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Lightning above the clouds

Swimming in a sea of superfluid light

Ultrafast Phenomena at the Nanoscale

Physics in daily life: flying (s)low

Museum Boerhaave

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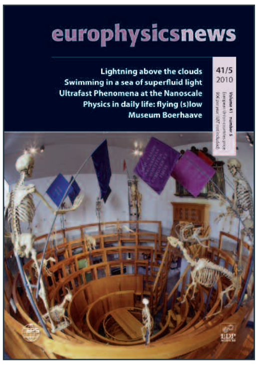

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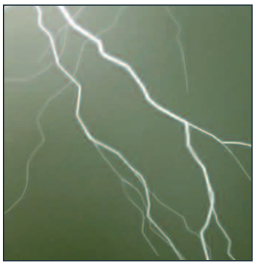
Cover picture: Reconstruction of the Theatrum Anatomicum of Leiden University. The original was built in 1596. See the museum review p.34



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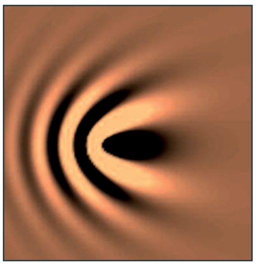

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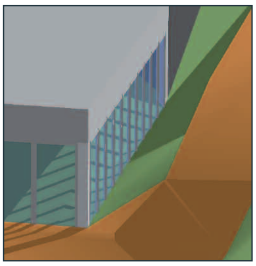
Swimming in a sea of superfluid light



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Some remarks concerning the EPS Strategy Working Group

The Strategy Working Group formed by the Council in March 2010 to review the EPS structure, mission and vision is about to reach its conclusions. During three intense meetings and through multiple exchanges of messages and documents in between, all the EPS has been and is analyzed in depth. All the Members of the SWG exchanged e-mails and documents almost each day between meetings. One can get an idea of the numerous points, which have been under discussion, by looking at the list raised at the first meeting in Mulhouse:

1) Key role of EPS in terms of:

- Bringing together the excellence in physics
- Physics visibility
- Advisory role on "scientific and educational issues"
- EPS publications and publication policy
- Integration of European physics community
- International relations outside Europe

2) Organization and governance of EPS

- Executive Committee composition
- EPS "parliament"
- Presidents' meetings and other selected meetings
- Role of the EPS Council
- General Assembly meetings (EPS is registered in France)
- Divisions and Groups.

3) Membership issues

- Early career people and students
- Associate Members, Member Societies and Individual Members
- 115 000 physicists in Europe
- Industry people, teachers and physics-related experts

4) Core activities (other than publications)

- Conferences
- Services
- Programs and projects
- Position papers
- Grants

5) Communication of EPS inside Society and outside

6) Brussels representation of EPS

7) EPS Office

In order to go deeper into each subject the SWG members were divided into sub-groups to make an analysis and to build a written Strategy Plan 2010+ along the following lines:

A. Political strategy

B. Operational strategy

B-1. Areas of strategic importance and priorities
B-2. Membership
B-3. Structure and governance

C. Financial and human resources

C-1. Financial questions
C-2. Staff and Office organization

In the meantime a broad consultation was carried out: personally I participated in board meetings of High Energy Particle Physics in CERN, Condensed Matter Division in Warsaw, Nuclear Physics Division in Warsaw, Austrian Physical Society board. The extensive exchanges with the IoP and DPG (personal meetings and phone calls) were very useful and they led to true common position and understanding. In addition, the letters sent to the SWG by the President of the French Physical Society and the Chairman of the Physics Education Division were substantial and clarified their positions.
The September meeting of the SWG in Bologna was then much easier, even if very laborious, and common views on almost all the important issues were reached.
We should remark that very well prepared meetings (mainly by President of SIF - EPS President Elect Luisa Cifarelli) and the determination of the SWG members to improve the EPS without any loss, seem to lead to a successful conclusion. The SWG will meet once more in Paris to finalize the written proposals but the principles are agreed upon.
The proposals will be discussed during EPS Council meetings. ■

■■■ **Maciej Kolwas**, President of the EPS

Change at the helm of EPL

Michael Schreiber succeeds Volker Dose as editor in chief

Following his highly successful term of three years, Volker Dose has handed over the responsibilities as Editor in Chief of EPL, to Michael Schreiber.

Volker Dose got his PhD at the University of Zurich in 1967 and was appointed Professor at the University of Würzburg in 1971. Later, he was Director and Scientific Fellow at the Max-Planck-Institute of Plasma Physics in Garching, and since 1991 has also been Full Professor at the University of Bayreuth. His research experience is very broad; it includes surface and plasma physics, collisions, magnetism and statistics.

When Volker took on the job of EiC in 2007, the journal *Europhysics Letters* had just changed its brand name to *EPL*. The intention was to convey that *EPL* is a global letters journal, which should not anymore be focused primarily on physics results from Europe. In the meantime, letters published by authors working outside of Europe — 18 % from America and 28 % from the Asia and Pacific area — have become nearly as numerous as those coming from within Europe. And it has just been announced that the Impact Factor of *EPL*, which had hovered around 2.2 for a decade or so, has risen by 30 % to 2.893. To a large part, this is the result of Volker's effort. Sure, an entire team of colleagues from Editions de Physique – Sciences (EDPS, which belongs to the Société Française de Physique), from the European Physical Society, the Institute of Physics Publishing (the publishing arm of IOP) and from the Società Italiana di Fisica has contributed to this success. Yet Volker inspired and led the team as *primus inter pares* towards this major achievement.

We welcome Michael Schreiber as the new Editor in Chief of *EPL*. A computational scientist, now, following a distinguished international career, full Professor at the Technical University of Chemnitz, Michael is full of enthusiasm and wants to steer *EPL* to further heights! Having published in *EPL* — extensively and covering a wide range of topics —, having been a co-editor and a member of the *EPL* Advisory Board, he is thoroughly familiar with this broad-band letters journal. His knowledge of many areas of physics, moreover, provides an excellent base for his new task.

Michael Schreiber interprets «Exploring the Frontiers of Physics», the adage of *EPL*, as an obligation to go beyond publishing excellent letters in established areas of physics; for him this maxim means also encouraging publication of work in promising new fields and applications of physics. In this way he will continue a development, which over the past few years has seen an enrichment of the journal through contributions from the fields of biophysics and quantum information as well as from statistical physics of economic and social processes.

In the name of the Board of Directors of the Europhysics Letters Association, I thank Volker Dose for his excellent leadership, and wish Michael Schreiber all the best for a successful and enjoyable time at the helm of *EPL*. ■

Martin Huber,
Chairman of the Board of the *EPLA*

▲ Volker Dose (left) handed over his tasks as Editor in Chief of EPL to his successor Michael Schreiber (right) at the meeting of the Editorial Board, held at CERN in early May 2010. The two EiCs together with Martin Huber, Chairman of the Board of the Europhysics Letters Association, are standing in front of one of the 128 radio-frequency cavities of CERN's now disassembled Large Electron-Positron Collider (LEP). This cavity originally stood 100 m below the surface, along the 27 km circumference of the tunnel that is now occupied by the Large Hadron Collider (LHC).

EPL: the first three years

With effect from January 1st, 2007 "Europhysics Letters" was renamed, the new branding being "EPL". Along with this formal change went a new vision and definition for the aims of EPL. These goals are i) to increase the number of publications by 64% to 1000 per year, ii) to increase the impact factor by 60% to 3.5, and to decrease the acceptance rate from 46% to 33% over a time horizon of five years.

In order to approach these ambitious aims a strategy promising success was required. In a first step the scientific spectrum of Europhysics Letters was evaluated in comparison to other established broad-band physics letters journals. The results revealed strengths above average in both general and interdisciplinary physics; an appropriate share in solid state and the PACS 40 group; and several areas that required further development. The policy which we have followed during the last three years has been to maintain the initial strengths and to try to cure the deficiencies. Initial topics to focus on for growth were chosen to be Plasma Physics, Particles and Fields, and Geophysics.

Extensive marketing and ideas for promotional material have been developed over the past 3 years in collaboration with the Management Committee with an emphasis towards growth and prestige of *EPL*. Our new series of "*Best of*" booklets sample the contents of *EPL* in any particular year by collating article abstracts and is very well received by delegates of conferences where *EPL* is on exhibit. This leaflet also provides a list of members of the Editorial and Advisory Boards, which meets with special interest from the readers. The objectives of our promotional activities include: engagement of more readers, search for new authors and referees, building visibility and promotion. In addition, an Open Access option was established on an "author pays" basis for all topics and Open Access "free of charge" for articles in "Particles and Fields" and in "Nuclear Physics" in anticipation of the CERN SCOAP³ initiative. Expansion and development in these areas has led to a significantly larger population of the physics community becoming aware of publishing opportunities available with *EPL*, a greater number of subscribers, and wider coverage of institutions and countries receiving the journal in online and/or print format. The entire dataset back to the beginning in 1986 is also available online. Download statistics are a feature of successful marketing and promotion and indicate a healthy interest from the community, averaging around 40,000 per month. These may be linked with citations, and the rising ISI Impact Factor reflects a growing interest and confidence from the community that *EPL* is developing as a prestigious top-tier publication.

Concomitant with these "external" actions the editorial procedure was subject to a critical review. The boosting of underdeveloped fields and the envisaged growth of the journal required an expansion of the Editorial Board from 33 in 2006 to 45 members in 2009. During the course of this expansion the fraction of North American Co-Editors rose by a factor of four thereby curing a previous deficiency. These scientists, active in research, are selected for their high expertise and reputation in order to boost the scientific quality of publications and prestige of *EPL*. Many are also active in submitting some of their own work for publication in *EPL*. Co-Editors enjoy considerable autonomy with the newly introduced possibility for accepting submitted articles on the basis of their own expertise, *e.g.* without requiring external review.

▲ **Volker Dose being thanked for his brilliant work as Editor in Chief.**

Such publications bear the notice "accepted by: name of co-editor". So far the record time between submission and acceptance is one day! Another appealing feature is the fast track option offered by *EPL*. Papers accepted for publication in less than 28 days from submission are published online within 15 days. Due to continuous efforts in streamlining the editorial process, the overall publication data exhibit an impressive 15% (median) reduction of the time between reception and acceptance with respect to 2006, the 2009 time span being 75 days. Other benefits for authors include an expanded list of 13 more specialized journals to which good papers which do not meet the *EPL* publication criteria can be transferred for further consideration. Also involved in the editorial work is *EPL*'s Advisory Board. The main duties of the members (former Co-Editors) have been defined as acting as adjudicators for appeal cases; selecting summaries of significant papers for publication as highlights in Europhysics News and *EPL*; preprocessing Comments and Replies; and advising the Editor-in-Chief on candidates for selection as new Co-Editors. The introduction of these duties has been positively echoed by Advisory Board members. The results of the activities described above can be characterized as follows: The number of published papers has increased by 40(64)%, the acceptance rate has remained stable at 46(33)%, and the impact factor has increased by 31(60)% . Numbers in brackets refer to five-year goals. The impact factor number lends hope for a further rise next year since the value for 2010 will also include significantly high citation data from 2009. The promotion of three selected fields has also been successful and shows increases in publications by 60% for Plasma Physics, 80% for Particles and Fields, and a factor of 4 for Geophysics. *EPL* seems to be on a promising track and we look forward to a prospering future. ■

Frederic Burr, Staff Editor
Volker Dose, past Editor-in-Chief
Graeme Watt, Executive Editor

Call for nominations for the 2011 EPS Gero Thomas Prize

The Gero Thomas Commemorative Medal was created in 2000 to honour the memory of G. Thomas, who was the Secretary General of the EPS from 1973 to 1997 and played an essential role in the growth and the development of the Society.

The Commemorative Medal is awarded to individuals for their outstanding service to the Society.

The G. Thomas Memorial Medal has been awarded in 2002 to E.W.A Lingeman (NL), in 2005 to J.L. Lewis (UK) and in 2008 to G. Morrison (UK). The EPS Executive Committee decided in its Meeting of 13/14 June 2008 in Skopje (MK) to award the EPS G. Thomas Medal on an annual basis. In 2009 the G. Thomas Prize recipient was J. Nadrchal (CZ). This year's recipient is Prof. G. Tibell from Uppsala Universitet (SE). The announcement can be read in Europhysics News, Vol. 41, No. 4 (2010) p. 05.

The Thomas Medal Selection Committee calls for Nomination of the 2011 G. Thomas Prize.

Prize selection rules

1. The Prize is given once a year
2. The Prize shall consist of a Commemorative Medal
3. The Prize shall be awarded to one (or more) individual(s)
4. The Prize shall be awarded without restrictions of nationality, sex, race, or religion
5. The Medal may not be awarded to any person currently member or having been member of the Executive Committee in the past three years
6. Candidatures are submitted by nominators (Member Societies, Divisions, Interdivisional Groups, Associate Members or Individual Members) as detailed below
7. Only individuals, with substantial service to the Society over a number of years in a variety of roles and whose achievements in physics research, industry or education were remarkable, are eligible for the Prize
8. Nominations shall be reviewed by a Prize Selection Committee appointed by the EPS Executive Committee. The Committee shall consider each of the eligible nominations
9. The final recommendation shall be submitted for ratification to the EPS Executive Committee.

Submission of nominations

To complete the nomination, the nominator is asked to provide the following documents:

1. The references of the nominee (Name, first name, full postal address, email address, phone and fax numbers)
2. A suggested citation (maximum 250 characters)
3. Nominee's academic and professional background, and professional honours
4. Three supporters statements

All proposals will be treated in confidence. Although they will be acknowledged there will be no further communication.

Nominations should be sent to:
G. Thomas Prize Selection Committee
Chair: Prof. H. Ferdinande
Universiteit Gent • Proeftuinstraat 86
BE-9000 Gent, Belgium
Email: hendrik.ferdinande@ugent.be

The deadline for submission of proposals is **15 January 2011**.

EPL – on the course to a prosperous future

To be selected as the new EiC of EPL is certainly a challenge for me to further enhance the quality and the reputation of this flagship journal of the European Physical Society. To be realistic, I have to admit that EPL is not (yet) in the same ballpark as Physical Review Letters, but it is a medium-term objective for EPL to become a serious alternative journal.

To achieve this aim, it is my intention to continue marketing those fields that have been identified during Volker's time in office as being under-represented in *EPL*. I also plan to further develop the fields of General Physics and Interdisciplinary Physics in which *EPL* is stronger than average. These are the *EPL* fingerprints and I deem them essential for a broadband letter journal, because they are most likely to attract colleagues to browse an entire issue in order to satisfy their curiosity about what might be new in other areas of physics. In my opinion, the possibility to browse such a collection of high-quality papers is one (though certainly not the only) reason why we still need a broadband letter journal nowadays, when internet and archive servers provide access to a large variety of sources on one click.

Coming back to hot topics that I deem to be of particular interest, let me mention topological insulators as an example. It is certainly not appropriate to publish an entire issue of *EPL* on such a selected special topic, but it has turned out to be very attractive to our customers to compile abstracts from articles highlighted by co-Editors into a "Best of …" booklet. Such collections are now being prepared on an annual basis, such as "Best of 2009". I think that instead of publishing special issues it should be worthwhile to provide respective "Best of …" samples for hot topics. The yearly booklets have already met with large interest and have become a good promotion tool for the included papers, in particular as these papers are free to read online for a full year.

All publications on the IOP website, including *EPL*, are free to read for 30 days from the publication date. This is an important access point for some authors, raising the visibility of the articles significantly. I am, however, afraid that this opportunity is not well enough known among possible readers and needs to be publicised even more in future. Beyond this 30-day opportunity Open Access 'forever' is available in a hybrid scheme where the author pays a 1000 Euro charge, which, by the way, covers only about half of the publication costs. This option has been exercised rarely in recent years, but I hope that more and more institutions will provide funds for such publication costs. Moreover, one should mention again that for a limited time all PACS 10 and PACS 20 articles are given Open Access forever free of charge. Besides these Open Access opportunities, it is worthwhile to note that *EPL* is available online and/or in print at more than 2400 institutions worldwide that are subscribers to the journal or to packages in which the journal is included. This global visibility is (another) good reason to publish in *EPL*.

A further, maybe not-so-obvious, reason is the status: *EPL* belongs to not-for-profit learned societies; the journal is owned by a partnership of 17 European physical societies and not by commercial publishers. Thus it belongs to the physicists and I hope that this is considered a valid incentive to select *EPL* for publication. *EPL* supports the physics community by publishing excellent science, and being selected as the new EiC I consider it my duty to do my best to serve the scientific community by steering the journal to further frontiers. Herewith, I refer to the byline of the journal title: "exploring the frontiers of physics". I want to take this motto very seriously and ask co-Editors and referees to view submissions critically on whether this aspect is fulfilled or not. In this context it is important to note that the Editorial Board is a team of more than 40 excellent scientists. These active researchers have an expert understanding of the needs of both authors and readers and can assure a constructive peer reviewing. It is certainly a strength that *EPL* is thus run by scientists for scientists. And to give another answer to the question of whether one still needs a letters journal nowadays, I think that the critical refereeing of manuscripts is an important argument in favour of publishing *EPL*.

However, neither co-Editors nor referees are omniscient and unfailing, and it is a growing concern for me that instances of plagiarism appear to be on the increase. I do not know whether this is due to better countermeasures, such as special software with which copy-and-paste articles can be detected, or whether it is due to corruption of morals. In any case, I will strongly act whenever such things happen and we are in close contact with other journals exchanging information about fraudulent behaviour.

It might also be a possibility that globalism contributes to plagiarism because copyright standards may not be the same and may not be so traditionally valued in some ▪▪▪

regions. But besides moral standards, obviously any copying will not explore the frontiers of physics and already for this reason it is unacceptable.

Nevertheless, although *EPL* is owned by Europeans and published in Europe, globalism is an important feature of *EPL* and it is my intention to foster this aspect by soliciting even more articles from outside of Europe. The number of published articles from North America has, fortunately, risen significantly in recent years. So has the number of submissions from China and India, although the number of publications from these countries has not quite kept abreast. Here is certainly a large field of opportunities to harvest. This is also true for many developing countries where few, but good, institutes do excellent research that needs to be represented appropriately in a global journal. I am committed to offer such a publishing opportunity in *EPL* and will try to attract more submissions from these institutions. Of course, it will be a challenge to convince the authors that exploring the frontiers does not refer to geographical frontiers, but to scientific frontiers.

What might be more interesting for the European community is the possibility of conference sponsorship. *EPL* has sponsored conferences in the past, but in future this will be focused on offering poster prizes for young scientists (perhaps up to 40 years old without permanent position) in order to highlight their excellent research, with the prospect of getting an excellent manuscript submitted from them.

