-organized by the University of Zurich and the Association of Swiss Scientific Olympiads (ASSO), the Swiss umbrella organization of the Scientific Olympiads in Biology, Chemistry, Mathematics, Informatics, Philosophy and Physics. The IPhO 2016 Steering Committee is co-chaired by Prof. Michael Hengartner, President of the University of Zurich, and Simon Birrer, member of the SwissPhO (Swiss Physics Olympiad). The academic committee, under the lead of the University of Zurich, is responsible for preparing challenging and creative physical problems under conditions of confidentiality. Finally, yet importantly, the organizers will need many volunteers during the IPhO to look after all the guests and make sure that the week runs smoothly.
The organization of the IPhO is also a financial challenge as the host countries take over all the expenses during the week. Although the host countries and the University of Zurich ensure the startup financing, the lion's share of the budget still must be covered by fundraising. The organizers are looking for financing partners to make the IPhO 2016 in Switzerland and Liechtenstein possible.

Support by the SPS

The Swiss Physics Olympiad (SwissPhO), whose members work as volunteers, organizes every year the Swiss Physics Olympiad, which selects the five students participating in the IPhO. This procedure stretches over a period of several months. A training camp and the final round, which decides over the participation in the IPhO, follow the preliminary round. SwissPhO has been happy to count on the generous support by the SPS for many years now. Besides, SPS donates special prizes to the national winners.

Contact:

IPhO 2016
Simon Birrer, Executive Chairman IPhO 2016,
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Gesellschaftsstrasse 25, 3012 Bern

Links:

www.ipho2016.org under construction
http://ipho.phy.ntnu.edu.tw

IPhO 2016 in a nutshell

Date: 10 – 18 July 2016
Host countries: Switzerland and Principality of Liechtenstein
Place: University of Zurich, Campus Irchel
Participating countries: approx. 90
Students: about 400
Leaders (accompanying persons): about 300
Volunteers: about 200
Total number of involved persons: about 1000
Budget: over CHF 4 Mio

The IPhO 2014 took place in July in Astana, Kazakhstan. The Swiss delegation achieved 2 silver medals, 1 bronze medal and 2 honorable mentions.
*From left to right: Rafael Winkler *, Pieter Stas, Nikita Rudin, Sebastian Stengele, Barbara Roos **
** = Winners of the "SPG Nachwuchsförderpreis 2014" at SwissPhO (see SPS Communications no. 43, p. 27)*

Progress in Physics (43)

Extended-focus optical-coherence microscopy – seeing the brain at work

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Laboratoire d'optique biomédicale, École Polytechnique Fédérale de Lausanne, theo.lasser@epfl.ch

The 2-dimensional (2D) scanning of brain structures with an optical Bessel beam allows for coherent 3D microscopy of living mouse brains up to 500 µm depth, while providing high lateral and axial resolution of < 2 µm. This is a minimally invasive imaging technique allowing to map brain structures, vascularisation and to perform a full assessment of quantitative blood flow at unprecedented acquisition rates.

During the last centuries, microscopy enriched biology and medicine with an ever-increasing image quality, providing high resolution with an increased contrast for a visualization of tissue and cell structures. Our biology textbooks testify with many images this undeniable impact of optical imaging. Besides this, imaging of tissue and cell processes has received increasing attention during the last decades, as these processes control and regulate tissue and cell function. But imaging of dynamic processes generates new challenges for optical image acquisition. As an important example, imaging blood flow and disease-induced alterations requires rapid three-dimensional imaging, where classical microscopy concepts meet their technical and physical limitations.

By the end of the 1980s, A. Fercher [1] and his co-workers at the University of Vienna (Austria) invented optical-coherence tomography (OCT), a low coherence interferometric imaging modality. In close analogy to ultrasound, OCT generates tomograms, so-called "depth profiles", which are sequentially acquired for synthetic tomograms. This interferometric imaging technique leads to a fast acquisition rate with an increased penetration depth. Consecutive tomograms are assembled to render a full 3D imaging stack. Due to the interferometric nature of OCT, the OCT contrast mechanism is given by the small variations of the index of refraction of tissues or cells causing a small sample reflection. Moreover, through the intrinsic optical amplification of these sample reflections, a strong signal can be detected. This results in a label-free imaging modality with an access to phase information. These features pave the route towards optical-coherence microscopy with an ever-growing field of novel applications.

In this article, we describe the current state of the art in optical-coherence microscopy (OCM) with a particular emphasis on brain and Alzheimer imaging. The promising outlook on future OCM developments [2-4] is a clear indication of the dynamism and breadth of potential contributions that OCM may make in the next coming future to biology and medicine.

The method – optical-coherence imaging

The set-up of an OCM instrument is based on a Mach-Zehnder interferometer (figure 1). A beam splitter divides the beam of a broadband light source into a reference (red in figure 1) and an illumination beam (blue in figure 1). The sample is laterally scanned in the x-y direction and the back-scattered sample beam interferes with the reference beam. The resulting interference signal is detected by the spectrometer. The crucial element in this interferometric set-up is the broadband source: its small temporal coherence leads to a "coherence gating" enabling a high axial resolution (coherence length $l_c \propto \lambda_c^2 / \Delta\lambda$). The interference resulting from the different tissue structures and layers manifests itself as a modulation on the spectrum due to constructive and destructive interference (spectral interferogram) [5, 6]. Applying a Fourier transform to these spectral interferograms (the so called *k*-spectrum) results in a depth profile. The entire depth profile is thus acquired in a single spectrum. This multiplexing advantage (no depth scanning needed), corresponding to the so-called Felgett advantage, generates a synthetic 3D image of the sample by fast lateral scanning. Thus, fast 3D imaging is made possible by this coherent imaging and opens the door towards minimally invasive structural and functional *in-vivo* imaging of small animals.

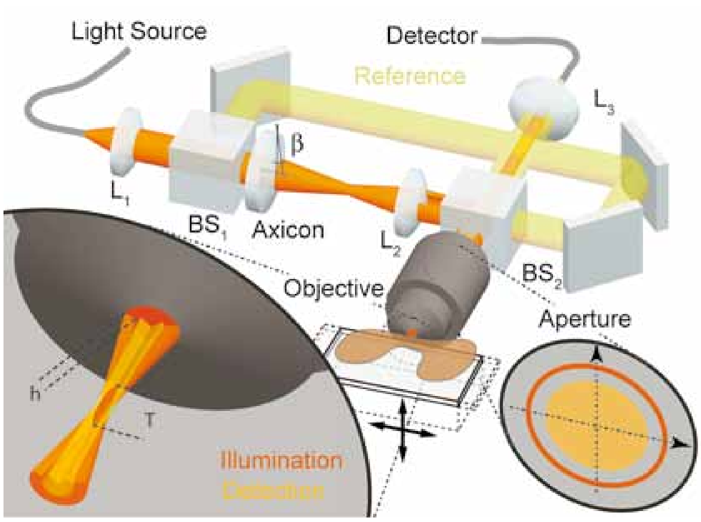


Figure 1: General set-up of an xfOCM system with Mach-Zehnder interferometer and spectral detection (spectral interferometer)

Spatial resolution

For most optical microscopy methods, spatial resolution is of utmost importance. In OCM, one illuminates the sample with a weakly focused Gaussian beam so that the probed sample receives a nearly uniform illumination over the whole depth. As in classical microscopy, the lateral resolution is given by the Abbe criterion and is a function of the numerical aperture (NA), whereas the temporal coherence length determines the decoupled axial resolution. Maintaining a uniform resolution over the whole field depth is more complicated than at first glance. The increased NA leads effectively to an increased lateral resolution, but the uniform sample illumination is squeezed by a strongly reduced

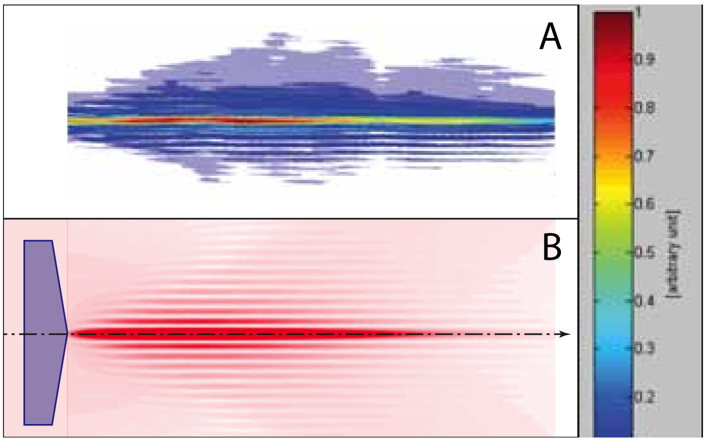
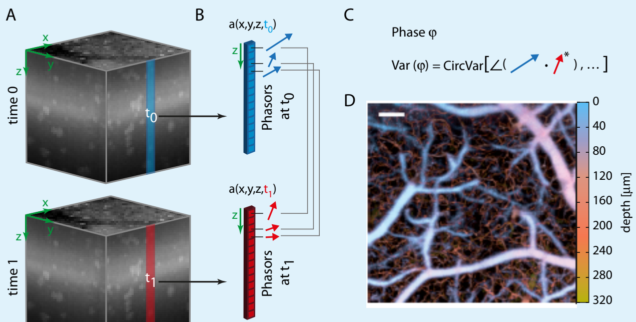


Figure 2: Bessel beam
(A) measured illumination (Ti:Sa laser 130 nm bandwidth / 50 nm depth of focus)
(B) simulated Besselbeam with an elongated illumination and side lobes

Rayleigh range. What is needed is a so-called "optical needle" with an almost constant illumination profile over an extended depth range. A so-called Bessel beam (figure 2) [7], generated by an axicon, fulfils these requirements and ensures a uniform narrow illumination profile over an extended depth. The combination of tube lens and objective "demagnifies" this Bessel beam to a lateral extent of about 1.5 μm over a depth range of approximately 500 μm ideally suited for the multiplexed OCM imaging approach.

Phase-variance Angiography

In OCT, each voxel of the image can be represented by a phasor describing the scattering strength (length) and the position of the scattering particles within the resolution volume (phase). In theory, if these particles are static, the corresponding phase will be constant over time. In the case of erythrocytes flowing through a capillary and due to the movement of these scatterers, the phase of their corresponding voxels will change with time. Therefore by analysing the temporal evolution of the phase, the dynamic and the static components can be separated to generate angiographic maps. In practice this is done by acquiring a series of B-scans (typically 4) at the same lateral x-position and calculating the spatial variance of their phase difference (see figure below).



Overview phase variance method: (A,B) Two time samples are taken at the same lateral location. To isolate the dynamic component, the circular variance over the phasors is calculated (C). As depicted, the presented method allows rendering angiographic maps of a rodent's cerebral cortex (D).

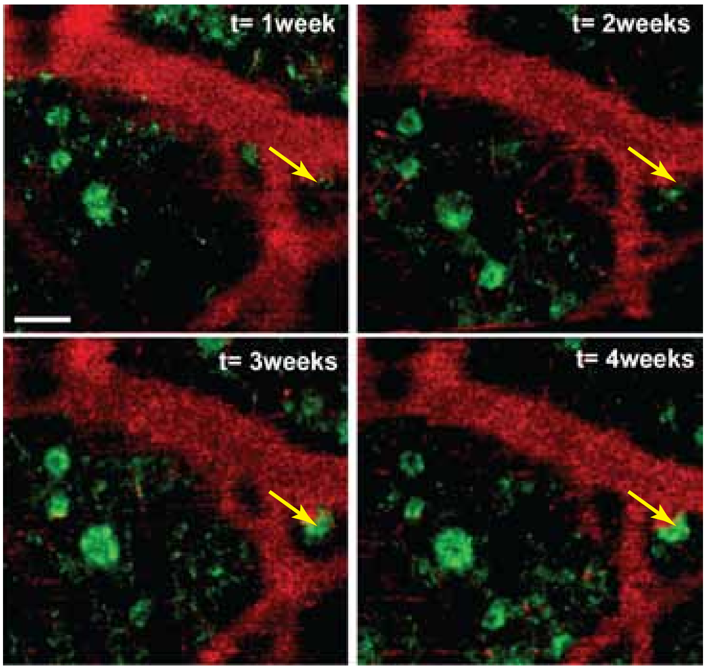


Figure 3: Longitudinal study of Alzheimers disease in an APPPS1-mouse

OCM and Alzheimer's disease research

In Alzheimer's disease, extracellular amyloid plaques, i.e. water-insoluble aggregates made of amyloid-beta (Abeta) proteins, are considered a major neuropathological hallmark of Alzheimer's disease. The exact toxic effects of these highly scattering proteins aggregates are however not yet fully understood. OCM allows a longitudinal label-free monitoring of amyloid plaque formation in the living mouse brain,

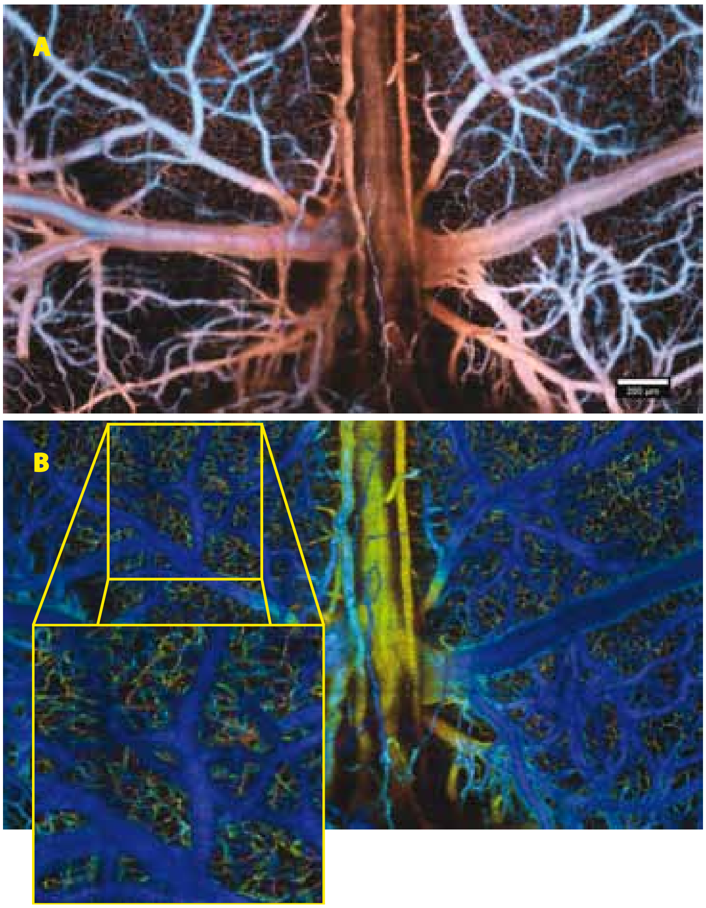
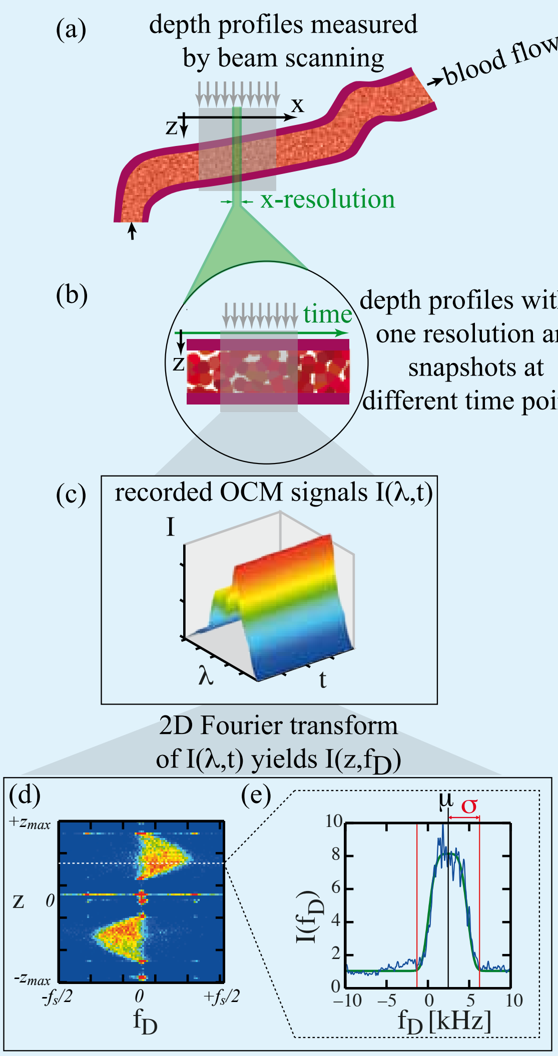


Figure 4: OCM phase-variance image of a mouse brain showing the vascularisation with micro-vessel structures measuring up to 8 µm across (corresponding to the diameter of a red blood cell)

Quantitative blood flow measurement

Complementary to angiography (see Infobox 1), velocimetric techniques perform a quantitative estimation of the blood flow speed by measuring the Doppler frequency shift induced by moving scatterers. Most velocimetric OCT methods only measure the velocity component along the optical axis. However, in most biological applications, many vessels and capillaries are directed almost perpendicularly to the optical axis. Therefore, we developed a technique for measuring the parallel and perpendicular flow components by quantifying the whole Doppler frequency *spectrum* (as opposed to only a single Doppler frequency), which is created when a high-resolution OCM system images moving scatterers. This Doppler spectrum can be measured by acquiring depth profiles in a densely sampled x-scan (oversampling), such that many (typically, 32) such profiles are acquired within one resolution element (a). Hence, the depth profiles recorded within this resolution element represent the same spatial position in the sample, but were recorded at different time-points (b). Therefore, for each spatial position, the OCM signal I(λ,t), is obtained as a function of wavelength λ and time t (c). By applying a 2D Fourier transform on these data, a Doppler spectrum is obtained for each depth position (d). Fitting this Doppler Spectrum and extracting its mean and standard deviation (e) allows calculating the parallel and perpendicular velocity components.



without prior administration of an amyloid-binding dye or a radioactive tracer [8]. As shown in figure 3, these scattering structures (diameter about 20–200 µm) increase in size and numbers during an observation period of four weeks.

The underlying interferometric principle of OCM allows an access to the optical phase. (Box 1) A simple reprogramming of the scan-protocol allows extracting the vasculature with a high spatial 3D-resolution. The vascularisation shown in figure 4 is a 3x4 mm section of a mouse brain. The fine deeply lying micron-sized vessels can be identified with a diameter of about 8 µm, corresponding to the size of individual erythrocytes. The re-location of these structural changes in affected areas of the brain can easily be retrieved with high accuracy while using the vascular network as a reference road map.

Further exploiting this phase information allows assessing the blood flow quantitatively (Box 2). The blood flow is modulated by the natural heartbeat cycle, but contains additional flow components, which are induced by neuronal brain activity. The localized blood flow increase in response to external stimulation is an indirect measurement of stimuli responses. In close analogy to functional MRI, OCM can be applied to functional brain imaging with an increased spatial resolution (typically 2 order of magnitude). For brain research, this results in the possibility to assess the functional responses induced by external stimuli or distortions, with high spatial and temporal resolution (see figure 5).

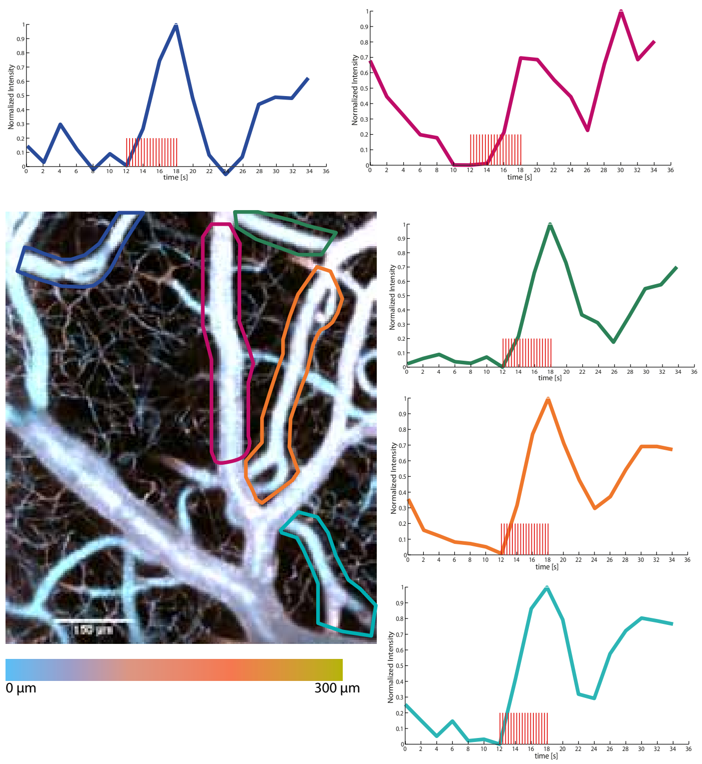


Figure 5 Mouse brain, somatosensory cortex showing vascular evoked responses to electrical stimulation of the contralateral hind-paw. Stimulation period is indicated by the red train of electrical pulses.

Outlook

The potential contributions and application areas of OCM are steadily growing. Due to this high sensitivity, gold nanoparticles can be detected down to a size of 2 nm. These findings have been recently exploited for photo-thermal optical lock-in OCM (poliOCM) [2]. This contrast enhancement adds high specificity to selected proteins and sub-cellular structures in a similar fashion to confocal fluorescence microscopy. Very recently, OCM has been extended to the visible wavelength range, which opens up completely new perspectives for high resolution cell imaging.

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Progress in Physics (44)

Spontaneous Helical Order of Electron and Nuclear Spins in a Luttinger Liquid

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Non-interacting 1D conductors

In a one-dimensional (1D) conductor, electrons are confined to move along a single direction, occupying only the quantum mechanical ground state orbital of the transverse dimensions of the wire. What is the electrical conductance of such a quantum wire? This fundamental question was answered by Rolf Landauer many years ago for non-interacting electrons in a clean, ballistic conductor: each spin species carries the quantum of conductance, e^2/h [1], with e the electron charge and h the Planck constant. For a spin degenerate 1D conductor with a single subband, the conductance is therefore $2e^2/h$. If the spin degeneracy is broken and transport of one spin direction is blocked, the conductance is thus reduced to $1e^2/h$. Similar to spin, other degeneracies such as valley degeneracies or multiple 1D subbands due to weaker confinement can also open additional conductance channels.

Conductance quantization is thus a hallmark effect of ballistic 1D noninteracting electrons and was first experimentally demonstrated in gate-defined quantum point contacts in a GaAs 2D electron gas in 1988 [2, 3]. The conductance increases in steps of $2e^2/h$ upon changing the width of the constriction with gate voltage, corresponding to population of 1D-subbands. Theoretically, it can be described in the framework of the Landauer-Büttiker formalism [1, 4]. The conductance quantization is independent of material and sample details, depending only on the number of subbands and the degeneracies present – thus referred to as *universal* conductance quantization. It is also closely related to the quantum Hall effect, where in a strong magnetic field, 1D modes appear at the edge of the sample, each carrying a quantum of conductance.

Interacting 1D conductors: Luttinger liquids

Electrons confined in 1D are genuinely different from free, non-interacting particles. This becomes relevant when replacing the short constrictions ("point contacts") of the first experiments with long wires, where the electrons are tightly confined within a single transverse mode for many Fermi wavelengths along the wire. Due to the Pauli principle, electrons cannot freely pass from one side of the conductor to the other. Instead, they immediately collide with their neighbors and due to the strong 1D confinement, they cannot pass around them. Thus, the effect of disorder and electron-electron (e-e) interactions is very much enhanced in 1D compared to higher dimensions. As a consequence, in clean wires, the electron motion is characterized by density waves arising from the collisions between neighboring electrons, and interactions between them lead to a strong renormalization of the properties of these collective, strongly correlated modes. What emerges is a Luttinger liquid (LL)

[5–8] exhibiting remarkably different physics compared to the Fermi liquid (FL) physics characteristic of 2D and 3D conductors.
Salient signatures of LL theory include ubiquitous power-law scaling, separation of spin and charge modes, and charge fractionalization, all recently observed in experiments [9, 10] performed on cleaved edge overgrowth (CEO) GaAs quantum wires [11, 12] (see box on cleaved edge overgrowth wires). CEO wires are one of the best realizations of a LL liquid known in nature. How do the e-e interactions and the resulting LL physics affect the conductance of the wire? For a clean LL of infinite length, the conductance is renormalized to $K_C\,2e^2/h$ for a spin degenerate system [13, 14], in principle allowing extraction of the LL interaction parameter K_C in the charge sector from the conductance. The corresponding interaction parameter K_S in the spin sector is normally fixed at $K_S = 1$ due to the absence of significant spin-spin interactions. For repulsive e-e interactions, $0 \leq K_C \leq 1$, where $K_C = 1$ corresponds to non-interacting electrons, $K_C < 0.5$ for long range interactions, and $K_C \to 0$ for interactions approaching infinite strength. The velocity of the LL charge modes is increased to v_F / K_C above the bare Fermi velocity v_F due to increasing stiffness in presence of repulsive e-e interactions $K_C < 1$.

