⟨S|P|S⟩ swiss physical society

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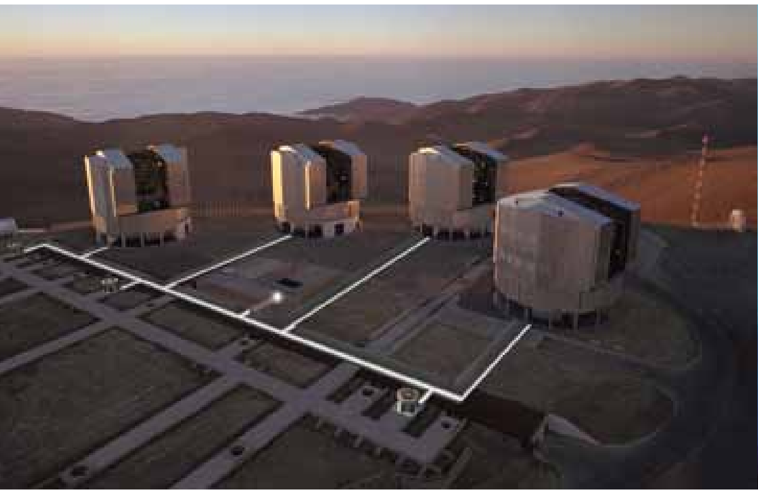
Photo: © Volker Graff

Annual Meeting of the Swiss Physical Society

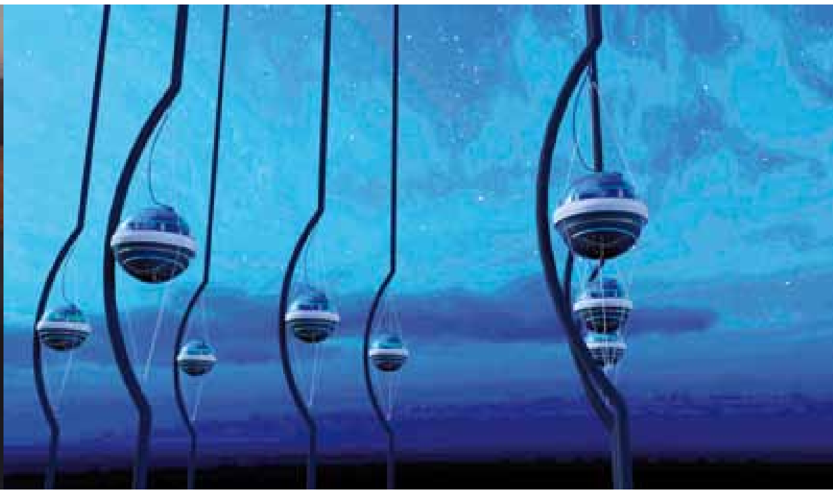
June 30 - July 2, 2014 · Uni Fribourg

Call for Abstracts: Submission Deadline March 15, 2014

More information on page 3



The ESO VLT array on Paranal Mountain in Chile performs high-resolution stellar optical interferometry. (see p. 19).
© Photo: ESO



The neutrino telescope IceCube has recently found spectacular results (p. 9) .The picture shows an artistic rendering of IceCube DOMs.
(Credit: Jamie Yang. IceCube Collaboration)

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SATW
Schweizerische Akademie der Technischen Wissenschaften
Académie suisse des sciences techniques
Accademia svizzera delle scienze tecniche
Swiss Academy of Engineering Sciences

SPS Annual Meeting 2014 in Fribourg, 30.06 - 02.07.2014

After 18 years the SPS will come back to Fribourg and hold its annual meeting in the modern "Pérolles 2" building at the Université de Fribourg, which celebrates, by the way, in 2014 its 125-year jubilee. This time the Swiss Institute of Particle Physics (CHIPP), the NCCR MUST, the Association MaNEP (emerged from the former NCCR MaNEP) and the Swiss Neutron Scattering Society will partake and thus ensure again a high quality program.
Many thanks to Prof. Antoine Weis and his local organisation team for their support.

Scientific Program

Plenary Session
Seven plenary talks, adressing latest advancements in different research fields will be presented, one starting the conference on Monday afternoon, the other six in the morning sessions on Tuesday and Wednesday.

- **Gabriel Aeppli**, PSI & ETH Zürich: *The next life of silicon*
- **Martin Beniston**, Uni Genève: *Shifts in mountain water resources in a changing climate: highlights from the EU "ACQWA" project*
- **Erwin Frey**, LMU München: *Pattern Formation and Collective Phenomena in Biological Systems*
- **Lukas Gallmann**, Uni Bern & ETH Zürich: *Attosecond science of solids and solid interfaces*
- **Teresa Montaruli**, Uni Genève: *Neutrino Astronomy at its sunrise*
- **Thomas Udem**, MPQ Garching: *Precision Spectroscopy of Atomic Hydrogen*
- **Matthias Troyer**, ETH Zürich: *Quantum Annealing and the D-Wave Devices*

Furthermore a public lecture is scheduled on Monday evening:

- **Fabiola Gianotti**, CERN: *The Higgs boson and our life*

Topical Sessions
The following parallel sessions will be held in the afternoons:

- Applied Physics
- Atomic Physics and Quantum Photonics
- Biophysics, Medical Physics and Soft Matter
- Condensed Matter Physics (KOND)
- Earth, Atmosphere and Environmental Physics
- Electronic Properties at Surfaces and Interfaces
- Frontier Experiments with Neutrons
- Functional Magnetics: From Nanomagnetism to Multiferroic Materials
- History of Physics
- Materials with Novel Electronic Properties - MaNEP
- NCCR MUST
- Nuclear, Particle- & Astrophysics (TASK)
- Plasma Physics
- Semiconductor Research in Industry
- Theoretical Physics
- Ultrafast structural and (sub)magnetization dynamics in solids

Dependent on the number and contents of the contributed papers, each topical session will be split into special thematic subsessions.

CHIPP will have its internal, non-scientific meeting on Monday afternoon, while the scientific contributions will be placed in the TASK sessions.

Poster Session

The poster session will be scheduled on 2 days, starting in the evening of June 30, in the frame of an apéro and continued on July 1st during lunch, with a buffet available (included in conference fees).

All posters are expected to be presented on both days.

The three most outstanding posters will be awarded with a "Best poster prize", sponsored by EPL journal. Additionally to the above requirement, the first author of the poster must be personally present at the conference in order to qualify for the selection. The awards will be given in a small ceremony on Wednesday.

The maximum poster size is A0 (portrait).

Award Ceremony

As every year outstanding scientific works will be honoured with the SPS awards, in the respective fields of General Physics (sponsored by ABB Research Center), Condensed Matter Physics (sponsored by IBM Zürich Research Laboratory), Applied Physics (sponsored by OC Oerlikon), and new for a work related to metrology (sponsored by METAS), each granted with CHF 5000.- .

The ceremony will be held on July 1st.

Conference Dinner

A conference dinner is scheduled for the evening of July 1st. More information will be available on the SPS web site soon.

General Assembly

The general assembly is scheduled for July 2nd, 2014. The agenda will be published in the next issue of the SPS Communications. We encourage all members to actively participate and contact the committee if special points of interest should be discussed at the assembly.

Vendors Exhibition

A vendors exhibition will be organized in parallel to the sessions. An invitation letter will be mailed within the next weeks to interested companies. If your company would like to join the exhibition, but did not receive the letter, please contact: sps@unibas.ch

Abstract Submission: Deadline March 15, 2014

You can submit abstracts to all topical sessions. The choice between an oral or a poster presentation of your contribution is possible. Due to the limited number of time slots the session organizers might however be forced to change oral presentations into posters. If possible, please mark both options in your submission. Abstracts shall not be longer than ca. 100 words, pictures are not allowed.

The submission of abstracts must be done online. Visit our webpage www.sps.ch and follow the link to the submission form. Further explanations are available there.

The full conference program will be available in May 2014 on www.sps.ch .

Conference Fees, Registration and Payment

The conference fees cover the participation to all sessions, including coffee breaks (all days), poster-apéro (Monday) and the lunchbuffet on Tuesday. One-day tickets are not available.
The conference dinner on Tuesday evening will be charged separately.

Pay your conference fee in time and save money !

The regular fees, as shown in the table below, hold for payments reaching us before June 1, 2014.

*Category (all prices in **CHF**):*	*Regular*
Non-Members	140.-
SPS Members	100.-
Members of Association MaNEP	100.-
Ph.D. Students who are NOT SPS members (*)	100.-
Ph.D. Students who are SPS members (*)	80.-
Students before Master/Diploma degree (*)	50.-
Plenary / invited speakers, awardees	0.-
Conference Dinner (**)	65.-
Special offer (see below)	150.-

(*) Students licence required
(**) free for plenary speakers

For payments made later than June 1 a surcharge of CHF 20.- will be added. This applies also for participants paying cash at the conference.

Attention: Fees are not refundable in case of cancellation.

Payments can be made to the following account:

Swiss Post - Postfinance, Account 80-8738-5, for Swiss Physical Society, 4056 Basel

If you pay from abroad, please use the following data:
IBAN: CH59 0900 0000 8000 8738 5
BIC: POFI CH BE XXX

Credit cards are not accepted.

Registration Deadline: June 1, 2014

Special offer for non-members:

Do you plan to participate in our meeting and want also to become a member of the SPS ? Then take advandage of our special offer of CHF 150.- covering the conference fees and the membership for 2014. (CHF 170.- after June 1) ! Just fill out the online-registration form, choose the option "Special offer", then download, print, fill and sign the admission form for new members, and return it as soon as possible to the SPS Secretariat.

The membership admission form is available on www.sps.ch/uploads/media/anmeldeformular_d-f-e.pdf .

(This offer does not apply for students and Ph.D. students. They still profit from the free first-year-membership and have only to pay the conference fee shown above.)

Additional information for selected sessions

KOND

The Condensed Matter section of the SPS encourages submission of abstracts to all related special sessions listed below, organized by the Association MaNEP Switzerland, the Swiss Neutron Scattering Society, and NCCR MUST. Further sessions on semiconductors, magnetism, spintronics, among others, will be organized as part of the regular KOND program.

Contact: Christian Rüegg, PSI and University of Geneva (christian.rueegg@psi.ch)

Materials with Novel Electronic Properties - MaNEP

The association MaNEP organizes a session covering all aspects of the physics of materials with novel electronic properties. A particular focus of the MaNEP program will be placed on functional magnetics and the electronic properties of surfaces and interfaces (see below).
Invited speaker: Pietro Gambardella, ETH Zürich

Contact: Félix Baumberger, Uni Genève (Felix.Baumberger@unige.ch)

Functional magnetics: From Nanomagnetism to Multiferroic Materials

The recent developments in nanomagnetism and novel magnetic materials have exploited the interplay between charge, spin, and lattice distortions in the solid state to control the properties of materials, both experimentally and theoretically. This session aims at bringing together the latest advances in the area of functional magnetics, such as multiferroic materials and interface magnetism, and to provide a forum for interdisciplinary discussions, with contributions from both invited and regular presentations.
Invited speakers: Manfred Fiebig, ETHZ, Harald Brune, EPFL and Igor Stolichnov, EPFL.

Contact: Cinthia Piamonteze (cinthia.piamonteze@psi.ch), Carlos Vaz (carlos.vaz@psi.ch), Swiss Light Source, PSI

Electronic properties at surfaces and interfaces

The session on "Electronic properties at surfaces and interfaces" will be dedicated to the newest developments and investigations of novel electronic states confined at surfaces or interfaces employing large facility based spectroscopies and other techniques. The material systems that will be covered range from thin films over oxide heterostructures to toplogical insulators.
Invited speakers: Fabio Miletto, Uni Naples and Milan Radovic, PSI.

Contact: Thorsten Schmitt (thorsten.schmitt@psi.ch), Ming Shi (ming.shi@psi.ch), Swiss Light Source, PSI

Frontier Experiments with Neutrons

The Swiss Neutron Scattering Society (SGN) is organising a focussed session on current and future use of neutron scattering as a probe in condensed matter physics. It will cover both scientific highlights and frontiers in instrumentation and source development. We particularly encourage abstract submissions from young scientists who primarily use neutron scattering for their research, whatever the topic. We hope that in this way, we will be able to present the full range of interests of the Swiss neutron scattering community. The SGN will also award its thesis medal during the session.

Contact: Tom Fennell (tom.fennell@psi.ch), Martin Mansson (Martin.Mansson@psi.ch), for the Swiss Neutron Scattering Society

Ultrafast structural and (sub)magnetization dynamics in solids

This session will concentrate on questions of ultrafast dynamics of the lattice, electronic and magnetic structure (magnetization). It covers both experimental and theoretical studies in the time window. It will bring together those who are interested in magnetization dynamics with those who are trying to understand how electronics and structure might interact on an ultrafast timescale. The NCCR MUST supports the session and contributions from outside of the NCCR are very welcome.

Contact: Urs Staub, PSI (urs.staub@psi.ch)

NCCR MUST

Contact: Ursula Keller, ETH Zürich (keller@phys.ethz.ch), Thomas Feurer, Uni Bern (thomas.feurer@iap.unibe.ch)

Semiconductor Research in Industry

Research on semiconductor physics is not only done at universities. This session wants to bring together people working in industry in order to give some insights in the range of applications and research topics done towards developing the next generation of semiconductor devices. The session will have some overview talks, but individually submitted contributions are highly welcome as well.

Contact: Kai Hencken, ABB Baden (kai.hencken@ch.abb.com)

Biophysics, Medical Physics and Soft Matter

The session will focus on topics from Soft Matter to Biological Physics and intends to bring together researchers in the fields of soft matter physics, biological physics and medical physics, bridging fundamental physics of liquids and colloidal systems with the complexity of living matter and living organisms. In complement to this session, a plenary lecture by Prof. Erwin Frey, LMU Munich on "Pattern Formation and Collective Phenomena in Biological Systems" will be held and should illustrate the wide range of phenomena encompassed by the biophysical community. During the session additional invited speakers will complement the submitted talks. A poster session will also be organized.

Contact: Giovanni Dietler, EPFL (giovanni.dietler@epfl.ch)

News from SPS Committee meetings (November - December)

Annual Meetings: At the occasion of the next Annual Meeting in Fribourg in 2014, a new section encompassing biophysics, medical physics and soft matter will be created. The next joint meeting with the Austrian Physical Society will be held on 1-4 September 2015 in Vienna.

The Bicentennial SCNAT 2015 is in preparation. There are different levels of participation for laboratories or museums to promote natural sciences to children and their parents. The aim is to reach a public that does not usually visit laboratories during open days. In addition to local events, a tour of Switzerland is planned together with the circus KNIE. The SPS has decided to contribute to the Bicentennial.

A "*Communication task force*" within the SPS Committee was created to reinforce the communication activities of SPS. Better information and publicity should aim at attracting more members. Moreover tighter links to SATW and industrial partners in general should be developed.

Lehrerfortbildung 2013: Two main events were organized in 2013, both in particle physics (*http://www.teilchenphysik.ch/cern-erobert-die-schulzimmer*). A first event with "Theory for physics teachers" took place in March in Bern followed by a visit at CERN in June. Due to the impact made on Swiss German teachers a second two-day event followed in November at CERN again. These visits triggered a "Matura Arbeit" at the Kantonsschule Sursee (LU). These events were supported by the SPS, CERN and the AGORA programme of the SNF. The SPS plans to organize once a year an event on a specific topic to bring teachers closer to the forefront of research and to share with them enthusiasm for physics. In 2014 "Modern Topics in Condensed Matter Physics" will be the theme of the event.
In the frame of the 60th Anniversary of CERN an event entitled "A Beam Line for Schools" will be organized at CERN for 16-19 year old students. Teams from schools will have the opportunity to run scientific experiments during 1 or 2 weeks (registrations are due by 31 January and written proposals are expected by 31 March 2014). The announcement is made worldwide and we are looking for a nice Swiss participation. Details on *http://www.teilchenphysik.ch/cern-laedt-schueler-zum-experiment-ein*.

Lehrplan21 (21 German-speaking cantons) produced a large amount of documents on the Physics-teaching aspects in primary schools. SPS could contribute with various information and documents. Instead of commenting on this Lehrplan, the SPS committee believes that it is more important to discuss with teachers to see how we can contribute and share our concerns.

Physics and Economy in CH: The impact of physics on economy in the EU has been assessed in an analysis published in 2013 by EPS ("The importance of physics to the economies of Europe", CEBR, EPS 2013). We are looking forward to extract the data relevant to Switzerland and to optimize its use in the Swiss field by contacting potential interested partners.

Editors, journals and societies are very much involved in the transition to *Open Access publishing*. EPS thinks there should be rules accepted by the whole communities to make this transition in a smooth way, to keep high standard in publishing and high level reviewed articles. For a number of reasons Open Access appears to be irreversible and one has to look how to make the transition the smoothest possible.

