europhysicsnews

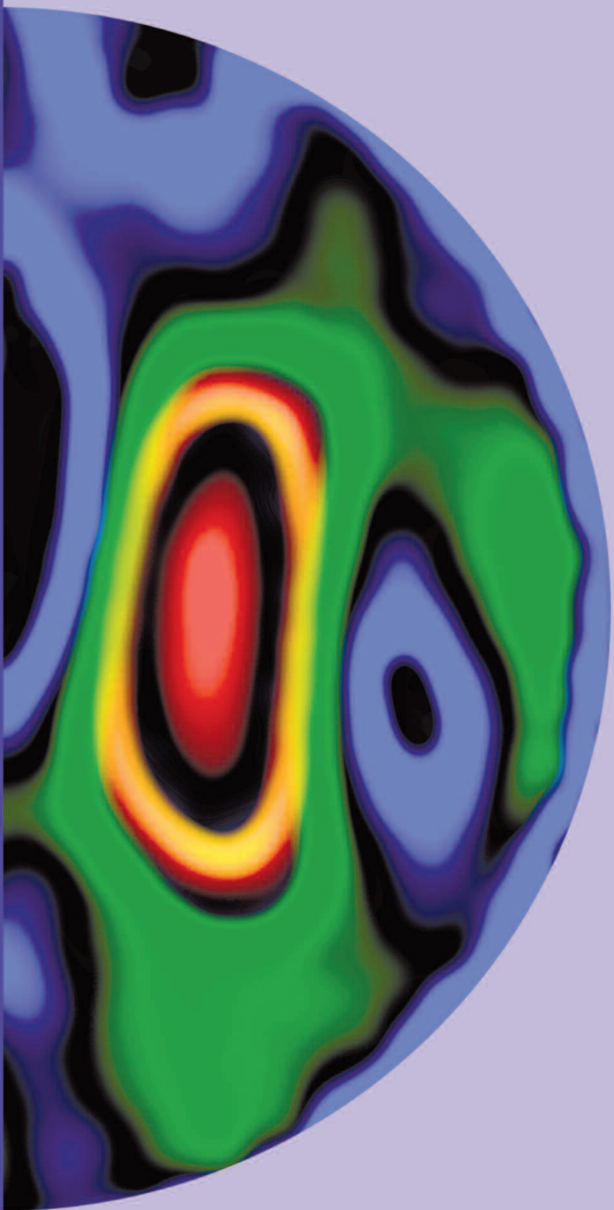
Astronomical theory of climate changes
Controlling atomic matter waves
The weight of an hourglass
Brave ducks
"Spend time in the past above the town"

41/3
2010

Volume 41 • number 3
Institutional subscription price:
88€ per year (without VAT)

Photon10

The UK's premier conference in optics and photonics



→ **23 – 26 August 2010**
University of Southampton, UK

→ **www.photon.org.uk**

The Photon conference series is the largest optics conference event in the UK. Photon10 is the fifth in the series, following Photon02 (Cardiff), Photon04 (Glasgow), Photon06 (Manchester) and Photon08 (Edinburgh).

This conference will comprise:

- Optics and Photonics 2010, the biennial conference of the IOP Optics and Photonics Division. The conference includes sessions representing the Groups of the Division, and from the Fringe Analysis Special Interest Group
- QEP-19, the latest in the series of conferences initiated in 1973 by the IOP Quantum Electronics and Photonics Group
- An Industry Technology Programme: sessions of particular interest to those in the optics industry
- An exhibition of the latest optics and photonics technology
- An area dedicated to lasers in celebration of the 50th anniversary of its discovery
- Plenary lectures from Professor Michael Lebby (Optoelectronics IndustryDevelopment Association (OIDA), USA), Professor Ken Grattan (City University London, UK), Professor Nikolay Zheludev (University of Southampton, UK) and Professor Colin Webb (Oxford Lasers, UK)
- Tutorials: Gentle Introduction to Cloaking by Allan Boardman, and Organic Photonics by Donal Bradley.

Abstract Submission Deadline:
26 February 2010

Early Registration Deadline:
23 July 2010

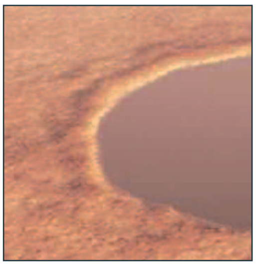
UKCPO UK Consortium for Photonics and Optics

IOP Institute of Physics

Quantum Electronics and Photonics
QEP-19 23–26 August 2010 University of Southampton www.QEP-19.org

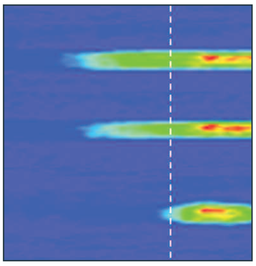
europhysicsnews

Cover picture: Three gold hourglasses, ©iStockPhoto.
See article of F. Tuinstra and B.F. Tuinstra p.25.



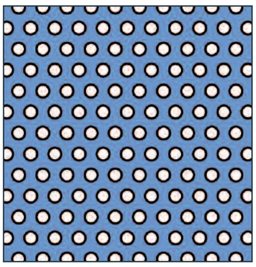
▲ PAGE 17

Astronomical Theory of Climate Changes



▲ PAGE 21

Controlling atomic matter waves



▲ PAGE 27

The weight of an hourglass

europhysicsnews
2010 • Volume 41 • number 3

Europhysics news is the magazine of the European physics community. It is owned by the European Physical Society and produced in cooperation with EDP Sciences. The staff of EDP Sciences are involved in the production of the magazine and are not responsible for editorial content. Most contributors to Europhysics news are volunteers and their work is greatly appreciated by the Editor and the Editorial Advisory Board. Europhysics news is also available online at: **www.europhysicsnews.org**.
General instructions to authors can be found at: **www.eps.org/publications**

Editor
Claude Sébenne (FR)
Email: claude.sebenne@impmc.jussieu.fr

Science Editor
L.J.F. (Jo) Hermans (NL)
Email: Hermans@Physics.LeidenUniv.nl

Executive Editor
David Lee
Email: d.lee@eps.org

Graphic designer
Xavier de Araujo
Email: x.dearaujo@eps.org

Director of Publication
Jean-Marc Quilbé

EPS Secretariat
address: EPS • 6 rue des Frères Lumière
68200 Mulhouse • France
tel: +33 389 32 94 40 • **fax:** +33 389 32 94 49
web: www.eps.org

Secretariat is open 09.00–12.00 / 13.30–17.30 CET except weekends and French public holidays.

EDP Sciences
Managing Director: Jean-Marc Quilbé

Production: Agnès Henri
Email: henri@edpsciences.org

Advertising: Jessica Ekon
Email: jessica.ekon@edpsciences.org

address: EDP Sciences
17 avenue du Hoggar • BP 112 • PA de Courtabœuf • F-91944 Les Ulis Cedex A • France
tel: +33 169 18 75 75 • **fax:** +33 169 28 84 91
web: www.edpsciences.org

Subscriptions
Individual Members of the European Physical Society receive Europhysics news free of charge. **Members of EPS National Member Societies** receive Europhysics news through their society, except members of the Institute of Physics in the United Kingdom and the German Physical Society who have access to an e-version at **www.europhysicsnews.org**. The following are subscription prices available through EDP Sciences.
Institutions: 88 euros (without VAT, European Union countries); 105 euros (without VAT, the rest of the world).
Individuals: 58 euros (VAT included, European Union countries); 58 euros (the rest of the world).

Contact: subscribers@edpsciences.org
or visit **www.edpsciences.org**

ISSN 0531-7479 • ISSN 1432-1092 (electronic edition)

Printer Rotofrance • Lognes, France
Dépôt légal: Juin 2010

European Physical Society
Strategy Working Group

The goal of the EPS as defined by the Constitution is *to contribute to and promote the advancement of physics, in Europe and in neighbouring countries, by all suitable means (acting) either directly or through its members or through Divisions and Groups created by its members or through corresponding or affiliated societies or similar bodies.*

In the past 42 years, the EPS has worked to build bridges allowing for information exchange and the strengthening of the European physics community through a well established conference structure, scientific publications, prestigious prizes and a variety of integration activities. EPS credibility derives from its representation (institutional, individual and topical), its geographical coverage (41 member societies), its implantation in the research community, and the activities of its members. Now the time has come for the EPS to examine whether its vision and activities correspond with current challenges and Member expectations.

Beginning at Council 2009, the Executive Committee began reviewing EPS strategy. Throughout 2009, the Executive Committee reviewed thematic priorities. These were presented at the meeting of the Presidents of IoP, DPG, SIF and the SFP in January 2010, where a broad consultation of all EPS members was suggested. Therefore the EPS Executive Committee prepared and presented a Strategy Consultation document. Independently, the IoP and DPG drafted a Joint Statement.

The EPS Council at its meeting in March 2010 considered the strategy of the EPS and adopted a proposal to create a working group to review EPS activities, mission and strategy. The working group is composed of representatives from Member Societies, Divisions and Groups, Individual Members, Associate Members as well as the President and Vice-president of EPS.

The working group will consult broadly on the mission and strategy of the EPS. The consultation process will take place until October 2010. A special meeting of Council is planned in November 2010 to discuss the draft recommendations. Council 2011 will discuss and adopt the final recommendations.

The guiding principles for the EPS vision should be to strengthen and modernise its activity profile, to provide added value for all categories of members and their activities, to represent the physics community at the European and Worldwide level and to maintain the spread of activities that characterise a learned Society.

To discuss the directions of the EPS evolution several aspects of a broad range of activities and possibilities should be studied. Let us mention only a few :
- Evaluation of EPS structures and governance;
- The role, input and activities of all categories of members of the EPS;
- Synergies based on the strengths of its Divisions and Groups and Member Societies;
- The level of involvement of the EPS together with Member Societies in European Science policy and the role of EPS as the representative of the European physics community;
- Modification of the budgeting process, allowing for a more dynamic allocation of resources to strengthen strategic priorities together with an increase of
  - EPS income based on a consistent and sustainable formula for the financial contributions of Member Societies;
- Improving communication channels and dissemination of information to and from all EPS bodies;
- Influence of new priorities on the Secretariat in its role to achieve the Society's objectives.

We actively support the working group and welcome the opportunity for an in depth review designed to increase the visibility and impact of EPS. We are confident that the EPS can use its strength to build up the European physics community, to stimulate new activities and better to serve its members. ■

Maciej Kolwas,
President of the EPS

The First European Energy Conference

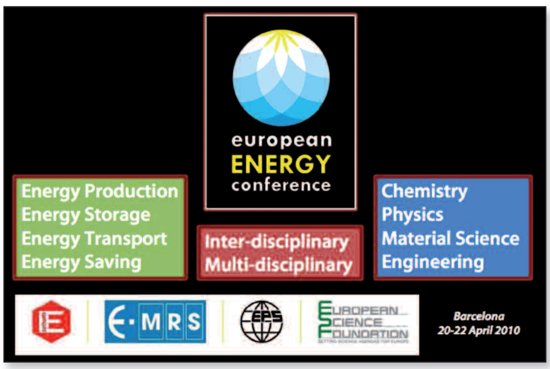
a joint undertaking of EPS, EuCheMS, E-MRS and ESF

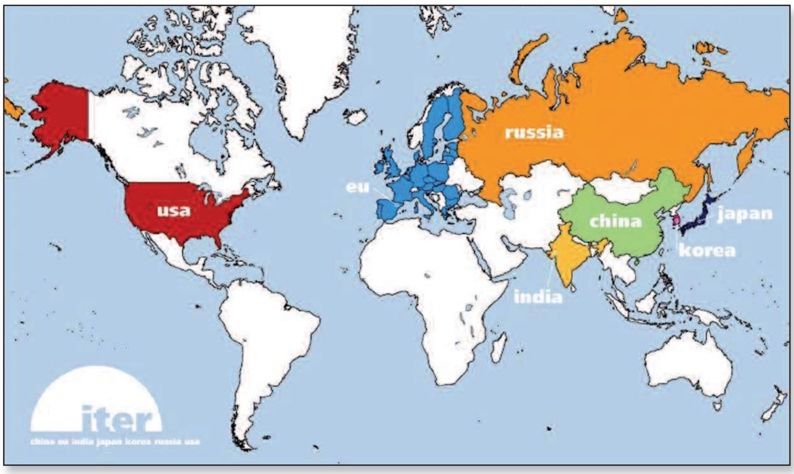
The «First European Energy Conference» was scheduled to start just as the airspace was gradually opened again to traffic, after volcano Eyjafjallajoekull had spewed out ash that had migrated into the atmosphere over Europe with the effect that air traffic over large parts of the continent and over the British Isles had to be halted.

Many pre-registered participants therefore had their flights cancelled and couldn't come to Barcelona. Nevertheless, the event was going ahead, albeit with a reduced schedule, running over two and a half, rather than four days. Yet even this abridged version clearly demonstrated the potential of a conference focusing on a vital theme with the collaboration and support of three major European Learned Societies – the European Physical Society (EPS), the European Association of Chemical and Molecular Sciences (EuCheMS) and the European Materials Research Society (E-MRS) – and the European Science Foundation (Figure 1).

With 280 pre-registered participants from 54 countries the interest in the Conference had been high, but in the end only about a third of the pre-registered participants made it to Barcelona. These were mostly younger – apparently more adventurous – scientists and engineers; in fact, only a few of the invited plenary speakers were eventually present in Barcelona. However, the Chair of the Scientific Organising Committee, Augustin McEvoy, was on site. Together with the very few Committee Members, who had arrived in Barcelona, he immediately prepared a replacement programme of 30 talks. All of these were given in plenary session and, after the day's lectures, people gathered in the reception area of the auditorium, kept on discussing in a relaxed atmosphere with drinks and snacks, and visited the fifty posters displayed.

▼ **FIG. 1:** The first European Energy Conference brought together scientists and engineers working in chemistry, physics and material sciences to comprehensively deal with all aspects of energy. The European Science Foundation assured the organisation.





▲ **FIG. 2:** Seven Parties, representing more than half the world's population, have joined their forces for the construction of ITER. The overall budget is 5 G€, with 90 % provided by partners as in-kind contributions.

The conference began on Tuesday afternoon. Two introductory talks set the stage by examining the relation between energy and the environment, and by weighing the 'pros' and 'cons' of the various methods of energy production. Then, as Barcelona was in easy reach for our Spanish colleagues, speakers who came from Spain gave the remaining talks of this first afternoon. Owing to its favourable insolation, Spain is a leader in photovoltaics. But Spain's strength, we learned, lies not only in advanced research by skilled and creative scientists and engineers, it also consists of science and management support extended beyond the borders of Spain – to Egypt and even to Abu Dabi.

The two ensuing full days of the conference started out with major keynote talks. On Wednesday, participants were introduced to the European umbrella strategy on energy innovation. This will be brought about through the Knowledge and Innovation Community (KIC) «InnoEnergy», a branch of the European Institute of Technology (EIT). The aim is to boost innovation for sustainable energy; and «InnoEnergy», indeed, is designed to cover the entire energy mix of the EU's Strategic Energy Technology (SET) plan.

«InnoEnergy» will be organised and managed as a business, in the form of a European Company (Societas Europaea, SE). It will formally start operating in June 2010 at a number of co-location centres (CCs) that are distributed all over Europe:

- CC 'Benelux' in Eindhoven and Leuven will deal with energy-efficient buildings, and address energy efficiency in highly populated areas;
- CC 'Sweden' in Stockholm will study and develop a smart super-grid

system for distributing electric energy, and also develop methods for energy storage;
- CC 'Poland Plus' in Krákow will work on clean coal technologies;
- CC 'Germany' in Karlsruhe and Stuttgart will engage in energy from chemical fuels;
- CC 'Alps Valleys' in Grenoble (also including Cadarache) will deal with sustainable nuclear technology; and
- CC 'Iberia' in Barcelona and Madrid, and extending into Portugal, will address solar, wind and other renewable energies, such as wave and tidal energy from the ocean.

Moreover, a co-location 'centre' distributed over most of the continent will be operated under the guidance of industrial companies like *Total* and *Électricité de France* (EDF).

Each co-location centre will be involved in research, development and education; for the latter segment, «InnoEnergy» will sponsor some University chairs. Financing will be a mix of seed money from the EIT (*i.e.*, direct EU funding), local contributions, applied-for financing through the EU Framework Programmes and, on a longer timescale, self-supporting income from patents, tuition fees etc. Funding is expected to increase from 50 M€ in 2010 to 156 M€ in 2014. The goals are ambitious: the strategy is supposed to insert 450 students per year into the labour market, and result in 15 patent applications annually.

Thursday, the second full meeting day, started with a keynote talk on ITER. This project – in Latin 'the way' – has a broad international participation (Figure 2). ITER is intended to show the scientific and technological feasibility of fusion energy for peaceful purposes. The principal goal is to achieve a gain factor of Q≥10 by producing ten times the input power of 50 MW, *i.e.*, generating an output power of 500 MW. The site of ITER is now under construction at Cadarache, located in France, about 100 km north of Marseille. The budget, estimated in 2001, of ITER is 5 G€, with 90 % in-kind contributions; 2 G€, *i.e.*, about 40 % of the overall budget has already been committed.

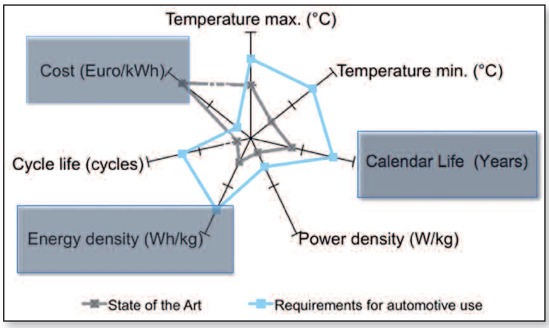
ITER will harness nuclear fusion, the process fuelling the stars, to produce energy on Earth on a large scale. ITER will produce energy
- by using an essentially limitless fuel that is available all over the world,
- without generating greenhouse gases,
- yet operating with intrinsic safety, and
- without producing long-lived/highly radioactive waste.

In contrast to fusion in a stellar interior, where a large volume is available and high pressure prevails, fusion on Earth takes place in a 'magnetic bottle', which confines the plasma within a volume – in the case of ITER – of 830 m^3. At least in the beginning, the fusion will occur between deuterium and tritium nuclei (rather than between protons as in the stars) and at temperatures of about 2×10^8 K to 3×10^8 K. The plasma will be heated by a current of 15 MA running through the vessel, and contained by a magnetic field of 5.3 T that is maintained by 48 superconducting coils. The fuel efficiency of the process is remarkable: 1 g of fusion fuel corresponds to 8 t of oil; on the other hand, the ITER machine will be rather large. With a height and width of ca. 30 m each, it will be nearly twice as tall, and about as wide but several times as deep as the Brandenburg Gate in Berlin.