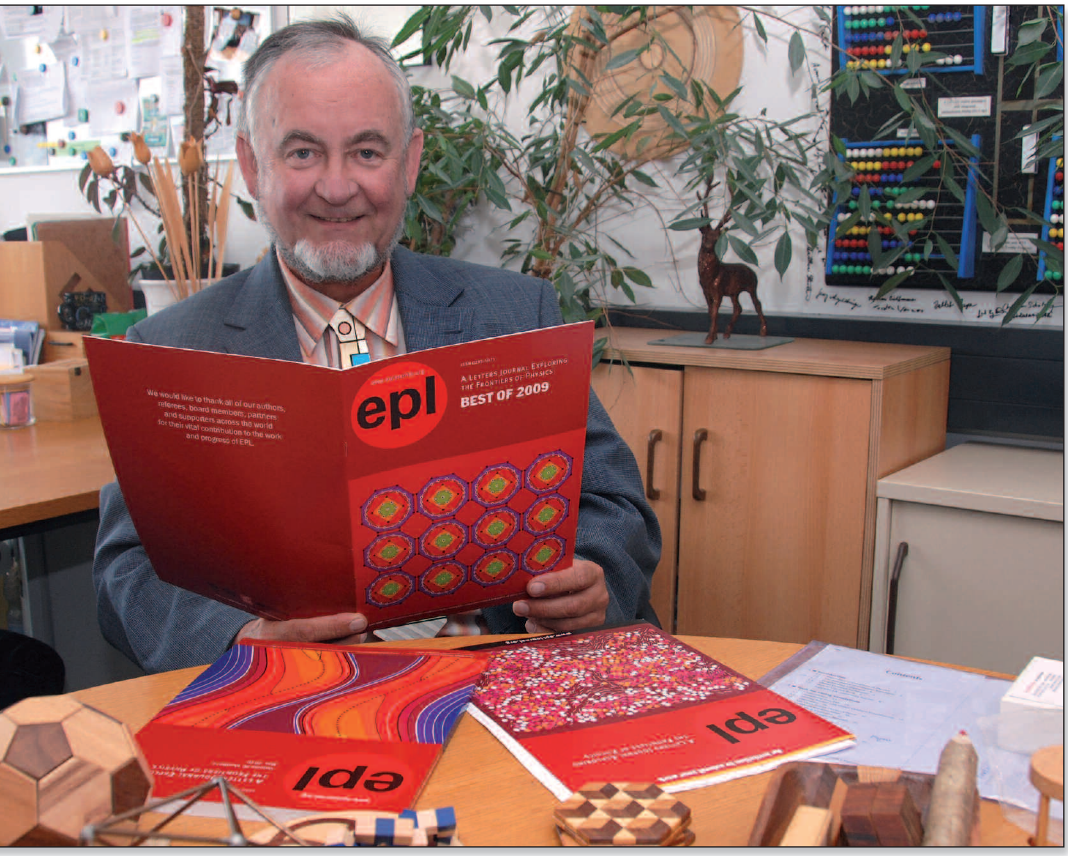
Whether a publication is excellent or not is nowadays often decided by the impact in terms of citations received. This is certainly a one-sided view, but it has to be accepted that bibliometric measures are becoming more and more attractive to science administrators who want to quantify the results of allocated funds or the previous success of prospective candidates for open positions. One respective metric is the ISI impact factor of a journal. This value has to be taken with more than one grain of salt. For individual publications, the impact factor of a journal does not mean anything; for an entire journal it has a limited meaning. One limitation is that it counts the citations of a paper in the two years subsequent to the publishing year and therefore it is rather short-sighted. Nevertheless it is widely recognized and thus the 30% rise of the *EPL* impact factor in the last year is very important. I intend to concentrate my efforts on identifying further topics of high citability and want to attract submissions that will be immediately cited frequently. So please submit your excellent work to *EPL*, especially if it will be cited more than 3 times in the next two years and will thus enhance the *EPL* impact factor. Of course I am aware that such a prediction of the number of citations is difficult, but one can always try. On the other hand, I certainly do not mean to exclude excellent papers with a long-term impact, even if they are not frequently cited in the beginning.

With such excellent submissions the success of *EPL* will be guaranteed and you will facilitate my work at the helm of the EPS flagship. Let me conclude that I consider it an honour to have been selected as the new EiC. I know from my previous experience with the journal as well as from the first 100 days in this job that I can rely on very good people in the *EPL* offices at Bologna, Bristol, Mulhouse, and Paris and, together with them, I am confident that *EPL* is on the course to a prosperous future.

Let me finally point out the silver jubilee of *EPL* in 2011. This 25th anniversary will be celebrated with a Symposium on "Frontiers in Physics" in the Bavarian Academy of Sciences in Munich on 2-4 May 2011, where young scientists from across Europe meet with distinguished physicists from all over the world. So please save the date.

I look forward to meet you in Munich, ■

▼ Michael Schreiber



Michael Schreiber,
Editor-in-Chief

Europhysics Prize 2010

The prize is awarded every 2 years by the Condensed Matter Division of the European Physical Society

The European Physical Society Condensed Matter Division is proud to announce that the 2010 EPS CMD Europhysics Prize is awarded to Hartmut Buhmann, Charles Kane, Eugene Mele, Laurens W. Molenkamp and Shoucheng Zhang for the theoretical prediction and the experimental observation of the quantum spin Hall effect and topological insulators.

Solids comprise a lattice of positively charged atomic nuclei and a cloud of negatively charged electrons. The electrons can have energies only within certain ranges of energy, known as energy bands. Each energy band contains a large number of discrete quantum states, and each state may be filled by up to two electrons, in opposite 'spin states.' The lowest energy is that of an electron most tightly bound to an atomic nucleus. Electrons having the highest energies are known as valence electrons, since they partake in chemical reactions; the band they inhabit is called the valence band. In semiconductors and insulators the quantum states in the valence band are nearly all occupied, and the gap to the next higher band, the 'conduction band' in which electrons can move about freely, determines how good a conductor (or insulator) the material is. The larger the gap, the harder it is for electrons to make the jump up, and the better the electrical insulating properties of the material.

Until recently the band structure of semiconductors was believed to be a textbook subject, with no more surprises to be discovered. The theoretical prediction of the quantum spin Hall effect, and the experiments that have confirmed it, show otherwise.

In the 3D space of the momentum vector of an electron, concentric surfaces of constant energy can be plotted. The surface for the most energetic electron in a solid is known as the Fermi surface. For free electrons the energy is proportional to the square of the momentum and the surfaces of constant energy are spherical, but in solids the relation is more complicated and the constant-energy surfaces depart from spherical shape. This work shows how radical that departure can be. A set of band insulators is now known to exist in which the topology of the band structure, not just its shape, implies the existence of edge or surface states that are insensitive to disorder in the lattice. These states impart to the material some unusual electromagnetic properties.

An insulating state with conducting states at its edges that are robust as a result of the stability of the topology of the band structure is already known: the 'quantum Hall state' observed in 2D systems at high magnetic fields. The present work concerns the existence of so-called topological insulators, which can exist at zero magnetic field and in which the electron spin interacts with the lattice of atoms (the spin-orbit effect). Research on the quantum *spin* Hall effect (of which **Shoucheng Zhang** of Stanford University was a pioneer), and a deeper understanding of the topological description of the quantum Hall state, have been crucial to the development of the notion of topological insulators. The key breakthrough was the 2005 work by **Charles Kane** and **Eugene Mele** (University of Pennsylvania). Taking a 2D hexagonal array of carbon atoms as an example (graphene), they predicted a class of insulators having robust gapless edge states for which the energy depends linearly on the momentum (giving rise to cone-shaped surfaces of constant energy), showing a remarkable pattern of electron spins.

Observation of this phenomenon was not possible in graphene, but the existence of an analogous phase in HgTe-based systems was predicted, and has been found experimentally by the group of **Hartmut Buhmann** and **Laurens Molenkamp** at Würzburg University. They demonstrated that the electrical conductance is quantised.

Generalization to 3D is under way, and also the prediction of related magnetoelectric effects. In addition there should be novel effects at the interfaces between topological insulators and other materials (such as superconductors and ferromagnets). But the major insight is that the topological classification of phases of matter is significant for seemingly simple systems such as band insulators, not just exotic strongly correlated systems. ■

EPS CONDENSED MATTER DIVISION

New members
of the EPS Executive Committee

Caterina Biscari
(1957, Modica, Italy)

Born in Italy, I lived in Spain since my childhood, and there I studied physics at the Universidad Complutense of Madrid, followed by a Laurea in Physics cum laude at the University of Naples in Italy. All my scientific career has been devoted to accelerator physics, starting with a fellowship at CERN, studying polarized beams in LEP. Since then I have addressed different types of accelerators, participating in projects of linacs like the RFQ2 at CERN, test facilities like CTF3 at CERN, colliders like DAPHNE at the Frascati LNF-INFN, laboratory where I have been working since 1985, and where I am now Technology Director.

For 25 years I have worked in accelerators projects dedicated to fundamental physics research, facing challenges of new ideas and realizations with the freedom of daring the most advanced technologies. Recently I am collaborating in the commissioning phase of a hadron-therapy facility at Pavia, CNAO. I am particularly satisfied by the opportunity of using my previous experience for the realization of a reliable and exact tool which will directly help people to improve their life expectation and quality.

I am member of the EPS-Accelerator Group since 2000, chaired the group from 2006 to 2008, and the conference EPAC'08, held in Genova in June 2008. My activity in this group and in the several related international committees is driven by the priority of communication among the people involved in similar projects, particularly on the European collaboration with the American and Asian communities, fostering common projects, aiming at a global communication environment, paying special attention to student attraction and formation.

I have been nominated EPS Fellow in 2009 '*for significant contributions to the design, construction and operation of particle accelerators, for the distinguished role in the international physics community and for the promotion of European Physical Society initiatives*'. ■

Luisa Cifarelli
(1952, Rome, Italy)

Luisa Cifarelli has been Full Professor of Experimental Physics since 1991, first at the University of Pisa, then at the University of Salerno, now at the University of Bologna, Faculty of Sciences and Physics Department (since 2001).

She was educated in Rome, at the French Lycée Chateaubriand, then studied at the Universities of Rome and Bologna, where her thesis supervisor was A. Zichichi (past President of the EPS). She then joined his research group. Her research interests have always been in the domain of very high energy Subnuclear Physics, in the framework of international collaboration projects and experiments carried out at major European laboratories such as CERN (Geneva, Switzerland) and DESY (Hamburg, Germany), and partially also in Astroparticle Physics at LNGS (INFN Gran Sasso Laboratory, L'Aquila, Italy). She has been studying, in particular, the production of "charmed" and "beautiful" mesons and baryons, and the features of multihadron final states in various kinds of interactions. She has been searching for fractionally charged particles (quarks) and for supersymmetric particles. In the last ten years she has been involved in the design, construction and running of the huge time-of-flight detector of ALICE (A Large Ion Collider Experiment) at CERN LHC (Large Hadron Collider). The experiment is meant to study proton-proton collisions, as well as ultrarelativistic heavy ion collisions (Pb-Pb), at extreme centre-of-mass energies. This is where the occurrence of fascinating phenomena, such as the deconfinement of quarks and gluons (in Pb-Pb interactions) could be investigated and where new, unexpected discoveries could be made.

She has served in several councils, committees and commissions: she has been a member of the CERN Council and of the INFN Board of Directors, she is at present member of the Admistration Council of Centro Fermi (Rome) and member of the Scientific Committee of the Ettore Majorana Foundation (EMFCSC, Erice). She is President of the Italian Physical Society, member of the European Physical Society and Fellow of the Institute of Physics. She is also fulfilling editorial duties in the ALICE Collaboration and in several physics journals' boards (*Il Nuovo Cimento, EPJ*).

Luisa plans to do her best to contribute to the growth and success of the EPS in order to increase its visibility in Europe and worldwide, increase its membership (especially among young people), increase its impact and outreach for the promotion of physics at all levels and in all domains (research and education), increase its role of federation of learned societies and of authoritative scientific opinion-maker, increase its potential of solidarity and cooperation organization with respect to less favoured countries (European and also non European). Communication is one of her major concerns for the EPS. Finally the preservation of the proven quality of EPS publications, and their integration in the European publishing context, will also be one of Luisa's priorities. ■

Els de Wolf
(1948, Amsterdam)

After several years as a research physicist at Shell International Oil Company, I work since 1987 as senior physicist at the Nikhef institute for subatomic physics in Amsterdam. First, as particle physicist in the ZEUS experiment at the HERA collider of DESY in Hamburg, studying deep inelastic electron-proton interactions. Since 2003, as astroparticle physicist in the Antares collaboration which is operating a cosmic neutrino observatory located at the bottom of the Mediterranean Sea. Currently, I am the project leader for the Nikhef contribution to the design and construction of the KM3NeT neutrino observatory, the future successor of Antares. At the University of Amsterdam, I am the director of the research Master of Physics. In order to contribute to science literacy in the Netherlands, in my free time, I am the chair of the 'Techniek Toernooi', a technology tournament for young children in the age group between four and twelve year. The first tournament took place during the World Year of Physics and was a.o. sponsored by the EPS.

As a member of the Dutch Physical Society NNV, I recognise the importance of the EPS as the body representing the view of physicists in the discussion in Europe about science research policy, science education and science-literacy in Europe. As a member of the Executive Committee I hope to contribute to this important role of EPS. ■

Nicola Cabibbo (1935-2010)

Nicola Cabibbo, leading particle theorist, professor at Rome La Sapienza University and one of the fathers of modern weak interaction theory, died on August 16, 2010 at the age of 75.

His best known, indeed fundamental, contribution, in 1963, elucidated the universal nature of the weak interactions: making use of what is now called the "Cabibbo angle", he related the weak decays of strongly interacting particles with and without "conservation of strangeness". This grew later into the three-quark family theory of today, which describes all quark mixing phenomena via the "Cabibbo-Kobayashi-Maskawa" matrix.

Nicola performed (with Gatto) the first physics studies for electron-positron colliders. He wrote numerous other influential papers on the strong and electroweak interactions and was also engaged in building parallel supercomputers for numerical simulations. Recently he had joined the NA48 experimental collaboration at CERN in studies of K mesons.

He played an important role also in science organization and policy. He was President of the Italian research institutes INFN (1983-1992) and ENEA (1993-1998), and since 1993 he was serving as President of the Pontifical Academy of Sciences.

His achievements were recognized by several honors. In 1991, he became one of the very first recipients of the EPS High Energy and Particle Physics Prize. He was also awarded the Sakurai Prize of the American Physical Society in 1989 and the Dirac Medal of the ICTP in 2010.

His many interests included American literature, sailing and photography. He remained a true gentleman, a person who was always approachable and softspoken. He will be deeply missed.

Luciano Maiani and Fabio Zwirner

ICTP announces Dirac Medallists for 2010 Award cites work on fundamental force of nature (Trieste, Italy) Italian physicist Nicola Cabibbo (University La Sapienza, Rome, Italy) and Indian-American physicist Ennackal Chandy George Sudarshan (University of Texas, Austin, Texas, USA) share the 2010 Dirac Medal and Prize given by the Abdus Salam International Centre for Theoretical Physics, Trieste, Italy.

The famous "Les Houches" School exported to Singapore

In July 2009, a summer session of the prestigious "Ecole des Houches" was organized in Singapore, the first ever outside France. The school was held at the Nanyang Technological University (NTU) and the session topics covered Ultracold Gases and Quantum Information.

Beside the hosting university (NTU), the school received support from the Centre for Quantum Technologies (CQT), the National University of Singapore (NUS), the Merlion Program (Singapore French Embassy), CNRS (PICS) and the University of Nice Sophia (BQR).

The principal objective of this Les Houches session in Singapore was to provide the best students within the Asia-Pacific region an opportunity to attend top-level courses typically provided by the Les Houches Advanced School in Europe. Indeed, it is a documented fact that Asian students seldom attend the sessions in France due to the distance and the funding. The courses of this one-month session were provided by a team of fourteen international lecturers to 63 students - more than half of them coming from Asia and one third being female students. There were also several social events like the celebration of the French National Day with Wine and Cheese party during dinner on 14 July and visits to parks of the Singapore Island.

As noted by Leticia Cugliandolo, Director of Ecole des Houches, France has an interest in strengthening scientific and academic links with the region and this appears as an excellent occasion to achieving this goal. It is hoped that the organization of this summer course will enhance closer scientific and technological cooperation between Asian and European research centers. In particular, one expects that Asian students will be keener to consider European and French universities and laboratories for their future studies. The signification of the event should be better appreciated within the recent ASEPS (Asia-Europe Physics Summit) initiative, held in Tsukuba (Japan) in March 2010, and aiming at reinforcing the Asia-Europe links. These include high-level training of young scientists. ■

M. Ducloy,
President of the
French Physical Society

▼ **Opening ceremony on 29 June 2009. Seated in the front row (from left): Prof Martial Ducloy, Prof Leticia Cugliandolo (Director, les Houches), Prof Kok Khoo Phua (Director, IAS, NTU), His Excellency Pierre Buhler (French Ambassador to Singapore) and Prof Guaning Su (President, NTU).**

The International Physics Olympiad 2010 in Zagreb

The 41st International Physics Olympiad (IPhO) was held in the Croatian capital from 17 to 25 July 2010. Representatives from 82 participating delegations were present, including 376 competing students from secondary schools and 154 leaders. For the first time competitors from Salvador participated.

The Olympiad was organized and opened by the Croatian Physical Society, President Silvija Tomić, and the University of Zagreb, Rector Aleksa Bjeliš. The chair of the Organizing Committee was Krešo Zadro and the discussions of the International Board (two representatives of each team) were moderated by Hrvoje Buljan.

The first theoretical problem was about an electric charge in the vicinity of a conducting sphere, where the idea of image charges greatly facilitates the computation of the electric field. The second problem dealt with flow of gases through chimneys and it happened to be the most difficult problem for the students. They had to determine first the minimal height of the chimney for its proper functioning, and more afterward. In the third problem a simple model for the matter in the atomic nucleus was suggested, based on the collision between two bare nuclei $^{16}O + ^{54}Fe \rightarrow ^{12}C + ^{58}Ni$ and to study the deexcitation of ^{58}Ni by gamma-emission.

There were two problems in the experimental part of the competition. In the first, students had to deal with the elasticity of a transparent foil (A4 size as used with overhead projectors) rolled into a cylinder. The second dealt with the forces between two coaxial magnets, shaped as rings and moving along a common axis. The formulations and solutions of the problems can be found at http://ipho2010.hfd.hr/. For the past Olympiads, see: http://ipho.phy.ntnu.edu.tw/.

After the competition, 35 participants obtained gold medals, 66 silver, 97 bronze and 66 honourable mention. The individual winner of the competition was Yichao Yu from China. He also received the award of the European Physical Society for the most innovative solution of a problem. The best score in theory was obtained by him, and, for experiments, by Zoltán Jéhn from Hungary. All five members of the teams from China, Thailand and Taiwan received gold medals.