Started in Ukraine in 2009, the *International Physics Tournament* (IPT) is made for young physicists already enrolled in a university. In 2013 in Switzerland there were 10 nations participating. In 2014, IPT will be held again in Switzerland from 21-26 April.

Antoine Pochelon, SPS secretary

Careers for Physicists

Review of the Joint Symposium of SPS, PGZ, YPF, VMP, FPU and FG 14 at ETH Zürich, 20th November 2013

Kai Hencken, SPS, Physics in Industry; Rolf Kaufmann, Physikalische Gesellschaft Zürich

What are physicists doing in their professional life? What is needed in order to make the transition from university to industry and start a successful career? These are recurring questions from students thinking about leaving the academic research for an outside career. In a symposium organized jointly by the SPS, the "Physikalische Gesellschaft Zürich" (PGZ), the "Young Physicists Forum" and the student organizations of ETH Zürich (VMP), Uni Zürich (FPU) and Uni Basel (FG 14), these questions were addressed by four physicists having done this step and working now in different areas. The possibilities to work as a physicist are very large. The four speakers gave an insight into some of the areas, where physical knowledge is widely used. They did not only talk about their careers but also about the work in their field. Also the challenges of working in industry and what skills are helpful, apart from a good knowledge of physics, were discussed.

Moritz Lechner, Co-Founder and Co-CEO of SENSIRION AG described his career as a founder of a small spin-off company that developed successfully into a player in the sensor market. Besides him a large number of physicists work at SENSIRION on different tasks ranging from the simulation of sensor devices to the development of software and the management of products.

Christoph Harder, Director of the Swiss Photonics Network, has worked for many years in the semiconductor industry starting at IBM Research developing laser diodes. Being exposed to the economy can lead to swings in the size and valuation of companies, including mergers and acquisitions one needs to be aware of, when working there. In the last years he founded his own consultance agency besides acting as director of the Swiss Photonics Network.

Henrik Nordborg, Professor at the University of Applied Science Rapperswil described the different steps in his career, working first on simulations for industrial applications in different positions before becoming professor. Working with customers can be a very demanding but also a very interesting job, because it requires to quickly recognize their needs and convert them into what can be done with the available tools. Whereas physicists are always welcome when they improve our daily life, they are greeted with much more skepticism when they are delivering bad news. Physicists have to cope with both aspects.

Finally **Urs Gamper**, Specialist Magnetic Resonance Systems at Philips Healthcare showed the importance of the biophysics industry for physicists. Switzerland is the country with one of the largest percentage of companies in this area and physicists are highly welcome by them. Most of the major medical applications like x-ray or NMR have been discovered and developed into successful applications by physicists.

After an initial presentation round, the students had the possibility to discuss with all speakers at an apéro. This lead to interesting and lively conversations ranging from more detailed questions about the existing and new upcoming application fields, but also about the necessary skills to succeed in industry.

The good resonance of all participants indicated again that the series of informal meetings, initiated by the SPS-Section "Physics in Industry", is a need to facilitate the students' transfer from university to industry, and consequently will result in a follow-up meeting in 2014.

Review of the SCNAT Congress 2013

Jan Lacki, Uni Genevè; Hans Peter Beck, Uni Bern

The annual congress of the SCNAT organized November 21 to 22 in Winterthur took opportunity of this year's hundredth anniversary of Niels Bohr's celebrated quantum model of the hydrogen atom to look back at a century of marvelous discoveries. Bohr's quantum model prompted an impressive number of discoveries both theoretical and experimental, from early quantum mechanics up to the Standard Model of particle physics and beyond.

The meeting started with a historical session reminding how much Bohr's model is a major milestone in the history of quantum physics. Danish historian Helge Kragh (Aarhus University) explained Bohr's breakthrough amid other attempts at understanding at the time the structure of the atom, while his French colleague Olivier Darrigol (CNRS, Paris) emphasized the role of Bohr's model in the creation of quantum mechanics. In the afternoon the discussions moved to the present day physics of hydrogen. In the session entitled "Hydrogen beyond Bohr" Thomas Udem and Randolf Pohl (both from MPI, Garching) discussed various aspects of high precision hydrogen spectroscopy as well as the challenges presented by the study of muonic atoms. The audience was impressed to learn that hydrogen spectroscopy is a source of experimental and technological innovation as well as a testground for high precision computations challenging the very foundations of our quantum physics. In particular, both speakers emphasized the challenge of the size of the proton which, according to spectroscopical data from muonic hydrogen, does not square with current wisdom gained from standard hydrogen. After coffee break, Michael Doser (CERN) explained how to obtain anti-hydrogen using a beam of slowed down anti-protons and getting these in contact with positrons inside sophisticated magnetic and electric field traps offering new tests for CTP symmetry and gravity to be established in the near future. Ruth Durrer (Geneva University) offered an exciting overview of the role of hydrogen in the study of the past and present Universe.

Reinhard Werner (Hannover University) presented avexing public evening lecture on "Die Bohr-Einstein Debatte zur Quantenmechanik". If at the time Bohr was perceived winning over Einstein, their debate, seen from today, requires a more subtle judgment.

The next day morning started with a session devoted to various spin-offs of hydrogen physics, from atomic clocks to Rydberg atoms and their surprising uses. Jacques Vanier (Montreal University) discussed brilliantly atomic clock metrology while his young colleague Frederic Merkt (ETHZ) came back to the topic of Rydberg states of atoms and molecules. The morning ended with one of the most exciting presentations of the meeting by Nobel laureate Serge Haroche (Collège de France, Paris) who showed how entangled Rydberg atoms could be spectacularly used in investigating such fundamental issues as Schrödinger's cat in real experiments.

The closing session of the meeting was devoted to current research going beyond the strict issues linked to hydrogen, from the problem of the stability of atomic nuclei to the present challenges of high energy physics. Yuri Oganessian (Dubna) explained our current understanding of the stability line of atomic nuclei while Heinrich Leutwyler (Bern University) presented a broad overview of ideas and developments that led to the Standard Model of particle physics and concluded that despite its success much leaves to be desired. The meeting ended up in a very impressive biophysics talk given by Rienk van Grondelle (Amsterdam University) showing the intimate physico-chemical workings of photosynthesis, which filled the audience with awe at Nature's complexity.

Aimed at a scientifically educated audience, the SCNAT meeting ambitioned to make current research accessible to non-professionals while giving opportunity to experts to meet and exchange. The speakers did all a fantastic job of keeping balance between scientific rigor and laymen accessibility, with some hundred fifty listeners on average filling tightly the nice aula of Zürich University of Applied Science. There was ample room for discussion during the coffee breaks and lunches, with professionals mixing with laymen. To everybody's opinion this annual meeting of the SCNAT was a major success, both scientifically and socially.

Obituary for SPS Member Markus Büttiker

On October 4, 2013, Markus Büttiker passed away, only 63 years old. With him the scientific community of Geneva, of Switzerland, and the world of solid state physics, lost one of the most remarkable representatives of the trade. His memory was evoked at a very well attended gathering on October 15, where several speakers told about reminiscences of Markus.

Markus was born in 1950, the oldest of 8 children, in Wolfwil (Switzerland). In 1974 he obtained his diploma with Professor Baltensberger at the ETHZ. After that, he went on to study for a PhD in Theoretical Physics with Professor Thomas in Basel. Markus finished his PhD in 1978, and the subject was "Dynamical aspects in voltage-controlled current instabilities." After a short post-doc in Basel, he moved to IBM Yorktown Heights, where he stayed until his move to the University of Geneva in 1994. Now his life changed from the comfort of IBM to the realities of a Swiss University, a transition he easily adapted to. He took all the duties of a full professor with dedication and care for detail, and was an appreciated teacher for undergraduates. He also acted as head of the theory department for almost 10 years, from 1998 to 2007.

During the last few years, it transpired that he had some problems with his health, cancer, as became clear to everybody only in the last weeks of his life. While he never shared his hopes or worries with his friends and colleagues, he was happy to see each one a last time, as he understood that the end was near. He left all of us, and his wife Michelle, while maintaining a state of serenity and rationality to very end.

His untimely death leaves all of us not only with sorrow, but also with many good reminiscences.

As a scientist, he leaves a legacy of discoveries which have changed the way in which people look at the electronic properties of materials at the nano-scale, many of which have become fundamental textbook subjects. The most outstanding and far-reaching of these is the development and application of scattering theory to a huge variety of different electronic transport phenomena. For his research, Markus Büttiker received two "Technical Achievement Awards" from IBM and in 1990 became "Fellow of the American Physical Society".

One of the strengths of Markus work is the clarity of his exposition combined with the depth of his insights, qualities which make reading his work a pleasure. That was indeed the scientific power of Markus: go to the essence of a problem. With simplicity and elegance, connect basic concepts to quantities that one can measure, without un-necessary technicalities. He certainly was a master in making clear-cut predictions while developing physical intuition. That, in its essence, is what physics is about. This all happened as a quite new field was starting and Markus was laying the foundations, developing ideas that would be used over and over again.

One of us (AM) has experienced this as a young scientist starting his PhD at the Scuola Normale in Pisa. Having to learn everything from scratch--studying the existing literature step by step--"meeting" for the first time Markus was an eye-opener. Through a streak of his papers dealing with a specific problem one could rapidly learn many of the difficult concepts that were often mentioned in other papers, but that were not clear before. Suddenly, after reading and thinking about some of Markus' papers, many logical steps would become clear, in a way that seemed entirely obvious, with everything falling into place. The rewarding feeling from this experience has remained very vivid throughout all these years.

Another legacy of Markus is his school. Through persistence and care, he was able to attract exceptional students and postdocs who would learn from his way of approaching problems. He supervised about 10 graduate students, and interacted fruitfully with a much larger number of postdoctoral fellows. This became in fact the important part of his activities while in Geneva. The regular coffees (at 10 o'clock) were an integral part of his method of interacting with the group. Everybody admired the earnestness of his approach in these discussions, but also in seminars, with remarks that were always interesting and to the point. These principles of research fan out and survive him in the successful careers of those who have been in contact with him.

While he would appear as somewhat reserved, on getting to know him better, he would come across as an interested, and open person, who would always listen and share his insights. This would not only include his theoretician colleagues, but even more so, he liked to help his experimentalist colleagues.

Until the very end, Markus wanted to look forward, even when he knew that not much time was left: He was very happy that he got his Fonds National Grant, and, of course even more so that he was awarded in summer 2013 an ERC Advanced Grant, with the perspective of being able to do scientific work in a group beyond retirement. He impressed those who visited him a last time with his care for leaving plans of doing the best for each member of his group. Probably, this is the message that he really wanted to leave us, and in particular the younger ones: always look forward and never give up your plans. If one follows this idea, then his teaching achievements will remain long beyond his untimely death.

We will keep a fond memory of a friend and a brilliant colleague.

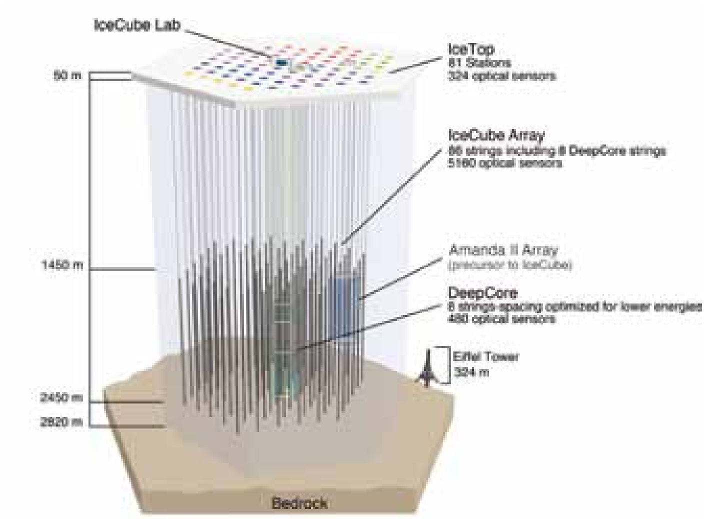
Jean-Pierre Eckmann
Alberto Morpurgo

Progress in Physics (38)

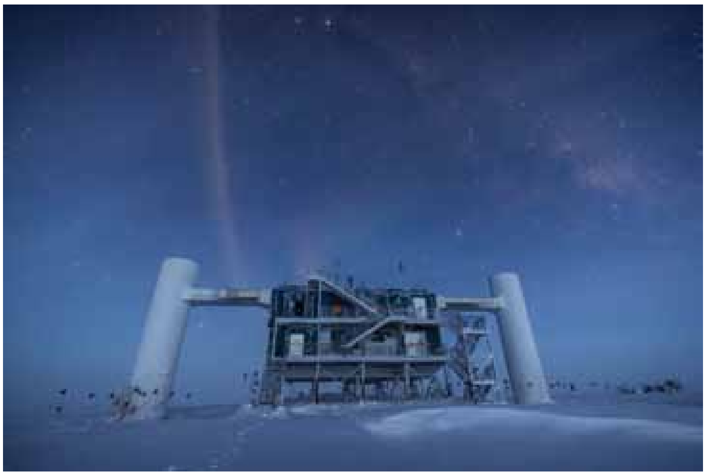
IceCube pushes neutrinos to the forefront of astronomy

Teresa Montaruli, University of Geneva, Teresa.Montaruli@unige.ch

When we think about astronomers, we picture them hidden in a dome on top of a mountain during sleepless nights. So how comes that in the news we have a telescope buried between 1.5 and 2.5 kilometers in the Antarctic ice that restlessly decodes information from the sky? What brought scientists to exploit their fantasy to the point of trying to see the far universe from the most remote location of the Earth, the South Pole?
After more than 20 years of pioneering the drilling technique in the ice and after the AMANDA detector was successfully operated at a smaller scale in the 90ies, its successor IceCube has found first signs of the most powerful messengers of the Universe: ultra-high energy neutrinos.



The IceCube Neutrino Observatory instruments a volume of roughly one cubic kilometer of clear Antarctic ice with 5,160 digital optical modules (DOMs) at depths between 1450 and 2450 meters. The observatory includes a densely instrumented subdetector, DeepCore, and a surface air shower array, IceTop.(Credit: IceCube/NSF)

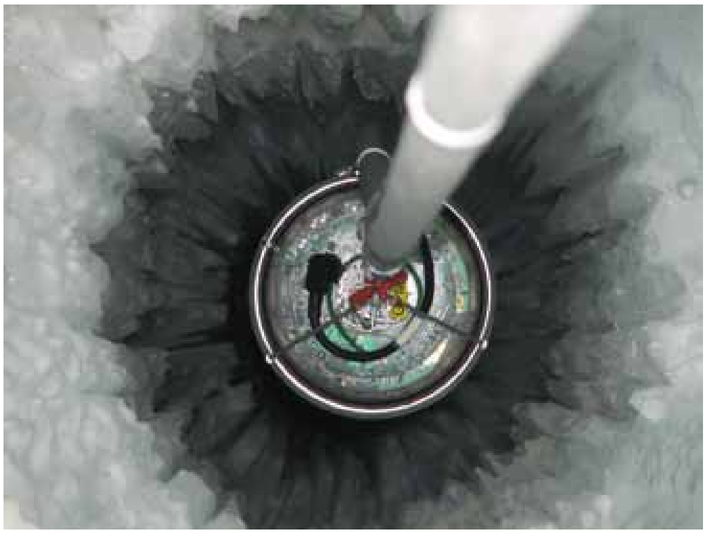


The IceCube Lab under the stars
The IceCube Laboratory at the Amundsen-Scott South Pole Station, in Antarctica, hosts the computers collecting raw data. Due to satellite bandwidth allocations, the first level of reconstruction and event filtering happens in near real time in this lab. Only events selected as interesting for physics studies are sent to UW–Madison, where they are prepared for used by any member of the IceCube Collaboration. (Credit: Felipe Pedreros. IceCube/NSF)

IceCube is huge, a cubic kilometre ice volume instrumented with 'electronics eyes' along 86 cables transporting power and data. They detect the weak blue light produced in a cone around the direction of charged particles when they travel faster than the speed of light in the medium. Rarely such light-emitting charged particles are induced by neutrinos that penetrate to the depths of IceCube. Such neutrinos are hidden between a huge amount of other particles and backgrounds and require quite an effort to be filtered out. Despite their more challenging detection, these elusive particles are potentially the most powerful messengers of the universe. They are the only possible tools we know to have the capability of traveling from the interior of sources up to the farthest regions of the observable universe.

In 1960 Greisen realized the power that these messengers could have in astronomy: they can open a new window on the non-thermal emissions of the Universe. These are not directly related to the temperature of matter in the universe but to acceleration processes in shocks caused by the death of stars, by the formation of jets coming out of black holes or by collisions of galaxies. Neutrinos provide a picture of such portions of the universe that are not accessible by messengers like the photons since they are lost on the way to us from their sources or they cannot exit the sources themselves.

