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Paul Langevin (1872-1946)

Black vs. white

Quantum magical helium clusters

Directory

An Interview with Sir Harold Kroto

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Cover picture: Enter into the ISS (International Space Station) Module in Universeum (see museum review p. 32)

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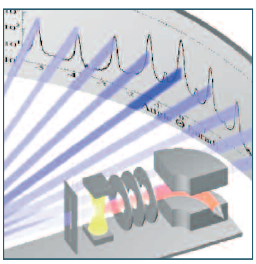
Paul Langevin (1872-1946)



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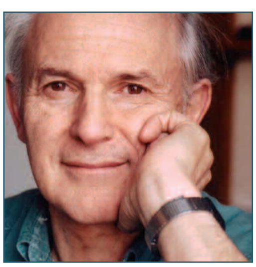
Matter-wave diffraction



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editorial

A physical challenge

Physics is intellectual, but also physical work. Every day physicists work to advance science, teach the next generation the nature of physics, disseminate research results to industry and fight against attacks on science from people led by beliefs.

These challenges are conducted in a climate of change throughout Europe. The EU funding system is being modernized, ERC is going "on air", and more money is flowing into science. Competition is strengthening and more and more funding is target specific, rather being given in support of societal development than for the development of a strong scientific base.

What are the solutions for physics to be more competitive in this process of selection among the sciences? One way to go is to work harder, to produce more excellent physics and even to redirect one's work towards more applied topics. But this is exactly what many physicists have been doing in recent years without any major improvement of their general situation. So what is wrong and what can be done? Being physical about physics is obviously not enough.

What is wrong is the public perception of physics; that physics is difficult and that physics belongs to the interior of black boxes that can be mass produced and discarded after use. Physicists themselves readily amplify this notion in several subtle ways, by maintaining the expert point of view and even by overemphasizing their expert role and in this way often oversell the direct importance of physics in society.

Reality is that modern life does depend on a spectrum of technologies, including not least social advances. A discipline cannot any longer defend itself alone as a discipline but must find its role among many other players that also contribute to society and its development. The last 20 years has proven hard for physics to assume this new role.

What can physics do to mediate this situation? Well, physics has one strong selling point that has not yet been fully marketed. That is physics education. Whether physics research is important or not, everybody accepts that physics education indeed is important. The principles of physics and the associated thinking behind physics are central in all aspects of the learning process. What we are talking about is the culture of physics in pre-university education. By nature most physicists are preoccupied by their research and their graduate students - only talking about this "external" educational challenge as a problem that others must solve.

The problem is that physics as a discipline has by and large been confined to universities. Once a physicist leaves university he or she takes up a job that belongs to a profession. The snag is that physics is not a profession, but rather a generalized set of tools, that can be utilized in many professions. By and large the professional physicist looses identity as a physicist and assumes a new identity in a profession. The result is a loss for the physics community. In contrast to physicists, engineers do have a strong professional attachment, resulting in strong professional engineering societies.

The way out of this situation is to redefine physics as more than a profession doing research. The time has come to reconsider research-based physics education. The well-being of physics is not defined only by those select few doing research, but by those many professional physicists working in various specialist areas throughout society. The time has come to put more emphasis on physics outside research!

Education is at the core of sustainable societies. It is my wish for the coming year that more emphasis will be put on development of educational tools, not only focused on selecting the most able and bright students for physics and physics research, but equally important - to provide society with a cultural mesh that does include physics as an important element in the formation of our views in general.

What does this mean? It means science for all, with emphasis on context. Energy, environment and ethics are with us to stay. It means a critical look at curricula often defined within a linear progression of reasoning: less can prove to be more if more are getting to know the power of physics reasoning. ■

Ove Poulsen, EPS President

BPU6

6th international conference of the Balkan Physical Union

Peter Melville, Martin Huber and Serkant Ali Cetin

BPU6 was held at the Beyazit Campus of Istanbul University in the centre of the old town from 22 to 26 August 2006. The main organizers were the Balkan Physical Union, the Turkish Physical Society, Istanbul University and Yildiz Technical University. EPS was one of the sponsors and was well represented, *e.g.* with past presidents Martial Ducloy and Martin Huber and former secretary Peter Melville giving invited papers. Among the ~800 participants from about 25 countries, the majority of the participants (85%) were from the Balkan region, with a significant number (45%) from Turkey, and others (15%) coming from all over Europe and from further afield. Invited speakers alone represented 17 different countries.

The conference covered the whole of physics, through ~50 invited talks, ~300 oral presentations and ~450 poster presentations, and was well organised by the Scientific Programme Committee chaired by Metin Arik (Bogazici University) and the international Advisory Committee chaired by Durul Oren (Rector of Yildiz Technical University), with Lidya Amon, General Secretary of the Turkish Physical Society, playing a vital role. There were plenary sessions at the start of the day, before splitting into seven parallel sessions (a split that was perhaps too fine as some sessions were poorly attended) and two hour poster sessions over noon.

There was also a Council meeting of the Balkan Physical Union at which Metin Arik from Turkey was elected as the new president of the Balkan Physical Union. As with all conferences a most important aspect are the opportunities to meet and get acquainted with other physicists, particularly from other countries. This was well catered for with generous buffet receptions on three evenings (welcome party at Istanbul University, reception at Dolmabahce Palace, dinner at the Archaeological Museum) and a boat trip on the Bosphorus on the fourth. The Turkish Physical Society, under the presidency of Baki Akkus (Istanbul University), gave full support to BPU6, and the general coordination of the conference was established by Serkant Ali Cetin (Dogus University). ■

From CERN*:

World's largest superconducting magnet switches on

Geneva, 20 November 2006. The largest superconducting magnet ever built has successfully been powered up to its nominal operating conditions at the first attempt. Called the Barrel Toroid because of its shape, this magnet provides a powerful magnetic field for ATLAS, one of the major particle detectors being prepared to take data at CERN's Large Hadron Collider (LHC), the new particle accelerator that is scheduled to turn on in November 2007.

The ATLAS Barrel Toroid consists of eight superconducting coils, each in the shape of a round-cornered rectangle, 5m wide, 25m long and weighing 100 tonnes, all aligned to millimetre precision. It will work together with other magnets in ATLAS to bend the paths of charged particles produced in collisions at the LHC, enabling important properties to be measured. Unlike most particle detectors, the ATLAS detector does not need large quantities of metal to contain the field because the field is contained within a doughnut shape defined by the coils. This increases the precision of the measurements it can make.

At 46m long, 25m wide and 25m high, ATLAS is the largest volume detector ever constructed for particle physics. Among the questions ATLAS will focus on are why particles have mass, what the unknown 96% of the Universe is made of, and why Nature prefers matter to antimatter. Some 1800 scientists from 165 universities and laboratories representing 35 countries are building the ATLAS detector and preparing to take data next year.

The ATLAS Barrel Toroid was first cooled down over a six-week period in July-August to reach –269°C . It was then powered up step-by-step to higher and higher currents, reaching 21 kA for the first time during the night of 9 November. This is 500 A above the current needed to produce the nominal magnetic field. Afterwards, the current was switched off and the stored magnetic energy of 1.1 GigaJoules, the equivalent of about 10 000 cars travelling at 70km/h, has now been safely dissipated, raising the cold mass of the magnet to –218°C.

"We can now say that the ATLAS Barrel Toroid is ready for physics," said Herman ten Kate, ATLAS magnet system project leader.

The ATLAS Barrel Toroid is financed by the ATLAS Collaboration and has been built through close collaboration between the French CEA-DAPNIA laboratory (originator of the magnet's design), Italy's INFN-LASA laboratory and CERN. Components have been contributed in-kind by national funding agencies from industries in France (CEA), Italy, Germany (BMBF), Spain, Sweden, Switzerland, Russia, and the Joint Institute for Nuclear Research (JINR), an international organization based near Moscow. The final integration and test of the coils at CERN, as well as assembly of the toroid in the ATLAS underground cavern, was done with JINR providing most of the manpower and heavy tooling. ■

* CERN, the European Organization for Nuclear Research, is the world's leading laboratory for particle physics. It has its headquarters in Geneva. At present, its Member States are Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom. India, Israel, Japan, the Russian Federation, the United States of America, Turkey, the European Commission and UNESCO have Observer status.

EPAC'06,

The European Particle Accelerator Conference

Christine Petit-Jean-Genaz, CERN

The European Particle Accelerator Conference (EPAC), is the biennial event organized by the EPS Accelerator Group (EPS-AG). The 10th conference in the series, EPAC'06, was a bumper edition with over 1000 participants from 33 countries. It took place in Scotland's beautiful capital city of Edinburgh from 26-30 June.

The conference programme was wide and varied, covering all aspects of accelerators and their technology. In particular, the meeting showed that the future of high-energy physics looks bright, thanks to a community that is generating a variety of innovative ideas which are being studied in world-wide collaborations. All-in-all EPAC'06 was a very successful edition, and this article reports only briefly on the highlights.

The very packed programme was articulated around eight main areas: circular colliders, linear colliders, light sources, hadron accelerators, beam dynamics, beam instrumentation, accelerator technology and applications of accelerators. The programme also featured a session on technology transfer and relations with industry. The programme offered 51 invited oral and 28 contributed oral presentations, and more than 1100 poster presentations. No more than two oral sessions were scheduled in parallel, and the poster sessions took place at the end of each afternoon, totally de-coupled from the oral presentations, to provide the best possible opportunity for all delegates to meet and communicate. A whisky tasting at the end of the first poster session certainly contributed to the excellent "spirit" which remained palpable throughout the event.

▲ Lutz Lilje and Axel Winter receive their prizes from Norbert Angert (GSI) Chairman of the 2006 award Jury.

A highlight of the conference was the EPS-AG 2006 Awards Ceremony. Three Prizes were awarded, to **Axel Winter** of DESY and Hamburg University, for merit and promise for the future, to **Lutz Lilje** of DESY, in recognition of his major role in the development and testing of high gradient superconducting RF structures, including his original contributions in the development of fast tuning systems, and to **Vladimir Teplyakov** of IHEP, Protvino, for the invention of Radio Frequency Quadrupole (RFQ) accelerator structure, in collaboration with **I.M. Kapchinsky.** RFQ has revolutionized the technique for accelerating low energy ion beams.

The conference's traditional "entertainment" talk was presented by **Sir Roger Penrose** from Oxford, with the intriguing title "Big Bang: An Outrageous New Perspective, and its Implications for Particle Physics", and Stefano Chiocchio from Garching, a leading member of the ITER fusion project team, gave an inspiring closing presentation on "ITER and International Scientific Collaboration". This brief report can only touch on the scientific programme. Interested readers are encouraged to consult the conference proceedings published at the completely open access Joint Accelerator Conferences Website (JACoW) [1].

Started in 1996 for the publication of the electronic proceedings of EPAC'96, the JACoW site currently hosts >50 sets of proceedings from 12 accelerator conference series [2], including scanned PAC and EPAC proceedings from before the electronic era.

But JACoW is not only a website. It is also an international collaboration in electronic publication of accelerator conference proceedings. JACoW collaboration editors receive hands-on training in electronic publication techniques at such conferences as PAC, EPAC, APAC, etc. and attend annual team meetings to stay abreast of developments. Contributions to the proceedings are thus processed on-line during these conferences, making for exceptionally speedy publication. As an example, the proceedings of EPAC'06 were published in pre-press format only 5 days after the conference, and on the JACoW site one month after the conference.

With totally free access, the JACoW site is located at CERN, Geneva with a mirror site at KEK, in Japan. The European home page gets 30,000 hits per year, and 250,000 papers are downloaded annually. Thanks to "JACoW page size", papers will print in the centre of a page, irrespective of the paper used, A4 or US Letter...

In 2004 the JACoW site was recognized as a service to the accelerator community. This would not have been possible without the efforts of each individual member of the Collaboration working in accelerator laboratories and universities all over the world. ■

References

[1] http://www.jacow.org

[2] APAC, EPAC, PAC, COOL, Cyclotrons, DIPAC, FEL, ICALEPCS, ICAP, ICFA Advanced Beam Dynamics Workshops, Linac, RuPAC

Proposed modification of the EPS constitution and by-laws

The EPS Executive Committee in consultation with the EPS Divisions and Groups will propose a modification of the EPS Constitution and By-Laws at the EPS Council meeting that will be held in London on March 23 and 24 2007. Rule 3.2 of the By-Laws describes the privileges of EPS Member Societies. To make EPS Conferences more accessible to members of Member Societies, Council will be asked to approve the following resolution amending the By-laws, to be added after the last paragraph of Rule 3.2:

"Members of Member Societies are entitled to the same reduction of registration fees at conferences organised by the SOCIETY and its Divisions and Groups as accorded to Individual Members." ■

21-year old Europhysics Letters matures to EPL

Graeme Watt, EPL Executive Editor

Short manuscripts (Letters) constitute a significant proportion of physics publications and they are by far the most cited articles. This is primarily due to the basic criteria that they should have scientific soundness, timeliness, importance and future impact, and be of general interest to the community (not necessarily just within physics).

In 2006 the Board of Directors for the flagship letters journal of the EPS, *Europhysics Letters*, identified a new vision for the Journal to become a leading home for ground-breaking physics research, to become the leading global physics letter journal and to become a broadband cross-disciplinary alternative for rapid publications (see the Editorial by the Editor-in-Chief, Denis Jerome, in January 2006).

Earlier this year the **EPL** Editorial Board and a Task Force of J Phys Editors provided suggestions for the future development of **EPL**. The Board of Directors acknowledged the positive contribution from these groups and tasked the newly appointed Executive Editor with constructing a workable development plan based on these recommendations. I presented a preliminary proposal to the EPS Executive Committee on 28 October and the essence is summarised below.

Achieving these goals will not be an instant process and will require improvement to the profile, visibility and impact of the Journal in terms of raising the volume and scientific quality of articles published, increasing the readership and reputation of the Journal and extensive use of electronic journal and website techniques for promotion, ultimately leading to improvements in the citation performance and the impact factors.

A new contract amongst the partners takes effect from January 2007. In addition to a change of branding to **EPL**, together with a new-style format, layout and colour scheme, work has already begun tackling some areas that will lead to major improvements including:

- speed of processing from submission through publication time;
- raising the quality and standard of the science articles accepted;
- significant increase in the breadth of science covered;
- pro-active engagement of the Editorial Board, Advisory Board and staff;
- development of an extensive marketing and promotion programme.

Processing speed

EPL currently has a rapid turnaround speed from submission to 'e-first' publication of less than 15 weeks. Various segments in the processing chain can still be stream-lined or operated more efficiently to reduce this time even further. Improvements will include expanding the database of knowledgeable referees, whilst maintaining a balanced workload for co-Editors.

In the future, on-line web access (available free for 30 days on registration) will replace e-first (and forthcoming articles).

Efficient use of the online submission, tracking and reporting systems will enable bottlenecks or problem areas to be quickly identified and resolved.

Raising quality

Guidelines for co-Editors and referees are being revised and expanded to enable detailed constructive feedback to be given promptly to the authors who will be encouraged to make rapid revision where necessary. Co-Editors should expect that referee reports will be fast, fair, consistent, reliable and constructive.

Adjustments to the structure and role of the co-Editor team and an increase in the database of active, responsive referees would significantly improve efficiency. The referee group need to be given clear, precise instructions on those aspects of the article that the co-Editor requires for timely reporting. Referees will be requested to supply a quality rating on articles so that highlights or promotional articles can be easily identified.

The instigation of a short workshop for referees could also be a useful addition. It is important that appropriate detailed feedback from referees is available to transmission back to authors as rapidly as possible so that revision can be made.

Breadth of science

The condensed matter community have a large stake in **EPL** at present, partly due to the large range of physics topics encompassed under the umbrella title. However, there are many other physics communities that would benefit extensively from interdisciplinary publication in a letters journal. Some high-profile development communities are already being targeted and encouraged to submit articles including the 4 LHC experimental teams, the Diamond and Soleil synchrotron beamline communities and the gravitational wave experiments Geo600 and VIRGO. Others will be followed in areas such as neutron spallation sources, free-electron lasers, superconducting magnets, heavy hadron therapy units & colliders, superconductivity, spintronics, adaptive optics techniques, opto-electronics, polymers, plasmas & lasers, quantum processes and life science areas of biophysics, nanotechnology, surface science, meta-materials. The list of high profile physics topics is endless.

Many of these communities may already have specialised journals for publishing lengthier papers but may not have access to a broadband letter publication which would identify and highlight their skills and techniques amongst other physics communities. **EPL** would provide a common letters forum for shorter, more interdisciplinary structured articles that go beyond the boundaries of single subject science.

In order to increase the broad appeal of the journal more emphasis will be placed on ensuring that introduction and conclusions sections are included in all articles and are written in a style understandable by a physicist not specialized in that field.

A range of new facilities are in operation, soon to be in operation, under construction, or proposed primarily for Europe (but also throughout the world). Over the next few years there will be a plethora of letters emanating from scientific studies using these facilities. **EPL** must concentrate on attracting and publishing some of the scientific highlights from these experiments.

Engagement

The composition and structure of the Editorial Board will require reviewing and modifying to ensure adequate and optimum representation, both regionally and in breadth of physics coverage. The role of members must clearly emphasise pro-active engagement as a team working to suggest enhancements and expansions to **EPL**. Members will be encouraged to adopt ownership of **EPL**, by composing 'editorials', promoting awareness at conferences, identifying articles to highlight and in general promoting **EPL** by publishing their own best papers in it and by attracting those from their colleagues.