During the Olympiad there were plenty of opportunities, in particular for the competitors, to visit places of interest in Croatia, including Gospić, the birthplace of Nikola Tesla (picture). The Olympiad was organized under rather stringent financial conditions, with very little attention from any local media or high level authorities from the host country, in contrast with previous editions. Nevertheless it was an enriching experience, in a beautiful country.

The next Olympiad was expected to be in Belgium, but the offer was withdrawn due to financial difficulties. Instead it will be in the Thai capital, 10-18 July 2011, at the Chulalongkorn University. As an additional initiative, prof. Yohanes Surya from Indonesia announced the establishment of another competition - the World Physics Olympiad - to be held in Bali, 28 Dec. 2011 – 3 Jan. 2012 with mostly the participation of the gold and silver medallists from the 2011 International and Asian Physics Olympiads. ■

▲ Tesla's house and a Tesla Monument in front of his birth house.

Viktor Urumov,
Saints Cyril and Methodius University, Skopje, Macedonia

Short news

▸ ECAMP X Poster Prize

The 10th European Conference on Atoms Molecules and Photons has been held in Salamanca, Spain, 4-9 July 2010. The poster Prize has been attributed to a communication entitled "Doubly charged ions in doped Helium droplets" by **S. Denifl[1], H. Schöbel[1], S. Zöttl[1], M. Daxner[1], C. Leidlmair[1], P. Bartl[1], T.D. Märk[1], D.K. Bohme[2], O. Echt[3], P. Scheier[1]**

[1] Institut für Ionenphysik und Angewandte Physik, Leopold-Franzens-Universität, Innsbruck, Technikerstraße. 25, A-6020 Innsbruck, Austria,

[2] Institute of Chemistry, York University, North York, Ontario, M3J 1P3 Canada,

[1] Department of Physics, University of New Hampshire, Durham, NH 03824, USA.

▸ Missing author

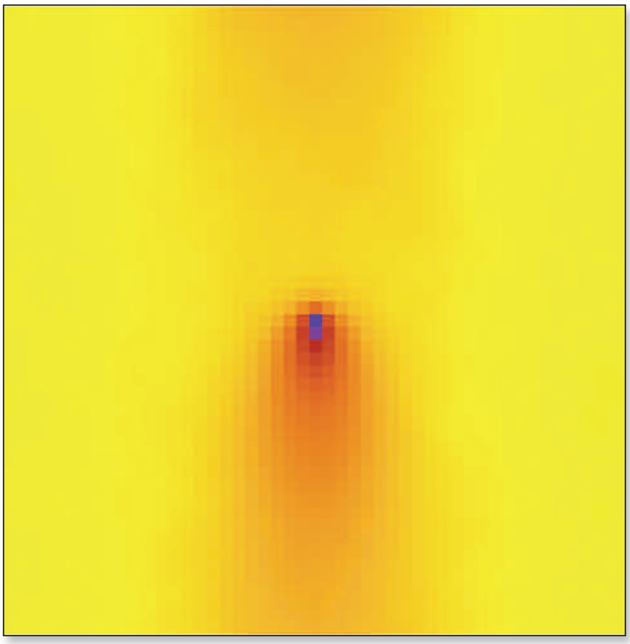
It seems that a 39th author in the person of Alessandro Fedrizzi has been omitted in the article of R. Ursu *et al.* entitled "Space-quest, experiments with quantum entanglement in space", *EPN* **40/3** (2009), 26. This had to be repaired.

Highlights from europeans journals

CONDENSED MATTER

Drag forces in fluctuating classical fields

Identical objects in thermally fluctuating fields experience a fluctuation-induced force between them. Examples include the famous critical Casimir force (generated by thermal rather than quantum fluctuations) [Fisher and de Gennes, *C. R. Acad. Sci. Paris B* **287**, 207 (1978)] and forces induced between proteins in lipid membranes via their coupling to membrane height or composition [Goulian, Bruinsma, and Pincus, *Eur. Phys. Lett.* **22**, 145 (1993)] degrees of freedom. Gaussian fields, linearly coupled to the position of a moving inclusion in the field can also induce a drag force as studied here.



▲ **Simulation of the average magnetization profile (in the rest frame of the magnetic field) about a point-like magnetic field in an Ising model moving at constant velocity. The resolution in the figure represents the average magnetization of the spin at the centre of the square on the Ising model's square lattice.**

The underlying physics is similar to that of a polaron - for a stationary inclusion, the polarization of the field is spherically symmetric, however when it moves the polarization field is deformed (Figure) and this deformation yields a drag. The drag force depends on the statics and dynamics of the field and the inclusion's interaction with the field. At low velocities v the drag force is generically linear in v, but for systems with long-range correlations, such as fields at critical points (for instance the continuous demixing transition for lipid membranes), the drag force can behave non-analytically as v^{Φ}, where $\Phi<1$. As the velocity is increased, the drag force increases to a maximum and then decays to zero as 1/v. This is because at high velocity the polarization cloud does not have sufficient time to develop and the drag is thus reduced. These effects could be measured experimentally, for example on membrane proteins dragged in membranes or on colloids dragged through binary liquid mixtures, using optical tweezers. ■

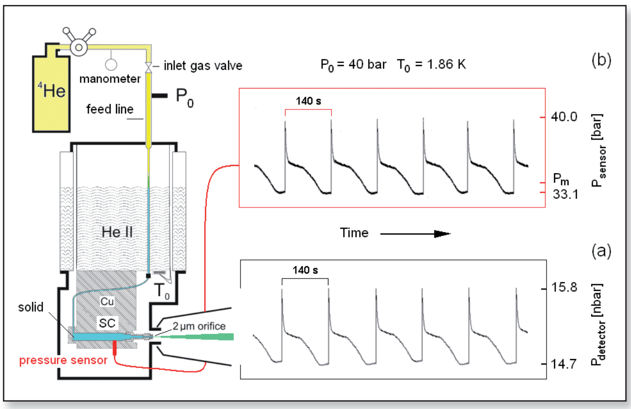
▮▮▮ **V. Démery** and **D.S. Dean**,
'Drag forces on inclusions in classical fields with dissipative dynamics', *Eur. Phys. J. E* **32**, 377 (2010)

CONDENSED MATTER

Geyser oscillations in the vacuum expansion of solid He

Following Galli and Reatto's scenarios for the existence of the Andreev-Lifshitz supersolid phase of ^4He as an effect of excess vacancies [*J. Low Temp. Phys.* **124**, 197 (2001)], the vacuum expansion of solid He through a micrometric orifice was suggested to inject excess vacancies into the bulk [R. Grisenti *et al*, *J. Electr. Spectr.* **129**, 201 (2003)]. Unexpectedly these vacuum expansion experiments exhibited, superimposed on the uniform He flow out of the orifice, spectacular periodic intensity bursts (*geyser effect*), with their period increasing for decreasing solid He temperatures or increasing pressures [G. Benedek *et al*, *Phys. Rev. Lett.* **95**, 095301 (2005)]. Anomalies were observed at temperatures below the lambda point, in a restricted pressure domain of the solid just above the melting pressure, suggesting frictionless flow. These early measurements, almost contemporary to Kim and Chan torsional oscillator experiments [*Nature* **427**, 225 (2004)], raised new

▼ **Vacuum expansion of solid ^4He exhibits identical oscillations in flow (a) in the source chamber (SC) pressure (b), thus providing new insight into the geyser effect.**



questions about the effective role of vacancies in explaining the regular collapses of the solid leading to the geyser bursts. The present study, while confirming the geyser effect over a wider temperature and pressure domains, provides an answer to those questions by monitoring the pressure inside the source and comparing data with the gas inlet valve (Figure) open and closed. The new results indicate that the geyser collapse does not occur near the orifice, as previously suggested, but at a plug in the feed line upstream of the source chamber. Each collapse is triggered by the increasing vacancy concentration which makes the solid behave much as a liquid. On this basis it is argued that vacuum expansion provides a novel approach for investigating exotic non-equilibrium phases of quantum solids such as helium. ■

G. Benedek, P. Nieto and **J. P. Toennies**, 'Geyser Pressure Oscillations in the Expansion of Solid Helium into Vacuum', *Eur. Phys. J. B* **76**, 237 (2010)

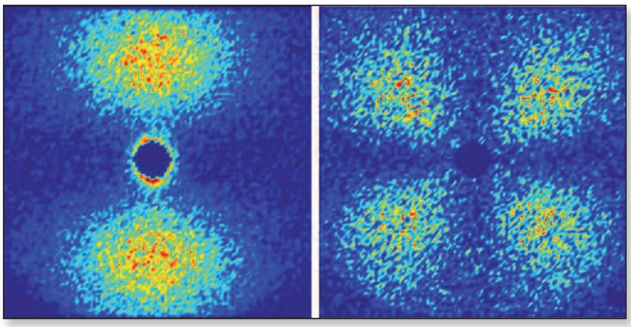
CONDENSED MATTER

One-D neutron-polarization **analysis on magnetic nanostructures**

Small-angle neutron scattering (SANS) is a prominent and powerful method to investigate the bulk of magnetic nanostructures on a length scale between a few and a few hundred nanometers. However, up to now, SANS was almost exclusively utilized with an unpolarized or a polarized incident neutron beam (denoted as SANSPOL), and an analysis of the spin state of the neutron after the scattering process is frequently not performed. The recent development of efficient ^{3}He spin filters (for cold neutrons) allows one to perform *routinely* one-dimensional neutron-polarization analysis (POLARIS) in a SANS experiment. The general equations for the non-spin-flip (nsf) and spin-flip (sf) POLARIS cross sections of a bulk ferromagnet suggest that a variety of angular anisotropies and asymmetries may be observed on a two dimensional detector.

First experiments on an FeCr based two-phase nanocrystalline alloy demonstrate the power of the POLARIS technique for the investigation of magnetic nanostructures. In particular, the analysis of the sf data, which does not contain the coherent nuclear scattering, permits the independent determination of the magnitude-squares of the three vector (Fourier) components of the bulk magnetization. In the figure below, the nsf data (left image) is a superposition of nuclear and magnetic scattering, whereas the sf channel at magnetic saturation (right image) exclusively contains the signal due to longitudinal (M_z) magnetization fluctuations; analysis of the sf data along certain directions in momentum space provides access to the transversal (M_x and M_y) spin components. Such studies are now feasible at the SANS instrument D22 of the Institut Laue-Langevin, Grenoble. ■

D. Honecker, **A. Ferdinand**, **F. Döbrich**, **C.D. Dewhurst**, **A. Wiedenmann**, **C. Gómez-Polo**, **K. Suzuki** and **A. Michels**, 'Longitudinal polarization analysis in small-angle neutron scattering', *Eur. Phys. J. B* **76**, 209 (2010).



▲ **Neutron non-spin-flip (left) and spin-flip scattering cross section of a nanocrystalline Fe-Cr-based alloy at magnetic saturation (B_0 = 1.31 T).**

STATISTICAL PHYSICS

The relationship between **quality and quantity in research**

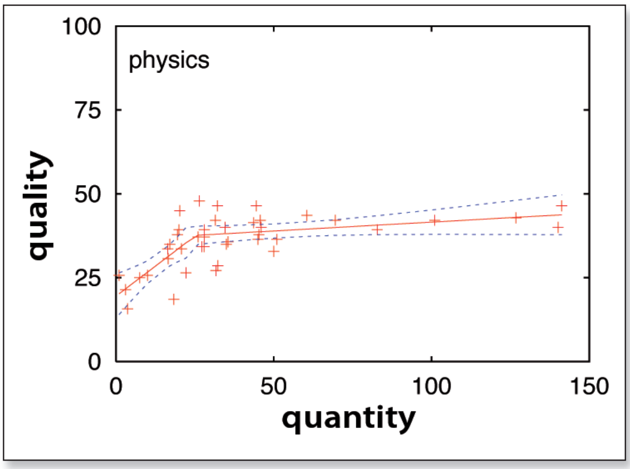
A new sociophysics model has led to quantification of the hitherto intuitive notion of critical mass in research. By treating research groups as complex systems, in which interactions between individuals are taken into account, a relationship between quality and quantity has been established. The model posits that the collaborative effect dominates quality, being an order of magnitude stronger than other factors such as individual calibre or institutional prestige. This means the strength of a research community is greater than the sum of its parts.

The research shows that there exist two critical masses, the sizes of which are discipline dependent. A small group is vulnerable and must strive to achieve the *lower critical mass*. Up to approximately twice this value, research quality is strongly dependent on the quantity of researchers. However, once beyond the value of the *upper critical mass*, research quality does not significantly improve with team quantity (the figure illustrates this for physics). The upper critical mass is interpreted as the maximum number of colleagues with whom an individual researcher can meaningfully communicate. When a group grows larger than this value, it tends to fragment. The lower critical mass is half the upper value, and for biology, physics and Earth sciences is 10, 13, and 15, while for pure and applied mathematics is about 2 and 6 respectively.

The research draws on data from evaluation exercises in Britain and France and suggests that to maximise the overall strength of a discipline, it is best to provide support for ▮▮▮

medium-size research teams to help them reach the upper critical mass, but that a policy of continued concentration is less effective above this limit. ■

R. Kenna and **B. Berche**,
'The extensive nature of group quality', *EPL* **90**, 58002 (2010)



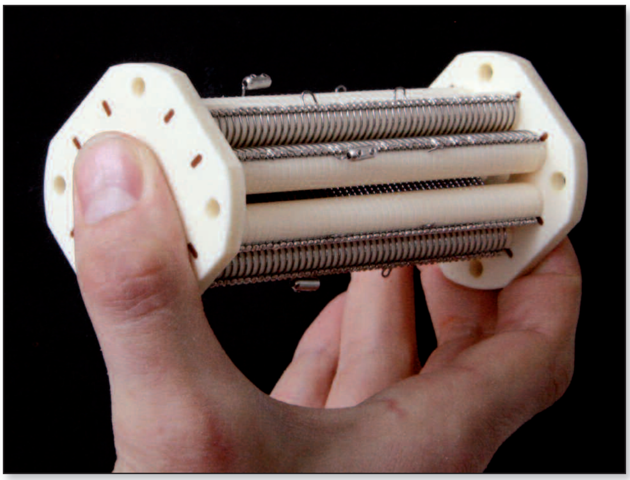
▲ **The quality of research groups plotted against the quantity of group members in physics.**

ATOMIC AND MOLECULAR PHYSICS

Compact Stark slower for polar molecules

Over the last decade, a variety of new tools have been developed to manipulate the motion of polar molecules, such as carbon monoxide (CO) and ammonia (NH_3), by using time-varying electric fields. It has been demonstrated that a beam of neutral polar molecules can be tuned to an arbitrarily low velocity – or even brought to a standstill – with a so-called Stark decelerator.
The operation principle of a Stark decelerator exploits the interaction between the polar molecules and electric fields and is similar to the manipulation of charged particles in a linear accelerator (LINAC). When a molecule in the appropriate quantum state moves through an inhomogeneous electric field, it gains "Stark energy" at the expense of its kinetic energy. Sending molecules through an array of such electric fields stages causes them to successively lose kinetic energy. The group of slow molecules that emerge from the decelerator is extremely mono-energetic, and can be used for various applications, ranging from high-resolution spectroscopy to trapping and molecular collision experiments.
The new Stark decelerator, shown in the photograph, uses tantalum wires instead of steel electrodes to create the electric field stages. This shortens the length of the decelerator by a factor of 10, to about 10 cm, yet still allows for full control over the molecules. This compact beamline is simple and easy to implement, and is also ultra-high vacuum (UHV) compatible. The latter feature makes the new Stark decelerator particularly attractive for use with cold-atom set-ups, in which UHV conditions are required. ■

▼ **Photograph of the hand-held wire Stark decelerator.**



A. Marian, H. Haak, P. Geng and **G. Meijer**,
'Slowing polar molecules using a wire Stark decelerator', *Eur. Phys. J. D* **59**, 179 (2010)

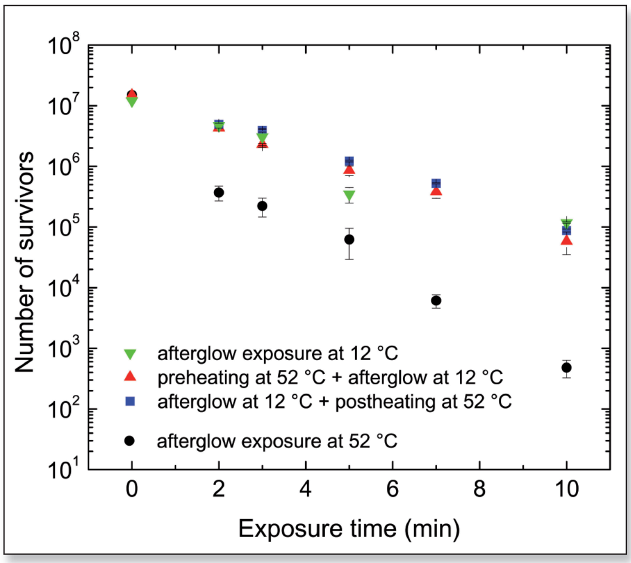
PLASMA

A more efficient plasma sterilizer for medical devices

Bacterial endospores, the most resistant microorganisms, can be inactivated by exposure to UV photons of the outflow of an N_2-O_2 discharge at reduced pressure (5 Torr). These photons are formed through N and O atom collisions in the discharge afterglow, which generate NO_γ excited molecules emitting in the 180-270 nm range (UV-C). Some of these N and O atoms can diffuse prior to combining into NO molecules, ensuring, contrary to UV lamps, inactivation within holes and crevices. These photons create lethal damage to the spore DNA, at a rate that increases with the spore-deposit temperature. At 68 °C, the number of survivors of *B. atrophaeus* spores after a 30 min exposure is one log less compared to 28 °C, hence a shorter sterilization process. Such behaviour occurs only when heat is applied, neither before nor after, but simultaneously with UV photons (figure): inactivation does not result from the addition of sub-lethal damage caused independently by UV radiation and by heat.
Heat provides the energy required to surmount the (small) potential barrier(s) encountered as the chemical reaction leading to the DNA lesion, once initiated by photon excitation, proceeds. The energy barrier corresponds to molecular (conformation) rearrangements, as the reaction develops to reach the final chemical state on the DNA strand. Assuming Arrhenius-law dependence on temperature, the activation

energy supplied by heat is 54 kJ/mol compared to that by photoexcitation, estimated ~ 440-460 kJ/mol, as for many chemical reactions. To the authors' knowledge, it is the first time that such a genuine synergy effect is demonstrated. ■

M.K. Boudam and **M. Moisan**, 'Synergy effect of heat and UV photons on bacterial-spore inactivation in an N_2–O_2 plasma-afterglow sterilizer', *J. Phys. D: Appl. Phys.* **43**, 295202 (2010)



▲ B. atrophaeus spore survival curves under four operating protocols: afterglow exposure (AE) at 12 °C; preheating at 52 °C followed, 3 h after, by AE at 12 °C; AE at 12 °C followed, 3 h after, by heating at 52 °C; AE at 52 °C.