Contrary to gamma-rays, which are produced also in electromagnetic phenomena associated to the presence of electrons and magnetic fields in the universe, neutrinos are signs of the presence of matter, such as protons and nuclei, accelerated in the universe. As we exploit high energy machines at CERN to learn about the fundamental properties



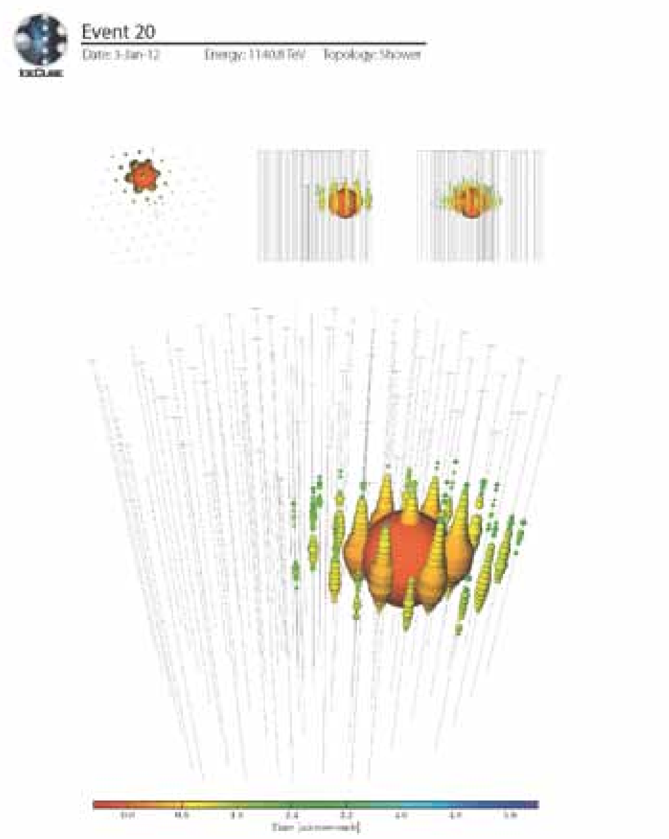
Inside an IceCube string: The deployment of each of the 86 IceCube strings lasted about 11 hours. In each one, 60 sensors (called DOMs) had to be quickly installed before the ice completely froze around them.(Credit: IceCube/NSF) of matter and the origin of the universe, similar goals can be achieved intercepting the powerful beams produced by the powerful primordial accelerators in the universe.

Once IceCube achieved its completion in 2011, the Collaboration made a huge effort to exploit the large dimensions of the detector and the powerful information recorded by such embedded photosensors with associated computers in the ice. By using background rejection techniques to eliminate particles produced in the atmosphere, 28 high-energy neutrino events of more than 50 Tera-electronvolts have been detected. The events, including two in the highest PeV energy region, cannot be explained by other neutrino fluxes, such as those from atmospheric neutrinos, nor by muons produced by the interaction of cosmic rays in the atmosphere.

The results above could be achieved only with the full detector. As a matter of fact only with a large enough detector the veto rejection technique of the atmospheric background can be successfully applied. The technique tags downgoing tracks that are typically produced by downgoing muons that are more than 5 orders of magnitude more numerous than atmospheric neutrinos. It is also capable of tagging atmospheric neutrinos, which are a dangerous background for astrophysical neutrinos, since muons and neutrinos are produced in the same meson decays in the atmospheric showers. Hence, when a muon crosses the detector, also an inner track, most probably due by a neutrino, can be tagged and rejected. This leaves more room to detect signal neutrinos directly produced in sources in the upper hemisphere of IceCube in the region above few tens of TeV. Previously we mostly used the lower hemisphere (so only one half of the sky) since we used the earth itself as a filter to select upgoing neutrinos against atmospheric muons. Now, the full sky can be covered with better sensitivity.

Once these high energy neutrino events have been collected, the analysis continued and we have achieved now a larger sample. A part of this has been unblended and is being published and another part is waiting for approval for unblinding. Unblinding is a procedure that prohibits analyzers to look into the signal region before they have selected their search criteria in order to not be biased by the desire for discovery.

By accumulating the statistics we will be able to understand better the energy spectrum of these events and to understand if they are compatible with shock acceleration in sources or with neutrinos produced in interactions of ultra-high energy cosmic rays on the microwave background left by the Big Bang. Identifying the sources is our next challenge. The ultra-high energy events produce huge light showers in the detector and it is not trivial to identify the direction with sub-degree accuracy. Nonetheless, the data acquisition system in IceCube is sophisticated and provides the full information on the time of each of the photons produced by particles. The associated charge released tells us how the energy lost by the particle distributes in time and space in the instrumented region. We have learned in time how to exploit this information better.



Event 20: 1140.8 TeV, January 3, 2012: This is the highest-energy neutrino ever observed, with an estimated energy of 1.14 PeV. It was detected by the IceCube Neutrino Observatory at the South Pole on January 3, 2012. IceCube physicists named it Ernie.

Twenty-eight events with energies around and above 30 TeV were observed in an all-sky search, conducted between May 2010 and May 2012, for high-energy neutrino events with vertices contained in the IceCube neutrino detector. (Credit: IceCube Collaboration)

Only after enough statistics will be accumulated, we will fully understand how the signal is reaching us. For the moment we know that the sunrise of neutrino astronomy has finally begun.

The IceCube Neutrino Observatory was built under a NSF Major Research Equipment and Facilities Construction grant, with assistance from partner funding agencies around the world. The NSF's Division of Polar Programs and Physics Division continue to support the project with a Maintenance and Operations grant, along with international support from participating institutes and their funding agencies. These include the University of Geneva funded by the Swiss National Science Foundation. The international collaboration includes 250 scientists.

The paper reporting the details of this scientific result is: "Evidence for High-Energy Extraterrestrial Neutrinos at the IceCube Detector," IceCube Collaboration: M. G. Aartsen et al. Science 342, 1242856 (2013). DOI: 10.1126/science.1242856, *http://www.sciencemag.org/lookup/doi/10.1126/science.1242856*

Progress in Physics (39)

Bloch meets Alzheimer

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Introduction

Has Felix Bloch ever met Alois Alzheimer? We don't know. In principle it would have been possible. If ever, they would have been open to collaboration. May be even more than researchers today fighting with the administrative hurdles and complicated, sometimes unwritten rules of todays research funding.

In fact not Bloch and Alzheimer met, but two young and enthusiastic scientists, two generations later, met at a conference ready to collaborate and mutually explore their competencies in order to fight against Alzheimer's disease. However, interdisciplinary work is not easy to initiate. In particular it is difficult to get funding without a track record in all disciplines involved. Some years later, and with the goodwill and support of many laboratories [1], the results are extremely promising. A method has been developed to monitor the progress of Alzheimer's disease right at the early beginning, which is not possible with other techniques. This method is not a diagnosis tool, but it allows studying the fundamental biochemical mechanisms involved. In addition, we can test the effect of medicaments on the disease in a short time frame.

In the following, we will summarize the basics of the Alzheimer's disease, the novel Bloch Surface-Wave (BSW) sensing concept and report our results. For further reading we refer to the literature [1].

The Alzheimer's Disease

Alzheimer's Disease (AD) is an aberrant and fatal neurodegenerative disease. As many as 35 million people worldwide are affected, hence it is the most common form of dementia. Alzheimer destroys brain cells, causing cognitive difficulties, memory loss and problems with behavior severe enough to affect work, daily-life routine and relationships even within the patient's families. (from Alzheimer 's Disease International: World Alzheimer Report 2013, http://www.alz.co.uk/research/world-report-2013).

From a pathological point of view, the presence of abnormal structures, formed by the misfolding and subsequent aggregation and deposition of specific proteins is found in the brain of AD patients. One of those structures, called amyloid plaques, are prime suspects in being in correlation with the onset of the disease. Specifically, amyloid plaques are generated by the self-assembling and fibrillization of Aβ peptides, the longest one being the Aβ 1-42, which are naturally formed by the cleavage of a neural transmembrane protein. In the AD, for factors that are still under debate, the concentration of the Aβ 1-42 peptide reaches abnormally high levels, which may be the cause for its aggregation [2].

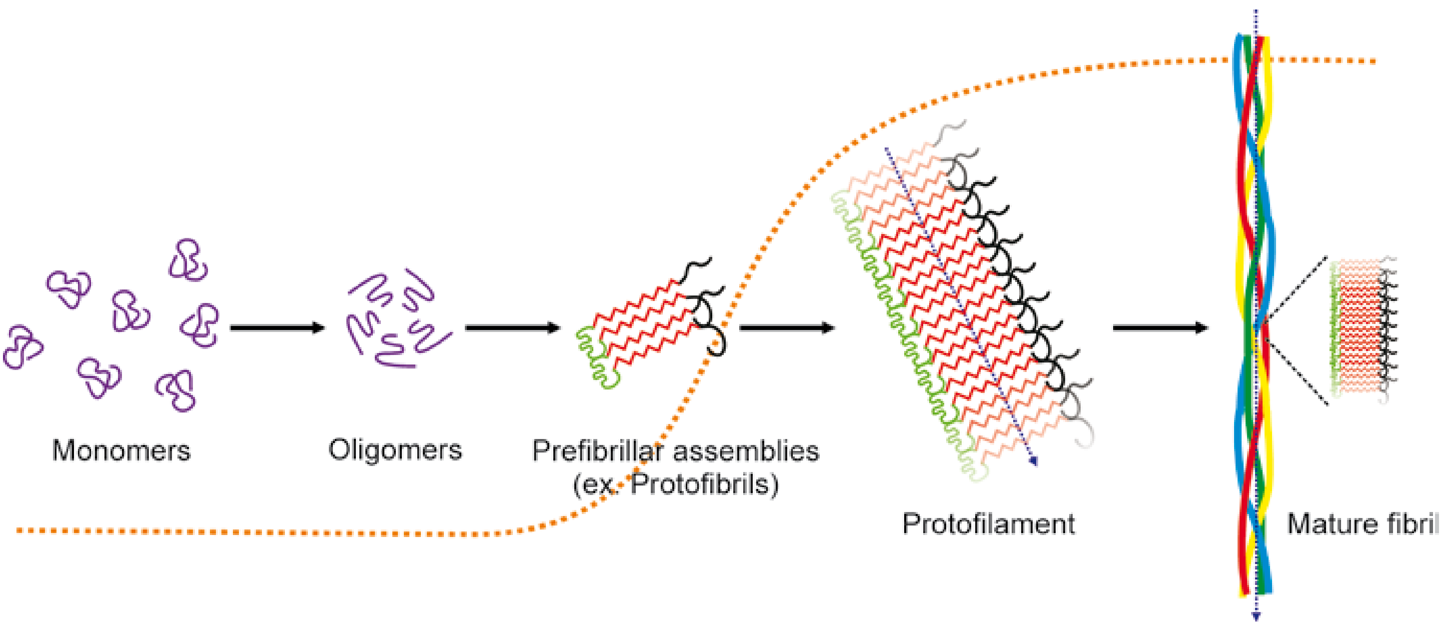

Figure 1: Schematic and simplified amyloid-beta peptide aggregation pathway. At a specific concentration and under pathogenic conditions, monomers can misfold and re-organize to form soluble aggregates commonly known as oligomers. The oligomeric complex rearrange to the prefibrillar assemblies, which are formed by the so-called beta-sheets structures (in red), typical of amyloid aggregates (petkova 2006). Two such cross-beta units comprise the protofilament, here represented in a simplified 2D-single layer. The mature fibrils are made by four protofilaments. The dotted arrow indicates the long axis of the fiber [6]. The dotted orange sigmoidal curve represents the signal obtained while monitoring the time-depending aggregation via the use of a standard amyloid detection technique (ThT binding essay, Congo Red staining, Dynamic Light Scattering, FTIR, etc.). Hence, those are not sensitive to the formation of the small, soluble and toxic oligomers, and the first part of the sigmoidal curve is commonly known as "lag-phase" [7].

Anyhow, the mere presence of this heavily dense Aβ peptide deposition is not enough to explain the neural death linked with the AD. As a matter of fact, recent research has led to the hypothesis that the neural cytotoxicity lies on the first, soluble oligomeric Aβ aggregated species, rather than on the insoluble fibrillar aggregates, forming the mature amyloid plaques [3,4]. The main occurring problem is that there are no available techniques able to reliably detect those oligomeric Aβ aggregates, since the classical amyloid detection techniques are sensitive to the mature-fibril formation and elongation (see Fig. 1), steps which occur when the AD has already started its escalation [5].

The lack of efficient and reliable diagnostic tools have seriously hampered the progress despite the application of increasingly sophisticated instruments and analytical methods. Even our understanding of the process leading from the soluble peptide to the amyloid plaques is full of gaps, sketchy at best. An enormous effort is devoted to diagnosing and treating AD without real success. The statement of Alzheimer cited at the beginning of box 1 clearly circumscribes the problem we are still confronted with almost 100 years after the initial discovery.

The Bloch Surface Wave Phenomenon

Why should we use optical surface waves to monitor the process presented in Fig. 1? Interesting is a concept that measures density variations (refractive index changes) at an interface and that is suitable for integration in a microfluidic system. The interface is the key for the proposed concept. It helps to enhance the local concentration by interactions with the molecules and generates a "clipping effect" once the molecules become too large.

It is well known that most of the bio-sensors used in proteomics are based on the exploitation of Surface Plasmon Resonance (SPR) at the surface of thin gold layers deposited on glass prisms. No other experimental method at the moment provides so much information from a single sensor [8].

The proposed platform based on Bloch Surface Waves (BSW) is an alternative biocompatible optical sensor to SPR. Exploiting the potential of surface electromagnetic waves at the surface of a one-dimensional photonic crystal (dielectric multilayer), for the first time, a BSW sensor has been applied to the *in vitro* detection of protein aggregation [1]. Such a sensor has a high potential. With the help of the photonic crystal, one can engineer the light distribution in order to generate a strong field enhancement near the interface within a desired observation zone. New performances for selectivity and sensitivity, otherwise impossible with SPR metal based sensors are delivered exploiting the variety of dielectric materials that can be used to produce the multilayer [9].

As the BSWs sustaining structure consists of dielectric materials, their losses can be made very low leading to narrower reflectance dip compared to other surface waves. Another advantage in using BSWs is the possibility of operating within a broad range of wavelengths, by properly designing a suitable multilayered structure. This tunable localized field confinement is particularly attractive for sensing applications [10].

Results

In this study [1], we present what we believe is the first demonstration of the application of a BSW-based approach to the detection of amyloid-beta peptide aggregation.