Looking at the way fusion power has taken in the past and is expected to take in the future, one may say that the European JET, the American TFTR and the Japanese JT-60 machines have proven the science by maintaining output power, in the case of JET, up to 16 MW for a few seconds. ITER's aim now is to prove both science and technology. It is expected that a power of 500 MW – over at least 400 s, but eventually up to steady state – can be generated by 2027. Given sufficient political support, this could then lead to an overall proof of science, technology as well as economy, with an output of 3 GW, towards the middle of the 21st century.

The alternative method to achieve fusion, namely heating by laser radiation where the plasma is contained by inertia – a method advanced predominantly in the USA –, was presented as well. This is to be pursued now in Europe by the proposed **H**igh **P**ower laser **E**nergy **R**esearch (HiPER) project.

While commercial power-generation by fusion lies still in the future, nuclear power stations generating their energy by fission, are numerous and have been in operation for a long time – most of these reactors are over 20 years old, some of them even 40 years. Worldwide, 440 such reactors generate 15 % of the electricity. 146 of these reactors are in Europe. Their fuel comes from politically stable countries, such as Australia and Canada. An initial mixture of 97 % of ^{238}U and 3 % of ^{235}U 'burns' to 94 % of ^{238}U, 1 % of ^{235}U, 1 % of Pu and 4 % of fission products. The problem arising from the latter – ▮▮▮



▲ **FIG. 3:** The technical challenges to be overcome before traction batteries are put on the road for everyday use. Safety is another essential, though not easily quantifiable challenge. (Credit: G. Hörpel and M. Winter, Westfälische Wilhelms-Universität Münster)

▲ **FIG. 4:** Some of the mostly young participants of the First European Energy Conference. (Photo: Piotr Swiatek, Forschungszentrum Jülich)

highly radioactive waste products generated by nuclear fission reactors – was, of course, also addressed during the Conference. A solution is needed, because the current energy production by fission generates an amount of waste that requires a Yucca-Mountain sized repository (the currently envisaged large US underground storage facility) every 20 years. However, a potential solution, actinide burning in a generation-IV reactor – a so-called breeder reactor – requires a much better knowledge of the neutron cross-sections. The «n_TOF» (neutron time of flight) project at CERN, produces the needed accurate cross sections. While these measurements initially had to be made almost exclusively by staff members, there is now an even participation of students and staff – giving hope that a new generation of physicists knowledgeable in nuclear sciences is being educated to deal in future with the problems of fission reactors.

The problem of efficiently storing electric energy was addressed in a talk on 'putting traction batteries on the road'. This gave an interesting insight in the challenges being faced in the development of batteries (*cf.*, Figure 3).

Given the reduced size of the meeting, all participants also got to hear talks that originally had been scheduled for specialised parallel sessions. This resulted in a kaleidoscopic view of work in energy-related issues that is carried out in Europe.

The spectrum of talks reached from experiments with bio-fuels, over efficient storage of hydrogen – in liquid form on carbon nanofibres or at moderate temperature in calcium hydride/magnesium boride composites – to low-energy architecture achieved through evaporative cooling of buildings by porous wall materials. Issues, such as forecasts of electricity demand (reaching from long-term to hourly predictions) and the use of superconductors in energy grids further expanded the range of topics.

In addition to the scientific-technical talks, a philosophy student (with an engineering background) led the audience through a discussion of social and ethical considerations: he showed that intergenerational justice is intertwined with sustainability and thus reminded everybody that we must include the posterity's interest in all our endeavours.

In a final talk entitled 'Proper funded – well prepared for energy research', the participants were shown the widely ranging programmes of the EU, where funds for energy research can be applied for. This topic is scheduled for a 'feature' in a forthcoming issue of EPN. It was also announced that the journal 'Energy and Environmental Sciences' would publish a special issue with refereed versions of talks given in Barcelona.

The impressive dedication of the conference organisers was gratefully acknowledged! The participants thanked the staff of the ESF Conference bureau, who had made their way by car from Brussels, as well as the members of the Scientific Organising Committee, who were present in Barcelona. Together, they had succeeded in turning a meeting that may have seemed doomed, when many speakers and participants cancelled their attendance, into an enlightening and highly enjoyable experience!

In conclusion, it is to be hoped that a second European Energy Conference of the same multi-disciplinary style – *i.e.*, involving EPS, EuCheM, E-MRS and ESF – will be organised again in two years' time. Indeed, if this reduced version of a European Energy Conference was so fascinating, what will it look like in full deployment? ■

Martin C.E. Huber, Former President of the EPS

Six Women Presiding EPS Member Societies

Of the 41 national societies member of the European Physical Society, six, that is 15%, have lady presidents! These are Albania, Croatia, Czech Republic, France, Italy and UK.

To make a career in physics is not easy because of the complexity of the field and the need to work with abstract conceptions based on mathematical models. A physicist working at the forefront of research has to be ready to fight against his limitations throughout his professional life. Knowledge is important – which can be acquired, as well as fantasy – which is part of the individual genetic makeup. A physicist should be sceptical – even about his own research results. Working in physics is not socially entertaining; for the most exciting periods, a physicist is often left to himself. One does not become a physicist to make big money. If talent and interest are necessary to be a physicist, why chose this as a career? A physicist can admire nature not only from pretty postcards but also understand and appreciate its inner beauty, the rules which govern it in its dynamics. In addition, the talent combined with the proper education and the working experience provides a physicist with a unique setting, which allows him to tackle and solve the unprecedented cases in research but also in business. And finally, the feeling of sudden understanding when a discovery is made is overwhelming – a challenge reserved, however, for only a few.

Up to now, I have been describing a physicist using a masculine pronoun. It has to be understood though that there is no genetic or social reason why women cannot also become excellent physicists. But they are rare and whereas everyone can cite from a long list with famous male physicists, Lise Meitner and Marie Curie are the only women that come to mind without access to Wikipedia. The lack of careers for women is not a problem of physics alone. Less than 1% of the directors of Germany's 2000 largest enterprises are women, and this fraction is decreasing.

Physics in Europe enjoys an exceptional constellation at present: I thought it might be of interest to hear more about the six women presidents of national physical societies and their exceptional careers. Their history might reveal, in an example, the specific and additional difficulties women encounter when studying physics and then working in this field. As they have overcome the obstacles put in their path, they might serve as role models helping other women to realise their own potential and encourage them to aim at positions as leaders. To gain some insight into their career trajectories, I sent them a questionnaire. This was not a popular move because the six women are as busy as our male colleagues. One answered my last (and undoubtedly smart) question "any other suggestions you may have " by "fewer questionnaires like this PLEASE!!". I considered this answer as encouragement; I am dealing with the right people here.

Now their stories:

In all cases the parents of the six women presidents did not educate and train their child for typical female roles. In some cases it was the father, in others the mother who foresaw an independent status for their child with an important future role in society on the basis of an excellent education and by specifically supporting "all non-girl interests". All presidents reported that they were excellent pupils, not only in natural sciences but in humanities and art as well. They could all have easily selected careers in fields other than physics. Their interest into physics grew from the ages of 12 to 15. The teachers – independent of whether they were male or female - played an important role. The outstanding intellectual capabilities of these gifted girls obviously motivated the teachers to go beyond the standard curricula introducing them into the cosmic wonders and the famous discoveries of physics and the heroes and heroines behind them. Special events during this period also played a role in making physics attractive and in their decision to select this field as their future profession – participation in a Physics Olympiad, educational programs of an astronomical observatory or summer camps, meeting others, more senior, with whom they could share their interests and obtain some guidance. For most, the atmosphere at school was pleasant. In one case, male school mates "accepted and even enjoyed" being around a bright girl who offered help and from whom home work could be copied. The best boys competed with "our" girls without jealousy. In another case, a woman teacher helped to overcome archaic views on the educational objectives for girls within the teaching staff. The liberal attitudes encountered in an elite school or the education in an all girls school were also important factors. At university, the women in our survey had to cope with being representatives of an extreme minority (1:10-100) in the undergraduate courses. This singular situation was in many cases a pleasant attraction for fellow students and the teaching faculty. The competition was generally fair and staff and students were respectful and polite. Only in one case, male students engaged in rude and questionable behaviour in the presence of a solitary female – ▪▪▪



▲ 1 Jocelyn Bell Burnell, President of the Institute of Physics (UK) (2008-2010); Visiting Professor at the University of Oxford. Field: Astrophysics. 2 Luisa Cifarelli, President of the Italian Physical Society (2008-2010) and president-elect of the EPS; Professor at the Bologna University, Italy. Field: High energy physics. 3 Antoneta Deda, President of the Alabanian Physical Society (2009-2012); Professor at the Tirana University, Albania. Field: Nuclear and environmental physics.

a childish and cowardly reaction, which should be noted and prevented by university administrations.

All of the six lady presidents finished their PhD successfully. The way into a PhD programme was largely determined by their personal environment and the boundary conditions within their country – the science network of their supervisors of the master thesis, family relations, the political situation, and the lack of possibilities at home. No one deciding factor can be deduced from this step which seems to be based on individual circumstances. Most considered themselves very lucky in how they got the contact to their PhD supervisor - in most cases a renowned scientist.

One gender-specific issue in this period however, was the need to cope with both professional and private interests and responsibilities. Some of them met their husbands (in 3 cases also a physicist) and had children while working for a PhD. They could nevertheless complete what had been started because they had a long-term goal, they found a good and affordable day care system (specifically in France and Soviet Union), and they had parents who could help, a supervisor with sufficient understanding and – most importantly – a husband who was supportive. One of the women presidents formulates as advice to girls with the ambition to go into sciences, "I would strongly recommend being highly careful when choosing a husband or partner (usually a higher barrier than children towards a scientific career)." The PhD is per se a difficult period. There are moreover specific risks exclusive to women, which are not related to the complexity of the field. During the PhD, women need therefore specific support to cope with the parallel development of profession and family to which we will come later.

In their professional life as trained physicists, the six presidents experienced the same jealousies and obstacles as their male counterparts. In addition, however, they had to face obstacles that existed only because of their gender: refusals, a harder fight for credibility, protective and patronising attitudes from men and the realisation that – independent of the cultural societal background - top positions are reserved for men only. They experienced discrimination - interestingly more subtle in research than in industry. Ulrike Detmers, a professor of economy and a successful German business woman knows both worlds. She recently said: "The true career obstacles are not the children but rather the old insider relations of men." In summary, the women presidents feel that they have to work harder to overcome prejudices and that reconciling work and family has required a tremendous management effort. But the setting of clear goals helps to overcome these problems. They also point out that they are equally determined to lead their professional life without sacrificing their femininity. Helen Mirren (Oscar winner for her role in "The Queen") said in a recent interview: "I like high heels and nail polish; the source of feminism is economic independence."

I was, of course, aware of the stony road to become a physicist as women. Therefore, I had the question whether they got what they had hoped for when they decided around the age of 15 to become a physicist. It is more impressive when they speak for themselves. Michèle Leduc says: "I got more than I thought when I started. I enjoyed research more than expected and more and more when getting older; I also enjoyed the human side of the profession, the meeting of so many bright people from everywhere in the world, and I enjoy being constantly living in the surrounding of young people". And Luisa Cifarelli adds: "Even more than hoped. My life as a physicist is hard and beautiful, demanding and rewarding, from both the scientific and human points of view. Advanced research projects in a worldwide collaboration scenario, bright pupils, top level encounters and meetings, achievements, results, sometimes honours, responsibilities, absolute lack of routine, etc., these are the many merits beyond my initial expectations." One of the presidents said that their talent to communicate pays off for women in physics as well. The proof of this talent is shown above. This is a lesson for men and clearly demonstrates that we miss out on half of the talent and enthusiasm when women are discouraged by protective structures and habits or wrong perceptions.

What can we learn from the interviews? Societal habits play a role in the parent's house. In western culture, girls growing up are not expected to play with machines and to enjoy building



▲ **4 Michèle Leduc, President of the French Physical Society (2008-2010); Professor at the Physics Laboratory of the École Normale Supérieure, France. Field: Atomic physics. 5 Silvia Tomic, President of the Croatian Physical Society (2007-2010); Senior Scientific Advisor at the Institute of Physics in Zagreb; Field: Condensed matter physics, Biological Physics. 6 Alice Valkarova, President of the Physics Society of the Czech Republic (2006-2010); DrSc at the Charles University, Prague, Czech Republic. Field: High energy physics**

and taking apart objects. The conception too often is that careers in fields that are considered difficult are reserved for boys. In addition, the economic and industrial situation of many countries simply does not provide any stimulation to go into physics. This discourages girls more than boys.

Talented girls around 15 should be encouraged to study physics by parents and teachers. The talent is recognisable in this period. Girls attracted by physics should believe in themselves and not listen to discouraging opinions when they come from archaic societal conceptions. They should develop ambition and passion. They should follow their dream but be ready to work hard.

What can be done from the outside? Between the ages of 12 and 15, the basic academic orientation is taken and physics associations should cooperate with schools and teachers to interest the talented girls in physics as well. As school physics curricula cannot accomplish this, specific programmes should be developed, which convey the attractiveness of physics and research. The national research institutions should open their gates and invite pupils at this age. Physics Olympiads and girl's days seem to be the right approach. At mixed schools, it would be helpful to have a women teacher responsible for supporting talented girls and to avoid discrimination whether its origin be the teaching staff or the fellow pupils. Such an officer might also help at the university where a predominant male society has to learn to deal with an extremely unbalanced situation.

More direct support is possible and necessary, specifically during the PhD period including affordable day-care facilities (nurseries, kindergartens, schools with afternoon activities) at universities and research institutions. Women with children should have the possibility to work at home via computer links without salary reduction. Job mobility should be enhanced in science specifically in cases where both partners are engaged in research. There has to be awareness that travelling is more expensive if day-care is necessary in the period of absence and financial compensation should be considered. Conference organisers should also provide facilities for mothers who bring their children. There should be programmes specific for those who return to work after matrimonial leave. A general culture of support and fairness is necessary in the work place so that women can meet professional demands and private duties. Women should join their own organisations dealing with gender issues and these organisations should be supported by learned societies – as is the case for EPS. Parity in all scientific and administrative committees making career decisions – recruitment, nomination, promotion, grants – should be imposed.

What can EPS do? All member societies should have devoted working groups of women in physics. They should cooperate with the support of EPS. A list of prominent women physicists should be available and used whenever committees have to be staffed or outstanding conference speakers be nominated (already done). EPS should ensure that all its committees have women on board. In all conference programme committees women should be well represented. This is the place where scientists get the opportunity to show their achievements and to demonstrate their capabilities. The conference programme committees must be fully aware of their responsibility to promote women physicists. Committee composition and deliberations should be monitored. It is also a concern of the lady presidents that the less privileged countries in and around Europe are not forgotten.

Examples of excellent programmes include the IOP Project JUNO and the Athena SWAN award scheme addressing and honouring good practices to better balance the under-representation of women. Direct practical and financial support is provided by the M. Hildred Blewett scholarship programme of the APS that supports women financially to return to physics research after interruption due to family reasons. I want to add the programme of the Christiane Nüsslein-Volhard foundation which financially supports young female PhD students to engage help at home.

Some day, the EPS will also be represented by a woman president. The day could be closer than you might think.

Conclusion: On March 20th, the EPS Council elected Prof. Luisa Cifarelli as the next EPS president. Her term will start in April 2011. Congratulation! ■

F. Wagner,
Past President of the EPS

Council Report 19-20 March 2010, Mulhouse, France

Council 2010 was organised on the campus of the Université d'Haute Alsace. Over 70 delegates attended. The meeting provided an opportunity to review the activities of the EPS and to decide on a process for developing a new EPS strategy.

The EPS President, Maciej Kolwas, began by placing the EPS in context, reminding Council of the goal of the EPS to contribute to and promote the advancement of physics, in Europe. The EPS has achieved this by building a community over the past 40, comprised of 41 Member Societies, 2700 Individual Members and 50 Associate Members and provides a forum at the European and international levels to inform develop and coordinate activities more effectively.

The EPS is involved in many physics education activities. In 2009, these included the second year of the study of the implementation of the Bologna Process in Physics Studies, the GIREP/EPEC Conference, innovative teaching practices in the Learning with Atlas @ CERN and support for the Young Physicist's Tournament. To more effectively coordinate and share information about these activities the EPS created of the European Education Platform, bringing together EPS actors in physics education and other learned societies and projects.

The Alliance for Physics Publishing has moved forward in 2009, bringing together learned society publishers and publications to look at concrete measure to harmonise the European publishing landscape and how to make European publications more attractive to authors. One instance where more collaboration has been beneficial is EPL, which has developed in terms of visibility and impact through the association of the EPS, the French Physical Society, the Institute of Physics (UK) and the Italian Physical Society.

The review of EPS activities highlighted the importance of Divisions and Groups. They organise conferences, award prizes, engage in outreach, and provide input into EPS, and implement policy. They provide the EPS with its scientific credibility. They represent all fields in physics and cover the essential transversal issue. In 2009, they organised 11 high profile conferences, with more than 5000 participants, and awarded 12 prestigious prizes.

Regular meetings with EPS Member Societies in 2009 permitted the exchange of information with the EPS. Common issues were discussed and common activities were considered and developed. The Executive Committee gained insight into the importance and role of the EPS in small to mid size societies.

The EPS approved a position paper on Open Access publishing that highlighted a need to improve the procedure for drafting and adopting such documents. In future, Member Societies and Divisions and Groups will be invited to submit their comments prior to publication. Moreover to increase EPS visibility, when they are released, position papers are to be communicated as widely as possible.

The Executive Committee began a review of EPS activities and strategy in June, and decided that it was necessary to consult widely with its members. Council approved the creation of a Strategy Working Group, which will make recommendations to Council in 2011 (for more, please see the editorial).

Elections for President-elect and for the Executive Committee were organised. Council listened to two inspiring talks from the candidates for President-elect, Luisa Cifarelli, and Carlos Ferreira. In close balloting, the EPS elected its first ever woman President, Luisa Cifarelli. She will take up office at the close of Council 2011. The members of the Executive Committee elected are: M. Auzinsch (2nd term), C. Biscari (1st term), H. Ferdinande (2nd term), A. Kastberg (2nd term), M. Knoop (1st term), C. Latimer (1st term), A. Proykova (2nd term), K. Wandelt (2nd term), E. de Wolf (1st term)

Council warmly thanked the outgoing members, Angela di Virgilio and Victor Velasco for their hard work and dedication. Fritz Wagner was congratulated for his success in raising the profile of the EPS and improving the communications with Member Societies and Divisions and Groups.

Council approved the statutes of the Solar Physics Division and the statutes of the Energy Group.

Council approved the award of the Gero Thomas Memorial Medal to Gunnar Tibell.

Council approved the following individuals as fellows of the EPS:

- Giorgio Benedek, Italy
- Roger Cashmore, UK
- Elisabeth Giacobino, France
- Hartmut Hotop, Germany
- Peter Knight, UK
- Olaf Scholten, Netherlands
- Annick Suzor-Weiner, France
- Lluis Torner, Spain

Council approved the following individuals as Honorary Members of the EPS

- Jocelyn Susan Bell-Burnell
- Gillian Gehring
- Theodor Wolfgang Haensch
- Claude Cohen-Tannoudji

As part of this year's Council meeting, R.D. Heuer, CERN Director General, gave a presentation of CERN and the LHC. The Council dinner was hosted at the impressive Mulhouse Automobile Museum.