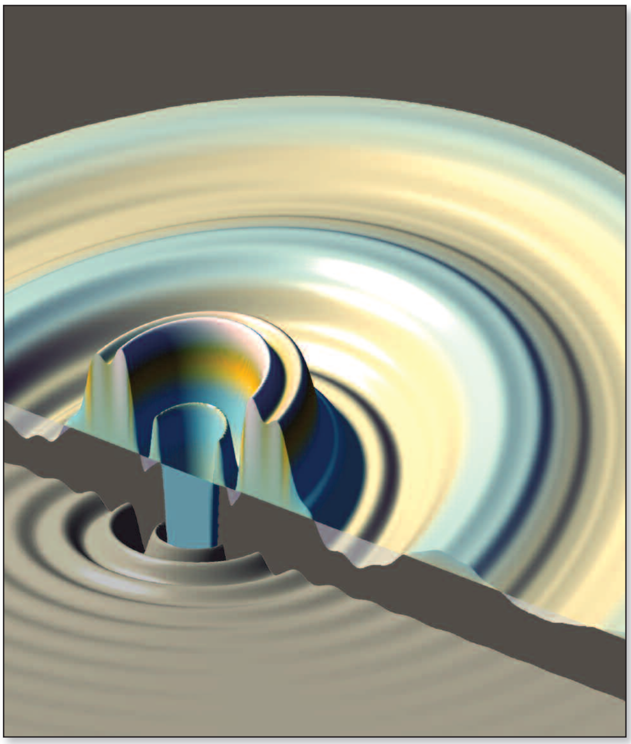
CONDENSED MATTER

Acoustic surface plasmon on Cu(111)

An acoustic surface plasmon (ASP) is a novel collective electronic excitation at metal surfaces. This new mode has a linear (or acoustic-like) dispersion, *i.e.*, it can be excited at very low energy and wavelength, allowing it to participate in many dynamical processes, such as chemical reactions and nanosensors at surfaces and sub-wavelength optics and photonic devices as well as new microscopy techniques.

After the original discovery of an ASP on the close-packed surface of beryllium it now has also been excited and detected on Cu(111). Thus, the ASP is indeed a general phenomenon on metal surfaces that support a partially occupied surface state within a wide bulk energy gap. Non-local screening of the surface electrons due to bulk electrons creates the ASP.

Of particular interest is the interaction of the ASP with light: nm-size objects at surfaces, such as atomic steps or molecular structures, can provide coupling between light and ASPs of much lower wavelength than conventional SPs. In this way, the new mode can serve as a tool to confine light in a broad frequency range up to optical frequencies on surface areas of a few nanometers, thus facilitating control of events at metal surfaces with both high spatial (nm) and high temporal (fs) resolution. Another consequence of the acoustic-like character of the ASP dispersion is that both phase and group velocities are the same, so signals can be transmitted undistorted along the surface. The theoretically estimated ASP decay lengths of 100 ~ 1,000 nm for medium (100 meV) to far (10 meV) infrared are an appealing prospect for the field of nano-optics. ■



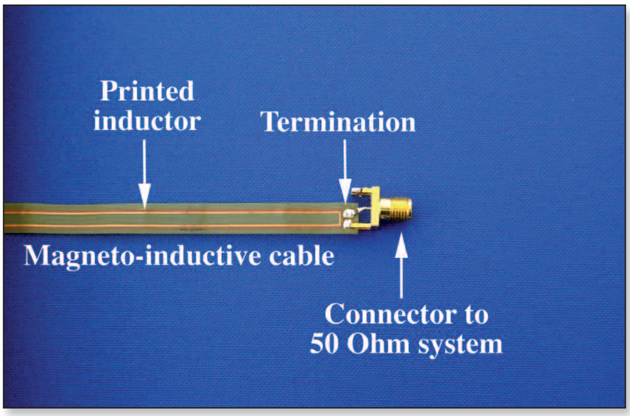
▲ Theoretically simulated electron surface wave patterns created by a point charge located close to a metal surface: The conventional Friedel oscillations (bottom) and a snapshot of the dynamical ASP wave (top) propagating from the center.

K. Pohl, **B. Diaconescu**, **G. Vercelli**, **L. Vattuone**, **V. M. Silkin**, **E.V. Chulkov**, **P. M. Echenique** and **M. Rocca**, 'Acoustic surface plasmon on Cu(111)', *EPL* **90**, 57006 (2010)

APPLIED PHYSICS

Broad-band coupling transducers for magneto-inductive cables

Magneto-inductive (MI) waveguides are periodic structures that operate by magnetic coupling between a set of L-C resonators. A current in one element will create a magnetic field, which then induces a voltage in a neighbouring element. This voltage in turn sets up a new current, which creates a new field. In this way, current waves can propagate along a chain of coupled resonators. Magneto-inductive waves have been ▪▪▪



▲ Flexible MI cable with 50 W coaxial connector.

observed in arrays of elements formed from discrete capacitors and inductors, and also in split ring resonators.

More recently, a flexible cable has been introduced, which allows the inductors and capacitors to be printed, by patterning copper layers on either side of a thin polyimide substrate. MI waveguides allow band-pass propagation at frequencies ranging from MHz to GHz, for applications ranging from data cables to safety-critical interconnects. Other applications include near field lenses, field concentrators and detectors for magnetic resonance imaging.

The performance of MI waveguides is steadily improving, Propagation losses have been reduced, and flexible cables allow bends with low reflection. However, a full range of components is needed before useful systems may be built. A key requirement is a simple method of connecting magneto-inductive and conventional systems. Since the characteristic impedance of a MI waveguide is both frequency-dependent and complex, this is not an easy task. This paper describes a very simple broadband resonant transducer capable of low-loss coupling between magneto-inductive waveguides and systems with real impedance. The transducer may even be formed automatically when a cable is cut, allowing MI waveguides to be spliced to conventional systems. This development should open up the new possibilities for practical applications of MI waves. ■

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ATOMIC AND MOLECULAR PHYSICS

Lyman–Birge–Hopfield emissions from electron-impact excited N_2

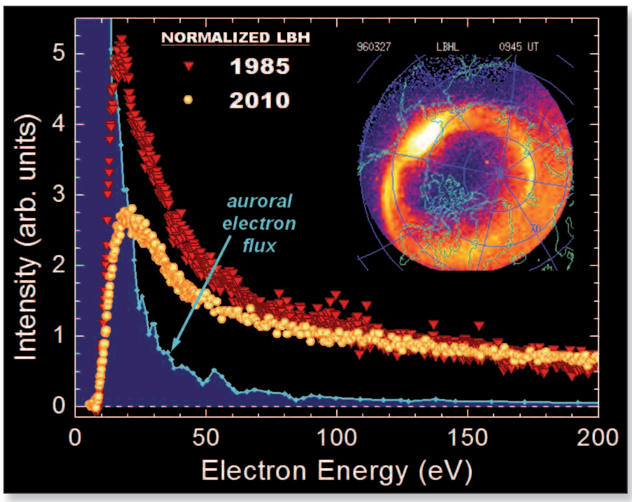
The Lyman-Birge-Hopfield (LBH) band system of N_2 ($a^1\Pi_g \rightarrow X^1\Sigma^+{}_{,g}$) is one of the most prominent emissions in Earth's upper atmosphere. LBH emissions are excited primarily through collisions with electrons, frequently produced by ionizing solar radiation and the solar wind. Strong LBH emissions also radiate from the nitrogen atmosphere of Titan, Saturn's largest moon. Space programs (NASA, ESA…) have launched numerous satellites with UV spectrometers to monitor these emissions.

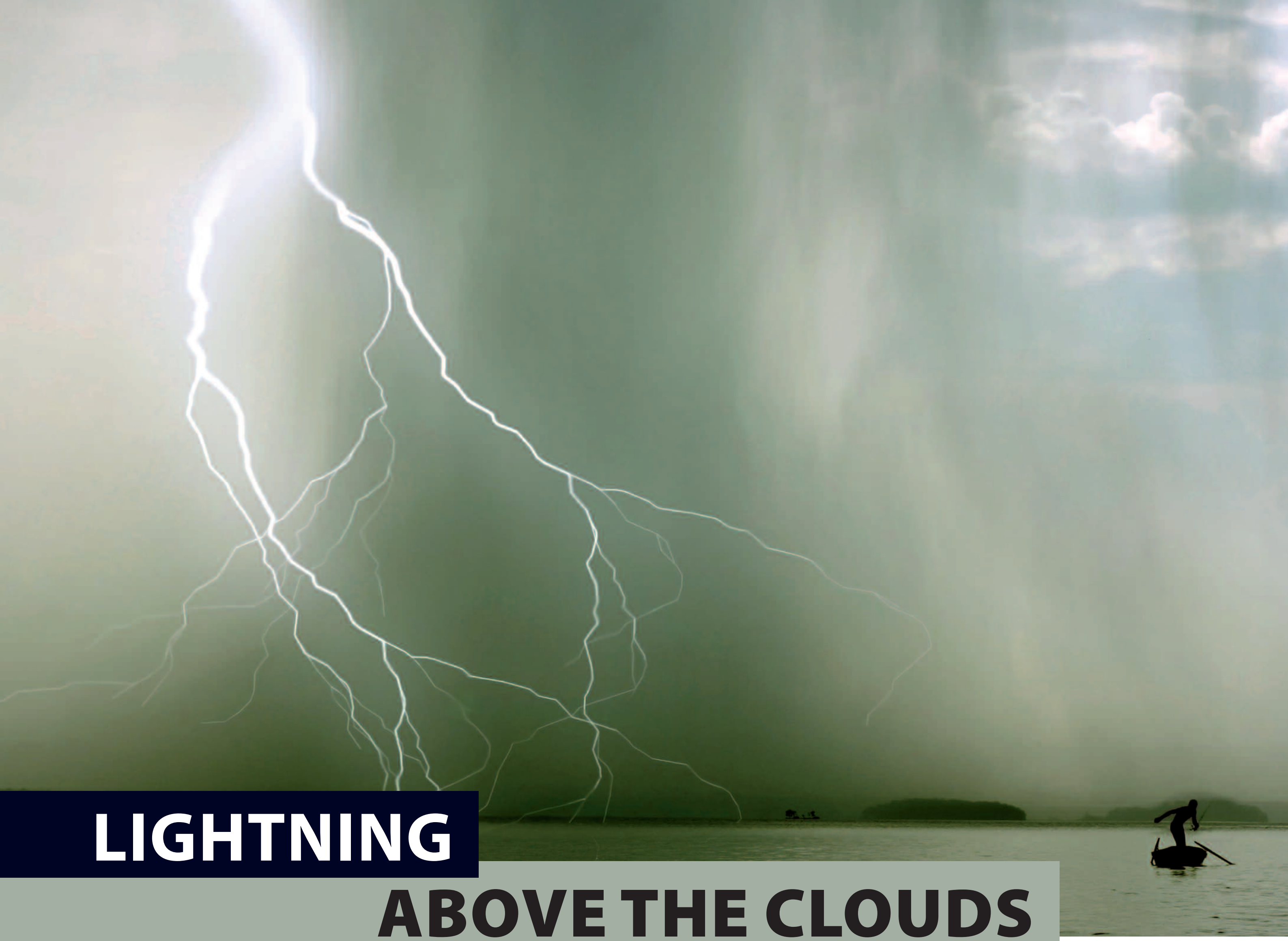
Recently, LBH emissions resulting from electron impact excitation of N_2 into the metastable $a^1\Pi_g$ state were re-examined. By careful attention to numerous experimental variables, such as background signal rates and pressure dependence, more broadly reproducible cross-sections were obtained. Surprisingly, the results differ significantly from the widely accepted benchmark published 25 years ago, which was found to be in error. This new study indicates that the LBH emission cross-section changes more gradually with electron impact energy than previously thought.

The results of this experiment can now be used by aeronomers to better determine the type and energy of collisions responsible for atmospheric radiation. LBH band emissions provide a sensitive diagnostic of the glowing upper atmosphere. For instance, these emissions are used to infer the N_2 density distribution and gas temperature, as well as the average energy and amount of electrons liberated by solar radiation (*i.e.*, dayglow photoelectron flux) and auroral events. The changing spatial distribution of LBH emissions are important observables needed to model space weather, which can seriously upset or even interrupt satellite communications and disrupt power grids. These laboratory results will also improve the interpretation of Cassini-Huygens's ongoing observations of Titan. ■

J.A. Young, **C.P. Malone**, **P.V. Johnson**, **J.M. Ajello**, **X. Liu** and **I. Kanik**,
'Lyman–Birge–Hopfield emissions from electron-impact excited N_2', *J. Phys. B: At. Mol. Opt. Phys.* **43** 135201 (2010)

▼ Electron impact induced LBH emission cross-sections of Ajello & Shemansky [*J. Geophys. Res.* **90**, 9845,1985] and Young *et al.* [*J. Phys. B* **43**, 135201, 2010] (normalized at ~200eV). Also shown is a typical auroral (secondary) electron flux distribution (at 120km altitude) from Jones *et al.* [*Planet. Space Sci.* **54**, 45, 2006] scaled to illustrate the abundance of low energy electrons. Inset: strong auroral and dayglow LBH emission intensities in the terrestrial northern hemisphere [credit: NASA].





LIGHTNING ABOVE THE CLOUDS

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The centuries-old quest to understand lightning received an unexpected boost 20 years ago. While testing a camera for a sounding rocket, a group of scientists recorded a huge electrical discharge tens of kilometers above a thunderstorm. This observation spawned a fertile area of research on transient luminous events in the upper atmosphere. Among other things, these phenomena may provide new clues to understand the physics of a lightning bolt.

▲ the beginning of the storm over the lake ©istockPhoto

On the night of July 5-6, 1989 a group of researchers led by the late John R. Winckler from the University of Minnesota was testing a low-light-level camera to be used in a sounding rocket. They pointed the camera northwards to a clear star field that happened to be just above a far active thunderstorm on the horizon. Two frames from their recording [1] showed a couple of huge flashes, extending tens of kilometers above the thunderstorm. What they had serendipitously observed was later called "**sprites**" by D. Sentman at the University of Alaska, Fairbanks, inspired by W. Shakespeare's "A Midsummer Night's Dream." Two decades after their discovery, sprites are providing clues about the Earth's mesosphere that they inhabit, and they help scientists to understand the nature of lightning discharges. Today we also know that sprites are just one species among a zoo of Transient Luminous Events (TLEs) in the upper atmosphere (see Figure 1).

The three stages of lightning

A lightning discharge develops in three stages [2]: first, the collisions between ice particles and water droplets together with gravity separate positive and negative charges inside the thundercloud and build up a voltage. Then a discharge grows, forming a so-called streamer-leader tree. Finally, when a conducting path is created between cloud and ground, the cloud discharges through the so-called return stroke; currents then reach tens or hundreds of kA, and the released Ohmic heat brings the channel temperatures up to 28000 K.

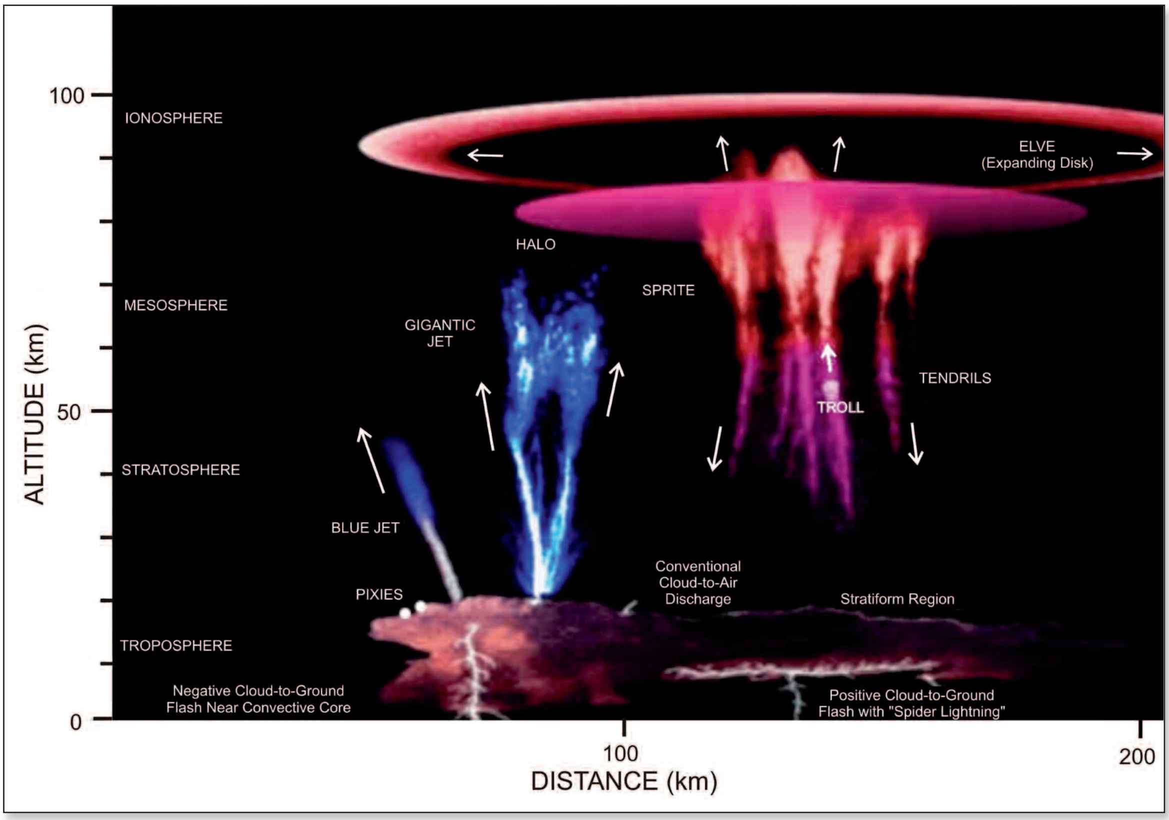
Today some of the hottest topics in lightning research are related to the second stage: the inception, growth and branching of a conducting channel in non-ionized air. Under normal circumstances, air is a quite poor conductor because free electrons rapidly attach to oxygen molecules. However, in a sufficiently strong electric field (higher than 3.2 MV/m in air at standard temperature and pressure) a free electron can gain enough energy to liberate a second electron when it impacts on a molecule, and an ionization avalanche sets in.