The BSW sensing detects variations in the refractive index of the media that is contact with the surface wave producer, the multilayer. The measurement consists in incubating a purified Aβ 1-42 sample in this condition, at 37°C. Hence, it is possible to monitor the variation of the Aβ 1-42 monomer concentration. In fact, during aggregation, the monomer concentration decreases, since the sensing chamber is vertically positioned and the Aβ aggregates tend to precipitate away from the sensing surface. The detectable signal is the

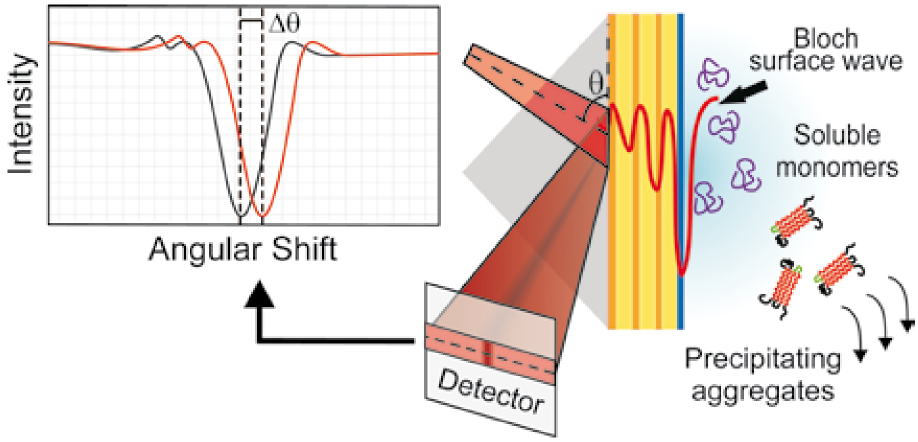

Figure 2: Schematic view of the BSW sensor. The lefts side shows the angular shift of the resonance curve due to the change of aggregation stage of Aβ 1-42 peptide measured on the right side by Bloch surface waves. [#]

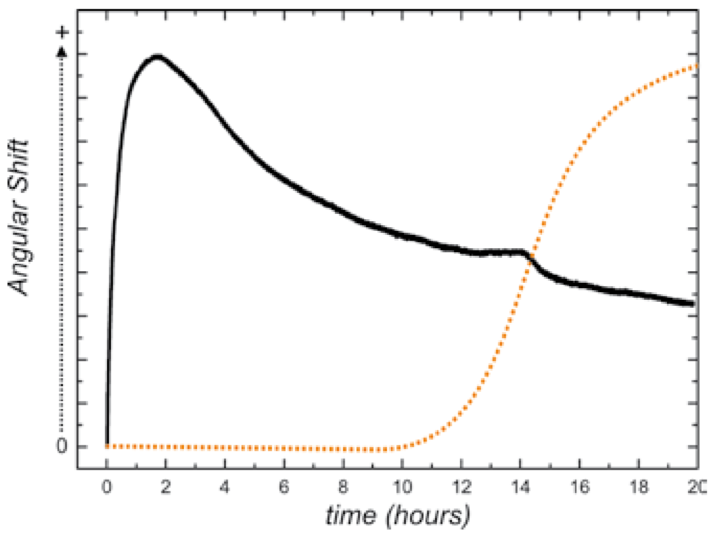

Figure 3: In black, real-time refractive index variation, in angular shift, of an Aβ(1-42) monomer peptide solution incubated at 37°C at the initial concentration of 17,3 µM in 10 mM Tris HCl, pH 7.4, as sensed by the BSW-based sensing approach. The dotted orange sigmoidal curve represents the signal obtained while monitoring the time-depending aggregation via the use of a standard amyloid detection technique, as represented in Figure 1. The two signals are obtained in the same time frame. [#]

Alois (Aloysius) Alzheimer (14.6.1864 – 19.12.1915)

Citation from Alois Alzheimer on Epilepsy: "*If we aim to understand the nature of a disease, to predict its prognosis, to elucidate its course and finally treat it prophylactically or therapeutically, we must have clear, precisely defined disease entities before us.*" [1]

Alois Alzheimer born in the Bavarian town of Marktbreit studied medicine between 1884 and 1888 in Berlin, Tübingen and Würzburg. During his career he has contributed equally to the development of modern clinical services for psychiatry as to the development of neuropathology. In 1888 Alzheimer started his career in the *Städtischen Anstalt für Irre und Epileptische* in Frankfurt am Main "working during the day with the patients and spending the evenings over the microscope" [2]. Alzheimer collaborated during this period with important experts in the developing fields of psychiatry, neuropathology and neurohistology making himself major contributions. In 1901 he met the 51 old patient, Auguste Deter, "who suffered from impaired memory and finally lost most of her higher mental functions". Deter died in Frankfurt in 1906, when Alzheimer was already working in München as scientific assistant (equivalent today to an assistant professor position) first and then as associate Professor of the well-known Professor Kraeplin dedicating the whole of his time to the work in his research laboratory. Alzheimer had kept the contact to the clinic, so that he could study Deter's brain identifying the amyloid plaques and neurofibrillary tangles using silver staining techniques. On the 3rd of November 1906 Alzheimer presented in Tübingen side by side the pathology and the clinical symptoms of presenile dementia [2]. This case marks the beginning of the Alzheimer's disease research. Most of the hallmarks of Alzheimer's disease were already described in this first study. In 1912 he was appointed as Full Professor of Psychiatry at the University of Breslau. On the way to Breslau he fell ill and never completely recovered. Alzheimer died at the age of 51 as a result of heart failure.

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[2] K. Maurer and U. Maurer, Alzheimer: The Life of a Physician and Career of a Disease. 2003, New York: Columbia University Press. 256 p.

shift of the resonance angle at which the evanescent wave is generated, as imaged on the detector array (see Fig. 2).

Figure 3 presents the real-time monitoring curve describing the variation of the refractive index, expressed in angular shift, correlated to the aggregation dynamics of the Aβ 1-42 peptide. A positive angular shift corresponds to an increase of the refractive index of the solution, vice versa, a negative angular shift corresponds to a decrease of the refractive index of the peptidic solution. One can notice that the signal decreases while the monomer concentration is depleted during the aggregation. On the other hand, a positive angular shift is reported at the very beginning of the measurement. We explain this event with the adsorption of the Aβ 1-42 peptide onto the sensing multilayer surface, which leads to a local increase of the refractive index, as sensed by the BSW.

This surface loading effect was further investigated [1]. We verified that the adsorption mechanism does not fully shield the monitoring of the Aβ 1-42 fibrillization that takes place in the bulk. Moreover, the adsorption mechanism itself occurs in the presence of prefibrillar aggregates. Specifically, we reported no appreciable surface loading in the presence of Aβ 1-42 mature fibrils, which were incubated in the sensing chamber under the same conditions as the initially mon-

Felix Bloch (23.10.1905 – 10.09.1983)

Felix Bloch was a Swiss physicist born at the beginning of the 20th century who contributed to the development of NMR, and for which he was awarded the 1952 Nobel Prize for "his development of new ways and methods for nuclear magnetic precision measurements", together with Edward Mills Purcell [1].
Bloch studied physics at the Federal Institute of Technology (ETH) of Zürich, where he had the extraordinary chance to attend courses given by, among others, Debye and Schrödinger. It was thanks to those names that he became aware of the new wave mechanics, a subject that he would never set aside during his whole life. For his PhD, Bloch studied with Heisenberg at the University of Leipzig, gaining his doctoral degree in 1928 with a thesis on the quantum mechanics of electrons in crystals, which established the quantum theory of solids. This thesis defined the well-known Bloch waves as a wavefunction for an electron in a crystal.
Other important names surrounded him during the continuation of his career, influencing Bloch's way to see and describe nature. He was working with Wolfgang Pauli in Zürich, Niels Bohr in Copenhagen and Enrico Fermi in Rome, before he went back to Leipzig to Heisenberg, assuming a position as lecturer.
With the ascent of Hitler in 1933, due to his Jewish origins, Bloch decided to leave Germany for the US, where he started working at Stanford University. Bloch's work in the new continent laid the basis for the development of the modern NMR, which is daily used in the form of MRI in medical diagnosis.
In 1954, almost 10 years after the end of the Second World War, Bloch returned to Europe. He worked as the first general Director of CERN, in Geneva. This European parenthesis did not last long, since he soon returned to Stanford in 1955, where he carried on his investigation on nuclear magnetism.
Felix Bloch died in 1983 in Zürich, at the age of 77, after spending a life devoted to modern (and future) physics.

From: Nobel Lectures, Physics 1942-1962, Elsevier Publishing Company, Amsterdam, 1964.

[1] M. Sohlman, (Ed.) Nobel Foundation directory 2003. Vastervik, Sweden: AB CO Ekblad; 2003.

omeric Aβ 1-42 sample. Moreover, we incubated Aβ 1-42 protofibrils at a concentration around 4 times higher than the initial concentration for the Aβ 1-42 initially monomeric sample, and the surface loading phenomenon extent, as sensed by the BSW, was dramatically minor.

These evidences allowed for the conclusion that the species that are strongly adsorbed onto the multilayer oxi-nitride surface have to be in a precise pre-fibrillar conformation, with a lower molecular weight than the average weight attributed to protofibrils [1]).

Conclusion

Combined with the spread of techniques prone to cure it, this biosensor has great prospective for the future. Our work demonstrates that an integrated approach based on biophysics, biochemistry and use of novel photonic detection methods will decisively contribute to elucidate the molecular processes involved in the early dynamic events of protein aggregation and fibrillogenesis.

Exploiting the use of this innovative real-time biosensing approach, it is possible to monitor the refractive index variation of an Aβ 1-42 peptide solution during its aggregation. We were able to indirectly monitor the formation of Aβ 1-42 fibril and, more interestingly, to cover the first steps of the amyloid aggregation pathway, which comprises the formation of the first toxic oligomeric species.

The precise identification of the Aβ 1-42 species interacting with the surface is yet to come. Nevertheless, we proved that the adsorption/desorption mechanism is specific and occurs during the time lapse corresponding to the so-called lag-phase, which is silent when investigated with the classical amyloid detection techniques.

This consideration opens the application of this BSW based approach to the direct in vitro screening for molecular factors that influence the oligomerization process. We expect a variation in the timing for the adsorption/desorption mechanism, in addition to a variation in the rate of the refractive index diminution during the fibrillization phase.

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[#] The figures are partial and simplified versions of the originals, which can be found as referenced [1].

Progress in Physics (40)

Crystallography at SLS, SINQ and SNBL

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Each year, the United Nations' Organization pays special attention to a field of great importance to society. Scientific topics were repeatedly in their focus: 2010 the biological diversity, 2011 chemistry, and next year, 2014, crystallography. The opening ceremony for the International Year of Crystallography[1] will be held on January 20 and 21, 2014 (IYCr2014) at the UNESCO headquarters in Paris. The International Union of Crystallography takes the lead in the organization of IYCr2014. The activities in this year complement the celebration in 2012 of the 100th anniversary of the discovery of Bragg's Law and pay tribute to the many Nobel prizes awarded to crystallographic research. Below we provide a selection of recent results obtained at the large facilities of Paul Scherrer Institute, PSI (SINQ and Swiss Light Source) and at the Swiss-Norwegian beamline of the European Synchrotron Radiation Facility, Grenoble, France.

1 Swiss activities for the UN year of crystallography: *http://www.sgk-sscr.ch/iycr2014-2/*

1D to 2D Na ion diffusion linked to structural phase transitions

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[1] Paul Scherrer Institute, Villigen, [2] Toyota Central R&D Labs, [3] Aichi, CROSS, Ibaraki, Japan, [4] ETH Zürich

Lithium ion batteries are highly efficient and provide electrical energy for laptops, mobile phones and lately also for a growing market of electric cars. One of the drawbacks of this technology is the low abundance of lithium on our planet (20 ppm in the Earth's crust), which makes the material expensive. A possible alternative might be the replacement

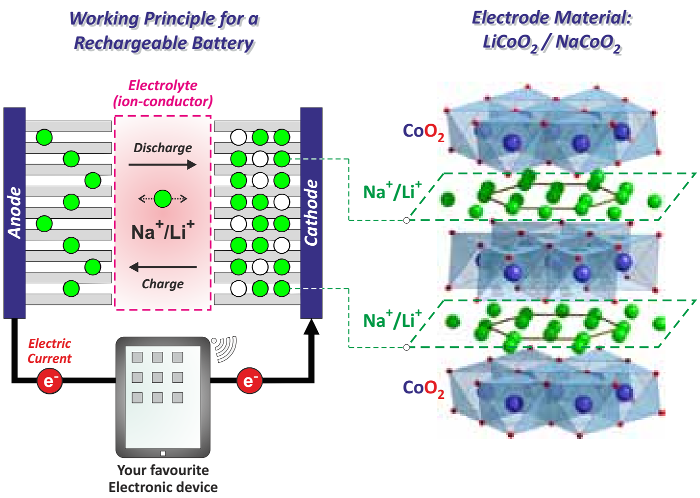

Fig. 1: Working principle of a Li^+/Na^+ battery.

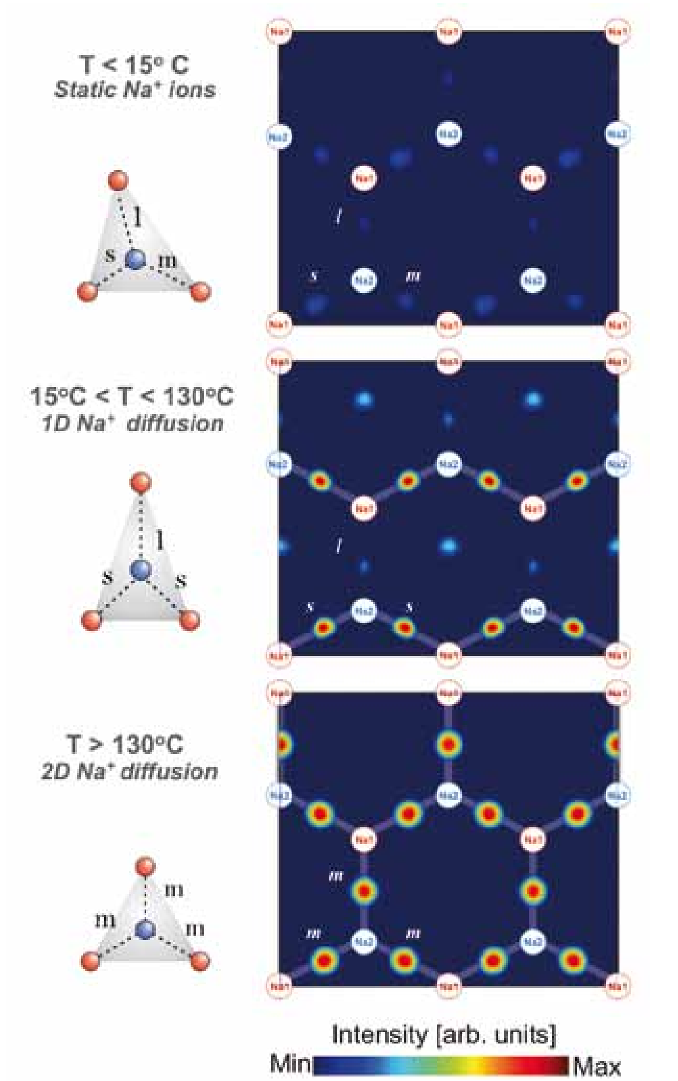

Fig: 2. Na^+ diffusion paths in $Na_{0.7}CoO_2$. Left panels: Na-Na distances at different temperatures in one of the Na layers (distortions enlarged). Right panels: residual scattering between the Na ions as determined from Fourier differences. The Na1/Na2 labels indicate the positions of the Na^+ ions in the layer. The paths chosen by the Na^+ ions during the diffusion process appear as red spots. At low temperatures (T < 15 °C) no red spots are visible, indicating that the Na ions are fixed to their positions. Between 15 and 130°C they move only along one-dimensional paths corresponding to the shortest Na-Na distances (labeled as 's' in the figure). Above 130°C all Na-Na distances (labeled as 'm') become identical and the Na^+ ions have enough energy to move within the whole layer [2].

of lithium for sodium [1] – an element with similar chemical properties but much more abundant, both in the Earth's crust (20'000) and in sea water (16'000 ppm). Sodium is bigger and heavier than lithium, resulting in larger batteries with reduced energy densities. However, this is not a significant drawback for stationary applications such as the storage of peak energy in solar panels or wind mills.

Charging and discharging of batteries occurs via Li^+/Na^+ ion migration in and out of the battery electrodes (Fig. 1). Therefore, in order to be able to develop the necessary sodium-based batteries, it is crucial to understand how sodium ions move within the relevant materials. An example of how crystallographic studies contribute to this fast growing, economically relevant field is provided by a recent investigation on the prospective cathode material $Na_{0.7}CoO_2$, built up from alternating atomic layers of cobalt oxide and sodium ions (Fig. 1 and [2]).

The experiments were carried out using the powder diffractometer HRPT at the Swiss spallation neutron source SINQ, Paul Scherrer Institute. The results visualized for the first time the paths along which Na ions move in this material (Fig. 2 and [2]). In addition, it was shown that these paths change considerably with temperature due to subtle changes in the crystal structure: below 15°C, the sodium ions can hardly move; between 15 and 130°C they move only along 1-dimensional zig-zag paths corresponding to the shortest Na-Na distances; at still higher temperatures (T > 130°C) all Na-Na distances become identical and the Na^+ ions have sufficient energy to move within the whole layer. That is, the character of the Na motion changes abruptly from one to two-dimensional as the temperature increases above 130°C [2]. One may now consider ways of optimizing the material's properties for energy storage, e.g., by slight modification of their structure or composition.

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Inversion centers and ferroelectric materials

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Materials with ferroelectric and magnetically ordered ground states have been known for more than forty years [1]. For a long time it was thought that such materials are quite rare, because one of the dominant mechanisms for ferroelectricity relies on empty d-shells on the transition metal ions, which naturally precludes magnetism. In the past decade, substantial progress has been made towards the identification of new magnetically ordered ferroelectrics, also called multiferroics. Different mechanisms have been identified such as the lone-pair activity of Bi in $BiFeO_3$, geometric effects in hexagonal rare-earth manganites and barium fluorides, and magnetically induced ferroelectricity. While in the first two mechamisms the onset of ferroelectricity and magnetic order occurs at vastly different temperatures, magnetically induced ferroelectricity features coupled magneto-electric phase transitions.

One of the very first materials for which magnetically induced ferroelectricity was demonstrated, is $TbMnO_3$ [2]: experiments using TriCS at PSI show that the magnetic structure is an incommensurate spiral that breaks inversion symmetry and thus generates ferroelectric polarization [3]. There are two magnetic phases: the high-temperature magnetic structure is described by only one irreducible representation, and has inversion symmetry. The low-temperature magnetic structure is described by two irreducible representations and breaks inversion symmetry precisely in a way that allows for ferroelectricity along the c-axis. This identification has been an important step in the understanding of this type of materials.