I would like to thank the EPS staff for their hard work and dedication for making this year's Council meeting a memorable experience. ■

David Lee,
Secretary General of the EPS

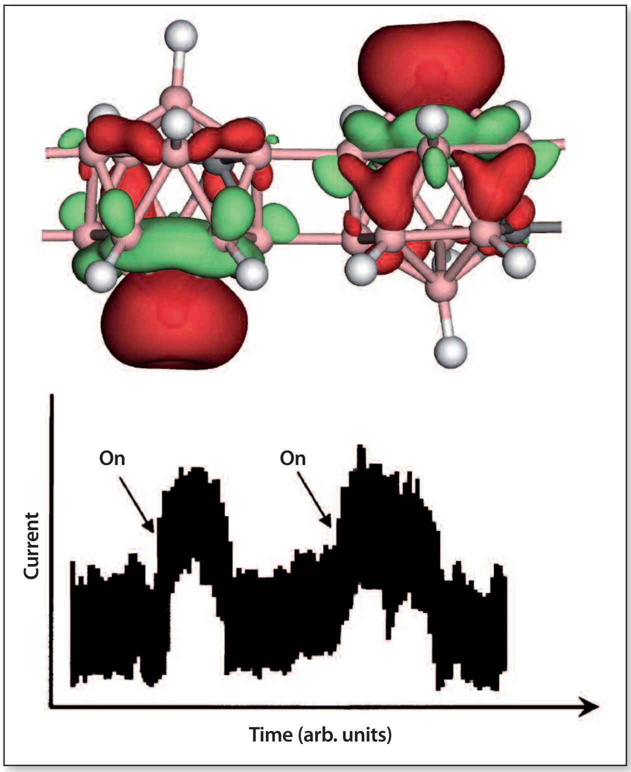
Highlights from europeans journals

CONDENSED MATTER

A new look at Boron Based Semiconductors

Semiconducting boron carbides have been discussed as suitable materials for solid-state detectors of slow neutrons for 50 years, but success has only been observed in the last decade. Using plasma-enhanced chemical vapor deposited films, based on $C_2B_{10}H_x$ icosahedra building blocks, detection of slow neutrons and neutron-voltaic (similar to photovoltaics, except with neutrons, not light) properties have been demonstrated. Recently, the successful transition metal (Mn, Fe, Co, Ni) doping of semiconducting boron carbides has proved to be a route to making successful homojunction diodes, and also the means to obtain detailed local structural information about this important but complex material with many polytypes via extended X-ray absorption fine structure (EXAFS) studies. Success in previous attempts to determine the local structure of the undoped semiconducting boron carbides by EXAFS studies has been elusive. Because the transition metal atoms provide a suitable strong scattering center, the local structure has now been obtained for some semiconducting boron carbides using EXAFS at the K-shell of the doping 3d transition metal.

▼ Top:The optimized structure spin distributions of Fe_2-$C_2B_{20}H_{14}$. As determined from the EXAFS results, the transition metal atoms sit on opposite sides in the apical sites on the adjacent icosahedra. Bottom: The first observation of currents generated at zero bias from incident neutrons by a semiconducting boron carbide device.



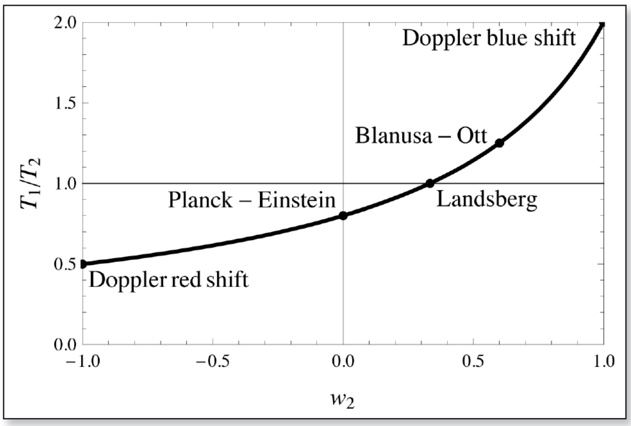
The 3d transition metals dope semiconducting boron carbides in an unusual manner: pair-wise substitution at the apical sites of adjacent icosahedra (Figure). Because of the favored sites, there is a large local magnetic moment associated with the transition metal atoms dimer pairs. Thus semiconducting boron carbides maybe have application not only in fabrication of solid state devices with slow neutron detection applications, but in devices with spintronic applications as well. ■

▮▮▮ **Jing Liu**, **Guangfu Luo**, **Wai-Ning Mei**, **O. Kizilkaya**, **E. D. Shepherd**, **J.I. Brand** and **P.A. Dowben**, 'The local structure of transition metal doped semiconducting boron carbides', *J. Phys D: Appl. Phys.* **43**, 085403 (2010)

RELATIVITY

About the temperature of moving bodies

By confronting relativity theory with thermodynamics the question of the proper transformation of the absolute temperature is most exciting. To this several answers have been historically offered, practically including all possibilities. In 1907 Planck and Einstein concluded that moving bodies appear cooler by a Lorentz factor. Following some preceding claims Ott has challenged this opinion in 1963 by stating that such bodies are hotter. Landsberg argued for unchanged values of the temperature in 1966. Several authors observed that for a thermometer in equilibrium with black body radiation the temperature transformation is related to the Doppler formula.



▲ The ratio of the temperatures shown by an ideal thermometer, T_1, and of the observed body, T_2, as a function of the speed of the heat current in the body, w_2. The relative velocity is v = -0.6 c.

Coming to the era of fast computers, a renewed interest emerged in such questions by modeling relativistic stochastic phenomena. Dissipative hydrodynamics applied to high energy heavy ion collisions also requires the proper identification of temperature and entropy.

The physical root of the paradox lies in the fact that the momentum exchange cannot be separated from the energy exchange at relativistic speeds. Beyond the two velocities of the interacting thermodynamic bodies the energy and momentum equilibration accentuates two additional velocities. By a Lorentz transformation only one of the four velocities can be eliminated. The remaining three reflect physical conditions on the system. The requirement of observer independent thermodynamic equilibrium leads us to a generalized Doppler formula. It depends on two physical velocities, the relative velocity of the bodies and the relative velocity of the energy flows inside the bodies. We reproduce the formulae of Einstein and Planck, Ott and Doppler according to respective physical assumptions on the energy flow. ■

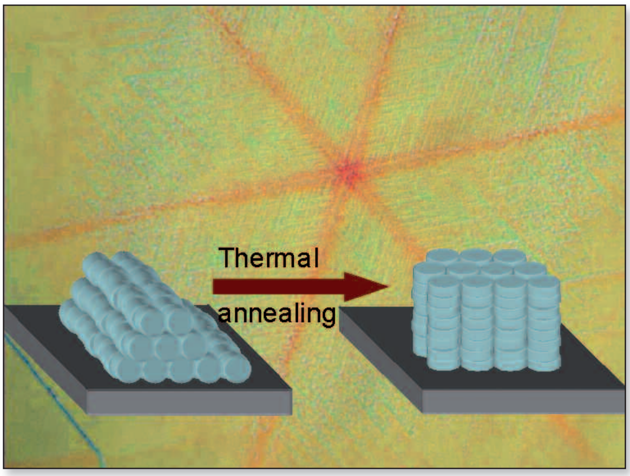
T. S. Bíró and **P. Ván**,
'About the temperature of moving bodies', *EPL* **89**, 30001 (2010).

CONDENSED MATTER

About discotic columnar liquid crystals

Discotic columnar liquid crystals have a remarkable capability to transport charge in just one direction, along the columns formed by stacks of their flat, aromatic, disk-like molecules. In the mesophases formed by such materials, the columns are arranged in a two-dimensional crystal lattice. These materials are potentially useful for organic solar cells, but to achieve good performance from such devices (which strongly depends on the quality of charge and exciton diffusion in the materials used) one needs to be able to prepare uniform thin films on conductive substrates with the axis of good transport along the columns vertical (this is called homeotropic orientation). The difficulties of achieving this are stressed in the paper by Grelet *et al.*, which describes structural investigations by grazing incidence X-ray diffraction on thin films of columnar liquid crystals. This work shows that a strong planar orientation (with columns parallel to the surface) is found for a very wide variety of discotic compounds, film preparation processes, film thicknesses, and types of solid substrate. This degenerate planar alignment corresponds to the worst orientation for carrying charges or excitons in organic devices, and can by explained by anchoring energy considerations. Nevertheless, the authors have discovered a specific thermal process that provides a convenient way to achieve homeotropic anchoring of hexagonal columnar liquid crystal films, which is the suitable alignment for photovoltaic devices. ■

▼ Anchoring transition from planar (columns parallel to the substrate) to homeotropic (columns normal to the interface) alignment after a specific thermal annealing observed by optical microscopy.



E. Grelet, **S. Dardel**, **H. Bock**, **M. Goldmann**, **E. Lacaze** and **F. Nallet**,
'Morphology of open films of discotic hexagonal columnar liquid crystals as probed by grazing incidence X-ray diffraction', *Eur. Phys. J. E* **31**, 343 (2010)

CONDENSED MATTER

Superfluidity of a perfect **quantum crystal**

In nature, helium II is the only liquid that exhibits Bose-Einstein condensation. All other substances are solid at such temperatures. This paper (see also a previous paper [V.A. Golovko, *Eur. Phys. J. B* **71**, 85 (2009)]) demonstrates that Bose-Einstein condensation can occur in the solid state as well. Moreover, it is shown that at absolute zero of temperature a crystal in which the condensate is formed (condensate crystal) is energetically preferable with respect to the same quantum crystal without condensate. Therefore, on lowering the temperature of the crystal there must somewhere happen Bose-Einstein condensation as in liquid helium. This opens a huge field for experimental investigations of Bose-Einstein condensation and of its influence on properties of solids.

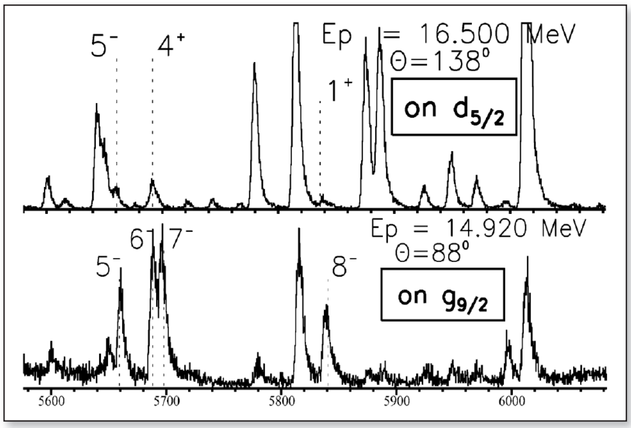
A condensate crystal can be superfluid as well as nonsuperfluid. It should be remarked that superfluidity is treated as a state whose symmetry is spontaneously broken because of an intrinsic superflow [V.A. Golovko, *Physica A* **246**, 275 (1997)]. In particular, this manifests itself in the known fact that helium II placed in an open vessel always crawls up the wall, out of the vessel. The absence of viscosity alone cannot explain why the liquid creeps up the wall against the force of gravity. The same phenomenon can occur in crystals. This paper shows that the condensate crystal can be superfluid at least in a metastable (excited) state. An interesting situation may occur in metals in which the positive ions that form the crystal lattice are bosons. The ionic system may well pass into a condensate state that might turn out superfluid. In this case we shall have ionic superconductivity because the ions have a charge. Therefore, along with electronic superconductivity a metal can possess ionic superconductivity and even the latter alone. ■

■■■ **V.A. Golovko**,
'Superfluidity of a perfect quantum crystal II', *Eur. Phys. J. B* **74**, 345 (2010)

NUCLEAR PHYSICS

Neutron-hole states in doubly-magic nucleus ^{208}Pb

The doubly magic ^{208}Pb nucleus continues to draw attention of nuclear spectroscopists due to its seemingly simple but rich structure features. This nucleus and its neighboring nuclei at the closed proton (Z=82) and the neutron (N=126) shells are ideal laboratories for studies of particle excitations and their interactions in a nuclear medium.



▲ **Energy spectra of outgoing protons given as a function of the energy of the final state in ^{208}Pb for two isobaric analog resonance energies in ^{209}Bi.**

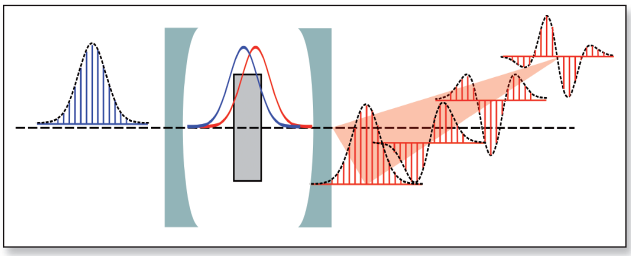
Precision measurements employing inelastic proton scattering and the high-resolution particle spectroscopy with the Q3D magnetic spectrograph at the Munich 14 MV tandem accelerator have discovered some earlier unobserved neutron particle-hole excitations with small cross sections.
The states of ^{208}Pb lying between 5 and 6 MeV excitation with a neutron-hole configuration of ($g_{9/2}$, j^{-1}) were observed in proton scattering at the resonance energy for the $g_{9/2}$ single-neutron isobaric-analog resonance (IAR) in ^{209}Bi. The energy and on-resonance angular distributions for the scattered protons were measured and used to identify five missing members of the ($g_{9/2}$ $f_{7/2}^{-1}$) neutron multiplet. These results will aid nuclear structure theorists to improve their models and nuclear interactions in the domain of the heavy elements. ■

■■■ **A. Heusler**, **G. Graw**, **Th. Faestermann**, **R. Hertenberger**, **R. Krücken**, **C. Scholl**, **H.-F. Wirth** and **P. von Brentano**, 'Observation of five high-spin members of the $g_{9/2}f_{7/2}$ multiplet in ^{208}Pb', *Eur. Phys. J. A* **44**, 233 (2010)

QUANTUM PHYSICS

Multimode sources of quantum states

Quantum states of light stimulate the interest of scientists because of their fundamental nature as well as their potential for applications in secure communications, computation and metrology. These benefit from the occurrence of two important quantum properties, namely entanglement (quantum correlations) and squeezing (quantum noise reduction) that some quantum states display. All these applications, when operated at the quantum level, become benchmarks inaccessible classically.
The range and flexibility of a specific application is enhanced with an increase in the number of modes involved in the quantum state. This explains the intense search for multimode quantum states. Typically, the generation of such states by means of optical devices needs experimental configurations whose complexity increases with the number of modes involved. In contrast, a practical source should be compact, scalable and permit to easily master the quantum properties of the generated states.



▲ **A frequency comb (blue) pumping an OPO cavity is converted into a signal filed (red). The multimode output is a superposition of quantum frequency combs.**

We have studied a special type of optical parametric oscillators (OPOs), which are the best sources of squeezed and entangled states and are by now routinely used for this purpose. We have shown that OPOs pumped by frequency combs, which are trains of ultra-short pulses having a well-defined repetition rate, are able to generate simultaneously many different frequency combs displaying squeezing and sharing quantum correlations. Such frequency combs correspond to well-defined linear superpositions of cavity modes (supermodes) and their quantum properties can be engineered by simply acting on the duration of the pump pulses.
Thus, a single source can generate, flexibly, multiple multimode quantum states, opening the way to new applications of non-classical light, both in metrology (*e.g.* the ultra-precise measurement of times and frequencies) and in the field of quantum information technologies. ■

■■■ **G. Patera**, **N. Treps**, **C. Fabre** and **G.J. de Valcárcel**, 'Quantum theory of synchronously pumped type I optical parametric oscillators: characterization of the squeezed supermodes', *Eur. Phys. J. D* **56**, 123 (2010)

ATOMIC AND MOLECULAR PHYSICS

Fourier-transform spectroscopy of the Sr_2 $^1S+^1S$ asymptote

There is currently considerable interest in the study of ultra-cold strontium atoms and molecules, which may have significant applications for example in the use of strontium as a precise optical frequency standard. Recent advances in photo-association have allowed ultra-cold Sr_2 molecules to be prepared in highly excited vibrational states and two groups have succeeded in producing Bose-Einstein condensates of ^{84}Sr atoms. In all these experiments atomic interaction properties are fundamental to understanding these phenomena. We have been able to significantly improve our knowledge of the atomic long-range van der Waals interaction coefficients C_6, C_8 and C_{10} and to derive a complete description of the molecular ground state potential energy curve. Using this molecular potential description it is possible to improve the precision of scattering lengths for all naturally abundant atomic compositions.