Experiments?

In any realistic experiment, the length of the LL will of course be finite, and FL leads will be attached to the LL at some point. Surprisingly and remarkably, for this more realistic scenario, theory predicts that the *universal* conductance quantization $2e^2/h$ is recovered for the clean, ballistic LL [15–18], irrespective of the strength of interactions K_C. This result can be understood in simple terms when considering that the resistance of a clean 1D quantum wire is really a *contact* resistance arising from the coupling of the higher dimensional modes into the single 1D wire mode, leading to back scattering and thus resistance. This contact process is occurring entirely outside the LL and thus contains no information about the LL and K_C. If the wire itself is ballistic, no further backscattering is caused inside the LL and thus no additional resistance appears. If some even weak disorder is present in the wire, however, the conductance is reduced with typical LL power laws [19, 20].
How do these theoretical predictions compare to experiments? Yacoby and coworkers in Ref. 21 have measured the conductance of ballistic CEO wires already in 1996. They find very well developed plateaus exhibiting quantized conductance as the number of transverse modes is controlled with a gate voltage. To everyone's surprise, however, the conductance quantization was not in units of $2e^2/h$, but rather a lower conductance step was seen, reduced as much as 25% below the universal values at a temperature $T = 0.3$ K. Interestingly, the reduction depended on temperature and source-drain bias V_{SD}, approaching the universal values at high T or V_{SD}. Subsequent attempts to understand this conductance suppression in terms of poor 2D-1D coupling and other possible explanations were inconsistent with important aspects of the data [21, 22]. Thus, the reported non-universal conductance quantization has remained unexplained and has presented an unresolved mystery ever since.

GaAs CEO wires at ultra-low temperatures

In a recent experiment published in 2014 in Physical Review Letters by C. P. Scheller et al. [23] and performed at the University of Basel in an international collaboration with Harvard University (A. Yacoby and G. Barak) and Princeton University (L. N. Pfeiffer and K. W. West), we have revisited the conductance quantization in very similar GaAs CEO wires (see CEO box), now performing experiments for the first time down to 10 mK. Previously, CEO wires were measured at 300 mK or higher temperatures [9, 10, 21, 22]. Obtaining ultra-low temperatures far below 100 mK is rather difficult and has required a significant experimental effort towards filtering and thermalizing the sample and its electrical wires, see [24] for details. Ultra-low temperatures were demonstrated both in-situ on the CEO samples via thermal activation of fractional quantum Hall states as well as in metallic Coulomb blockade thermometers operated under the same conditions, giving an electron temperature of 10.5 ± 0.5 mK at dilution refrigerator temperature $T = 5$ mK. Advancing to ever lower temperatures in quantum transport experiments in nanoscale samples is an ongoing effort at

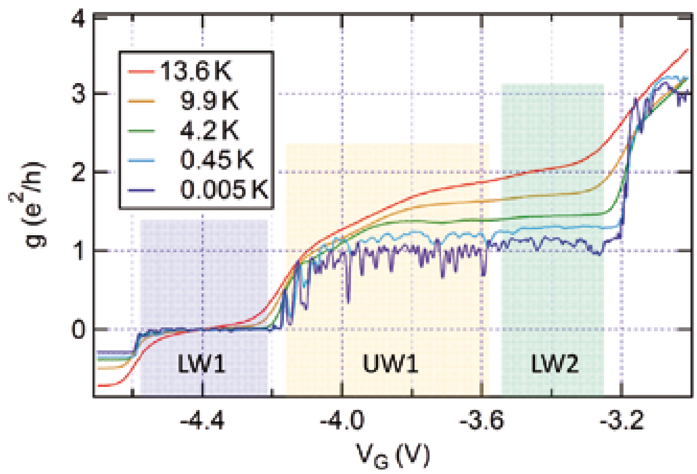

Figure 1: Conductance plateaus of a CEO double wire as a function of temperature

Gate voltage traces of the differential conductance $g(V_G)$ are shown at temperatures T as labeled. Colored bands indicate wire-mode populations: purple: only first mode of the lower wire is occupied (LW1), yellow: first upper wire mode is added (UW1) and green: second LW mode is added (LW2). At the highest T, the thermally smeared remainder of the UW1 plateau approaches $2e^2/h$ (red curve). In addition, at elevated temperatures, we observe a feature reminiscent of the '0.7' structure [26] (shoulder of suppressed g at lower end of plateau). For the lowest T, however, the UW1 conductance plateau is reduced strongly to $1e^2/h$. This is contrary to the expected T-dependence of a 0.7-feature, which rises to $2e^2/h$ at low-T [26].
Conductance oscillations appear at the lowest temperatures, suppressing g below a flat plateau. These are understood as Fabry-Perot type quantum interference arising from scattering outside the ballistic 2 μm wires. Full transmission ~100% is obtained at the maxima of the g-oscillations, which are taken as the relevant measure δg of the wire conductance (see [23] for details). Traces are shifted in g to align LW1 plateaus at g = 0 in order to subtract the LW contribution to the conductance. While UW-LW tunneling is very weak in the 2 μm short gated segments, much stronger UW-LW coupling results for the semi-infinite UW-LW overlap next to the gated region. This LW contribution is subtracted in order to obtain the conductance δg of the UW first mode only, which is adiabatically coupled to the reservoirs. Note that the LW g-contribution is independent of gate voltage V_G since the very long UW-LW overlap is not under the gate.

the University Basel, ultimately striving for the microkelvin temperature range by incorporating advanced nuclear refrigeration schemes [25], with the goal of opening the doors for new physics.

The results reported in [23] are rather striking: The conductance of the first wire mode reaches $1e^2/h$ at $T \sim 100$ mK and remains fixed at this value for lower T, while the electron temperature falls far below 100 mK. At high $T \gtrsim 10$ K, the conductance approaches the expected universal value $2e^2/h$ (see Fig.1 and 2). This suggests lifting of the electron spin degeneracy, yet without an external magnetic field. The same behavior was seen in all investigated samples, is robust against variation of the wire electron density and persists at moderate magnetic fields (up to 3 T). Further, application of even a small source-drain bias voltage acts to destroy the low-conductance state, driving the conductance back towards $2e^2/h$, similar to temperature. This suggests the emergence of a new, small energy scale in the physics of the wire. We emphasize that in the high temperature range $T \geq 0.3$ K, our results are fully consistent with the previous experiment [21].

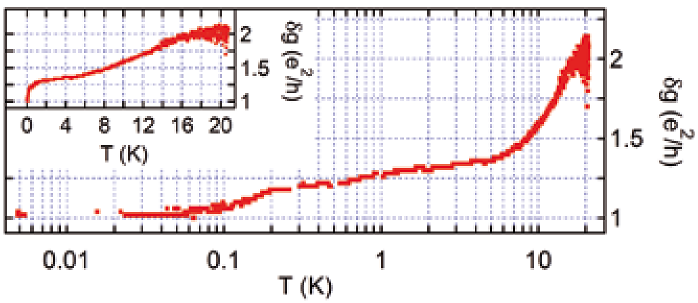

Figure 2: Conductance reduction by a factor of 2

Conductance δg of the first mode of the UW as a function of temperature on a logarithmic axis (linear axis in inset), extracted from conductance plateau traces as in Fig. 1. Small but discrete steps in g result from a histogram binning effect. We note that the transition from $2e^2/h$ to $1e^2/h$ occurs over a very broad temperature range spanning about 2 orders of magnitude in temperatures. Such broad cross-overs are a characteristic signature of LL physics.

A detailed analysis of the data has been performed [23], considering all possible models we were aware of, including non-interacting electrons, e-e interactions only within the wire and also in the 1D electron gas outside the wire (variations of LL physics), poor 2D-1D coupling in presence of LL correlations, an incoherent LL due to Wigner crystal formation and, finally, also the effects of spin-orbit coupling. While some of these models can capture certain aspects of the data, clear and significant inconsistencies appear with salient features of the experiment. Ultimately, all of these models had to be rejected. Only a recent theory of helical nuclear spin order in a LL by Braunecker, Simon and Loss [27] can account for the experimental observations without inconsistencies, remaining as the figurative "last theory standing".

Helical Nuclear Spin Order

The conceptual advance made by this recent theory [27] may be daring and profound, yet it is at the same time simple and natural: our discussion of 1D conductors and GaAs wires in particular so far has neglected the nuclear spin. In fact, all stable isotopes of both Ga and As have nuclear spin $I = 3/2$. Each transverse wire cross section contains 10^3 to 10^4 nuclear spins which can couple to the electron spin via the hyperfine interaction, defining a new type of central spin problem in a LL. Thus, in this sense, the wires investigated in the experiments operate in a "quasi"-1D regime where a single electronic mode couples to a large number of nuclear spins. The theory then proceeds to calculate the consequences of this, predicting profound and non-trivial results, outlined here.

Below a cross-over temperature T^*, an effective Ruderman-Kittel-Kasuya-Yosida (RKKY) interaction, strongly enhanced by e-e interactions of the 1D electronic modes, forces the nuclear spin system via the hyperfine interaction into helical order [27] (see also box 2). The resulting large Overhauser field with spiral texture in space acts back on the electronic system where a large gap opens – pinned at the Fermi energy – for half of the low energy electronic modes. A helical (spin-filtered) LL thus forms and causes the reduction of the conductance by a factor of 2 in the absence of an external magnetic field, applicable similarly for single and double wires [28] and even for arrays of wires [29]. A novel state of strongly correlated quasi-1D quantum matter is therefore predicted, where nuclear spins and the half-gapped electron spins are locked into order in a conjoined helical spin state of perfectly synchronized and phase locked spiraling of electron and nuclear spins, as depicted in Fig. 3. This new state is a thermodynamic ground state of the system protected by a gap, rather than a dynamic polarization effect caused by driving out of equilibrium. Finally, the spin helix state is a clear manifestation of LL physics present in the electronic sector. In absence of LL correlations, the ordering temperature quickly drops to much lower temperatures.

Comparison to Experiment

The cross-over temperature T^* predicted by theory depends strongly on the LL interaction parameter K_c. While neither determining K_c from experiment nor estimating it theoretically is trivial, reasonable values [9, 10] for the single mode case are approximately 0.4, resulting in a $T^* \sim 0.2$ K, while $K_c = 0.3$ already gives $T^* \sim 0.6$ K. Considering that full nuclear order and $g = 1e^2/h$ is obtained only at $T \ll T^*$ and zero polarization with $g = 2e^2/h$ only at $T \gg T^*$, these ordering temperatures are consistent with the experiment.

Further, a very broad, washed out transition occurring over a large range of temperatures would be expected for a LL system – as observed here in the experiment. In addition, a Zeeman splitting smaller than the induced electronic gap

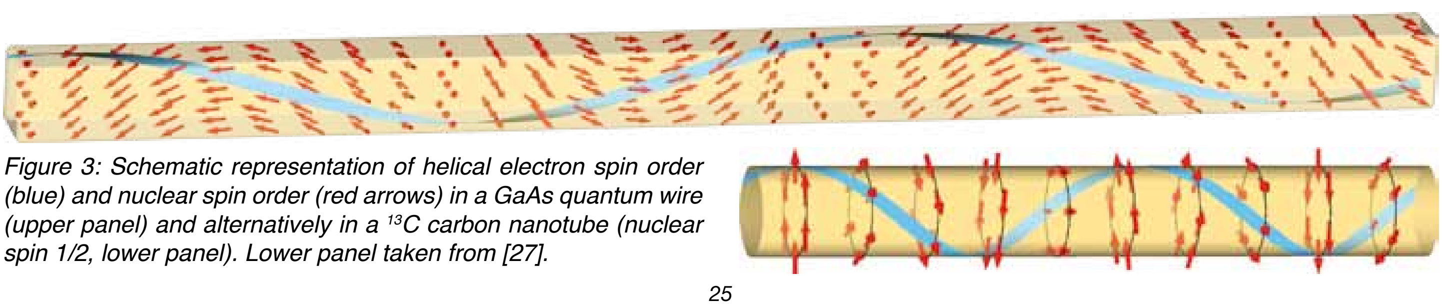

Figure 3: Schematic representation of helical electron spin order (blue) and nuclear spin order (red arrows) in a GaAs quantum wire (upper panel) and alternatively in a ^{13}C carbon nanotube (nuclear spin 1/2, lower panel). Lower panel taken from [27].

should affect neither the nuclear order nor the conductance strongly, consistent with the observed insensitivity to moderate magnetic fields (up to 3 T). Finally, strong sensitivity to source-drain bias could be related to the energy to destroy the nuclear spin helix. However, this could also have other origins, including resistive heating.
Several clear characteristics are present in the data that support the nuclear spin helix model without contradiction: the conductance reduction by a factor of 2 followed by a saturation, a crossover temperature in the observed range, a very broad transition, sensitivity to source-drain bias and finally, insensitivity to both a small Zeeman splitting and change of density. Nevertheless, all present data stem from electronic transport measurements, and no direct evidence for nuclear spin order is currently available. Further experiments are required to learn more about this system.

Future Experiments?

Directly probing the nuclear spin helix with a scanning magnetometer would be very difficult: the wires are buried hundreds of nanometers below the surface, the nuclear magnetic moments are tiny (with only few electrons present in the wire), and there is no overall magnetization to be detected due to the spiraling and self-canceling nature of the polarization. Further, we note that it is difficult to estimate what the effect of an NMR type excitation is on the system, what the low energy nuclear spin excitations are, and whether a detectable resistive signal would result. Work is currently under way to investigate these and other questions, both in theory and experiment. Tunneling spectroscopy with two parallel wires can be used to map the electronic dispersions of the wires [9], and might be used to observe the partial spin gap below T^*. In any case, the data presented in [23] are striking and stand alone, irrespective of the model used for interpretation.

Hottest nuclear spin order

If nuclear spin order was indeed observed in the experiment [23], then this would constitute by far the highest temperature at which nuclear order was reported to date. Due to the tiny size of the nuclear magnetic moment, nuclear dipole-dipole interactions are extremely weak, leading to ordering only at extremely low temperatures, typically at microkelvin or lower temperatures. However, also in 3D bulk systems, enhancement of nuclear spin-spin interactions via hyperfine coupling and conduction electron RKKY mechanism have

GaAs cleaved edge overgrowth (CEO) quantum wires

CEO wires are fabricated starting from a high-mobility 2D electron gas (2DEG) in a GaAs quantum well by cleaving the wafer inside the ultra-high vacuum MBE chamber and over-growing another modulation doping sequence on the freshly cleaved edge. The additional Si doping from the overgrowth at the edge combined with rearrangement of the resulting band structure leads to accumulation of charges and formation of quantum modes along the CEO edge. Thus, a quantum wire is created running along the 2DEG cleaved edge forming a 1D electron gas (1DEG) consisting of a few transverse modes, see [11, 12] for fabrication details.
Along similar lines, double wire (DW) samples featuring two parallel quantum wires at the cleaved edge can be created. Here, only the upper 2DEG is doped and populated in the double quantum well wafer, while both upper wire (UW) and lower wire (LW) at the edge are populated and conducting (see Fig. 4). The LW is only weakly tunnel coupled to the UW through a 6 nm thick AlGaAs barrier, giving a tunneling conductance of 0.03 e^2/h at zero B-field for a 2 µm long segment. Hence the 2 µm long DWs are considered as independent parallel resistors, with total conductance given by the sum of each conductance.
A top gate of 2 µm length allows for local depletion of the 2DEG below it (see Fig.4), thus creating wire segments isolated from the 2DEG under the gate, as desired. Further, the gate voltage can control the number of modes in both the upper and lower wire under the gate (though not separately in each), down to the single mode LL regime. The gated 2 µm wire segments – in the following referred to as the "wires" – are extending into the ungated, semi-infinite 1DEGs on each side (samples are about 5 mm long), which in turn are connected to the adjacent 2DEG and its ohmic contacts, thus allowing for measurements of the wire conductance. The 2DEG-1DEG contact of effectively semi-infinite size together with a gate-defined and smooth *1DEG* to single-mode wire transition assure an overall adiabatic coupling to the LL wire.
The resulting quantum wires are of exceptional quality, probably the best realization known today of a clean 1D conductor. Beyond gate-control of the charge density and transverse modes populated, a mean free path of more than 10 µm and a very large transverse subband spacing of ~ 20 meV make these wires ideal for studying e-e interactions in 1D and LL physics. Such wires display the probably strongest evidence for LL physics to date, such as spin-charge separation [9] and charge fractionalization [10]. However, CEO samples are extremely difficult to produce and prepare for measurement, forcing our present experiment to resort to the limited stock of wires currently available. Due to the lower quality of single wire samples (fabricated more than 15 years ago), we have focused our measurements primarily on more recently fabricated clean double wires. (The Wegscheider group (ETH Zürich) is recently working on fabricating new CEO wires.)

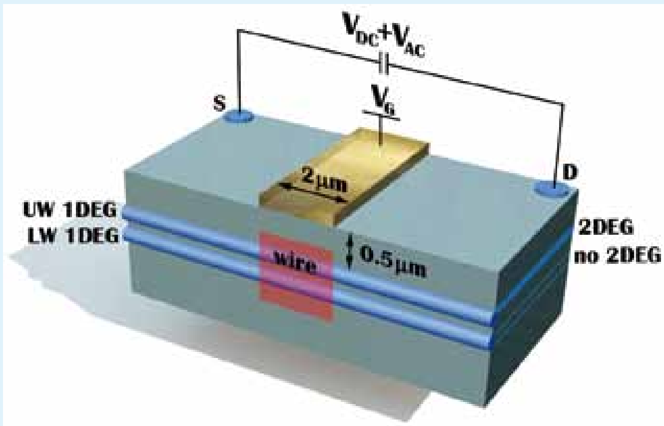

Figure 4: Double-wire device schematic.

been observed [30], for example in metals or strongly correlated conductors, giving ordering temperatures as high as 0.4 mK (2.6 mK) for the hyperfine-enhanced rare-earth Van-Vleck compounds $PrNi_5$ ($PrCu_6$), respectively [31]. The mechanism is similar to the one described above. However, in a 1D conductor (LL), the e-e interactions are very much enhanced compared to 3D. Further, strong and intricate feedback between electronic and nuclear modes further enhances the ordering temperature. Together, this leads to spontaneous nuclear order already in the 100 mK range for the GaAs LL wire, at two orders of magnitude higher temperatures compared to bulk systems.
Another interesting aspect of the GaAs wire is its capability to be gated: the electrons can be depleted from the wire with

Electron and nuclear spin helices: Peierls instability and RKKY interactions

The combined ordered state of nuclear spins and electrons arises through a feedback process closely connected with the Peierls instability, a generic effect in any 1D conductor. The Peierls instability is best explained by considering the upper part of Fig. 5 representing the band structure of a 1D conductor. If the conductor is exposed to a periodic potential with spatial period of half the Fermi wavelength, electron scattering on this potential leads to a momentum transfer of $2k_F$, with k_F the Fermi momentum. The electron states near both Fermi points at $\pm k_F$ mix due to the periodic potential, a gap opens, and the system becomes insulating. Exposing the electron system to a spiral magnetic field like potential with period of half the Fermi wavelength, as created by a nuclear spin helix, leads to a *spin-selective Peierls transition* [31]. Scattering on the helix has the same effect of inducing a mixing of the states at $\pm k_F$, yet with the additional effect that a momentum transfer of $+2k_F$ is accompanied by an upflip of the electron spin, and a $-2k_F$ transfer with a downflip (or vice versa if the helix rotates in the opposite direction). Consequently, only half of the electron modes can undergo the Peierls transition and become insulating, while the other half with the non-matching spins remains conducting and forms a helical (spin-filtered) conductor.

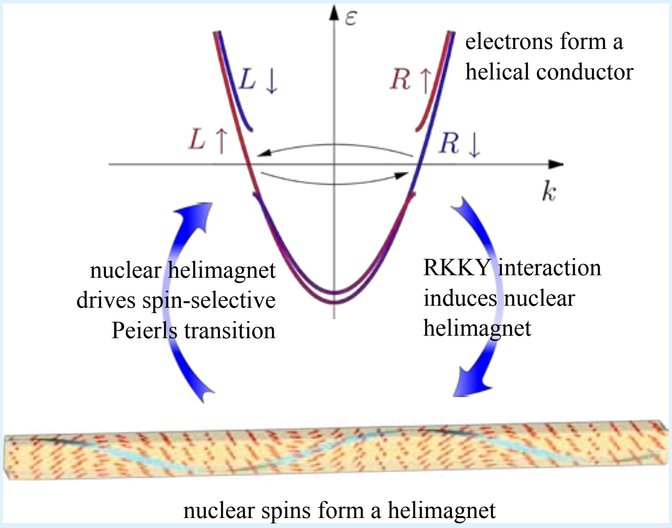

Figure 5: Illustration of the feedback mechanism stabilizing the joint nuclear spin and electron order. The RKKY interaction between nuclear spins mediated by the electron conductor induces nuclear magnetic order in form of a spiral with spatial period of half the Fermi wavelength. The backaction of the periodic magnetic potential formed by the nuclear spins causes selective spin-flip scattering between the two Fermi points, opening a gap for one half of the opposite spins and leaving the other half in a spin-filtered, helical conducting state. In turn, the RKKY interaction becomes stronger and the joint ordered state is strongly stabilized by this feedback effect, together with a strong renormalization by e-e interactions.

The Peierls instability is also the origin of the nuclear spin helix. The dominant interaction between the nuclear spins is the Ruderman-Kittel-Kasuya-Yosida (RKKY) interaction, which is an indirect long-range interaction mediated by the electron system. A spin exchange between a nuclear spin and an electron spin creates locally a magnetic excitation in the electron system that propagates through the conductor and can induce a further spin exchange with a distant nuclear spin. The result is an effective Heisenberg interaction between the nuclear spins with an interaction strength given by the electron response function for magnetic excitations, the electron spin susceptibility. In momentum space, the latter is strongly peaked at $2k_F$ (for normal as well as for helical conductors), which is nothing but the manifestation of the Peierls instability, and it shows that the energetically most favorable state for the nuclear spins is to form a $2k_F$ spatial modulation. A detailed analysis of the ordering transition and its stability then reveals that the nuclear spins order in form of the helix shown in Figure 5, with clockwise or anticlockwise helicity as well as the plane in which the spins rotate selected by a spontaneous symmetry breaking. The spin-selective Peierls transition enhances the strength of the RKKY interaction, and this feedback between the subsystems, together with a strong renormalization of the coupling strengths by electron interactions, leads to a strong stabilization of the combined ordered state of nuclear spins and electrons.
Traditionally, order between electron and spin systems can be split into two classes. First the class, in which the spins and the electrons form a joint strongly correlated state, such as in Kondo lattice systems at temperatures below the Kondo temperature [32]. Second the class of the type of nuclear magnets in three-dimensional metals [33], in which the nuclear spins order due to the presence of the electrons, yet the electrons themselves are unaffected by the nuclear spins. The state shown in Fig. 5 forms an intermediate class, in which nuclear spins and electrons order individually but are tightly bound together through a self-consistent feedback mechanism [27]. In this case, the nuclear spins order due to their effective RKKY interaction, which is mediated through the electrons, but do not form a coherent correlated state with them. Yet through their ordering they generate a magnetic superstructure, the nuclear spin helix, that acts back on the electrons. This back action triggers the formation of a spiral electron spin density wave for half of the conduction electron modes. The other half remains conducting in a strongly renormalized helical (spin-filtered) state and further stabilizes the nuclear helix.

a gate voltage, hence also removing the nuclear order. One can thus gain electrical control over nuclear spin order.

Future prospects of helical Luttinger liquids

The prospects of helical nuclear spin order are exciting and far reaching for a number of reasons: first, the ordered wire is a helical conductor with opposite spins moving in opposite directions, therefore acting as an excellent spin filter. Second, in the ordered phase, any nuclear spin fluctuations would be fully suppressed, thus eliminating the predominant source of decoherence in GaAs electron spin qubits (if such a qubit could be realized in the 1D wire). This was predicted earlier [27] (see also the inaugural article of the *Progress in Physics* series, from April 2007, http://www.sps.ch/artikel/progresses/the_pleasures_on_the_road_to_a_quantum_computer_1/) and served as one of the original motivations for work on this subject.