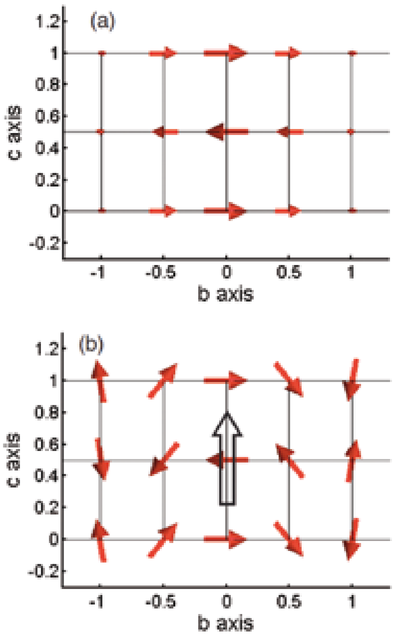

Fig. 1. Schematic of the magnetic structure of $TbMnO_3$ at (a) T=35 K and (b) T=15 K, projected onto the b-c plane. Filled arrows indicate direction and magnitude of Mn moments. The longitudinally modulated phase (a) has a point of inversion while the spiral phase (b) does not. Hence, electric polarization indicated by the unfilled arrow is allowed in (b) but not in (a). Data were collected on the TriCS diffractometer at SINQ [3].

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[3] M. Kenzelmann, A. B. Harris, S. Jonas, C. Broholm, J. Schefer, S. B. Kim, C. L. Zhang, S.-W. Cheong, O. P. Vajk and J. W. Lynn, Phys. Rev. Lett. **95**, 087206 (2005).

Protein micro-crystallography at the SLS

M. Wang, Paul Scherrer Institute, Villigen

During the last decade protein crystallography has been revolutionized at third-generation synchrotron radiation facilities by the development of undulator beamlines with a high-degree of automation. The recent upgrade of protein crystallography beamline X10SA at the SLS has successfully delivered a 10 × 10 µm² sized X-ray beam (Fig. 1) with a high flux density by combining beam shaping apertures and a smaller undulator gap. Sub-micron precision in both sample rotation and translation has been reached with a new micro-diffractometer. In addition, the highly sensitive and

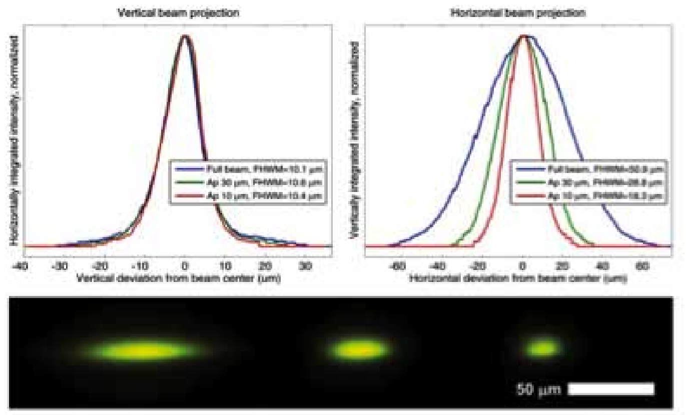

Fig. 1: Top left: Vertical beam projections obtained by integrating the intensity at the beam spot in the horizontal direction. Top right: Horizontal beam projections. Bottom row from left to right: Full beam, and beams through the 30 and 10 µm apertures, imaged by the on-axis sample microscope on a YAG:Ce scintillator screen.

noise-free pixel array detector PILATUS 6M has been upgraded to reach a 25 Hz frame rate. The micro-beam, precision sample stage and faster X-ray detector have enabled development of a new fast 2D scanning routine (grid-scan) for identifying the best diffracting parts of crystals and locating micro-crystals in a high-throughput manner.

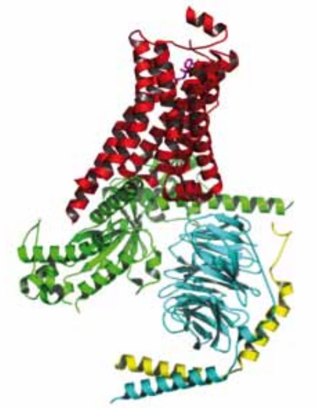

Fig. 2. Crystal structure of activated beta-2 adrenergic receptor in complex with Gs. The receptor is colored red, Gα green, Gβ cyan and Gγ yellow. T4 Lysozyme and nanobody, which were used to facilitate crystallization, are omitted for clarity. Rendered from PDB entry 3SN6.

A micro-beam with grid-scan capability is essential for membrane protein crystallography because crystals of membrane proteins are often very small (<10 microns) and often impossible to visualize due to the lipidic cubic phase (LCP), which turns opaque upon cryo-freezing. The LCP crystallization methods have been applied successfully in crystallizing G-protein coupled receptors (GPCR) and their complexes (Figure 2) – a large family of membrane proteins, which are the targets of one third of available therapeutic drugs on the market. The micro-crystallography developments at the SLS have recently enabled two international pharmaceutical companies to determine their very first membrane protein structures with crystals grown in LCP.

Crystallography of nanoparticles

A. Cervellino, N. Casati, Paul Scherrer Institute, Villigen

Structural features of nanoparticles (NPs) are investigated at the Materials Science beamline of the Swiss Light Source (SLS). Having recently been upgraded, this beamline delivers undulator radiation for X-ray powder diffraction (XRPD) and surface diffraction experiments in a continuous energy range from 5 to 35 keV [1]. The powder diffraction station is fitted with highly efficient Mythen II detectors [2], having capability for simultaneous (time-resolved) SAXS-WAXS experiments. In particular, so-called total scattering methods have been applied at this station to investigate structural features of NPs with unprecedented accuracy. For example, the structure of Fe_2O_x (x=2.67–3) NPs, prepared as magnetite and partly oxidized under different conditions, has been determined. It was shown that they consist of a magnetite core with a shell of partly ordered magnetite and possibly – if an amorphous hydroxide precursor was used – a residual surface layer of amorphous hydroxide. The relative depth of the oxidized layer shows a dependence on particle size (Fig. 1). Magnetic properties associated to these NP systems have also been measured and correlated with the determined structural features [3].

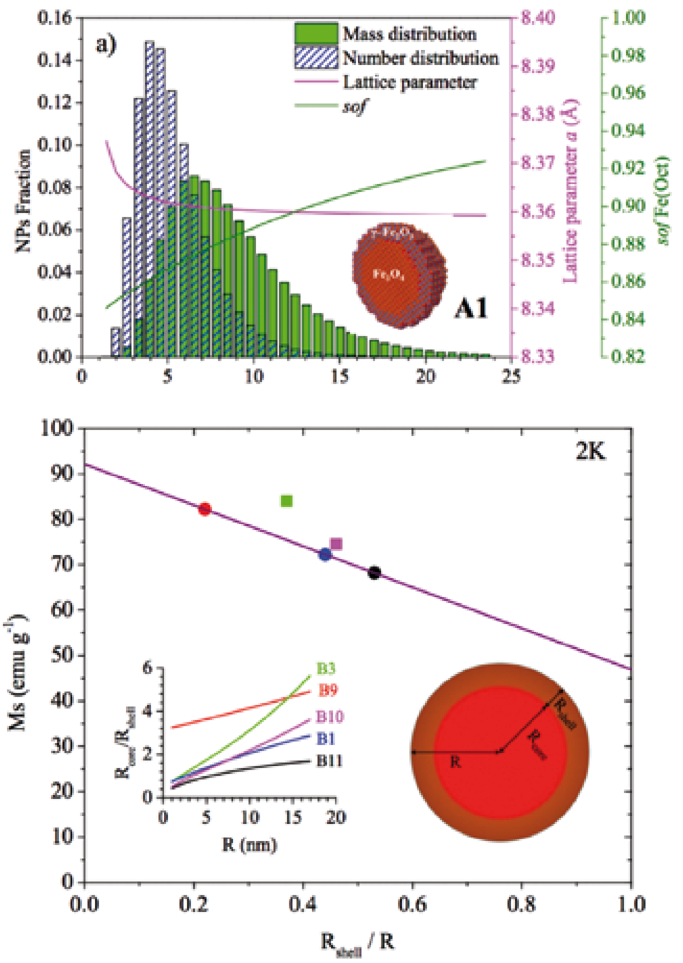

Fig. 1. Fe_2O_x NP oxidation and magnetism. Above: Number- and mass-based size distributions for the sample A1. Solid lines depict the size-dependent lattice parameter (purple curve) and sof of Fe(oct) (green curve). NPs consist of a Fe_2O_3 core and an oxidized Fe_3O_4 (maghemite) shell. From ref. [3]

Another example is the crystallization of calcium phosphate (hydroxyapatite) [4]. Starting from an amorphous precursor, the role of citrate anions in defining the shape of crystallizing apatite NPs was studied. Their shape breaks the hexagonal symmetry of the crystal lattice and this type of symmetry breaking is crucial to understanding the biological process of bone formation.

[1] P. R. Willmott et al., J. Synchrotron Rad. (2013). **20**, 667-682.
[2] A. Bergamaschi et al., J. Synchrotron Rad. (2010). **17**, 653-668.
[3] R. Frison et al., Chem. Mater., 2013, in press.

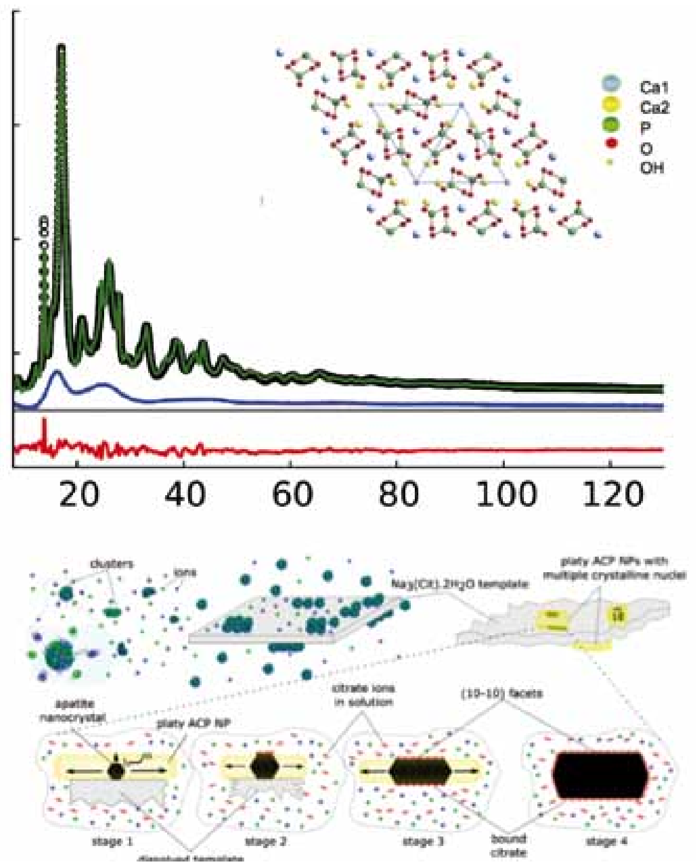

Fig. 2. Crystallization of hydroxyapatite in the presence of citrate. Above: XRPD pattern fit as an ensemble of NPs. From this, the size and shape distributions of several samples at different maturation times have been determined. Below: schematic of the symmetry-breaking crystallization process of hydroxyapatite from an amorphous precursor in the presence of citrate. From ref. [4].

[4] J. M. Delgado-López et al, Adv. Func. Mater. (2013). DOI: 10.1002/adfm.201302075.

Diffuse scattering: Structural information between the Bragg spots

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Both Norway and Switzerland have relatively large and exceptionally active scientific communities using X-ray diffraction and absorption. To overcome the limited supply of synchrotron beamtime available at large-scale facilities, the Swiss and Norwegian scientists formed in 1990 a consortium and obtained access to a bending magnet port at ESRF with two branch lines: one dedicated to single-crystal diffraction and the other to powder diffraction, EXAFS and topography. Since the start of operation, more than one thousand publications have appeared using data from the SNBL, making it one of the most successful beamlines at ESRF.

While initially the emphasis was on the investigation of pharmaceutically relevant materials, the main focus of activity is now oriented towards energy-related research. Instrumentation development targeted at in-situ experiments

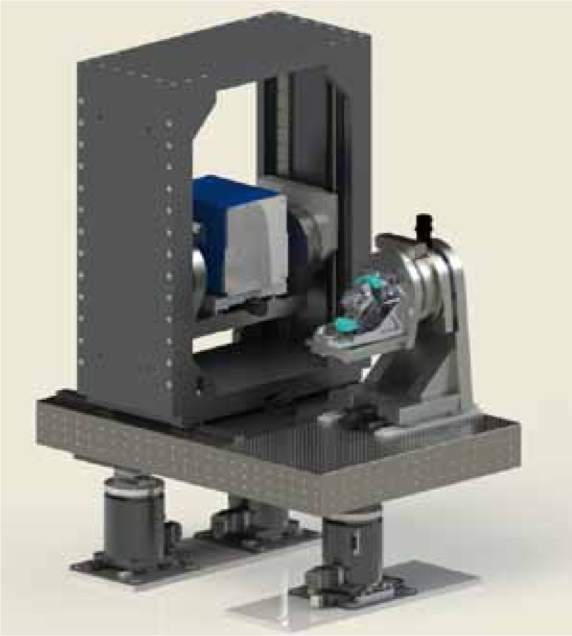


Fig. 1: Layout of the SNBL diffractometer with the new PILATUS detector from DECTRIS/Baden, Switzerland.

has also been an important aspect of the beamline work in recent years, particularly for studying catalytic reactions and hydrogen storage. A recent example [1] illustrates the use of combined powder diffraction and x-ray spectroscopy to investigate the concept of inverse sigma transformation of a zeolite framework to generate a new structure by removal of a layer of framework atoms. For single-crystal experiments, users have exploited either the characteristics of a large area image plate detector or of a CCD detector mounted on a multi-axis diffractometer. Very recently, the image plate system has been replaced by a hybrid pixel array detector of the latest generation (a PILATUS 2M detector supplied by Dectris Ltd, Baden) mounted on a very flexible and versatile diffraction platform. The diffractometer with the PILATUS detectors is shown in Fig. 1. One of the scientific areas for which the new setup is particularly well suited is the investigation of diffuse X-ray scattering in single crystals. For example, a group led by Alexander Tagantsev from the Ceramics Laboratory of EPFL has investigated the lattice dynamics of antiferroelectric lead zirconate using inelastic and diffuse X-ray scattering techniques and Brillouin light scattering [2]. The diffuse X-ray scattering patterns together with the modelled distribution are shown in Fig. 2. The results show that the antiferroelectric state is a 'missed' incommensurate phase and that the paraelectric to antiferroelectric phase transition is driven by the softening of a single lattice mode via flexoelectric coupling. These findings resolve the mystery of the origin of antiferroelectricity in lead zirconate and suggest an approach to the treatment of complex phase transitions in ferroics.

The combination of high brilliance and high x-ray energies provided by the bending magnet source at the ESRF also allows the users of SNBL to investigate the effects of high pressure with diamond anvil cells. A most unexpected and puzzling phenomenon that can be observed under high pressure, is negative linear compressibility. In a collaboration between the beamline staff and the University of Oxford [3] it was possible to reveal that the molecular framework material $Zn[Au(CN)_2]_2$ exhibits the most extreme

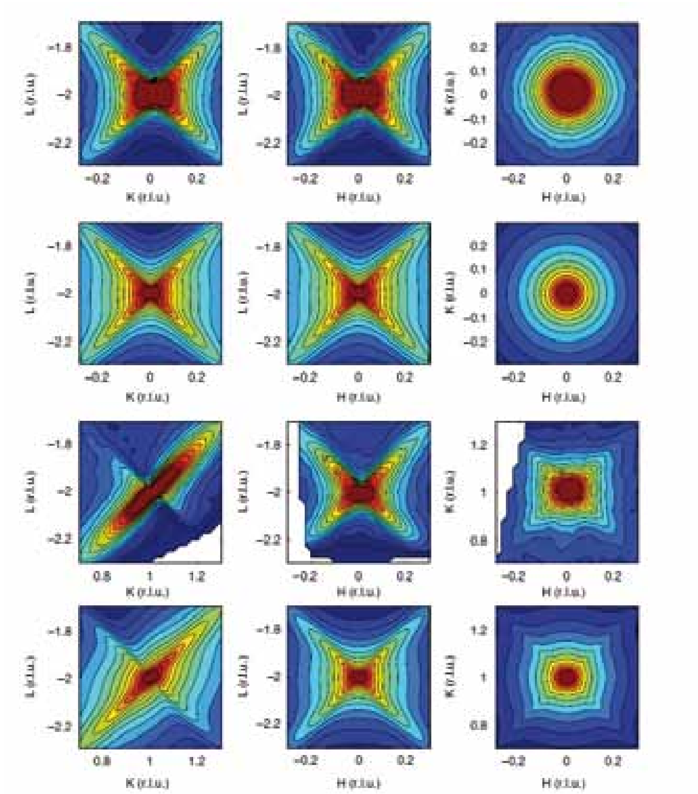


Fig. 2: Diffuse X-ray scattering patterns around the (0,0,-2) and (0,1,-2) reciprocal lattice points in lead zirconate at 550 K. Rows 1 and 3 show the experimental patterns, rows 2 and 4 the theoretical ones [2].

and persistent negative linear compressibility behavior yet reported: under increasing hydrostatic pressure its crystal structure expands in one direction at a rate that is an order of magnitude greater than the typical contraction observed for common engineering materials. In these and similar studies, it is the combination of the excellent characteristics of the source and the high performance of the new generation of pixel detectors that opens up many exciting avenues of research in the fields of solid state physics and crystal chemistry using synchrotron radiation.