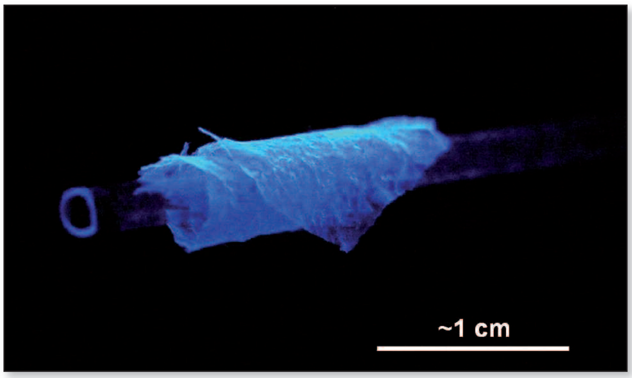
The results were determined by using laser excitation of deeply bound molecules and observing the subsequent fluorescence using a high resolution Fourier-transform spectrometer. Highly excited vibrational levels, up to v″=60, were observed, which have an outer turning point at an internuclear distance of 23Å 0.1cm^{-1} below the atomic asymptote. Such observations and the derived molecular potentials also prove that population transfer in the reverse direction is possible. Thus one can create ultra-cold Sr_2 molecules in the rovibrational ground state from the molecules in highly excited vibrational states by a two-photon process. The necessary transition frequencies can be directly calculated from the potential energy curves from the present work with a precision of better than 0.01 cm^{-1}. ■

A. Stein, **H. Knöckel** and **E. Tiemann**,
'The $^1S+^1S$ asymptote of Sr_2 studied by Fourier-transform Spectroscopy', *Eur. Phys. J. D* **57**, 171 (2010)

OPTICS

Free-standing 'plastic-like' photonic membrane

The development of light-emitting plastics has been an important new trend over the last 20 years. These soft-materials are based on the ever-growing family of carbon-based molecules with semiconducting properties. Advances in light amplification and lasing in such materials offer the vision of conformable, even disposable active photonic devices with cheap and simple mass production. Now researchers of the University of Strathclyde (Scotland) have devised a novel nanocomposite, which brings soft laser materials one step



▲ Membrane rolled around a glass pipette.

closer to applications. They used light-emitting 5nm-size Truxenes-core Oligomers (T_3) as active elements in a polymeric host matrix. Upon the addition of a 370-nm sensitive photo-acid generator, this original nanocomposite can be cured in the same fashion as a photoresist, while retaining the light-emission properties of T_3 in combination with the protective aspect against moisture and oxygen of the matrix. Substrate-based processes for the fabrication of flexible plastic films are readily realisable with this approach but a substrate-less method on water proves to also work due to the nanocomposite's wettability and specific gravity. The process involves the deposition and UV curing of the nanocomposite to form ~100-µm thick membrane that can be taken off the water surface and possibly applied to an object (see figure). The optical characteristics of the free-standing plastic membrane were assessed by exciting it with a 355-nm pulsed laser beam shaped as a stripe. The edge photoluminescence detected from the membrane has two regimes: normal spontaneous emission and stimulated emission when the pump energy density reached a given threshold (390µJ/cm^2): this is an indication that optical gain can be triggered within the membrane. In addition, no degradation of the light-emitting properties was noticed for energy densities up to 720µJ/cm^2. These characteristics should enable more advanced mechanically-flexible photonic devices. ■

B. Guilhabert, **N. Laurand**, **J. Herrnsdorf**, **Yujie Chen**, **A.R. Mackintosh**, **A.L. Kanibolotsky**, **E. Gu**, **P.J. Skabara**, **R.A. Pethrick** and **M. D. Dawson**,
'Amplified spontaneous emission in free-standing membranes incorporating star-shaped monodisperse π-conjugated truxene oligomers', *J. Opt.* **12**, 035503 (2010)

MATERIAL SCIENCE

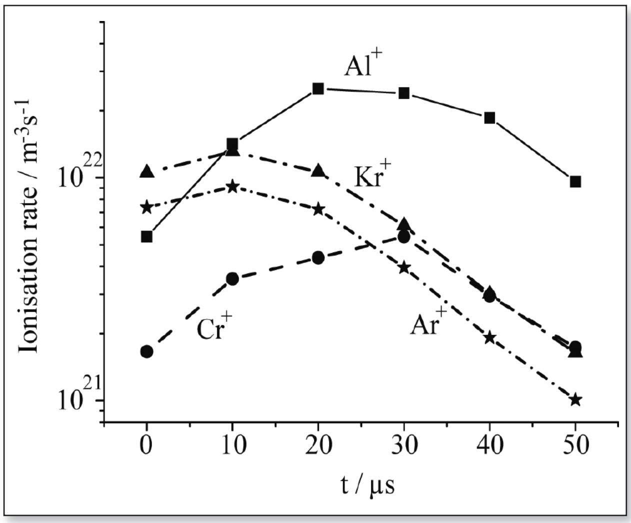
Understanding HPPMS PVD

High power pulse magnetron sputtering (HPPMS) is a modern and promising technology within the field of physical vapour deposition (PVD). Using high power pulses (peak power up to 1 MW), the HPPMS technology offers outstanding advantages regarding adhesion, hardness and density of thin films. Further, in contrast to common magnetron sputter ion plating (MSIP) techniques, complex-shaped tools can be coated with high thickness uniformity, especially on surfaces oriented non-parallel to the target. This effect is based on the high amount of ionised species, which can be affected by electric fields. Indeed, coatings deposited by HPPMS show outstanding properties, however, the fundamental processes during an HPPMS pulse are not explained, yet.

To understand these processes we measured the intensities of the spectral lines of chromium, aluminium, argon, krypton and molecular bands of nitrogen during a (Cr,Al,Si)N HPPMS coating process in an industrial coating unit using an absolute calibrated Echelle spectrometer (ESA-3000). Furthermore, we used the rotational distribution in the N_2(C–B,0–0) vibration band and the molecular nitrogen photoemission (N^+_2 (B–X)) to determine the gas temperature, electron density n_e and electron temperature kT_e. With these parameters, the ionization rates of Al, Cr, Ar and Kr atoms and the deposition densities of Al and Cr atoms are calculated. Using Doppler shift of the atomic lines in the emission spectrum the average velocity of sputtered atoms is measured. Using time resolved measurements we determined different parameters such as the internal plasma parameters n_e and kT_e, ionisation rates of Al, Cr, Ar and Kr atoms, sputtering and deposition densities with a time resolution of 20 μs. Thus, a maximum ionisation rate of 5×10^{22} $m^{-3}s^{-1}$ for Al^+ ions and deposition densities of 1.75×10^{20} $m^{-2}s^{-1}$ for chromium and 1.7×10^{22} $m^{-2}s^{-1}$ for aluminium are determined. These investigations show again the high potential of HPPMS and lighten up some fundamental processes during an HPPMS pulse. ■

S. Theiß, **N. Bibinov**, **N. Bagcivan**, **M. Ewering**, **P. Awakowicz** and **K. Bobzin**,
'Time resolved optical emission spectroscopy of an HPPMS coating process', *J. Phys. D: Appl. Phys.* **43**, 075205 (2010)

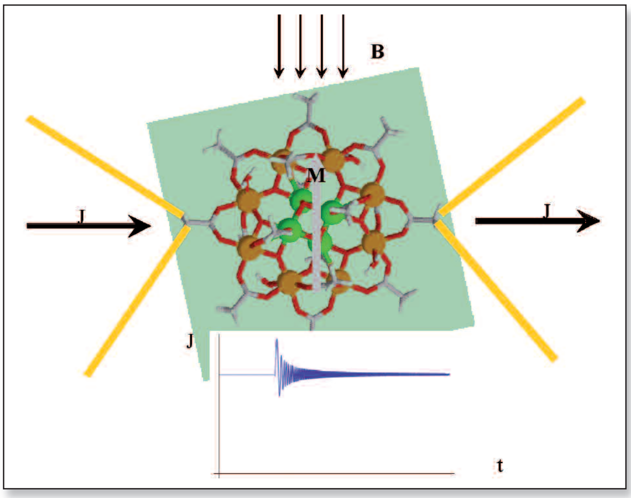
▼ **Ionisation rates during an HPPMS pulse in an Ar/Kr/N_2 mixture with AlSi(90:10)Cr20 target.**



MOLECULAR PHYSICS

Single magnetic molecule between conducting leads

A magnetic molecule is an ultimate limit of a nanomagnet that, one day, can become a computer memory unit. Such molecular nanomagnets also exhibit a field-controlled quantum tunneling of the magnetic moment. This effect adds magnetic molecules to the list of candidates for qubits - elements of quantum computers. Search for a fast electric control of magnetic states of a nanomagnet has inspired a number of experiments with a single magnetic molecule between conducting leads (Fig).



▲ **Quantum reversal of the magnetic moment of the molecule causes oscillation of the tunneling current through the molecule.**

Magnetic moment of a molecule is made by electron spins. The change of the spin angular momentum, due to, *e.g.*, the reversal of the magnetic moment, generates a mechanical torque. In macroscopic magnets this effect is known as Einstein - de Haas effect. Quantum mechanics makes it special: If one tries to reverse the magnetic moment of a molecule by the magnetic field, the probability of the reversal oscillates in time before the molecule settles with its magnetic moment along the direction of the field. This effect is known as Landau-Zener effect. The theory of Jaafar, Chudnovsky, and Garanin combines the Landau-Zener effect with the Einstein - de Haas effect. It shows that the oscillating expectation value of the magnetic moment makes the expectation value of the torque to oscillate as well. This leads to the wiggling of the molecule inside the electrical contact. As in a tunneling microscope capable of detecting very small displacements of individual atoms, the tunneling current through a molecular contact must be extremely sensitive to the orientation of the molecule. The current should, therefore, develop an ac component that follows quantum-mechanical oscillations of the molecule. This suggestion poses an interesting challenge to experimentalists. ■

R. Jaafar, **E.M. Chudnovsky** and **D.A. Garanin**,
'Single magnetic molecule between conducting leads: Effect of mechanical rotations', *EPL* **89**, 27001 (2010)

CONDENSED MATTER

No classical diamagnetism for **particles on a closed surface**

In thermal equilibrium, the Bohr-van Leeuwen theorem predicts null magnetic moment for a system of classical charged particles in an external time-independent magnetic field. To understand this surprising result physically, it is often pointed out that the boundary of a system plays a subtle role: The charged particles in the bulk undergo orbital motion which gives rise to a nonzero diamagnetic moment, but there is also a paramagnetic moment arising due to incomplete orbits of particles which bounce off the boundary in a cuspidal manner. This paramagnetic contribution exactly cancels the diamagnetic one so that the net magnetic moment vanishes. Recently, based on this intuitive picture and supported by numerical simulations, Kumar and Kumar concluded that there exists a nonzero classical diamagnetic moment for a particle moving on the surface of a sphere where, due to the absence of any boundary, no such cancellation occurs and hence the nonzero diamagnetic moment.

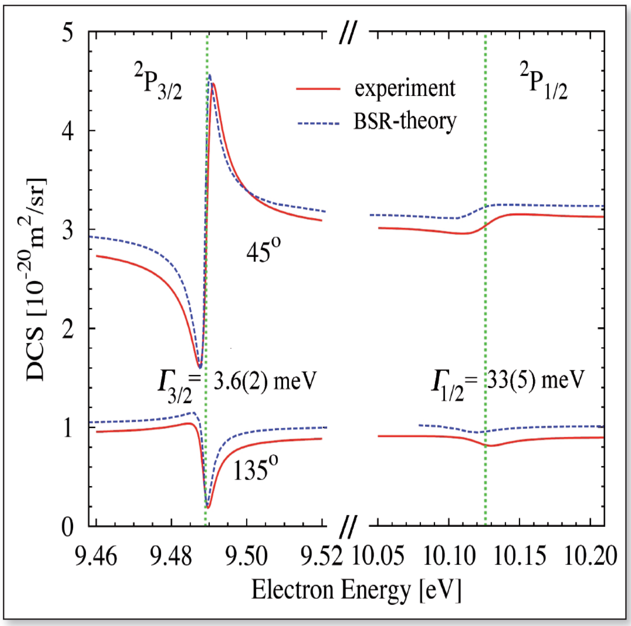
However we show analytically that, in the long time limit, a classical system consisting of particles moving on a closed curved surface is indeed described by the equilibrium (canonical or microcanonical) distribution, and therefore the average magnetic moment is zero. This demonstrates that the previously claimed role of the boundary for having a zero magnetic moment is a misleading one because the average magnetic moment, as argued by us, must vanish even for a finite boundary-less system which has been shown to have an equilibrium distribution. In principle, one can understand the reason for vanishing of the magnetic moment as following. In thermal equilibrium, the velocity distribution of a particle depends neither on the position nor the direction of the velocity. Therefore the corresponding magnetic moment, which is proportional to the average of the vector product between position and velocity, is zero. ■

P. Pradhan and **U. Seifert**,
'Nonexistence of classical diamagnetism and non-equilibrium fluctuation theorems for charged particles on a curved surface', *EPL* **89**, 37001 (2010)

ATOMIC PHYSICS

New light on the $Kr^-(4p^5 5s^2)$ **Feshbach resonances**

Low-energy electron scattering from atoms and molecules is dominated by anion resonances (temporary negative-ion states), which have a profound influence on elastic and inelastic collision processes, including electronic and vibrational excitation as well as anion formation through dissociative electron attachment. In the rare-gas atoms, the lowest-lying resonances are very narrow, with a typical energy width in the meV range. They are formed by attachment of the scattering electron to a core-excited level, yielding a spin-paired outer ns^2 shell around a core vacancy.



▲ **Differential cross section for elastic e–Kr scattering around the $Kr^-(4p^5 5s^2)^2P_{3/2,1/2}$ resonances. The line shapes, deduced from fits to the experimental data at scattering angles of 45° and 135°, are compared with predictions from a fully relativistic 31-state B-spline R-matrix (close-coupling) theory. The vertical lines indicate the positions of the resonances.**

Although unstable, these negative-ion states are rather immune to auto-detachment and thus long-lived. Progress in experimental and theoretical methodology has recently allowed for a detailed characterization of sharp resonance structure in both elastic and inelastic electron scattering from He, the heavy noble gases Ne–Xe, and N_2. Energy resolutions down to 4 meV were achieved in some cases and an angular range from 10° to 180° was covered with a high signal-to-noise ratio. The figure shows results for e–Kr scattering at energies in the vicinity of the $Kr^-(4p^5 5s^2)^2P_{3/2,1/2}$ Feshbach resonances. Very good agreement between the experimental and theoretical results for the angle-dependent resonance lineshapes and the absolute cross sections is observed. The width Γ of the $^2P_{1/2}$ resonance, which decays predominantly to the $(4p^5 5s)^3P_{2,1}$ excited states of Kr, is nearly ten times that of the $^2P_{3/2}$ resonance, which can only decay to the ground state. ■

T. H. Hoffmann, **M-W. Ruf**, **H. Hotop**, **O. Zatsarinny**, **K. Bartschat** and **M. Allan**,
'New light on the $Kr^-(4p^5 5s^2)$ Feshbach resonances: high-resolution electron scattering experiments and B-spline R-matrix calculations', *J. Phys. B: At. Mol. Opt. Phys.* **43** 085206 (2010)

MILUTIN MILANKOVIĆ

AND THE ASTRONOMICAL THEORY OF CLIMATE CHANGES

* **Zoran Knežević** * Astronomical Observatory, Belgrade * DOI: 10.1051/epn/2010301

Is human activity changing world climate to the point of no return? A global warming trend results from a superposition of human influence and natural causes, both short term and long term. Understanding the different processes and their time scales is therefore vital to make accurate predictions about the future climate.

▲The Milankovic Crater in the northern territory (the Arcadia Planitia). © K. Veenenbos

The idea that Earth's climate underwent severe changes in the geological past has become widely accepted only in the first half of the 19th century, due to the work of Playfair, Schimper, Venetz, Charpantier and many others, and somewhat later in particular of L. Agassiz [1]. They claimed that the moraines present in many alpine valleys, or the erratic granite blocks standing on the geologically unfitting bedrock are due to the fact that "the big ice-sheets like those seen at present-day Greenland once covered all the territories where such stones have been found". At the same time the expression "Die Eiszeit" was introduced in an ode written by K. Schimper. Even the famous German poet Johann Wolfgang von Goethe back in 1829 states: "to have a lot of ice a cold weather is needed, thus I presume that an epoch of great cold at least over Europe passed".

Still, there were many who opposed the idea of the Ice Ages, and the debate lasted for the entire century. At the very beginning of the 20th century A. Penck and E. Brückner [4] proposed that the glaciations took place four times in the Quaternary geological period, with three interglacial intervals of unequal duration in between. Although we now know that the climate changes were much more complex than this simple scheme predicts, the fact that the Ice Ages did take place in the past has been firmly established and not seriously disputed afterwards.

Different mechanisms have been considered to explain the changes of Earth's climate, including also astronomical ones. Soon after the publication of Agassiz' work, J. Adhémar [2] proposed that the precession of the Earth's axis of rotation is responsible for the Ice Ages. Although the simple mechanism he considered was soon rejected, Adhémar actually showed that the astronomical and geological phenomena can be related, and that the long term variations of the Earth's motion can possibly lead to climate changes.

The most remarkable early theory of the Ice Ages, which consistently combined the achievements of different sciences, was undoubtedly the theory by J. Croll [3]. Croll correctly interpreted the influence of the eccentricity of Earth's orbit upon the duration of the seasons and its coupling with the precession of the rotation axis. He was the first to consider the changing obliquity of the rotation axis, thus completing the list of relevant astronomical mechanisms causing climate changes. He also pioneered the idea of the feedback effect due to the reflectance of the incoming radiation from the surface covered by ice, and proposed that the eccentricity-driven amplification of the ocean currents augments the heat exchange between equatorial and polar regions.

Croll's theory at first attracted geologists, but it has soon been found that its results do not match the observations. As later explained by Milanković, the failure of Croll's theory is due mostly to the fact that the influence of the variable obliquity of the Earth's axis of rotation upon the insolation was not properly taken into account. Although his results were not correct, Croll was the one who laid the foundations of a comprehensive multidisciplinary approach to the climate change study, which eventually led to our contemporary understanding of these complex phenomena.

Following Croll, there were several attempts at improving his theory and results (Ball, Pilgrim, Hargreaves, Spitaler), but with not much success. The most important astronomical theories of the Ice Ages were therefore critically discussed by the great Austrian climatologist J. Hann , who concludes that the effects proposed as giving rise to climate changes are not strong enough, so that from the astronomical viewpoint one could rather expect that Earth's climate is more stable than variable.

This was the situation with the astronomical theory of climate changes when Milutin Milanković (Eng. Milankovich or Milankovitch, Ger. Milankovitsch) stepped onto the scene.

Milutin Milanković (1879-1958): biographical notes

▼ FIG. 1: Milutin Milanković. Photo from 1922.

Milutin Milanković was born on May 28, 1879 in Dalj, in the Austro-Hungarian Empire (nowadays Croatia). He was the eldest of the seven children of a Serbian family of local merchants and landlords. Being of sensitive health, he received his elementary education at home (in "the classroom without walls"), learning from his father Milan and from the private teachers, but also from numerous relatives and friends of the family, some of whom were renowned philosophers, inventors and poets. The secondary school he attends in nearby Osijek, completing it in 1896. The same year he enrolls in Civil Engineering in Vienna, and graduates in 1902 with the best marks. Only two years later he becomes the first Serb with a PhD degree in technical sciences. In a short, but amazingly successful engineering career he worked for a company specialized in reinforced concrete and built dams, bridges, aqueducts and factory halls throughout the Austro-Hungarian Empire and eastern Europe. How good he was in this work is best illustrated by a decision of his professors to apply Milanković's system in the reconstruction of one of the wings of the Vienna Technical High School itself.

It was his persistent wish to become a scientist which made Milanković take over the chair of applied mathematics at the University of Belgrade in 1909. He remained professor for the next 46 years, giving the last lesson to the students in celestial mechanics in 1955. He became a member of the Serbian Royal Academy (Serbian Academy of Sciences and Arts) in 1920, serving as its vice-president from 1948 until his death. For a brief period he served as Dean of the Faculty of Philosophy and later also as the Director of the Astronomical Observatory of Belgrade.

Soon after settling down in Belgrade Milanković learned about the problem of climate changes, to which he would devote most of his time and effort in the decades to come. He published the first paper on the subject as early as in 1912, and collected all he had done in his seminal "Kanon der Erdbestrahlung und seine Anwendung auf das Eiszeitenproblem" [7], completed in 1941. He was also the first to calculate the temperatures on the inner solar system planets; he developed a theory of secular motion of Earth's poles, worked on the reformation of the Julian calendar and occasionally on the theory of relativity. He authored several textbooks, a number of popular books on the history of science, as well as a comprehensive autobiography.

Milanković passed away on December 12, 1958, and is buried in the family vault in his native Dalj.