Last but not least, a helical LL brought into contact with a BCS superconductor can serve as a platform for Majorana fermions exhibiting non-Abelian braiding and allowing for fault-tolerant topological quantum computing. It has been shown [31] that the helical LL induced here by a nuclear spin helix is equivalent to a Rashba spin-orbit (SO) wire in presence of a magnetic field which opens a $k = 0$ helical gap. The strength of the equivalent Rashba-type SO interaction is given essentially by the Fermi wave number k_F , i.e. corresponds to a spin-orbit length of about $2\pi / k_F \lesssim 100$ nm – a very strong and thus useful SO interaction. Unlike the Rashba wire, the gap of the helical LL is always pinned at the Fermi energy. This is a clear advantage over the Rashba wire, where the chemical potential (density in the wire) has to be carefully tuned into the gap (fixed at an energy defined by the wire SO coupling strength).
While inducing a superconducting proximity effect in a GaAs CEO wire is a challenging, maybe daunting goal, it is maybe conceivable to add a thin Al layer (superconducting critial temperature of 1.2 K) to the overgrowth sequence – Al is always needed and available in high-mobility GaAs MBE systems. With magnetic field applied in the plane of the Al layer, the corresponding critical field can exceed the bulk critical field of ~ 10 mT by orders of magnitude, thus potentially allowing for the creation of a topological phase in a magnetic field, with Majorana fermions at its ends. We hope that the experimental results already presented here are an important step in the direction of new developments in this exciting field of research.

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Progress in Physics (45)

Uniaxial Stress in GaAs Nanowires Reveals an Unprecedented Light Emission Tunability and Novel Bandstructure Transitions

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[4] CrayoNano AS, Trondheim (Norway)

The semiconductor industry faces today two of the biggest challenges in its history, i.e. the future of CMOS scaling and the limits in bandwidth and energy of the current technology of interconnects. As the transistor device dimensions (i.e. the technology node) shrink below 100 nm, physical phenomena like size quantization and short channel effects start to interfere with traditional scaling laws. At the same time, the power dissipated in electrical interconnects to enable the communication between an increasing amount of transistors is rising above 80% of the total energy used on the chip, and the amount of heat that can be removed from each chip is saturating [1]. To overcome the limitations in transistor performance and to enable integrated photonic communication on chip, a combination of different strategies has been proposed at the device level: strain engineering, novel materials and device structures.

The nanowire structure has the ideal geometry for the electrostatics of CMOS transistors and, at the same time, allows a direct integration of III-V materials on silicon, enabling ultimate transistor performance and the integration of light sources directly on silicon. Strain engineering would enable the realization of transistors with increased channel mobility and, in the context of active photonic devices, permit to tune the wavelength of emission and improve the performance of solid state lasers (reducing the threshold current, suppressing the Auger recombination and inter valence band absorption processes, controlling the polarization [1]). Inspired by such a wide range of possible applications, we have explored the synergistic interplay of strain effects in III-V nanowires. Nanowires promise exceptional mechanics and a large range of elastic deformation, which can have unexpected effects on their electronic and optical properties.

We apply uniaxial stress to single nanowires exploiting the mechanical degrees of freedom that the substrate can offer (Figure 1). Continuum mechanics teaches us that perfectly uniaxial stress and reproducible mechanical deformations can be obtained and controlled with sub-nanometer resolution by bending a thick substrate on the millimeter scale. In this way, it was possible to apply uniaxial stress mechanically to the nanowire in a continuous and reversible way, both in compression and tension. To investigate the effects of strain on the nanowires we rely on optical spectroscopy: we can obtain an accurate picture of the bandstructure using photo-

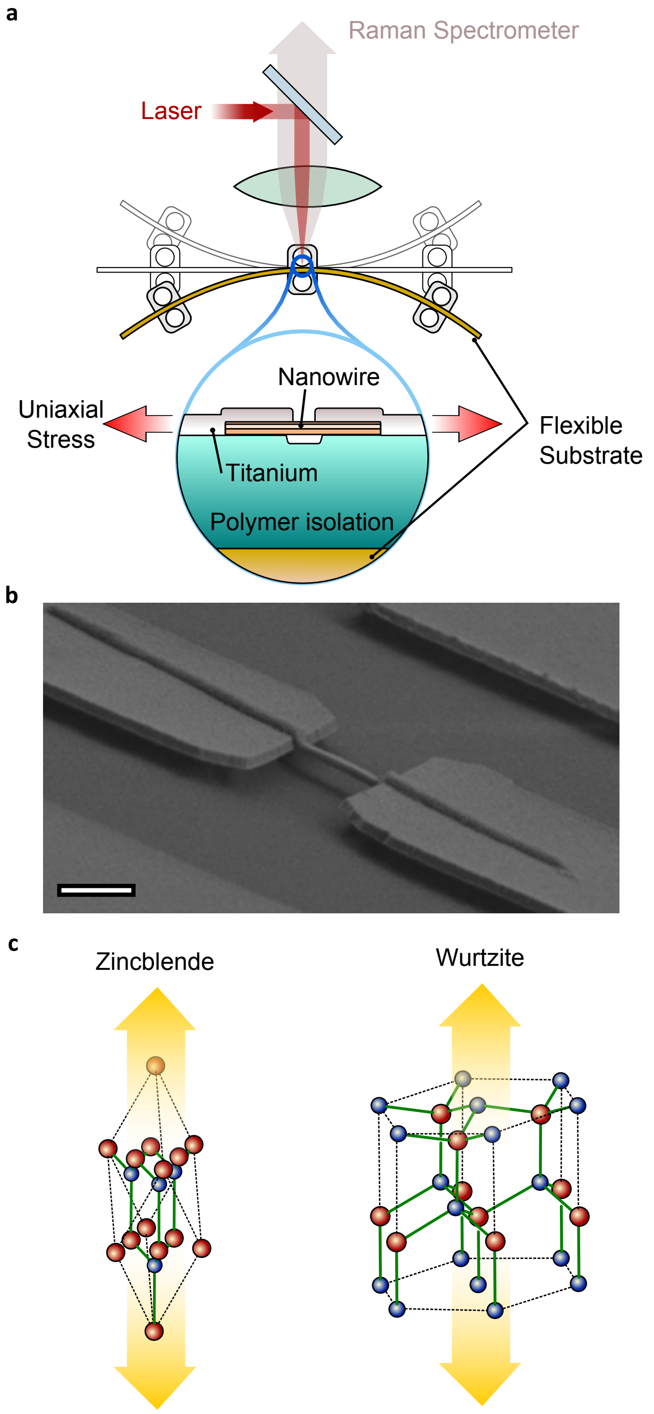

Figure 1. Application of stress to individual nanowires. (a) Schematics of the bending mechanism used to apply stress to individual nanowires structures (shown in cross section). The nanowire is excited using a He-Ne laser, and the PL and Raman signal are collected via an optical spectrometer. (b) Scanning electron microscopy image of a freestanding nanowire clamped by Ti contacts to a flexible substrate. Scale bar is 1 µm. (c) Deformation upon uniaxial stress of the Zincblende (left) and Wurtzite (right) crystal unit cells.

luminescence (PL) spectroscopy, as well as of the lattice dynamics using Raman spectroscopy. Studying such spectra as a function of the polarization can offer a broad insight on the physics of the strain effects. Polarization-dependent PL enables to resolve the symmetry of the conduction and valence band states involved in the light emission processes. In Raman spectroscopy, controlling the polarization of the laser and of the detected light allows the identification of the contribution of individual phonon symmetries. This information can be translated into an estimate of the axial strain and Poisson ratio of the nanowire, which provides together the full characterization of the strain tensor experienced by the nanowire. GaAs was chosen as the ideal material system to study, for many reasons: Zincblende GaAs is considered as the material that enabled the foundations of semiconductor-based solid state lasers and light-emitting devices; when grown at nanoscale dimensions, novel crystal structures like Wurtzite can be synthesized and new degrees of freedom to tailor electronic and optoelectonic properties are available.

Our experiments have shown that, indeed, the nanowire geometry enables the expected enhancement of the strain effects in GaAs. We demonstrated that by tuning the strain continuously, from tension to compression and up to 3.5 %, the PL of Zincblende GaAs nanowires can be red-shifted by 290 meV [2]. We have observed a much more pronounced PL shift in tension than in compression (see Figure 1a), and have attributed this phenomenon to the different symmetry character of the top valence band: heavy hole under tension, light hole under compression. Fingerprints of symmetry breaking due to the anisotropic nature of the nanowire deformation were found also in the Raman spectra, in which polarization-dependent measurements allowed the unambiguous identification of distinct phonon contributions. Because of the linear relation with stress, the energy shift of the Raman peaks (see Figure 1a) were used to determine the axial strain induced in the nanowire and to infer information about the Poisson ratio in the [111] direction (0.16 ± 0.04). To test the consistency of the 8-band k·p model (see Figure 1b) with the measurement, we extracted the band-edge deformation potentials (a = –8.6 eV ± 0.7 eV and d = –5.2 eV ± 0.7 eV), which are consistent with those of bulk GaAs and with our initial assumptions.

Even larger shifts of the PL could be demonstrated by applying strain to Wurtzite nanowires [3]. Using PL spectroscopy and varying the strain over a range of ±2 %, we demonstrated a remarkable energy shift of 345 meV due to transitions between the bright conduction band and the heavy hole band (low energy peak in Figure 3a), and a smaller shift of 257 meV for transitions involving the light hole band the bright conduction band (high energy peak in Figure 3a). While the tunability of the luminescence is the most remarkable process that takes place in Zincblende GaAs under strain, Wurtzite GaAs shows a richer physics. We demonstrated for the first time that uniaxial strain can be used to induce a transition on the band structure from a direct bandgap to a pseudodirect bandgap configuration. In the latter, which is characteristic of Wurtzite crystals, the semiconductor shares some of the properties of direct bandgap and some of indi-

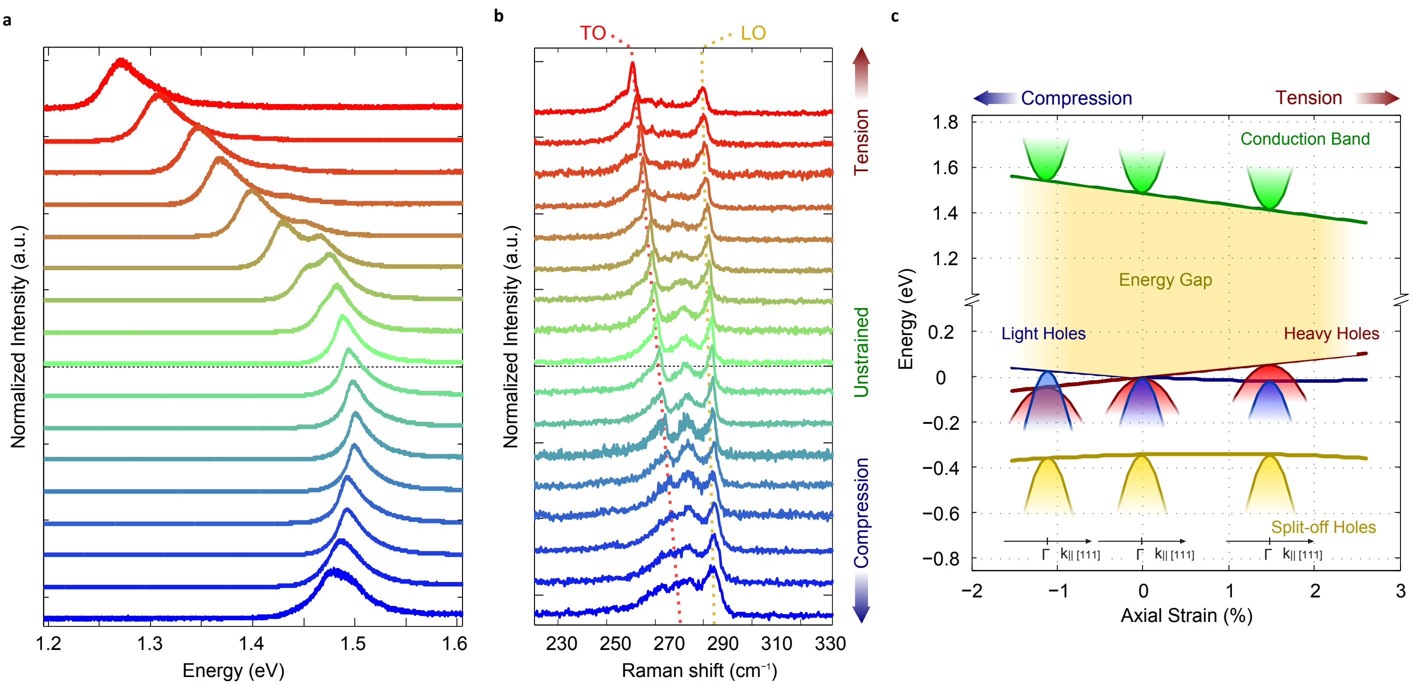

Figure 2. Effect of tensile and compressive stress on the optical properties of the core–shell GaAs–$Al_{0.3}Ga_{0.7}As$–GaAs nanowire. (a) PL spectra measured for different values of applied uniaxial stress. Under compression, the peak shifts weakly and nonlinearly with increasing stress, whereas under tension, a peak splitting is observed together with a strong red shift for the low-energy contribution. (b) Normalized Raman spectra of the GaAs-like phonons (230–330 cm^{-1}) for different values of uniaxial stress. All Raman peaks are observed to shift linearly with stress to higher wavenumbers under compression and to lower wavenumbers under tension. A guide to the eye is included for the peak position of the transversal optical (TO) and longitudinal optical (LO) of the GaAs core. (c) Expected shift of the conduction and valence band edges according to an 8-band k·p model. Heavy-hole band (red) and conduction band (green) edges shift linearly in energy with opposite slope. The light-hole band (blue) energy follows a quadratic dependence on uniaxial stress because of strain mediated spin–orbit interaction with the split-off band (yellow). The small bandgap variation under compression is due to a similar shift of the light-hole band and the conduction band in this stress regime. The substantial red shift observed under tension is related to the change in the symmetry character of the highest energy valence band from light-hole to heavy-hole type.

rect bandgap materials. The relation between energy and wave-vector is indistinguishable from the one of direct bandgap materials: the conduction band minimum and valence band maximum are located at the Γ-point and the respective wavefunctions overlap strongly in the wave-vector space. However, because of symmetry reasons, the optical dipole transitions between these states occur with low probability. The material is therefore a poor light emitter, like indirect bandgap materials. Leveraging on the strain degree of freedom, we have shown that both direct and pseudodirect bandgap configurations can be achieved using a Wurtzite GaAs nanowire (Figure 3c). When tensile stress is applied, the direct configuration can be obtained and the nanowires emit light efficiently; upon compression, the pseudodirect configuration is achieved and light emission can be suppressed by more than three orders of magnitude. The splitting between the dark and bright conduction bands could be tuned continuously over a range of more than 230 meV. Using the Raman scattering spectra as relative strain gauge (Figure 3b) and fitting the optical transition energies to the k·p model, we were able to determine all band structure parameters of the Wurtzite GaAs nanowire in unstrained conditions, i.e., the crystal field (197 meV ± 50 meV) and spin-orbit splitting (293 meV ± 129 meV), the bandgap (1.41 eV ± 8 meV) and, most importantly, the splitting between the bright and the dark conduction bands (33 meV ± 47 meV). Mechanical properties, such as the Poisson ratio along the c-axis (0.17 ± 0.17), and the phonon deformation potentials of the GaAs and AlGaAs optical phonons have also been determined.

These results constitute a solid foundation to the understanding of strain effects on the optical and electronic properties of III-V nanowires. Their implications promise to have high technological relevance, for GaAs and other III-V nanowire electronic and optoelectronic devices.

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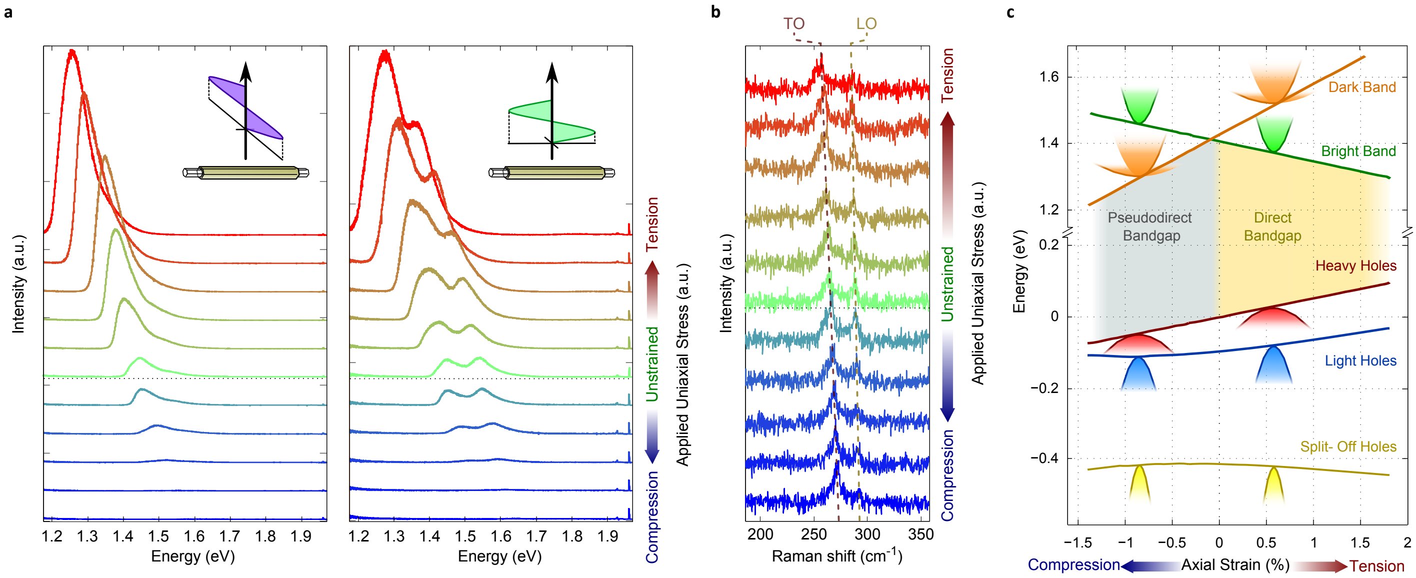

Figure 3. Uniaxial stress effects in Wurtzite GaAs nanowires. Optical spectra collected from a strained Wurtzite GaAs nanowire. The spectra acquired with increasing tensile stress are shown in red, those acquired with increasing compression in blue. The spectra shown in green close to the dashed line are collected without any strain applied. (a) PL spectra acquired with polarization orthogonal and parallel to the nanowire axis are shown in the centre and right panel, respectively. The analyzer configuration is sketched in the inset of each panel. (b) The Raman spectra are shown in the left panel and have been collected with both the laser and the detector polarization aligned with the nanowire axis (scattering configuration not shown). The dotted lines are a guide-to-the-eye to indicate the positions of the phonon peaks attributed to the GaAs transversal optical (TO) phonon with symmetry A1 and the longitudinal optical (LO) phonon with symmetry E1. (c) A 10 band k·p model of the uniaxial stress effects in Wurtzite GaAs. Heavy holes (in red) shift linearly towards higher energies when tensile stress is applied. Light holes (shown in blue) and crystal-field split-off holes (shown in yellow) are coupled by the spin–orbit interaction and undergo nonlinear shifts. In the conduction band, the bright band shifts linearly towards lower energies because of the isotropic component of tensile strain. The dark conduction band shifts towards lower energies under stress, with opposite direction compared to the bright conduction band. The nanowire band structure has a direct bandgap configuration (shaded area in yellow) when the bright conduction band has the lowest energy, and a pseudodirect bandgap configuration (shaded area in grey) when the dark conduction band is lowest. The direct-to-pseudodirect transition occurs when compressive stress is higher than 0.12%.

Milestones in Physics (6)

Liquid Crystals, LCDs and Optical Alignment of Molecules

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Introduction

Since the invention of the twisted nematic (TN) field-effect by Schadt and Helfrich in the Central Research Laboratories of Roche, Basel, in 1970 [1], the liquid crystal display (LCD)-technology has made remarkable progress. Electric field-effects determine the operating principles of today's LCDs. They are based on macroscopic molecular liquid crystal (LC)-configurations with specific boundary conditions whose voltage dependent polarization states switch virtually loss-free [2].

The building block concept of LCDs enables the integration of silicon-driving electronics and complex optical thin-films. LCDs cover virtually all applications of the communication between man and machine, ranging from reflective displays in digital watches to ultra-high resolution television LCDs. Interdisciplinary R&D between physics, material sciences, synthetic chemistry, semiconductor electronics, and engineering spurred progress since the beginnings in 1970. The turnover of the LCD industry reached $130billion in 2013.

Apart from the twisted nematic effect continued interdisciplinary R&D of the author and collaborators mainly at Roche, led to new electro-optical effects, new liquid crystal materials and to a contact-free, optical alignment technology for LC-molecules. For details of the article c.f. ref. [2]

State of the art of electronic displays in 1970

The first observation of a liquid crystalline phenomenon was made in 1888 by the Austrian botanist Reinitzer, Graz. However, it was realized only in the 1930s that liquid crystals are not suspended micro-crystals but a new state of matter exhibiting long-range molecular order. In 1918 Björnstahl published the first study of an electro-optical effect in liquid crystals. Upon ion-flow through a negative dielectric anisotropic liquid crystal (LC)-film he observed light scattering under his microscope. In the mid-1960s industrial research groups in the US and in Europe became interested in liquid crystals for potential electronic display applications. The few liquid crystals known at the time were unstable, and their melting temperatures were far above room temperature and/or covering too narrow temperature ranges for practical use. Only few of the numerous anisotropic LC-material properties, which are relevant for LCDs, were known, and reliable experimental means for their determination had yet to be developed.

Fig.1: Electronic displays end of 1960s: a) Nixie tubes, b) dot matrix LEDs, c) first OLED prototype of 1969 (~20x20x1mm).

Most scientists considered liquid crystals to be exotic and of primarily academic interest. In 1963, i.e. 45 years after Björnstahl, Williams re-discovered current-induced light scattering in liquid crystal films at RCA Princeton. In 1968 Heilmeier and Zanoni [3] extended his work towards practical liquid crystal displays and denominated their display dynamic (light) scattering (DS)-LCD. Their work triggered interest in liquid crystals. However, dynamic scattering suffered from serious drawbacks such as electro-chemical decomposition, poor optical contrast and power consumption.

Spurred by scientific curiosity and by the advancing semiconductor industry in the late 1960s, research groups around the globe started searching for new physical concepts for electronic displays. A flat shape and compatibility with the low voltage and power requirements of emerging complementary metal oxide semiconductors were some of the visions. However, none of the many different research strategies followed by scientists and engineers met the demanding goals. Compared with Nixie tubes, the emerging inorganic light emitting diodes (LEDs) used in digital matrix displays were most advanced (Fig. 1). Even exotic ideas at the time, such as a display based on organic light emitting diodes (OLEDs) were pursued. The first primitive OLED prototype was made by the author during his post-doctoral studies at the Canadian National Research Council, Ottawa (Fig. 1). With their reputation of being unstable and poorly visible, liquid crystals were only one of many options.

Invention of the twisted nematic (TN) field-effect

Triggered by the dynamic scattering work of Heilmeier and in line with the trend of business diversification at the time, the pharmaceutical company Roche, Basel, established a liquid crystal research group in 1970. It included collaboration with former Brown Boveri (now ABB) for jointly developing dynamic scattering LCDs for medical electronics equipment. The experimental physicist Schadt had joined the R&D group of Roche shortly before Helfrich also joined from RCA. When the two scientists met, they took advantage of the freedom at Roche to select and pursue individual research topics. Both scientists questioned the performance of the current-induced dynamic scattering and started searching for new display operating principles. Their goals were macroscopically ordered LC-configurations which change their polarization state in electric fields. However, loss-free molecular switching required polarization detection and surface-alignment of the long molecular LC-axes at the display boundaries. They were aware of the additional complications which this implied, namely the use of sheet polarizers and potential lifetime problems due to LC-alignment. Polarizers reduced brightness by more than 60%, and LC-alignment of the display substrates by mechanical brushing was a mysterious procedure. Moreover, they both added complexity and costs.

Intrigued by a twisted polarization microscopy observation by the French crystallographer Mauguin [4] in 1911, Helfrich had the idea to apply a voltage to a positive dielectric anisotropic twisted nematic liquid crystal film for untwisting the helix into a vertically aligned on-state. Contrary to the management of RCA, and despite many open questions, Schadt was attracted by the idea and began to design and perform a series of experiments. Questions were whether dynamic scattering would prevent vertical field-alignment and whether repetitive switching was possible. Due to the lack of positive dielectric anisotropic room temperature liquid crystals Schadt first used the high melting PEBAB known from the literature since 1910 and synthesized by his chemist colleague Scherrer. Most of the initial TN-experiments of the author failed. Retrospectively, failure was due to a combination of inadequate LCs, unknown impurities, weak and irregular molecular surface anchoring and erratic wave-guiding.