However, in most electrical discharges, including lightning, the background electric field is almost everywhere one to three orders of magnitude below the breakdown value. Therefore a simple (linear) ionization avalanche will not grow. The basic breakdown mechanism under these circumstances is provided by so-called "**streamers**": a sort of adventurers that delve into non-ionized air and pave the way for further ionization waves. They are thin, ionized channels embedded in non-ionized air in an electric field below the breakdown value of 3.2 MV/m (see figure 2). The ionized region acts as a conductor and enhances the field around its narrow tip, focusing it into a small area where it can reach several times the breakdown value. By ionizing the air in this area, and by moving the space charge layer forward, the streamer advances and focuses the field into a region further ahead. The streamer extends with a velocity of 10^5 to 10^7 m/s that relates to the drift velocity of free electrons.

In a lightning discharge, a corona of streamers paves the way for the so-called "**leader**". While streamers essentially stay cold and eventually return to their non-conducting equilibrium state, leaders maintain conductivity through higher currents and consecutive Ohmic heating and eventually support the short-circuit between cloud and ground.

Streamers therefore are an important but elusive process in lightning discharges, but they occur in splendid isolation in two other cases. First, they very efficiently convert pulsed electric power into chemical products like ozone that can be used for disinfection, air cleaning or break-up of volatile organic components;

▼ **FIG. 1: The zoo of transient luminous events (TLE's) generated by thunderstorms. Most names are taken from Shakespeare's Midsummer Night's Dream. Elves and sprites are the most frequent. Ground and ionosphere can be considered as equipotential; the thundercloud is the voltage supply separating electrical charges. The break-down electric field is proportional to air density; therefore it decreases strongly with altitude. [Fig. by D.D. Sentman, Univ. Alaska in Fairbanks.]**



industrial applications are very energy efficient, if the subsequent plasma heating is avoided [3]. Second, streamers appear in a most spectacular manner above thunderstorms in the form of sprite discharges, as first recorded by Winckler and his team.

Firework above the thunderclouds

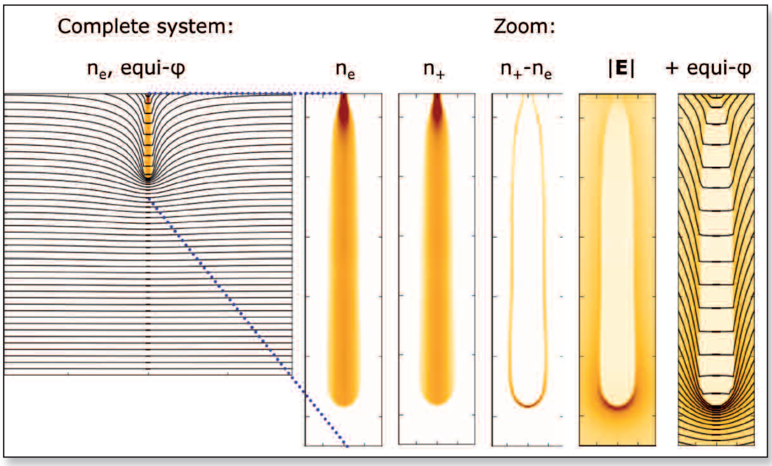
Although the first scientifically documented observation of sprites in 1989 was by accident, it was not completely unexpected. In 1925, C.T.R. Wilson, who later won a Nobel Prize for his invention of the cloud chamber, had already suggested a mechanism for the initiation of discharges above a thundercloud [4].

The electrical breakdown threshold depends on air density. The reason is that electrons can gain energy more easily from a given electric field if they experience fewer collisions. If we move upwards in the atmosphere, the air density decreases exponentially (by about a factor 2 every 5 km) and so does the breakdown field. But the electric field created by the return stroke together with the equipotential earth is approximately dipolar and hence decays more slowly. Therefore above a certain altitude the breakdown threshold is reached and a discharge is initiated: this is the basic mechanism of sprites.

Sprites are composed of streamers, the same structures that pave the way for lightning, only rescaled by the lower air density to be tens to hundreds of meters wide and tens of kilometers long (see Box about scaling). This has been confirmed by high-speed recordings of sprites at up to 10000 frames per second [5] and laboratory photographs with exposure times of nanoseconds [6]. In both cases one sees that light is emitted predominantly from a small region around the tip of the channel, where the electric field is high and ionization is significant.

There are several reasons why sprites have become a hot research topic among physicists and geoscientists. First, they allow us to study the physical process that guides the propagation of a thunderbolt, but without the added complication of streamer-leader transition and return stroke. Leaders are probably not present in upper atmospheric discharges because Ohmic heating is much weaker there; this follows from evaluating scaling laws (see Box) for the Poisson equation [7]. So if you want to understand a lightning stroke, you better might look tens of kilometers above it.

Second, sprites inhabit one of the less known layers of the Earth's atmosphere: the mesosphere; sometimes also termed the "ignorosphere". At those altitudes, air is too rarefied to support a balloon but still would cause too much friction to a satellite; therefore there are very few direct measurements of air properties and chemistry. Sprites generate intense optical emissions and a careful study may reveal more information about the mesosphere.



▲ **FIG. 2: Simulation of a streamer discharge in air between two planar electrodes. The streamer starts from a needle electrode inserted into the upper electrode. Shown are from left to right: the complete simulation volume below the needle electrode with electron density in the streamer (colored) and electrical equipotential lines; and zooms into the streamer finger with electron density n_e, density of positive ions n_+, space charge density n_+-n_e, electric field strength |E|, and the field strength again, now with equipotential lines overlaid. [Fig. by V. Ratushnaya, CWI Amsterdam.]**

Observing and modeling sprites

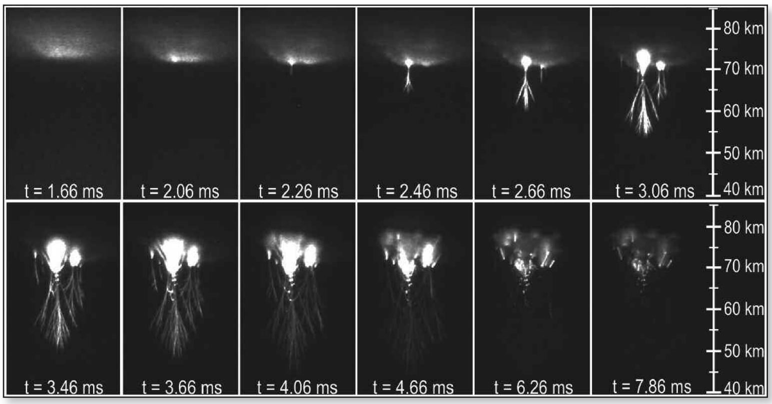
Since sprites were first observed by Winckler's team, researchers have steadily improved their instruments. Now it is possible to obtain time-resolved movies of the complete development of a sprite [5], [8] (see figure 3) and perform detailed spectroscopy of the emitted light.

To remove the atmospheric absorption and scattering, several teams have decided to move their instruments to space. This approach was pioneered by the joint USA-Taiwan instrument ISUAL that has been operating aboard the FORMOSAT-2 satellite since 2004. Europe will have its own orbiting instruments soon: the European Space Agency (ESA) is now building an instrument called ASIM (Atmospheric Space Interactions ▮▮▮

Scaling laws

The dominant length scale in a typical streamer discharge is the electron mean free path l between ionizing collisions with neutral molecules. It is inversely proportional to the molecule density n of the gas: $l \sim 1/n$. Therefore all lengths determined by electron motion scale like $1/n$. The kinetic energies of the electrons have to reach the ionization threshold of the gas molecules which is a molecule-specific value and independent of the gas density; therefore the characteristic electron energies do not depend on gas density. Therefore also the characteristic electron velocities are independent of gas density n. As lengths scale like $1/n$ and electron velocities are independent of n, times have to scale as $1/n$ as well. As energies are independent of n, voltages are independent of n, and therefore electric fields scale as n, as they have dimension of voltage over length.

The air density at 83 km above sea level is about 100.000 times smaller than at ground level. Therefore if lengths and times are measured in centimeters and nanoseconds for an atmospheric pressure streamer, they scale to kilometers and fractions of milliseconds in a sprite at 83 km.



▲ **FIG. 3: The evolution of a *halo* up to time t=2.06 ms and the successive *sprite* discharge above a thundercloud is filmed with 5000 frames per second. Atmospheric altitude is indicated on the right. At time t = 0, a lightning return stroke starts transporting electrical charge to earth, generating an electric field above the cloud. This field creates first a halo at the lower edge of the ionosphere and then a sprite. In the lower row, one can also see the reconnection process between a streamer tip and a pre-existing channel [8].**

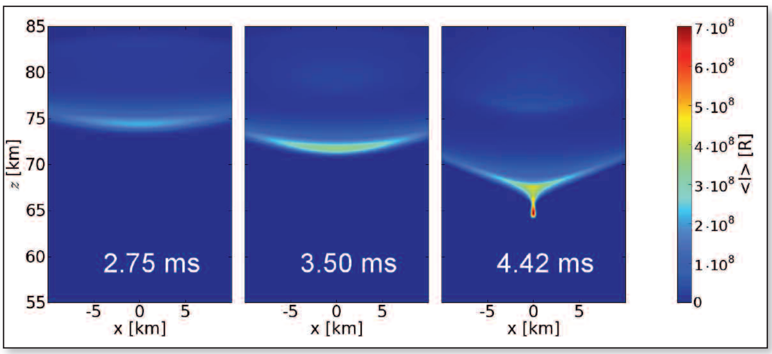
Monitor) that will operate from the International Space Station; its launch is scheduled for 2013. Also the French CNES develops their own micro-satellite TARANIS (Tool for the Analysis of RAdiation from lightNIng and Sprites), scheduled for 2015.

Given the complexity and inaccessibility of the sprite phenomena, it is not surprising that computer simulations are playing an increasingly important role.

One example is the initiation of sprites from halos. Halos are wide, saucer-shaped diffuse optical emissions from the lower ionospheric edge that often precede the sprite (see figure 3). Using realistic altitude and ionization profiles, our simulations [9] could follow that process and show how after a lightning discharge the boundary of the ionosphere is sharpened into an unstable edge, from which a streamer shoots out (figure 4).

Also with the aid of simulations, we have postulated that the upper portions of a sprite streamer channel are negatively charged [10]. That may explain why frequently the positively charged streamer tips are attracted to a previous channel, as seen also in figure 3.

▼ **FIG. 4: Simulation of halo and emerging sprite. The simulation uses a gas discharge model, air density varying with altitude, an initial electron density profile corresponding to fair weather night time conditions and the electric field generated by lightning stroke and ionospheric response. The largely varying length scales (down to scales of meters in the space charge layer of the sprite) are caught through adaptively refined numerical grids moving with the structure [9].**



Outlook

In the 20 years since their first observation, research has established some basic characterization and understanding of sprites. But many questions remain: What does the emergence altitude of sprites tell us about the state of the meso- and ionosphere? How many greenhouse gases are produced by lightning and sprites, and in which stage of the discharge does this happen? Are terrestrial gamma-ray flashes (TGFs) related to sprites? TGFs [11] are sudden bursts of highly energetic radiation associated with lightning strokes whose precise origin is under debate. Do sprites exist on other planets [12]? There they would be the first observable signature of lightning when approaching the planet from space.

Lightning and upper-atmospheric discharges are surely among the most spectacular phenomena in nature. And physically similar streamer discharges are most interesting in plasma and high voltage technology and in plasma medicine. The same research therefore can create new technology, explain lightning, and explore our mesosphere and the atmospheres of other planets from a distance. ■

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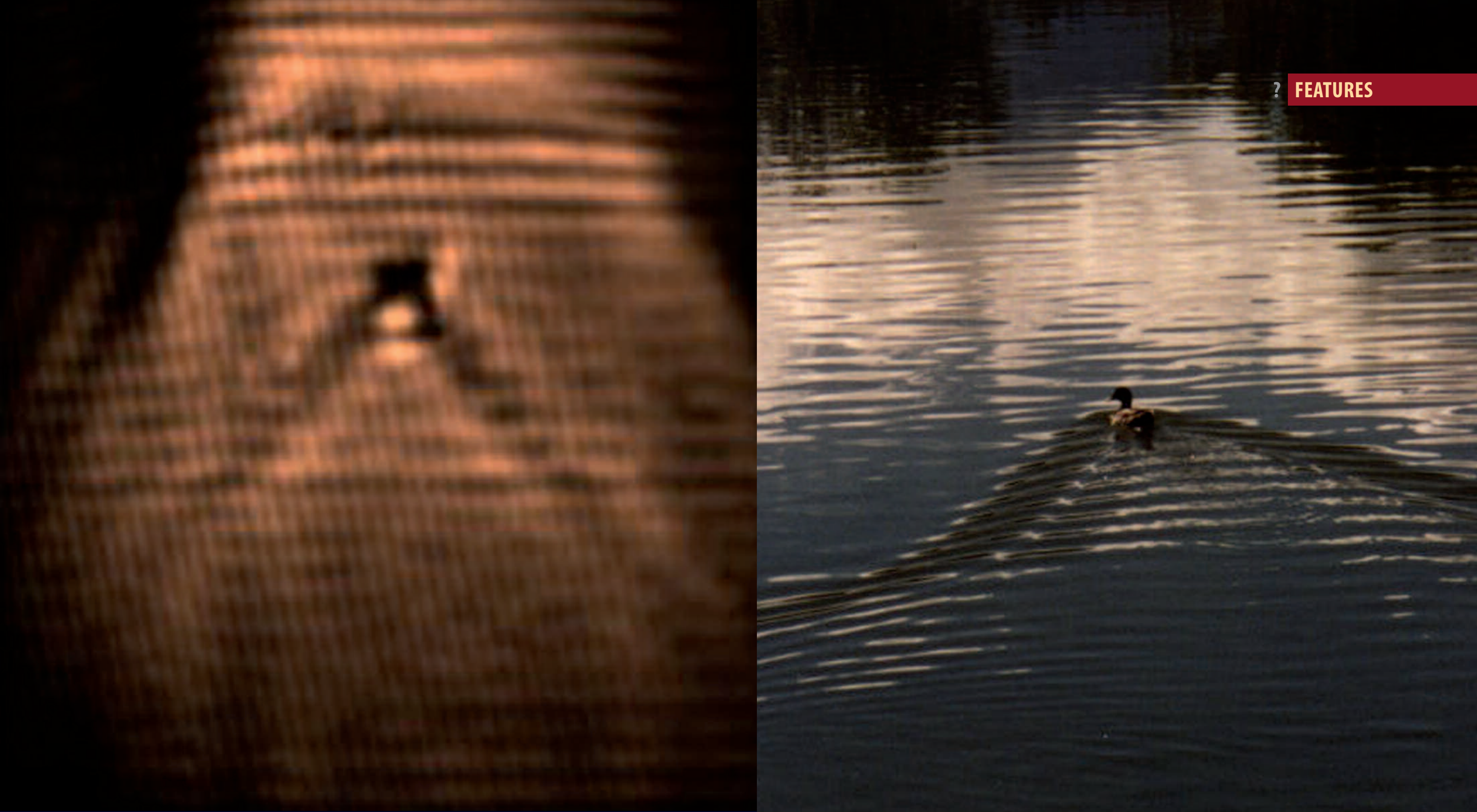

SWIMMING IN A SEA OF SUPERFLUID LIGHT

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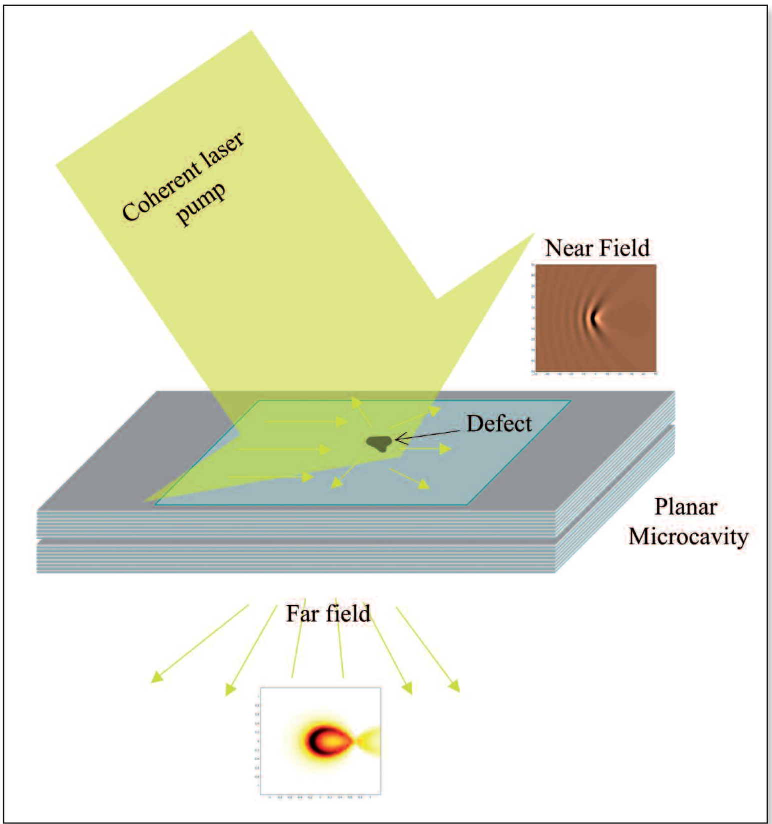
An implicit assumption of Newton's corpuscular theory is that the basic constituents of light do not mutually interact. Once they have been emitted by the source, they travel through homogeneous media along straight lines until they get reflected, refracted or absorbed. What would have happened had Newton foreseen the possibility of efficient collisions between these corpuscles? Would he have imagined the possibility of having a kind of luminous liquid of such particles?

▲ FIG. 1: Left hand panel. Experimental image of the Cherenkov-like wake pattern created by a defect in a flowing photon fluid (courtesy of A. Amo *et al.*, Laboratoire Kastler-Brossel, Université Paris 6 and CNRS, France). Right hand panel: wake pattern behind a swimming duck (photograph courtesy of Fabrice Neyret, ARTIS-CNRS, France).

To the best of our knowledge, it is not clear whether such questions ever crossed Newton's thoughts. In the following decades, the rising success of Huygens' wave theory of light completely deflected the interest of the physics community from these speculations. Even though the corpuscular theory of light had a sudden revival at the beginning of the twentieth century when Einstein put forward his theory of the photo-electric effect, the idea of observing collective hydrodynamic behaviour in a fluid of interacting photons had to wait another few decades until the very recent spectacular observations of superfluidity of light.