The Astronomical Theory of Climate Changes

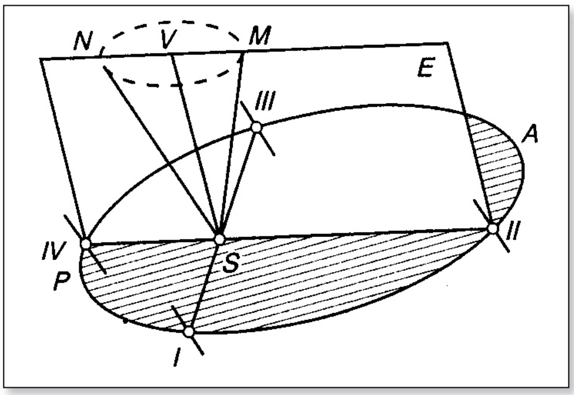
The orbital forcing of climate changes is based on the astronomical mechanisms giving rise to the changes of insolation (the amount of radiation received at the top of the atmosphere of the Earth), and on the physical mechanisms governing propagation of the received energy through the atmosphere and the response at the Earth's surface. We shall describe the astronomical mechanisms here, closely following Milanković's explanations as given in the "Kanon".

The astronomical mechanisms giving rise to the changes of insolation are three: the secular variations of the eccentricity of the Earth's orbit, the precession of the Earth's axis of rotation, and the variations of the obliquity of the rotation axis. A schematic representation of the three mechanisms is given in Figure 2. Here, S is the center of the Sun, SV is perpendicular to the Earth's elliptical orbit (the ecliptic), and SN parallel to the Earth's axis of rotation, perpendicular to the equatorial plane. The angle VSN represents the inclination of the axis of rotation or the obliquity of the ecliptic.

The eccentricity of Earth's orbit changes with time, due to perturbations by other planets. The changes are quasi-periodic, have different amplitudes, and take place on different time scales. For the problem of ice ages during the Quaternary the most important changes are those with periods of about 100,000 years (actually this is a set of terms due to interactions of terrestrial planets with Jupiter and to their mutual interactions) and of 405,000 years (an indirect effect due to interaction of Venus with Jupiter), modulated by a number of effects of shorter and longer periods [5]. The variation of the eccentricity affects the distance of the Earth from the Sun in the perihelion P, when the Earth is closest to the Sun, and in aphelion A, when it is farthest away (see Figure 2); this changes the amount of solar radiation received at the Earth, inversely proportional to the square of the distance. The eccentricity variation also affects the duration of the seasons, thus changing the average amount of daily insolation received at the Earth in the summer half and in the winter half of the year. The cardinal points I and III in Figure 2 denote the equinoxes, the beginning of the spring and autumn, while points II, and IV denote the northern hemisphere summer and winter solstices, respectively (opposite for the southern hemisphere). Since the eccentricity of the Earth's orbit changes in a narrow range, from essentially 0 to approximately 0.06, this only marginally affects the total amount of radiation received at the Earth, but rather more significantly the duration of the seasons.

The precession of Earth's axis of rotation was known already in the ancient times, but it was only I. Newton who showed that it is due to the non-spherical shape of the Earth. Our planet has an equatorial bulge, and the gravitational attraction from the Moon and the Sun causes a retrograde rotation of the axis so that the nodes of the equatorial plane, the equinoxes, move in the direction opposite to the daily rotation of the Earth. The axis describes the circular cone NSM, depicted in Figure 2. The corresponding plane E, which contains the axis and the solstices, moves clockwise around the axis SV, completing a full revolution in about 26,000 years (the Platonic year). Due to the perturbations from the planets, the major axis of Earth's orbital ellipse, connecting perihelion and aphelion, moves counterclockwise, towards the cardinal points. Therefore these points perform a full revolution (from perihelion to perihelion) in about 21,000 years. The position of the axis is given by the value of the longitude of perihelion with respect to the moving point of vernal equinox (in other words, the longitude of perihelion with respect to the moving vernal point is given by the sum of the longitude with respect to the fixed vernal point and the precession).

It is this motion of the axis that, coupled with the eccentricity, determines the length of the seasons and affects the climate. When, for a given eccentricity, the longitude of perihelion attains 90°, the lengths of the summer half-year on the northern hemisphere is very near its maximum, and that of the winter half-year near its minimum. The total amount of radiation received in the summer half of the year is being distributed over a longer time span and the average radiation per unit time drops to its minimum. The opposite happens in the winter half-year, with an increase in average radiation. This reduces the seasonal contrast on the northern hemisphere, favoring the formation of permanent ice. At the same time, the opposite happens at the southern hemisphere, where the seasonal contrast gets amplified, resulting in short warm summers during which all the ice formed during long cold winters actually melts. When the longitude reaches 270°, the same happens, but with the roles of the hemispheres exchanged. Now the seasonal contrast is at a minimum on the southern hemisphere, and at a maximum on the northern hemisphere. When the longitude is 0° or 180° the annual seasons are of equal duration, and both hemispheres stand on par.



◄ **FIG. 2:** Scheme to represent the astronomical mechanisms giving rise to climate changes (see text). From Milanković's "Kanon".

Perturbations by planets also change Earth's obliquity. Currently, the obliquity amounts to some 23.5°, which is close to its mean value over the period of about 41,000 years. The oscillations can be quite irregular from one cycle to another in terms of the maxima and minima, retaining however an amplitude within a narrow range of approximately ±1.3°. The obliquity also shows a steady, nearly linear increase over a very long time span, interrupted by a sharp drop close to the present, due to the passage through a secular resonance [5].

Although the changes in the obliquity are rather small, they give rise to significant climate variations. An increase of the tilt of Earth's axis increases the incident angle of the solar radiation at the poles, thus also increasing the amount of heat received at the surface and the resulting temperature. At the same time this causes very little change at the equator, thus reducing the geographical contrast of the insolation (note that at an obliquity of 54° the difference between polar and equatorial region would vanish entirely). On the other hand, an increase of the obliquity augments the seasonal contrast of the insolation, both contrasts being simultaneously reduced and accentuated on both hemispheres. Put together, the three astronomical mechanisms described above, with their coupled effects and complicated short and long term variations, give rise to changes in

Earth's insolation and thus in its climate. The three basic cycles of these changes of 21,000, 41,000, and 100,000 years are often called "Milanković's cycles".

A full account of the physical part of the theory of climate changes is outside the scope of this short review, thus we shall conclude with the final result of Milanković's work, his famous curve representing the secular variations of the summer insolation, shown in Figure 3.

Concluding remarks

Although Milanković did not discover the astronomical mechanisms described above, nor was the first to recognize their importance for the climate changes, he certainly was the first to fully comprehend and mathematically rigorously determine their place in the complicated interplay of various factors. Let us quote in this regard J. Laskar and his collaborators [5]: *"Since then, the understanding of the climate response to the orbital forcing has evolved, but all the necessary ingredients for the insolation computations were present in Milankovitch's work."*

Milanković was perhaps not the first to consider the insolation distribution or to suggest a particular choice of the indicative latitude or time of the year in which to compare the results, but he was the first to accurately compute the climate response to the insolation forcing. Nor may he have been the first to compute each individual step of the astronomical theory of climate changes, but he was the first to compute, in full detail and with necessary precision, all three steps: the astronomical parameters, the insolation and finally the climate response. It is therefore that he can be called the father of climate modeling.

Milanković's theory was the first of its kind that could be confronted with the evidence from other sciences and verified through independent research. He did, however, not live to see the theory proven. Although many data have already been collected in the 1950's, the real breakthrough came only after his death, in the mid 1970's, with the results of the CLIMAP project [6]. Since then a great number of data has been gathered confirming the role the orbital forcing in shaping of the climate of the Earth. This also brought a well deserved recognition to the pioneers of this scientific achievement and to Milutin Milanković in particular: craters on the Moon and Mars bear his name, as well as an asteroid (1605 Milankovitch). In addition, the European Geosciences Union established a Milutin Milanković Medal for outstanding achievements in long term changes and climate modeling. A big boulevard in Belgrade as well as several schools and astronomical societies throughout Serbia bear his name to preserve the memory of the great scientist with his people. ■

About the author

Zoran Knežević is a Serbian astronomer. His major scientific contributions are in the field of movement of small celestial bodies. As of 2002, he is the director of Astronomic Observatory of Belgrade and the president of Serbian National Astronomy Committee.

References

[1] L. Agassiz (1840), *Études sur les glaciers,* Neuchatel.

[2] J.A. Adhémar (1842), *Révolutions de la mer, déluges periodiques,* Paris: Bachelier.

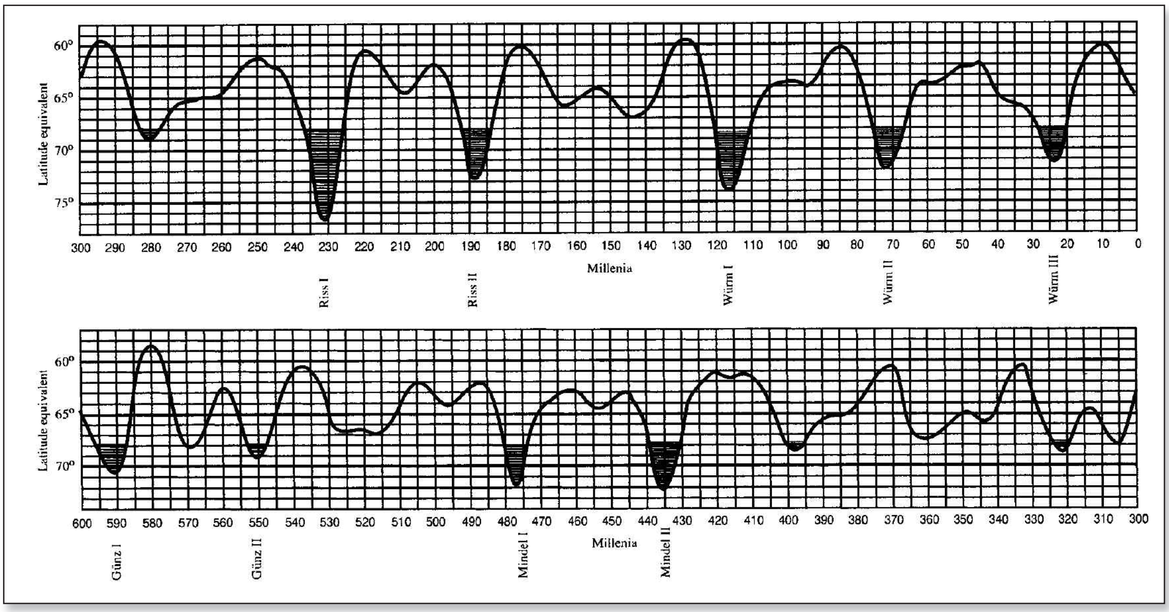
[3] J. Croll (1889). *Discussions on Climate and Cosmology.* London.

[4] A. Penck, E. Brückner (1901-1909). *Die Alpen Im Eiszeitalter.* (3 Vols.) Leipzig: Tauchnitz.

[5] J. Laskar, P. Robutel, F. Joutel, M. Gastineau, A.C.M. Correia and B. Levrard (2004), *Astronomy and Astrophysics* **428**, 261.

[6] J.D. Hays, J. Imbrie and N.J. Shackleton (1976), *Science* **194**, 1121.

[7] M. Milankovitch (1941), *R. Serb. Acad., Spec. Publ.*



▶ **FIG. 3:** The secular variations in summer insolation for 65° North over the past 600,000 years, given in terms of latitudinal variations. For example, some 10,000 years ago the insolation at 65° was the same as that at 60° nowadays, and the insolation around 230,000 years ago was the same as the present one at 77°.

© iStockPhoto

O. Morsch[1✣], D. Ciampini[1,2] and E. Arimondo[1,2*]

[1] CNR-INO, Largo Pontecorvo 3, 56127 Pisa, Italy

[2] CNISM UdR Pisa and Dipartimento di Fisica, Università di Pisa, Largo Pontecorvo 3, 56127 Pisa, Italy

✣E-mail: morsch@df.unipi.it, *E-mail: arimondo@df.unipi.it

DOI: 10.1051/epn/2010303

CONTROLLING ATOMIC MATTER WAVES BY SHAKING

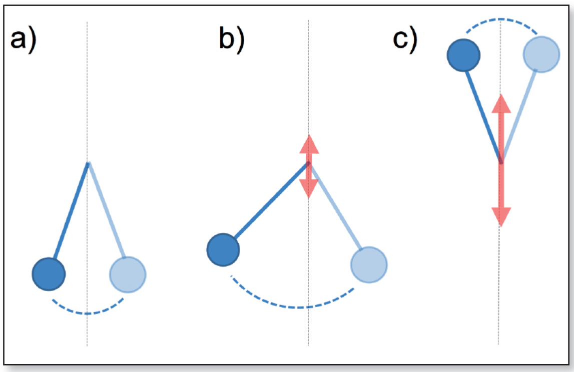
Quantum particles tunneling between the sites of a periodic lattice can be made to slow down, stop or turn around by shaking the lattice back and forth. This simple method suggests a new kind of quantum control and the creation of "dressed matter waves".

Apparently simple and well-understood physical systems can show surprising behaviour under certain circumstances, especially when they are strongly driven from outside. Take, for instance, a simple rigid pendulum. Its bob (the mass at its lower end) will swing back and forth sinusoidally if it is slightly displaced from its downward equilibrium position. If we now hold its pivot and shake it up and down, this simple swinging motion can be radically modified, and for some particular frequency and amplitude of the shaking the pendulum can even invert its equilibrium position and start oscillating with its bob above the pivot rather than below it [1] (see Figure 1). This surprising behaviour also carries over into the quantum world. In quantum physics, one of the key processes without an analogue in the classical world is tunneling. A quantum particle - an atom, for instance - trapped in a potential well can "tunnel" through a classically forbidden barrier into an adjacent well and back again (Figure 2(a)), giving rise to a to-and-fro motion reminiscent of a pendulum's swinging motion. If the wells are now shaken back and forth (or, alternatively, an oscillatory force is applied to the particle), the tunneling of the particle is modified: its amplitude can be reduced or even completely suppressed as shown in Figure 2(a) [2,3], and for certain parameters of the shaking the particle's quantum mechanical phase can be inverted in the process (which corresponds to the classical pendulum's swinging upside down). This principle can also be extended to a series of potential wells forming a periodic lattice structure. A particle trapped in one of the wells can be prevented from tunneling into neighbouring wells by an appropriate choice of the frequency and amplitude of the shaking (Figure 2(b)). This phenomenon, which was initially proposed as a method for controlling the propagation of excitons in insulating crystals [4], is known as "dynamical localization" [5].

Atoms in artificial crystals

Over the past two decades it has become possible to study the quantum dynamics of particles in periodic potentials using ultra-cold atoms trapped in laser-induced standing waves, so-called optical lattices [6,7]. Essentially, one starts with a gas of atoms at room temperature, cools them down to a few billionths of a degree above absolute zero (using a combination of laser cooling and evaporative cooling techniques) and then traps the atoms with crossed laser beams that create a "light crystal". In this way, it is possible to mimic the dynamics of electrons in crystal lattices, but with the added advantage that one has full control over the geometry of the lattice and can even "look inside" the crystal by simply switching off the laser beams that create it in the first place. Using these (and some other) tricks we were able directly to observe dynamical localization in the laboratory.

In our experiments we achieved a situation that closely resembles the idealized picture in Figure 2(b). After creating an extremely cold cloud of rubidium atoms (so cold, in fact, that – very simply speaking - they all occupied the lowest possible energy level of the laser trap, thus forming a Bose-Einstein condensate) we switched on a laser beam that was retro-reflected by a mirror, giving rise to a one-dimensional standing wave at the position of the rubidium atoms. This standing



▲ **FIG. 1: When a simple pendulum (a) is strongly driven by shaking its pivot up and down, its dynamics can be substantially modified (b) up to the point where the pendulum oscillates upside-down, with the bob above the pivot (c).**

wave, in turn, resulted in a dipole force on the atoms that varied periodically in space - an optical lattice. When we now switched off the laser trap that confined the cloud in the direction of the lattice, the atoms were free to tunnel into empty lattice sites to the left and to the right, causing the cloud to expand. For the laser powers used in our experiments (which determine the depth of the lattice wells and hence the tunneling probability) the cloud expanded to about four times its initial size in 200 milliseconds (see Figure 3). We then repeated the experiment with the same laser powers, but this time we shook the reflecting mirror (which was mounted on a piezo-electric transducer) back and forth. As a result, the cloud of atoms now expanded less in the same time [8]. Indeed, if the amplitude and frequency of the shaking were chosen appropriately, the expansion could be stopped completely!

Although this may come as a surprise - one might expect a strongly shaken quantum system to expand more rather than less - it is easy to write down the mathematical equations that explain this behaviour. In fact, the external driving can be absorbed into the theoretical description by using so-called Floquet states, which are ubiquitous in studies of classical and quantum systems with an explicit periodic time dependence [2,5]. For the case of particles tunneling between lattice sites this leads to an effective tunneling parameter J_{eff} given by

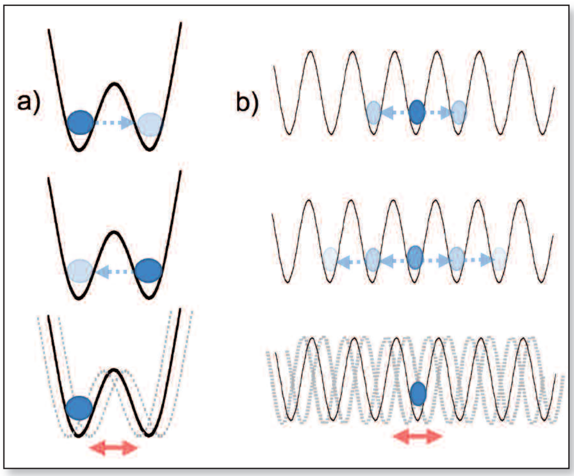
$$J_{eff} = J J_0(K_0).$$

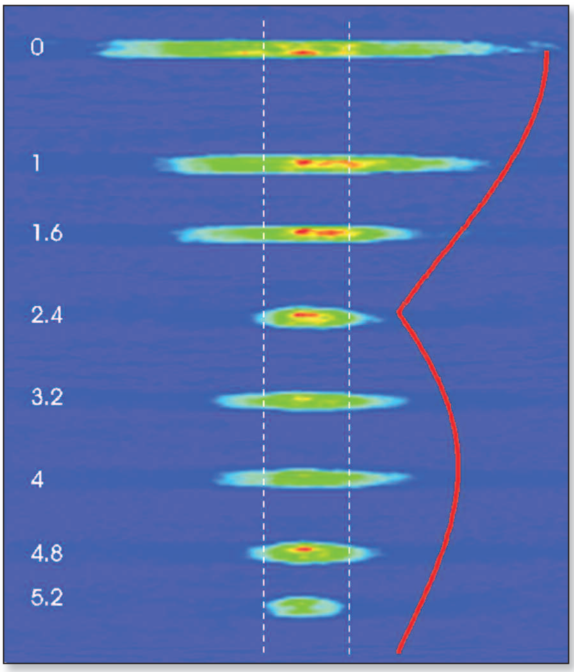
In this formula J is the "bare" tunneling parameter of the stationary lattice that characterizes how easily an atom can tunnel between sites. The bare J is multiplied by a zero-order Bessel function J_0 which has as its argument the shaking parameter K_0 (given by the ratio of the strength and frequency of the shaking). Since the Bessel function goes to zero for $K_0 = 2.4, 5.2....$, this formula predicts that at these values of the shaking the parameter, J_{eff} also goes to zero and tunneling is suppressed - which is exactly what we found in our experiments.