An Advisory Board (formed of retired Editors) contains the corporate history of the Journal. Members will be encouraged to become involved with promotional aspects and act as ambassadors in addition to their more critical tasks of adjudicating difficult cases or conflicts of opinion and responding to author appeals.

A recently formed Management Committee, to deal with the day-to-day operation and communication, represents each of the partner production facilities. This compact team will interact frequently, informally and report monthly, circulating key statistics to review and assess development and marketing ideas. This frequent communication, mostly via e-mail but with site visits to ensure all members are aware of the complexities of having production activities spread across the continent, will ensure that problems are identified and dealt with promptly and that there are no hidden surprises.

Marketing

The focus for 2006 was on enabling a smooth transition for customers and readers to the new format and style. This has also involved conveying the strategic vision to the **EPL** community. Extensive marketing and promotion material is being developed by the Product Manager, Gabby Russell, in collaboration with the Management Committee, Boards and other staff as required. Key features to watch out for throughout 2007 include:

- Engagement of more readers — promoting highly cited papers on website; summarising quality articles for technical and popular magazines; press articles; sending articles to scientists nominated by the authors; developing promotional flyers; using the website to publish 'useful' statistics
- Search for new authors and referees — sending highest quality articles to influential physicists for comment; distributing sample issues at conferences & workshops; inviting 'highlighted' authors to resubmit
- Building visibility and promotion — new one-page flyers; possible special issues or topical editorials by co-Editors; sponsorship of poster prizes or conference lunches; strong presence at national and international conferences.

And finally

Having identified obvious areas in which improvements would lead to greater impact and visibility for **EPL**, the detailed communication, setup and actions have already begun. Commencing with the first issue of 2007 (Volume 77, No 1) watch out for the new-style, new-size, new-colour scheme format as *Europhysics Letters* emerges as **EPL**. I invite you to submit your next scientific letter for publication in this exciting new physics letters journal, published in Europe. ■

Report on MPTL11

11th workshop on Multimedia in Physics Teaching and Learning

L. Mathelitsch[1] and R. Sporken[2]
[1] Univ. Graz • Austria, [2] Univ. Namur • Belgium

The 11th Workshop on Multimedia in Physics Teaching and Learning was organized at the **University of Szeged** (Hungary) from Sept. 20 to 22, 2006 by **Prof. M. Benedict**. It was attended by about 60 participants representing more than 15 countries. The scientific program offered 6 invited talks, 9 oral contributions and 14 interactive posters.

The topics of the presentations showed a broader range compared to previous workshops:
P. Maroti (Univ. Szeged, Hungary) gave an overview on simulations in biology and biophysics,
V. Albrecht (Univ. Frankfurt, Germany) introduced web- and exercise-based learning modules as elements of knowledge construction in geography, and
H. Schmidt (Univ. Darmstadt, Germany) gave an insider-view into the world of industrial research and development.

Three talks showed how much excellent multimedia material has already been developed and is available for use at schools and universities:
W. Christian (Davidson College, USA) concentrated on open-source libraries, whereas **F. Esquembre** (Univ. Murcia, Spain) introduced an open-source program which facilitates to a large extent the creation of simulations and curricula applications.
B. Mason (Univ. Oklahoma, USA) presented the outcome of an extensive evaluation of MM software on electricity and magnetism, performed in cooperation by an American (MERLOT) and a European group. This is the continuation of a program in which one field of physics is investigated each year: it starts with a worldwide search for MM programs, which are then surveyed and evaluated resulting in recommendations for excellent products.
Finally, **J. Turso** (Univ. Torun, Poland) gave an overview on the use of multimedia applications in Polish schools as a national report.

On the occasion of MPTL11, the **Eötvös Plaquette** of the Hungarian Academy of Sciences was awarded to Prof. **Hans-Jörg Jodl** "*for outstanding and devoted activities in the field of physics education and for his long and successful cooperation with Hungarian physicists and physics teachers*". The MPTL community recognized this event as a great honour to Hans-Jörg Jodl, who was the founder of MPTL and who has been its very active chairman for the first ten years.

10 years of MPTL seems also to indicate a transition regarding its aims and content. In the past decade the development of good material has been the centre of efforts and (wo)manpower. This year's workshop has shown clearly that a vast amount of MM material exists, both commercial and freely available. At least some of this material is of very high quality. Hence, there is now a need to focus on ways to implement MM into school and university lectures and curricula. Examples of best practice exist, but thorough investigations on the use of effectiveness of MM in physics education are not common. Managing this transition will be a major challenge to the MPTL community, since developing and testing software requires different approaches and competences than evaluating its use and didactic benefit.

The next MPTL workshop will take place at the **University of Wroclaw**, Poland, from **Sept. 15 to 19, 2007**; the organizer will be **Prof. Ewa Debowska**. ■

The foundation of the Ukrainian Physical Society

Oleksandr Slobodyanyuk
Chairman of UPS Coordination Board Bureau in 1989-95

This year Ukraine celebrated its 15th Independence Day. The Ukrainian Physical Society (UPS) was founded a year earlier and has now existed for 16 years. This paper describes the foundation of the UPS as the first truly independent scientific society in Ukraine and summarizes its activities during the first seven years.

UPS from the very beginning was conceived and designed as a free association created by physicists on their own initiative independent of any state body or other public organization. In the USSR (before 1991 Ukraine was one of the formally independent Soviet republics) all scientific and engineering societies were controlled to different degrees by Party or State authorities. In the Soviet Union science was divided into 3 branches:

a) academic science carried out in the research institutions of the National Academy of Sciences (NAS);
b) science in universities, polytechnics and other higher education institutions;
c) so-called industry science that was carried out under different ministries, for example, the Ministry of Radio and Electronics, of Shipbuilding or of the Defense Industry.

◀ The first UPS President Professor V. G. Baryakhtar (second from left) with his team: O. Slobodyanyuk, the author, Chairman of the UPS Coordination Board Bureau (third from left), Prof. V. Andreev, Executive Secretary of the UPS Coordination Board Bureau (left) and Prof. I.S.Gorban' (right) who later became the second UPS President. The picture was taken around 1993.

In the Ukraine this organization led to strict centralization of all resources, which were made available exclusively from Moscow offices or more often as second- or third-hand funding and with vertical hierarchical management in all three branches. Horizontal links between physicists working in similar fields but employed by different institutions were very weak. Also the imposed secrecy requirements did not allow the development of a coherent physics community.

It is interesting to note that in contrast to chemists a nationwide society of physicists was never founded in the USSR. During Gorbachov´s liberalization in the late eighties, however, the founding of the Moscow Physical Society was announced and in November 1989 a constitutional congress of the Physical Society of the USSR was held in Moscow. This organization still followed , however, the model of centralized structures.

In the Ukraine the first practical steps to establish a democratic self-governing organization of professional physicists, independent from state and traditional academic bureaucracy, were made already in 1989 - two years before the disintegration of the USSR. The goal was to bring together physicists irrespective of their affiliation and to integrate Ukrainian physicists into the international physics community.

Physics in the Ukraine has a long and successful past. In one of the oldest and largest centres of physical science in the Ukraine, in the Kharkov Institute of Physics and Technology (the KIPT, earlier referred to as the Ukrainian Institute of Physics and Technology) that was established in 1928, a nuclear reaction was realized on October 10, 1932 - for the first time in the USSR. Lithium atoms were used in fission experiments with accelerated protons. In 1931, in this institute, L.V.Shubnikov organized the first cryogenic laboratory in the USSR where for the first time liquid hydrogen and helium were obtained. L.D.Landau, who worked at the KIPT from 1932 to 1937, formed an internationally known school of theoretical physics. N.Bohr, P.Dirac, R.Peierls and other famous foreign scientists visited the Institute. At that time the Kharkov journal "*Physikalische Zeitschrift der Sowjetunion*" had contributions in German, English and French. In postwar years the KIPT was one of the most active participants in the development of atomic energy in the USSR. It also served as a base for the formation of new physics institutes in Kharkov, namely, the Institute for Low Temperature Physics and Engineering, the Institute for Radioelectronics of NAS of Ukraine and others. The network of physical institutes covered all Ukraine with main centres in Kiev, Kharkov, Donetsk, Dnipropetrovsk, and Lviv. In the 1990's the number of professional physicists in the Ukraine (Academy of Science, universities, industry) was estimated to amount to 10,000-12,000.

In 1989 an initiative group of physicists from institutions and departments in Kyiev, Kharkov, Donetsk, and Lviv met to popularize the idea of an Ukrainian Physical Society, to contact colleagues throughout Ukraine and abroad, to prepare a constitutional congress and to draft a constitution for the new Society. The guiding principles were: no lifelong appointment in the organization of the society but regular rotation within the elected bodies, no centralization, no concentration of power, no domination by Kiev - but a proportional representation of local and regional physics communities. No restrictions were imposed on membership of other scientific societies, particularly of other physical societies.

In January 1990 delegates from all regions of Ukraine came to the constitutional congress that was held at the Bogoliubov Institute for Theoretical Physics of the NAS in Kiev. It established the Ukrainian Physical Society and adopted its constitution. Professor V. G. Baryakhtar was elected as the first UPS President. In May 1990 the UPS, as an all-Ukrainian scientific organization, was officially registered by the special decree of the Council of Ministers of the Ukrainian Soviet Socialist Republic signed by the chairman of Council of Ministers of Ukraine!. It is a historical irony that UPS was founded in a period without a legal basis for public organizations (the Law of Ukraine on Associations of Citizens was adopted only in 1992) and many so called public organizations of that time shared this fate (even including the Communist Party itself).

It was a break-through in the consciousness of many people that a scientific society was established, not by the decisions of state officials but in a true bottom-up process by the scientists themselves. From this point of view the establishment of the UPS was one of the first shoots of a new civil society in Ukraine. In the decade thereafter many other professional societies in Ukraine were formed following the example of the UPS.

In the following years a number of UPS Task Forces and Committees were created: an Editorial Commission, and Committees on Conferences, on Library Physical Funds, on the Young Physicists, Students and Scholars Problems, on Grants and Scholarships, etc. So dozens of UPS members were involved in different UPS bodies and many UPS members although not being formally members of UPS committees and task forces contributed significantly to UPS activities.

UPS found the support of the top academic management e.g. from the Department of Physics and Astronomy of the Ukrainian NAS and of the directors of their physical institutions. Rectors of universities and Deans of physics departments supported UPS in different ways and found this society a new and useful component of the science structure in Ukraine. It was obvious that many of them enjoyed the possibility to exercise democratic procedures as were standard for the international scientific community and are now also at home in Ukraine.

Just after its official registration UPS began collaboration with other physical societies. Co-operation agreements were signed with the physical societies of Russia, of St.- Petersburg, of Poland and with the APS, and others. E.W.A. Lingeman visited Kiev in 1991 as a first step in establishing relations with the European Physical Society. In 1992 we made contact directly with Gero Thomas, the EPS Secretary General and in 1994 a UPS delegation headed by Prof. I. Vakarchuk, the then Vice-President (in 1998-2001 the UPS President), attended the meeting of the EPS Executive Committee in Krakow, Poland that led to UPS becoming a an affiliated Member Society of EPS.

One of the critical points in the development of the Ukrainian physical community was a lack of timely information on international physics events and grant opportunities. This was still the time before the internet. UPS was strongly engaged in obtaining relevant information and in delivering it to all its members irrespective of affiliation and position. The most important communication platform turned out to be the "Physical Messenger" newsletter. Eventually, the possibility to communicate via e-mail expanded. This development was supported by the APS, the International Science Foundation (ISF) and the Eurasian Foundation.

Another important step in the provision of information by UPS was the building of a bridge between APS and UPS for delivering and distributing physical journals published by the American Institute of Physics. This problem was solved in an unusual but very practical and efficient way. In May 1992 during the visit to Kiev of George Gamota, a member of the APS Task Force for the FSU, an Agreement for Reciprocal Membership Privileges was signed. APS established a matching membership programme and a few dozen of UPS members from different regions of Ukraine were adopted as Associate Members the APS within this membership programme. Their function was to receive the journals and to deliver them to designated libraries. The lists of journals and of recipients were published in the "Physical Messenger" newsletter, followed, two years later, by a listing of journals provided by the EPS and in this way were made available to the whole Ukrainian physical community.

The UPS as a non-profit, non-governmental organization turned out to be an efficient authority for the delivery and the fair distribution of international help so that physics in the Ukraine could survive the first few years after the disintegration of the USSR. Specifically, UPS was empowered to collect applications from Ukraine for the Emergent Grant Program as established by APS, the Soros International Science Foundation, and by Sloan. The UPS succeeded in gaining tax exemptions for grant money and delivered the funding to the recipients via a special task force.

In 1993 the first School-Seminar on Condensed Matter Spectroscopy was organized jointly by UPS and APS. Dozens of experienced physicists from the West, the Ukraine and the FSU delivered lectures to mostly young physicists from Ukraine and neighboring countries. It turned out to be an effective way for young physicists to make personal contacts with western experts in their fields. In the following years a series of such summer schools were held in different places in the Ukraine and after 1994 they continued as recognized EPS conferences.

On 31 January 1995 the Ukrainian Physical Society held its third annual Congress with 93 delegates from 37 regional and local UPS-affiliated organizations representing more than 1,700 members. The congress provided a forum for discussion and approval of several constitutional amendments and society activities. Perhaps the most important result of the congress was the approval of voting procedures for the next UPS President (1995 - 1997). During the Congress participants nominated, by secret ballot, three candidates and six candidates for three Vice-president positions and in April the same year each UPS member participated by mail in the election. This marked the first election of the UPS president by the society members in the organization's five years history.

In June 2006, when the Ukraine celebrated its 15th anniversary, the EPS Executive Committee met for the first time in Kiev. In retrospect, nobody in the 1990's dared to imagine that a day would come when a joint session of EPS and UPS officials could be arranged in Kiev without the need to obtain permission from state authorities or from anyone else. ■

Errata

Alexandru Proca (1897-1955) and his equation of the massive vector boson field Dorin N. Poenaru and Alexandru Calboreanu - Europhysics News Vol. **37**, No. *5* (September/October) pp. 24-26

Page 25 First Column

a) Row 24 from the top the sentence "Scalar j and vector ..." should be replaced by 'Scalar φ and vector ...'

b) Row 13 from the bottom the string "which not only was in conflict with relativity, but led to wrong quantitative results" should be deleted.

International Physics Olympiad 2006

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

International Physics Olympiads (IPhO) represent the largest international competition for non-university students in solving physics problems. The competitions started on the initiative of Kostial, Kunfalvi and Scislowski, professors from Prague, Budapest and Warsaw [1]. The first Olympiad was held in Warsaw in 1967 with five participating countries from Eastern Europe. The last 37th Olympiad was a huge event organized in Singapore at Nanyang Technological University with 82 participating teams and 384 competing students.

The competition has two parts: theoretical and experimental, each of five hours duration. In the theoretical part the first problem dealt with interference of neutrons travelling different paths in a homogeneous gravitational field and the second problem considers images obtained by a pinhole camera of a rod moving with constant velocity and taking into account relativistic effects. The last question contained five independent items related to various everyday situations: digital camera, paper ignition by magnifying glass, boiling an egg, lightning and size of capillary vessels.

The experiment was organized around a microwave source used to perform several tasks: to set up a Michelson interferometer to measure the wavelength of the source, to observe interference of waves on thin films which in this case is quite sizeable, to determine the refraction index of the polymer sample, and to investigate total internal reflection including the effect of frustration. Finally the lowest order Bragg reflection from a hidden macroscopic square wire lattice is used to determine its constant. The complete text of the problems from this and many previous Olympiads are accessible by Internet [2].

The best score was obtained by Mailoa Jonathan Pradana, a student from Indonesia. The only team with all its members winning gold medals was from China. According to the IPhO Statutes the competition is among individuals and there is no official ranking of participating national teams. Nevertheless all leaders and competing students watch the results with great interest.

Here a table is provided summarizing the results from five recent Olympiads for participants from different regions of the world. The division is made on the basis of geography and history, but depending on the point of view contains some arbitrariness. According to the adopted division Western Europe includes the fifteen members of the European Union as it was a few years ago, plus Cyprus, Iceland, Lichtenstein, Norway and Switzerland, Eastern Europe includes the Baltic States, now separated from the former Soviet Union and finally the results of participants from Israel and Turkey are grouped with other Asian countries. So far only three teams from Africa participated on a few occasions, so they are not included in the table. The first row in each group of numbers represents the number of participating teams from the region for a given year, the number of individual participants and the number of teams which did not receive any distinction. The second row in the same grouping provides the number of participants receiving gold, silver and bronze medals, as well as the number of students with honourable mention obtained for a given year and particular region. Many European students obtain some distinction, but most of gold medals go to students from Asian countries. The early exposure of young people to physics and its methods, by way of competitions, is known to be an efficient way to attract toward careers closely related to physics [3].

Besides the competition itself, very important part of the Olympiads are their cultural, scientific and social content. The last Olympiad was attended by four Nobel laureates (C. N. Yang, D. Oscheroff, M. Koshiba and A. Ciechanover) and one Templeton Prize winner (P. Davies) who gave lectures and shared their thoughts with the students. Visits to impressive modern laboratories (for nanotechnology, biomedical engineering, robotics, aerodynamics wind tunnel and others) were organized for students, leaders, observers and visitors. The sight-seeing in the colourful and dynamic city-state of Singapore added many memorable experiences for all participants.