Light and quantum gases: historical developments

The first evidence of interactions between light waves was reported in the early 1960's, soon after the first demonstration of laser operation, inaugurating the novel field of nonlinear optics. So far, most textbook presentations of non-linear optics are based on a purely wave picture of light based on Maxwell's equations including a nonlinear polarization term. Given the weak value of the nonlinear susceptibility of most optical media, nonlinear optical experiments require in fact the use of strong fields containing a huge number of photons. In this regime, the coherent field approximation underlying ▸▸▸



▲ **FIG. 2: Sketch of a planar microcavity system resonantly excited by a coherent laser field. The continuous-wave laser beam injects photons, which propagate along the cavity plane. The photon density is controlled by the laser intensity; the excited cavity photon field oscillates at the same frequency as the incident laser; the cavity photon flow velocity is tuned by changing the laser incidence angle. Near-field microscopy of the emitted light gives direct access to the real-space photon density profile, while far-field angle-resolved measurements provide the momentum distribution. Scattering of the flowing photons occurs on either natural or artificial defects. The injected photons can display a collective fluid behavior as soon as the microcavity embeds a material with a sizable optical nonlinearity.**

Maxwell's equations provides an extremely accurate picture of most nonlinear optical phenomena. The small quantum corrections due to the corpuscular nature of light are generally described in terms of the so-called quantum fluctuations around the classical field. In practice, including these corrections is necessary only when shot noise becomes an issue or the device is specifically designed to highlight some quantum features.

The historical evolution of our understanding of gases has followed a specular path: since Demokritus' atomistic hypothesis, the picture that one learns at school involves an assembly of point-like material objects flying across the container and interacting with each other via frequent binary collisions. These collisions guarantee that the gas is able to locally relax to a thermal equilibrium state, which in turn allows for a hydrodynamic description of the system. This purely corpuscular description is accurate as long as the thermal de Broglie wavelength $\lambda_{dB} = (h^2/2\pi m k_B T)^{1/2}$ of the particles is much shorter than the mean interparticle distance. The situation changes drastically at lower temperatures, when the wave nature of the indistinguishable particles starts playing a crucial role as well as their Bose (or Fermi) statistics.

Bose-Einstein condensation is among the most dramatic consequences of quantum statistics. The ground state of a weakly interacting gas of integer-spin Bose particles sees most of the constituent bosons being piled up into a single quantum state and sharing the same one-particle wave function. The evolution of such a Bose-Einstein condensate can then be described in terms of a complex-valued classical matter field that evolves according to a nonlinear Schroedinger equation for the macroscopic wave function, the so-called Gross-Pitaevskii equation. In a nutshell, the material particles are losing memory of their corpuscular nature, which is taken over by their wave character.

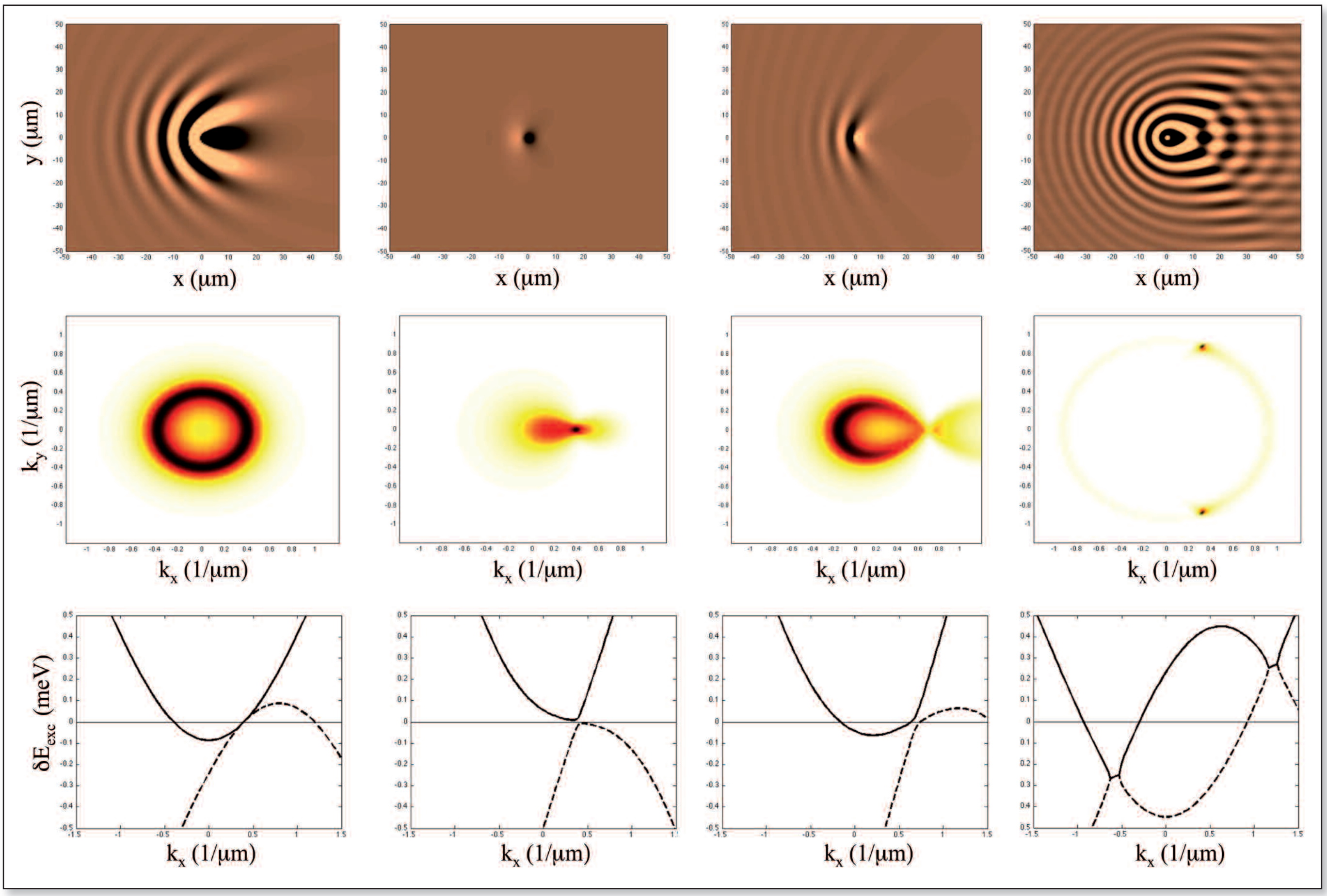
Quantum hydrodynamics of a Bose-Einstein condensate then shares many analogies with nonlinear optics. The Gross-Pitaevskii equation for the Bose-condensed atomic matter field plays the same role as Maxwell's equation for the electromagnetic field in a nonlinear optical medium. The nonlinear term describing binary atom-atom interactions corresponds to the nonlinear polarization contribution. Since its original proposal in the early 1960's, the Gross-Pitaevskii equation has turned out to be an extremely useful tool to describe the peculiar quantum hydrodynamic properties of superfluids, *e.g.*, their ability to flow without any apparent dissipation along a pipe even in the presence of some wall roughness.

Collective effects in photon hydrodynamics

Stimulated by the striking success of the description of a Bose-condensed gas of material particles in terms of a coherent matter wave, in the late '80s researchers started undertaking the opposite path, trying to transpose ideas from quantum hydrodynamics to the emerging field of nonlinear optics. Specific attention was paid to collective behaviour. Among the first developments in this direction, pioneering studies of quantized vortices in laser devices unveiled a fascinating description of the field dynamics in terms of superfluid hydrodynamics of an optical fluid [1].

In particular, it was soon realized that two-dimensional planar microcavity geometries such as the one sketched in Fig.2 can offer interesting advantages in view of the experimental manipulation and diagnostics of the fluid via the incident and the emitted light, respectively [2]. This development immediately pinpointed a most significant difference between optical fluids and traditional, condensed-matter ones. While the basic constituents of matter (e.g. Helium atoms) are stable particles for cosmologically long times, photons have a finite and short lifetime (of the order of picoseconds in typical semiconductor microcavity systems). To maintain a stationary state, the light fluid then needs to be continuously replenished by some pumping mechanism and its non-equilibrium stationary state arises from a dynamical balance between pumping and losses rather than from a true thermal equilibrium state. The first theoretical studies of quantum fluid effects in optical systems were presented and discussed in Ref. [3]. The fundamental analogies and differences between a standard close-to-equilibrium Bose fluid and the non-equilibrium photon fluid were later explored in Ref. [4]. In particular, it was shown how the scattering from defects in the microcavity can be efficiently suppressed by judiciously choosing the driving laser parameters. This regime of photon superfluidity is illustrated in the second column of Fig.3. Note in particular the disappearance of the resonant Rayleigh scattering ring from the momentum distribution. Correspondingly, the real-space density perturbation remains localized in the vicinity of the defect. The underlying mechanism can be understood in terms of a direct generalization of the usual Landau criterion: superfluidity is observed whenever energy conservation prevents elementary excitations from being created in the moving fluid. Remarkably, the suppression of scattering by defects critically depends on the collective nature of its elementary excitations and cannot be explained in a standard single-particle picture of independent photons. In a standard dilute Bose condensate at equilibrium, *e.g.* of ultracold atoms, this condition is verified as long as the fluid is flowing at speeds slower than the speed of sound. With a suitable choice of the laser intensity (controlling the photon density), of the laser frequency (imposing the photon field oscillation frequency) and of the incidence angle (determining the in-plane photon flow velocity), a different regime of super-sonic flow can be accessed. This regime is illustrated in the third column of Fig.3: as the flow speed is faster than the sound velocity, elementary excitations are now efficiently created by the defect into the fluid. As a direct consequence of their linear energy-momentum dispersion, the density perturbation pattern has a Cherenkov-like conical shape in the wake of the defect. In addition, a series of parabolic precursors appears upstream of the defect. In addition to these quite standard behaviours, recently observed also in atomic systems [6], the non-equilibrium nature of the photon fluid allows for a much richer variety of collective

▼ FIG. 3: Theoretical patterns describing the interaction of an otherwise spatially homogeneous photon flow with a point-like defect in the cavity. Top row: real-space images of the photon density profile. The defect is located in the center. Middle row: corresponding momentum distributions. Bottom row: energy-momentum dispersion of the collective elementary excitations in the photon fluid; solid lines correspond to the physical, positive-norm modes, dashed lines to the negative-norm "ghost" ones. First column from left: the low-density regime of non-interacting photons. Second column: superfluid regime of sub-sonic flow. Third column: Cherenkov regime of super-sonic flow. Fourth column: anomalous «Zebra-Cherenkov» pattern in the vicinity of a parametric instability in the flow. Parameters can be found in Refs. [4]. Spectacular experimental results confirming these theoretical predictions have been recently published in Ref. [5]. An example is shown as a background image under the title. Comparison of experimental and theoretical images can be freely downloaded at the page: www.nature.com/nphys/journal/v5/n11/suppinfo/nphys1364_S1.html



features. While in equilibrium systems the particle density and the chemical potential are fundamentally related by the so-called equation of state, in the non-equilibrium case the analogous quantities (photon density and field oscillation frequency) can in fact be independently tuned by controlling the external driving laser. This remarkable fact leads to exotic propagation features with no analog in close-to-equilibrium quantum fluids. As a most striking example, we have illustrated in the rightmost panels of Fig.3 the «zebra-Cherenkov» pattern that is created by the defect when the photon fluid is not far from a parametric instability.

The recent experiments

Following these theoretical predictions, the experimental quest for a photonic superfluid was quickly launched. So far, this challenge has been carried out mostly in planar semiconductor microcavities in the so-called strong light-matter coupling regime [2]. In these systems, the elementary excitations consist of a superposition of a cavity-photon and a quantum well exciton, the so-called polaritons. These bosonic particles combine the advantages in manipulation and detection that are provided by their photonic component with the strong binary interactions that instead originate from the excitonic one. Furthermore, the advances in the growth techniques are now able to fabricate planar semiconductor microcavities with weak structural disorder and therefore perfectly suitable for studies of polariton hydrodynamics.

Bose-Einstein condensation of polaritons was firmly demonstrated for the first time by a Grenoble-Lausanne collaboration, which immediately triggered investigations of the superfluidity properties of the polariton condensate. The first experimental studies by the UAM group addressed quantum fluid effects in wave packet propagation [7] and later the metastability of supercurrents in vortex geometries [8]. Meanwhile, experiments performed by the group of A. Bramati and E. Giacobino at Laboratoire Kastler Brossel in Paris have shown spectacular evidence of photon superfluidity in the sense of the Landau criterion [5]. In contrast to other configurations, the resonant coherent pumping allows in fact for a quantitative theoretical modeling of the experiment in terms of a nonlinear differential equation that generalizes the Gross-Pitaevskii equation to the non-equilibrium context. The agreement of the experimental observations with the theoretical predictions of Ref. [4] turns out to be very good. Even if coherence is imposed to the fluid from the outset, typical signatures of superfluidity are apparent: suppression of scattering on a defect for low enough flow speeds and the appearance of a Cerenkov-like pattern in the case of a supersonic flow. A typical experimental pattern in the Cherenkov regime is reproduced in the background image under the title of the present paper.

The future: strongly correlated photon gases

While the peculiar superfluidity properties of non-equilibrium condensates under different pumping configurations are still raising interesting conceptual questions [9,10], a new research direction on strongly correlated photon gases has recently moved its first steps with a few preliminary theoretical investigations. The first proposals have addressed the possibility of observing the transition from a superfluid to a Mott insulator state in a photon gas confined in an array of cavities [11]. Unfortunately, an experimental realization of this physics is likely to be severely disturbed by the finite lifetime of the photon. Other predictions of this same Bose-Hubbard model look instead more robust, and may even take advantage of the non-equilibrium nature of the photon gas to produce novel states of matter. As a simplest example, the possibility of creating a gas of impenetrable polaritons in a one-dimensional geometry has been predicted [12]. Unambiguous signatures of the strongly correlated nature of such Tonks-Girardeau gas have been predicted to appear in quantities as simple as the absorption spectrum. From this perspective, the presence of a radiative decay channel is more an advantage than a hindrance, as it allows to extract information on the quantum many-body state of the gas from the statistical properties of the emitted light.

At the present stage of the experimental research in this direction, the most demanding step appears to be the identification of a nonlinear optical medium with a strong enough nonlinearity to enter the so-called photon (or polariton) blockade regime. In this regime, the presence of a single photon (or polariton) is able to detune the cavity resonance of a large enough frequency to prevent a second resonant photon (or polariton) from entering. Once again, a promising possible solution to this problem is suggested by the analogy with atomic gases: the photon-photon collision amplitude has been anticipated to be dramatically enhanced at Feshbach resonance on an intermediate biexciton state [13]. Other schemes to enhance the effective strength of photon-photon interactions taking advantage of the strong dissipative nonlinearities of coherently driven atomic media or of quantum interference effects in suitably designed geometries have also been recently proposed [14].

It is therefore legitimate to believe that the quantum physics of strongly correlated photon fluids has all the potential for a very bright future! ■

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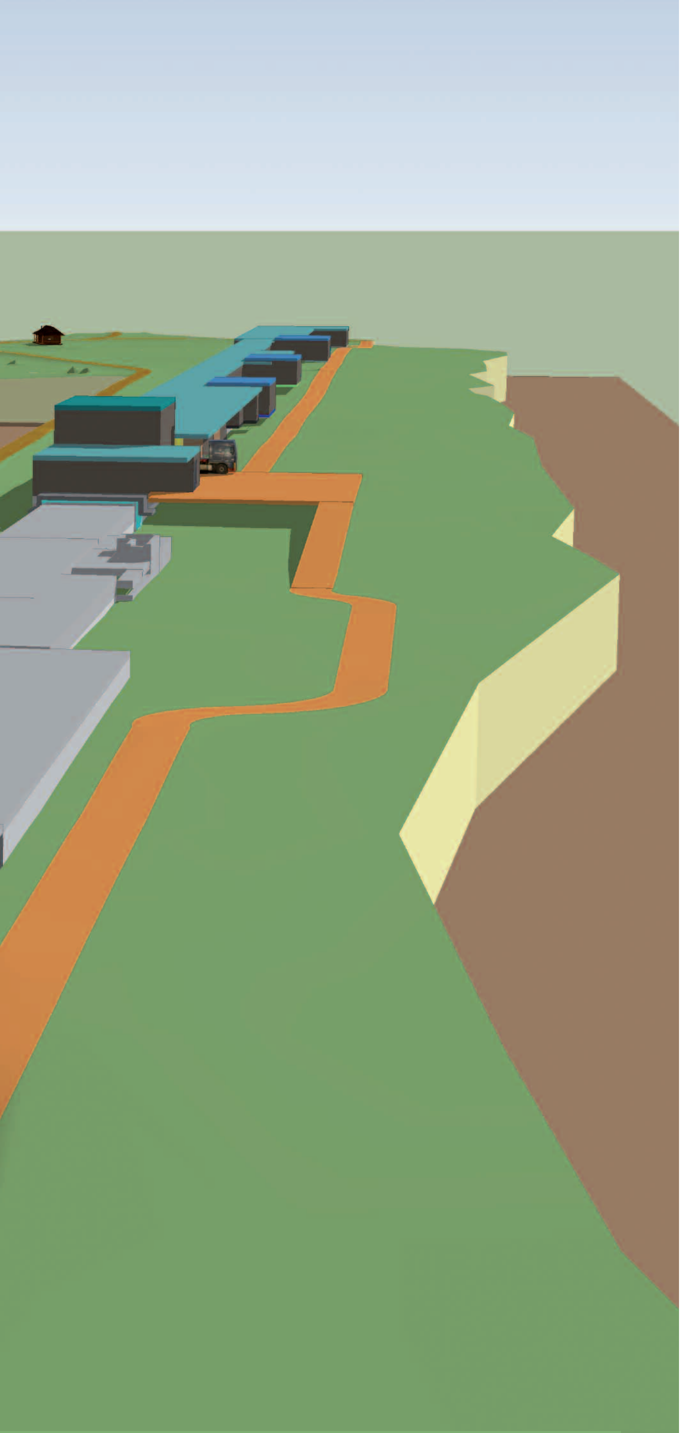
ULTRAFAST PHENOMENA AT THE NANOSCALE:

NOVEL SCIENCE OPPORTUNITIES AT THE

Next generation X-ray sources, based on the X-ray Free Electron Laser (XFEL) concept, will provide highly coherent, ultrashort pulses of soft and hard X-rays with peak intensity many orders of magnitude above that of a synchrotron. These pulses will allow studies of femtosecond dynamics at nanometer resolution and with chemical selectivity, and will produce coherent-diffraction images of organic and inorganic nanostructures without the deleterious effects of radiation damage. The PSI SwissFEL is one of presently four XFEL projects worldwide.