Swinging "upside down": the negative tunneling parameter

Another expected consequence of the above equation is the appearance of a negative effective tunneling parameter in the regions where the Bessel function becomes *negative*, *e.g.* between the first two zeroes at K_0=2.4 and K_0=5.2. As can be seen in Figure 3, in the expansion experiment the sign of J_{eff} does not seem to matter. That the extra minus sign in the effective tunneling parameter is actually there can, however, be demonstrated using a simple trick. This involves creating a matter-wave interference pattern very similar to an optical interference pattern in a multiple slit experiment. Rather than shining coherent light on an array of thin openings in a screen, one releases the atoms trapped in the optical lattice and allows their wave functions to spread out and overlap each other. After a short time (about 20 milliseconds in practice) one takes a snapshot of the atomic distribution which exhibits a pattern of bright and dark stripes, just as in the optical analogue (incidentally, a nice demonstration of the wave nature of atoms). If the atoms in all the lattice sites have the same phase, this interference pattern will have a dominant bright peak in the middle and smaller peaks at regular distances on either side of it (Figure 4(a)). In the case of a negative J_{eff}, however, the extra minus sign means that atoms in neighbouring lattice sites must have opposite phases (this is called a staggered state) as

▼ **FIG. 2: The tunneling of a quantum particle between two potential wells can be suppressed by shaking the wells back and forth (a). In the same way, a particle can be prevented from spreading inside a periodic potential (b).**





▲ **FIG. 3: Dynamical localization of Bose condensates tunneling inside a shaken optical lattice (in-situ absorption pictures). For particular values of the shaking strength K_0 (indicated on the left) tunneling is suppressed completely. The vertical white dashed lines indicate the width of the condensate at t=0, and the red line is the theoretical prediction (modulus of the zero-order Bessel function of K_0).**

shown in Figure 4(b). The result is that the interference pattern is shifted and now exhibits two equally bright peaks centred about the forward direction indicated by the arrow in Figure 4. This shifting of the interference pattern is a clear indication that we have, indeed, created the quantum equivalent of the inverted pendulum shown in Figure 1.

Taking all of the above together we conclude that by periodically shaking our optical lattices we can essentially tell the atoms what to do: move slowly, stop completely or "swing upside-down". A simple vibrating mirror in our setup, therefore, allows us to tune the tunneling dynamics of the atoms to our needs. This is an extension to matter waves of a concept that is well-known in atomic physics: the dressed atom [9]. In the dressed atom picture, the behaviour of an atom in a strong laser field is explained by "dressing" its quantum states with those of the laser photons. Similarly, we can call the quantum states that we produce by shaking optical lattices "dressed matter waves" [10].

Shaking atoms to order

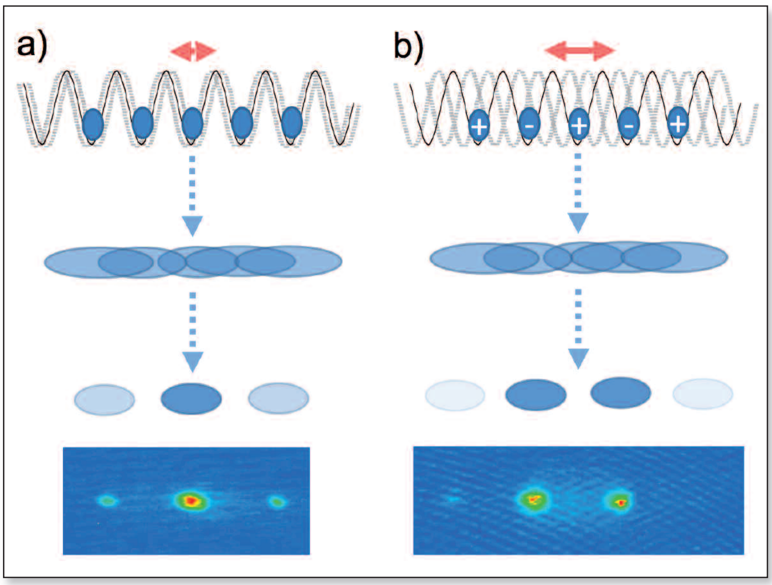
In order to demonstrate the usefulness of that picture, we performed an experiment in which we dressed the rubidium atoms in such a way as to make them undergo a quantum phase transition from a superfluid to a Mott insulating state and back. That phase transition was theoretically studied for bosons in crystal lattices in the 1980s [11] and experimentally realized with cold atoms in lattice in 2002 [12]. The idea behind it is that when particles in a crystal lattice are prevented from tunneling freely between the lattice sites, Heisenberg's uncertainty principle tells us that the increased knowledge of the position of an individual particle has to be compensated by a decrease in the knowledge of its quantum-mechanical phase. Ultimately, in the Mott insulating state all the particles are pinned down to a well-defined lattice site, and their relative phases must therefore be completely random. This also means that we can detect this phase transition by observing the interference pattern of the atoms: once the phases are randomized, the interference peaks in Figure 4 become blurred and indistinguishable.

It is straightforward to extend our methods described above to three-dimensions, and our setup for realizing the Mott insulating transition is shown in Figure 5. In order to induce the quantum phase transition all we had to do was to load our Bose condensates into shallow optical lattices in which the atoms could tunnel easily between sites. After that, we started shaking all three lattices more and more until the effective tunneling parameter was reduced sufficiently in order for the phase transition to occur. At that point, the peaks of the interference pattern became blurred as expected, but appeared again when we stopped shaking the lattices so that tunneling could resume [13].

Perspectives

Being able to tell quantum particles what to do simply by appropriately shaking them around suggests new applications in the quantum control of cold atoms. In ▮▮▮

▼ **FIG. 4: Atoms released from shaken optical lattices with a positive (a) and a negative tunneling parameter (b) produce distinctive interference patterns that contain information about the relative phases of atoms in adjacent wells. For the negative tunneling parameter in (b), a staggered state is created in which neighbouring wells have opposite phases. The pictures at the bottom were obtained experimentally by imaging the interfering atoms around 20 milliseconds after they had been released from the optical lattice.**



fact, the "dressed matter waves" thus created can exhibit properties that are hard to find in naturally occurring systems, such as the negative tunneling parameter mentioned above. In a triangular lattice, such a negative J_{eff} can, for instance, mimic frustrated spin systems [14] and also simulate other complicated Hamiltonians that are difficult to study in solid state materials. Also, the properties of the Floquet states that govern the dynamics of particles in strongly driven potentials are not fully understood yet. In particular, it is still an open question how Floquet states can adiabatically follow a parameter variation in the driving. These and other problems can now be experimentally studied with cold atoms in optical lattices. ■

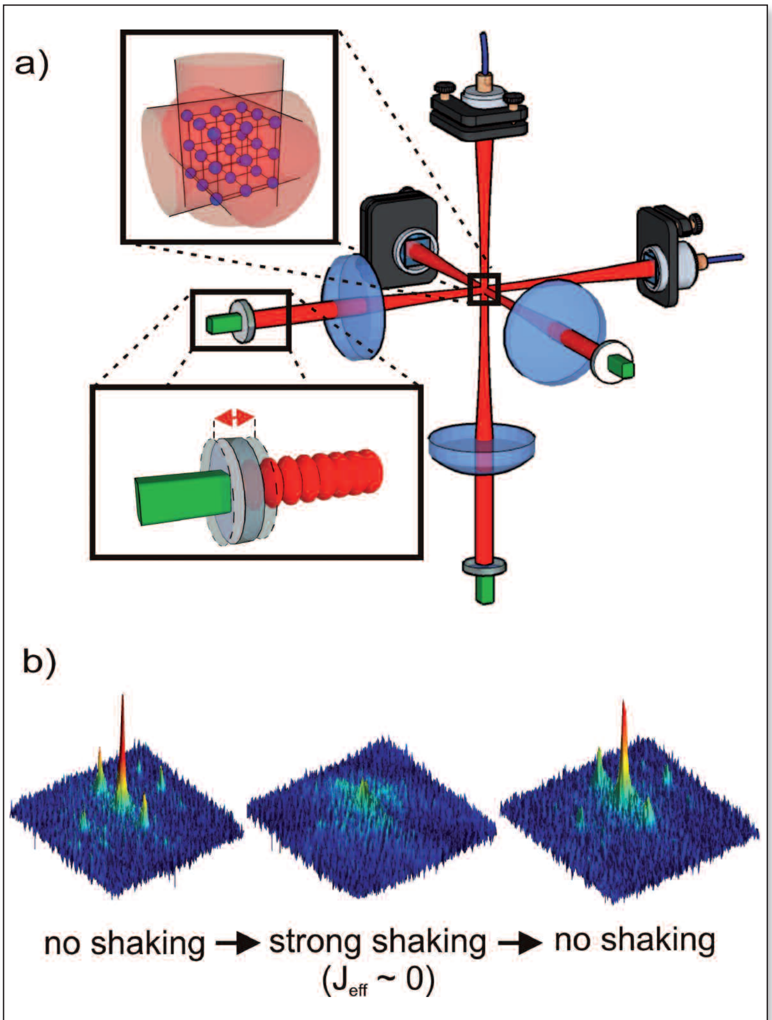
About the authors:

Oliver Morsch studied physics at Oxford University, where he received his B.A. in 1995 and completed his D.Phil. thesis in 1999. He then moved to Pisa, Italy, first as a Marie Curie Fellow and subsequently as Senior Researcher at the CNR (National Research Council). His research interests include Bose Einstein condensates, optical lattices and Rydberg atoms.

Donatella Ciampini is a researcher at the Faculty of Science of the University of Pisa, from which she received her Ph.D.in 2002. Her main research interests are in the field of light-matter interaction in Bose-Einstein condensates: ultra-cold collisions, photoionization and Rydberg atoms excitation, quantum transport in optical lattices, dynamical localization in periodically driven systems and dressed matter-waves.

Ennio Arimondo studied physics at the University of Pisa and the Scuola Normale Superiore in Pisa. Since 1980 full professor, first appointment at the University of Naples and later at the University of Pisa.

▼ **FIG. 5: Experimental setup for a three-dimensional shaken optical lattice (a). The bottom blow-up shows a retro-reflecting mirror mounted on a vibrating piezo-electric transducer that causes the standing wave to shake back and forth. In this setup the superfluid-to-Mott insulator transition can be induced by loading the atoms into a static lattice in which they can tunnel freely and then increasing the amplitude of the shaking until the effective tunneling parameter is sufficiently small. The phase transition shows up in an interference pattern as a vanishing of the clear interference peaks (b). By decreasing the shaking amplitude this transition can be reversed.**



More information about the research group can be found at: www.df.unipi.it/gruppi/arimondo/index.htm.

Acknowledgements:

The authors would like to thank the PhD students and post-docs participating in the experiments described in this article: H. Lignier, C. Sias, A. Zenesini, Y. Singh and J. Radogostowicz. We acknowledge funding by the MIUR (PRIN-2007), OLAQUI (EC FP6-511057), and NAMEQUAM (EC FP7-225187).

References

[1] E.I. Butikov, *Am. J. Phys* **69**, 755 (2001).

[2] F. Grossmann, T. Dittrich, P. Jung, and P. Hänggi, *Phys. Rev. Lett.* **67**, 516 (1991).

[3] E. Kierig, U. Schnorrberger, A. Schietinger, J. Tomkovic, and M.K. Oberthaler, *Phys. Rev. Lett.* **100**, 190405 (2008).

[4] R.E. Merrifield, *J. Chem. Phys.* **28**, 647 (1958).

[5] D.H. Dunlap and V.M. Kenkre, *Phys. Rev. B* **34**, 3625 (1986).

[6] O. Morsch and M. Oberthaler, *Rev. Mod. Phys.* **78**, 179 (2006).

[7] I. Bloch, J. Dalibard, and W. Zwerger, *Rev. Mod. Phys.* **80**, 885 (2008).

[8] H. Lignier, C. Sias, D. Ciampini, Y. Singh, A. Zenesini, O. Morsch, and E. Arimondo, *Phys. Rev. Lett.* **99**, 220403 (2007).

[9] C. Cohen-Tannoudji, *Cargèse Lectures in Physics*, (ed. M. Lévy) Vol. 2, 347 (Gordon and Breach, 1968).

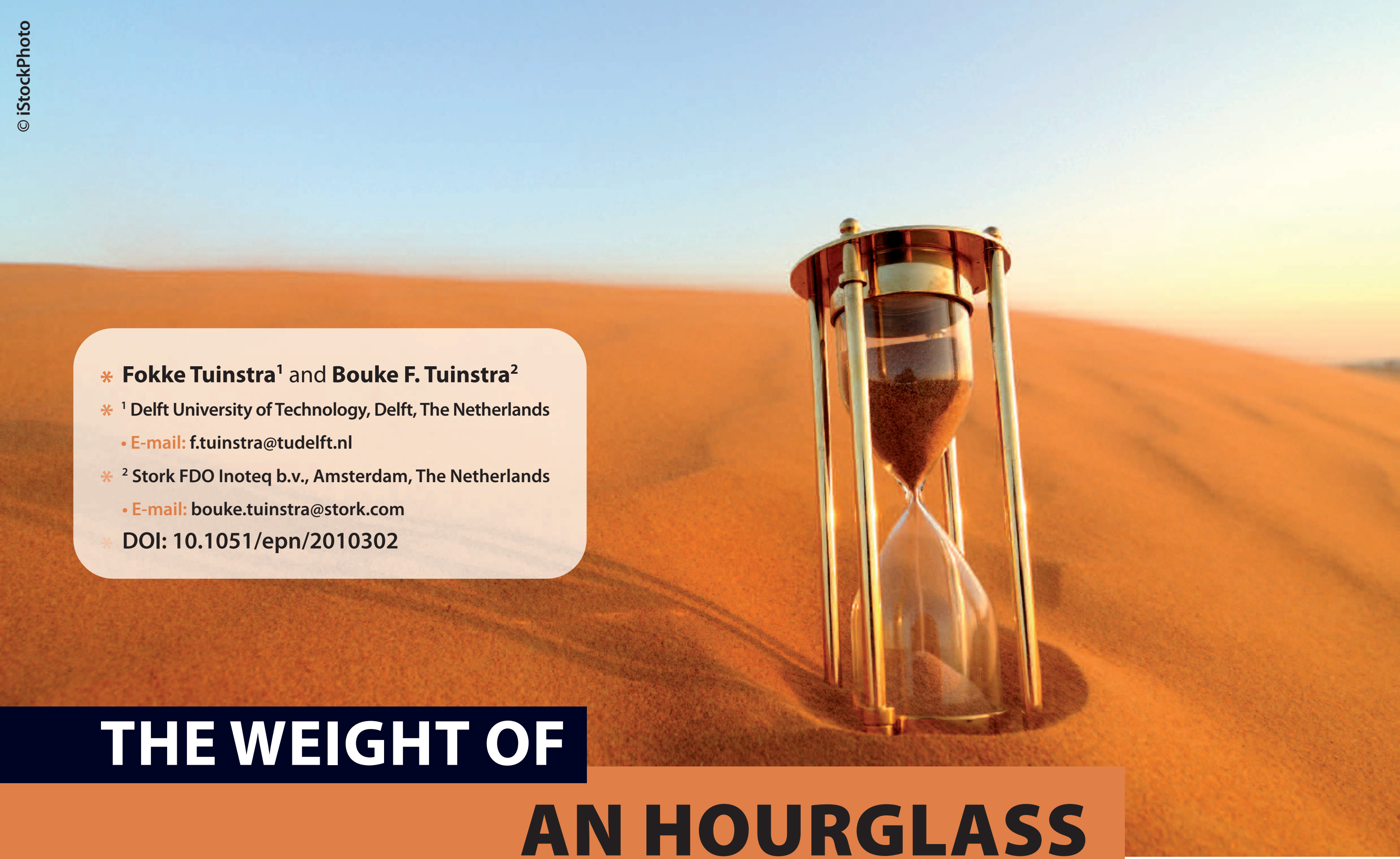
[10] A. Eckardt, C. Weiss, and M. Holthaus, *Phys. Rev. Lett.* **95**, 260404 (2005).

[11] M.P.A. Fisher, P.B. Weichman, G. Grinstein, and D.S. Fisher, *Phys. Rev. B* **40**, 546 (1989).

[12] M. Greiner, O. Mandel, T. Esslinger, T.W. Hänsch, and I. Bloch, *Nature* **415**, 39 (2002).

[13] A. Zenesini, H. Lignier, D. Ciampini, O. Morsch, and E. Arimondo, *Phys. Rev. Lett.* **102**, 100403 (2009).

[14] A. Eckardt, P. Hauke, P. Soltan-Panahi, C. Becker, K. Sengstock, and M. Lewenstein, *Europhys. Letters* **89**, 10010 (2010).



Fokke Tuinstra[1] and **Bouke F. Tuinstra**[2]

[1] Delft University of Technology, Delft, The Netherlands

• E-mail: f.tuinstra@tudelft.nl

[2] Stork FDO Inoteq b.v., Amsterdam, The Netherlands

• E-mail: bouke.tuinstra@stork.com

DOI: 10.1051/epn/2010302

THE WEIGHT OF AN HOURGLASS

It is a favourite question in science quizzes: Does an hourglass in operation weigh less or more than in the static state? The 'airborne' part of the sand makes it lighter, and the impact of the sand hitting the bottom makes it heavier. The classical question is: "Do they compensate?" But it is more interesting than that, as a thorough scientific approach will show.

A special feature of an hourglass – or egg timer – is that the mass flow $\dot{m}$[kg/s] of sand through the narrow orifice is fairly independent of the sand level. This is caused by the granular nature of the sand. The flow m is present in the free-falling stream of sand but also in the slowly moving dense mass in the upper compartment. If the free-fall time of the sand is τ, the weight of the free-falling mass is $g.(\dot{m}\tau)$. When hitting the surface in the lower compartment, it exerts a momentum per second, *i.e.*, a downward force $(g\tau)$ on the surface. This force exactly compensates the missing weight of the sand that is in free fall. This was the beautiful argument to conclude that the weight should stay the same. However, in 1985 Shen and Scott [1] showed that the centre of mass (c.o.m.) of the sand is not moving down at constant speed, but is *decelerating* during the steady operation of an hourglass. That causes a subtle gain of its weight on a balance. With an ingeniously constructed hourglass they even managed to confirm the presence of excess weight. However, with their set-up it was not possible to measure the effect in a quantitative way.