On a Saturday morning in the fall of 1970 the author succeeded for the first time to reproducibly switch and observe polarization changes in a twisted nematic configuration between crossed polarizers. Now, as so often happens in physics, new surprising findings were made. Other than initially thought Schadt found that to achieve optical extinction it was not necessary for the electric field to fully unwind the liquid crystal helix. To his great surprise 2.5 volts were sufficient to block light transmission; i.e. twenty times less than the saturation voltage which estimates from elastic theory for untwisting suggested. The experiments also showed no interference effects; the helix acted as an achromatic waveguide. Moreover, he found that it was sufficient for the electric field to deform essentially only the central part of the helix for complete suppression of wave-guiding, and neither elastic fatigue of surface alignment nor dynamic scattering occurred. This confirms the saying of Niels Bohr that nothing exists before it is measured. Schadt and Helfrich immediately filed a Swiss TN-LCD patent application on 4th December 1970 and published their results in the February 1971 issue of Applied Physics Letters [1]. The reason for the rush of patent filing and submission of a short article with preliminary results was an information leak at Brown Boveri.

Figure 2 illustrates the threshold voltage and the big difference between the optical and the mechanical response of a 90° twisted nematic LCD versus applied voltage. The computed LC-director configurations in Fig. 2 depict the respective mechanical and optical on- and off- states. A theory

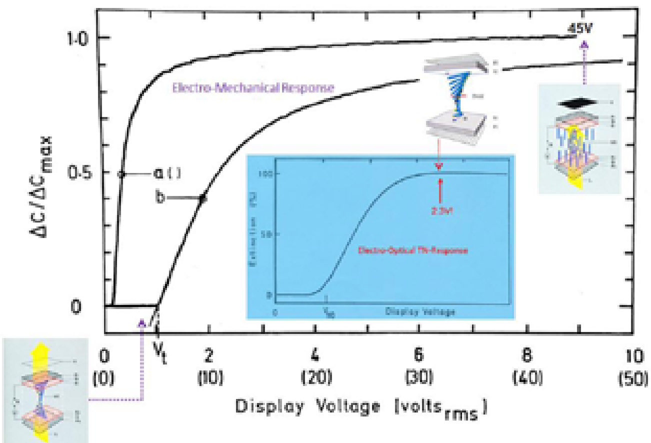

Fig. 2: Mechanical nematic helix director deformation (graphs a, b) and optical TN-LCD transmission (insert) between crossed polarizers versus applied voltage.

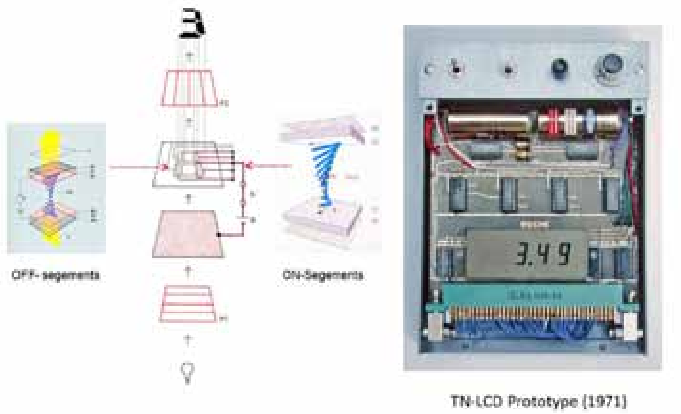

Fig.3: Schematic of a 7-segment addressed TN-LCD director-configuration in its off- and on-state. TN-LCD prototype made by the author (1971).

describing the complex electro-optics of twisted nematic LC-configurations did not exist at the time. A computer model based on the Stokes 4x4 matrix formalism was developed by Berreman at Bell labs three years after the publication of the TN-effect. Fig. 3 shows the first TN-LCD prototype made by the author and its seven-segment addressing scheme. Wave-guiding enables low operating voltages, achromatic optical response, broad field of view and small cell gap dependence of TN-LCDs. This paved the way for industrial implementation of the new technology.

Stop and new start of liquid crystal R&D at Roche

The publication of the twisted nematic effect spurred a strong interest of the scientific community and the electronics industry in field-effects. However, the potential of TN-LCDs and the use of liquid crystals in electronic devices continued to be questioned by many for years to come. One of the skeptics of the Roche LC-project was a new manager of its Central Research Labs. He declared liquid crystals to be "überflüssige Kristalle" (superfluous crystals) and ordered to stop liquid crystal research. The collaboration with BBC was terminated; Schadt was about to leave Roche and Helfrich left for the Freie Universität Berlin where he changed fields. The head of global Roche research convinced Schadt to stay. In the next two years the author searched for electro-optical effects and charge-transport phenomena in biophysics.

In the mean-time, leading Japanese watch and electronics companies had realized the potential of the TN-invention. In the spring of 1973 the head of the legal department of Roche asked Schadt to explain the relevance of the pending Swiss TN-LCD patent. The reason was an offer by Seiko to buy the TN-patent rights. The author outlined its big potential, the importance of liquid crystal materials and suggested licensing the TN-patent non-exclusively world-wide. Roche reactivated its liquid crystal activities, established a TN-licensing group and started manufacturing liquid crystals. This led to the first commercial TN-LCD mixtures. The author was given the opportunity to establish an interdisciplinary liquid crystal research team consisting of physicists and synthetic chemists. His research on electro-optical effects and new liquid crystals continued. One intriguing puzzle was the alignment of LC-molecules at display boundaries which – as shown below – initiated the LPP photo-alignment technology 20 years later. Because the physics of field-effect LCDs and LC-material properties were in their infancy, the author and his team started developing new experimental techniques for identifying and determining all relevant liquid crystal material parameters. This provided the basis for their search for correlations between molecular structural elements, LC-material properties and display performance. Goals were better LCs and the establishment of a solid intellectual property basis for Roche's emerging liquid crystal material business. Apart from TN-licensing Roche became a leading LC-material manufacturer.

Progress towards increased information content of LCDs

Important goals from the beginnings were improved optical performance and increased information content of LCDs. To achieve these goals, the development of dedicated LC-materials, new electro-optical effects and new display addressing schemes was crucial. Moreover, efficient backlighting, polarization recovering reflectors, color filters, optical retarders and wide-view films had to be developed and integrated into LCDs.

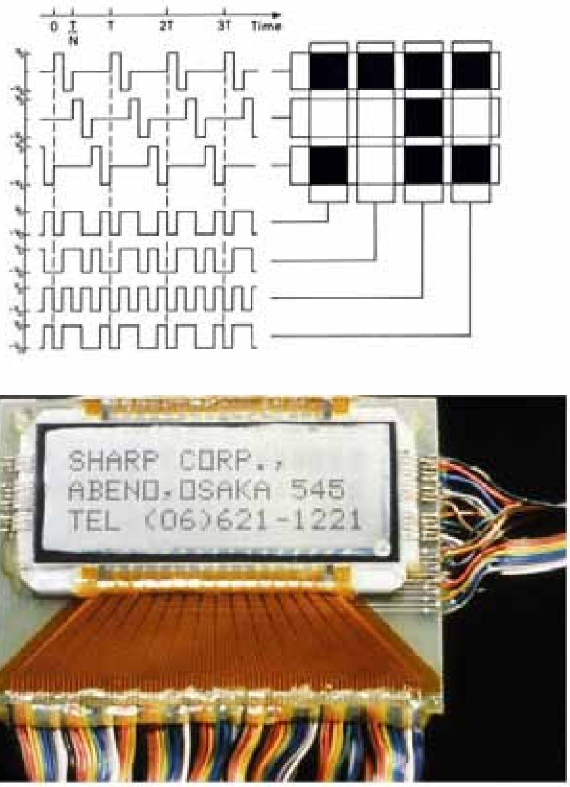

Fig.4: Time-multiplexed addressing scheme of the line and column electrodes of a TN-LCD (top). Time-multiplexed TN-LCD with 1200 pixels but only 96 connections (~1980).

Progress made in device physics and LC-materials enabled the development of medium information content TN-LCDs in the 1980s. The increase of information content broadened their applications from seven-segment digital watch displays to calculators, portable games, etc. Another step towards LCDs with increased information-content was the development of time-multiplexed addressing of matrix electrode arrays by Kawakami and Alt and Pleshko (Fig. 4). The development of more than 90° twisted nematic configurations with steeper electro-optical characteristics, i.e. supertwisted nematic (STN)-LCDs, by Scheffer and Nehring and others enabled – together with the development of infinitely steep and fast-responding STN-mixtures by the author and co-workers – a strong increase of the information content of LCDs (Figs. 5, 6). LCDs started to challenge the bulky cathode ray tube computer monitors. However, limited contrast, colored off-states, not yet developed wide-view compensation films, and the inherently slow response times of STN-LCDs hampered the development of flat panel LCD television. Parallel to the development of thin-film transistor (TFT)-addressing of the TN-LCDs the search started for planar- and vertically aligned electro-optical LC-configurations with broader fields of views.

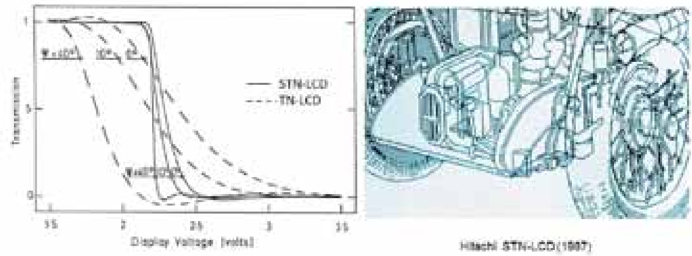

Fig.5: Voltage and viewing angle dependence $\Psi(V)$ of a TN-LCD and an early STN-LCD (1987).

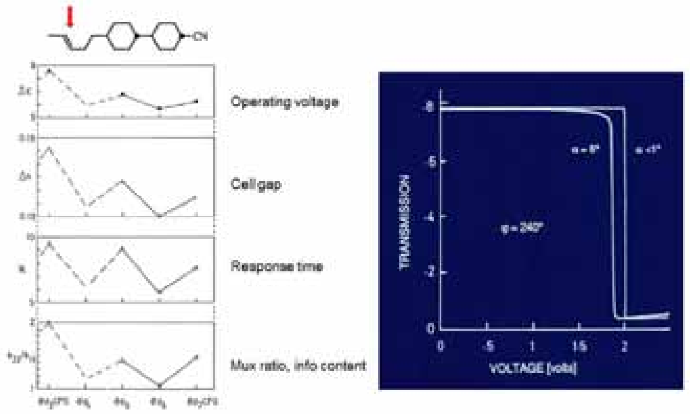

Fig.6: Left: Odd-even effects in alkenyl liquid crystals versus double-bond position in the side-chain. Dielectric anisotropy $\Delta\epsilon$, birefringence Δn, visco-elastic ratio κ and splay/bend elastic constant ratio k_{33}/k_{11}. Right: alkenyl LC-mixtures enabling infinitely steep transmission-voltage characteristics of STN-LCDs (1991).

Already in 1974 Brody et al had realized the compatibility of the TN-LCD with thin-film-transistor (TFT)-addressing. They made the first TFT-addressed TN-LCD with the driving TFTs integrated onto the LCD glass substrate. Pulse-sequential TFT-addressing of TN-pixels enabled the transfer of the multiplexing problem into the driving electronics. This resolved the contradicting STN-requirements between high-information content, gray scale reproduction and fast response (Fig. 7). However, it took R&D more than another twenty years until TFT-addressed TN-LCDs had reached a stage in the 1990s justifying large scale investment in TFT-LCD manufacturing.

Information content, short response and LC-material properties

The introduction of double-bonds into specific side-chain positions of liquid crystal molecules by Schadt and co-workers in 1987 led to numerous important commercial liquid crystal families and provided new scientific and technological insights into correlations between molecular structural elements, LC-material properties and display performance. Alkenyl LCs enabled – for the first time – efficient molecular tuning of virtually all LC-material properties via shifting C=C double-bonds in flexible hydrocarbon side-chain(s) from odd to even positions (Fig. 6). This enables for instance LC-mixtures with broad nematic temperature range and large bend/spay elastic constant ratios k_{33}/k_{11} for infinitely steep

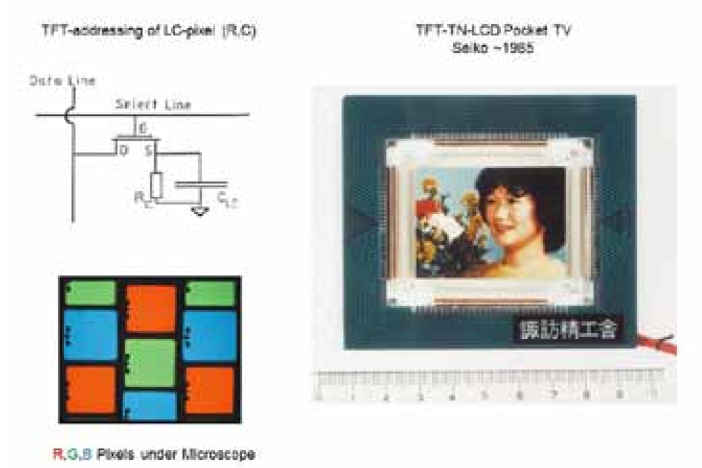

Fig.7: Thin-film transistor (TFT)-addressing scheme and microphotograph of the R, G, B color filters pixels of an early television TFT-TN-LCD.

electro-optical LCD-characteristics and maximum multiplexability (Fig. 6). The author attributed the odd-even effects to the formation of molecular nano-ensembles whose shapes depend on the position d_x of C=C double-bonds in the side-chain (Fig. 6). Because small viscoelastic ratios γ_1/κ are prerequisite for fast LCD-response, optimization of this parameter without sacrificing temperature range is crucial for instance for television (TV)-LCDs. This became possible by combining non-polar, short-chain alkenyls with LCs comprising long rigid cores.

Non-mechanical surface alignment of liquid crystals by optical means

Uniaxiality, anisotropic surface anchoring forces and the generation bias tilt angles between the long axes of liquid crystal molecules (LC-director) and the display substrates characterize field-effect LCDs. Prior to photo-alignment by side-chain photo-polymers, LCD-substrates were aligned by mechanically buffed polyimide films. Since buffing is a macroscopic process microscopic alignment patterning cannot be achieved. Moreover, brushing generates dust, alignment defects and reduces LCD contrast. Despite the relative simplicity of mechanical brushing, its surface interactions are not really understood even today; brushing is more of a craft than a science. The origin of the complex anisotropic interaction forces causing liquid crystal molecules to align on surfaces has intrigued the author since his early twisted nematic (TN)-experiments. In his search for correlations between molecular structures, LC-material properties and LCD performance, he suspected that – apart from the rather well understood topological and steric interactions – anisotropic Van der Waals interactions to play a crucial role. However, apart from perfect vertical LC-alignment via steric interactions, it was unknown whether and how stable LC-alignment could be realized by molecular means. In the late 1980s Schadt started several new R&D projects with his liquid crystal research team at Roche. One was the collaboration with the research group of the late Professor Titov, NIOPIK, Moscow, on fast responding ferroelectric electro-optical effects and first attempts towards photo-alignment. Two different types of LC-photo-alignment materials were known, namely azobenzenes and polyvinyl cinnamate (PVMC). The aligning mechanism of azobenzenes due to a conformation change upon exposure to linear polarized light was well understood, whereas the mechanism causing LC-alignment on PVMC was unknown.

Photo-alignment and alignment patterning by side-chain photo-polymers

Although the stability of LCDs that were photo-aligned by PVMC was poor, the author attempted to elucidate the underlying LC-aligning-mechanism and developed an opto-molecular LC-alignment model. This linear photo-polymerization (LPP)-model is based on the idea that optical excitation of π-electrons in double-bonds of nearest neighbor cinnamoyl moieties in a pre-polymer film must be (3D) direction-dependent. Therefore, the probability for 2+2 cycloaddition of C=C double bonds is largest for bonds lying parallel to the plane defined by the electric field vector ***E*** of incident polarized UV-light and its propagation direction (Fig. 8). As a consequence anisotropic molecular distributions result which generate sufficiently strong anisotropic Van der Waals interaction to align adjacent LC-molecules. Moreover, 2+2 cyloaddition simultaneously stabilizes the film enabling patterning of the LC-alignment along different directions via a single photo-mask. However, the poor performance of PVMC made it questionable whether side-chain photo-polymers with sufficient light-stability could be developed. Moreover, LC-alignment on PVMC occurred – as with azobenzenes – *perpendicular* to the polarization direction of incident polarized UV-light. Due to this cylinder symmetry it was impossible to simultaneously achieve uniaxiality and bias tilt with PVMC. Four years later, the author and co-workers succeeded in developing the first side-chain photo-polymers which combined uniaxiality with non-cylinder symmetry under oblique polarized UV-exposure (Fig. 8). This paved the way for stable photo-alignment and multi-domain alignment pattering of all types of field-effects.

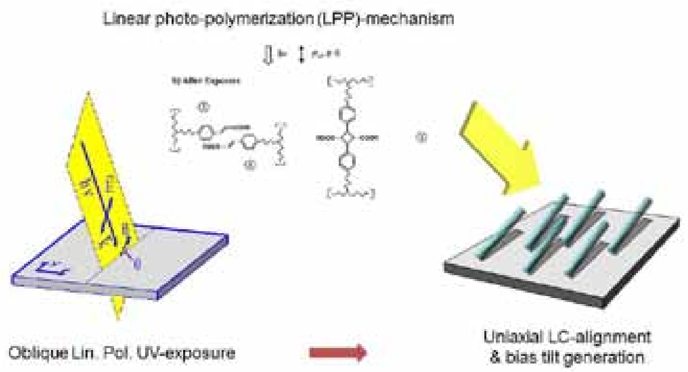

Fig.8: Molecular model of linear photo-polymerized (LPP) LC-alignment by polarized UV-light. Oblique polarized UV-exposure of LPP-substrate generates tilted, uniaxial LC-alignment.

Fig.9: Single- and dual-domain photo-aligned TFT-addressed TN-LCD and corresponding nematic director configurations in the on-state; c.f. the much enhanced field of view of the dual domain configuration.

As a result, LCDs with broad fields of view (Fig. 9), shorter response times, ultra high resolution and improved brightness became possible. Fig. 10 shows the four-domain vertically aligned nematic (VAN)-configuration of a LPP-photo-aligned, television LCD.

Fig.10: LPP-photo-aligned/patterned TFT-TV-LCD (Sharp, 2009) with partly switched four-domain MVAN-molecular configuration (insert).

Photo-alignment/pattering of anisotropic liquid crystal polymer (LCP)-films

The LC-molecules in the sandwich configurations of an LCD are surface-aligned by *two* substrate boundaries; i.e. uniaxial aligning forces act on bottom and top of the LC-layer. The author wondered whether anisotropic surface interactions would not only align the LC-monomers in LCDs but also liquid crystal pre-polymer (LCP) films deposited on a *single* aligned substrate. However, in 1993 it was unknown how far the aligning information would extend into a pre-polymer LCP-film with its top surface exposed to air. Because liquid crystals were reported to vertically align at LC-air interfaces it was uncertain whether uniform LCP director configurations could be realized. Moreover, it was unknown whether photo-patterning of the alignment of adjacent LCP-pixels along different directions was possible. Director-deformation due to interfering elastic deformations at pixel-boundaries and thermal disorder were likely to occur. It was also questionable whether photo-patterned pre-polymer LC-configurations would survive subsequent polymerization without destruction of macroscopic LC-order. Despite these uncertainties the author and his co-workers started the development of photo-aligned liquid crystal polymer films on single substrates in the early 1990s. The goals were photo-aligned and photo-patterned optically anisotropic LCP thin-films with photographic resolution. The copy of surface alignment and its defect-free transfer into the bulk of adjacent LCP films proved feasible in the mid-1990s. Moreover, optical bias tilt generation enabled arbitrary alignment of the slow optical axes of the index ellipsoids of LCP films in space.

The optics is illustrated in Fig. 11. The two LPP-aligned and photo-patterned LCP pixels in Fig. 11 are photo-aligned by a 40 nm LPP-alignment film (not shown) on a transparent plastic substrate under 90° and 45° respectively. The respective LCP-directors (slow optical axes) copy the underlying alignment. Due to its optical retardation $\Delta nd = \lambda/2$, the right-hand pixel rotates incident linear polarized light P by $\pi/2$ rendering it transmissive between crossed polarizers. The slow optical axis of the left pixel is parallel to P, therefore, its polarization state is not affected and it appears black (Fig. 11). LCP photo-alignment via digital photo-masks enables ultra-high resolution retarder images with grey scale reproduction (Fig. 11). Moreover, the technology enables numerous other chiral and achiral optical thin-films, such as photo-patterned retarders for 3D-LCDs, optical security elements, cholesteric band-pass filters, etc.

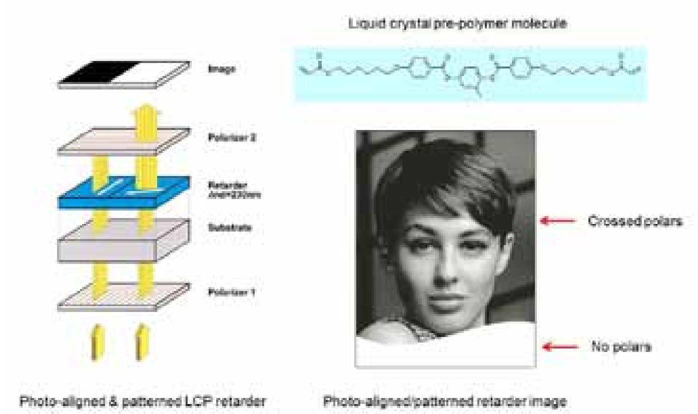

Fig.11: Left: Photo-aligned and photo-patterned liquid crystal polymer (LCP)-retarder pixels (1 µm thin). Right: Digitized LCP-retarder image between crossed polarizers (upper part) and no polarizers (bottom part). Top: Pre-polymer liquid crystal molecule (optical anisotropy $\Delta n \sim 0.25$).

Roche sells its liquid crystal business; foundation of Rolic

In 1994 Roche decided to focus its core business on life sciences, terminating or selling its non-pharmaceutical business activities, including its liquid crystal business. The entire nematic liquid crystal material patent portfolio of 64 LC-families, each granted in 10-12 countries, was sold to Merck KGaA, in 1996. Based on the strong intellectual property (IP) position on photo-aligned LCDs, optical thin-films and materials which the author had developed with his interdisciplinary research team since the late 1980s, the spin-off company Rolic (Roche liquid crystals) was founded in 1994. Forty-four basic photo-alignment patents on devices and new materials, each filed in 10-12 countries, were transferred from Roche into the new company. Analogous to the TN-licensing business of Roche 30 years before, the photo-alignment portfolio of Rolic provided the basis for its licensing and technology transfer business. The author acted as its first CEO. He and his co-workers continued R&D on photo-alignment, started licensing the new technologies and collaborating with LCD manufacturers and optical film-companies world-wide. In line with Roche's exit strategy, Rolic was sold to a Swiss investor end of 1996.

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Martin Schadt is one of the pioneers of modern LCD displays, honoured among others by the European Inventor Award for Lifetime Achievement. His impressive biography can be found under http://de.wikipedia.org/wiki/Martin_Schadt .

Physics Anecdotes (18)

The importance of mechanical clocks or tandem Van de Graaff accelerators for high-resolution nuclear spectroscopy

Bernhard Braunecker

Introduction

The following report looks at the history of tandem Van de Graaff accelerators. They were installed worldwide at many universities during the 1960s, and many of them are still in use today, e.g. in medicine, material or space science. Their original application was in high-precision nuclear spectroscopy using mono-energetic beams of heavy ions with energies < 100 MeV, either in a continuous or in a pulsed mode.
In ***Part I*** we explain why the tandems were ideal for certain studies. However, they also created for us students a particular social atmosphere. Hard work in technology - seldom in physics! - gave young physicists the confidence to scrutinise the socio-political structures of the time in the academic world.
In ***Part II*** (which will appear in one of the next "SPS Communications") we show that driving an accelerator needed a profound understanding of beam generation and acceleration physics, even if the machine was a commercial product. As a counter example we illustrate how wrong handling of the operators led to a serious fire damage of the Tandem ion source at Erlangen University.

Part I

Different Accelerator Types

During the early years most tandems were installed and maintained by HVEC in Burlington, USA. At the same time the development of the large electron and proton synchrotrons and linear accelerators was largely left to the powerful machines which recently succeeded in proving the existence of the Higgs particle at CERN. Their main difference from their smaller relatives, the tandems, was that the big machines produced and produce huge amounts of data, from which sophisticated algorithms identify those few events predicted by theory. Tandems, on the other hand, were operated in a more deterministic way to systematically probe nuclear fine structures. To this end one could choose the most appropriate particles, their energy, and in certain cases even their energy spread. Hydrogen and deuterium beams could be accelerated as polarised particles. One could acquire a beam in a continuous mode to measure absorption/scattering cross-sections or alternatively in a pulsed mode to analyse the time-dependent reactions of the target nucleus under study.