The next IPhO will be held in Iran, 13-22 July 2007 in the city of Isfahan. ■

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Year Place	Western, Europe	Eastern Europe	Former USSR	Asia	Australia and New Zealand	South and Central America	North America
2006 Singapore	19 - 92 - 1 2+4+25+28	15 - 73 - 1 3+11+16+25	11 - 50 - 1 3+12+12+8	25 - 118 - 4 22+20+23+13	1 - 5 - 0 1+1+3+0	7 - 25 - 3 0+0+2+6	2 - 10 - 0 6+1+1+1
2005 Spain	19 - 92 - 3 2+2+12+28	14 - 66 - 2 7+7+12+2	11 - 55 - 1 7+4+13+16	18 - 90 - 2 27+9+21+11	1 - 5 - 0 1+1+2+1	8 - 33 - 2 0+1+2+10	2 - 10 - 0 2+2+1+4
2004 South Korea	19 - 91 - 4 1+2+10+23	15 - 69 - 2 4+6+16+27	10 - 48 - 0 4+8+15+11	17 - 84 - 2 17+16+20+16	1 - 5 - 0 2+0+2+1	6 - 23 - 1 0+1+2+5	2 - 10 - 0 3+2+3+1
2000 United Kingdom	18 - 86 - 9 1+0+8+13	15 - 73 - 4 3+1+7+20	9 - 43 - 3 2+2+5+8	13 - 64 - 3 9+6+16+13	1 - 5 - 0 0+1+1+3	5 - 21 - 3 0+0+1+3	2 - 10 - 0 0+1+4+2
1999 Italy	17 - 81 - 0 0+13+15+20	15 - 73 - 1 5+19+15+16	8 - 35 - 0 8+11+6+3	14 - 65 - 1 14+21+12+9	2 - 10 - 0 0+2+2+4	4 - 17 - 0 0+2+1+4	2 - 10 - 0 3+3+3+1

▲ **First line:** Number of participating countries – number of students – number of teams without any prize.
Second line: Number of gold, silver and bronze medals and honourable mentions

International school of space science 2006:

The Physics of the Sun: The Active Sun on your Active Desktop

Prof. Francesca Zuccarello [1] and Prof. Loukas Vlahos [2]
[1] Università di Catania, Dipartimento di Fisica e Astronomia, [2] Department of Physics, University of Thessaloniki

The School is part of a project named SERSES (Series of Events on the Relations in the Sun-Earth System and Space Weather), that consists of 6 Training Courses and 1 Closing Conference (see www.cifs-isss.org/sersesprogram.asp). L'Aquila (Italy) welcomed the 2006 edition from March 27th to April 1st.

In particular, the Course "The Physics of the Sun: The Active Sun on your Active Desktop", was aimed at providing a series of up to date reviews in selected research fields related to the Physics of the Sun and to give the students the opportunity to interact with the speakers by using the numerical codes, provided by the speakers, and elaborated for the modelling and analysis of the physical processes described in the reviews. The School had the following format: Description of the Subject - Model – Software Description - Practical Software Learning.

The program was equally distributed between theory and observations, in order to let students to have the opportunity to learn how to analyse data acquired by several instruments and to allow the observers to approach the theoretical modelling, and both, theorists and observers, to use and eventually to implement the codes, providing them a fund of complementary skills which will help them in their career development.

The main topics treated during 5 plenary sessions were: magnetic field configurations and extrapolation; magnetic flux tube dynamics; emergence and evolution of active regions; magnetic reconnection; flares; particle dynamics.

The School was held in L'Aquila, in the Scuola Superiore "Guglielmo Reiss Romoli", and was attended by 24 students, evenly distributed between PhD students and post-docs. During the last session the students could play a primary role by presenting their own scientific results; this offered them the possibility to discuss and exchange ideas directly with leading scientists of their research field and to stimulate cooperation in view of the possibility to present future new results during the following SERSES Courses or Closing Conference. ■

▶ Prof. Loukas Vlahos, co-organizer of the school

Nanoscience education in Europe

Tibor Gyalog, President of the Swiss Physical Society

Nanoscience and technology have evolved into a leading research topic in science. This can be illustrated by the size of last year's International Conference on Nanoscience and Technology (ICNT) [6], held on 31st July – 4th August, 2006 in Basel, Switzerland. The conference celebrated the 25th anniversary of the invention of the Scanning Tunneling Microscope in 1981 by Gerd Binnig and Heinrich Rohrer, which is often referred to as the birth of nanoscience. During this conference 600 talks were given, 900 posters were presented and among the 1500 participants, there were no less than 4 Nobel prize laureates: Gerd Binnig and Heinrich Rohrer (Nobel Prize in physics 1986), as well as John C. Polanyi and Jean-Marie Lehn (Nobel Prizes in chemistry 1986 and 1987).

◀ Outreach projects on nanoscience and nanotechnology have been launched all over Europe. The Nanorama exhibition in Basel (Switzerland), presented during the international conference ICNT 2006, attracted more than 3000 visitors. The guests could get an insight into Scanning Probe Microscopy, Computing with Schrödinger's cat, Electronic Noses, Fullerenes and Nanotubes, Medical Applications and into some other related topics.

Besides the purely scientific sessions, the conference included a special session on nanoscience education. At first sight, this might sound strange, since it is uncommon that a new research topic in physics gets its own curriculum. But indeed, in nanoscience things are a little different because of its explorative nature and disciplinary complexity. Nanoscience deals with all kind of structures that measure just a few nanometers, especially individual atoms and molecules. At this level, we see a blurring of boundaries between the classical disciplines such as physics, biology and chemistry. Up to now only interdisciplinary teams have proven able to explore the laws governing the nanoworld. Therefore new paradigms in education are required and new university curricula are needed.

Nanoscience Curricula at the University level

When scientists started the endeavour of nanoscience research, initial experiments immediately showed the main difficulty •••

▲ Pioneering Nanoscience Curricula have been established in various European Universities thanks to the existence of Centres of Excellence in Nanoscience. The internet addresses of the institutions are listed in the link list.

••• that had to be overcome: teams composed of researchers originating from different disciplines had to get used to each other. The style in which a physicist pursues experiments is sometimes diametrically opposite to the style in which a biologist plans them and also the vocabulary used about identical issues may be completely different. In order to overcome such obstacles for future generations of scientists, various universities around the globe have implemented new curricula dealing with nanoscience. The students enrolled in these curricula represent the next generation of researchers who hopefully will be able to switch from chemistry to biology or physics without being bound by the barriers of disciplines.

The implementation of a new interdisciplinary Bachelor or Masters program, however, is quite a difficult job requiring a lot of fine touch. Nanoscience in its whole breadth includes physics, chemistry, biology, medicine and aspects of even other disciplines. The combination of all these classical fields is only possible through a reduced depth of coverage in most individual disciplines. The developers of nanoscience curricula have to fulfil a difficult optimisation task. It is necessary to keep in mind that representatives of various disciplines declare their own field to be the most important one and therefore the optimization process between breadth and depth is a rather delicate task.

Some economic leaders in industry declare nanotechnology to be the base technology of the industrial revolution in the 21st century. These optimistic visions underpin the arguments for the creation of optimal study programs in this new discipline. The job market already reacts positively to young nano-scientists; this might be considered as a proof that optimistic visions are not completely wrong and, even more, that pioneering nanoscience curricula are a success.

The University of Basel was among the first to establish a Bachelor curriculum in nanoscience, which exploited existing possibilities of studying molecular biology, physics and chemistry. Multidisciplinarity is maintained throughout the Bachelor as well as the Master curricula. The students involved in the Bachelor program have a certain flexibility to select courses of particular interest already during the second year. The Bachelor program ends with one year of intensive laboratory work, which offers the opportunity of carrying out a wide range of experiments. During the Master program, the students work in research laboratories on two pilot projects before they do their Master thesis [1]. The possibility of studying at the forefront of scientific research is provided thanks to the Swiss Nanoscience Institute in Basel, a national centre of excellence.

In London, an MSc and a postgraduate diploma in nanotechnology have been established jointly by the London Centre for Nanotechnology and other departments of University College. The curricula are designed as one-year courses and combine lectures given by representatives from different departments with practical work within one of the various research groups. Many other student programs exist in the UK; most of those offered are listed in [2].

The Interdisciplinary Nanoscience Center (iNANO) in Aarhus (Denmark) has established an educational program that incorporates a broad spectrum of basic, advanced and specialized courses. Its purpose is to provide students with a sufficiently broad basis to be able to conduct interdisciplinary nanoscience research and, at the same time, obtain disciplinary depth and specialized skills in selected areas. The iNANO curriculum works as a model for and has been adopted by many other universities. To meet the demand for researchers in nanoscience and nanotechnology, the graduate school "iNANOschool" has been established [3].

The University of Hamburg offers project-oriented courses in nanoscience at the undergraduate level, which are accompanied by a series of lectures on nanoscience topics including Scanning Probe Microscopy. In addition, various E-learning modules on nanoscience topics have been developed. At the graduate level, special classes on nanoscience topics have been introduced [4].

The University of Lund offers a nine semester program leading to a Master's degree that is a symbiosis of education and research. Real multidisciplinarity is accomplished from the very beginning of the studies, combining the breadth of nanoscience with some depth in each of the disciplines involved. The program is composed of two parts: A basic block of three years that is followed by a 1.5-year specialization, where the students attend courses in their field of interest and carry out a diploma project in a cutting-edge research environment [5].

Most of the programs mentioned above are still under evaluation. The next consolidation step will hopefully be the co-ordination of the different programs and an intensive exchange between those responsible for the curricula in order to sustain a high quality.

In the United States several forums have been established in order to co-ordinate the nanoEducation and Training efforts [7].

Demand for education on different levels

The outcome of the World Year of Physics (for a brilliant review see *EPN* **37/6** p. 8) was proof that we have to open our minds for new means of science education from primary school to high school and that we must not forget the general public. Within the context of nanoscience, an important advantage is that we do not have to change the public perception, but are able to build it up from scratch.

Due to the growing economic importance of nanotechnology and as a result of the broad media coverage, the demand for nanoscience education on different levels has been rising exponentially during the last decade. Public interest is becoming more and more focused on the importance of technological applications, i.e. in information and communication technology, development of novel materials and medical applications in diagnostics and therapy. The public is concerned about visions for the near future, but also about aspects of safety and risk. National centres of excellence in nanoscience, such as at the University of Hamburg or the University of Basel, have pursued nanoscience outreach projects for some time by offering education programs for teachers, pupils and the general public.

The topics typically covered in a physics class at high schools rarely have links to the everyday life of the pupils and even less to the science columns of the daily newspapers; this has been postulated to be an important reason for the bad perception of physics. Nanoscience education at the high school level might be a means to increase the attraction of science classes, since it deals with questions covered in the media. Its interdisciplinary character may even raise the interest of pupils although the re-education of science teachers represents a major challenge. Therefore outreach projects in nanoscience focus on three target groups: science teachers, pupils and the general public.

The University of Hamburg offers summer schools on nanoscience topics for schoolteachers. In Basel, special courses are organized within a framework of regular continuing education for teachers. The feedback is very positive. However, these kinds of offerings have attracted only few participants due to the additional workload on the teachers' shoulders.
To overcome this barrier, courses are directly organized for pupils. Guided tours, seminars and accompanied practice work in a real research environment are offered. The pupils receive some insight into the work of a scientist, which is considered much more effective than watching one of the various new movies on nanoscience [8]. Therefore, laboratory equipment, *e.g.* scanning probe microscopes, is provided to schools at very low cost together with technical support for installation and running the system [4,9].

To conclude, let me present a few examples of nanoscience outreach projects. At the moment such kind of efforts are evolving very rapidly due to the need for information on topics raised by the media. Nearly all science museums are working on the development of a section on nanoscience. The famous Science Museum of London established an exhibition named "Antenna on Nanotechnology" with the slogan "small science, big deal".

In Germany, a huge Nanotruck is touring from city to city. Inside the truck is an exhibition, which invites the public to learn more about nanoscience and technology and competent stewards are ready to answer all questions. More than 100,000 guests have visited the Nanotruck within the first three years.

In Switzerland, the Technorama in Winterthur near Zurich will open its nanoscience exhibit in spring 2008. A similar but much less professional travelling exhibition named Nanorama [10] was set up and presented for the first time during the ICNT conference in Basel. It is being transported among various science events within Switzerland and is expected to travel through Southern Germany and Eastern France in 2007 and 2008.

Copies of some of the exhibits have been produced and will be hosted in the Science House Rust, a science centre within the "Europa Park", Germany's biggest amusement park. The latter already has a long tradition in science education since it has hosted 80 research institutions from universities and industry three days a year in order to present "Touching Science". More than 20,000 visitors have been registered in autumn 2006 during the three-day festival "Science Days". Among them were over 16,000 pupils who met with nanoscience and nanotechnology for the first time. Let us hope that they enjoyed the event and that in a few years they will register for one of the numerous European Bachelor programs in nanoscience, thereby constituting the next generation of interdisciplinary scientists who will help boost the industrial revolution of the 21st century. ■

About the Author

Tibor Gyalog received his PhD in 1998 for his theoretical work on atomic-scale friction. He has been teaching at the University of Basel since 2000 and has led various nano-education projects in Switzerland.

He was Swiss co-ordinator for the WYP2005 and became president of the Swiss Physical Society in 2006. He is now responsible for communications of the Swiss Nanoscience Institute in Basel and directs the Nanorama travelling exhibition.

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A new call for proposals

On November 30, fourteen European countries including all Western Balkan countries jointly published a new call for proposals.

This SEE-ERA.NET Joint Call is a pilot case for the cooperation of the participating countries in the field of research funding. The design of the call is based on research on the priorities and needs of the Western Balkan countries with a view to their better integration into the European Research Area.

The main theme of the call involves networking of scientists, who can only jointly apply for multilateral research projects, network projects or summer schools. Funding will be provided in the thematic areas "Environment", "Information and Communication Technologies", and "Food, Agriculture and Biotechnology".

Participating countries are: Albania, Austria, Bosnia and Herzegovina, Bulgaria, Croatia, France, Germany, Greece, Hungary, the Former Yugoslav Republic of Macedonia, Montenegro, Romania, Serbia and Slovenia.

This initiative is part of the Southeast European Era-Net (SEE-ERA.NET), a project financed by the European Commission. The main objective of this project is to explore and exploit synergies among bilateral Science & Technology agreements of the partner countries.

More information in the info package and at the website: www.see-era.net/pjc ■

Call for the Plasma Physics Division PhD. award

The European Physical Society (EPS) Plasma Physics Division announces its PhD Research Award 2007. Up to three prizes will be awarded to recognise work of exceptional quality carried out by young physicists as part of their PhD research in any area of plasma physics.

More information, including instructions for nominations, can be obtained at http://plasma.ciemat.es/awards.shtml

The deadline for nominating a candidate for the 2007 awards is 16th February 2007. Self-nominations will not be accepted. ■

Highlights from european journals

UV photodissociation of H_2 and D_2: not so simple!

Photodissociation of H_2 is the simplest chemical reaction, but a recent paper based on experiments carried out by a collaboration working at the Lawrence Berkeley Laboratory Advanced Light Source (ALS) has shown that our understanding of it is far from complete. The photodissociation process involves the correlated motion of strongly interacting particles, often having large potential and/or kinetic energy. As such, it serves as a prototype of a many-body system far from equilibrium. Photodissociation of H_2 by VUV photons is important in a host of important applied problems as well, including fusion plasmas, interstellar and intergalactic media, and the dynamics of planetary atmospheres.

Using photons with energy between 25 and 60 eV to break apart H_2 target molecules, the researchers measured the amount of vacuum ultraviolet Ly-α fluorescence produced by atomic hydrogen photofragments as a function of the dissociating photon energy. This energy region is difficult to analyze theoretically, because both target electrons are excited simultaneously by the single incident photon. The results are shown in Figure 1, along with the earlier results of Glass-Maujean and coworkers [1], and a state-of-the-art time-dependent Schrödinger equation calculation reported in conjunction with the current experimental results [2].

While the two experimental data sets are in qualitative agreement with each other, they differ significantly from the theoretical result, a difference that is not significantly improved even after the effects of cascading from higher-lying levels are taken into account. These differences highlight the crude nature of our understanding of this fundamental problem, and have implications for the accuracy of models for astrophysical and low-energy plasmas. ■

J.D.Bozek, **J.E.Furst**, **T.J.Gay**, **H.Gould**, **A.L.D.Kilcoyne**, **J.R.Machacek**, **F. Martín**, **K.W.McLaughlin**, and **J.L. Sanz-Vicario**,
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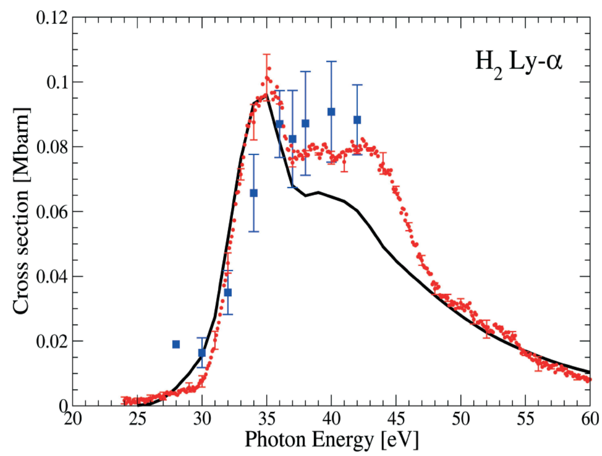
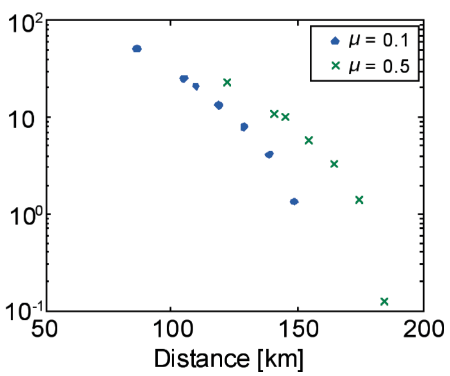


► Atomic hydrogen Ly-α fluorescence cross section vs. incident dissociating photon energy. The red (experimental) and black (theory) data are from ref. [1], and have been normalized to each other at 34 eV. The absolute (blue) experimental data of ref. [2] are also shown.