We have designed a multiple-orifice set-up that can be used for quantitative measurements using state-of-the art laboratory weighing equipment. We will show that the theoretical result can be confirmed by measurements. Furthermore, we will present a more thorough analysis of the motion of sand in an hourglass that allows us to understand the mechanism behind the increase in weight.

Hundreds of holes

The set-up we used is shown in figure 1. It allows us to accurately measure the weight increase, even with a standard balance. The hourglass has two special features.

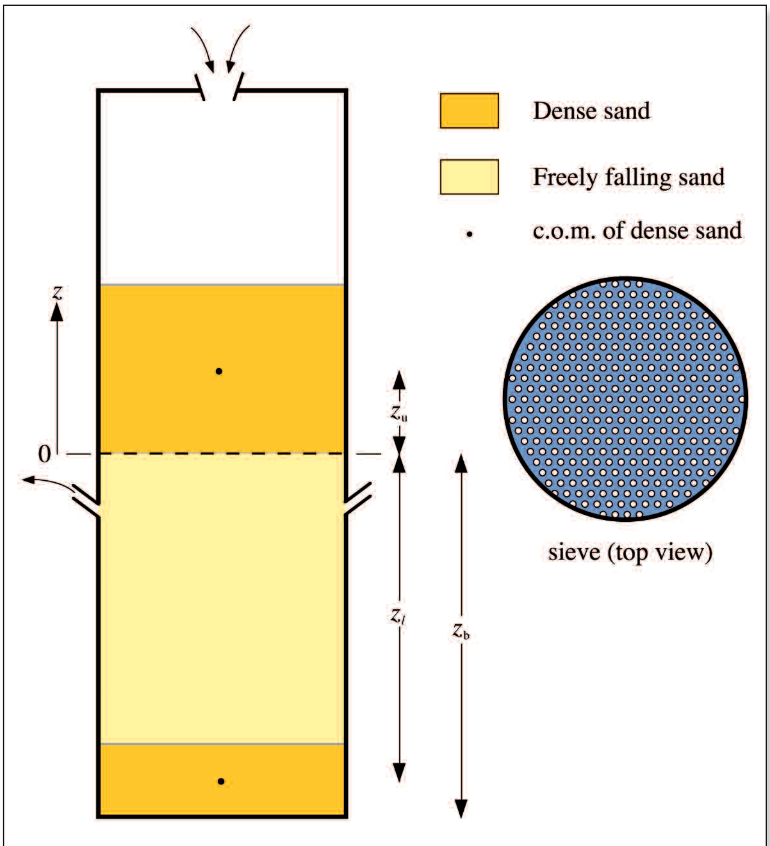
a. The upper and lower compartments have an identical cylindrical shape. This has the advantage that the weight effect to be measured is constant during the discharge of the hourglass.

b. The single orifice in a standard hourglass has been replaced by a plate containing a few hundred identical holes, which we will call the sieve. This suppresses the noise and increases the mass flow which amplifies the effect we are looking for.

In the approach of Shen and Scott [1] the deceleration of the centre of mass of the sand is presented in a general, though complex, formula. For the cylindrical shape the calculation is reduced to an elementary exercise in statics. The z-coordinate of the c.o.m. of all of the sand in the hourglass is found to be:

$$z_{com} = \frac{1}{M}[z_u.m_u + z_l.m_l]$$

where M is the total mass and the indices *u* and *l* stand for upper and lower, respectively. The mass that is in free-fall does not show up here. The argument from the introduction tells us that its contribution can be considered to be accounted for in m_l (= M - m_u).



▲ **FIG. 1: Design of the cylindrical multiple hourglass. The initial height of the sand column in the upper compartment is L (*i.e.*, z = L). The top level is descending at a constant speed of L/T. T is the time at which z = 0. The sand level in the lower compartment is rising at the same speed. The total sand mass is M. The sand levels in both compartments stay horizontal and flat. z_b is the height of the lower compartment. The positions of the c.o.m. of all of the sand in the upper and lower compartment are given by z_u and z_l respectively. The operation is started by removing an aluminium sheet which initially is located directly underneath the sieve. Both compartments are vented.**

Since z_u, z_l, m_u and m_l all change linearly with time, their products appearing in z_{com} change quadratically. Therefore, the second time derivative of z_{com} is not zero but independent of the time t and one finds a constant downward force:

$$F = \frac{2M.L}{T^2} \quad (1)$$

The cylindrical form is not the crucial step that makes a quantitative experiment possible, but it is, first of all, the large number of holes. When a standard hourglass is placed on a balance, it will be quickly observed that during operation its weight is far from steady. There are several sources for excessive noise. The most conspicuous source is formed by the uncontrolled avalanches occurring on the conical slopes in both the upper and the lower compartment. A second source of instabilities is the fluctuating gas pressure difference across the orifice. This temporarily blocks the orifice by stabilizing arches of sand. When enough gas has seeped upward to equalise the pressure, the formed domes will collapse. [2,3,4]. These domes of sand continuously form and break down. This can even cause periodic oscillations in the flow [4]. Both effects are avoided in the design used here.

The experiment

The hourglass consisted of two polycarbonate cylinders, each having a diameter of 8 cm and a length of 20 cm. They were cut out of soda bottles. Mounted on top of each other they were separated by a flat plate as shown in figure 1. In this plate, 230 holes with a diameter of 2.0 mm were drilled (the 'sieve'). Initially, the holes are blocked by an aluminium plate. Ordinary silver sand from a garden centre was used to fill the hourglass. Large grains were removed by sieving them out. The maximum diameter of the grains was 0.2 mm, so the expected flow is well within the granular flow regime [3]. After filling the upper compartment with one litre of sand (≈1.6 kg) the setup was mounted on a balance which could weigh up to 2 kg with an accuracy of 0.01 gram (10^{-4} N). To start the measurement, the aluminium plate is removed manually.

We first determined the sand flux through the sieve, collecting the sand during a discharge of the upper compartment. The sand flow was $\dot{m}=(M/T)=67.8\pm 0.8$ g/s and constant as expected (see figure 2).

We also determined the constant speed v of the descending top level of the sand: v=(L/T)=0.84±0.06 cm/s. According to formula (1) the extra force should then be $2\dot{m}.v=1.14\pm0.10\times10^{-3}$N, (equivalent to 0.116±0.010 gram). During the discharge of the hourglass the balance showed an excess reading of 0.121±0.006 gram, which is in excellent agreement with what we would expect. (see figure 3).

At the end of the discharge a hump is observed. It is due to the last bit of sand in free fall. Its presence and actual size will be discussed in the next section. After the discharge we observed that some very fine sand dust had settled around the setup, apparently escaped through the ventilation openings. This may be the reason of the slightly negative slope during the discharge.

The resulting additional weight is a rather small fraction of the weight of the total sand mass M.

For a classroom demonstration a more substantial effect would be more convincing. This may be achieved by broaching the holes. An extension of the diameter of the orifices from 2 mm to 3 mm would, according to the theory and experiment [2,5], shorten T by a factor $(1.5)^{-2.5} = 0.36$, thus increasing the excess weight to about 10^{-2} N (or 1 gram of mass). So a much less delicate balance could be used. The reduction of time T to 7 s would still allow an accurate weight measurement.

Taming the free fall

The calculation of the motion of the c.o.m to arrive at equation (1) leads us to the correct answer but fails to give us any insight in the underlying physics. We therefore prefer to follow the changing momentum of the sand and look at the corresponding force diagram.

Imagine in our experiment we forgot to insert the sieve. On removing the aluminium sheet, the whole sand mass M would drop down at once. The balance would have a rough ride, its static reading would be disturbed by a sudden oscillation, as sketched in figure 4. The momentum starting at zero will return to zero at the end of the process. For the force diagram, being the time derivative of the momentum, this implies that the surface area of the negative part and the positive part of the oscillation should be the same.

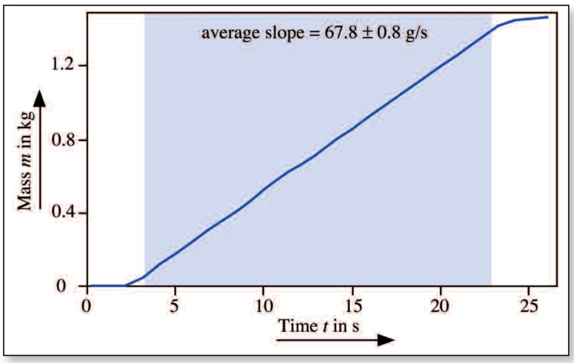
In the actual hourglass, the sieve is an *obstruction* which impedes the free fall into a slow controlled motion.

Above the sieve a dense sand mass is slowly moving downward at constant speed, below it a small fraction of the mass is speeding up in free fall. The orifice is, metaphorically speaking, causing a traffic jam. As on a motorway, after slowly having passed the site of the accident, the traffic density decreases dramatically as it is speeding up. The cause is simple: in a stationary situation, the number of cars per second passing any site along the road will be the same. The higher the speed the lower the density. The same applies to any stationary single flow of matter, like the sand in the hourglass. Along the stream the mass per length unit ρ'[kg/m] is inversely proportional to the speed v. The momentum per unit length ρ'v is constant. It is equal to the fixed flux $\dot{m}$, which is limited by the obstruction. The total momentum of such a stream thus is $\dot{m}$ times its length, whatever changes in the cross section or speed may occur. If the top levels in both compartments in the hourglass are flat, the momentum of the moving sand is $\dot{m}$ times the distance between these levels. And the force is the rate of change of that distance. The rough free-fall has been tamed by the obstruction and controlled by the constant flux $\dot{m}$ it allows to pass.

If we take the orifice - or in our case the sieve - as the reference height, and call the distance from the orifice the upper and lower levels L_u and L_l respectively, the total momentum is $p=\dot{m}(L_u+L_l)$, rendering a force

$$F = -\dot{m}\left(\frac{dL_u}{dt} + \frac{dL_l}{dt}\right). \qquad (2)$$

Apparently the only terms that matter are the speeds of the moving lower and upper sand levels. Watching a discharging hourglass we note that absolute rest exists below the lower level and above the upper one and in addition in between both levels an absolute stationary



◄ **FIG. 2:** Mass of sand collected during discharge of the top compartment through the sieve into a free-standing bowl.

state is observed. So indeed the only physical changes in the overall state are the positions of the sand levels L_u and L_l.

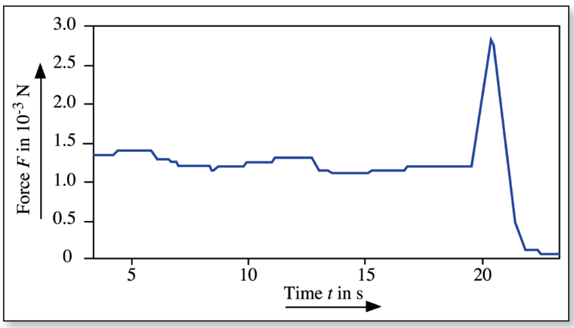
It is the change of these levels themselves giving rise to a loss of momentum per second. In our cylindrical set-up both rates are equal to L/T and since $\dot{m}$=M/T, we obtain formula (1).

Figure 5 shows the momenta and the corresponding forces as a function of time. The momenta of both terms are tapering off linearly from ML/T to zero at time T. The resulting force is constant.

Compared with figure 4, the narrow positive *crash* peak is now smeared out over time T, which is orders of magnitude larger than the duration of the crash.

What happened to the initial dip?

Before and after the discharge, all of the sand is at rest. The blue momentum curve should drop from zero at t = 0 to the value - 2L×$\dot{m}$. The drop cannot be instantaneous. The length of the sand stream that acquires momentum is increasing during a short period τ, ending when the cascade hits the floor of the lower compartment. It causes a very short but strong dip in the force diagram. As in the force diagram of figure 4, the surface area of this dip must be equal to the positive part of the diagram, though it is compressed to a pulse. In our experiment this pulse is completely swamped by the forces needed to remove the aluminium sheet. For this reason we had to discard the first few seconds in figure 3. As a result, the throughput time T can not be determined with acceptable accuracy. Figure 5 does not predict the hump at the end observed in the experiment (fig.3). In the ideal setup, the lower compartment should be filled precisely up to the sieve ▮▮▮



◄ **FIG. 3:** Results of an experiment with the multiple hourglass: the additional force exerted by the running hourglass on the balance.

when the upper compartment gets empty at $t = T$. In practice this is hard to achieve. A small gap ΔL between the final sand level and the sieve is unavoidable. In our experiments the gap was smaller than 1 cm. The last bit of sand falling as the upper compartment is empty reduces the length of the sand stream suddenly with the speed of fall. For $\Delta L < 1$ cm, this would result in a surface area of a hump to be less than $\Delta L\dot{m} \approx 0.007$Ns. The area observed in fig 3 is of the order of 0.004 Ns, suggesting that the gap effectively is about half a centimeter wide.

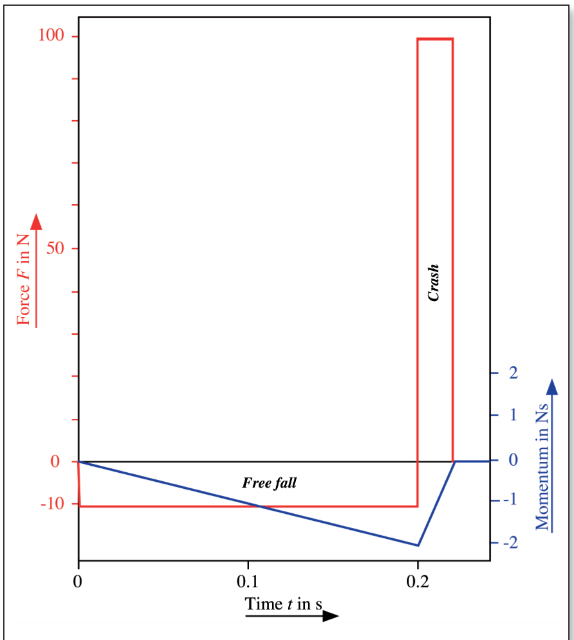
Formula (1) is not exact because of the starting pulse and the hump at the end. Both these effects, however, take times in the order of only a few tenths of a second; negligible compared with T, which is more than 10 seconds.

Physics of the flowing sand

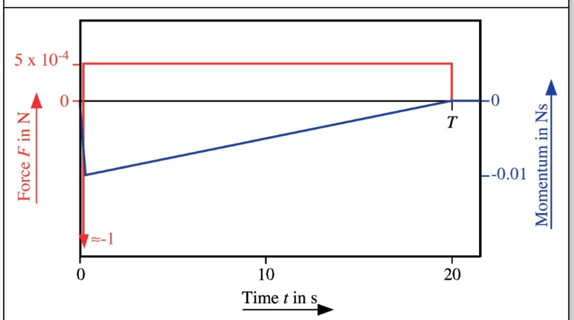
The only active region in an hourglass lies between the sand levels in the two compartments. The rest of the sand is dead weight. The amount of sand in motion is constantly decreasing as follows from the continuously decreasing distance between the two sand levels. At the lower level a mass $\dot{m}$ per second is transferred from the moving mass to the dead weight. So that is the place where the momentum is annihilated and consequently that is the place where the extra force is exerted.

The eye-catching tiny cascade in an hourglass seems not to contribute to the extra weight. Why don't we see any effect of it in the theoretical results, where only the speed of the two sand levels seems to matter? Doesn't the speed of the falling sand in the cascade contribute to the momentum? It sure does, but in exactly the same way as the slow moving sand in the upper compartment. At any place along the flowing sand, the contribution to the momentum is exactly $\dot{m}$ per meter. The role of the cascade is not different from the slow moving compact sand above the sieve. This corresponds to the idea put forward in the introduction that the impact of freely falling sand compensates for its weightlessness. We now see that this cannot be exactly true. The reason is that the free falling sand enters the cascade at a finite speed while at the same time the surface of the lower compartment rises with a finite speed to meet it at the lower end.

In the old days it was a miraculous practice of some milkmen to pour milk from a jug at an appreciable height into a pot on a balance. If they stopped pouring exactly at the moment that the pointer on the scale reached the one kilogram mark, the final content collected in the pot was exactly one kg (that is, one liter), regardless of the height they were pouring from. We now understand that this is only approximately true, but it certainly was good practice in the dairy business. ■



▶ **FIG. 4:** Sketch of the change of momentum (blue) and force (red) as a function of the time during the free fall of 1 kg sand over a distance of 0.2 m in a closed container. Since the momentum returns to its original value, the time integral of the force is zero.



▶ **FIG. 5:** Momentum and force as a function of the time during the discharge of a cylindrical multiple hourglass loaded with M = 1 kg sand, a discharge time of T = 20 s and a height of the compartments L of 0.2 m.

About the authors

Fokke and **Bouke Tuinstra** (father and son) both received their PhD at Delft University of Technology. **Fokke** is professor emeritus of the TU-Delft where he taught solid-state and general physics. His research comprises the molecular structure of sulphur, Raman spectroscopy of graphite, incommensurate crystals and surface phenomena.

Bouke is a chemical engineer working in product and technology development in the field of energy conversion. His primary scientific interests are in modeling of materials and processes involving the transport of heat and matter.

Acknowledgement

We would like to thank J.M.H.M. van Veen for his assistance with the measurements.

References

[1] K.Y. Shen and B.L. Scott (1985), *Am. J. Phys.* **53**, 787.

[2] R.M. Nedderman, *Statics and Kinematics of Granular Materials*, Cambridge University Press, Cambridge (1992).

[3] X. Wu, K.J. Måløy, A. Hansen, M Ammi and D. Bideau (1993), *Phys. Rev. Lett.* **71**, 1363.

[4] B.K. Muite, M.L. Hunt and G.G. Joseph (2004), *Phys. of Fluids* **9**, 3415.

[5] J. Flores, G. Solovey & S. Gil (2003), *Am. J. Phys* **71**, 715.

[6] V. Becker and T. Pörschel (2008), *Granular Matter* **10**, 231.

© iStockPhoto

PHYSICS IN DAILY LIFE: BRAVE DUCKS

* L.J.F. (Jo) Hermans * Leiden University, The Netherlands * Hermans@Physics.LeidenUniv.nl * DOI: 10.1051/epn/2010304

Remember how hard it was to first break the sound barrier? It took several fatal attempts by brave pilots before Charles ('Chuck') Yeager finally managed to fly faster than the speed of sound on the 14th of October, 1947. The problem was: by the time an aircraft approaches the speed of sound, the sound wave crests pile up in front of the plane. It then has to push through this barrier of compressed air in order to go faster than the waves. Once it is faster than the sound waves, an interesting situation occurs, quite similar to the case of a bullet moving at supersonic speed. The wave fronts produced have an enveloping circular cone, the 'Mach cone'. It is easy to see that the half apex angle of the cone, θ, is related to the speed of sound c and the speed of the plane ν by $\sin\theta = c/v$. Since there are no sound waves outside the Mach cone, the plane will pass us before we actually hear its sound.