Technical Features of Tandems

Tandems were characterised by some outstanding parameters.

(1) A large variety of heavy ions, apart from H and D, which could be accelerated: He, N, C, O, Si, Cl, P, S,.., U, including expensive isotopes like ^{13}C or ^{37}Cl.
(2) Extremely good energy stability together with an energy spread of only a few keV, allowing fine-tuning of energy and ensuring constant beam intensities at the target.
(3) Excellent beam quality (spatial coherence) for lossless beam transfer, narrow spot focusing and precise shaping of the intensity profile.
(4) The possibility of generating polarised H and D particles and keeping the degree of polarisation from the ion source to the targets to analyse nuclear spin-spin interactions.
(5) Tunable generation of nanosecond pulses for dynamical studies such as nuclear decay processes after Coulomb excitation or time-of-flight measurements to identify fission products after nuclear reactions.

Social Aspects

The experimental work at and around the accelerator was challenging, but also stimulating. Since the accelerator was operated by a professional service team only during the daytime, the tandem had to be run at night by physicists. Thus every student had to learn a number of technologies to obtain their *tandem driving licence*. This training on the job helped them considerably with their own experiments and, more importantly, created a unique team spirit.

Principle of Operation

The central part of the tandem Van de Graaff (Figure 1) was the high voltage terminal which was loaded by a moving belt charger to positive voltages between 6 and 10 MV, depending on the tandem type, and in some special cases even up to +25 MV. The terminal was placed inside a pressure vessel some 10 m to 25 m in length with a diameter of several metres and filled with gas of 6 to 8 atm, either nitrogen or, preferably, SF_6 to minimise 'tank sparks'. These were unpredictable flashes from the terminal to the tank walls, which sounded like hammer strokes and were acoustically monitored by microphones. It was a favourite prank to hit the tank during long night sessions with a rubber mallet to wake up the colleague at the operator desk, who would panic and immediately drive down the terminal voltage.
Two vacuum tubes for the beam transport connected the terminal to the tandem's entry and exit flanges, both lying at ground potential. Each tube consisted of a series of glued ceramic segments with metal electrodes (some were gridded), which were connected by a resistor chain from the terminal to the ground. Then both column currents caused well-defined potential distributions along both tubes, which not only accelerated the ions, but also focused the incoming collimated beam onto the terminal, and, vice versa, produced a collimated beam at the tandem exit.

Negative to Positive Ions

The conversion of the arriving negative ions to positive ions was accomplished by electron stripping reactions within a gas target inside the terminal. However, gas targets were soon replaced by targets of thin carbon layers, which had not only better conversion efficiency but also reduced the occurrence of dangerous 'tube sparks'. They also defined

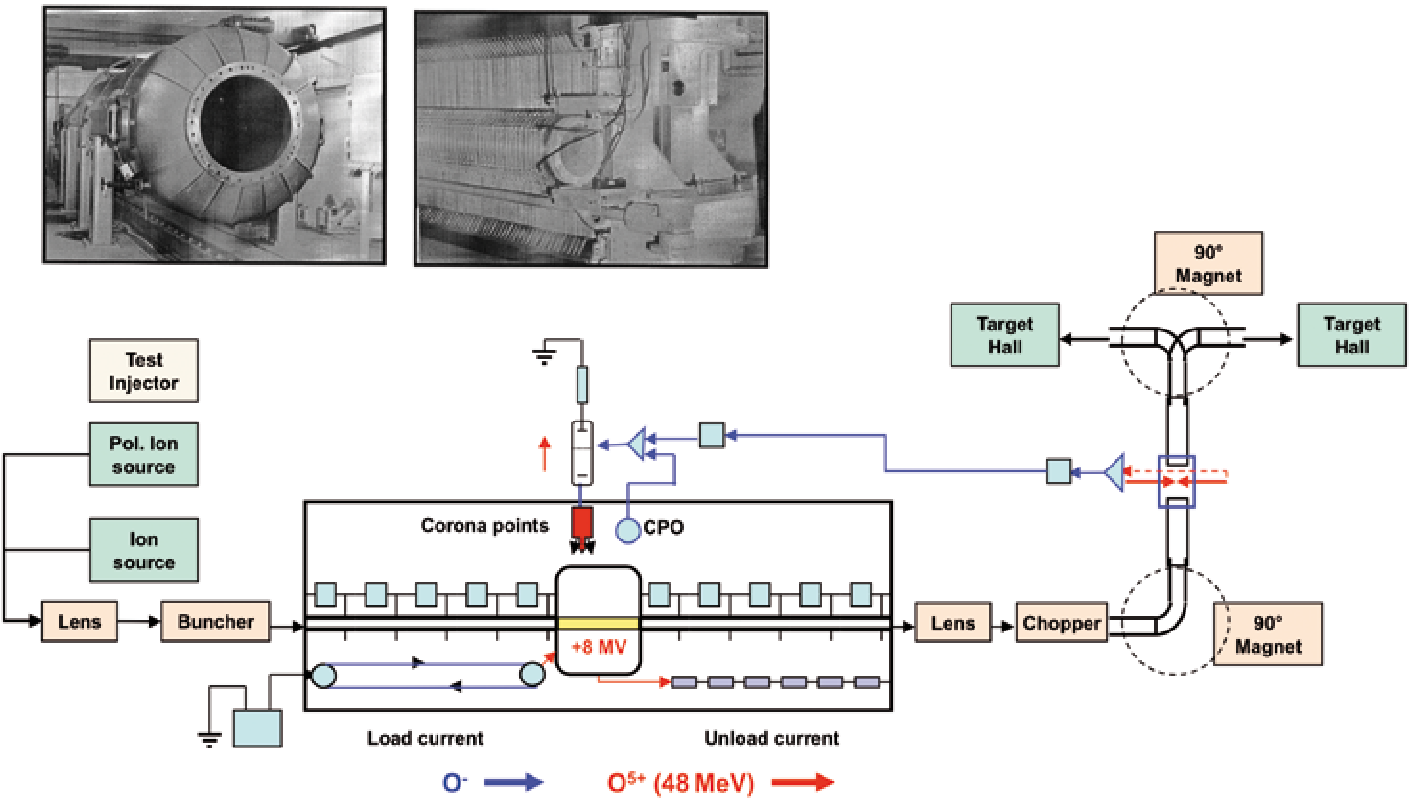

Figure 1: Negative ions are injected, converted to positive ions and post-accelerated

exactly where the positive ions were generated, knowledge needed for correct adjustment of the beam optics at the high end. Since the lifetime of the carbon targets was limited to a few hours or days, however, depending on the operation, about twenty of them were mounted on a revolving wheel by us physicists. This target holder was driven by a mechanical clock and switched via an insulating nylon string from outside the tank.

The positive ions were post-accelerated down to ground potential. If, for example, we injected O^- into the terminal at +8 MV, where the stripping conversion to O^{5+} was dominant, the second acceleration led to the final beam energy of 48 MeV.

Beam Optics

Ion optical components were needed to guide and manipulate the beam from the ion source to the experimental setups in the target halls.

Beam lenses: focusing elements at the low end side were *electrostatic collimator* or *Einzel lenses* consisting of two, respective three cylindrical electrodes, where in the latter case the first and the third ones were at the same potential, whereas the potential of the second one was changeable in order to vary the focal length. The *combination of many cylindrical segments* at different potential for focusing has already been mentioned. When the beam was deflected by a *magnet* either to bend the ions into another direction or for momentum analysis, the beam component normal to the magnet field lines was also focused, and the component in field direction was defocused. The focusing / defocusing properties of deflecting magnets could be further influenced by the shape and the orientation of the pole shoes. To compensate for the resulting astigmatism or in some cases to enforce it (when focusing on a slit was required) *quadrupole* lenses (electrostatic for low energy beams and magnetostatic for high energy beams) were installed at both sides of the tandem. The spherical and the astigmatic focusing power could be varied.

Beam steerers: these were condensator plates for shifting the beam in both lateral directions. They were installed outside and inside the tandem to treat without loss the beam through both acceleration tubes and from the accelerator to the target halls. Operators needed some experience to steer the beam correctly through all the optical elements, slits and magnets. Wrong steering could cause the beam to hit the metal electrodes in the ceramic tube segments and thus trigger dangerous 'tube sparks', which could result in 'burned-in' traces in the ceramic insulators. If this happened too often, one had to short-circuit the damaged tube segment, which reduced the focusing properties of the whole tube. As a last resort one would have to replace the very expensive tube!

Monochromacy

The terminal voltage fluctuations had direct impact on the final ion energy. Even under the best conditions the voltage of several MV varied between 500 and 1,000 V. The main reasons for this were unavoidable material inhomogeneities of the rubber impregnation of the charging belt, which stochastically varied the charge current but were periodic with the belt frequency of some Hertz. To stabilise the terminal voltage a special 'corona point' module (see Figure 1), placed close to the terminal and *sucking off* positive charges, was connected to the anode of a triode placed outside the tank.

The triode current was controlled twice: first, by the signal of a capacitive pick-off detector (CPO) inside the tank, which monitored fast terminal voltage fluctuations and, second, by the difference signal of two electrodes, installed inside the beam tube between both 90° bending magnets. Both electrodes were adjusted to define a narrow slit < 0.5 mm, on which the beam was focused by the optics, i.e. by the second acceleration tube segments, a magnetic quadrupole lens and the first 90° bending magnet. The magnet field was tuned such that only ions of the desired momentum could pass through the slit. Slower or faster ions consequently hit one of the electrodes and the resulting difference signal changed the triode current and thus the terminal voltage. The combination of both control mechanisms kept the ion energy fluctuations at few keV.

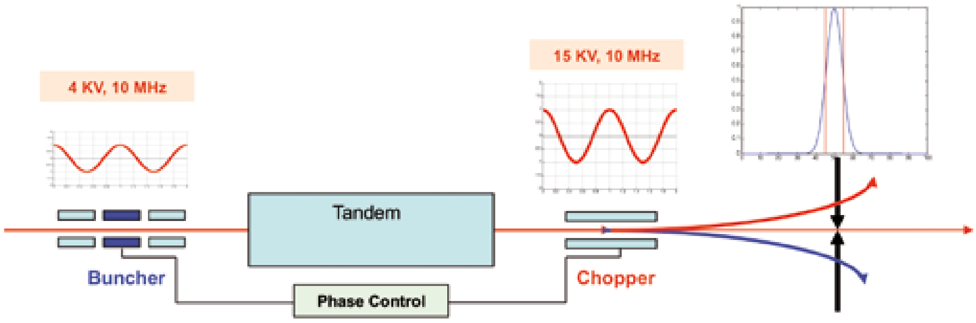

Figure 2: The combination of a pre-bunching klystron and a post-chopping steerer generated nanosecond pulses of heavy ions

Pulsing System

The pulsing system for the HVEC tandem accelerator at the University of Erlangen was a combination of a pre-injection klystron *buncher* and a post-acceleration *chopper*. It was developed to produce pulses of protons, deuterons and especially heavy ions up to mass 16 with pulse widths of some nanoseconds. The beam *chopper*, installed at the tandem high end (Figure 2), was a beam steerer, driven by a sinusoidal deflection voltage of about 15 kV amplitude for rf frequencies between 3 and 10 MHz. The electric field swept the beam across a second slit pair, oriented orthogonally to the one used for energy stabilisation, to cut out beam pulses of nanosecond duration. The purpose of the beam *buncher*, installed at the tandem low end for technical reasons, was to increase the pulse intensity of the chopped beam. It was a two-gap klystron, where the central electrode was modulated by a sinusoidal voltage of about 4 kV amplitude and the same chopper frequency. The phase relation between both modulation voltages had to be carefully adjusted and kept constant to sweep the chopped beam exactly across the slit when the pre-bunched ion pulse arrived.

Experimental Results

- First tests on the bunching system were performed from 1965 to 1967 with a test injector (Figure 3), whereby a beam of 40 keV H^- ions and 15 µA dc was transformed to pulses 2.7 ns wide with 100 ns repetition time and a peak factor of 13. In a second test run with 40 keV O^{2-} ions and 8 µA dc, pulses 1.9 ns wide, with 330 ns repetition time and a peak factor of 50 were measured. The higher peak factor of O^{2-} was explained by the smaller energy spread of the ions: whereas the H^- ions were generated by charge exchange $H_3^+ + H_2 \rightarrow H^-$ with an energy spread of ± 350 eV, the O^{2-} ions were obtained by the krypton impact reaction $Kr^+ + O_2 \rightarrow O^{2-}$ with ± 60 eV *).
- The whole *buncher* and *chopper* system was tested in 1968 with H^+ ions of 6 MeV (500 nA dc), obtaining pulses 7 ns wide, with 100 ns repetition time and an efficiency factor of eight. In a second test run with O^{4+} ions of 18 MeV (100 nA dc) pulses 6.8 ns wide, with 330 ns repetition time and an efficiency factor of 13.5 were measured **).
- The experience gained meant our colleagues could later measure the half-life of the 137 keV level in ^{57}Fe following Coulomb excitation ($T_{½}$= 8.5 ± 0.4 ns) and perform several mass analysis measurements with the O^{4+} ions of ^{10}B (^{16}O, X) Y heavy ion reactions ***).

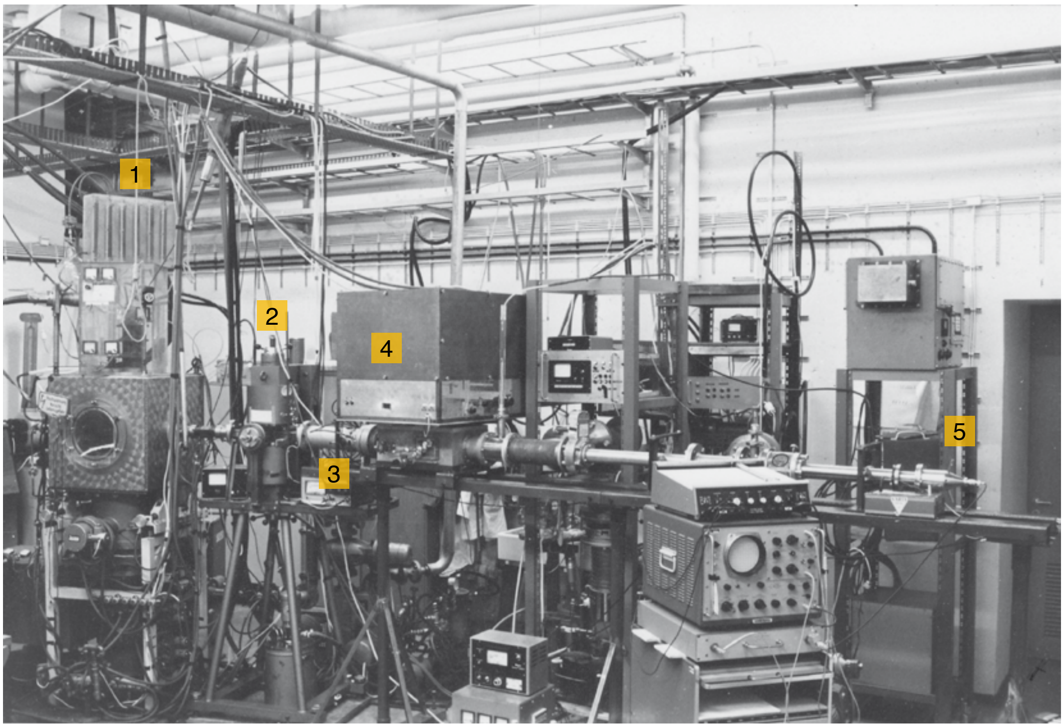

Figure 3: Test injector: ion source (1), deflecting magnet (2), quadrupole lens (3), buncher (4), Faraday cup (5)

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Physik und Gesellschaft

Energiepolitik, wo ist die Stimme der Physiker?

Jean Pierre Blaser, Andreas Pritzker

Im Zusammenhang mit der sogenannten Energiewende häufen sich in Politik und Medien absurde Sprüche, und Wunschvorstellungen werden zu Planungsgrundlagen, wobei Manches an Irreführung grenzt, wie wir im folgenden zeigen werden. Zu leise ist die Stimme der Physiker und Ingenieure, die in der Lage wären, schon mit einer 'Back-of-the-envelope' Rechnung zu zeigen, wie unrealistisch oder gar falsch gewisse Vorschläge sind. Und die wichtigen Institutionen wie die ETHs, das PSI und eben auch die SPG wären eigentlich zu öffentlichen Klarstellungen verpflichtet.

Zur Einleitung: Der Strombedarf der Schweiz im Sommer und Winter

Die Statistiken des Bundesamtes für Energie BFE [1] zeigen, dass wir im Sommer kein Problem mit der Deckung des Strombedarfs haben. Da kann man problemlos jeweils ein Kernkraftwerk für einen Monat Revision abstellen und erst noch beträchtliche Energiemengen exportieren.
Das grosse Problem ist das Winterhalbjahr. Der mittlere Landesverbrauch beträgt dann rund 8.8 GW, und diese Leistung wird etwa wie folgt erbracht:

Kernkraftwerke	*3.3 GW*
Wasserkraft - Laufkraftwerke	*1.2 GW*
Wasserkraft - Speicher-Stauseen	*2.4 GW*
Einfuhr von Elektrizität	*1.6 GW*
Diverse	*0.4 GW*
Sonne durch KEV	*0.006 GW*

Knapp 40 % liefern die Kernkraftwerke, gut 40 % die Wasserkraft, und 20% müssen wir importieren – letzteres entspricht fast der Leistung von zwei grossen Kernkraftwerken. Nach der Energiewende würde im Winter etwas mehr als die Hälfte des konsumierten Stroms fehlen. Die Annahme, dieser Anteil könne durch 'Erneuerbare' sowie durch Sparen kompensiert werden, ist völlig unrealistisch.

Die KEV als Beispiel von sinnlosem Aktivismus

Die Kostendeckende Einspeisevergütung (KEV) ist ein Instrument des Bundes, welches zur Förderung der Stromproduktion aus erneuerbaren Energien eingesetzt wird. Die KEV deckt für den Produzenten die Differenz zwischen Aufwand und Marktpreis.

Den im Sommer anfallenden KEV-Strom kann man gar nicht brauchen. Die Wasserkraft liefert dann so viel Strom, dass man sogar mehrere GW exportieren muss. Der KEV-Strom wird also unter praktisch vollem Verlust der durch Strompreisaufschläge und Subventionen bedingten recht grossen finanziellen Mittel einfach exportiert. Und der im Winter erzeugte KEV-Strom liefert keinen merkbaren Beitrag.

Die KEV nützt energetisch nichts und kostet sehr viel, ist also reiner politischer Aktivismus. Und das sollte man sagen!

Für den fehlenden Strom im Winterhalbjahr taugt die Sonnenenergie nicht

Ein grosses thermisches Kraftwerk erzeugt 1 GW Elektrizität als Bandenergie. Installierten wir als Ersatz ein Photovoltaik-Kraftwerk, bräuchten wir Solarzellen für etwa 10 GW Spitzenleistung, denn die mittlere Verfügbarkeit liegt praktisch bei 10 Prozent. Für diese Spitzenleistung brauchen wir Solarzellen mit einer Fläche von 70 km^2 mit einem effektiven Landbedarf von rund 200 km^2 freiem Gelände.

Um die nach dem Wegfall der Kernkraftwerke und Verzicht auf den Import von fossilem Strom fehlende Leistung von etwa 5 GW im Winterhalbjahr mit Sonne zu produzieren, wären Sonnenkraftwerke mit insgesamt 1000 km^2 Fläche notwendig, und zwar an geeigneter Lage. Sogar der Nordhang des Wallis würde dafür nicht genügen, abgesehen von den Auswirkungen auf Tourismus und Weinproduktion.

Die geographische, politische und finanzielle Realisierbarkeit – noch dazu rechtzeitig auf die Energiewende hin – ist völlig undenkbar, und zudem müsste man noch das enorme Speicherproblem lösen.

Die Speicherung wird zum zentralen Problem, auch global

Die Nutzung der 'neuen Erneuerbaren' steht und fällt mir der Stromspeicherung. Überhaupt wird sich diese als Schlüsselfaktor für die künftige globale Energieversorgung herausstellen.

Wenn unser Ersatz-Solarkraftwerk an einem schönen Tag während sechs Stunden 8 GW liefert, so geht 1 GW davon direkt in den Verbrauch, derweil wir die restlichen 7 GW während der sechs Stunden speichern müssen, um sie über Nacht, in den nächsten trüben Tagen oder gar für den nächsten Winter als Bandenergie abrufen zu können.

Für grosse Energiemengen und mit gutem Wirkungsgrad sind nur die Speicherseen geeignet [2]. Die Grande Dixence als grösstes derartiges Kraftwerk in der Schweiz kann mit der Leistung eines 1 GW-Kernkraftwerks jährlich etwa viermal gefüllt werden. Da beim Solarkraftwerk mehr als zwei Drittel der Leistung im Sommer anfallen, wären für die Deckung der wegen der Energiewende fehlenden 5 GW Bandenergie im Winter insgesamt ein Dutzend neuer grosser Pumpspeicherwerke notwendig.

Bei der Windenergie sieht es etwas besser aus, aber es gibt immer wieder Wettersituationen, bei denen tagelang nirgends in Europa der Wind bläst. Und es braucht ja nicht einmal Flaute, denn wenn der Wind nur halb so stark weht wie bei der Auslegung der Turbine angenommen, hat man nur noch etwa 10% Leistung, da diese von der dritten Potenz der Windgeschwindigkeit abhängt. Demnach ergibt sich auch hier ein Speicherbedarf, um kurzfristige bis wochenlange Ausfälle zu kompensieren.

Um unsere so wichtige Autarkie beim Strom zu sichern, müssten also dringend neue Speicherseen gebaut werden. Die Realisierung ist wegen der Probleme (Geographie, Wasser zur Füllung, Investitionen, Naturschutz, Umsiedlungen) unklar. Und kein Politiker spricht davon!

Aufgrund der hydrologischen Verhältnisse funktionieren Speicherseen nur in Ländern wie der Schweiz. Global gäbe es nur die Umwandlung von Strom in chemische Energie, die man leicht lagern und transportieren kann. Der Wirkungsgrad der Umwandlung von Strom in chemische, dann wieder mechanische Energie ist aber gering, er beträgt beispielsweise bei der Wasserstoff-Technologie rund 25%. Dabei wären noch grosse logistische Probleme zu lösen: Wie baut man ein Tankstellennetz für flüssigen Wasserstoff (minus 250° C) für die Traktoren der Bauern in Afrika?

Betrachtet man die global benötigte Menge Primärenergie, heute etwa fast 100 Millionen Barrel Erdöl pro Tag, so erscheint die für eine Wende von 'Fossil' zu 'Erneuerbar' erforderliche chemische Speicherung nicht realisierbar. Man müsste, verglichen mit heute, viel mehr Primärenergie produzieren und würde viel davon wegschmeissen!

Geothermie ist Kernenergie ...

Als angeblich umweltfreundlich und erneuerbar wird von der Politik im Hinblick auf die Energiewende Geothermie angepriesen und gefördert. In Wirklichkeit wird Erdwärme genau wie in einem KKW durch nukleare Prozesse erzeugt, nämlich durch den Zerfall der in der Erdkruste vorhandenen Isotope Thorium-232, Uran-238 und -235 sowie Kalium-40.

Ein Beispiel für die sträfliche Unwissenschaftlichkeit der Politik: Bei den Zerfallsketten von Uran und Thorium entsteht – wie beim KKW – radioaktiver 'Abfall', z.B. das Edelgas Radon. Dieses entweicht leicht aus dem Gestein, sodass in vielen Gebäuden im Alpengebiet eine beträchtliche radioaktive Strahlung gemessen wird. Da das Radon mit der Luft eingeatmet wird und Alphateilchen emittiert, bestand grundsätzlich die Gefahr von Lungenkrebs. Eine detaillierte Studie der Universität Zürich zeigte aber, dass im Gegenteil die Häufigkeit von Lungenkrebs in der Schweiz in den Radongebieten geringer ist als an den Orten, wo es kein Radon gibt [3]. Trotzdem führt unser Bundesamt für Gesundheit ein mit viel Geld subventioniertes Sanierungsprogramm für 'Radon-gefährdete' Gebäude durch.

Im Gegensatz zu Uran und Thorium zerfällt Kalium-40 direkt zum Edelgas Argon oder zu einem Kalzium-Kern. Wichtig zu wissen: Kalium spielt bei den Lebensvorgängen auf der Erde eine wichtige Rolle, auch im menschlichen Metabolismus. Wir haben fast 200 Gramm davon in unserem Körper. Davon sind 0.1 Promille unvermeidlich das natürlich radioaktive Kalium-40. Das bedeutet, dass wir lebenslang jede Sekunde etwa 5000 radioaktive Zerfälle in unserem Körper haben. Jeder Mensch ist also mit 5000 Becquerel radioaktiv. Diese 5000 Becquerel entsprechen etwa der Radioaktivität der Fische in Fukushima, die als angeblich gefährlich entsorgt wurden, weil sie 100 Becquerel pro Kilo aufwiesen.