Superconductors help quantum communication

Quantum key distribution (QKD) enables two users to create a shared, secret, random key for encrypting data, enabling communication with security based on the fundamental laws of physics. Most optical fiber-based QKD systems employ easy-to-use avalanche photo-diodes with low efficiency and high dark count rates, which limit the maximum distance over which a secret key can be distributed. In contrast, the work presented in demonstrates the gains in secret bit rate and transmission distance that can be achieved by using ultra-low-noise high-efficiency superconducting transition-edge sensors. These sensors detect photons by measuring the minute change in temperature when a photon is absorbed in a small superconducting sample biased on the edge of the superconducting-to-normal transition, where the rapid variation of resistance with temperature creates an extremely sensitive thermometer. By using transition-edge sensors in a novel switched interferometric QKD system, researchers were able to successfully generate error-corrected, privacy-amplified secure key over 148.7 km of dark optical fiber at the standard mean photon number (μ) of 0.1, while use of higher mean photon numbers enabled key distribution over 184.6 km. Finally, use of much lower mean photon numbers enabled key generation secure against powerful photon-number-splitting attacks over 67.5 km, setting three new records for optical fiber quantum key distribution. Improvements in detector properties and the use of decoy states to protect against photon-number-splitting attacks are expected to lead to further increases in link length and secret bit rate. ■



◄ Secret bit rate as a function of transmission distance along a dark optical fibre using a low-noise transition-edge sensor, analysed at mean photon numbers (μ) of 0.1 and 0.5.

P.A. Hiskett, **D. Rosenberg**, **C.G. Peterson**, **R.J. Hughes**, **S. Nam**, **A.E.Lita**, **A.J. Miller** and **J.E. Nordholt**
"Long-distance quantum key distribution in optical fibre" *New J. Phys.* **8** 193 (2006)

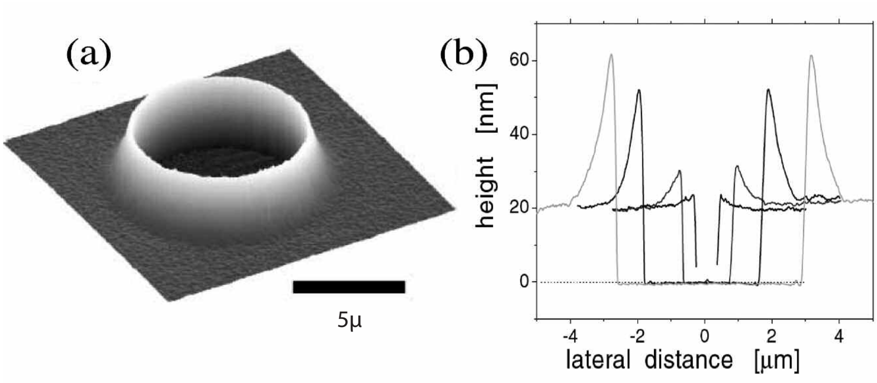
Why a 2D polymer film becomes 3D?

During the past ten years, thin polymer films have revealed unexpected stability features and a large variety of dewetting morphologies and dynamics. Since the first experimental study of Brochard-Wyart *et al.* in 1994, many detailed studies on both deposited and freely suspended films have been conducted. The viscoelastic properties of these films clearly play an essential role in their behaviour. Previous numerical and analytical methods were able to reproduce the observed very asymmetric shape of the rim, but were less successful in explaining the dewetting dynamics, *i.e.* the rapid decrease of the velocity of the film edge. In the past three years, a new scaling approach for the dewetting of thin polymer films has been developed, assuming the existence of a plug flow and taking the (linear) viscoelasticity of these films into account. This scaling approach is supported by a detailed analytical analysis and confirmed by the present numerical study and the associated references.

Not only the rim morphology is captured, but the time evolution of its width and height and the velocity of the edge are calculated. The approach allows a prediction for the opening velocity of holes in freely suspended films as well as for the velocity of the straight edge in supported film, given the viscoelastic parameters of the film (elastic modulus E, relaxation time τ_r) and the friction law between the film and the substrate (usually described by a power law).

A striking experimental result is the presence of residual stresses in most of the films studied, due to the very common effect of the spin coating fabrication process. These stresses can lower the stability of polymer films and considerably accelerate the dewetting process. ■

T. Vilmin and **E. Raphaël**,
"Dewetting of thin polymer films", *Eur. Phys. J. E*, **21**, 161 (2006)

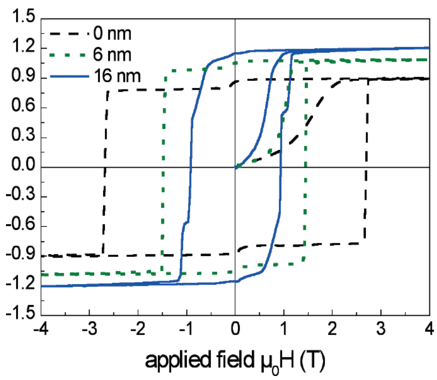


◀ Birth of a rim at the edge of a supported PS film of thickness 24 nm. **(a)** AFM picture **(b)** side view after 1, 5, 40 and 80 min of dewetting at 120°C (C. Reiter *Phys. Rev. Lett.* **87**, 186101 (2001).

Multilayers combine the best of both worlds

The ongoing quest for better hard magnetic materials for use in the numerous permanent magnet applications of modern society culminated in the development of the widely used rare earth/transition metal-based intermetallic phases $Nd_2Fe_{14}B$ and $SmCo_x$ ($x \approx 5$-7). An analogous situation holds for thin film permanent magnets, which are of immense interest due to the ongoing miniaturisation of electromechanical and electronic devices. The combination of both a rare earth sublattice with large uniaxial magnetocrystalline anisotropy as well as a transition metal sublattice with large magnetic moment within one intermetallic phase provides the essential intrinsic properties. Together with an appropriate microstructure and unique alignment of the uniaxial anisotropy axis, these are the ingredients for the high coercivity (H_c), high remanence (J_r), square shaped hysteresis and large energy density $(BH)_{max}$. Nevertheless, the highest saturation polarisation remains significantly lower than the value of $J_s = 2.5$ T achieved in soft magnetic Fe-Co alloys. Thus, the logical solution is the preparation of hard/soft magnetic heterostructures, which combine the good coercivity of a hard magnet with the optimum saturation polarisation of a soft Fe-Co phase. This approach leads to the development of nanocrystalline, exchange coupled magnetic materials, where the desired remanence enhancement can be achieved through an intimate mixture of both phases, making use of the underlying, local physical effect: the intergranular coupling of neighbouring spins. Unfortunately, so far the magnetic texture is not maintained at its optimum level and, thus, though exchange coupled, these materials do not achieve the properties of a well textured single phase material.

In a fully epitaxial growth process, the present group in Dresden is able to prepare $SmCo_5$/Fe/$SmCo_5$ trilayers by pulsed laser deposition, where the easy magnetisation axis of both hard magnetic layers is uniquely aligned in the substrate plane and the growth relation promises a continuous number of repeats without a degradation in texture. By varying the individual layer thickness, the average coupling can be tuned to result in largely improved energy densities. ■



▲ Magnetic hysteresis of epitaxial $SmCo_5$(25nm)/Fe(x)/$SmCo_5$(25nm) trilayers with x = 0, 6 and 16 nm along the MgO [001] substrate edge, i.e. parallel to the $SmCo_5$ c-axis. With increasing Fe layer thickness, the remanent polarization J_r and energy density $(BH)_{max}$ improve by 30 and 50 %, respectively, while keeping coercivity μ_0H_c at an acceptable high level of 0.9 T.

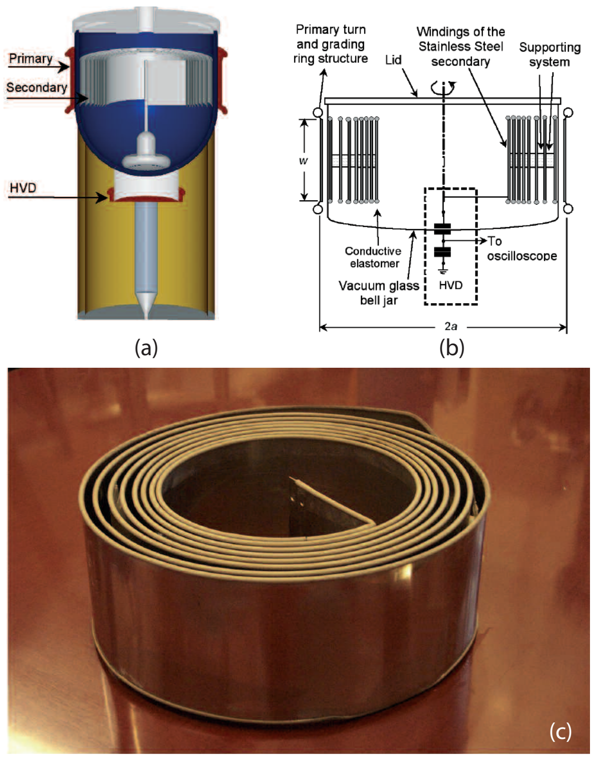
V. Neu, **K. Häfner**, **A.K. Patra** and **L. Schultz**,
"Fully epitaxial, exchange coupled $SmCo_5$/Fe/$SmCo_5$ trilayers" *J. Phys. D* **39**, 5116 (2006)

Magnetic insulation

In many important applications, power is delivered in very short but huge bursts, and at a voltage that may be 10 000 times greater than that of the normal domestic supply. Although it is often possible to use conventional forms of solid insulation, if the voltage exceeds about 500 kV it becomes essential for special purpose oil to be used. In the case of a transformer required in a high-energy pulsed power system, this may result in both the size and the mass becoming prohibitive.

An elegant way of avoiding the need for oil is to employ magnetic insulation, a modern technology that has so far only been adopted in two-dimensional situations such as parallel-plate transmission lines. If the electrical field between the plates becomes sufficient to cause the insulation between them to break down, this is manifested in a flow of electrons in a straight line between the plates. However, if a magnetic field is applied in a direction that is parallel to the plates, the electrons are diverted into a circular path. If the magnetic field is sufficiently high the path radius becomes less that the conductor separation, so that the electrons no longer cross the gap between the two conductors and magnetic insulation is achieved.

To date the seemingly insurmountable problems introduced by the three-dimensional geometry of the transformer have prevented the use of magnetic insulation, despite the enormous benefits that would result from the reduced physical size and weight. Nevertheless, the present research at Loughborough has overcome these problems by an ingenious electro-mechanical design, and has produced two forms of transformer in which magnetic insulation is achieved in quite different ways. The paper describes the construction and testing of the first of these, with the constructional details being shown in the accompanying figure. The magnetic insulation is provided by the primary current of the transformer, leading to the technique being termed magnetic self-insulation, and it has been proved suitable for use at voltages up to 500 kV. The work is in progress on the second form of transformer, which employs a separate energy source to provide the magnetic field, and it is suitable for very much higher voltages than is the first. ■

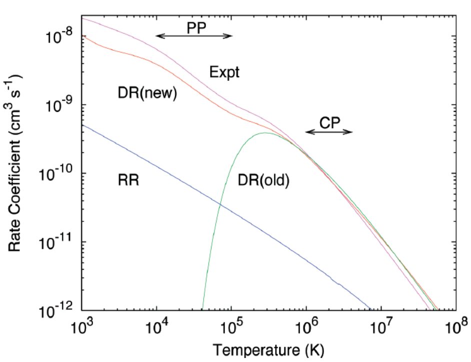


M. Istenic, B. M. Novac, J. Luo, R. Kumar and I. R. Smith, "A 0.5 MV magnetically self-insulated pulsed transformer" *J. Phys. D: Appl. Phys.* **39** (2006) 4529

◀ Transformer details
(a) winding arrangement
(b) drawing explained
(c) high-voltage secondary winding

Electron-ion recombination in astrophysical photo-ionized plasmas

The spectra of active galactic nuclei (AGNs) observed by the satellites Chandra and XMM-Newton exhibit a broad feature (an unresolved transition array – UTA) due to strong X-ray absorption by iron M-shell ions. Modelling the shape of the UTA can give insight into the physical environment of the absorbing medium. However, ab initio theoretical modelling of the UTA has been constrained by the inability to produce a consistent ionization balance for these iron ions (Fe^{7+}—Fe^{13+}). The balance (i.e. charge-state distribution as a function of temperature) is between the rate of electron-ion recombination and photo-ionization. We show that the recombination rate (coefficient) has been underestimated by an order of magnitude at photo-ionized plasma temperatures due to the omission of the contribution from (resonant) dielectronic recombination, with only the contribution from non-resonant radiative recombination included in the past. We have also carried-out a detailed comparison of the results of our calculation for Fe^{13+} with the high-energy-resolution measurements made recently at the Heidelberg heavy-ion Test Storage Ring. Similar, large, contributions from dielectronic recombination are found for Fe^{8+}–Fe^{12+} ions at photo-ionized plasma temperatures. These new recombination rate coefficients have significant effect on the ionization balance of the iron ions which give rise to the UTA and new modelling results are awaited with interest. ■



◀ Rate coefficients for Fe^{13+}. Purple curve, experimentally based dielectronic recombination (DR) [Schmidt *et al*, *Astrophys. J.* **641**, L157 (2006)]; red curve, new theoretical DR; green curve, old theoretical DR, as used by modelling codes; blue curve, theoretical radiative recombination (RR). Typical temperatures where Fe^{13+} exists in photo-ionized plasmas (e.g. AGNs) and electron collisional plasmas (e.g. the sun) are indicated by PP and CP, respectively.

N. R. Badnell, 'Dielectronic recombination of Fe^{13+}: benchmarking the M-shell'. *J.Phys.B* **39**, 4825 (2006).

Paul Langevin (1872-1946)

From Montmartre to the Panthéon: The Paris journey of an exceptional physicist

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Ecole Supérieure de Physique et Chimie Industrielle de Paris • France
DOI: 10.1051/epn:2007001

Paul Langevin has been an emblematic figure in the first half of the 20th century. He has been a principal player in all the major scientific revolutions of his time: Relativity, Quantum Mechanics and Statistical Physics. He has invented "Sonar", the system of underwater detection using ultrasonic echography, so important now for medical imaging.

He has also involved himself in the social and political causes of his age: human rights, pacifism, the fight against the rise of fascism and Nazism in Europe. He has been in 1923 among those walking for Peace, with Einstein, in the streets of Berlin.

He believed in the power of Science and Reason to bring more justice and happiness into the life of man. For him education, and particularly science teaching, was the best means to reach this goal.

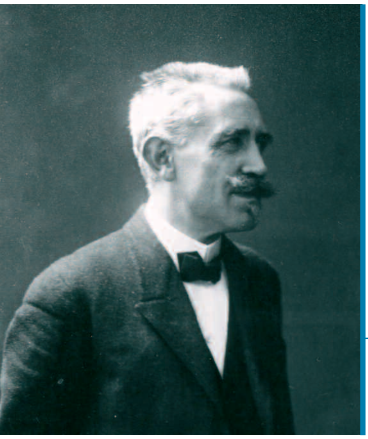
Biography

'I grew up, after the 1870 war, between a republican father and a mother devoted in her sacrifice. They had witnessed the Paris siege and the bloody repression of the Commune. Through their accounts, they developed in my heart the horror of violence and the passionate desire for social justice' (Paul Langevin).

Paul Langevin was born in Montmartre, at the "Bateau Lavoir", on January the 23rd, 1872. After the Lavoisier School, he studied at the "Ecole de Physique et Chimie Industrielles (ESPCI) , of the city of Paris" (1889-1891) then at "Ecole Normale Supérieure" (1894-1897).

In 1898-99, he stayed for some time in the Cambridge laboratory of J. J. Thomson at a time when the latter was working his way to the discovery of the electron. In 1902, he defended his PhD thesis on ionized gases, a subject on which he had started to work in Cambridge. A few weeks later, he was called to act as a substitute for Eleuthère Mascart for his lectures in physics at the Collège de France. It was an exceptional start to his career, even for that time and would be quite impossible now, which placed him, at thirty, among the most eminent members of the scientific community in Paris.

In 1905, he became Professor of Physics at ESPCI, at which he was later Director of Studies for 16 years (1909-1925). In 1909, he was appointed to the prestigious position of titular Professor at the "Collège de France". He participated actively in the Solvay Physics meetings from their first in 1911, was elected as a member of its scientific committee in 1921 then as President in 1927, in succession to Lorentz. He was elected to the French Academy of Sciences in 1934.



◀ **Fig. 1:** "Paul Langevin" in Paris (1922) photographed by Henri Manuel. © ESPCI-CRH.

On 30 October 1940, Langevin was arrested at the ESPCI by the Germans and put in jail for a few weeks before being placed under house arrest in Troyes. He escaped to Switzerland in May 1944 under the identity of Léon-Philippe Pinel, thanks to a false ID card procured by Frédéric Joliot-Curie.

After the "Liberation", he returned to his activities at ESPCI and at the Collège de France. He became President of the French "Ligue des Droits de l'Homme" (Human Rights League), succeeding Victor Basch, and a member of the atomic energy committee of the Academy of Sciences, together with Frédéric Joliot-Curie and Louis de Broglie, in 1945. The next year, he became an assistant delegate for France at UNESCO.