Sound waves bear many analogies to water waves. Look at a duck, for example, speeding through a deep pond. See the V-shaped pattern of waves trailing the swimming duck? Doesn't it look like he is fighting the 'wave barrier' of water in front of him and producing a two-dimensional version of the Mach cone? Brave duck!

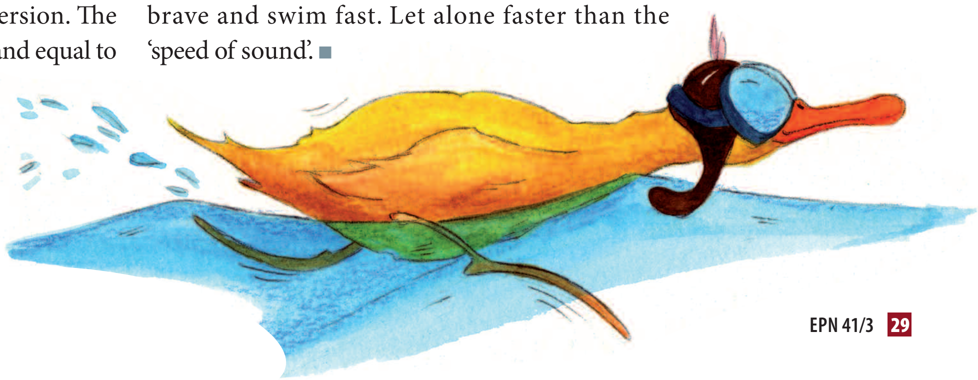
This certainly is an appealing thought. But it's wrong. What we may perceive as a 2-D version of a 'Mach cone' actually consists of two envelopes of a feathered pattern of dispersive waves.

Despite the analogies between water waves and sound waves, there are a few essential differences. Sound waves in air travel at a fixed speed without dispersion. The phase velocity c is equal for all wavelengths and equal to the group velocity. For supersonic flight this leads to the simple expression for the 'Mach angle' given above.

Water waves are much more complicated. They travel at the interface of two media, and are governed by gravity. Let us look at the deep-water limit, which is a good approximation for the duck as well as for ships on the ocean. Unlike sound waves in air, the phase velocity of the waves V depends on the wavelength, with long waves traveling faster than short waves. They follow the dispersion law $V = \sqrt{(g/k)}$ where g is the acceleration of gravity and k the wave number $2\pi/\lambda$. In other words, the speed of the waves is proportional to the square root of their wave length. At any speed of the duck or the ship, there will be waves running along with the same speed, whereas in the supersonic-flight case all waves are overtaken by the plane.

The complicated behaviour of the waves behind a duck or a ship in deep water was first worked out by Lord Kelvin (William Thomson), and is often referred to as 'Kelvin wake pattern' or 'Kelvin ship waves'. Kelvin was the first to find that, indeed, the wave pattern is bounded at either side by a straight line at an angle of 19,5 degrees with respect to the direction of the ship. This sounds like an awkward angle, resulting from a rather lengthy derivation. The angle may sound less awkward if we write it down in its precise form, as arcsin (1/3). In turn, the 1/3 results from the fact that the phase velocity given above is twice the group velocity. But the important thing is: this odd angle is fixed and characteristic for this type of wave. It has nothing to do with speed.

Too bad for the duck: In order to produce the V-shaped Kelvin wave pattern, he doesn't have to be brave and swim fast. Let alone faster than the 'speed of sound'. ■



"Spend time in the past above the town" –

An exhibition of old scientific instruments in the water tower of Szeged (Hungary)

The Roland Eötvös Physical Society and the University of Szeged had the unique opportunity in 2006 to create a museum in a renovated water tower to exhibit a collection of old, classical experimental instruments donated by the secondary schools and the University of Szeged. The scientific instruments and tools dating from the end of the 19th and early 20th centuries are used as part of an educational programme or public outreach on contemporary physics.

▼ **FIG. 1: The first water tower made of reinforced concrete in Hungary (Photo:Otto Becker).**

The water tower is an industrial historical building that determines the appearance of Szeged (Fig. 1), a town located in the south-eastern part of Hungary on both banks of the river Tisza, close to the borders with Serbia and Romania. It is the first water tower constructed from reinforced concrete in the country. It was built in a secessionist style between 1903 and 1904 according to the plans of Dr. Zielinszki Szilárd (1860-1924) who was the first Hungarian doctor of technical sciences. The water tower with a capacity of 1,000 m^3 is still in use today. It has been full restored between 2005 and 2006 to become a successful tourist attraction. A unique example of such architecture in the country, its height reaches 54.9 meters including the flag pole, which is also made of reinforced concrete.

Having climbed up its long stairs, one can admire from the top windows the palaces of Szeged, the River Tisza and the immense Great Plain. The visitor will find some memorial documents of the Great Flood of 1879. This is the most dramatic year in the city's history. Indeed the water of the river Tisza broke through the protection dams, flooding and virtually washing away the entire city. Only 5% of the buildings remained standing! Thus 1879 is also the year of the rebirth of Szeged.

In the last few years tens of thousands of visitors have climbed up the spiral stairs leading to the terraces in order to enjoy a view of the city and to become acquainted with the history of the tower.

The Exhibition

The purpose of this museum is to maintain the values and the tradition of the city and to inform the public on the old valuable scientific, educational and technical instruments. The main effort is to identify the instruments and tools, repair them and document them according to contemporary catalogues. With each description comes a corresponding drawing from the time of its manufacture. The descriptions address the daily visitors as well as the professionals.. The collection is rather rich with more than 100 pieces dating from 1860 until 1930. The instruments, most of them still working, are displayed in eight different glass showcases according to a specific theme (Fig. 2 & 3)

Our first intention was to exhibit scientific instruments in an accessible place with an historical touch. Taking advantage of the architectural specificity of the water tower a Foucault pendulum was placed in its center to demonstrate the rotation of the Earth on its own axis. Suspended at the sixth floor by a 25 m long steel string, the swinging bowl welcomes the entering visitors.

There are some local peculiarities among the exhibited objects. We are indeed very proud, for example, of the old X-ray photographies made by István Homor, a local physics teacher (Fig. 4). He showed these photos to the public in January of 1896, only one month after the publication of the famous article by Roentgen (December 1895)! Another example is a collection of discharge tubes made by a Szegedien master, Oszkár Hollmann in 1916 (Fig. 5).

The Activities

Since the inauguration several programmes have been organized in this science museum. Once a month or on specific occasions such as the *World Water Day, the Researchers'Night, the Museums' Night, etc.*, the visitors can not only see the tools but also work or experiment with them. More extended education programmes are organized for groups of elementary and secondary school students from Szeged, from Hungary or foreign countries. Advanced registration is required to participate to these events.

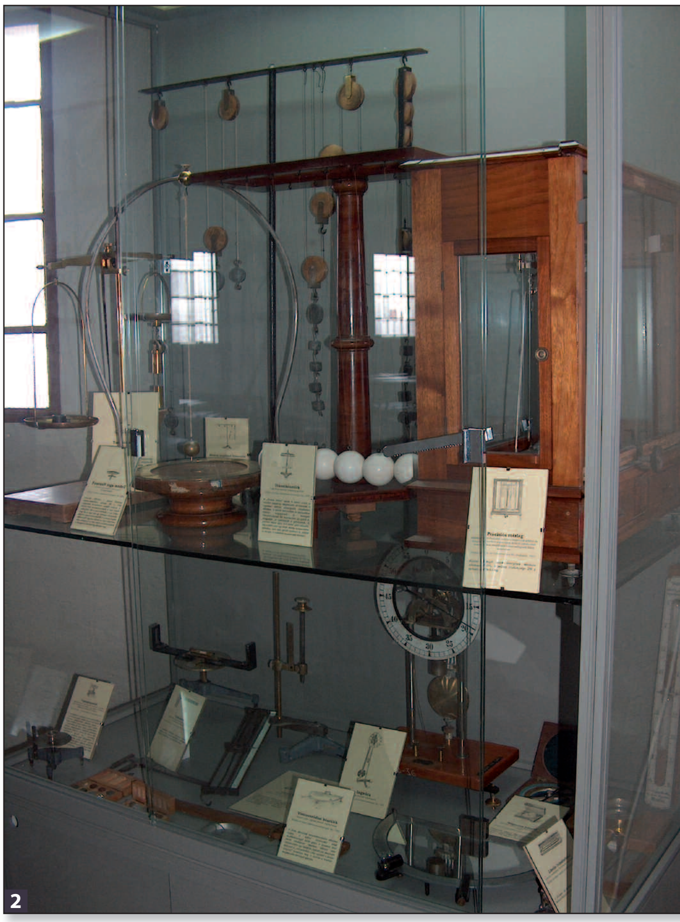
Series of physics lectures are occasionally held on different topics such as thermodynamics, wave motion, optics, magnetism, etc., completed with experiments using contemporary instruments or tools. In order to build up good relationships with different local public organizations (Public Coffeehouse, Association of Head of Schools, People College Zsombó, etc.) we contribute to the cultural life of the town. By giving lessons to university students or teachers who participate in educational training workshops, our aims are also to present and discuss the various methods of scientific knowledge transfer. For these reasons the Physics Methodology Group (www.physx.u-szeged.hu/modszertan), whose research area includes the investigation of the strategy and methods of outdoor science, deals with the hosting of visitors, the maintenance and upgrade of the exhibitions.

The Future

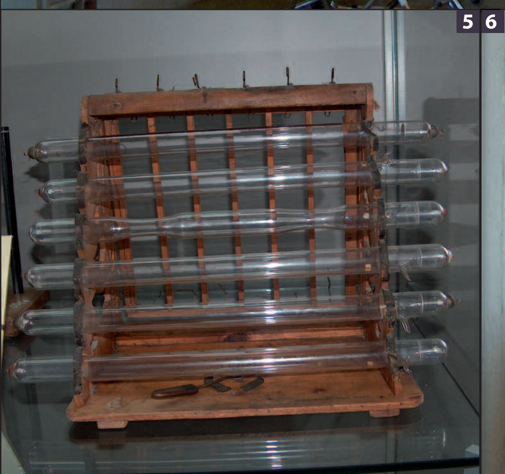
Our most important task is the continuous development of the PR activities related to the museum. The first step is to prepare the museum's website, which will provide a virtual tour in the exhibition. With this project we intend to extend our network to a broader international scientific community. One basic condition for future developments is of course to find or generate the appropriate funding. Potential sponsors or supporting members are welcome. ■

About the Author

Dr. Katalin Papp, associate professor, Department of Experimental Physics, University of Szeged, H-6720 Szeged, Dóm tér 9. Hungary
www.physx.u-szeged.hu/modszertan
e-mail: pkat@physx.u-szeged.hu



▲ **FIG. 2:** One of the showcases of the exhibit.
▼ **FIG. 3:** On the seventh floor of the water tower.
▼ **FIG. 4:** X-ray photos.
▼ **FIG. 5:** Discharge tubes.
▼ **FIG. 6:** The visitors



Europhysics News Recruitment

Contact **Jessica Ekon** • e-mail advertisement@edpsciences.org
EDP Sciences • www.edpsciences.org • Phone: +33 (0)1 69 18 92 40 • Fax: +33 (0)1 69 18 18 11

Experimental Particle Physics LHCb Team Leader Position "Horia Hulubei" National Institute of Physics and Nuclear Engineering

The 'Horia Hulubei' National Institute of Physics and Nuclear Engineering (IFIN-HH, www.ifin.ro) at Bucharest seeks applications for a research leadership position as Team Leader of the IFIN-HH partnership with the 'LHCb - A Large Hadron Collider beauty experiment' Collaboration (http://lhcb.web.cern.ch/lhcb/) at CERN-Geneva. The successful candidate will have a PhD in particle physics and a minimum of fifteen years of progressive research practice, with at least 20 particle-physics papers published within ISI journals. Former experience in the LHCb area and, preferably, in research and personnel management as well as international research projects would be advantageous. Curriculum vitae, list of publications, a statement of the research interest, and three letters of recommendations from experts in the field should be sent via e-mail to ralucas@nipne.ro. Applications will be accepted until July 31st, 2010.

University of Kent • Queen Mary University of London • Royal Holloway University of London • University of Southampton • University of Surrey • University of Sussex

Your choice from six universities • Two-year programme • 120 ECTS credits

MSc in Physics (EuroMasters)

Join our network of world class research groups to create a personalised programme

Year One - Your choice of SEPnet university
Taught master level courses including specialised research

Year Two - Advanced Research
Option to change locations to a SEPnet partner university in South East England or a research institution which may include CERN, Rutherford Appleton Laboratory, ISIS, Diamond or the National Physical Laboratories.

SEPnet Scholarships available

This programme is conducted in the English Language and is compatible with the European Credit Transfer Accumulation System across the European Union and other collaborating European countries.

Apply now at www.sepnet.ac.uk/euromasters

The Foundation for Fundamental Research on Matter (FOM) promotes, co-ordinates and finances fundamental and applied physics research in the Netherlands. It is an autonomous foundation responsible to the physics division of the national research council NWO. FOM employs about 950 people, of whom about 325 are PhD students and 100 are post-docs, who work at FOM research institutes and in university laboratories. Additional funding is obtained via the Technology Foundation (STW), the European Union, and industry.

PhD-students Physics and Chemistry of Extreme UV Multilayer Optics

Ultrathin films find a major application in multilayer optics for the reflection of short-wavelength light. Designed for Extreme UV wavelengths, i.e. 13 nanometer, such multilayers have recently enabled the sensational development of a high-resolution lithographic technology for the manufacture of integrated circuits. At the basis of this achievement was forefront fundamental research at FOM on the thin film and solid state physics of such multilayer optics. FOM has now started a new multidisciplinary research programme to study the basic physics and chemistry required for further usage of multilayer optics in lithography, aiming at new classes of EUV-optics. The research will take place at the FOM Institute for Plasma Physics Rijnhuizen (Nieuwegein), and at a new FOM laboratory at the lithography equipment manufacturer ASML (Veldhoven), using its unique EUV radiation and analysis facilities.

Research field. The interaction of high-intensity ion and photon beams with thin film surfaces is a fundamental and fascinating process. It involves both ion- and photon-induced physical reactions as well as photo- and plasma chemistry at the surfaces. The experimental approach will be to isolate the individual processes and to control them at the atomic and molecular level, with support from analytical and numerical methods like Particle-In-Cell plus Monte Carlo. The studies include molecular and particle contamination and new, spectroscopic detection methods. The scientific programmes at Rijnhuizen and ASML include worldleading research activities in each of these areas, exploiting high flux photon sources and ion beam generators, equipment to study surface photochemistry from the infrared to the extreme UV, atomic-scale layer growth set-ups and surface analysis facilities, state-of-the-art (particle) inspection and diagnostics and a range of numerical tools. The research is done in close collaboration with other industrial and academic parties, including Carl Zeiss SMT, the renowed ISAN Institute (Moscow) and the University of Twente.

Research topics. The available PhD positions include topics such as:

- Particle and molecular contamination on patterned surfaces, involving novel spectroscopy-based techniques for particle inspection of reticles and the study of molecular contamination in the presence of patterns (location ASML).
- Energy dependent surface photochemistry, involving the specific photochemistry of e.g. physisorbed hydrocarbons or water at different photon energies under UHV conditions, including the relative importance of direct photo-induced processes (location ASML).
- Kinetic studies of EUV-induced plasma chemistry using numerical tools like the Particle-In-Cell plus Monte Carlo method to model plasma generated by a combined action of photo-ionization and surface release of secondary electrons (location FOM).
- Plasma-surface interaction at EUV surfaces, including erosion of surfaces and multilayer structures due to exposure to high ion fluxes, as well as studies on physical sputtering, H-enhanced atom mobility, and chemical surface actvities (location FOM/ASML).
- Layer interface interactions in multilayer EUV mirrors down to the monolayer level, with the aim to identify and control interface processes in ultrathin compounded systems with high optical contrasts (location FOM).
- Modification of the optical response of EUV optics by addressing both the optical as well as the thin film growth aspects, including anti-reflectance coatings,
  diffractive filtering systems, and multilayers with new optical responses (location FOM).

Qualifications. Applicants should have a Master degree in Experimental or Technical Physics or Chemistry, or an equivalent diploma giving access to doctoral studies. Experience on either surface photochemistry, plasma physics, plasma/ion surface interactions, thin film physics, material science, optics or spectroscopy is an advantage.

Employment Conditions. FOM offers a stimulating work environment in an area of applied, forefront research. When fulfilling a PhD position at FOM, you will get the status of junior scientist. You will have an employment contract for the duration of 4 years and can participate in all the employee benefits FOM offers. The gross monthly salary starts with € 2037,- in the first year and increases to € 2610,- in the fourth year of your employment. The salary is supplemented with a holiday allowance of 8% and an end-of year bonus of 8.33%. A high-quality training programme is part of the agreement. The research has to result in a thesis at the end of the four year term with FOM. Depending on the topic, the positions are based at Veldhoven or Nieuwegein; they are available immediately.

Information. Employment conditions are laid down in the 'CAO onderzoekinstellingen' and can be consulted at the FOM website (www.fom.nl under 'Personnel' or 'Personeelsinfo'). General information on working at FOM can also be found at the FOM website. For further information please contact Prof. dr Fred Bijkerk or Drs. Eric Louis on +31 30 6096999, or mail to f.bijkerk@rijnhuizen.nl or e.louis@rijnhuizen.nl.

Application. Your letter of application with resume can be sent to drs. Karijn Heling, FOM Institute for Plasma Physics, P.O. Box 1207, 3430 BE Nieuwegein, The Netherlands or by e-mail to: vacancies@rijnhuizen.nl.
Please note 'vac. no 10/003' in your application letter.

Acquisition to this vacancy is not appreciated.

FOM

HAKONE XII

XIIth International Symposium on High Pressure Low Temperature Plasma Chemistry

September 12 – 17, 2010
Trenčianske Teplice
Slovakia

Scope

Hakone is a bi-annual symposium which brings together scientists and engineers working on chemical and physico-chemical phenomena in non-thermal plasmas operating at atmospheric pressure. The objective is to exchange ideas on fundamental aspects of these discharges and to discuss current developments on their applications in various fields like gaseous and water treatment, generation of radiation, biological aspects, surface processing, …

Topics

- Fundamental problems of high pressure discharges
- Modelling and diagnostics
- Molecular synthesis and decomposition
- Ozone generation and applications
- Generation of radiation in high pressure discharges
- Depollution and environmental applications
- Surface processing and technology (cleaning, coating, etching and modification, equipment)
- Biological applications
- Miscellaneous

Invited Lectures

Fundamental processes	M. Allan (Switzerland)
Patterned DBDs	J.-P. Boeuf (France)
Pollution control	Hyun-Ha Kim (Japan)
Plasma in medicine	K.-D. Weltmann (Germany)
Progress in industrial ozone generation	J. Lopez (USA)

For more information and registration please visit:
http://www.fmph.uniba.sk/hakoneXII