... und einen wesentlichen Beitrag kann sie nicht liefern

Der geothermische Temperaturgradient beträgt im Mittel etwa 25°C pro km Tiefe. Der Wärmefluss lässt sich aus dem Temperaturgradienten und der thermischen Leitfähigkeit des Erdbodens berechnen und ergibt weltweit im Mittel nur etwa 0.06 Watt/m^2. In der Schweiz liegt er – je nach Konzentration der radioaktiven Elemente und der Wärmeleitfähigkeit des Bodens – etwa zwischen 0.04 und 0.1 W/m^2.

Mit diesem geringen Wärmefluss lässt sich die Geothermie bei uns nicht nachhaltig nutzen. Der geothermische Wärmeertrag der Grundfläche von 500 m^2 eines Einfamilienhauses beträgt nur 500 x 0.06 = 30 Watt, eine verglichen zum Wärmebedarf für die Heizung völlig verschwindende Energie. Bei einer Wärmepumpenheizung kommt noch dazu, dass man eigentlich gar keine Energie spart. Wenn man elektrische Energie aus Wasserkraft nutzt, ist diese eben dreimal mehr wert als thermische Energie. Und wenn man infolge des Ausstiegs aus der Kernenergie den Strom für die Wärmepumpe aus einem Fossil-Kraftwerk beziehen muss, braucht man praktisch genau so viel Energie wie wenn man direkt mit Gas heizen würde.

Und für ein Kraftwerk ist es noch schlimmer: Mit den möglichen Wirkungsgraden bräuchten wir für 1 GW Elektrizität etwa 5 GW Erdwärme. Mit 0.06 W/m^2 Erdwärmefluss ergibt sich dafür eine Fläche von rund 100'000 km^2, die in 5000 m Tiefe fast auf den Meter genau thermisch zu erschliessen wäre! Und da die Schweiz ja nur 41'000 km^2 gross ist, könnten wir also nicht einmal ein halbes KKW ersetzen.

Der erneuerbare Teil der Erdwärme ist also vernachlässigbar klein. Diese lässt sich nur nutzen mit dem, was in der Fachliteratur 'Thermal Mining' genannt wird, d.h. man kühlt einfach einen Bereich des Erdbodens graduell immer mehr ab.

So wird neuerdings auf diese 'Tiefengeothermie' gesetzt, etwa bei Versuchen in Basel und St. Gallen. In Tiefen von 4000-5000 m liegt in günstigen Gegenden die Temperatur im Bereich von 150-200°C. Durch gewaltsame Frakturierung des Fels (mit der Gefahr von Erdbeben) soll eine Wasserzirkulation ermöglicht werden, und mit dem heissen Wasser oder Dampf kann man dann ein Fernheizungsnetz speisen. Strom produzieren kann man auch etwas, aber nur mit schlechtem Wirkungsgrad, weil die Temperaturen gering sind.

Können wir mit derartigem 'Thermal Mining' ein KKW ersetzen? In einem Kubikkilometer Fels bei 150 bis 200°C Temperatur ist eine gewaltige Wärmemenge gespeichert. Mit dieser Wärme könnten wir ein halbes Jahr lang 1 GW Elektrizität erzeugen. Dann aber wäre die Temperatur gefallen und die Tiefengeothermie-Anlage unbrauchbar geworden, und zwar praktisch für immer, denn das Wiederaufheizen durch den natürlichen Erdwärmefluss würde Tausende von Jahren dauern. Nachhaltig?

Die Geothermie ist also Kernenergie, nicht erneuerbar und höchstens für begrenzte lokale Anwendungen (Heizung) brauchbar. Sie kann keinen relevanten Beitrag bei der Energiewende leisten.

Sparen und Effizienzsteigerung ist Wunschdenken

Für die Energiewende seien Effizienzsteigerung und Stromsparen wichtig. Abgesehen davon, dass die graue Energie beim Ersatz von alten durch energetisch günstigere Geräte nirgends eingerechnet wird, können wir der Politik nicht gerade ein gutes Zeugnis ausstellen, da sie es nicht einmal geschafft hat, die 10 GW Abwärme aus unseren Kernkraftwerken für die Fernheizung zu nutzen. Zudem sind nicht die Apparateschilder, sondern das Verhalten der Konsumenten ist entscheidend, und dieses folgt nicht Zahlen, sondern Gefühlen. So wird die Hausfrau, die stolz eine neue eco-grüne Waschmaschine kaufte, mit gutem Gewissen aus hygienischen Gründen eventuell sogar noch mehr waschen.

Angesichts der in den nächsten Jahrzehnten zu erwartenden Verfügbarkeit von billigem Erdgas wird unser Gesellschaftssystem kaum wirksame Eingriffe des Staates in die persönliche Lebensweise dulden. Die vielen 'Lenkungsabgaben' sind reiner politischer Aktivismus, weitgehend wirkungslos, lediglich ein Heer von Beamten wird beschäftigt um zu berechnen, Ausnahmen zu verwalten, Rückzahlungen zu tätigen und Massnahmen zur 'sozialen Gerechtigkeit' zu finden. Und auch mit wirklich drastischen Massnahmen könnte wohl nur eine Stabilisierung und kaum eine Reduktion des Stromverbrauchs erreicht werden.

Energieforschung: Was bringt sie wirklich?

Die Politik wird nicht müde zu verkünden, dass eine mit genügend grossen Subventionen finanzierte 'Energieforschung' sicher die notwendigen neuen Technologien finden wird. Die Energieerzeugung ist aber voll durch die schon lange bekannten Naturgesetze bestimmt. Und diese kann man weder durch viel Forschung noch mit politischen Abstimmungen ändern.

Bei der Weiterentwicklung von Produkten und Verfahren der Energietechnologie sind einige Entwicklungen natürlich möglich, aber das ist Sache der Industrie, die es besser kann. Uns fehlen Beispiele dafür, dass Energieforschung als solche wirklich etwas gebracht hat. Ergebnisse, die sich letztlich in der Bereitstellung oder besseren Nutzung der Energie ausgewirkt haben, wurden stets durch Grundlagenforschung in Natur- und Ingenieurwissenschaften erarbeitet, und zwar ohne politische Weisungen und Subventionen.

[1] Bundesamt für Energie: Schweizerische Elektrizitätsstatistik 2012
[2] Hermann Pütter: Die Zukunft der Stromspeicherung. Naturwissenschaftliche Rundschau, 66. Jahrgang, Heft 2, 2013
[3] Georges Schüler und Matthias Bopp: Atlas der Krebsmortalität in der Schweiz 1970-1990. Basel, Birkhäuser-Verlag, 1992

Physique et Société

L'énergie du soleil sous toutes ses formes

Atelier du "Young Physicists Forum" sur la technologie de l'énergie, Winterthur 17-18 mai 2014

Antoine Pochelon

Ce sont une bonne trentaine d'étudiants (22) et d'étudiantes (10) des universités suisses, provenant pour moitié de Suisse romande et de Suisse allemande qui se sont réunis les 17 et 18 mai 2014 dans le cadre du Technorama de Winterthur pour un atelier sur les technologies de l'énergie. Organisée dans le cadre du Forum des Jeunes Physiciens (YPF, Young Physicists Forum) en collaborations avec la Société Suisse de Physique (SSP), la rencontre a permis d'approfondir ce thème dans une ambiance conviviale.

L'YPF a été créé en 2009 à l'instigation de la SSP, grâce au soutien financier de l'Académie suisse des sciences naturelles (SCNAT) et de sa plateforme MAP. Le but du Forum est d'encourager la communication entre les différentes sociétés d'étudiants en physique, ainsi qu'avec les physiciens professionnels membres de la SSP afin de créer une plateforme de discussion sur des sujets d'intérêt commun. Ce week-end de séminaires, comme lors de cette rencontre à Winterthur ou les visites de laboratoires sont les moments forts dans l'année.

C'est donc le samedi en début de soirée que les jeunes sont arrivés à l'auberge de jeunesse, dont le nom - "Depot 195" - situe bien l'ambiance particulière des lieux. Nous sommes à Winterthur, dans le quartier proche de la gare. Tout dans ce quartier atteste d'un passé d'industrie lourde qui a été reconverti, transformé, sans renier ce passé qui est ici intentionnellement donné à voir. Comme pour mémoire. C'est un symbole des transformations profondes qui ont touché le tissu économique et technique de la Suisse au cours des dernières décennies. L'hôtel a été taillé avec goût dans un ancien dépôt industriel en en conservant le style. Dépaysement garanti! Les étudiants, arrivés ce samedi soir ont déjà bien investi le lieu et le parc voisin, "Beer and socialising" est au programme.

Dimanche matin dans une ambiance d'auberge de jeunesse, le petit déjeuner réunit tous les étudiants autour de la grande table devant l'hôtel. Damian Göldi et Silvan Etter, les organisateurs du YPF ont tout prévu pour une table accueillante, de plus déjà bien réchauffée par les rayons déjà vifs du soleil.

Et ce sera bien du soleil et de son énergie – sous deux de ses formes - qu'il sera question aujourd'hui.

Le workshop a lieu dans une salle du Technorama. La Société Suisse de Physique ainsi que de nombreux domaines de la physique couverts par la Société sont tout d'abord présentés par A. Pochelon. Les qualités d'un physicien? Esprit de découverte, curiosité, analyse, travail intense… joie de trouver, de savoir, de participer à la résolution de problèmes techniques, voire de problèmes de société, elles sont nombreuses les qualités et les aptitudes développées dans une formation de physicien. Avec l'émergence de nouvelles disciplines basées sur la physique, le nombre de sections au sein de la SSP, couvrant chacune des domaines différents de la physique, est passé de quatre à dix en une quinzaine d'années, reflétant l'évolution parallèle qui a eu lieu au niveau académique. Mais le monde de la science ne devrait pas se limiter aux milieux académiques …

L'expérience politique récente en Suisse souligne l'importance cruciale de cultiver le contact entre le monde de la recherche et celui de la politique et de l'économie, la nécessité de développer une culture des sciences. Comme le résume le président de l'Académie suisse des sciences et de SCNAT, l'astrophysicien Thierry Courvoisier: «La science doit avoir plus de poids dans les décisions politiques».

Tahan Pangaribuan, pilote aux nombreuses heures de vol et actuellement coordinateur des opérations au sol de « Solar Impulse » a développé dans un exposé remarquable les enjeux de l'avion solaire "Solar Impulse", embarqué vers un tour du monde en 2015. En tant que coordinateur des opérations au sol, il participe donc à la préparation et à la planification des missions. Comme dans toutes les grandes premières, il n'existe aucune référence préalable, et les stratégies doivent être inventées à partir de zéro.

Tahan Pangaribuan exposant la problématique de l'avion solaire.

Dans un exposé avec pour thème: "Fusion energy: from the Sun to fusion plasma large experiments", Antoine Pochelon, EPFL, nous a fait parcourir le chemin qui mène des réactions prenant place dans le soleil depuis 4.5 milliards d'années à la réalisation d'une source d'énergie quasi-inépuisable sur Terre. En effet, avec le Deutérium contenu dans un litre d'eau et du Lithium - en réserve suffisante sur la planète – cela représente l'équivalent de 300 litres de pétrole. Il s'agit là d'un scénario durable, sans CO_2. Ne nécessitant pas de réaction en chaîne, la réaction peut être appelée intrinsèquement sûre, il n'y a pas de déchets de combustion radioactifs. Seule la machine devient radioactive à l'usage, son retraitement devant toutefois permettre de mettre les mains dessus (« hands-on ») après 50-100 ans (voir *SPG Mitteilungen* 36 (2012) 12-14). Un grand réacteur de fusion – ITER – est actuellement en construction à Cadarache, France avec pour 7 membres la Chine, la Corée du Sud, l'Inde, le Japon, la Russie, l'UE dont la Suisse, les USA. Plus de la moitié de l'humanité y participe donc. Le tokamak de l'EPFL à Lausanne fait partie des 3 tokamaks retenus depuis début 2014 par l'UE pour effectuer le programme de recherche de l'EUROFusion.

De l'avis même des étudiants, les présentations étaient très intéressantes, très bien reçues et ont mené à des discussions enthousiastes qui se poursuivaient encore au déjeuner dans le restaurant du Technorama. La visite de l'exposition a été un plaisir pour tous les participants même si le temps disponible était un peu court. A la fin de la journée, certains participants demandaient aux organisateurs quand un prochain événement de ce type aurait lieu.

L'organisation d'un tel workshop fait partie du challenge ! Cruciale en effet dans cette préparation est la démarche de réunir des conférenciers adéquats pour la bonne couverture du sujet. Ce qui n'est pas forcément une mince affaire et demande temps et consécration. Surtout, ce n'est pas toujours compatible avec la vie d'étudiant, quand les délais sont aussi fixés par la session d'examens ou le travail de diplôme à rendre. Et pour palier à un carnet d'adresses qui par nature est toujours en construction, il faut s'y prendre très largement à l'avance pour avoir le temps de se faire conseiller dans cette recherche de conférenciers. La SSP possède un réseau efficace qui devrait être mis à profit dès le début des recherches.

Mais en fin de comptes, établir des liens entre les étudiants et les chercheurs dans l'industrie ou l'académie se révèle finalement fécond pour toutes les parties, aussi au niveau de l'organisation. Et à plus long terme, la nature d'un tel atelier ainsi que tous les exposés présentés sont une source d'inspiration pour les étudiants dans la recherche de débouchés.

Le groupe des étudiants participant au workshop devant le Technorama de Winterthur.
Photos: Damian Göldi

Histoire de la Physique (11)

1946-1960: Une période difficile pour la physique genevoise (part 2)

Jan Lacki, Uni Genève

*Le debut de cet article est apparu dans les dernières **Communications de la SSP**, no. 43.*

[La partie 1 de cet article se terminait au moment où la faculté des sciences de Genève décidait enfin de rechercher un véritable remplaçant d'envergure pour Stueckelberg qui avait démissionné en décembre 1949. Au printemps 1952, trois théoriciens de renom étaient pressentis, Weisskopf, Pais et Wannier.]

On convenait que Stueckelberg qui restait attaché l'Institut de Physique en tant que professeur honoraire et chercheur devait avoir son mot à dire: la faculté était consciente que « son influence et celle de ses amis [pouvait] jouer un certain rôle ». De fait, Stueckelberg faisait savoir qu'il « fera opposition si on envisage un professeur de second ordre, mais il ne bougera pas s'il est question de M. Weisskopf » et qu'il n'avait non plus aucune objection à la venue de Pais. Il «[faisait] toutes réserves » par contre concernant Wannier, son ancien assistant, « dont il lui serait désagréable de voir candidature »[34].

Les réserves de Stueckelberg n'émurent manifestement pas la faculté puisque celle-ci chargeait Extermann de prospecter auprès des successeurs pressentis Wannier inclus. L'affaire devenait de plus en plus pressante: on n'hésitait en effet pas à interpeller directement le Département de l'Instruction Publique (DIP) comme les firent les « physiciens suisses qui se sont étonnés du retard mis au renouvellement du titulaire de la chaire de physique théorique » [35] ou encore Pauli qui intervint pour suggérer quelques noms parmi ses élèves.

La faculté allait de nouveau mal estimer les exigences d'un candidat de prestige digne de la succession Stueckelberg. Des signaux d'alerte sur l'importance de moyens à engager s'étaient pourtant manifestés: Extermann constatait lors de ses démarches que les pressentis américains liaient leur intérêt pour Genève avec la possibilité d'engager dans leur équipe non seulement des assistants mais aussi des professeurs agrégés ce qui ne pouvait qu'effaroucher les Genevois habitués à des équipes bien plus modestes. De fait, certains à la faculté s'interrogeaient sur l'importance qu'ils voulaient vraiment donner à la chaire théorique au vu du coût d'une succession de prestige qui risquait sérieusement de conduire à un « déséquilibre des forces de la faculté, de l'Institut de Physique et à une impasse financière insoluble » [36]. Au sein de l'Institut de Physique d'autres besoins restaient en effet à satisfaire: la question de la création d'un enseignement de physique générale différencié de celui médecins et ainsi mieux adapté aux futurs théoriciens rappelait que l'on n'avait toujours pas pourvu le second poste d'expérimentaliste prévu dans la succession de Weiglé. Extermann ne manquait d'ailleurs pas de rappeler à ce sujet combien la gestion de l'Institut en l'absence d'un autre collègue, susceptible de le décharger d'une partie de ses lourdes taches administratives, l'éloignait de sa recherche.

La venue éphémère de Wannier

Pour éviter ce que certains membres de la faculté n'hésitaient pas à taxer de « mégalomanie » on décidait de pousser plus loin les pourparlers avec Wannier dont on espérait les prétentions plus modestes. Quant au problème de la création d'un enseignement de physique expérimentale destiné aux théoriciens, on le résolvait en nommant, en attendant d'ouvrir le concours pour la chaire extraordinaire, un chargé de cours [37]. La nomination du successeur de Stueckelberg ne touchait cependant pas à sa fin. Début 1954 on hésitait encore sur la procédure: la faculté tenait à procéder par appel pour souligner l'importance accordée au nouveau venu et lui donner tout le prestige nécessaire pour ses futurs contacts avec l'équipe du CERN mais le président du DIP Picot n'y était pas favorable. La situation se compliqua encore un peu plus quand Wannier fit savoir qu'il ne pouvait pas prendre ses fonctions avant l'été 1955. Refroidie par le peu d'empressement montré par Wannier, la faculté rouvrait aussitôt les dossiers d'autres candidats. Même si l'appel à des personnalités de renom comme Weisskopf ou Pais n'était désormais plus d'actualité [38], des théoriciens à la réputation montante restaient à l'étude, notamment Res Jost et Felix Villars. On soulignait à leur propos qu'ils avaient sur Wannier l'avantage d'être toujours dans le circuit académique sans pour autant lui être inférieurs sur d'autres points [39].

Malgré la volonté du DIP d'en finir au plus vite la faculté voulait prendre son temps. La réussite des physiciens locaux à assurer l'intérim lui permettait certes de temporiser mais il y avait d'autres raisons à ne pas trop se presser: des nouvelles pistes pour la succession continuaient de surgir. En avril, on apprenait que Raymond Daudel, collaborateur de Louis de Broglie laissait entendre son intérêt pour Ge-

34 Il est difficile de savoir si cette réserve avait un fondement scientifique ou si elle ne résultait que du désagrément de voir un ancien subordonné accéder à une position dominante.

35 Collège des professeurs ordinaires de la faculté (P. O.) du 11 mai 1953.

36 Ibid.

37 P. O. du 29 octobre 1953. La charge de cours fut confiée début 1954 à Georges Béné, à cette époque privat dozent à Genève et membre du CNRS. Béné allait dans les années qui suivirent être promu professeur associé puis finalement être nommé à la chaire extraordinaire (voir P. O. du 28.11.1960).

38 Weisskopf posait comme condition préliminaire à sa venue l'établissement confirmé du CERN à Genève. Le futur genevois du CERN restait en effet en suspens : un référendum contre sa présence venait d'être lancé et en attendant le vote (27-28 juin 1953), la faculté suspendait les tractations avec Weisskopf. Pais de son côté avait entre-temps refusé d'envisager Genève

39 P. O. du 25 janvier 1954. Villars continuait à l'époque sa carrière au M.I.T comme professeur assistant et semblait y avoir des bonnes perspectives de promotion alors que Jost était membre de l'Institute for Advanced Study de Princeton.

nève avec l'assentiment du Nobel français. Une nouvelle encore plus prometteuse tombait avec la nomination de Felix Bloch aux fonctions de premier directeur du CERN. C'est probablement Stueckelberg lui-même qui suggéra que l'on pouvait essayer de s'attacher les services du Nobel suisse puisqu'en tant que directeur du laboratoire européen il allait être déjà sur place et de surcroît dans les locaux de la physique genevoise [40]. Outre celui de ne pas devoir assurer l'intégralité du salaire d'une sommité comme Bloch, ce montage offrait l'avantage d'amener à l'Institut de Physique les assistants et le matériel personnel de Bloch, une aubaine jugée à l'époque inespérée [41]. De fait, Bloch laissait entendre officieusement qu'il acceptait de collaborer comme professeur à l'enseignement genevois selon un « statut spécial » sans contrepartie financière autre que symbolique. Le DIP joua le jeu: en acceptant de décharger Bloch de toute obligation liée habituellement à une chaire contre juste « des conférences organisées ad hoc » [42] il lui accordait de fait un statut proche d'un professeur au Collège de France [43]. Bloch confirmait peu après officiellement son intérêt.

Les services de Bloch acquis, la quête d'une personnalité prestigieuse était terminée et il ne restait plus à la faculté qu'à choisir une personne pour prendre en charge l'enseignement théorique ordinaire, problème qu'un concours « normal » devait pouvoir amplement régler. Il se déroula entre le 1er juillet et le 1er septembre: on enregistra les candidatures de Konrad Bleuler (Uni. Zürich), Pierre Bouvier (Collège de Genève), Hersz Wermus (Institut Central ORT de Genève pour la formation d'instructeurs des écoles techniques), André Petermann (Manchester), Felix Villars (M.I.T.) et Grégoire Wannier (Bell Labs). Mis à part Wermus et Villars tous étaient d'anciens élèves ou collaborateurs de Stueckelberg. Lors de la séance du 10 octobre 1954 la commission de nomination proposait en première place Wannier et en deuxième Villars. Malgré les services rendus par Wannier et l'engagement moral qu'Extermann estimait lui devoir, la faculté ne suivit pas l'avis de la commission: après un débat d'où ressortit clairement que Villars jouissait, outre la forte recommandation de Scherrer, d'un fort soutien local, c'est lui qui remporta d'une courte longueur le vote [44]. Les champs d'activité respectifs des candidats n'étaient pas étrangers à cette préférence. La physique du solide de Wannier, bien que s'inscrivant mieux dans les travaux de l'Institut genevois, vit son importance éclipsée par la physique nucléaire et corpusculaire portée par un Villars dont la velléité de collaboration étroite avec le CERN ne faisait aucune doute. Pour finir, on espérait que Villars, de dix ans cadet de Wannier, allait avoir des prétentions salariales plus modestes.

40 Les premiers membres du CERN, arrivés à Genève depuis peu, furent provisoirement installés dans le tout nouveau bâtiment de l'Institut de Physique ; cela n'alla d'ailleurs pas sans provoquer un certain émoi auprès des physiciens genevois qui se sentirent quelque peu « envahis » (procès verbal de la séance plénière du 15 juillet 1953).

41 P. O. du 29 avril 1954.

42 Lettre de Bloch à Extermann du 11 mai 1954, AEG, P. O. du 21 juin 1954.

43 Lettre du doyen Wenger à Bloch du 21 juin 1954, AEG.

44 P. O. du 14 octobre 1954. Dans une lettre à Picot du 23 juillet 1954 Pauli avait déjà fait savoir que Villars constituait à ses yeux le meilleur candidat suisse pour le poste.

Encore une fois, la suite ne se passa pas comme prévu. La préférence donnée à Villars était remise en question quand la commission de préavis décidait en janvier 1955 de recommander au DIP la nomination de… Wannier. Les motifs de ce revirement ne sont pas clairs. Certaines informations indiquent que l'attachement d'Extermann pour la candidature de Wannier avait pesé dans la décision. Quoi qu'il en fût, dans les mois qui suivirent, alors que Lacroix continuait toujours la suppléance, le DIP, la faculté et Wannier négocièrent les conditions précises de sa venue. Le nouveau professeur ordinaire de physique théorique prenait finalement son fonctions à l'automne 1955. Les deux chaires ordinaires laissées vacantes depuis presque dix ans se voyaient enfin repourvues.

Tout semblait finalement rentré dans l'ordre même si tout n'était pas parfait: la chaire extraordinaire de physique expérimentale dont l'enseignement était assuré provisoirement par le chargé de cours Georges Béné restait à pourvoir alors que le beau projet de la collaboration avec Bloch avait capoté puisque ce dernier avait entre-temps renoncé à son poste au CERN pour retourner aux Etats-Unis. Un autre coup de théâtre allait troubler le semblant de normalité retrouvée. Au cours de l'été 1956, quelques mois seulement après son engagement, Gregoire Wannier faisait parvenir une lettre de démission au nouveau président du DIP Borel: suite à l'intervention du doyen Chodat cette démission était transformée en une demande de congé pour le semestre d'hiver 1956-57. Lors de la discussion au Collège des professeurs ordinaires (P. O.) on se doutait que la demande de congé n'allait pas garantir le retour de Wannier. De fait, ce dernier démissionnait pour de bon en février 1957 [45].