Paul Langevin died on October the 30th, 1946. National funerals were celebrated on 19 December 1948 when the ashes of Paul Langevin and Jean Perrin were transferred to the Panthéon, in Paris.

▲ **Fig. 2:** "False ID card with which Langevin escaped to Switzerland in 1944" © ESPCI-CRH.

Scientific work

The scientific work of Paul Langevin is very rich and covers several domains in Physics.

Magnetism

The thesis of Pierre Curie (1895) reported on an experimental study of the magnetic properties of matter in which he gave his famous law: the magnetic susceptibility of paramagnetic materials varies as $1/T$, where T is the absolute temperature. Langevin gave a theoretical explanation, assuming that each atom or molecule carries a magnetic moment and that the magnetization comes from a competition between the action of the magnetic field and the random thermal motion. Using Boltzmann's factor, $\exp(-E/kT)$, he found easily the $1/T$ law (1905). He assigned the magnetic moment to the electrons orbiting locally around the atoms or molecules. He did not quantify the magnetic moment (the spin was not yet known), but his demonstration remains valid for the $1/T$ law, since it comes only from the Boltzmann factor. His results were immediately used by Pierre Weiss (1906), who introduced a molecular field to describe the interaction of the magnetic moments following Langevin's model, so explaining ferromagnetism.

Relativity

According to his assistant, Edmond Bauer, Langevin had the idea to associate a mass (inertial) to the energy of photons or electrons as early as 1904. He suggested that the mass should be equal to E/c^2. He never published this formula and fully recognized Einstein's priority in the proper formulation of the special theory of relativity. He had been immediately enthusiastic about this theory and acted strongly to make it accepted and taught by French physicists. As early as 1910-11, he devoted his lecture course at the Collège de France to it. He gave many lectures on the subject and proposed the famous paradox of the travelling twins to illustrate the notion of time dilation. He invited Einstein to lecture at the Collège de France just after the first World War, at a moment when the contact between French and German scientists was difficult. Albert Einstein was finally able to come in 1922 and his lectures have had an immense impact. An experiment to illustrate the paradox of the travellers has been conducted by the US Navy in 1971, using two twin atomic clocks. However its interpretation is not simple because one has to take into account the acceleration to which the travelling clock is submitted, inducing a slight delay. Langevin and Einstein remained very good friends all his life. Here is what Einstein wrote in a homage to Langevin published in "La Pensée" in 1947: *'It seems to me certain that he would have developed the special theory of relativity if it had not be done elsewhere; he had already recognized clearly its main points'.*

Brownian motion

The study of Brownian motion, the movement of colloidal particles in suspension in a liquid, has been of great importance in physics. It is a proof of the thermal motion of a liquid on the molecule scale. Einstein gave a first theory of the effect (1905) with his famous formula relating the diffusion constant D to the viscosity constant k. Einstein's approach was macroscopic and used thermodynamics. Langevin (1908) proposed a new approach. He followed the motion of one particle and accounted for the molecular collisions by a random force. This "Langevin's equation" has proved its particular usefulness in the study of the molecular fluctuations of numerous systems, including non-equilibrium thermodynamics. It is still used by biophysicists to study biological fluids which contain many particles in suspension.

◀ **Fig. 3:** Left to right: A. Einstein, P. Ehrenfest, P. Langevin, H. Kammerlingh Onnes and P. Weiss in 1920. © ESPCI-CRH.

Ultrasonic echography

During the 1st World War, Langevin, working with an engineer named Chilowski, put together the "Sonar", to be used to detect submarines through their reflection of ultrasonic waves. The invention benefitted from the studies of Pierre and Jacques Curie on piezoelectricity. Piezoelectric quartz crystals had been shown to be excellent ultrasound emitters and detectors. Their first transducer, the Florisson-Langevin probe, was a mosaic of quartz plates glued between two steel foils. It can be seen working in the Space of Science of ESPCI in Paris, among several other experiments on ultrasound. The technique of ultrasonic echography is now very commonly used in medical imaging and Langevin is universally recognized as its inventor.

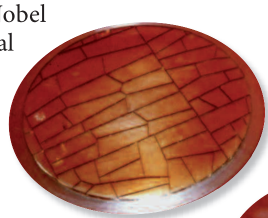
As a physicist, he played a fundamental role in the diffusion of knowledge among scientists, the Solvay meetings being the best example. Through his teaching and lectures at the Collège de France, he exerted a strong influence among his colleagues and students: Henri Abraham, Edmond Bauer, Marcel Tournier, Fernand Holweck, Jean Saphores and later, Jacques Salomon, Frédéric Joliot, Léon Brillouin and Francis Perrin.

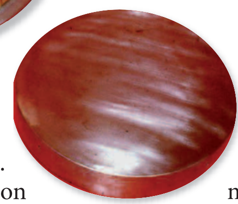
The committed person

The commitment of Langevin started with the Dreyfus affair. When a student in Cambridge he received a letter from Charles Péguy in 1898, which persuaded him to add his signature to the immense number of others on the famous petition in favour of Dreyfus. In 1899 he asks for admission in the French "Ligue des Droits de l'Homme". From the end of the First World War to the start of the Second, his commitment to human rights increased dramatically. He supported the strike of the railroad workers, the revolt of the Black Sea sailors and involved himself in the "League of Nations". As an active pacifist, he fought against nationalism, and worked for international scientific cooperation. In 1923, one year after Einstein's visit to Paris, he walked with him in Berlin in a demonstration for human rights. By now a member of the central committee of the French "Ligue de Droits de l'Homme", he became its vice-president in 1927.

The rise of the fascist movement in the thirties reinforced his militant activity. With Henri Barbusse and Romain Rolland, he joined the French section of the World Committee against War and Fascism and became its President in 1935. On 12 February 1934, he participated, with Victor Basch, President of the "Ligue des Droits de l'Homme", in the huge demonstration in Paris and on the 5 March, he was one of the three signatories of the text founding the Committee of Vigilance of Antifascists Intellectuals (CVIA), with the ethnologist Paul Rivet and the philosopher Alain. The recipient of mass popular support, he chaired the meeting of leftist organisations on 8 June 1935 to prepare a large demonstration for the occasion of the next 14th July. Although a pacifist, Langevin renounced a blind and absolute pacifism, favouring a firm attitude towards Hitler. A vote on this being against him, he resigned from CVIA in May 1936. With Victor Basch, he chaired the committee in favour of republican Spain and went to London to meet W. Churchill and many other Parliament members, to try to convince them of the risks of non-intervention. While close to the communist party but not yet a member (he became one in 1944) and a founder of the Circle of the new Russia, he nevertheless condemned in 1939 the German-Soviet pact, in accord with other French scientists

(F. and I. Joliot-Curie, Henri Laugier, Aimé Cotton). With Norman Angell, a recipient of the Nobel Peace Prize, he co- directed the journal "Clarté" and, in 1939, he founded "La Pensée", a "journal of modern rationalism", with Georges Cogniot and Georges Politzer.





Science and education

To Langevin, science, education and political action belonged to the same commitment. As early as 1904, he showed his interest towards the questions of education and scientific learning, giving lectures on the subject. Throughout his life and particularly after 1930, he insisted on the *'human value of science'*, the *'social role of the learned'* or *'science as a factor of moral and social evolution'*, *'science and liberty'*, *'science and peace'*, *'thought and action'*. He was President of the French Society of Pedagogy (1922), a member of the reform committee of the "Ecole Unique" (1925) and President of the "Union Rationaliste". He gave many talks, opened up science to the general public, and created the workers University (1932). He even involved himself in the new development of the time, that of radio communication, as, for example, a member of the advisory group on radio programmes and broadcasting and as chairman of the administrative council of "Radio Liberté", with Léon Blum and Paul Vaillant-Couturier. In 1931, he went to China, as a member of an international committee of the "League of Nations", to make proposals for the reform of the Chinese educational system.

After the Second World War, he chaired the Commission on the reform of the French educational system. The report "Langevin-Wallon" was submitted to the government on June 17th, 1947 by the psychologist Henri Wallon who had succeeded in the chair following the death of Langevin at the end of 1946. This report has strongly influenced the post-war reforms of the French educational system. ■

About the Authors

Julien Bok, professor emeritus at the University of Paris VI. Former director of the Solid State Physics laboratory of Ecole Normale Supérieure and later of the Solid State Physics Laboratory of ESPCI. His main contributions are in the field of transtport properties of semiconductors and theory of superconductivity.
Catherine Kounelis is currently the head of the Library and of the Scientific Archives Center of the ESPCI. She organised recently an exhibition of Langevin's drafts and photographs and co-authored La Physique de Paul Langevin. Un savoir partagé with M.-C. Bustamante. Her main research interest is in the history of science with emphasis on 19th- and 20th- century chemistry and physics.

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▲ **Fig. 4:** The Florisson-Langevin probe. It was made of a mosaic of single crystal quartz plates glued between two steel foils. The plate thickness is calculated to give a resonance at 1.3 MHertz. © ESPCI and French Navy.

Black vs. white

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Does a dark-painted front door get hotter in the sun than a white-painted one?

"Of course", says a layman, pointing out that a black surface absorbs solar radiation much better than a white one. "Should make no difference" says another layman with some science background, adding that a surface that absorbs well must also emit well. A physicist overhearing the conversation nods vaguely, remembering things like microscopic reversibility and detailed balance. But his intuition tells him it is not that simple. What precisely is happening here?

Let's do the experiment. On a bright and sunny day with little or no wind, we find the temperature of a white door to be 43°C, and that of a dark green door 66°C. The difference is clear: beyond the shadow of any doubt, the first layman was right.

Of course. It is obvious that the white paint remains cooler. The door surfaces absorb in the visible region of the EM spectrum, but emit in the infrared. According to Wien's law, the wavelengths differ - roughly speaking - by a factor of 20, viz., the ratio between the temperature of the sun's surface and our ambient temperature of 300 K, if we assume that the sensitivity of our eyes is optimized with respect to the solar spectrum. That means that we are dealing with 0.5 μm vs. 10 μm.

The optical properties can vary dramatically over such a range. And they do. Almost all common surfaces are 'black' around 10 μm. If we look up their emissivity at such wavelengths, we find values near 1 for almost anything: Common paints have values around or above 0.9, irrespective of colour. Even water and glass fall into that category, with emissivities well above 0.9. Metals, of course, are an exception. If they are clean and polished, such that multiple reflections are avoided, their emissivity is around or below 0.05.

But normal paint does not contain metal. The conclusion is, therefore, that the difference in temperature between the two doors is caused by their different absorption in the visible region. For the emission, all paints are equally black, except for Aluminum paints which can have emissivities below 0.3.

There is also a lesson here for our home heating: All radiators can be considered black, even the white ones: There is no need to deviate from our interior decoration taste as long as we stay away from Aluminum paint and the like.

What happened to the detailed balance argument? Obviously, detailed balance holds, but we have to consider one and the same wavelength. If we do, emission and absorption coefficients are equal. If, for example, copper looks reddish, it must absorb primarily green or blue. So if we make copper *emit* visible light, *e.g.*, by introducing some copper salt into a hot flame, detailed balance tells us that it should emit green or blue. And sure enough, it does.

Matter-wave diffraction of quantum magical helium clusters

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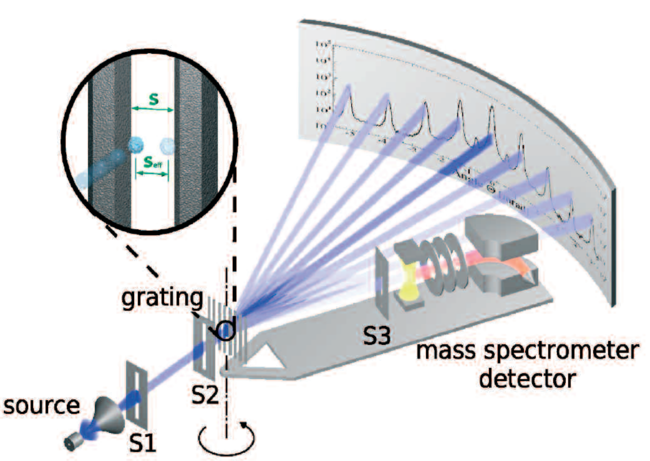
DOI: 10.1051/epn:2007003

Back in 1868 the element helium was discovered in and named after the sun (Gr. "helios"), an extremely hot environment with temperatures of millions of degrees. Ironically today helium has become one of the prime objects of condensed matter research at temperatures down to 10^{-6} Kelvin. With its two very tightly bound electrons in a 1S shell it is virtually inaccessible to lasers and does not have any chemistry. It is the only substance which remains liquid down to 0 Kelvin. Moreover, owing to its light weight and very weak van der Waals interaction, helium is the only liquid to exhibit one of the most striking macroscopic quantum effects: superfluidity. First recognized in 1938 by Pyotr Kapitza (Nobel prize 1978) the many macroscopic manifestations of superfluid behavior have over the last 70 years garnered a tremendous theoretical effort, but even today the statement made some years ago still holds "the explicit connection between superfluidity and Bose Einstein Condensation is not trivial" [1].

Small clusters of helium atoms, the subject of this report, also show a number of strange magic-like quantum properties not found in any of the other many clusters under investigation. For example, the existence of the helium dimer, which has long served as an important model system for quantum chemistry, was questioned up to about 10 years ago. The problem was that even minute energetic differences decide on whether the dimer has a bound state. In 1993 the first published claim of its detection in a molecular beam of clusters using a mass spectrometer met with skepticism because of the complications arising from extensive fragmentation following electron impact ionization. The existence of the helium dimer was finally established in 1994 when our group was able to detect the matter-wave diffraction of He dimers from a nanostructured transmission grating [2].

The properties of larger helium clusters are of great interest for nuclear many-body theoreticians because of the many close analogies between nuclei and helium clusters. Helium atoms have the advantage over nucleons, that their interactions depend only on the interatomic distance and do not involve complicated tensorial terms.



◄ **Fig. 1:** Schematic diagram of the cluster beam apparatus used for the diffraction of small He clusters. The entire apparatus is divided up into several vacuum compartments (not shown). The mass spectrometer detector is operated in an ultrahigh vacuum of 10^{-11} mbar to suppress the residual gas background. The inset illustrates the interaction of the clusters with the grating bars and the resulting reduction in slit width.

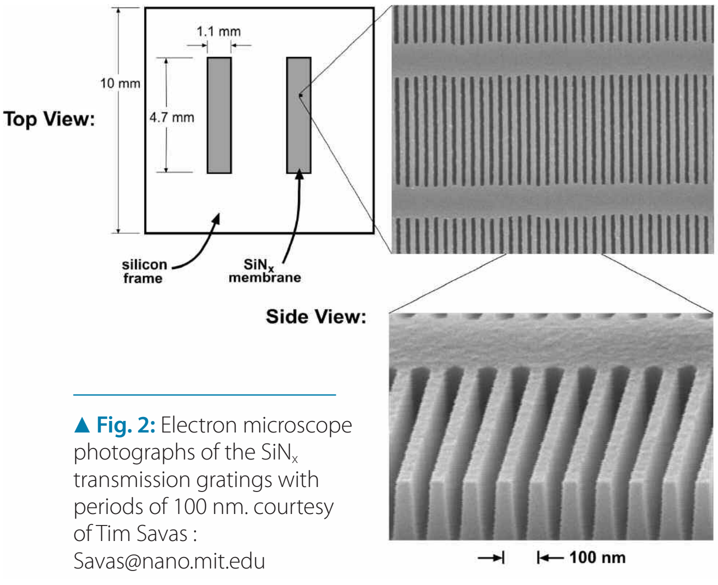
Finally, helium clusters are the only clusters which are definitely liquid. This property led to the development of a new experimental technique of inserting foreign molecules into large helium clusters, which serve as ultra-cold nano-containers. The virtually unhindered rotations of the trapped molecules as indicated by their sharp clearly resolved spectral lines in the infrared has been shown to be a new *microscopic* manifestation of superfluidity [3], thus linking cluster properties back to the bulk behavior of liquid helium.

Today one of the aims of modern helium cluster research is to uncover the secrets of superfluidity by a bottom-up approach, starting from the smallest cluster, the dimer, and proceeding on to larger clusters with more than 50 atoms. And indeed our experiments have uncovered a number of new bizarre and magic quantum phenomena at all sizes as is discussed in the following sections.

Matter-Wave Diffraction as a Non-destructive Mass Spectrometer

The break-through in establishing the existence of the dimer derives from the fact that diffraction depends only on the de Broglie wavelengths of the particles passing *through* the slits and therefore allows for the *non-destructive* analysis of the clusters in a molecular beam. Atom beam diffraction had been demonstrated in 1988 by David Pritchard and his group at MIT, but their apparatus was limited to alkali atoms and dimers, which can be converted with near 100 % efficiency into ions when they strike a hot tungsten wire. Helium atoms and their clusters can only be detected by the much less efficient process of electron impact ionisation.

An overview of our cluster beam apparatus is shown in Fig.1. The clusters are produced in a cryogenic free jet expansion of helium gas at a temperature $T_0 \leq 100K$ and $P_0 \approx$ 1-100 bar pressures into a high vacuum. They grow in size in the course of the dramatic cooling accompanying the adiabatic expansion. The heart of the apparatus is the free standing SiN_x grating (Fig.2) with an exact period of 99.90 ± 0.05 *nm* and typically 50 % transmission through the slits, which are only 50 *nm* wide. Similar gratings were first fabricated in 1995 in the group of Prof. Hank Smith at MIT by his student Tim Savas. This was a remarkable technological achievement since even today more than 10 years later, despite the spectacular advances in nanotechnology, it has not been possible to reduce the dimensions of *free standing* structures.