[1] E. Verheyen et al., Nature Materials, **11**, 1059–1064 (2012)
[2] A. K. Tagantsev et al., Nature Communications, **4**:2229 (2013)
[3] Andrew B. Cairns et al., Nature Materials, **12**, 212–216 (2013)

Outlook

The complexity of materials requires a combination of probes and studies over a wide range of length, energy, and time scales in order to be able to investigate their structural, electronic and magnetic properties. While these studies are of fundamental interest and increase our understanding of the complex correlations and interactions that are at work in such systems, materials are essential for technological applications ranging from IT devices to energy harvesting and storage. Of equal importance is macromolecular crystallography and pharmaceutical research. Swiss scientists are in the unique position to profit from the availability of large facilities delivering neutron, photon and muon beams for their research. Under construction is the free electron laser SwissFEL, which will deliver ultrashort X-ray pulses for flash crystallography.

Milestones in Physics (3)

Swiss research institutes and industries play a leading role to measure both quantities 'time' and 'length' with ever increasing accuracy, reliability and flexibility. Smart optical metrology concepts are the key to success. In the following we present from a first hand account how progress in optical interferometry and length measurement with nanometer precision has emerged.

Heterodyne Interferometry

René Dändliker, Honorary Member SATW and SSOM, Fellow OSA and EOS

I will tell you the story of heterodyne interferometry from my personal point of view and based on my own experience. In 1960 the first lasers were realized, in 1963 I got my diploma in physics from the ETH in Zürich and started my scientific career as Ph.D. student at the newly founded Institute of Applied Physics (IAP) at the University of Berne with the task of doing laser research, having no idea neither of lasers nor of optics. Together with two friends from the ETH, HP Brändli and Heinz Weber, and some other young colleagues, we had a very successful time during the following years, working on cw HeNe lasers, pulsed solid-state lasers, and nonlinear optics.

Heterodyne laser interferometry

To learn more about this new field of lasers, we organized in 1964 an International Symposium on Laser Physics and Applications [1]. H. de Lang and J. Haisma of Philips Research Center in Eindhoven reported on the polarization behavior of HeNe lasers with Zeeman splitting in an axial magnetic field, and F. T. Arecchi and A. Sona of the C.I.S.E Laboratories in Milano presented results on long distance interferometry over 120 m with a HeNe laser. A few years later, Zeeman splitting in HeNe lasers was used to stabilize the emission at the center of the Ne-transition at 632.8 nm (red light): a short Zeemann split HeNe laser emits two oppositely rotating circularly polarized components of the same longitudinal mode at slightly different frequencies due to induced dispersion, separated by about 2 MHz, which can be measured as an electronic beat frequency with a photo detector behind a linear polarizer. Thanks to their orthogonal polarizations those two optical frequencies can be separated by appropriate polarizing elements and sent independently into the two arms of a Michelson interferometer. The observed beat frequency at the interferometer output carries the optical phase difference of the two arms: **optical heterodyne interferometry was born!** During my stay at the Philips Research Laboratories from 1969 to 1970, I had the opportunity to work with this type of heterodyne interferometry. The heterodyne laser interferometer was commercialized by Hewlett Packard in 1970 and became the workhorse for linear displacement and velocity measurements in high precision machinery up to 40 m with a resolution of 1 nm and a typical accuracy of ±0.4 ppm.

Heterodyne holographic interferometry

When I moved in 1970 to work at the Brown Boveri Research Center in Baden, Switzerland, one of the main research topics was the application of holographic interferometry for object deformation and vibration measurements, as suggested first in 1965 by Powell and Stetson [2]. Deformation of the object appears as interferometric fringe patterns in the reconstructed image. Visual inspection of these interference patterns is limited to an accuracy of 0.5 fringe, or 0.25 fringe at its best. Remember: at that time no electronic storage and no digital evaluation of optical images were available since CCD video cameras and digital frame grabbers became only commercially available around 1985.
However, for quantitative deformation and vibration studies more accurate measurement and interpolation of the fringe pattern is required. Heterodyne interferometry would be the solution to measure directly the optical phase difference in the fringe pattern. Since double exposure holographic interferometry is the most common and convenient kind of holographic interferometry, we had to find a solution to store the two wave fields (before and after the object deformation) independently in the hologram, so that during reconstruction the required optical frequency difference between the two interfering light fields can be introduced. The most convenient realization is to use two different reference waves. The first experimental results obtained in our laboratory together with my two colleagues, B. Ineichen and F. Mottier, were published in 1973 [3]. The frequency offset (80 kHz) between the reconstructed light fields was produced with a rotating radial diffraction grating. The reconstructed image was scanned with a photo detector and the phase of the beat signal was measured with a conventional phase locked amplifier. The reproducibility of the phase reading was at any position within 0.2°, which corresponds to less than 1/1000 of a fringe. Further improvements and applications of heterodyne holographic interferometry are presented in volume XVIII of the book series *Progress in Optics*, edited by Emil Wolf [4].

During the following years after 1979, when I had moved to establish a research activity in applied optics at the newly founded Institut de Microtechnique at the Université de Neuchâtel, Switzerland, the experimental improvements and the theoretical limitations of two-reference-beam holographic interferometry was further investigated by R. Thalmann for his Ph. D. thesis (1986). Contrary to laser interferometry with a Michelson interferometer, holographic interferometry of solid objects works with a non-cooperative target, i.e., scattered light from a rough surface, giving rise to speckles in the image of objects. The statistical properties of interference detection in speckled images and the resulting phase errors were theoretically and experimentally investigated [5].

Meanwhile, around 1985, CCD video cameras and digital frame grabbers became available for image processing and evaluation. For moderate accuracy and spatial resolution, quasi-heterodyne techniques (phase-stepping) had been developed, which allow electronic scanning of the image by photodiode arrays (CCDs) or TV cameras and computer assisted digital phase evaluation [6]. Quasi-heterodyne holographic interferometry with TV detection is nearly as simple as standard double-exposure holography, and it does not require any special instrumentation apart from a video electronic data acquisition system. Therefore, it was also used in commercial equipments. That was for me the end of heterodyne holographic interferometry. An overview of the state of art in 1994 of two-reference-beam holographic interferometry is given in [7].

Heterodyne interferometry for measuring microvibrations

When I just arrived at Neuchâtel in 1978, we were asked to measure the in-plane vibration amplitude of quartz resonators for the watch industry. These resonators are a few millimeters in size, oscillate typically at 32 kHz and the mechanical amplitudes are in the sub-micrometer range. Heterodyne interferometry was the method of choice. However, the object is not a mirror, the laser light is scattered by the rough surface, giving rise to speckles. Heterodyne interferometry for measuring microvibrations was investigated theoretically and experimentally by J.-F. Willemin for his Ph. D. thesis (1984). The equipment consists of two different parts, the optics, which has to be adapted to the object and the movement to be measured, and the electronic signal processing. The light source is typically a 633 nm HeNe laser with a few mW output power. In-plane as well as out-of-plane displacements and vibrations of objects with diffusely scattering surfaces are measured in real time. Microvibrations with amplitudes down to 1 nm and frequencies up to 5 MHz were analyzed at a spatial resolution of 35 µm.

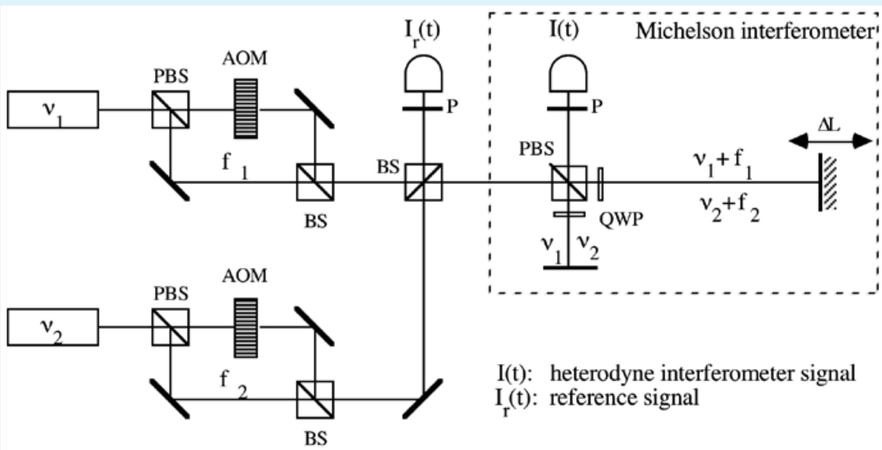
In collaboration with S. M. Khanna and C. J. Koester at the College of Physicians & Surgeons of the Columbia University, New York, we developed a noninvasive optical system for the study of the function of inner ear in living animals [8]. The objects whose vibration is to be measured (e.g., individual hair cells in the organ of Corti) are small (about 10 µm) and the reflectivity very low (about 0.001%). The confocal laser interferometer has a spot size of about 2 µm and a sectioning depth of about 20 µm. It is integrated into a white light optical sectioning microscope, which allows to visualize individual cells of the organ of Corti. Thanks to the heterodyne detection gain (reference beam power about 0.1 mW), the detection is shot-noise limited, even for very low collected light power from the object. The heterodyne signal is analyzed with a commercial low noise FM demodulator in the range of 10 Hz to 100 kHz. With an illumination power of 50 nW in the focal spot, which is below the damage threshold for the cochlear cells, the vibration sensitivity is better than 1 pm (for 1Hz bandwidth.)

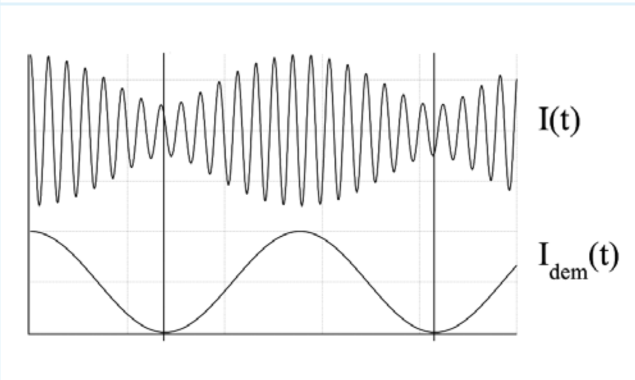
Super-Heterodyne for Multiple-Wavelength Interferometry

Laser (heterodyne) interferometry allows to measure displacements or distances up to at least 10 m by interferometric techniques. However, absolute distance measurement with a resolution of better than 0.1 mm over several meters cannot be covered by classical interferometry or by current time-of-flight metrology. Multiple-wavelength inter-

1. Super-heterodyne Detection

R. Dändliker, R. Thalmann, D. Prongué, Opt. Lett., ***13****, 339-341 (1988)*





Super-heterodyne detection enables high-resolution measurements at arbitrary synthetic wavelengths $\Lambda = \lambda_1 \lambda_2/|\lambda_1-\lambda_2|$ without the need for interferometric stability at the optical wavelengths λ_1 and λ_2, or separation of these wavelengths optically. The optical setup consists of two heterodyne interferometers with laser sources of the optical frequencies ν_1 and ν_2 for the two wavelengths λ_1 and λ_2, and several beam-splitters (PBS polarizing and BS non-polarizing) to separate and recombine the different paths. For each wavelength (optical frequency), slightly different heterodyne frequencies f_1 and f_2 are generated by the acousto-optical modulators AOM (typically f_1=40.1 MHz and f_2=40.0 MHz). Because f_1-f_2 is chosen small compared with f_1 and f_2, the detector output has the form of a carrier-suppressed amplitude-modulated signal

$$I(t) = a_0 + a_1\cos(2\pi f_1 t + \phi_1) + a_2\cos(2\pi f_2 t + \phi_2).$$

After amplitude demodulation, one gets a sinusoidal signal

$$I_{dem}(t) = a_{12} \cos[2\pi(f_1 - f_2)t + (\phi_1 - \phi_2)]$$

at the frequency f_1-f_2= 100 kHz which is equivalent to the heterodyne interference signal for the synthetic wavelength Λ, with $\phi = \phi_1 - \phi_2 = 4\pi\Delta L/\Lambda$. The phase accuracy of the super-heterodyne detection is better than $2\pi/200$.

ferometry (MWI) is, as classical interferometry, a coherent method, but it offers great flexibility in sensitivity by an appropriate choice of the different wavelengths. Indeed, the use of two different wavelengths, λ_1 and λ_2, permits to generate a synthetic wavelength $\Lambda = \lambda_1\lambda_2/|\lambda_1-\lambda_2|$, much longer than the two individual optical wavelengths (***Infobox 1***). This method thus makes it possible to increase the range of non-ambiguity for interferometry and to reduce the sensitivity of the measurement. Moreover, this technique is also applicable to rough surfaces. My interest in MWI was triggered in 1987 by a request of ESTEC, the European Space Research and Technology Centre, for a study and evaluation of a metrology concept for large structures in space. In the context of this study the concept of super-heterodyne MWI was developed [9] and in 1987 a corresponding patent was deposited by our industrial partner Wild Heerbrugg AG. Super-heterodyne detection permits to measure the phase difference of two optical frequencies that cannot be resolved by direct optoelectronic heterodyne detection.

Further improvements and applications were studied by Y. Salvadé for his Ph. D. thesis (1999). Laser diodes locked to different lines of a passive frequency comb using a Fabry-Perot resonator allows one to obtain an absolute calibration of the synthetic wavelengths through electronic beat-frequency measurements. Experimental results show that a calibration of the synthetic wavelength in the millimeter range with an accuracy of better than 10^{-5} is feasible (***Infobox 2***). After a discussion with T. W. Hänsch (Nobel Prize in Physics 2005) at Theo Tschudi's 60th birthday party in Darmstadt, he invited me to present a paper on MWI for absolute distance measurement at the IQEC 2002 in Moscow. I presented the concept of using an active comb spectrum of a mode-locked laser instead of a Fabry-Perot resonator comb (***Infobox 3***). In 2006, this concept was experimentally verified [10]. Experimental results demonstrated the generation of a **90 µm** synthetic wavelength (frequency difference of 3.3 THz) calibrated with an accuracy better than 0.2 parts in 10^{-6}. Since the phase accuracy of the super-

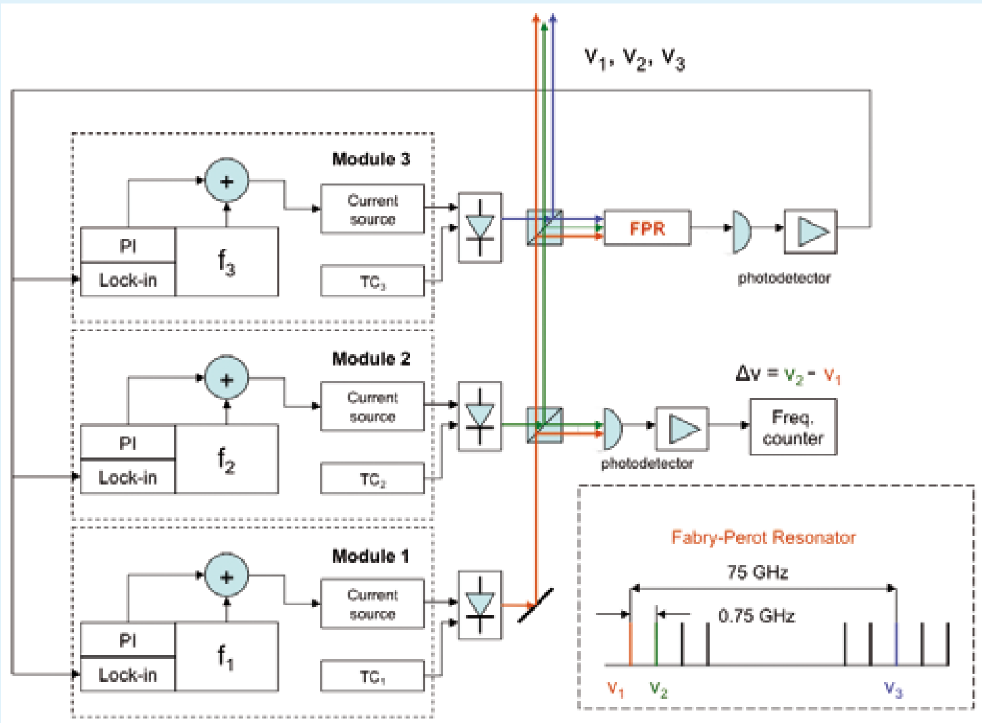
2. Calibrated Multiple-Wavelength Source using a Passive Frequency Comb