Three enduring trends in investigations of structure and function in the natural sciences are "smaller", "faster" and "more complex". And by far the preferred tool of such investigations is electromagnetic radiation – light. Major advances in the investigation of matter with light have been the invention of IR and visible lasers, with their capability of bright, ultra-short (fs) pulses, and the advent of high-brightness synchrotron X-ray sources, which allow atomic-resolution imaging and chemically-specific spectroscopy. The new generation of light sources, the X-ray Free Electron Lasers (XFEL), will encompass all three above-mentioned trends in a single instrument. An overview of length and time scales (Figure 1) indicates where an XFEL will



◀ Preview of SwissFEL

SWISSFEL X-RAY LASER

make the strongest impact – in particular below the μm scale of optical microscopy and below the ns scale of pulsed synchrotron X-rays. We are speaking, for example, of biomolecular aggregates and small inorganic molecules, and of ultrafast magnetic recording and molecular vibrations.

An enduring wish is to image matter at X-ray resolution, a task which is complicated by the lack of low-aberration X-ray lenses. Also here, the XFEL offers a solution: coherent diffraction. By nature, XFEL radiation has a high degree of spatial coherence, implying that scattering by a thin phase object shows a rich "speckle" (Figure 2), which, using recursive phase-retrieval algorithms, permits a diffraction-limited, real-space reconstruction of the object [1].

Finally, a major difficulty in nm-scale studies of matter with both X-ray scattering and electron microscopy is sample degradation by radiation damage. Ironically, the ultra-short, ultra-bright pulses from an XFEL have the potential to circumvent this problem – by a technique called "diffract-and-destroy". Due to photoemission and Auger processes, a nanoscale object exposed to a single XFEL pulse (10^{11} – 10^{12} photons), will rapidly become positively charged and, on the scale of 50 fs, undergo destructive "Coulomb explosion" [2]. Hence a 10-20 fs XFEL pulse will record the scattering from, to a good approximation, as yet undamaged material. Note that approximately the same number of photons is supplied in a 20 fs XFEL pulse as in a full second of 3rd generation synchrotron radiation.

Operating principle

As in a synchrotron, XFEL light is created by the passage of a pulse of relativistic electrons along a periodic magnet array – an "undulator" (Figure 3a). For reasons of beam quality, a single-pass linear accelerator is required for the XFEL, in contrast to the circular storage ring of the synchrotron. And as for the synchrotron, the emitted wavelength λ is related to the undulator period λ_u, the maximum undulator field B_0 and the relativistic electron energy factor γ (total energy divided by rest mass energy) by the undulator equation:

$$\lambda = \frac{\lambda_u}{2\lambda^2}\left(1+\frac{K^2}{2}\right) \qquad (1)$$

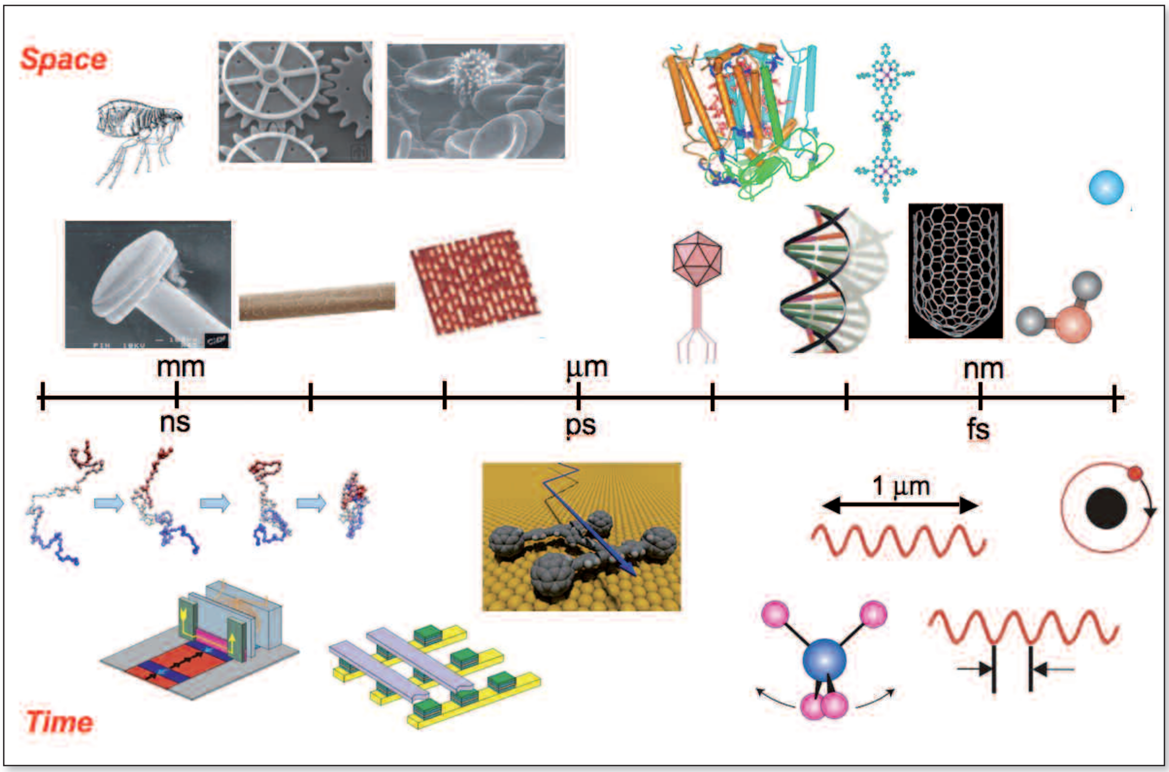
where the undulator "K-factor" is given by $K = eB_0\lambda_u/2\pi mc$, and m is the electron mass.

The long XFEL undulator length (60 - 100 m, vs. 2 - 4 m at a synchrotron) produces sufficiently strong undulator radiation to subtly alter the electron trajectory, causing a sub-division of the electron pulse into "micro-bunches", whose spacing is just the emission wavelength λ (Figure 3b). The resulting coherent radiation initiates a positive feedback effect – more radiation, better defined micro-bunches, more radiation, ... – which exponentially amplifies the light via "self-amplifying spontaneous emission" (SASE) (Figure 3c). It should be noted that SASE is a highly stochastic process, generally resulting in quite irregular X-ray profiles, in both time and frequency. Efforts are underway, also at PSI, to use laser-seeding techniques to produce Fourier-transform-limited XFEL pulses [4].

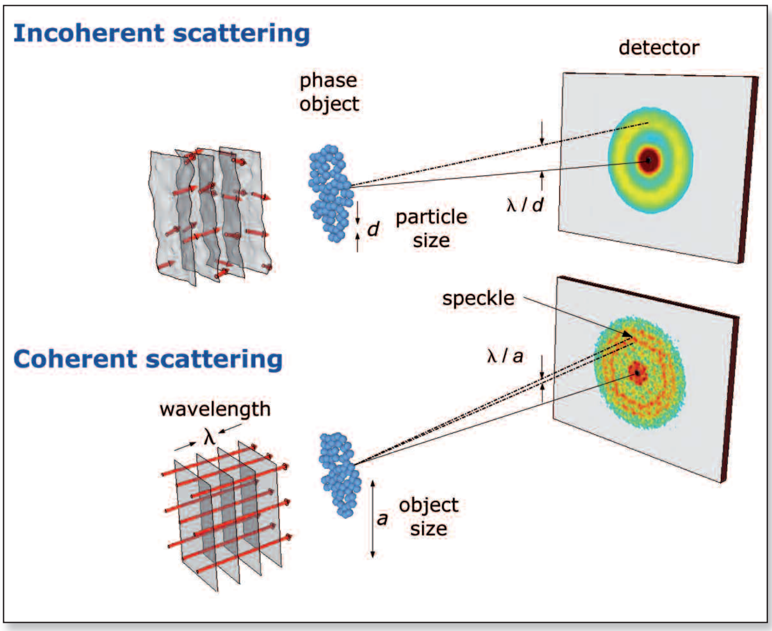
Other XFEL projects

Worldwide, there are presently three funded XFEL projects: the LCLS (US), SCSS (Japan) and European XFEL (Germany) [5-7] (see Table 1). Parliamentary approval of the SwissFEL project [8], at the Paul Scherrer Institute, Villigen-Würenlingen, Switzerland, is anticipated for mid-2011.

▶ **FIG. 1:** The XFEL will bring novel opportunities to study matter at µm to nm resolution and on the ps to fs time scale.



A major difference between the European XFEL and the SwissFEL is the use in the European project of superconducting accelerator technology. This dictates a pulse structure with many micro-pulses (2700 micro-pulses at 220 ns separation) per macro-pulse, resulting in a much higher average flux. Such a pulse structure is optimal for dilute samples, such as molecular gases, and coincidence experiments, but it complicates the recovery of a condensed matter sample, as well as the efficient readout of imaging array detectors.



▲ **FIG. 2:** Whereas the Debye-Scherrer rings of incoherent scattering only yield the particle size d, the rich speckle seen with coherent scattering allows an accurate reconstruction of the entire object [1].

SwissFEL

The 720 m long SwissFEL [8] (see Figure 4) at the PSI site in Villigen-Würenlingen, Switzerland, is the shortest of the current XFEL projects. Although it has the lowest electron energy, it will still be capable of producing hard (λ = 0.1 nm) X-rays. In the initial phase, it will provide simultaneous operation of two beam lines, the hard X-ray line *Aramis* (λ = 0.1 – 0.7 nm) and the soft X-ray line *Athos* (λ = 0.7 – 7 nm), with possible later extensions of both wavelength ranges. Each line will sequentially serve three experimental areas - *Aramis*: "coherent diffraction / scattering", "pump-probe" and "generic"; *Athos*: "pump-probe imaging / scattering", "pump-probe spectroscopy" and "inelastic scattering". *Aramis* will specialize on short pulse (10 fs) SASE operation, and *Athos* will offer variable polarization control and, with laser-seeding technology, Fourier-transform-limited pulses. Both beam lines will have as an option a "broad-band chirped" mode, with a bandwidth of 1%, for single-shot spectroscopic measurements involving an energy-dispersive detector. Among the synchronized sources of pump radiation pulses to be included in the SwissFEL facility will be an independent, accelerator-based terahertz source, capable of producing non-ionizing, half-cycle or wave-train radiation with high maximum peak field strengths (3 T, 10^9 V/m).

Science applications

The uniform 10 ms spacing of the X-ray pulses from the SwissFEL is particularly suitable for applications in condensed matter science. Whereas a higher repetition

Project	Length (m)	$E_{electron}$ (GeV)	λ_{min} (nm)	Peak brightness (ph/s/mm²/mrad²/0.1%bw)	Pulse structure	undulator beamlines
LCLS	1500	13.6	0.15	1×10^{33}	120 Hz	1
Japan XFEL	1000	8	0.1	0.5×10^{33}	60 Hz	1
Europ. XFEL	3400	17.5	0.1	5×10^{33}	2700 × 10 Hz	3
SwissFEL	720	5.8	0.1	0.5×10^{33}	100 Hz*	2

▲ TABLE 1: Comparison of XFEL projects. "0.1% bw" refers to a relative photon energy bandwidth of 10^{-3}. As mentioned in the text, the pulse structure of the European XFEL consists of trains of 2700 micro-pulses, repeated 10 times per second. * It is under consideration to operate the SwissFEL with two micro-pulses per macro-pulse, one for each undulator beam line.

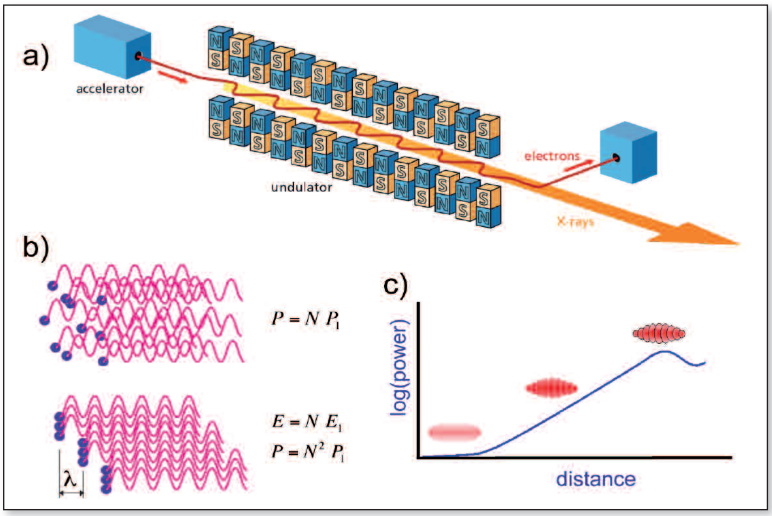
rate, such as will be produced by the European XFEL, is desirable for dilute samples such as gases and plasmas, the 100 Hz rate of the SwissFEL is well-suited to solid or liquid samples, which will require a certain recovery or repositioning time. Furthermore, the majority of experimental methods proposed for the SwissFEL incorporate imaging detectors with several million pixels, whose read-out rates are well-matched to the X-ray pulses. A survey of the prospective user community was carried out in the form of a series of Workshops, and the resulting SwissFEL Science Case [9] comprises five chapters: ultrafast magnetization processes, catalysis and solution chemistry, coherent diffraction from nanostructures, ultrafast biochemistry and dynamical effects in correlated electron materials. Here we present three selected proposals.

a) Switching dynamics in magnetic nanostructures

In the continuing effort to enhance the storage capacity and switching performance of magnetic media, the highly stable magnetic vortex states of thin disks (*e.g.*, Permalloy, 20 nm thick, 200 nm diameter) are being investigated both experimentally and theoretically [10] (see Figure 5). It is known that application of an in-plane field pulse can switch between the up (red) state and the down (green) state, but an experimental method with both the spatial and temporal resolution required to visualize this process is lacking. Using the magnetic contrast from X-ray Circular Magnetic Dichroism (XMCD), coherent, circularly-polarized synchrotron X-rays resonant with the L_2 and L_3 absorption edges of 3d-magnetic ions can produce static holographic images of ferromagnetic films [11]. A single pulse from the *Athos* beam line will suffice to produce such an image, and combined with rapid switching by a synchronized THz pump pulse, it will be possible to follow the switching process at the required resolution.

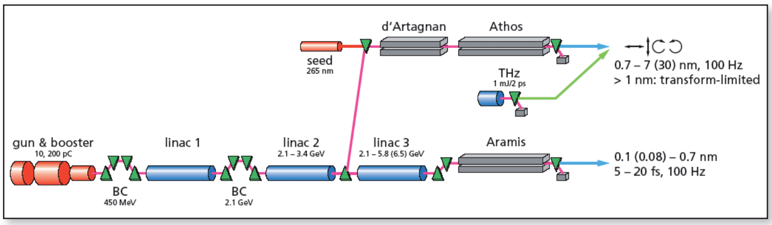
b) Intermediate states in heterogeneous catalysis

A further example of nanoscale dynamics with hitherto unobservable intermediate states is chemical reactions at catalytic surfaces (*e.g.*, see Figure 6). It has been proposed [12] that such a reaction can be initiated under

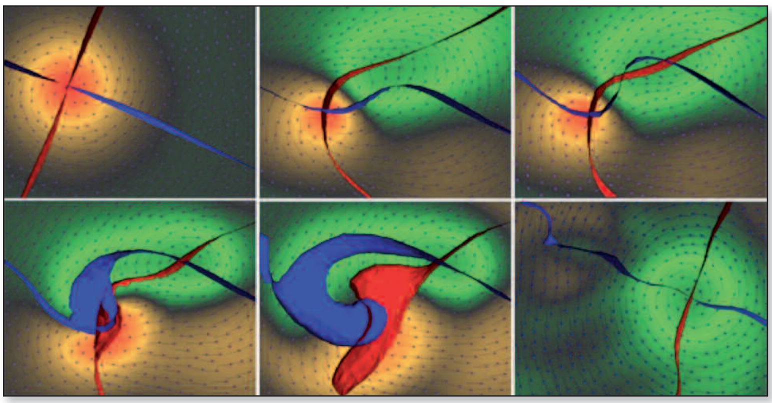


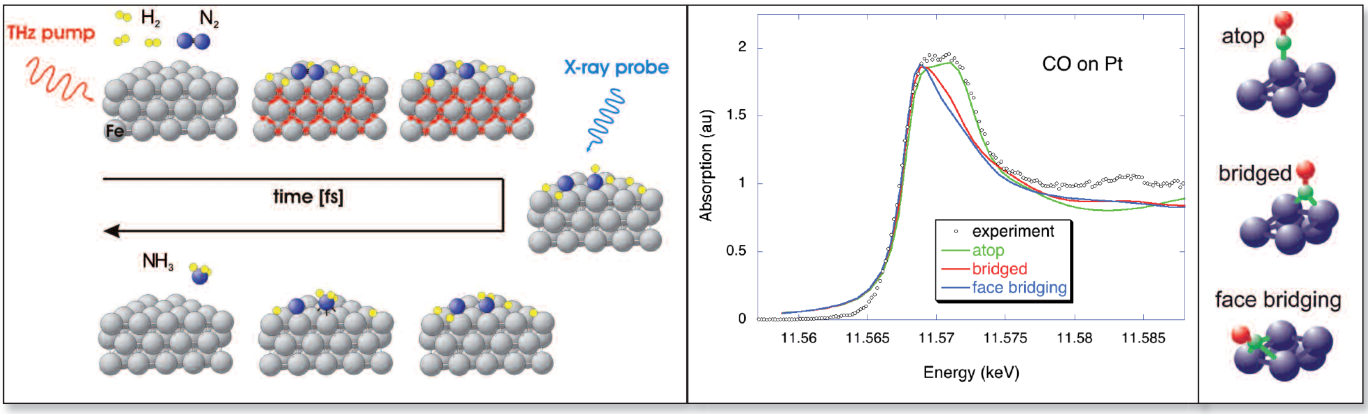
▲ FIG. 3: Schematic principle of XFEL operation [3]: A relativistic electron pulse from a linear accelerator (a) traverses a long magnetic undulator. The initially incoherent undulator radiation (b) becomes increasingly coherent as the "micro-bunching" process sub-divides the pulse into coherently-emitting slices. Saturation is reached at the end of the undulator (c), at which point the electrons are discarded. The relative power gain of this instrument over the incoherent synchrotron is equal to the electron number per pulse: N≈10^9 ! (E and P are the total field strength and total emitted power; E_1 and P_1 the field strength and emitted power from a single particle).

▼ FIG. 4: The schematic layout of the SwissFEL X-ray laser facility, including the electron injector (gun and booster), two electron bunch-compressors ("BC"), three linear accelerator ("linac") sections and hard (*Aramis*) and soft (*Athos*) X-ray beam lines. An external laser and the additional d'*Artagnan* undulator allow seeding of *Athos*, and a synchronized THz source is available for non-ionizing pumping.