▲ **Fig. 2:** Electron microscope photographs of the SiN_x transmission gratings with periods of 100 nm. courtesy of Tim Savas : Savas@nano.mit.edu

According to Louis de Broglie all moving particles have a wavelength λ, which is inversely proportional to their translational momentum,

$$\lambda = \frac{h}{M \cdot v} \tag{1}$$

where M is the particle mass. In the case of helium clusters $M = N \cdot m$, where m is the mass of one atom. The diffraction angles are then given by

$$\theta \cong n\frac{\lambda}{d} = \frac{h}{dNmv}, \tag{2}$$

where n is the diffraction order. Since the clusters all have the same velocities the diffraction angles are inversely proportional to N, the number of atoms in the cluster. In complete analogy to an optical grating spectrograph each cluster is expected to appear at a diffraction angle depending only on its number size.

Fig.3 shows a series of diffraction patterns for a room temperature source (T_0 = 300 K) and decreasing source temperatures T_0 = 60, 24 and 6K. Especially noteworthy is the huge range in the detected signals over four orders of magnitude which makes it possible to detect a large number of diffraction orders. This was a delightful surprise, not envisaged when we first contemplated these experiments. According to Eq.(2) the peaks at angles halfway between the dominant monomer peaks at T_0 = 60, 24, and 6 K can be assigned to the helium dimer (see especially Fig 3(e)). Additional structures at smaller angles seen at T_0 = 6 K are due to the trimer and larger clusters, to be discussed later. Our 1994 experiments and subsequent studies provided the first unequivocal experimental evidence for the existence not only of the helium dimer, but also of the trimer, tetramer and larger clusters.

The excellent resolution in these experiments is made possible by the inherently sharp velocity distributions $\Delta v/v \sim 1\%$ of He beams produced in free jet expansions from 5 μm dia pin holes. This feature and the narrow (~10 μm) collimating slits S1 and S2 (Fig.1) provide for large wave packets with longitudinal and transverse coherence lengths of 10 nm x 20 μm, respectively. Fortunately the small clusters in free jet expansions have the same sharp velocities as the atoms, which are typically $v \cong 200 - 300 m/\text{sec}$ depending on the source temperature. Another important feature of the apparatus is a stable construction to allow an angular reproducibility of the order of 10^{-6} rad. The detection of low signals of only 1 count/s of either the He^+ or He_2^+ fragments is facilitated by the inherently low background on these masses in ultra-high vacuum chambers, the basis for the ubiquitous helium leak detector used by vacuum experimentalists.

The diffraction technique has been used to discover and identify a number of other unusual clusters. Small $^4He_m{}^3He_n$ clusters have attracted considerable attention from theorists because of spin pairing of the fermionic ^3He atom constituents. Altogether 11 tenuous complexes including the three-body halo molecule $^4He_2{}^3He$ and the pseudo-Borromean complex $^4He_2{}^3He_2$ could be identified by diffraction [4]. The diffraction experiments have also been applied to mixed HeH_2 dimers as well as H_2 and D_2 clusters. Unfortunately it has not been possible to produce small pure clusters of ^3He with less than about 500 atoms which are predicted to exhibit striking shell-closing effects, like the electrons in an atom, leading to magic number stabilities. The interatomic potentials are the same as in ^4He, but the smaller mass rules out a bound dimer. The smallest stable cluster, according to the most recent calculations, consists of 32 atoms. Thus the detection of small ^3He clusters remains a challenge for future work.

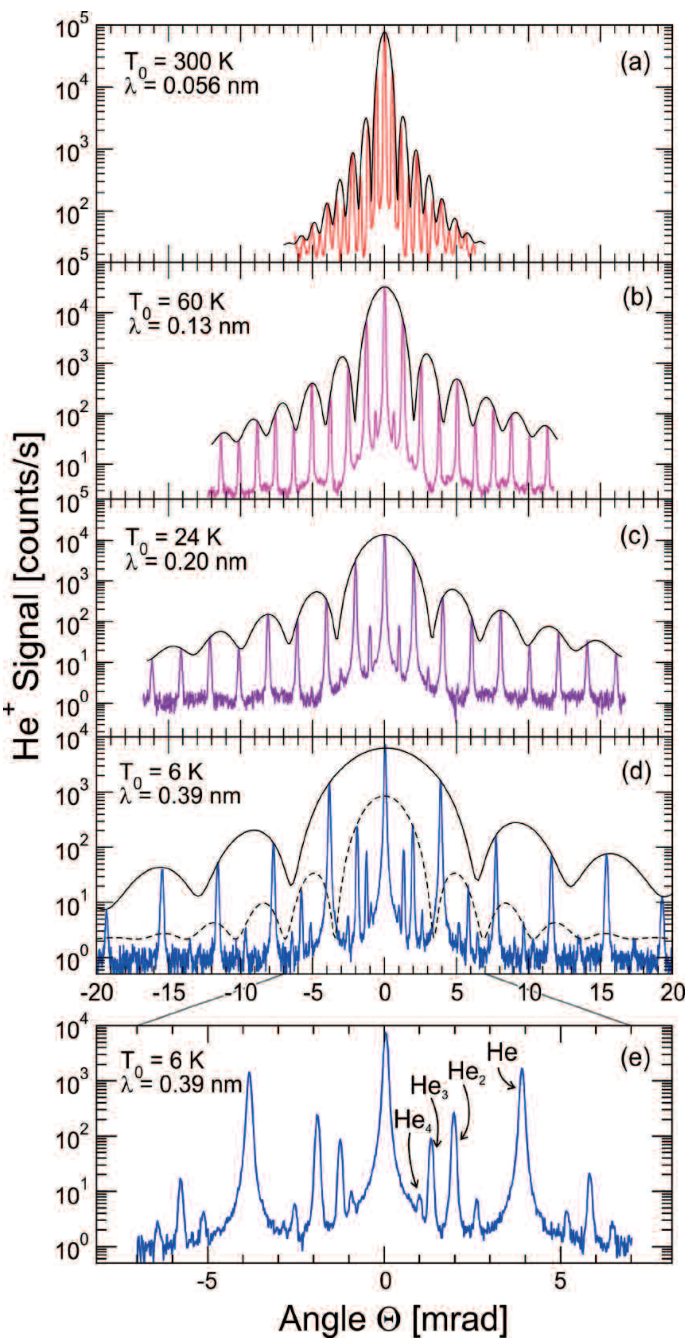
These experiments illustrate the advantages of the diffraction method. It does not suffer from the ambiguities resulting from fragmentation in a mass spectrometer since the diffraction experiment appeals only to the wave nature of those clusters which pass through the slits without an appreciable phase shift. The size analysis takes full advantage of *wave-particle duality* so that even the most weakly bound species can be detected. This technique opened up a vast new field of neutral particle non-destructive mass analysis.

Measurements of Cluster Properties via Matter-Wave Diffraction

The intensities of the diffraction peaks provide information on the interactions of the particles with the grating bars as well as the geometrical sizes of the clusters. As is well known from the analogy to optics the distribution of the peak intensities over various diffraction orders is given by the "slit function", which is the same as the Fraunhofer pattern for diffraction from a single slit. Thus the angular halfwidth of the envelope of the peak height distribution is given by $\Delta\theta = 0.88\,\frac{\lambda}{S_{eff}}$, where S_{eff} is the effective width of a single grating slit. Experiments with different rare gases He, Ne, Ar, Kr and D_2 reveal intensity patterns which are modified by the van der Waals interaction with the grating bars, which causes a reduction in the effective slit width. This led to the first determination of the van der Waals coefficients for ground state rare gas and Na atoms [5] and electronically excited metastable atoms [6].

Large differences are also found between the slit function of He atoms and that of the dimers which are best seen at T_0 = 6 K (Fig.3(d)). As illustrated in the inset of Fig. 1, dimers which come too close to the bars will break up and their effective slit width is reduced by ½ $\langle R\rangle$, where $\langle R\rangle$ is the expectation value of the interatomic distance of the two atoms in the dimer (see Eq.(B5) in the box) a result which agrees with a rigorous three-body scattering theory. The size of the dimer determined in this way from data similar to Fig. 3 (d) is $\langle R\rangle = 5.2 \pm 0.4$ *nm* [7]. The extraordinary size of the dimer can be appreciated by comparing it with the H_2 molecule for which $\langle R\rangle = 0.074$ *nm*. We even go so far as to claim that the helium dimer is the largest naturally occuring ground state molecule in the universe. Since its average interatomic distance is about 3.5 times larger than its classical outer turning point the molecule exists mostly in the classically ···

··· forbidden region of space, a property which in Nuclear Physics is referred to as a halo state. This large size of the dimer has the bizarre effect on scattering from a gas of Kr atoms that the Kr atoms collide in 98% of the collisions with either one or the other of the He atoms (see Eq.(B6)) and can even pass between the two He atoms without breaking the bond [8].



▲ **Fig. 3:** (a) to (d): Diffraction patterns measured for different source temperatures at source pressures ranging from 150 to 1.5 bar (top to bottom). The major peaks are from helium atoms and have been fitted to the corresponding slit functions (solid line curves). Dimers are seen half way between the first order atom peaks at θ_1, for $T_0 \leq 60$ K. The dimer slit function fitted to the dimer peaks up to n = 9 at $T_0 \leq 6$ K is shown by the dashed curve. (e): Trimers (1/3 θ_1) and tetramers (1/4 θ_1) are also clearly resolved at $T_0 \leq 6$ K.

The theory of halo states (Eq.(B3)) also makes it possible to calculate from $\langle R\rangle$ the binding energy of the dimer to be $E_b = 1.3\cdot10^{-3}K\,(1.1\cdot10^{-7}eV)$. In view of its weak binding it became clear that the dimer has only a ground vibrational state, and no rotational states other than the ground state j = 0, making it a spherical molecule. Fig.4(a) shows the radial density distribution

Box: Quantum Two-Body Halo states

The He dimer and possibly $^3He(H_2)$ are the only known molecular analogs of the halo state of the deuteron. Two- and also many-body halo states have been observed in a number of other nuclei. Halo systems are described in first order approximation by neglecting the inner potential. This is justified by the large extent of the wave function into the classically forbidden region R > R_{out}, where R_{out} is the outer classical turning point. There the radial wave function is given by

$$\varphi(R)\rightarrow\frac{e^{-kR}}{R},\,for\ R > R_{out} \qquad \text{(B1)}$$

where $k=\sqrt{2\mu E_b}/\hbar$, and μ is the reduced mass and E_b, the binding energy. The average radius is easily calculated

$$<R>=\frac{4\pi\int_0^\infty R\frac{e^{-2kR}}{R^2}\cdot R^2dR}{4\pi\int_0^\infty\frac{e^{-2kR}}{R^2}\cdot R^2dR}=\frac{1}{2k} \qquad \text{(B2)}$$

and therefore

$$<R>^2=\hbar^2(8\mu E_b)^{-1} \qquad \text{(B3)}$$

The projection of along a Cartesian coo rdinate in a direction perpendicular to the grating bars is given by

$$\langle X\rangle=\frac{\iint|X|\sin\vartheta\, d\vartheta\, d\phi}{\iint\sin\vartheta\, d\vartheta\, d\phi}=\frac{1}{2}\langle R\rangle \qquad \text{(B4)}$$

where $|X|=\langle R\rangle\sin\vartheta|\cos\phi|$. Thus the reduction in slit width due to the finite size of the dimer is

$$S_0 - S_{eff}=\frac{1}{2}\langle R\rangle \qquad \text{(B5)}$$

The large size of a halo system also affects its interactions with other particles as first pointed out by Roy Glauber in 1955 [15]. According to Glauber the neutron and proton in the deuteron are so far apart that other nucleons or π-mesons will only be scattered from either of the constituents except when one lies in the shadow of the other causing an eclipse. Thus the classical cross section is given by

$$\sigma_2=2\sigma-\frac{\sigma_1^2}{4\pi\langle R\rangle^2} \qquad \text{(B6)}$$

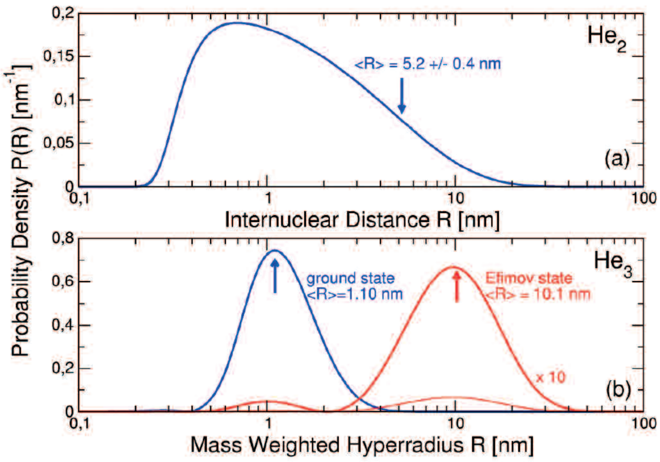
where σ_1 and σ_2 denote the cross sections for scattering from the halo, or one of its constituents, respectively. The second term on the right is the eclipse correction. This effect has recently been found for the He dimer in scattering from Kr atoms [8] for which the eclipse correction amounts to only 2 %. Thus in 98 % of the collisions the Kr atom interacts only with one of the He atoms, implying, moreover, that it can pass between the He atoms without breaking the dimer bond!

of the two bound atoms in the dimer. From the scattering length, given by $\alpha = 2\langle R\rangle = 10.4\ nm$, the asymptotic ($T \to 0$) total scattering cross section can be calculated to be $\sigma = 8\pi\alpha^2 = 2{,}720\ \mathrm{nm}^2$. Thus the enormous size of the dimer, its miniscule binding energy, and the gigantic He-He scattering cross section are all manifestations of its small mass and weak binding.

Table I compares the ground state helium dimer with the electronically excited dimer, which correlates asymptotically to the 2 $^3S_1$ and 2 $^3P_0$ states, and with the sodium dimer in a highly excited vibrational state. In Table I it is interesting to note the remarkable physical similarities between the halo state of the deuteron and that of the He dimer. Of course the deuteron is more tightly bound by a factor 10^{13} in the energy but is smaller in size by 6 orders of magnitude (Table I), which is consistent with Eq.(B3).

These dimer results also provide a discriminatory test of quantum chemical calculations of the van der Waals potential between two He atoms, one of the most important benchmarks for accurate calculations. The giant He-He cross section also explains the extremely low temperatures ($\approx 10^{-3} K$) in He atom free jet expansions widely used as a medium for cooling large molecules to facilitate their high resolution spectroscopic investigations. And, of course, a precise He-He potential curve is needed for understanding the many unique properties of the bulk liquid, including its superfluidity, as well as the unusual properties of the solid.

The size of the trimer has also recently been measured using the same method described above [11]. As proposed by Lim and coworkers in 1977 the He trimer is the only naturally occurring three-body system presently expected to exhibit an exotic quantum state, first predicted in 1970 by the Russian nuclear theorist Vitali Efimov. Efimov pointed out that if the binding between any two of three identical bosons is critical, *i.e.* if $E_b = 0$, and $a = \infty$, then the three-body system would have an infinite number of bound states. As opposed to ordinary bound states, however, the Efimov states disappear when the strength of the two-body potential is *increased*. Thus these states only exist in extremely weakly bound and, in fact, even for very slightly *unbound* systems. Despite many searches a three-body Efimov state has not been found in nuclear systems. Recent calculations predict a huge average distance between the individual atoms for the first excited Efimov state of $< r > = 0.96\ nm$. The average distance between the atoms in the ground state, although much smaller, still is quite large and equals. The measurements of the trimer slit function yield an average bond distance in the trimer of $< r > = 1.^{+0,4}_{-0,5}\ nm$ [11]. With the concentration of Efimov trimers estimated to be about 10 % the expected concentration-weighted average bond distance comes to $< r > = 1.7\ nm$, which is 0.2 nm larger than the experimental upper limit of 1.5 nm. Thus this experiment could not convincingly confirm the existence of the excited Efimov state of the $^4He_3$ with the size predicted by theory.



▲ **Fig. 4:** **(a)** Schematic diagram showing the probability density of the 1 S halo state of the He dimer and **(b)** The first excited Efimov and ground state of the He trimer as a function of an effective hyperspherical radius. The average radius of the dimer <R> = 5.2 ± 0.4 nm is more than 3 times larger than the classical outer turning point R_{out} = 1.4 nm of the interatomic potential (not shown). The first excited Efimov state of the trimer is even larger.

Indirect evidence for the existence of an Efimov state in magnetically tuned laser cooled 10 nK Cs gas has recently been reported [12].

Unexpected Magic He Cluster Sizes

In subsequent experiments the angular resolution was improved from $80\cdot 10^{-6}$ to $20\cdot 10^{-6}$. This made it possible to single out clusters with up to about 20 atoms. At diffraction angles less than $5\cdot 10^{-4}$ *rad* corresponding to larger clusters a disturbing background from the large intensity of He atoms in the beam was eliminated by adjusting the mass spectrometer to He_2^+, to provide a measure of only the clusters in the beam. These experiments revealed a series of well-defined peaks, shown in Fig.5(a), which suggested the presence of stable magic cluster sizes [13]. This came as quite a surprise since the early calculations by nuclear theoreticians had repeatedly ruled out any exceptional magic number stabilities in ^{4}He clusters.