On ignore les raisons du soudain départ de Wannier. Il est certain que l'atmosphère entourant l'Institut de Physique et son fonctionnement n'était pas tout à fait sereine: un certain nombre de documents font état de problèmes. Le procès verbal de la séance des P. O. du 5 octobre 1956 évoque un « malaise qui semble régner actuellement à l'Institut de Physique ». Des difficultés survenues à l'occasion du paiement de certaines factures liées à l'équipement de l'Institut avaient ternies les relations entre le DIP, le Département des Travaux Publics et l'Université, mais ce dossier qui impliquait surtout Extermann n'avait en principe pas pu influer sur la situation de Wannier. Une autre dossier pu jouer un rôle. Depuis sa nomination comme ordinaire, Extermann assumait également la direction de l'Institut dont l'activité s'identifiait jusqu'à là aux yeux de tous avec la physique expérimentale. On se souvient comment, lors de la succession de Weiglé, la direction de l'Institut fut tacitement confiée à son remplaçant expérimentaliste (et non pas au théoricien Stueckelberg). Les années d'après-guerre voyaient pourtant s'accélérer la montée en puissance de la physique théorique. Son importance était renforcée par la question, à l'époque omniprésente dans les décisions institutionnelles, des études nucléaires et des promesses de généreux financement pour les développer. D'autres directions de recherche s'affirmaient également et ainsi, au milieu des années 50, l'identification entre l'Institut de Physique et le Laboratoire de Physique Expérimentale commençait à être ressentie comme une anomalie. On soulignait ainsi que le terme « institut », désignant avant tout un laboratoire dé-

45 P. O. du 25 février 1957.

diée à un domaine de recherche donné, n'était plus propre à couvrir les activités aussi multiples que celles logées dans le nouveau bâtiment, physique expérimentale, théorique, géophysique et d'autres encore [46]. C'est la raison derrière le changement de nom qui vit dans ces années l'Institut de Physique devenir « Ecole de Physique ».

Les changements dans les rapports de force entre les différents domaines de la physique allaient se ressentir sur les plans administratifs et hiérarchiques: la première moitié de 1956 vit une réflexion sur le règlement de l'Institut de Physique et en particulier sur l'organigramme de sa direction. Pour satisfaire au nouveau schéma, Extermann démissionnait de la direction de l'Institut pour devenir « que » directeur de l'Institut de Physique Expérimentale alors que la direction de l'Ecole était confiée au collège de professeurs de physique. Ces changements étaient certes de nature à renforcer la position de Wannier mais ils montrent surtout le déséquilibre disciplinaire au moment où Wannier prenait ses fonctions. Il se peut que Wannier n'eut pas la patience de les attendre mais il eut sans doute encore d'autres raisons. Quoi qu'il en fût, en attendant la nomination des deux ordinaires manquants, la faculté nommait un comité de gestion temporaire incluant Extermann et Béné, et présidé par le doyen Chodat [47].

La nomination avortée de Villars

Avant même le départ définitif de Wannier on s'activait déjà pour remedier à ce nouveau coup dur. Roger Lacroix, que l'on avait promu au poste de chef des travaux, reprenait la suppléance et la faculté reprenait ses contacts avec des possibles successeurs [48]. Un nouveau dossier venait compliquer encore plus la situation: fin 1956 la faculté entamait l'examen de la création d'une nouvelle chaire de « physique nucléaire » qui allait porter le nombre de professeurs de physique à quatre si l'on incluait la chaire extraordinaire de physique expérimentale [49]. Les raisons derrière cette décision sont multiples mais la perspective de subventions considérables que la Confédération s'apprêtait à octroyer pour développer le champ des études nucléaires avait sans doute joué le plus grand rôle. Comme la distribution de ces fonds devait se faire selon l'importance des centres suisses comptée en nombre de chercheurs et projets, Genève, comme d'autres institutions, faisait tout pour se positionner au mieux dans la course. Il n'est pas possible d'aborder dans cet article les détails de l'affaire des subventions fédérales dont les retombées sur la politique académique genevoise (et au-delà) furent capitales. Qu'il me suffise de mentionner que les années qui allaient suivre virent plusieurs coups de théâtre avec en toile de fond toujours l'enjeu des subventions pour la recherche nucléaire.

Les contacts repris dès février 1957 avec Villars, manifestement peu rancunier, étaient prometteurs et laissaient espérer que sa venue sur appel allait combler, cette fois-ci pour de bon, le vide laissé par la démission de Stueckelberg. Il ne s'agissait pas que de la physique théorique: l'arrivée du nouveau professeur ordinaire devait aussi aider à stabiliser un Institut dont la marche dépendait, pour certains, trop d'un seul homme (Extermann) dont les agissements causaient dans les coulisses institutionnelles une certaine préoccupation. Une fois de plus les espoirs des autorités académiques allaient être déçus. On apprenait en février 1958 que Villars renonçait à accepter l'appel de Genève alors que tout semblait converger jusque là vers un accord. Malgré le fait qu'il était entre-temps devenu américain et la vexation subie lors du choix de Wannier, Villars réagissait d'abord favorablement à la relance des Genevois. Venu sur invitation du président Borel en mars 1957 pour prendre la mesure de la situation locale, Villars le rencontrait de nouveau en mai en présence du doyen qui rendit compte de l'entrevue en des termes très optimistes [50]. Une autre rencontre tout aussi positive eut lieu en juillet. Mais d'autres enjeux dépassant largement la question de la physique théorique se jouaient dans les coulisses dont on ne découvrit l'ampleur et le rôle déterminant qu'après coup.

Les documents dont on dispose pour retracer ce nouveau échec de la succession Stueckelberg sont d'autant plus fournis qu'ils rapportent le début d'un grave conflit entre Richard Extermann et ses autorités de tutelle, conflit qui allait en fin de compte déboucher, deux ans plus tard, sur sa mise en congé [51]. Dans la séance du 28 avril 1958 le doyen, après avoir annoncé le renoncement de Villars, rendait Extermann directement responsable du fiasco. Son rapport joint au procès verbal nous en apprend plus: par un double jeu qu'il aurait pratiqué vis-à-vis de sa faculté, Extermann aurait fait capoter non seulement la venue de Villars à Genève mais aussi (et surtout) un plan général de développement de la physique genevoise sur fond des promesses de la manne fédérale pour les études nucléaires. Avec les documents à disposition et surtout avec le recul d'aujourd'hui, on peut penser que les torts étaient partagés. Lors de ses négociations avec Villars, la faculté par l'entremise de son doyen, et en accord avec le DIP, lui avaient proposé une mission plus large. Il s'agissait de constituer un plan de réorganisation de l'Institut de Physique et de développement de ses activités dans le domaine du nucléaire. En octobre Villars rendait aux autorités genevoises un mémorandum, « Propositions pour la réorganisation de l'Institut de Physique à l'Université de Genève » qui exposait en même temps les conditions de sa propre venue. Certains points de ce projet, en particulier le découpage que Villars préconisait pour les futures recherches de l'Institut heurtèrent les vues d'Extermann qui reprochait à Villars de ne pas respecter ce qui se faisait déjà à Genève [52].

Cette divergence affecta les rapports entre les deux hommes mais c'est une autre raison qui fut déterminante dans le renoncement de Villars. Le « Plan Villars » incluait un volet régional qui exposait ses vues sur la collaboration et l'édification des projets communs avec les autres centres romands. L'enjeu était, comme déjà mentionné, la répartition des fonds fédéraux pour le développement des recherches

46 P. O. du 5 octobre 1956.

47 Ibid.

48 Ibid.

49 P. O. du 5 novembre 1956.

50 P. O. du 24 juin 1957.

51 Début 1960, le président du Département d'Instruction Publique nommait de son propre chef une commission d'expertise pour évaluer la marche de l'Institut de Physique. Quelques mois après (20 juillet), Extermann se voyait « accorder » un congé par le Conseil d'Etat genevois; malgré son opposition et la bataille juridique qui s'en suivit, il ne repris plus ses fonctions.

52 Entre autres ses recherches spectroscopiques

nucléaires. Mais Villars n'était pas le seul à réfléchir a cette époque à la réorganisation de la recherche genevoise et romande. Le « groupement des physiciens suisses » et celui des physiciens romands développaient de leur côté et largement à l'insu des autorités genevoises une autre stratégie pour capter aux mieux les subsides de la Confédération. Profitant de son rôle central dans la physique genevoise et de sa bonne implantation dans les milieux romands et suisses (il jouissait de l'appui de Scherrer), Extermann participait activement à l'élaboration de ce plan qui ignorait les velléités des autorités politiques et décanales genevoises. Alors que le « plan Villars » suivait l'avis de ces dernières en accordant à Genève la part belle en faisant d'elle le pôle de toute recherche nucléaire romande autour duquel les autres centres devaient s'organiser, le plan des physiciens romands, plus fédérateur, jouait la carte régionale et tenait surtout compte des initiatives déjà existantes.

Quand Villars alla consulter les responsables des autres centres romands il fut fraîchement accueilli car perçu comme l'émissaire d'un certain « impérialisme » genevois. Il comprit que les chances de voir son plan accepté étaient nulles, d'autant plus qu'à Genève Extermann et ses protégés avaient entre-temps obtenu, avec l'appui de Scherrer, des subsides fédéraux importants. Bien qu'il ne liait pas formellement sa venue à la réussite de son plan, Villars jetait tout de même l'éponge laissant Extermann et la faculté s'accuser mutuellement d'avoir ignoré sciemment les démarches de l'autre [53]. Malgré le conflit ouvert entre Extermann et sa Faculté, l'année 1958 ne connut pourtant pas d'autres esclandres, du moins publiques.

L'engagement de Jauch

Le fiasco de l'engagement de Villars obligeait la faculté à repenser à nouveau l'organisation de la physique genevoise. L'une des conséquences était l'abandon du projet de la chaire de physique nucléaire dont la Faculté réalisait qu'elle n'avait plus les moyens (on considérait qu'Extermann les avait déjà accaparés). Cela signifiait aussi qu'il fallait repenser à nouveau le profil de recherche du futur professeur de physique théorique. Jusqu'ici la perspective de l'ouverture d'une chaire en physique nucléaire expérimentale déterminait ce dernier comme un théoricien du même domaine; désormais on voulait mettre plutôt l'accent sur la physique du solide, un autre domaine mis en exergue dans le mémorandum de Villars [54]. On le voit, le sort de la chaire de physique théorique continuait à être lié, bon gré mal gré, aux chaires expérimentales.

La rédéfinition du profil de la chaire théorique explique que le suivant théoricien pressenti pour l'occuper fut Robert Schafroth, élève et assistant de Pauli, spécialiste reconnu de la supraconductivité professant à l'époque à Sydney. Bénéficiant des faveurs des autorités genevoises dès juin, Schafroth acceptait l'appel mais demandait de bénéficier d'une équipe élargie des théoriciens, un professeur extraordinaire, un chargé de cours et un assistant [55]. Sa nomination était proposée à l'unanimité lors de la séance des professeurs ordinaires de la faculté le 7 juillet 1958. Le sort devait pourtant frapper encore une fois la physique théorique genevoise. Alors qu'il devait prendre ses fonctions au début de l'année académique 1959, Robert Schafroth disparaissait tragiquement dans un accident d'avion [56].

Tout était à refaire, de nouveau. Les choses allèrent cette fois plus vite: lors de la séance des ordinaires du 15 juin 1959, Richard Extermann rapportait une suggestion de Stueckelberg qui attirait l'attention sur Josef Maria Jauch, « en contact avec le CERN et dont la venue serait des plus favorables ». Les liens de Jauch avec le CERN tombaient à point: la faculté [57] venait juste de prendre connaissance d'un projet de la *Société Académique* de Genève préconisant la création d'une chaire de physique nucléaire « orientée vers l'emploi des hautes énergies, en vue de constituer une équipe pouvant préparer des expériences à l'Institut, en contact étroit avec le CERN, pour utiliser ensuite les puissantes machines dont dispose ce centre » [58].

Lors de la séance des ordinaires du 29 juin 1959 la commission des chaires de physique proposait à l'unanimité à la faculté la nomination immédiate de Jauch; celle-ci s'empressait d'accepter ainsi que peu de temps après les autorités politiques. Il fallut quand même attendre encore une année pour voir le nouveau professeur prendre ses fonctions. En mission scientifique à Londres durant l'année académique 59-60, Jauch venait cependant de temps à autre à Genève et participait déjà à l'organisation du futur enseignement de l'Ecole de Physique. Parmi les dossiers où sa voix compta avant même qu'il n'intègre Genève il y eut le dossier de Stueckelberg.

La réintégration de Stueckelberg

Depuis quelques années déjà la Faculté assouplissait sa position vis-à-vis de l'ancien professeur de théorie. Quant il fallut pallier à l'arrivée retardée de Jauch, on s'interrogea si son enseignement ne pouvait pas être partagé entre Lacroix et Stueckelberg. Ni Jauch ni la faculté n'osèrent encore franchir le pas en demandant au DIP la réintégration de

53 Au rapport du doyen Extermann opposait le sien qu'il lut lors de la séance du 23 juin ; il y rejetait toute la faute sur le doyen dont il dénonçait le peu d'écoute et les manières dictatoriales.

54 P. O. du 28 avril 1958.

55 Dans sa biographie de Pauli ("No time to be brief", Oxford University Press, 2010), Ch. P. Enz donne des détails supplémentaires sur Schafroth en livrant un détail intéressant: alors qu'il préparait sa venue à Genève, Schafroth aurait proposé à Enz de le réjoindre comme professeur associé (p. 452). En fait, Charles Enz allait réjoindre Genève quelques années plus tard comme professeur ordinaire.

56 P. O. du 15 juin 1959.

57 Après des études à l'ETH, Jauch se rend aux États-Unis pour travailler sur sa thèse avec E. Hill à l'université de Minnesota. Retourné en Europe en 1940, il devient assistant de Pauli qu'il suivra deux ans après pour retourner aux Etats-Unis et devenir professeur-assistant à l'université de Princeton (1942-1944). En 1946, Jauch accepte le poste de professeur associé puis de professeur ordinaire de physique théorique à l'université d'Iowa. Il retourne en Europe en 1959 en tant qu'officier de liaison de l'Office of Naval Research à Londres.

58 La faculté, qui s'était d'abord formalisée de l'intrusion dans ses affaires d'une instance extérieure, avait finalement acceptée d'examiner de plus près cette suggestion reconnaissant le grand appui que la *Société Académique* avait donné des années auparavant au projet d'un nouvel Institut. La chaire devint une réalité en 1961: après avoir pressenti Valentin Telgdi dont la candidature capota finalement pour un problème de nationalité, la faculté proposait la nomination de Ernst Heer à l'époque professeur associé à Rochester (P. O. du 23. janvier 1961).

Stueckelberg parmi les enseignants réguliers. On demanda de nouveau à Lacroix d'assurer tous les cours en réservant à Stueckelberg l'enseignement doctoral [59].

Courant été 1960 le doyen genevois rencontrait le président de la Commission des intérêts professionnels universitaires de Lausanne pour « discuter de la situation financière de Stueckelberg ». On devine entre les lignes que plus que sa situation financière, c'était son affiliation à l'une ou l'autre des institutions que l'on se disputait. Peu après, la faculté genevoise reconnaissait « le grand intérêt de retenir à Genève M. Stueckelberg »: des voix soulignaient à ce propos qu'on « devrait confier à ce savant, dans le cadre de l'enseignement de la physique théorique, une participation ou une direction aux séminaires et aux recherches ». On s'accorda, avant même sa prise de fonctions, de consulter Jauch « sur la possibilité de réintégration de M. Stueckelberg à la faculté » [60]: on le voit, beaucoup d'eau avait coulé sous les ponts et avait emporté avec elle l'ostracisme qui frappait Stueckelberg depuis sa démission.

Pour Jauch, l'affaire était entendue. Une des ses premières actions académiques fut, dès sa première participation officielle au conseil des professeurs ordinaires, le 24 octobre, de demander la réintégration de Stueckelberg dans la faculté à titre de professeur ordinaire *ad personam*. La faculté suivit son avis et se montra prête à appuyer sa demande auprès du DIP. Cette fois-ci les autorités politiques entrèrent en matière. Les certificats médicaux produits, les enseignements que Stueckelberg assurait déjà à Lausanne et Berne, et la confiance que lui accordaient le Fonds National Suisse et la Commission Atomique Suisse produisirent leurs effets. Lors de la séance du 23 janvier 1961 la faculté demandait officiellement la réintégration de Stueckelberg pour le semestre d'été pour lui confier 2 heures d'enseignement [61]. La boucle était bouclée.

Epilogue

La nomination de Joseph Maria Jauch à la chaire de physique théorique allait être finalement la bonne. Elle donna à la physique genevoise le patron dont elle avait depuis longtemps besoin: responsable de près ou de loin de la nomination de la plupart de professeurs qui constituèrent, dans les années suivantes, l'équipe de l'Ecole de Physique, Jauch façonna non seulement la théorie genevoise, mais l'intégralité de l'organisation et de la marche de l'institut genevois dans les années suivantes. On en retrouve les effets parfois encore aujourd'hui. La réussite scientifique de Jauch fut aussi considérable: grâce à ses travaux et ceux de ses collaborateurs, Genève devenait un centre important de physique théorique, en particulier dans le domaine des fondements et des applications de la mécanique quantique. Mais ceci est une autre histoire [62].

59 P. O. du 26 octobre 1959. Les multiples services que Roger Lacroix rendit durant ces années en suppléant à pas moins de trois ordinaires allaient finalement lui valoir une promotion à une charge de cours.

60 P. O. du 15 juillet 1960.

61 Enseignement « portant en particulier sur la thermodynamique, la mécanique statistique, la relativité restreinte et générale et une introduction à la théorie des champs ».

62 Je compte revenir sur cet aspect de l'histoire de la physique genevoise à une autre occasion.

Kurzmitteilungen - Short Announcements

Nachrichten der SCNAT - News from the Academy of Natural Sciences (SCNAT)

Wir berichten hier über ein einige wichtige Themen der SCNAT, die bei der Delegiertenversammlung (DV) in Bern am 23. Mai 2014 und bei der "Séance de réflexion" in Solothurn am 19. Juni 2014, unter der Leitung des wiedergewählten Präsidenten Prof. Thierry Courvoisier, diskutiert wurden.
Die Kontakte zum Parlament wurden 2013 weiter verstärkt und der Audit der SCNAT durch das Staatssekretariat für Bildung, Forschung und Innovation (SBFI) zeigte insgesamt ein gutes Ergebnis. Der Jahresrechnung 2013 kann man entnehmen, dass infolge kurzfristiger Auflösung von Reserven 2013 ein Defizit vermieden werden konnte. Künftig wird aber diese Budget-Flexibilität weitgehend entfallen. Damit bleibt das Budget 2014 auf status quo und die Rahmenkredite für die Plattformen unverändert wie im Berichtsjahr 2013. 2015 wird der erstmalig kleinere Anstieg des Bundesbeitrages insbesondere zur Vermeidung des Defizits und als Führungsmittel für den Vorstand verwendet. Aus diesem Grund wird eine Stärkung der kleinen Plattformen oder der Aufbau von neuen Schwerpunkten kaum realisiert werden können.
Die Annäherung der vier Akademien der Wissenschaft Schweiz (a+) schreitet - zwar langsam, aber doch stetig - voran. Dies dank der Bemühungen von T. Courvoisier, der auch noch a+ Präsident ist. Ein Portal Naturwissenschaften Schweiz ist im Aufbau mit anfänglich sechs Themenportalen, insgesamt sind ca. 20 vorgesehen. Jede Gesellschaft erhält als Grundangebot ein Kurzportrait. Die ersten Portale sollten im November 2014 online sein. Infolge ungenügender Sponsoring-Zusagen für die Produktionsphase des Jubiläums "200 Jahre SCNAT" musste das Projekt redimensioniert werden. Die Tournee mit dem Zirkus Knie entfällt, stattdessen ist eine kleine Tournee mit 3 Themen in 12 Städten geplant.
Für die strategische Mehrjahresplanung (MJP) 2017–2020 wurden an der DV Vorgehen und Timing vorgestellt. Die Mitwirkung der Gesellschaften ist erwünscht und Vorschläge werden bis zur nächsten DV am Freitag, 28.11.2014 erwar-

tet. Speziell interessiert, wo und wie die Mitgliedsorganisationen die Ziele der Akademie unterstützen können und mit welchen Beiträgen (weitere Infos beim SCNAT Sekretariat). Bei der "Séance de réflexion" des erweiterten Vorstands in Solothurn wurde hauptsächlich über die MJP diskutiert. Folgende Fragen wurden gestellt: Welches sind die Aufgaben/Leistungen der Foren im Vergleich zu denjenigen der Plattformen? Wie können die verschiedenen Plattformen zu den thematischen Schwerpunkten (z.B. Klima, Energie, Biodiversität, Gentechnik, Grüne Wirtschaft, Ressourcen) beitragen? Machen sie auch Politikberatung? Wie weit sind sie mit der Nachwuchsförderung (ausser Reisekostenbeiträge für die Studierenden) und mit dem Dialog mit der Öffentlichkeit? Erfreulich ist die explizite Erwähnung der SPG als eine der (wenigen) Fachgesellschaften, die mit unkonventionellen Ideen aufwartet, die zu unterstützen und zu fördern sich lohnt! So wird die Plattform MAP der SCNAT den Druck einer Studie über "The importance of physics to the economy of Switzerland" finanziell unterstützen, die mit eindrucksvollen Zahlen belegt, dass die Erfolge heute prosperierender Wirtschaftszweige auf Frühinvestitionen in Basis- und Angewandter Physik beruhen. Das wird in Zukunft noch ausgeprägter der Fall sein.

Bei der Plattform MAP sind folgende Neuigkeiten zu erwähnen: Der Schläfli-Preis 2014 wurde dieses Jahr für astronomische Arbeiten verliehen (siehe nachfolgenden Bericht), die Roadmap in den Forschungsinfrastrukturen für die Astronomie wurde abgeschlossen. Der Europäische Rat hat am 26.5. die Empfehlung des "European Strategy Forum on Research Infrastructures (ESFRI)" zur Implementierung von drei priorisierten FI-Projekten verabschiedet. Das Förderprogramm "MINT Schweiz" stösst auf grosses Interesse. 158 Gesuche sind eingegangen; zur Verfügung stehen 1,5 Mio Franken. Zurzeit läuft die Begutachtung, Zusprachen erfolgen im September, Start der Aktivitäten ist ab Januar 2015 vorgesehen. Der Rigi Workshop 2015 wird im Januar 2015 gemeinsam mit der Plattform Biologie zum Thema "Mathematical and Computational Modeling in Life Sciences" organisiert (siehe S. 54).

Christophe Rossel

The *Alexander Friedrich Schläfli Prize* honors the work of young Swiss researchers since 1866 and rotates among the different platforms within SCNAT. This year the platform MAP (Mathematics, Astronomy, Physics) was in charge and selected the field Astronomy and Astrophysics for the award. The prize amounts to CHF 5000 and can be shared by up to two researchers. In 2014 Julien Carron (performing research in cosmology) and Xavier Dumusque (working on the discovery of extrasolar planets) shared the prize. *http://www.scnat.ch/d/Preise/Prix_Schlaefli/Preistraeger/2014/index.php*

Julien Carron obtained his PhD in 2012 in the group of Prof. Simon Lilly of the ETHZ Institute of Astronomy with a thesis on "The information content of galaxy surveys". Presently he is Postdoctoral Fellow at the Institute of Astronomy at the University of Hawaii in Honolulu with Prof. Istvan Szapudi.

Spatial distribution of galaxies

The largest structures we observe in our Universe form under the action of gravity over enormous distances. The careful observations and subsequent analysis of these structures allow us to test or improve our understanding of fundamental physics, such as alternative theories of gravity and the real nature of dark energy and dark matter. In his research J. Carron contributed to shed light on how to optimally describe these structures and extract the most useful information from their observations. He could show that in cosmology traditional approaches, such as those used in the analysis of the Cosmic Microwave Background, become very inefficient when these structures grow in size, due to the very specific imprint of gravity on their statistical properties. The methods introduced by him permit the design of alternative approaches, that describe better large scale structures and how to extract information optimally in order to constrain physical theories.

Xavier Dumusque received his PhD in Geneva in 2012 in the group of Stéphane Udry with a thesis about 'Mitigating stellar signals in the quest for other Earths'. He is presently postdoctoral fellow at the Havard-Smithsonian Center for Astrophysics in Cambridge, USA.