▼ FIG. 5: Switching is simulated in a magnetic nanostructure [10]. Application of an in-plane field pulse (80 mT, 5 - 60 ps) to an up vortex (red) generates an intermediate vortex-antivortex-vortex state, which, after "annihilation", evolves to a down vortex (green).





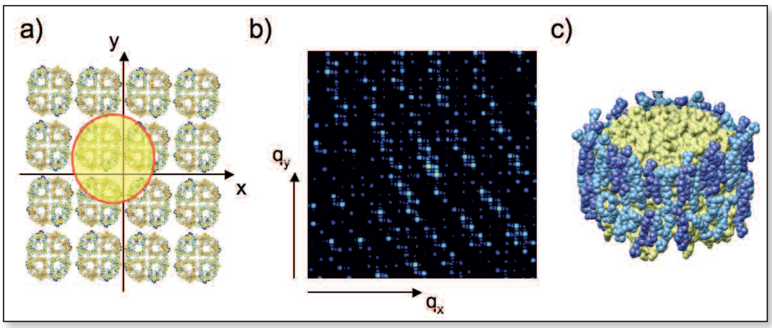
▲ **FIG. 6:** A catalytic process, in this case the Haber-Bosch production of ammonia, is initiated with a THz pulse and queried with a broadband X-ray pulse. The site-specific XANES spectrum, here for static CO on Pt [13], can be acquired with a single pulse from the XFEL.

▼ **FIG. 7:** 2D-membrane protein crystallography. A series of single-shot XFEL exposures (spot size: 100 nm) (a) are taken, each of which yields a coherent diffraction pattern (b). The data are combined, using the ptychographic method [14], to achieve a molecular structure at atomic resolution (c).

nearly equilibrium conditions with non-ionizing THz radiation – either by resonantly exciting local vibrations or by physically displacing ionic species with a half-cycle pulse. The local environment of a selected chemical element can then be queried, with a single broadband XFEL pulse and an energy-dispersive detector, via its XANES (X-ray Absorption Near Edge Spectroscopy) signature.

c) 2D-crystallography of membrane proteins

With the completion of the Human Genome Project, the focus of microbiology has shifted from genomics to proteomics – what is the structure, and hence the function, of the proteins coded in our DNA? Of particular interest as targets for intelligent drug design are the membrane proteins, which control access to the cell and its nucleus. But since by nature these proteins prefer a 2D-environment, they are particularly difficult subjects for conventional 3D-protein crystallography. The low scattering power and high sensitivity to radiation damage further complicate X-ray and electron scattering approaches. With "diffract-and-destroy", it is believed that the XFEL will circumvent radiation damage, and advantage can be taken of its high spatial coherence to retrieve the missing crystallographic phase information. But even an ultra-bright XFEL pulse produces very little scattering from a 2D-protein crystal (see Figure 7) – of order 10 photons per Bragg reflection. One would like to combine the scattering from many separate XFEL shots, each performed on a fresh 2D-microcrystal, but account must be taken of the uncertain orientation of each sample. An elegant method [14] of combining coherent diffraction data from differently oriented 2D-crystals is "ptychography", from the Greek "to fold", and simulations show that repeated measurements at different tilt angles will yield molecular structures with atomic resolution.



Outlook

Progress is continuing on the realization of several XFEL projects worldwide: the LCLS in California is producing prodigious amounts of spectacular data, and the interest in XFELs of the scientific community is rapidly growing. If parliamentary approval is granted for the SwissFEL during 2011, operation in Villigen-Würenlingen can begin in 2016. The Paul Scherrer Institute welcomes input from all interested parties. ■

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PHYSICS IN DAILY LIFE: FLYING (S)LOW

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When thinking about energy-efficient travel, why not use our imagination and try to construct a vehicle that has zero resistance? In fact, we do not have to invent it. It already exists. It's the airship, or zeppelin, named after its developer, the German count Graf Ferdinand von Zeppelin. It does not need high speeds to stay airborne, in contrast to a plane. Neither does it have the annoying rolling resistance of a car. So this looks like the ideal way of transport, viewed from a perspective of energy.

Or does it? All the above may be true if we just want the zeppelin to float at a fixed spot. But what happens to its efficiency once it starts moving?

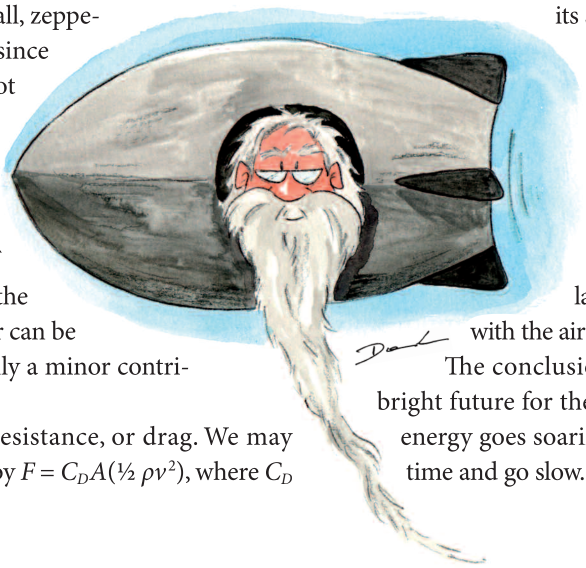
We can easily make a back-of-an-envelope estimate. All we have to do is to work out the air resistance of the airship, keeping in mind that the resistance (in newtons) is equivalent to the energy use per unit distance (in joules per metre, or kJ/km if you wish). To keep it simple, let us compare the airship with a car. This is a fair comparison: in contrast to a plane at high altitude, a car moves through air at ambient pressure, just like a zeppelin. After all, zeppelins are bound to fly low, since Archimedes' law would not allow them much lift in thin air.

And if we consider speeds of 100 km/h at the very least (just think of a zeppelin in headwind!) the rolling resistance of the car can be ignored, since it makes only a minor contribution at such high speed.

So let us look at the air resistance, or drag. We may remember that it is given by $F = C_D A(½\, \rho v^2)$, where C_D is the drag coefficient, A the frontal surface area, ρ the air density and v the speed. For a fair comparison we should take the value of A per passenger in both cases. For a car, this is about 0.5 m^2. For a zeppelin we may take the dimensions of the Hindenburg, the airship that made history when it tried to land in New Jersey back in 1937. It had a diameter of 41 metres and carried about 100 passengers. This yields a frontal area of 13 m^2 per passenger. Obviously, there is no way that this can compete with a car. Even if we take into account that the value of C_D for the cigar-shaped zeppelin may be lower than the value for a car by a factor of three (0.1 *vs.* 0.3, say), the airship loses by an order of magnitude.

We can check our estimate using the Hindenburg's technical data. It had a top speed of 135 km/h and its engines had a power P of 3560 kW in total. If we work it out, realizing that $P = Fv$ we find that, indeed, a car beats the airship by a factor of 7 or 8.

If we remember that a full airplane is about half as fuel-efficient as a full car, we conclude that a plane is also superior to the zeppelin by a wide margin, even though its speed is much higher.



This may come as a surprise, but the reason is obvious. For one thing, the airship has this enormous volume, giving rise to large air resistance. Secondly, the density of the air through which it moves is larger by a factor of 4 compared with the air at cruising altitude of a plane.

The conclusion is inevitable. There is no bright future for the airship, even if the price of energy goes soaring. Unless we *really* take our time and go slow. ■

MUSEUM BOERHAAVE, LEIDEN (THE NETHERLAND)

Museum Boerhaave, the Dutch national museum for the history of science and medicine, was founded in 1929. August Crommelin, deputy director of the Leiden Physics Laboratory and the first director of the museum, felt the need to protect collections of nice instruments against a looming demise. In that sense, there is a parallel with the Museum of the History of Science (Oxford, 1924) and the Istituto e Museo di Storia della Szienza (Florence, 1930).

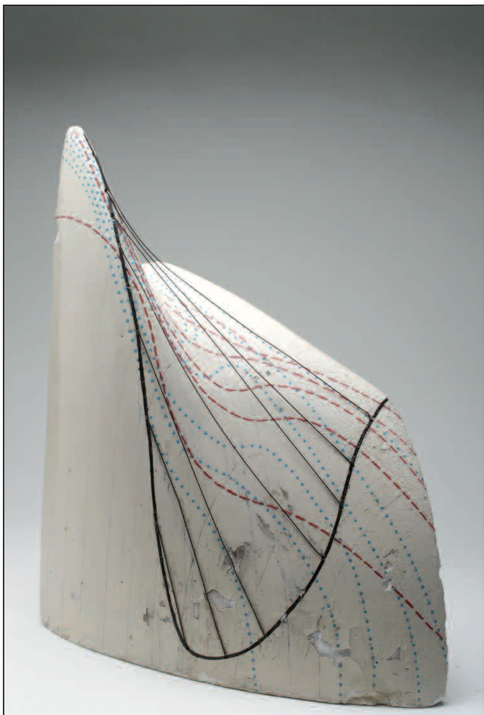
▲ One of the upper floor rooms of Museum Boerhaave, dedicated to the 17th century, the Dutch Golden Age. The showcases display the pendulum clock invented in 1657 by Christiaan Huygens and some lenses he made in collaboration with his brother.

Crommelin took on the fate of the instruments that Heike Kamerlingh Onnes, pioneer of refrigeration, had relegated to the attic when he arrived in 1882 and started to transform the Leiden Physics Cabinet into a research laboratory. That collection included lenses used by Christiaan Huygens, air pumps and many more demonstration instruments from the eighteenth-century, mostly produced by Jan van Musschenbroeck. Later years of glory are represented by the apparatus Kamerlingh Onnes used in 1908 to liquefy helium, or the three dimensional molecule models of Jacobus Hendricus van 't Hoff, the beginnings of stereo chemistry.

But the ambitions of the new museum reached higher. Crommelin and his co-workers soon ventured into the countryside in search of new acquisitions. The collection thereby transcended the local level and included the entirety of natural sciences and medicine. The highlights include the Golden Age with a big quadrant used by Snellius, microscopes by Antoni van Leeuwenhoek and telescopes and clocks by Christiaan Huygens.

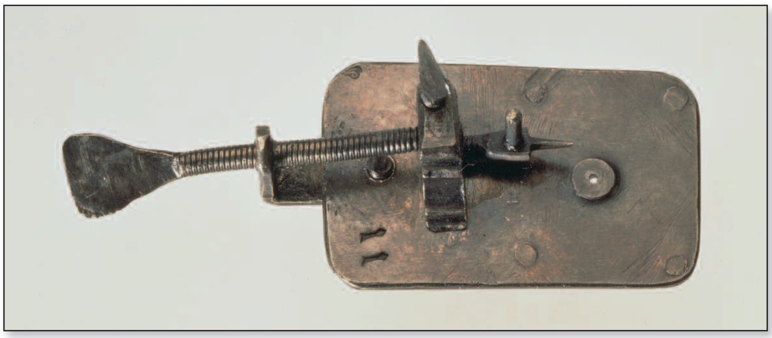
As a national museum, Museum Boerhaave also collects instruments and devices from non-university institutions like the industrial laboratories of Philips and Shell. The artificial kidney of Dolf Kolff, also a top-class piece, was developed in a provincial hospital in Zwolle during World War II. The collection now has some 40,000 instruments, books, prints, etc. Since 1991, the museum is housed in the former Caecilia Hospital in the Leiden city centre, the place where in 1636 Leiden University created the first academic hospital and where Herman Boerhaave lectured at the bedside of interesting patients.

It works out well that the accent has shifted within research into the



► Plaster model of a Gibbs surface, constructed to test the theory of mixtures of Johannes Diderik van der Waals, ca. 1905.

history of science over the past decades from a history of ideas to attention for material aspects. Researchers nowadays are also interested in context, in tap grease and lubricant, in the person behind the scientist and his or her instrument. Increasingly often, we see initiatives to make the material culture of science the subject of study. That culture has mainly been preserved thanks to the deeds of museums. Nonetheless, studies into the history of science have traditionally played out in libraries and archives, based on texts and illustrations. The result is that museum objects are displayed without any reference to their historical context, while the history of science often deals with ideas disconnected from matter.



▲ Microscope, Antoni van Leeuwenhoek (1685-1725). Van Leeuwenhoek, a tradesman from Delft, is commonly known as 'the Father of Microbiology'. Using his handcrafted single lens microscopes, he was the first to record bacteria and spermatozoa. His microscopes were able to magnify up to ca. 300 times.

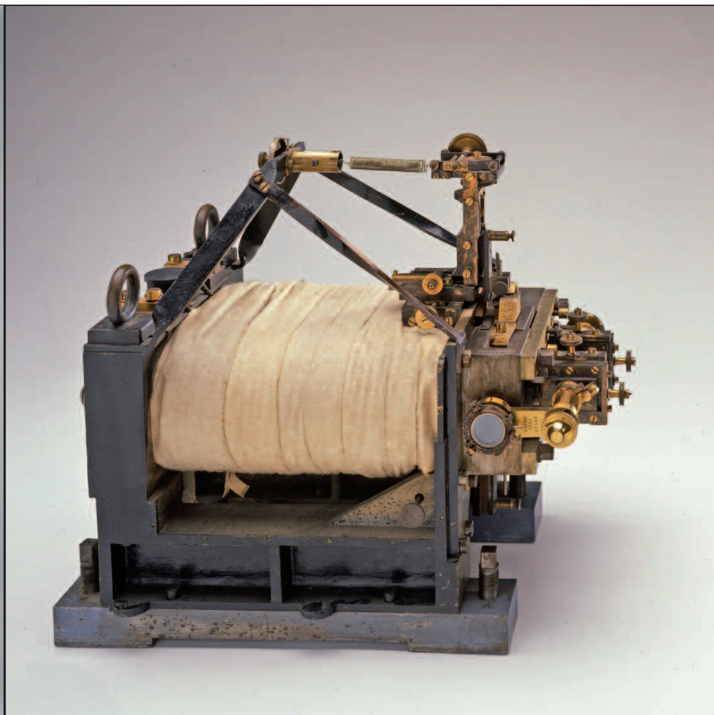
Museum collections can also be of service to academic education. Second-year bachelor degree science students at Leiden University who follow the introductory 'history of natural sciences' programme go to Museum Boerhaave to see the material form of abstractions such as the 'Second Golden Age' or 'Book of Nature'. At a higher level are the master's students of medical history, history of mathematics or natural sciences and, not to be forgotten, art history, placed in a position at the Museum Boerhaave to get a close look at forceps, astrolabes and microscopes while the lecturer explains how they work and their context in cultural history. In such a lecture one notices immediately that the eighteenth-century, ornately decorated microscope undeniably bears the message of 'the Book of Nature' by Jan Swammerdam. Or that Kamerlingh Onnes and Einthoven (Nobel prize laureate, the first to make an electrocardiogram), who had their laboratories only dozens of metres from each other in the centre city of Leiden, would *have* to have argued, given the colossal pumps of the former and the string galvanometer so sensitive to vibrations of the latter.

That education to students can be expanded to the museum store: there, the objects can be taken in hand for further inspection. How do forceps feel? How precise is that astrolabe? The store is also a place for research. For example, the optical properties of Huygens lenses in the collection of the Museum Boerhaave were precisely determined, yielding important information about the quality of his telescopes. ■

Dirk van Delft,
Director of Museum Boerhaave

▼ Hydrostatic balance, ca. 1730 made by the Leiden instrumentmaker Jan van Musschenbroek. With this instrument professor Willem Jacob 's Gravesande was able to demonstrate the Law of Archimedes.

▼ Louis Thomas Jérome Auzoux (1797-1880) was a true artist in *papier-mâché*. His anatomical models, most of which can be dismantled, are world famous.



▼ String galvanometer, Willem Einthoven, ca. 1910. The First electrocardiograph was so large that it could not be placed next to the patient's bed. Hence a connection was made between patient and instrument using a telephone line. Einthoven won the Nobel Prize for Medicine and Physiology in 1925.

EUROMAGNET CALL FOR PROPOSALS FOR MAGNET TIME

The next deadline for applications for magnet time at
the **LABORATOIRE NATIONAL DES CHAMPS MAGNETIQUES INTENSES**
(ex GHMLF & LNCMP / www.lncmi.cnrs.fr)
the **HIGH FIELD MAGNET LABORATORY** (www.ru.nl/hfml/)
and the **HOCHFELD LABOR DRESDEN** (www.fzd.de/hld)
is November 15th, 2010.

Applications can be done trough an on-line application form on the website: http://www.euromagnet.org from October 15th, 2010.

Scientists of EU countries and Associates States* are entitled to apply under FP7 for financial support according to the rules defined by the EC.
*listed on ftp://ftp.cordis.europa.eu/pub/fp7/docs/third_country_agreements_en.pdf

For further information concerning feasibility and planning, please contact the facility of your choice.

Tenure Track Assistant Professor of Physics

The Department of Physics at Lehigh University seeks to fill a tenure-track position at the Assistant Professor level beginning in August 2011. Candidates should have a PhD in Physics (or equivalent), a strong interest in teaching at both the undergraduate and graduate levels, and the ability to develop a strong and innovative research program in Experimental Condensed Matter Physics with an emphasis on nanoscale systems, for example in areas such as quantum physics of nanostructures, transport at the nanoscale, or nanophotonics.

The Department of Physics has established research programs in condensed matter physics – with focus areas on ferroelectrics, carbon nanomaterials, nonlinear optical materials, biological systems, and semiconductors – as well as in statistical physics, plasma physics, astrophysics, and atomic and molecular physics. We expect the successful candidate to strengthen and complement existing fields, and to participate in interdisciplinary activities with faculty in other departments, as represented by the Center of Advanced Materials and Nanotechnology (www.lehigh.edu/nano), the Center for Optical Technologies (www.lehigh.edu/optics), and Lehigh's Energy Research Initiative.

Applicants should e-mail a single PDF file containing a cover letter describing their area of expertise and major contributions, a curriculum vitae, a statement of research and teaching interests, a list of publications, and the names and affiliation of three references, to the Chair of the Physics Search Committee, Department of Physics, Lehigh University, at inphys@lehigh.edu. Consideration of the candidates will commence on December 27, 2010. The College of Arts and Sciences at Lehigh University is committed to increasing the diversity of the college community and curriculum. Candidates who can contribute to that goal are encouraged to apply and to identify their strengths or experiences in this area. Lehigh University is an Equal Opportunity Affirmative Action Employer. Lehigh University provides comprehensive benefits including partner benefits.

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Geilo Advanced Study Institute

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Subtopics

A. Gas, liquid, particle/granular flow
1. Microfluidics
2. Flow of soft materials
3. Granular flow
4. Multiphase flow

B. Flow in and of organic/living systems
1. Flow at high Reynolds numbers
2. Motility in micro – and macroorganisms
3. Flow in biological branching structures
4. Flow and diffusion inside living cells

C. Turbulence (Short status)

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Deadline for application: **January 14, 2011**

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