To analyze the unexpected features in the intensities they were transformed to obtain the underlying cluster size distributions G(N) shown in Fig.5(b) for the three diffraction patterns in Fig.5(a). The same features are seen in all three G(N) distributions even though the diffraction patterns appear to be quite different. The undulatory features modulate the exponential-like fall-off as emphasized by taking the ratio to the smoothed ···

▼ **Table 1:** Some Exceptionally Large Two-body Systems

Species	Size of constituent[m]	Distance between constituents [m]	Binding energy [eV]	Potential depth [eV]	Lifetime [sec]	Ref.
Deuteron	$\sim 8\cdot 10^{-16}$	$4.3\cdot 10^{-15}$	$2.2\cdot 10^{6}$	$25\cdot 10^{6}$	∞	-
He_2 $(v=0)$	$\sim 10^{-10}$	$52\cdot 10^{-10}$	$9.5\cdot 10^{-8}$	$9.4\cdot 10^{-4}$	∞	[7]
$Na_2\ X^1\Sigma_g^+$ $(v=65)$	$\sim 2\cdot 10^{-10}$	$30\text{-}100\cdot 10^{-10}$	$1.2\cdot 10^{-5}$	0.69	∞	[9]
$He_2^*\ O_u^+$ $(v=0\text{-}5)$	$\approx 3\text{-}5\cdot 10^{-10}$	$100\text{-}800\cdot 10^{-10}$	...	$8\cdot 10^{-6}$	$\geq 10^{-8}$	[10]

••• fall-off (Fig.5(c)). This G(N) distribution is in itself of great interest since it represents the first unambiguous measurement of the size distribution of neutral clusters produced in a free jet expansion. The results have made it possible to test theories of homogeneous nucleation in much greater detail than previously possible.

Since all the total energy calculations rule out beyond a doubt any magic stabilities for ^{4}He clusters we had to look for another explanation for these unexpected features. Fortunately at that time Jesus Navarro and Rafael Guardiola (Valencia) had succeeded in applying the Diffusion Monte Carlo technique to the calculation of the excited cluster states. Their results for the entire range of sizes up to N = 50 are shown in Fig.6(a), where they are superimposed on the calculated chemical potential (the energy needed to detach one atom) $\mu(N) = \frac{\Delta E(N)}{\Delta N}$ [13], where $E(N)$ is the total internal energy. Then it became clear that the magic numbers found in our experiments correlated with those specific sizes at which a cluster acquires an additional bound state.

In order to understand how the addition of a bound state can affect the intensities it is necessary to consider in detail where the clusters stop growing in the expansion. Downstream of the orifice the rapidly decreasing density quickly drops below a value sufficient to maintain thermodynamic equilibrium. This point is called the "sudden freeze" distance and beyond this "point of no-return" the clusters no longer undergo collisions. Thus to a good approximation the cluster concentrations are determined by the equilibrium constant at the sudden freeze distance. Generally it is assumed that the growth of large clusters can be described by simple accretion: $He_{(N\text{-}1)} + He \rightarrow He_N$. The equilibrium constant K(N) for this reaction is given by the ratio of partition functions, Z, for a cluster with N atoms to that with N - 1 atoms. If the N$^{\text{th}}$ cluster acquires an additional bound state its partition function will differ significantly from that for the next smaller N - 1 cluster and K(N) will jump in size. But for the next N + 1 cluster both Z_{N+1} and Z_N will have the same number of bound states and K(N+1) will fall back to a value close to that for N - 1 (Fig. 6(b)). The jumps in the ratios Z_N/Z_{N+1} agree nicely with the magic numbers in Fig.5(c).

Thus the observed magic numbers $\mathcal{N}$ are not at all related to the cluster stabilities, but have a new kinetic origin. These experiments confirm both the accuracy of the elementary excitation levels, as well as of the chemical potential. Finally it is interesting to point out that the energy levels in Fig.6(a) deviate significantly from those expected from the standard liquid drop model developed for nuclei. If the "soft" radial density distribution function of the clusters and a decrease in the surface tension with decreasing number of atoms is accounted for then, indeed, a correspondingly modified liquid drop model is consistent with the results. It is intriguing to note that this combined theory-experiment investigation sheds insight into the internal states of small clusters, which are expected to be superfluid [3]. These discrete states are the finite size forerunners of the famous bulk phonon-maxon-roton dispersion curve, predicted by Landau, which provides the microscopic basis for understanding many superfluid phenomena in the bulk. ■

About the Authors

Oleg Kornilov is currently setting up a femtosecond soft x-ray facility as a post-doc in the Lawrence Berkeley National Laboratory, University of California at Berkeley. He did his Ph.D research in Göttingen (2004) under the direction of **J. Peter Toennies**, who is an emeritus director at the Max Planck Institut für Dynamik und Selbstorganisation (formerly MPI für Strömungsforschung). At present he is especially interested in superfluidity in hydrogen clusters

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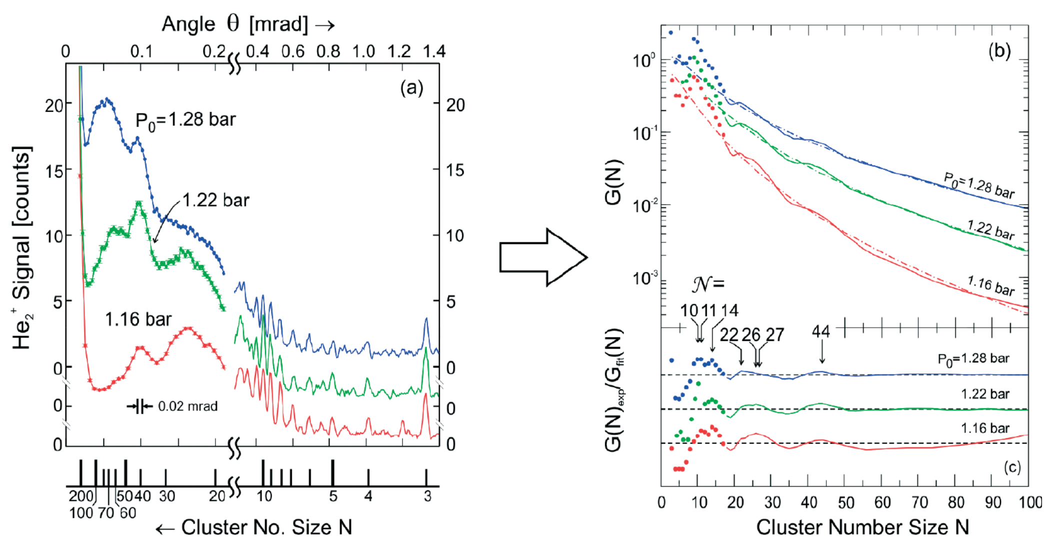
► **Fig. 5:** (a) Three typical diffraction patterns measured at high resolution for T_0 = 6.7 K and source pressures of P_0 = 1.28 bar, 1.22 bar and 1.16 bar. (b) The size distributions G(N) obtained from a deconvolution of the raw data in (a) are plotted as a function of cluster number size N. (c) The curves in (b) have been divided by the average slope to emphasize the deviations. The maxima are assigned to the magic numbers $\mathcal{N}$ indicated by arrows in (c).



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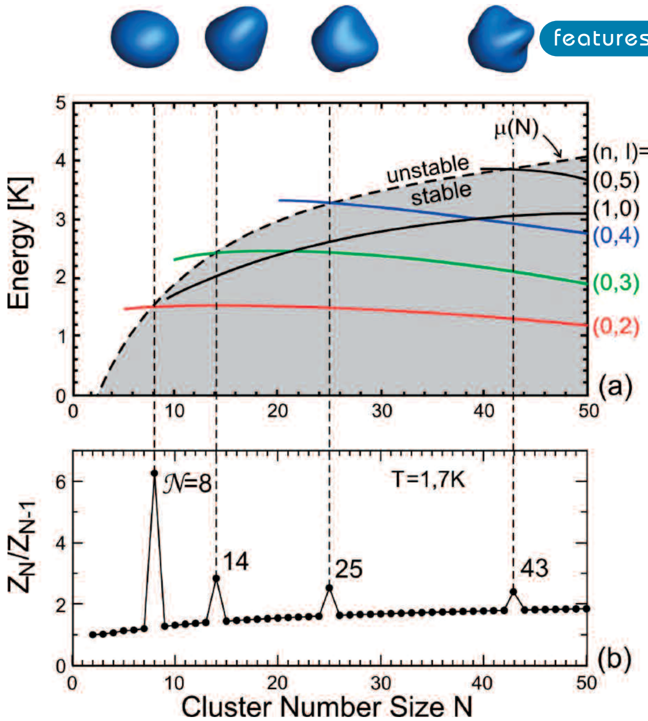

▲ **Fig. 6:** **(a)** The energies E(nl) of the collective excitations for different values of the radial and angular momentum quantum numbers (n,l) and the chemical potential (energy needed to evaporate one atom) are plotted as a function of N. **(b)** The ratio of the partition functions Z_n/Z_{N-1} is plotted versus N for an assumed cluster sudden freeze temperature of T = 1.7 K. At the threshold values in (a) the ratios show maxima, which explain the observed magic numbers N. The distorted spheres at the top illustrate the shapes of the clusters corresponding to each of the newly bound states.

An Interview with Sir Harold Kroto

Patrícia FN Faísca [1] and Sílvia Estácio [2],
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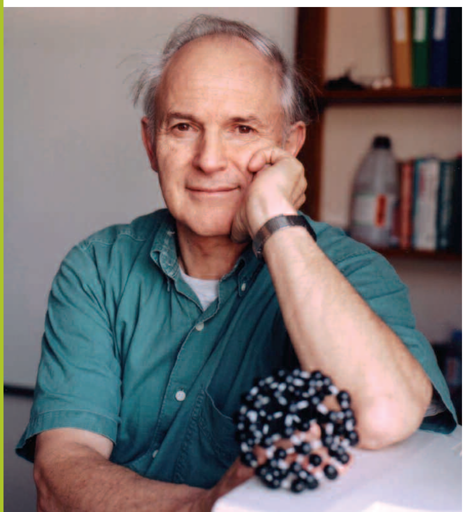

Harold Kroto was born in 1939 in Wisbech, Cambridgeshire, and brought up in Bolton, Lancashire. In 1961, after getting a first class honours BSc degree in chemistry at the University of Sheffield, he took a PhD in molecular spectroscopy of free radicals produced by flash photolysis. He moved to Canada in 1964 where he spent two years at the National Research Council (Ottawa) doing post-doctoral research in electronic and microwave spectroscopy. During 1966 he studied liquid phase intermolecular interactions by laser Raman spectroscopy at the Bell Laboratories in the USA.

In 1967 he was offered a position at the University of Sussex where he became a Professor in 1985. He was elected a Fellow of the Royal Society in 1990, and a Royal Society Research Professor in 1991. In 1996 he was awarded a knighthood for his contributions to chemistry and, later on that year, his contribution to the discovery of C60 Buckminsterfullerene, was recognized with the Nobel Prize in Chemistry. In 1995 he inaugurated the Vega Science Trust (www.vega.org.uk) to create science films of sufficiently high quality for television and Internet broadcast.

Professor Kroto is currently at Florida State University.

Professor Kroto's research interests are diverse and have covered several topics. In the'70s his work on the production and spectroscopic characterisation of unstable species and reaction intermediates with labile multiple bonds, led to the creation of the first molecules with carbon-phosphorus double bonds. His strong interest in interstellar chemistry and his work on linear carbon chain species set the roots for the discovery of C60. Presently, his research interest focuses mainly on fullerene chemistry and cluster science (Further information is available from http://www.sussex.ac.uk/chemistry/profile1523.html).

Besides his scientific accomplishments, Professor Harold Kroto has also received vast recognition for his work as a graphic designer.

A detailed autobiography may be found at http://nobelprize.org/chemistry/laureates/1996/kroto-autobio.html.

Introduction

In the winter of 2005 Professor Kroto visited Lisbon where he gave a public lecture "2010 a NanoSpace Odyssey" that closed a series of colloquia running in parallel with the exhibition"In Light of Einstein: 1905-2005" hosted by the Gulbenkian Foundation. This event, designed and developed under the leadership of Ana Maria Eiró and Carlos Matos Ferreira, involved the participation of a team of scientists from the University of Lisbon and from the Technical University of Lisbon. During the visit Prof Kroto was interviewed by Patricia Faísca of the Centro de Física Teórica e Computacional da Universidade de Lisboa and by Silvia Estácio of the Grupo de Física Matemática da Universidade de Lisboa. The interview that follows below was originally published in 'Gazeta de Física' which is the Bulletin of the Portuguese Physical Society.

When have you decided to become a scientist?

I don't think I ever decided. It just fell into place. I was interested in art and graphics, science, tennis and playing the guitar. I was not particularly good at playing the guitar, because I had learned too late, and I kept loosing in tennis. So, I was not going to be a Wimbledon champion. But I was good in art and graphics. Then I went to the University and I did science. This seemed to me a safer choice to start a career because it was important to ensure survival. Art became secondary although it was my major interest. As I wanted to stay in the University - was having a good time - I ended up doing a PhD in chemistry. Then, since I wanted to live abroad, I went as a post-doc to Canada and I also lived in the USA for a while. I went back to England because I was offered a job there - I had to have a job - and I thought, "I will do it for five years and if it does not work I will go into art school and I will do graphics". It turned out that it went reasonably well and therefore I never got round into doing the thing I wanted to do, that is graphics. So, I never really made that decision "I want to be a scientist!" – I am not even sure that I want to be a scientist now. I want to be interested in what I am doing at a time. I did not even think that I wanted to be a professor. I wanted to earn a living and do everything I could as well as I could. My research was going reasonably well and I was happy with the idea of being a professor. It came a time when I actually thought of doing research in part-time to go into graphics, design and art. But that project "evaporated"when we discovered C60. So, maybe I will start my career as a graphic artist in the next couple of years. I do not know. I have got so many other things on my plate. I never made any plans, things just happen, life just happens.

In your Nobel autobiography you say that at some stage you became interested in Chemistry, Physics and Mathematics exactly in this order. What attracted you most in Physics?

In physics I was fascinated by quantum mechanics and quantum theory. I think quantum mechanics is the greatest intellectual breakthrough of the 20th century since it deals with the microscopic world on which everything is based. In fact I am really a chemical physicist. There is chemistry and physics and on that borderline there is spectroscopy which is what I am still interested in. Physics allows one to understand atomic and molecular spectroscopy from a quantum mechanical basis. Although I am not a particularly good mathematician, I am good enough…. But I am not a particularly good physicist. I think that to be a really good physicist one needs to have a stronger, more fundamental mathematical understanding than the one I have. But for chemistry and chemical physics it is enough to understand quantum mechanics just up to a certain level.

Was your background in Physics an important determinant for the discovery of C60?

No, I do not think it was. From my point of view, the discovery of C60 happened because I was interested in chemistry in space. I did some nice work in that area during the 70s because I got interested in the fact that space is full of molecules and atoms. The discovery of C60 happened in the follow-up of that work. I met Rick Smalley, who had developed a fantastic apparatus for vaporizing metals, when I was visiting Bob Curl at Rice University. I thought that Rick's apparatus would be able to vaporize carbon and should show us something interesting about molecules in space. It was not a very important experiment on my agenda. It had been sitting in the back burner for several years. While I was in Rice I thought we could do this little experiment and then this very big surprise came out.

The story of the discovery of C60 is beautiful. It sounds almost like a fairy tale. Can you recall those days in 1985? Exactly what happened?

There were two experiments planned. A very simple experiment which was particularly interesting to me and a more complex one which was as interesting to me as it was also to Bob Curl and Rick Smalley. This second experiment was very difficult and so we decided to do the simple experiment as a starter. I got a phone call to do it and I went over immediately to Rice. There I worked mainly with the students, in particular with Jim Heath, but also with Sean O'Brien, and Yuan Liu. After a couple of days, the experiments were going very well, but the results were showing a surprising and very striking feature. We can make an analogy between vaporizing something with throwing a whole load of cards. What was happening looked as if the cards were coming down in the same particular order every time. A load of carbon atoms is thrown up in space and, instead of linear chains of all different numbers just like I was expecting-there was something which was very strong, stronger than anything else, just around number 60. That was very surprising. Then we completely diverted ourselves to looking at that, scratching our heads about what it might be. And then, of course, we came to the conclusion that it might be the soccer ball structure. That was a big surprise! We were totally elated by this discovery because, although it was not yet confirmed, we were all convinced that we were right. I remember being so much elated that on my return back to England, when I was seated in the airplane, I though it would not have needed engines to fly me over the Atlantic. I remember thinking that some people would ask me "Did you have a good time?" and that I was going to answer, "Yeah, do you know what we discovered?" and I would tell the whole story.

Then we had a few headaches because half a dozen papers said we were wrong. It was very difficult at that time. I decided that I would spend 5 years trying to prove it correctly because if it was not correct I wanted to be the one to show it. I do not agree with scientists who put out a theory and let other people prove it one way or the other. I think that is unethical science. There are people who do that and I criticize people for doing that, particularly Fred Hoyle, who was a very famous British scientist, a cosmologist or physicist or whatever. He put out a lot of theories that were total nonsense.

Then, together with Rick's group, we did some studies which all fitted very nicely with what we had suggested and we gradually built up circumstantial evidence to indicate we were right.

Would you agree that there is always a certain degree of serendipity in every major scientific discovery?