E. Zimmermann, Y. Salvadé, R. Dändliker, Opt. Lett, **21***, 531-533 (1996)*

Laser diodes locked to different lines of a passive frequency comb using a Fabry-Perot resonator allows to obtain an absolute calibration of the synthetic wavelengths through electronic beat-frequency measurements. The block-diagram shows the realization of a calibrated three-wavelength source. It consists of three laser diodes, LD_1, LD_2, and LD_3, operating at the frequencies ν_1, ν_2, and ν_3, respectively. Two of them (LD_1 and LD_2) are stabilized on two consecutive resonances of a common stable Fabry–Perot resonator (FPR) used as frequency discriminator. In our experiment, the FPR had a free spectral range (FSR) of 750 MHz ($\nu_{21} = \nu_2 - \nu_1 = 0.75$ GHz). The corresponding beat frequency of 750 MHz is detected and measured by a frequency counter with electronic accuracy. The third laser diode (LD_3) is tuned from ν_1 to ν_3 over N resonances of the FPR. The frequency difference $\nu_{31} = \nu_3 - \nu_1 = N\,\nu_{21}$ is then known with the same accuracy as the electronically calibrated beat frequency ν_{21}. For N = 100, we obtained $\nu_{31} = 75$ GHz, which yields a synthetic wavelength of $\Lambda = 4$ mm. Experimental investigations were performed with commercial GaAlAs monomode laser diodes. For the locking of the laser frequencies on the desired resonances of the FSR, a portion of the light from the different lasers is launched into the FPR. The center frequencies of the lasers are brought, by means of temperature tuning (TC), near a resonance peak of the FPR at which the feedback loop is closed. To permit the stabilization of the laser sources, the optical frequency of the diodes is modulated by a modulation of the injection current at $f_1 = 10$ kHz, $f_2 = 40$ kHz, and $f_3 = 50$ kHz. The excursion of the optical frequency is approximately 1 MHz, which is much less than the resonance width of the FPR. These frequency modulations are then transformed by the FPR into intensity modulations, which are detected and synchronously demodulated with the lock-in amplifiers to yield the error signal for the feedback loop.

Experimental comparison with a HP laser interferometer prove that the electronic calibration of the synthetic wavelength of $\Lambda = 4$ mm is feasible with an accuracy better than 10^{-5}, although the corresponding beat-frequency (75 GHz) is well beyond the range of electronic photodetectors.

With the reported three wavelength source it is possible to measure distances without ambiguity within 0.2 m with a resolution of better than 10 µm.



heterodyne detection is better than 2π/200, this synthetic wavelength allows to resolve the optical wavelength of 1.3 µm (Nd:YAG) and to reach therefore nanometer accuracy.

Another special application of super-heterodyne laser interferometry has been developed for the Very Large Telescope Interferometer (VLTI) of ESO (European Southern Observatory) at Paranal [11]. Specific observations with the VLTI require a highly accurate laser metrology system to monitor, along several hundred meters, the internal optical path followed by the stellar light. This metrology system involves an accurate phase detection scheme. For the required accuracy of 5 nm over a differential optical path of 100 mm we have developed a high-resolution laser metrology system based on super-heterodyne detection.

From Optical Wavelength to Frequency

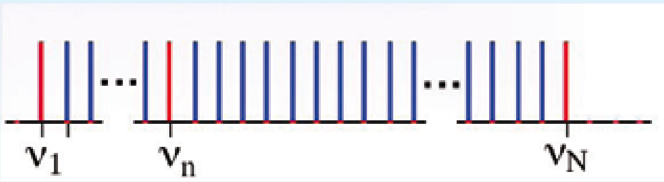
In classical optical interferometry fringes are observed and light is characterized by its wavelength. In 1960 the meter definition was based on the wavelength of the orange-red emission line of the Krypton-86 atom in vacuum. But only the advent of highly coherent and stable cw lasers allowed to measure electronic beats (MHz) of optical frequencies and direct optoelectronic detection of the interference phase by heterodyne laser interferometry (commercialized 1970). Interferometry is phase, and phase is related to frequency. Contrary to the wavelength, the frequency is independent of the refractive index of the medium and frequencies can be measured with very high accuracy by counting periods (definition of the second by the frequency of atomic clocks). Arthur L. Schawlow (Nobel Prize in Physics 1981) stated therefore: "**Never measure anything but frequency!**", which means 560 THz instead of 532 nm for visible light. Since 1999 optical frequency metrology has become reality, using frequency-comb spectra together with opto-electronic beat frequency and heterodyne detection [12].

Acknowledgment: My thanks go to Bernhard Braunecker who suggested the subject and supported me in the writing with many helpful comments.

3. Calibrated Multiple-Wavelength Source using an Active Frequency Comb

The following figure shows the system layout parameters as proposed by R. Dändliker at the IQEC 2002, Moscow, leading to small synthetic wavelengths ($\Lambda \approx 60$ µm).

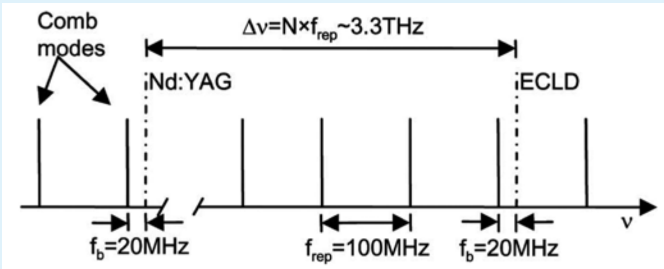
Spectrum of a mode-locked cw fs laser
Example: $\delta\nu = \nu_2 - \nu_1 = 500$ MHz
$\nu_n - \nu_1 = 10^2\,\delta\nu = 50$ GHz $\Longrightarrow \Lambda_n = 6$ mm
$\nu_N - \nu_1 = 10^4\,\delta\nu = 5$ THz $\Longrightarrow \Lambda_N = 60$ µm



This layout was later modified and experimentally verified by N. Schuhler, Y. Salvadé, S. Lévêque, R. Dändliker, R. Holzwarth, Opt. Lett., **31**, 3101-3103 (2006):

An active frequency comb is based on a fs mode-locked laser, whose repetition rate, f_{rep}, defines exactly the frequency separation $\delta\nu$ between two adjacent modes of its frequency spectrum. Several cw lasers can be locked to different modes of the comb by beat frequency measurements and electronic phase locked loops. The stability of the laser frequency separation is determined entirely by the relative stability of the frequency reference used to control the repetition rate of the fs laser. To cancel the frequency drift of the comb, either the comb can be self-referenced or one of the lasers can be locked onto a molecular transition and the comb locked to that laser through control of the comb offset.

The tunable two-wavelength source consists of a Nd:YAG laser ($\lambda_1 = 1.319$ µm), an external cavity laser diode (ECLD, $\lambda_2 \approx 1.3$ µm), and finally a mode-locked fiber laser (Menlo Systems TC-1500). A 10 MHz fre-



quency reference with a relative uncertainty of $<10^{-11}$ is provided to the comb by a radio-controlled master clock synchronized to the carrier frequency of the Swiss time signal (HBG), which is derived from an atomic clock. This reference is used by the TC-1500 to generate two sub-references (100 MHz and 20 MHz) with the same relative uncertainty. The concept of the mutual stabilization of the lasers is as follows: one comb mode of the mode-locked fiber laser is locked to the master Nd:YAG laser, and the ECLD is locked in turn to another comb mode. In practice, the repetition rate is phase locked to the 100 MHz reference signal by changing the pump power of the fs laser. For each cw laser, the beat signal f_b with the closest mode of the frequency comb is detected and phase locked to the 20 MHz signal. The frequency comb is stabilized on the Nd:YAG laser by controlling the length of its cavity. The ECLD is locked to the comb by tuning its injection current. To prove the feasibility, we directly operated with a small synthetic wavelength of $\Lambda \approx 90$ µm ($\Delta\nu \approx 3.3$ THz). Experimental comparison with a calibrated 5529A HP laser interferometer (accuracy ± 0.02 ppm) prove that synthetic wavelengths as small as 90 µm can be generated with an accuracy better than 0.2 parts in10^6 (0.2 ppm). Since the phase accuracy of the super-heterodyne detection is better than 2π/200, this synthetic wavelength allows to resolve the optical wavelength of 1.3 µm (Nd:YAG) and to reach therefore nanometer accuracy. Using frequency-comb spectra together with opto-electronic beat-frequency and heterodyne detection, optical frequency metrology has become reality.

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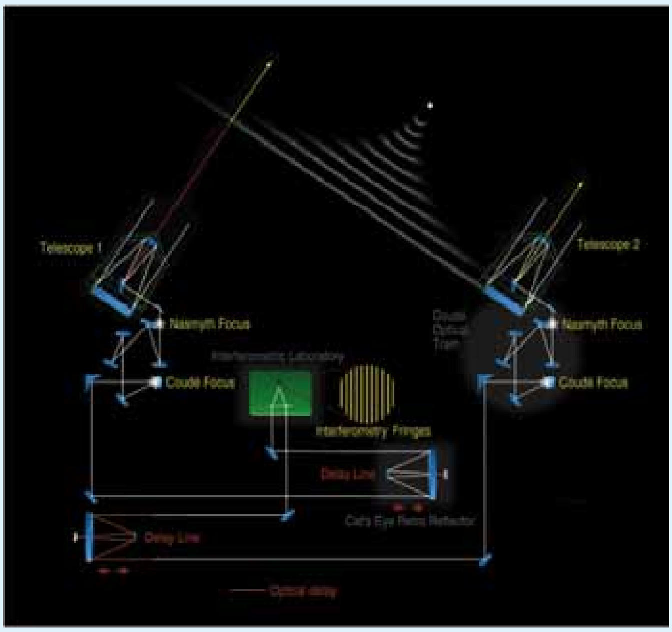
4. Astronomy

Another special application of super-heterodyne laser interferometry has been developed for the Very Large Telescope Interferometer (VLTI) of ESO (European Southern Observatory) at Paranal [11]. The VLTI allows the coherent superposition of the stellar light collected by two 8-m-diameter telescopes separated by more than 100 m. In order to achieve this, the optical paths for the light captured by the two telescopes must be equal and kept constant to within a fraction of a micron using movable optical delay lines.

The **PRIMA instrument** (Phase Referenced Imaging and Micro-arcsecond Astrometry) aims to improve the performance of the VLTI by observing at the same time as the object of interest (science object) a bright reference star close to it. The light from both objects travels through a delay line which is controlled by observing the interference fringes of the reference star and ensures the compensation of the optical path between the two telescopes. A differential delay line is then used to apply the necessary remaining compensation to the path followed by the light of the science object. In the VLTI, the light captured by two telescopes follows a train of 25 mirrors distributed along a subterranean path of approximately 200 meters, before being coherently combined. The fringe signals are affected by static optical path differences and by time-varying optical path fluctuations due to vibrations of mechanical structures, air turbulence inside the interferometer and delay line motion.

The **PRIMA laser metrology system** is being developed to monitor optical path differences and optical path fluctuations encountered by two stellar objects inside the VLTI during phase-referenced observations. The concept of the PRIMA metrology, developed by ESO in collaboration with the Institute of Microtechnology of Neuchâtel (IMT), is based on "super-heterodyne laser interferometry", where two heterodyne Michelson interferometers are operating simultaneously and have common optical paths with both observed stars through the VLTI optical train, except for the differential delay line which compensates for the position of the science object with respect to the reference star. Each interferometer arm length reaches up to 552 m (return way). The design goal is to measure the optical path difference (differential delay



line, up to 120 mm) with an accuracy of 5 nm. A prototype of the laser metrology system was tested at the Paranal Observatory [*]. Because the PRIMA star separators were not yet available on the Unit Telescopes, it was not possible to propagate the metrology beams inside the VLTI optical train in two physically separated channels (i.e., four interferometric arms), as it will be during "real" PRIMA operation. Therefore the two heterodyne interferometers were common path, which corresponds to the case when the star separators will be in calibration mode. The results obtained during full-scale testing over a path of up to 520 m confirmed that the super-heterodyne assembly of the PRIMA metrology prototype is compatible with the aimed nanometer accuracy level.

However, the **final integration of the entire PRIMA instrument into the VLTI system** failed up to now. The extreme complexity of the whole system seems to require much higher precision for all optical and mechanical components in the delay lines, the beam separators and the polarizing elements to improve the differential laser interferometry. ESO and the PRIMA project group at the Observatory of Geneva are still working on solutions.

[*] S. A. Leveque, R. Wilhelm, Y. Salvade, O. Scherler, R. Dändliker, Towards nanometer accuracy laser metrology for phase-referenced interferometry with the VLTI, Proc. SPIE vol 4338, 983-994 (2003)

History of Physics (10)

History of Crystallography in Switzerland

Hans Grimmer, Paul Scherrer Institute

Introduction

Crystallography evolved from the study of the form of mineral crystals and of the anisotropy of their physical properties. After the discovery of X-ray diffraction by Laue (1912), the focus of crystallography shifted to structure analysis; chemists became the main users of crystallographic methods. Crystallographic institutes at universities were established first in Zürich, 1949 in Bern, in the 1970s in Geneva, Lausanne, Neuchâtel and Basel. In the beginning, the main focus in Switzerland was on methods and general principles. Due to the increasing demand of chemistry and biology institutes and the materials sciences, the focus shifted to the determination of ever more complicated structures, to disorder in crystals and to their dynamic properties. Crystallography laboratories were established also in institutes of chemistry and structural biology. The structure analysis of biological macromolecules and their application in drug design, although very successful and of great economic importance, will be mentioned only shortly in this article.

In addition to X-rays, neutrons became in the 1960s important probes to investigate crystals. Synchrotrons became a much more versatile and brilliant source of X-rays than X-ray tubes, especially when synchrotrons dedicated to the production of X-rays were built in the 1980s. Such sources are out of reach of university institutes, they were made available at Paul Scherrer Institute (PSI) in Switzerland and at national and international centres abroad. With the availability of the sources also the development of the corresponding beam-lines and of new applications gradually shifted from the universities to neutron and synchrotron radiation centres. As a consequence, full professors of crystallography who retired after 2000 were either not replaced or replaced at a lower level. On the other hand, joint appointments at PSI and Swiss universities, in particular ETH and EPFL have become common.

Crystallography overlaps with many sciences: mineralogy, solid state physics and chemistry, molecular biology, pharmacy and materials science. Crystallography is increasingly perceived as providing indispensable tools rather than as a science of its own at the crossroads of these disciplines [1].

The beginnings

Crystallography developed from mineralogy in the 17th century, when regularities in the forms of crystals and anisotropies of their physical properties were discovered. The term "Crystallographia" was actually introduced 290 years ago by the Swiss physician and scientist M. A. Kappeler [2]. In the 19th century the mathematical classification of 3-fold periodic structures was developed with the derivation of the 7 crystal systems, the 14 lattice types, the 32 crystal classes and the 230 types of space groups [3].

In 1855, the Polytechnic Institute (called ETH since 1911) was established in Zürich. Systematic crystallographic research started in Switzerland with Gustav Adolf Kenngott, who was Professor of Mineralogy at ETH from 1856 and at the University of Zürich (UZ) from 1857 until his retirement in 1893. The main activities of his successor Ulrich Grubenmann (1893-1920) were in petrography, where he made use of polarisation microscopy and chemical analytic methods. He was succeeded by Paul Niggli (1920-1953). All three were strong personalities and served the ETH as rectors, Niggli became rector also of UZ [4].

When Max von Laue was "Privatdozent" in Munich under Arnold Sommerfeld, he had in the beginning of 1912 the idea that X-rays might show interference effects with crystals. Paul Knipping and Walter Friedrich performed the experiments, showing interference spots compatible with the cubic symmetry of ZnS crystals. Laue's explanation of these spots proved the wave properties of X-rays and, simultaneously, the space group symmetry of crystals, i.e. that crystals are 3-fold periodic. Laue was not interested in determining the structure of crystals. This endeavour was started in England in 1913 by William Lawrence Bragg and his son William Henry Bragg. Laue received the Nobel Prize for physics in 1914, the Braggs in 1915. British crystallographers remained the leaders in structure determination until the 1960s.