Detection of exoplanets

During his PhD, Xavier Dumusque focused on detecting the smallest possible planets outside the Solar System. Other worlds can only be detected indirectly by observing the light of stars hosting planets, and its Doppler variation due to the joint movement of the star-planet system. However, stars are evolving as a function of time, which perturbs these observations. His work especially addressed this intrinsic noise of stellar origin (accustic oscillation modes, granulation, stellar activity) in order to find observing strategies to correct for those. This method was applied to the detection of an Earth-mass planet orbiting the second closest star to the Solar System, Alpha Centauri B, the smallest planet in mass ever investigated. Now, as a postdoc in the USA, he continues his research on the same topic, and discovered recently a planet, Kepler-10c, that seems to belong to a new class of extremely massive rocky planets. This new class is challenging present planetary formation scenarios.

The jury of the Prix Alexander Friedrich Schläfli 2014 consisted of Friedrich-Karl Thielemann, Departement Physik, Universität Basel (president), Daniel Pfenniger, Observatoire astronomique, Université de Genève; Willy Benz, Physikalisches Institut, Universität Bern; Georges Meylan, Laboratoire d'astrophysique, EPF Lausanne; and Michael Meyer, Institut für Astronomie, ETH Zürich.

Friedrich-Karl Thielemann

EPS activities

Since the acceptance of its new Strategy Plan 2010+ the European Physical Society (EPS, https://www.eps.org/) has strongly enhanced its information policy for its individual and associate members and its member societies. News and facts are published on its webpage and in particular in its electronic newsletter (e-EPS, http://www.epsnews.eu/) in addition to the traditional magazine *Europhysics News* (EPN), which publishes highlights, feature articles in physics and opinions of interest to its members. Some of the recent activities of the EPS Executive Committee and EPS Staff can also be found in e-EPS with Conference and Prize announcements. Worth to mention are the updates on the International Year of Light 2015 and on the newest EPS Historic Sites. One of the latest examples is the 600 MeV SynchroCyclotron, the first CERN accelerator built in the 1950s, and declared Historic Site during a celebration ceremony for the 60th anniversary of CERN. Also mentioned in several recent occasions is the planning of an EPS supplementary secretariat in Brussels in order to develop contacts to the EU Commission and other scientific bodies. Indeed engaging with policy makers and political stakeholders is an essential mission to defend the interests of the scientific community at large and to provide a clear voice for physics in Europe. In this context one focus will be set on the task to find some solutions to the difficult position of Switzerland with respect to HORIZON2020 and ERASMUS+. Swiss reseachers are also encouraged to favor scientific publications in european journals, starting with EPL (formely Europhysics Letters) and the series of European Physical Journals (EPJ) and the European Journal of Physics (EJP).

Christophe Rossel

Bücherecke - Le coin aux livres

Philipp Schöbi / Helmut Sonderegger (Hrsg.):

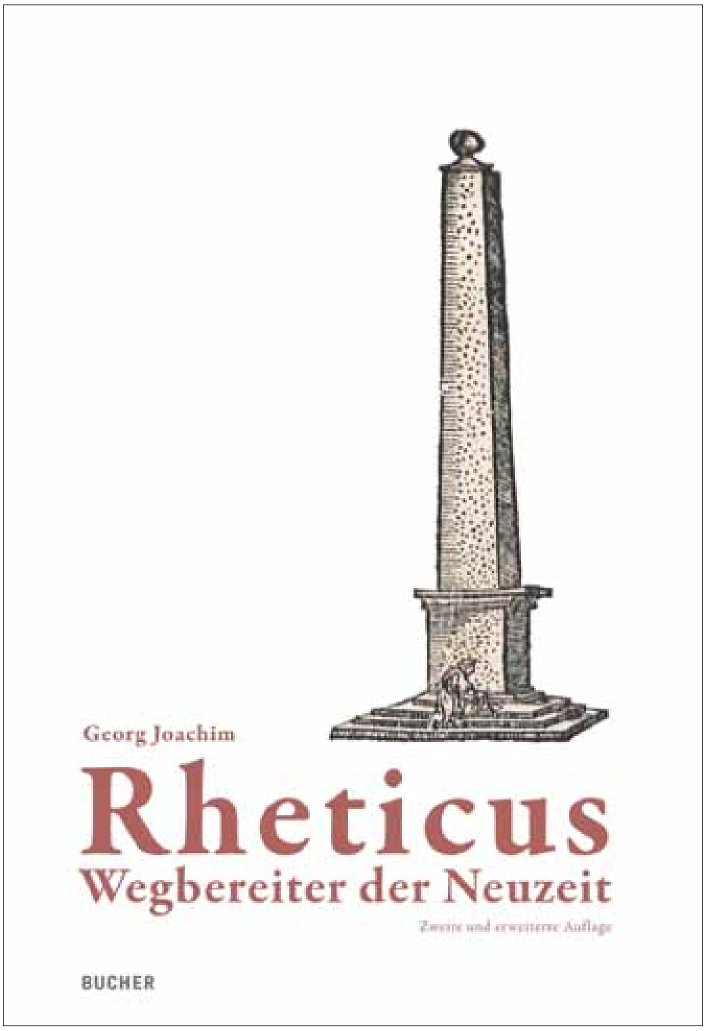
Rheticus – Wegbereiter der Neuzeit. Eine Würdigung.

Zweite und erweiterte Auflage, gebunden, 256 Seiten, Bucher Hohenems 2014, ISBN 978-3-99018-263-5

Im April dieses Jahres wurde in Feldkirch / Vorarlberg eine Neuauflage des Buches über Rheticus vorgestellt. Der Feldkircher Naturwissenschaftler Georg Joachim Rheticus, ein Zeitgenosse Luthers und Paracelsus, war der engste Vertraute von Kopernikus. Sein aussergewöhnlicher Lebensweg wurde in den SPG-Mitteilungen bereits geschildert (http://www.sps.ch/artikel/physik_anekdoten/rheticus_der_erste_kopernikaner_14/).

Die Würdigungsschrift ist eine stark erweiterte Neuauflage des 2010 erschienenen gleichnamigen Buches, erscheint beim Bucher-Verlag Hohenems und wurde durch den Grafiker Georg Vith zu einem wahren Augenschmaus gestaltet. Sie wird nicht nur 170 farbige Bilder, sondern sehr viel Neues und bisher Ungeahntes über Rheticus enthalten. Den Herausgebern Philipp Schöbi und Helmut Sonderegger war es ein besonderes Anliegen, Leben und Werk von Rheticus in einem größeren Zusammenhang und eingängig lesbar darzustellen.

Der Inhalt des Buches gliedert sich in vier Teile: 1. Einbettung in die Zeit, 2. Leben und Werk von Rheticus, 3. Ein Wissenschaftler moderner Prägung, 4. Ergänzungen und Übersichten. Nebst diversen Beiträgen der Herausgeber finden sich in der Neuauflage drei Aufsätze von Karl Heinz Burmeister, dem maßgebenden Rheticus-Forscher unserer Zeit, ein Artikel des Feldkircher Stadtarchivars Christoph Volaucnik sowie eine durch den Historiker Norbert Schnetzer aktualisierte Rheticus-Bibliografie. Der renommierte ETH-Astronom Harry Nussbaumer unterstreicht zudem mit seinem Beitrag *Ohne Rheticus kein Kopernikus* die Bedeutung von Rheticus in der Wissenschaftsgeschichte. Mit dem neuen Buch wird auch erstmals eine Zeittafel zu Rheticus vorliegen.



Jörg Hadermann, Hans Issler, Auguste Zurkinden:
Die nukleare Entsorgung in der Schweiz 1945-2006

Verlag Neue Zürcher Zeitung 2014, 200 Seiten, 74 Abbildungen, ISBN 978-3-03823-890-4

Drei unmittelbar beteiligte Persönlichkeiten haben in verdankenswerter Weise die Geschichte der nuklearen Entsorgung in der Schweiz aufgearbeitet: Hans Issler, langjähriger Direktor und Präsident der NAGRA, Jörg Hadermann, Leiter des Labors für Endlagersicherheit am PSI und Auguste Zurkinden, Leiter der Sektion Radioaktive Abfälle der HSK. Andreas Pritzker, Mitglied des Direktoriums des PSI, zeichnet für die Gesamtredaktion.

Die Geschichte der nuklearen Entsorgung ist auch die Geschichte der Kernenergie, aber nicht nur: in den ersten Jahren stammten die radioaktiven "Rückstände", wie man damals sagte, vorwiegend aus Medizin, Industrie und Forschung (MIF). Selbst für jemand, der diese Geschichte von Anfang an bewusst mitverfolgt hat, ist es zuweilen reizvoll, auf Überraschungen zu stossen, auf Ereignisse, die aus heutiger Sicht undenkbar sind: Wer kann sich vorstellen, dass in einer Industrieausstellung ein Kernreaktor einfach so zu Demonstrationszwecken in Betrieb genommen wird? So geschehen 1955 in Genf!

Die Autoren erinnern uns in ihrem Buch an viele solcher Meilensteine der Entwicklung der Kernenergie. Man nimmt erstaunt zur Kenntnis, dass die ersten abgebrannten Brennstäbe zur Wiederaufbereitung nach Frankreich und England verschifft wurden, ohne dass die Rückstände – also die hochaktiven Spaltprodukte – zurück genommen werden mussten; oder dass die schwach- und mittelaktiven MIF-Abfälle bis 1982 im Meer versenkt wurden.

Bald nach der Inbetriebnahme der ersten drei Kernkraftwerke 1969 bis 1972 zeichnete sich aber immer deutlicher ab, dass wir die Entsorgungsprobleme in Zukunft nicht mehr würden exportieren können. So gründete man 1972 in weiser Voraussicht die NAGRA, die Nationale Genossenschaft für die Lagerung radioaktiver Abfälle. Genossenschafter waren und sind bis heute die Kernkraftwerkbetreiber und der Bund, der die Verantwortung für die MIF-Abfälle übernommen hatte.

Das Protokoll der darauffolgenden Geschichte ist eine beklemmende Lektüre. Diese Geschichte ist eine Abfolge von guten Ideen, seriöser Forschung und politischen Fehlschlägen. Typisch dafür sind zwei Episoden, die schliesslich weit mehr wurden als Episoden: Die Projekte "Gewähr" (der Bundesrat wollte, dass die Lösung des Problems bis Ende 1985 gewährleistet sei) und Wellenberg, das Projekt eines Endlagers für schwach- und mittelaktive Abfälle in Nidwalden. Die Autoren schildern die Ereignisse und Etappen mit einer seltsam distanzierten Kühle, die keinen Einblick gibt in die Gefühle, die sie bei unverständlichen Bundesrats- und Volksentscheiden befallen haben müssen. Ein einziges Mal blitzt eine Spur von Sarkasmus auf: Wenn die Argumente der Gegner der beiden Wellenberg-Abstimmungen kommentarlos einander gegenübergestellt werden: In der ersten Abstimmung hiess es, man könne nicht über den Sondierstollen und das Endlager gleichzeitig abstimmen; in der zweiten, in der das Endlager nicht mehr zur Diskussion stand, man könne nicht einem Sondierstollen zustimmen, ohne zu wissen ob man dereinst zum Lagerkonzept etwas zu sagen haben werde.

Die Geschichte des Wellenberg ist typisch für die Geschichte der Bemühungen um die nukleare Entsorgung in der Schweiz, sie ist aber auch typisch für das hier besprochene Buch: Der epische Kampf um das Vertrauen des Nidwaldner Volkes ist auf gerade mal 10 Seiten abgehandelt. Das ist möglich, weil sich die Autoren auf eine technokratische Beschreibung der Projekte und den Ablauf der Ereignisse beschränken. Die Frage, wie man das Vertrauen der Stimmbürger hätte gewinnen können, respektive die Frage, wie man es verspielt hat, wird nicht gestellt, geschweige denn diskutiert.

Dieser technokratische Ansatz ist nicht nur die grösste Schwäche des Buches, er ist wohl symptomatisch für die ganzen Anstrengungen, das Entsorgungsproblem zu lösen. Sie beschränkten sich auf die technisch-wissenschaftlichen Aspekte und vernachlässigten die sozialpsychologische Seite. Die Frage ist nicht nur "wie dicht ist das Gestein?", mindestens ebenso wichtig ist die Frage "wie gewinne ich das Vertrauen der Bevölkerung?". Es gibt im Buch einen kurzen Abschnitt zum Thema Öffentlichkeitsarbeit, aber die üblichen PR-Aktionen genügen nicht, wenn das Gelingen der Aufgabe von den Gegnern mit allen Mitteln verhindert wird. Wunderbar konzipierte Ausstellungen können informieren, aber sie schaffen nicht Vertrauen. Ein herziges Männchen mit einem Bohrer auch nicht. Offenbar war man sich in all den Jahren nicht bewusst, dass die Gegner der Kernenergie in der Frage der nuklearen Entsorgung ihre Schlacht von Waterloo schlagen: Die "ungelöste" Frage der radioaktiven Abfälle ist das einzige ihnen verbliebene Argument gegen die Kernenergie. Darum darf die Lösung nicht gelingen. Man findet in diesem sonst höchst lesenswerten Buch keinen Hinweis, dass dieses fundamentale Problem jemals erkannt worden wäre und dass über entsprechende Strategien nachgedacht worden sei.

Simon Aegerter, Wollerau

150 Jahre Maxwell Gleichungen

Symposium über ein erstaunlich junges Gleichungssystem, das unser Leben prägt wie kaum ein anderes.

Samstag 11. Okt. 2014, 10:00 - 12:30

ETH Zürich, Hörsaal HG F5
Rämistrasse 101, 8092 Zürich
Haltestelle ETH/Universitätsspital

09:30 - 10:00 Eintreffen & Kaffee

Thomson, Maxwell, Lorentz and the Apogee of Classical Physics
Jan Lacki, Université de Genève

Von Maxwell zu Higgs
Thomas Gehrmann, Universität Zürich

11:00 - 11:30 Pause

Lichteinfang in Solarzellen, eine moderne Anwendung der Maxwell-Gleichungen
Rudolf Morf, Paul Scherrer Institut

Magnetlager - Maxwell in Aktion
Reto Schöb, Levitronix GmbH

Eintritt frei
Keine Voranmeldung
Gäste willkommen

$$\nabla \cdot \mathbf{D} = \rho$$
$$\nabla \cdot \mathbf{B} = 0$$
$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$
$$\nabla \times \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t}$$

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Es ist mittlerweile fast schon Tradition, dass PGZ und SPG alljährlich im Herbst ein gemeinsames Samstag-Morgen-Symposium an der ETH in Zürich ausrichten, das sich an eine breite, an Physik interessierte Zuhörerschaft richtet. Das begann 2010 mit ***Wissenschaftskommunikation im Zeitalter elektronischer Medien***, danach folgten 2011 und 2013 ***Careers for Physicists*** und dazwischen 2012 ***Die Allgemeine Relativitätstheorie und ihre Anwendungen***.

Dieses Jahr wird das 150jährige Jubiläum der Maxwellgleichungen gefeiert, wobei das Jubiläum durchaus auch um ± zwei Jahre hätte verschoben werden können. Kein anderes Gleichungssystem hat seitdem die Physiker so beeindruckt, begeistert und stimuliert wie dieses, das selbst den gestrengen Ludwig Boltzmann einst bewog, dem zweiten Teil seiner "Vorlesung über Maxwells Theorie der Elektrizität und des Lichts" (1893) als Geleitwort den abgewandelten Vierzeiler aus Goethes Faust (Der Tragödie erster Teil) voranzustellen: "*War es ein Gott, der diese Zeichen schrieb, die mit geheimnisvoll verborgnen Trieb, die Kräfte der Natur um mich enthüllen, und mir das Herz mit stiller Freud erfüllen?*"

In vier Vorträgen werden das historische Umfeld von Maxwell, der Weg zur aktuellen Elementarteilchenphysik, eine moderne Anwendung aus der Festkörperphysik und schliesslich als Beispiel für heutige Hochtechnologie das Thema Magnetlager vorgestellt.

Nachfolgend die Zusammenfassungen der Vorträge:

Thomson, Maxwell, Lorentz and the Apogee of Classical Physics
Jan Lacki, Université de Genève

The achievement of a complete theory of electromagnetism is certainly one of the most glorious episodes, not only of 19th century physics, but of the whole of physical sciences. Not only did it elegantly describe electrical and magnetic phenomena within a single framework, it did so introducing in physics a new scheme of explanation, that of fields purveyors of force, extending through space, propagating, and hence enabling non-instantaneous effects. This was a major innovation with respect to the reductionist and until then dominant mechanical distant-action way of conceiving phenomena. Such was its success that already at the end of the 19th century the "electromagnetic world view" was attempting to reduce mechanics (inertia) to field theory and this is indeed the intellectual scheme we are still in today.
The success of Maxwell's electrodynamics came as a conjunction of several bright intuitions and moves. It took Faraday's genius to concentrate, in his experimental investigations, on the physical effects in intermediate space between wires and surfaces carrying currents and electric charges, it took Thomson's mathematical virtuosity to understand that Faraday's fancy lines of force could find a mathematical description connecting them to the rich mathematical arsenal of partial differential equations.

Von Maxwell zu Higgs
Thomas Gehrmann, Universität Zürich

Die Maxwell'sche Theorie der Elektrodynamik hat einen herausragenden Einfluss auf die Formulierung der theoretischen Physik entfaltet. Die Konzepte von Ladungsträgern und Feldern wurden hier erstmals eingeführt. Die Symmetrien der Maxwell-Gleichungen führten zur Entwicklung der speziellen Relativitätstheorie und der Eichtheorien der modernen Elementarteilchenphysik. Im Rahmen der Quantenelektrodynamik gelang erstmals die Formulierung einer relativistischen Quantenfeldtheorie. Symmetrie und Symmetriebrechung in Feldtheorien haben auch 150 Jahre nach Aufstellung der Maxwell-Gleichungen eine zentrale Rolle in der theoretischen Physik, so wurde beispielsweise das vor kurzem am CERN LHC entdeckte Higgs-Boson erstmals im Rahmen eines feldtheoretischen Mechanismus der Symmetriebrechung postuliert. Dieser Vortrag gibt einen Überblick über die Entwicklung von klassischen und quantisierten Feldtheorien und diskutiert deren Einfluss in der aktuellen Forschung.

Lichteinfang in Solarzellen, eine moderne Anwendung der Maxwell-Gleichungen
Rudolf Morf, Paul Scherrer Institut

Die modernen Entwicklungen auf dem Gebiet der Nanotechnologie haben die Voraussetzungen dafür geschaffen, dass man jetzt geometrische Strukturen auf der Skala der Wellenlänge des sichtbaren Lichtes und auch noch wesentlich feiner nach Wunsch herstellen kann. Das ergibt für optische Elemente ganz neue Gestaltungsmöglichkeiten. Damit man diese für geeignete optische Funktionen einsetzen kann, gilt es Methoden zu entwickeln für die Lösung der Maxwellgleichungen feiner geometrischer Strukturen. Die dafür notwendigen mathematischen Methoden werden im Vortrag in einer auch für Nichtfachleute verständlichen Weise diskutiert.
Eine besonders wichtige Anwendung solcher Beugungsstrukturen erlaubt den Einfang des Sonnenlichtes in sehr dünnen Halbleiterschichten. Besonders interessant ist dabei die Anwendung von Beugungsstrukturen bei Halbleitern mit indirekter Bandlücke wie Silizium und Germanium. Die Absorptivität ist dabei für Photonenergien nahe der Bandlücke sehr gering, so dass Lichteinfang einen signifikanten Beitrag zur Absorption bewirken kann.

Magnetlager - Maxwell in Aktion
Reto Schöb, Levitronix GmbH

Der Magnetismus hat die Menschheit seit jeher fasziniert und die Idee, Gegenstände mit Hilfe von magnetischen Kräften schweben zu lassen, dürfte schon alt sein. 1820 wurde der Elektromagnetismus durch Oersted entdeckt und durch Argo, Ampère, Biot, Savart, Faraday sowie andere erforscht und einer formelmässigen Beschreibung zugeführt. Maxwell steht das Verdienst zu, den Elektromagnetismus in ein System von vier Differentialgleichungen zu fassen. Mit Hilfe der Maxwell Gleichungen und unter Zuhilfenahme moderner Mikro- und Leistungselektronik werden Magnetfelder so weit beherrschbar, dass sich mit ihrer Hilfe ferromagnetische Körper frei schwebend lagern und antreiben lassen. Auf der Basis solcher elektromagnetisch gelagerter Antriebe lassen sich beispielsweise Herzunterstützungspumpen oder Pumpen für hochreine Flüssigkeiten für die Halbleiter- und Pharmaindustrie herstellen.

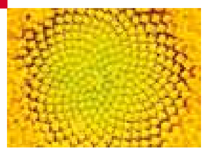
Rigi-Workshop for Young Scientists 2015

Do you use mathematical or computational models for your research? Are you interested in biological networks?

Then we warmly invite you to come to the workshop Mathematical and Computational Modeling in Life Sciences on top of Mt. Rigi (*www.rigikulm.ch*) from January 18 to 20, 2015.

Mathematical and computational modeling is becoming more and more instrumental in life sciences; the data complexity and the high number of interacting components, from molecules to animals, render intuitive reasoning very difficult. The aim of the Rigi Workshop is to present cutting-edge topics from the life sciences which require mathematical and computational modeling. The workshop is open to all PhD students (postdoctoral applications are also considered) working at Swiss universities.

Please find all details on *http://biologie.scnat.ch/rigi-workshop/*
Registration is open until September 30, 2014.



January 18 – 20, 2015, Rigi-Kulm

- **Engage in the promising research area at the interface between biology and mathematics**
- **Discuss cutting-edge results from neighbouring disciplines**
- **Meet people that can boost your own research**
- **Present your own research**

Invited speakers:

Dagmar Iber, Department of Biosystems Science and Engineering, ETH Zurich
Pattern Formation during Development: Morphogen Gradients and Turing Pattern
Patterning on Growing Domains

Christian Mazza, Department of Mathematics, University of Fribourg
Basic notions of time-continuous Markov chains with illustrations from systems biology
(signalling and metabolic pathways, chemical reaction networks…)

Oliver Ebenhöh, University of Düsseldorf
Differential equation-based dynamic models of photosynthesis and metabolism
Constraint-based models of metabolic networks

Louis-Félix Bersier and Rudolf Rohr, Department of Biology, University of Fribourg
Food Webs in an ecological environment
Stability of complex ecosystems

This 3-day course is held in English.
PhD students from all Swiss institutions of Higher Learning are most strongly encouraged to apply. Postdoctoral applications are also considered. Applicants are asked to submit a research title/abstract and a short letter of motivation for attending before September 30, 2014. The organizing committee will select 40 of the most outstanding applicants to participate in this workshop.

Organizer: Dr. Christian Mazza (Department of Mathematics, University of Fribourg), Jean-David Rochaix (Department of Molecular Biology, University of Geneva)

For further information and registration: **http://biologie.scnat.ch/rigi-workshop**

Presented by the Platforms Biology and Mathemathics, Astronomy and Physics (MAP) of

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26. bis 27. September 2014 im Schloss Pöllau

ECHOPHYSICS

Pöllauer Tage der Physikgeschichte

„Und dennoch bewegen sie sich...“


Boltzmann

Öffentliche Vorträge – Freitag, den 26. September 2014

9:00	Maxwell’s Dämon: Seine Historie und Entzauberung im Wechselspiel von Thermodynamik und Informationswissenschaften | Univ.-Prof. Dr. Heinz Krenn
9:45	Irreversibilität: Von der Boltzmanngleichung zu den Fluktuationstheoremen | Univ.-Prof. Dr. Christoph Dellago
10:30	Kaffeepause
11:00	Josef Stefan, Revolutionär und Pionier der Atomistik der Materie. Wege zum Verständnis der Bewegung der Atome | Univ.-Prof. Dr. Gero Vogl
11:45	Die „Perle“ Stefan-Boltzmann-Gesetz | Univ.-Prof. Dr. Heinrich Mitter
12:30	Mittagspause
14:00	Geschichte der Atomhypothese | Dr. Sonja Draxler und Univ.-Prof. Dr. Max E. Lippitsch
14:45	Entropie ohne Atome | Univ.-Prof. Dr. Jakob Yngvason
15:30	Kaffeepause
16:00	Das Sortieren von Atomen „One by One“ – Boltzmanns Vermächtnis in der Massenspektrometrie | Univ.-Prof. Dr. Walter Kutschera
16:45	Evolution der Kooperation | Univ.-Prof. Dr. Karl Sigmund
17:30	Umtrunk und Ausstellungsbesuch ECHOPHYSICS
19:30	Evolution gesehen durch die Brillen der Physiker und der Biologen | Univ.-Prof. Dr. Peter Schuster
20:30	Buffet

Alle Vorträge finden im Festsaal des Schlosses Pöllau statt, der Eintritt ist frei. Für Speisen und Getränke ist gesorgt.

Organisation: Peter M. Schuster, Präsident von ECHOPHYSICS

Gestaltung: Oliver L. P. Schuster

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