Yes, up to a certain point that is true. I would say that there are great discoveries that were not serendipity. There are people who try to build something and they know *a priori* that there is a strong possibility that their discovery might work. Let me give you an example. The discovery of the laser (or the maser itself) was not a serendipitous breakthrough because Charles Townes thought it could be possible by looking at Einstein's equations. I think that the serendipitous aspect in this case is not the discovery itself but the way in which it has revolutionized our world: CD players, communications, and eye surgery, just to mention a few. The way the laser revolutionized the technology and the world where we live was totally unforeseen. On the other hand, ours was a serendipitous discovery in the sense that we were not expecting to find the soccer ball. Scientific breakthroughs are not all of the same kind. I do not know enough about the discovery of the transistor, that made computers possible, but Bardeen, Shockley and Brattain may have well thought of that ahead of time. I think one could say, however, that some major discoveries are not predicted. The latter are very important because they change the paradigm; they change our vision of the world. An example of a discovery of that kind is showing the existence of antiparticles by looking at Dirac's equations in Quantum Mechanics. I may not be right but this is the way I look at it. It is a bit like the square root of -1. If we use Pythagoras theorem we only take the positive root to this equation, despite there being two possible roots. Now, someone with the wonderful mind of Dirac would say "Hang on, let us not throw away the negative root. What does it mean?" And Dirac identifies it with a negative energy and concludes that there are antiparticles. I think Dirac's discovery can be used as an example of a serendipitous discovery. Serendipitous discoveries are probably the most important from a fundamental point of view in the sense that they change our understanding of things. The laser's discovery did not actually change our understanding of the world because it was predicted •••

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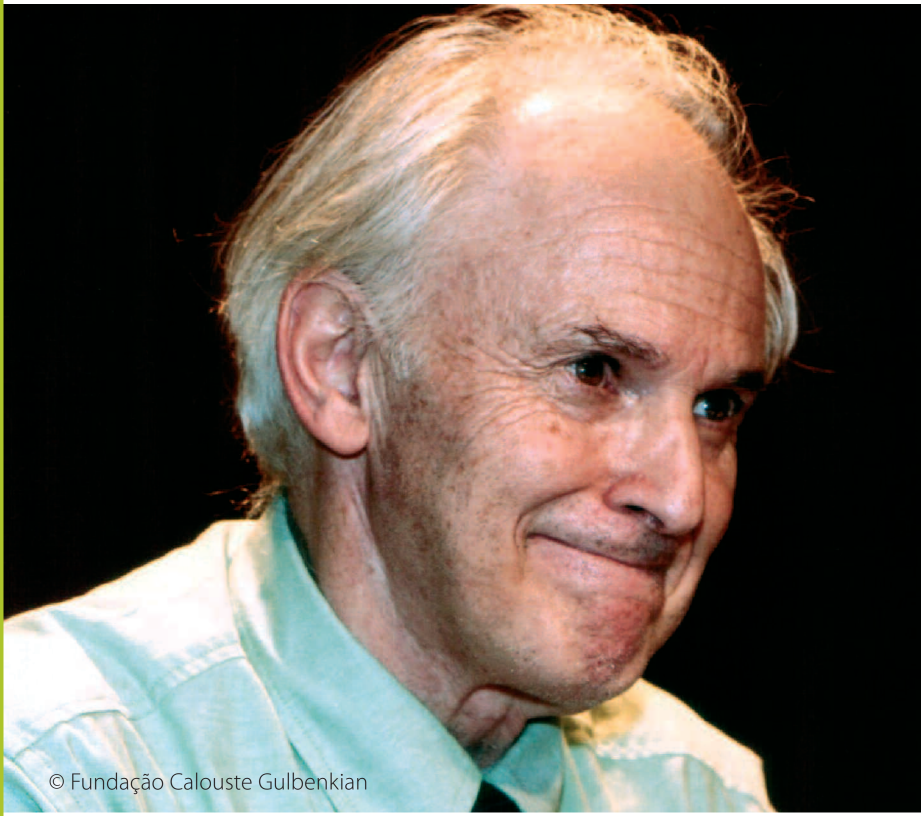
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••• by Einstein's equations. However, no one actually appreciated it until later, until Townes tried to build a maser. But Townes did not change the theory. The serendipitous breakthroughs change our fundamental understanding of things.

In terms of fundamental science how would you evaluate the impact of your discovery?

I think the chemistry of C60 is in its very early days but it has already changed our view of sheet materials. There are 1- dimensional, 2-dimensional and 3-dimensional crystals and graphite is effectively a 2-dimensional crystal. The discovery of C60 showed that on a small scale 2-dimensional sheets actually curve into cages, which is an important finding. I think the chemistry of C60 has only just started partly because science is so well developed that even big discoveries will take a long time to break into applications where things are already fully in place. Consider the example of silicon-based technology. Gallium arsenide (GaAs) could be an alternative to silicon (and possibly better than silicon) but it would never break through because there is so much research going into silicon which, for that very reason, is getting so much better, that for other materials to break in they would have to be better than silicon but without that much research. The same reasoning applies to C60. C60 will break through in areas where the known technologies are not so well developed and *so* mature. I would guess that if C60 is to be a major contribute to useful devices it will be in molecular electronics, which has not really started, and where it has got very interesting properties. But billions have been spent on silicon research and unless molecular electronics can clearly show up as a better alternative it won't move forward. But it may do one day...

Do you feel that the discovery of C60 – possibly the most beautifully designed molecule in the Universe – was a reward for your passion for design?

I never thought of it that way. It's possible but I don't know... It's a nice thought!

Can you tell us what your views on interdisciplinary research are?

I know what multidisciplinary research is. I am a chemical physicist so I cover both chemistry and physics. I think the future is going to bring biologists, physicists and chemists together and that we will obtain great benefit by bringing the ideas from one area to another. When you get stuck in a rut, a person from another field may probably help you if you work together. If you know only slightly (less?) about other fields than yours you can make breakthroughs because you need to be naïve in science. The older you get the more stupid you are because you accept more received wisdom and you shouldn't do that in science.

How do you feel about computational work?

Computational work has to be hand-in-hand with experiment. It shouldn't be open-ended. You should be racing with an experimental horse. If the computation is too far ahead of experimental confirmation, then my guess is that it is not so worthwhile. I worry about computations that are too far ahead of the experimental technology that surrounds them. That's my own personal opinion. Experiments are ultra-important. And I see many, many examples, in very simple cases, of how wrong you can be. The discovery of C60 is just one of them. There are a lot of theoreticians doing work on carbon and none of them predicted what C60 would be.

What advice would you give to a young person taking their first steps in scientific research?

I would say do it only if you're curious and passionate about it. Otherwise it's very hard although I know that other areas are difficult too. But if you are in the University you have to teach, you have to do research, you have to look after students, you have to do some administration, and you have to get research grants... It's not easy and I don't think it is any easier now than it was for me. I think I had a very tough start and I survived it. But I didn't know how tough it was because when you're young you're resilient. But don't go into research to win prizes. When kids ask me how to win a Nobel Prize I say I don't know. I certainly didn't go into research to win the Nobel Prize; it never had an important effect on me. It was only after the discovery of C60 that I thought there was a possible chance of getting the Nobel Prize. But I was very satisfied with the work I had done before that important discovery. I was satisfied with my chemistry-in-space work and with my laboratory work in various areas of phosphorous and sulfur chemistry. That was fine and if I had not done anything else I would have felt that those were worthwhile satisfying contributions. And after that I would have done anything else. Now, C60 is over for me and I'm doing something else. Winning an award is simply a bonus!

In 1995 you inaugurated the Vega Science Trust to create science films of sufficiently high quality for network television broadcast. Why?

It started just like everything else. I was giving a lecture in London, which I wanted to record, and I got a disastrous recording of it. So, I decided to contact a BBC producer who was interested in recording lectures like the one I'll give today. He told me that since this sort of productions was not a major planning area for the BBC it would cost us a certain amount of money to do a decent job. I got some funding and we did record it again. Then we did a second recording of a lecture by Bill Klemperer, a Professor from Harvard, who is a very good lecturer and someone I have a great admiration for. And then a third one turned up. It was then that we decided to set up a foundation, the VEGA SCIENCE TRUST, to do projects of that kind. In the meantime, my colleague, who had a position in the BBC, more-or-less disappeared due to a conflict of interests, and, to some extent, I was left holding the baby myself. He was very important at the beginning, for the first two or three programmes, but now we have more than 100 programmes. Moreover, the idea went on a bit further because the internet became a very important technology and now, many of our programmes that were originally showing on the BBC - and in fact over 50% of them still are - have gone on to our Web site and can be watched free worldwide. And now that is my major commitment. Television is finished as an educational or cultural thing. More than 90% of the material on TV is nonsense, terrible and not worth watching. For me the Internet is the future broadcaster because any individual can broadcast. You can make a program yourself and put it on in your website and any individual will be able to see it in any part of the world. That is a fundamental difference and it is fantastic!

Did you feel at that time, i.e. in 1995, that young people were beginning to lose interest in the hard sciences? In your opinion what may be causing such loss of interest?

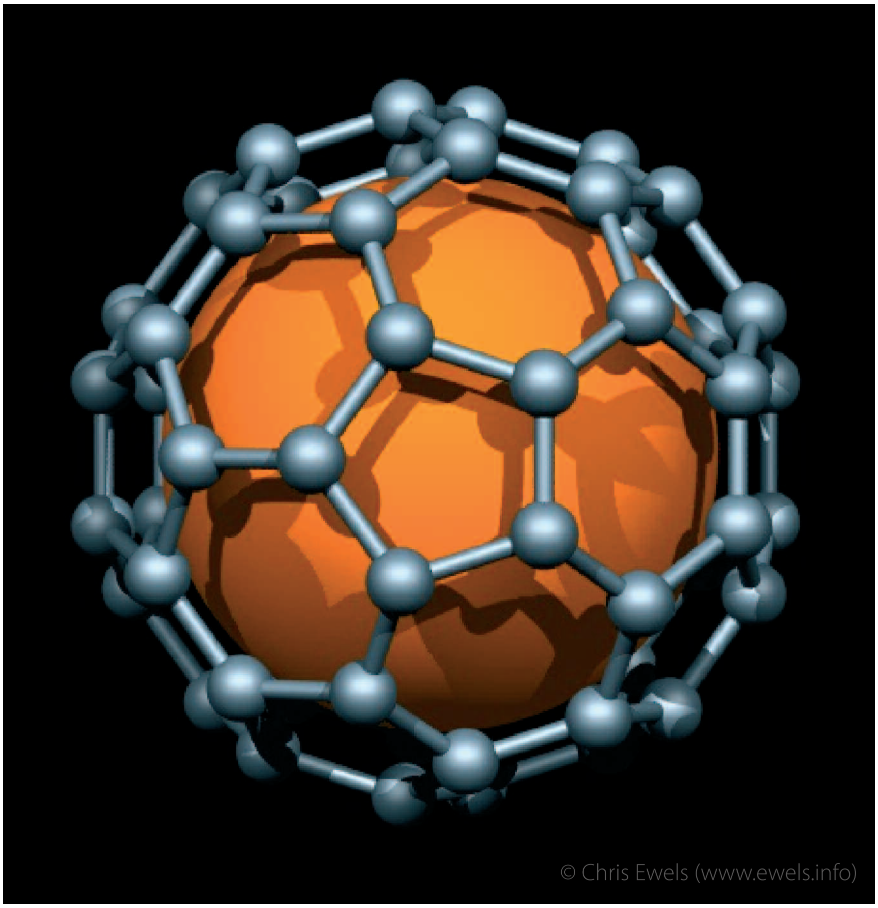
Yes there is a problem with the hard sciences although there has been a little bit of a shift back in the UK. I think there are lots of reasons that explain that and one of them is the following. In the West life is just too easy and there is no quick way into modern technology. For example, years ago when the old phone did not go you just fixed it and that is something you can't do nowadays with mobile phones. We have moved away from a repair-oriented technology to a throw away technology and that is, in my opinion, one of the most important barriers. I became a scientist by fixing things. In my father's factory I fixed the apparatus and because of that I learned how things worked. I made my own radio, and I will always remember switching it on and a voice coming out of this thing, it was incredible! It was just like magic! I think experiences of that kind just do not happen very often, not to enough kids. Somehow the modern child is not really made aware of just how fantastic modern technology is and what's more, if you have a mobile phone, you open it up and you don't know what the hell is going on in there. You don't develop, in general, a real respect for technology unless it breaks down and you manage to fix it yourself. That is something you can't do with modern technology. That's one reason. Of course there may be others, but I think that's a very important one.

Will you tell us about your favourite popular science book?

I think the most important popular science book, at least for me, is 'The Demon Haunted World' by Carl Sagan and I recommend everybody to read it, not just scientists. It's about the issues that concern me. The irrationality of the way things are going at the present time, mystical nonsense and things like that. I think the rational science community has to form an alliance with people that have grown up with mystical ideas. Otherwise they will be driven into the hands of the fundamentalists. Then, I suppose other books that I quite enjoy are some of Feynman's books,

If you were back in the 1960s would you still take an undergraduate degree in chemistry?

No, I think I would have probably gone into graphics and design. But it was a fantastic time! I may still have done it because I never though it was the final decision. The problem is that I don't do anything unless I do it to the best of my ability. But nowadays there are many more options for young people and, what is more important, I would be less dependent on funding. Well, I don't know the answer! ■



Universeum, a science discovery centre in Göteborg

Sten Ljungström [1] and Christophe Rossel [2]
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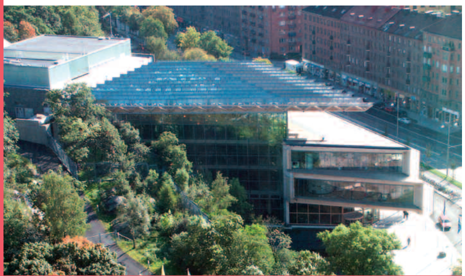

▲ The Universeum in Göteborg (Sweden)

Universeum, also called Sweden's national science centre, is much more than just a museum. It serves as a meeting place for various fields of scientific research, the academic world, the private sector and the school system - a national and international crossroad for young and old alike. With half a million visitors yearly it is by far the largest science centre in Sweden. It is located downtown Göteborg on the Swedish west coast. The building, designed by the architect Gert Wingårdh, was built in 2001 with a strict ecological thinking in every detail. In 2003, it was nominated the most beautiful building in Sweden.

The Universeum's mission "*Enhance the interest in natural science*" was given by its founders: the Chalmers University of Technology, Göteborg University, the Göteborg Region and the Chamber of Commerce.

The basic idea is to propose interactive experiments that increase young people's desire to enhance their knowledge and to become actively involved with natural sciences, technology, and environmental awareness. The main target groups are children, teenagers, their parents and teachers as well as the numerous tourists.

Universeum includes a mixture of living and technical exhibitions. It features one of the most exciting aquarium installations in Europe, a living South American rainforest model, a Swedish landscape as well as a large workshop for experimentation, combining thus nature and technology. The actual exhibitions are about nanoscience, space adventure, telecommunications, car crash safety, the human body, sport etc. The center's holistic concept is based on a humanistic approach where man, society, technology, arts and Nature are all parts of the same context.

"Universeum is unlike any other place I have been" says an enthusiastic visitor. It shows you the world and teaches you about it. Universeum has different 'zones' - take the 'elevator' up to the top floor and then work your way down. First you go through "Water's Way" which tells you about the people, animals and plants in Sweden. From there you go into the "Ocean Zone" - one of the most interesting parts of Universeum. There is a large tank where you can go and pet stingrays. In the Ocean Aquarium you can walk through a glass tunnel and see many different kinds of sharks swimming over your head - it is unbelievably cool! Then you enter into the 'Rainforest', humid and warm, where birds and butterflies - the biggest ones I've ever seen - fly overhead. Other areas of Universeum are: "Kalejdo", "Explora" and the "Gallery". All of these areas show different aspects of natural sciences and technology in an interactive way! For example, the area "Kalejdo" explains the laws of physics, from the smallest to the largest, i.e. from quarks to the intergalactic universe. The exhibit on space science is also a favourite of the public and includes an exact model of a module of the International Space Station as well as a special room displaying our solar system with its planets.

There is a continuous demand from teachers at all levels for information about the latest results in research, understandable by non-specialists. Therefore the museum proposes ongoing training opportunities for teachers and the framework structure for an undergraduate program. It offers also a school program with original concepts for informal learning and aims to be an active forum where young people can bring their own ideas, meet scientists and exchange experiences.

Since it takes knowledge to convey knowledge the Universeum has several specialists dedicated to communicating to the youngsters the interest and enthusiasm for fields such as biology, biotechnology, chemistry, physics, mathematics, geology, environmental sciences and zoology.

In September 2006 started a new exhibition on car safety entitled "Crash, boom, bang". Its content was developed and produced with partners from the Swedish automotive industry, Chalmers University, a local hospital, the police and other traffic authorities in Sweden. The main themes are: pre-crash safety, with preventive actions to avoid accidents and reduce the number of yearly casualties, and post-crash safety, where the aim is to minimize the consequences of an accident. In the model of a crash lane the importance of safety belts and deformation zones can be tested and demonstrated by slow motion movies.

The car crash exhibition attracts many teenagers who would not normally go into a science centre and often because some are just in the process of training for their driving licence.

Among many interactive stations it is worth mentioning the most popular ones: the cabin of a modern Volvo truck for large vehicle driving simulation, a police car with all its electronic equipment including a laser speed detector or an Alcotest instrument. In another set-up, three visitors can compete as to who has the fastest reaction and test their ability in performing simultaneous activities while driving, such as radio tuning, mobile phone handling, speed control, etc.

An extensive prevention programme is proposed in connection with the exhibition.

A trip to Universeum is a must when you are in Göteborg. More information on opening hours and special events can be found on the website: www.universeum.se ■

▼ Automobile crash test simulation

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