The cross-fertilization between crystallography and neighbouring disciplines is shown by the fact that Peter Debye became 1911 Professor of Theoretical Physics at UZ, succeeded by Max von Laue in October 1912.

In 1915 Debye developed in Göttingen together with his PhD-student Paul Scherrer a method to determine the distances between neighbouring lattice planes from the diffraction of X-rays by crystal powders, known as Debye-Scherrer method. In 1920, the ETH appointed Debye and Scherrer as professors of physics and the above-mentioned Paul Niggli as Professor of mineralogy and petrography [4].

The "Zürich school of crystallography" [3]

Niggli made important contributions to mineralogy and petrography, but his main interest was in showing how symmetry considerations can be used to determine the space group and the structure of crystals. In particular, his book "Geometrische Kristallographie des Diskontinuums", published in 1919, became the precursor of the volume "Space-group symmetry" of today's "International Tables of Crystallography" and already contained the concepts and tables that are most important for structure determination. Niggli collaborated with mathematicians as Georg Polya at ETH and Heinrich Heesch at UZ. Using symmetry and modern mathematical methods for the solution of general problems in crystallography is a distinctive feature of the research by Niggli and many of his successful students, often referred to as the "Zürich school of crystallography" [3].

In 1932 Conrad Burri was appointed professor for special mineralogy and petrography, whereas Niggli continued lecturing on crystal structure, crystal physics and crystal

chemistry. These courses, named 'general mineralogy', were compulsory for chemists during their first three semesters [4].
In collaboration with EMPA, X-ray equipment was installed. Since 1930 it was run by Ernst Brandenberger, who later became professor of materials science and testing, as well as a director of EMPA [4].

After the sudden death of Niggli at age 64, Fritz Laves, who had finished his thesis under Niggli, succeeded him from 1954 to 1976. He is best known for his work on the crystal structure of metals and alloys, where he was mainly interested in general structural principles from a crystal-chemical point of view, e.g. the 'Laves phases', intermetallic phases with composition AB_2 [5].
The "Institute for Crystallography and Petrography" was strengthened by the appointment of two associate professors at UZ and ETH, Alfred Niggli (a pupil of Paul Niggli) in 1960 for crystal structure research and Walter Max Meier in 1966 for crystallography and mineral synthesis. Niggli, best known for his work in mathematical crystallography, was full professor from 1966 to his death in 1985. Meier was full professor 1973-1992; financially supported by Mobil Oil, he and his group determined the structure of many zeolites by powder diffraction.
The chemical institutes created their own chemical crystallography group, led with great success by Jack Dunitz from 1957 to 1990.

Bern
Zürich remained the unique center of crystallography until 1949, when Werner Nowacki [6], who had earned his doctorate under Paul Niggli with work on homogeneous space partitions into domains of influence, became professor in Bern. He founded the Section of Crystallography and Structural Studies. Feeling that the interests of crystallographers were not adequately represented by the "Swiss Society of Mineralogy and Petrology", he initiated the "Swiss Society for Crystallography" in 1968 and became its first president [7].
Nevertheless, Nowacki was very productive also in mineralogy by investigating the sulfosalt minerals found in the Lengenbach deposit in the valley of Binn. In order to determine the chemical composition of these often very small crystals he founded the Laboratory of Electron Microprobe Analysis in 1964.
When Hans-Beat Bürgi succeeded Nowacki in 1979, the Laboratory of Chemical and Mineralogical Crystallography was established. Bürgi's main interests are in static and dynamic structural chemistry, whereas research in mineralogical crystallography was continued by Thomas Armbruster and research in mathematical crystallography by Peter Engel. When Bürgi retired in 2007 (and became permanent academic guest at the organic chemistry institute of UZ) the Laboratory was split into the Laboratory for Mineralogical Crystallography led by Armbruster and the Laboratory for Chemical Crystallography led by Piero Macchi.

Crystallography in the French speaking part of Switzerland
Hans Schmid joined the Battelle Geneva Research Center in 1957, where he worked on the synthesis and potential applications of ferroelectrics, ferromagnetics and ferroelastics for display and data storage. In 1964 he synthesized a variety of boracites, in which he discovered for the first time, in collaboration with Edgar Ascher, the simultaneous occurrence and mutual coupling of ferroelectricity, ferromagnetism and ferroelasticity in the same phase [8]. From 1977 to 1996 Schmid was Professor of Applied Chemistry at the University of Geneva.

In Geneva, a chair of crystallography was created in 1970, headed by Erwin Parthé until his retirement in 1993 [9]. His main interests were alloys and intermetallics. He developed a standard presentation of inorganic crystal-structure data, which helps to recognize similar structures. The results were published in a four volume series "TYPIX Standardized Data and Crystal Chemical Characterization of Inorganic Structure Types".
Klaus Yvon held a second chair 1982-2009. His main interests were new compounds for energy storage (metal hydrides) and energy conversion (superconductors, ferromagnets).
At present, Radovan Cerný is in charge of teaching crystallography and Céline Besnard runs a service of structure determination.

Dieter Schwarzenbach taught crystallography at the University of Lausanne first as lecturer, then 1973-2001 as professor. He is an expert for the determination of electron densities in crystals. Gervais Chapuis joined him in 1975 and was full professor 1991-2009. He investigated incommensurate structures by diffraction and molecular dynamics. They initiated and led a project for the construction of a beam line at the European Synchrotron Radiation Facility (ESRF) in Grenoble. This effort resulted in the Swiss-Norwegian Beam Lines (SNBL), which started operation in 1995. In 2003 the Institute of Crystallography was transferred from the university to EPFL. Two former members of the institute, Phil Pattison and Kurt Schenk, are now attached to the X-ray diffraction service of the EPFL Institute of Chemical Sciences and Engineering (ISIC).

Helen Stoeckli-Evans taught chemical crystallography at the University of Neuchâtel 1972-2009, moving up from lecturer to professor. From 1997 to 2006 she was responsible for the small molecule crystallography service BENEFRI of the universities of Berne, Neuchâtel and Fribourg. The service was reorganized in 2006 and is now run jointly by the Institute of Microtechnology of the University of Neuchâtel and the Swiss Center for Electronics and Microelectronics (CSEM) under the responsibility of Antonia Neels, a former collaborator of Helen Stoeckli.

At the University in Fribourg, the group of Katharina Fromm grows crystals and determines their structure for its research in the coordination chemistry of nano- and biomaterials.

Basel
Two years after the foundation of the "Biozentrum" of the University of Basel, Johan N. Jansonius started in 1973 as research group leader in the Department of Structure Biology. Prof. Jansonius retired in 1998. In 1997, Tilman Schirmer was promoted to Associate Professor in the above-mentioned department.

The Laboratory for Chemical Crystallography of the University of Basel started in 1980, led by Margareta Zehnder (Neuburger-Zehnder). It is now run by her husband Markus Neuburger, mainly as a service laboratory for structure determination.

Of course, important bio-crystallographic research was done in the pharmaceutical industry, e.g. by Markus Grütter, (a PhD student of Jansonius) at Ciba-Geigy (later Novartis) before he moved to UZ, or by Fritz Winkler at Hoffmann-LaRoche before he moved to ETH.

Newer developments in the Zürich area

When Walter Steurer was appointed Professor at UZ and ETH in 1993 after the retirement of Walter Max Meier, the institute was reorganized as "Laboratory of Crystallography"; it is now attached to the ETH department of materials. Steurer's main research fields are quasicrystals, their structure analysis and description and the interpretation of both Bragg and diffuse scattering. Research on zeolites and powder diffraction continues with Lynne McCusker and Christian Bärlocher.

With the appointment in 2010 of Nicola Spaldin as Professor of Materials Theory and in 2011 of Manfred Fiebig as Professor of Multifunctional Ferroic Materials, the department of materials has considerably strengthened its competence in developing new multifunctional materials.

Structure determination is done also in other departments of ETH. Michael Wörle is responsible for X-ray analysis in the Laboratory of Inorganic Chemistry led by Reinhard Nesper.

Timothy Richmond is 1987-2014 full professor for the Crystallography of Biological Macromolecules, Nenad Ban since 2007 for Molecular Structural Biology. Fritz Winkler (1999-2009) and Gebhart Schertler since 2010 professors for Structural Biology headed simultaneously the Biology Department at Paul Scherrer Institute (PSI).

The leading position in crystallography-related research of ETH in the German speaking area [10] is due to all these contributions.

Also the activities at UZ deserve mentioning: Coming from Novartis, Markus Grütter was 1997-2013 full professor for macromolecular structural biology. Anthony Linden manages the X-ray crystallographic facility at the organic chemistry institute.

In the laboratory of Alex Müller at the IBM Research Center in Rüschlikon, Georg Bednorz synthesized in 1974 perovskites ($SrTiO_3$) for his diploma work. He obtained his doctorate at ETH under the supervision of Heini Gränicher and Alex Müller. Back at IBM, he and Müller synthesized oxides that they considered to be candidates for super¬conductivity. In 1986 they found in $La_{1.85}Ba_{0.15}CuO_4$ a superconducting transition temperature T_c = 35 K, higher than the highest known T_c in metals. For this discovery, they received the Nobel Prize for physics in 1987 [11].

Anke Weidenkaff is head of the Laboratory for Solid State Chemistry and Catalysis at EMPA Dübendorf and teaches at the University of Bern. Alex Dommann, who applied X-ray diffraction to the characterization of coatings for industrial applications first at "Neutechnikum Buchs" and then at CSEM in Neuchâtel is now at EMPA St. Gallen.

The neutron sources at PSI [12]

Walter Hälg, since 1955 at ETH and full professor 1960-1984 started neutron scattering at the nuclear reactors SAPHIR and DIORIT of the Swiss Federal Institute for Reactor Research (EIR) in Würenlingen. The first instrument was a two-axis neutron diffractometer, used for single crystal studies of magnetic phase diagrams in external magnetic fields up to 6 Tesla. Albert Furrer was 1984-2004 head of the Laboratory for Neutron Scattering (LNS). In his period, EIR and the Swiss Institute for Nuclear Research (SIN) merged in 1988 to the Paul Scherrer Institute (PSI), and the Swiss Spallation Neutron Source SINQ was built and started operation in 1996. Successors of Furrer were Joël Mesot 2004-2008, who is now director of PSI and Professor at ETH and EPFL, Andrey Zheludev 2009-2010, now at ETH, and Christian Rüegg since 2011. Crystallographic research at LNS is done mainly in the diffraction group. Using the strong features of neutrons, Peter Fischer, group head until 2002, made important contributions to hydrogen storage in metals, the structure of high temperature superconductors and to magnetism. At present, the diffraction group at SINQ runs a single crystal neutron diffractometer and two powder diffractometers, one using thermal and the other cold neutrons. These instruments allow experiments in a wide range of temperatures, pressures and magnetic fields, e.g. for powders at temperatures between 50 mK and 1800 K, pressures up to 100 kbar, in magnetic fields up to 4 T. Dynamic properties of crystals are investigated in the spectroscopy group. This group operates five spectrometers. Some of its research topics are high temperature superconductors, critical phenomena in ferroelectrics, magnetism and colossal magnetoresistance.

Since 25 years, Switzerland is a member state of the Institut Laue-Langevin (ILL) in Grenoble; it also participates in the planning of the European Spallation Source (ESS) to be built in Lund, Sweden.

The synchrotron radiation source SLS at PSI

Switzerland is a member state also of the European Synchrotron Radiation Facility (ESRF) in Grenoble, which started operation in 1994, and is engaged, in particular, in running the Swiss-Norwegian Beamlines (SNBL), as mentioned above.

In order to satisfy the increasing demand of synchrotron light, the Swiss Light Source (SLS) was constructed at PSI. Research at the SLS started in 2001 under J. Friso van der Veen, who is also Professor of Experimental Physics at ETH 2000-2014. The SLS provides photon beams of high brightness for research in materials science, biology and chemistry. At present, 18 beamlines are in operational mode, using synchrotron radiation at wavelengths ranging from the VUV to the hard X-ray regime.

Four laboratories operate these beamlines, provide user support and do research of their own: "Macromolecules and Bioimaging" runs among others 3 beamlines dedicated to macromolecular crystallography, "Catalysis and Sustainable Chemistry" runs among others the PHOENIX beamline for X-ray microspectroscopic measurements (μ-XAS and μ-XRF), "Micro- and Nanotechnology" runs the X-ray Interference Lithography beamline. The various groups of "Condensed Matter and Materials Science", headed by Frithjof Nolting, operate 11 beamlines. At the MS beamline powder and surface diffraction techniques are used for research in condensed matter and materials science; at the two soft X-ray beamlines SIS and ADRESS the spectroscopy techniques ARPES and RIXS are used to investigate novel materials like high-temperature superconductors and low-dimensional magnets; the soft X-ray beamline SIM serves to study electronic and magnetic properties of thin films, multilayers, and bulk systems of metals and oxides; ultra-fast phenomena in solids are studied at beamline FEMTO using 100 fs X-ray pulses for diffraction or spectroscopy. Even shorter pulses will be available at the X-ray free-electron laser (SwissFEL) under construction at PSI.

The Swiss Society for Crystallography [7]

As mentioned above, the Swiss Society for Crystallography (SSCr) was founded in 1968 with Nowacki as its first president. The society included from its beginning members interested in crystal growth, which formed a section with activities of their own. Already in 1969, the SSCr was admitted as a member society of the 'Schweizerische Naturforschende Gesellschaft', the predecessor of the 'Swiss Academy of Sciences' (SAS). The SSCr is a member society of the International Union of Crystallography (IUCr) and of the European Crystallographic Association (ECA).

With financial support of the SAS, the SSCr produced a copiously illustrated brochure describing fascinating aspects of pure and applied crystallographic research in Switzerland. The German version 'Kristallographie in der Schweiz' appeared in 1999, the French version 'Cristallographie en Suisse' in 2001 [13].

In addition to many national meetings, the SSCr has organized several European meetings: A highlight for the society and its section was the organization of the 3rd European Crystallographic Meeting (ECM-3), immediately followed by the 1st European Conference on Crystal Growth, which both took place in Zürich in 1976. In 2006 the European Powder Diffraction Conference (EPDIC-10) was organized in Geneva and in 2016 ECM-30 will take place in Basel.

Table 1 shows the main officers of the SSCr. Until 2009 the chairman of the section for crystal growth acted as vice-president of the society, until 1993 the secretary acted also as treasurer.

A majority of the SSCr officers were employed by a university, but also the Basel pharmaceutical industry is well represented with two presidents and with the treasurers from 1993 to 2010. The president Ascher worked at Battelle, the vicepresident Scheel was 1968 -1982 at IBM Rüschlikon, 1989-2001 at EPFL, since 2001 self-employed. The growing importance of the neutron and synchrotron sources for crystallography is reflected by the fact that two of the SSCr presidents, the secretaries since 2002 and the editors of the 'SGK/SSCr Newsletter' since 1998, all work at PSI.

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Period	President	Vicepresident	Secretary	Treasurer
1969-1972	W. Nowacki (Uni Bern)	E. Kaldis	P. Engel	P. Engel
1972-1975	E. Ascher (Battelle, Geneva)	E. Kaldis	P. Engel	P. Engel
1975-1978	A. Niggli (Uni / ETH Zürich)	H. J. Scheel	P. Engel	P. Engel
1978-1981	E. Parthé (Uni Geneva)	H. Arend	W. Petter	W. Petter
1981-1984	H. P. Weber (Sandoz, Basel)	H. Schmid	W. Petter	W. Petter
1984-1987	D. Schwarzenbach (Uni Lausanne)	S. Veprek	H. Flack	H. Flack
1987-1990	J. Daly (Hoffmann-LaRoche, Basel)	S. Veprek / E. Kaldis	H. Flack	H. Flack
1990-1993	M. Dobler (ETH Zürich)	E. Kaldis / J. Bilgram	H. Stoeckli-Evans	H. Stoeckli-Evans
1993-1996	H. Stoeckli-Evans (Uni Neuchâtel)	J. Bilgram	G. Chapuis	F. Winkler
1996-1999	G. Chapuis (Uni Lausanne)	J. Bilgram	V. Gramlich	F. Winkler
1999-2002	H. Grimmer (PSI, Villigen)	H.J. Scheel	V. Gramlich / R. Cerny	J. Priestle
2002-2005	R. Cerny (Uni Geneva)	H.J. Scheel	H. Grimmer	J. Priestle / M. Hennig
2005-2009	W. Steurer (Uni / ETH Zürich)	H. Scheel / K. Fromm	J. Schefer	M. Hennig
2009-2012	K. Fromm (Uni Fribourg)	M. Schiltz / J. Schefer	J. Schefer	M. Hennig / P. Macchi
2012-	J. Schefer (PSI, Villigen)	P. Macchi	D. Sheptyakov	P. Macchi

Table 1: The main officers of the Swiss Society for Crystallography (SSCr)