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The acoustics of a concert hall

Tricks of the trade to boost your h-index

IYL2015 opening ceremony

The European Science Foundation

Hearing overcomes uncertainty relation

46/1
2015

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The acoustics of a concert hall

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Tricks of the trade to boost your h-index

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Hearing overcomes uncertainty relation

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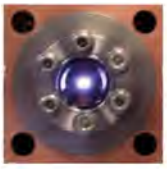

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[EDITORIAL]

Lessons from a Giant

A quotation well-known to physicists is Newton's acknowledgement of the debt he owed to others in his work: 'if I have seen further it is by standing on the shoulders of giants'. We in the global physics community have lost our own contemporary giant on January 27 with the death aged 99 of Charles Townes, whose work on the maser and laser essentially opened up the fields of modern optical and atomic physics and their many associated applications.

The story of Townes's life and his discovery of the principles of maser operation is well-known. He shared the Nobel Prize in Physics in 1964 for his work on maser and laser devices and from 1966 until 1970, he chaired NASA's Science Advisory Committee for the Apollo Lunar Landing programme. He also was involved in many other committees and organisations, served as University Provost and was also past-president of the American Physical Society. His commitment to and enthusiasm for science was lifelong, and he continued to carry out research actively after his 'retirement', in fact publishing as first author a paper describing stellar dust distributions at the age of 96! His writings and works have had very broad impact in many other areas of science, technology and policy.

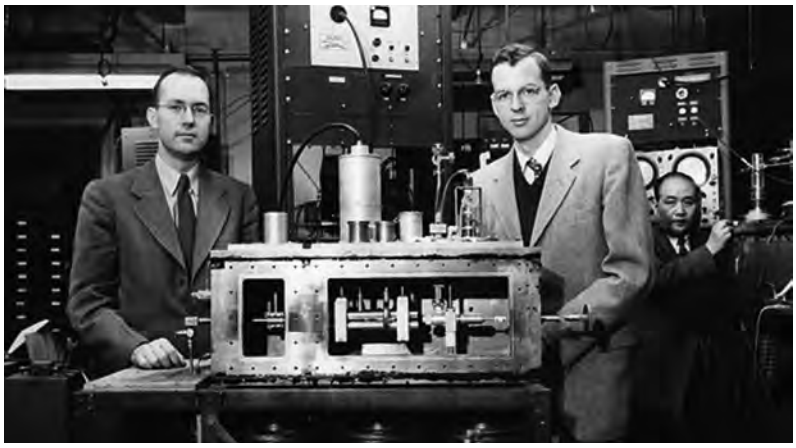
What prompts me especially to write about Charles Townes in this first editorial of 2015 is the fact that his example is of so much relevance to us all as EPS both celebrates the International Year of Light and begins a strategic programme towards influencing science policy in Europe. Charles Townes certainly saw the many reinforcing and positive links between basic science and engineering, but he was a very strong advocate for improving understanding amongst the public and politicians of the economic impact of long term basic research. In an interview appearing in a 2013 production for South Carolina ETV, he says clearly: 'Politicians can't support science so strongly because it isn't going to pay off immediately. It pays off many years later. The laser is now billions of dollars of business, but it's been about 50 years…" This is a message that EPS along with many other partners has been struggling with little success to have heard by decision-makers for years now, but we must be persistent and keep trying.

Politicians can't support science so strongly because it isn't going to pay off immediately. It pays off many years later.

I am approaching now the end of my mandate as EPS President, and although I have been very strongly supported by many committed scientists who volunteer their time to EPS and other societies, or who work on policy and other government committees, I am convinced more than ever that the number of physicists who take on the task to spread this message is far too small. Many more of us need to get involved, and this was something I tried to convey to a broader audience when I had the honour to speak at UNESCO Headquarters on the 19 January at the Opening Ceremony of the International Year of Light. Given the particular theme of light science being celebrated, I did not hesitate to again quote Charles Townes who wrote in his book *How the Laser Happened: Adventures of a Scientist* that he '...always felt that scientists should provide public service from time to time.'

It is of great concern that at the same time that science becomes more and more essential to the running of modern society, it is understood by the public less and less. Having in 2015 an International Year on a science theme provides a wonderful lever for us to promote the importance of physics and science in general, but it really is only the start. In my view, one of the most important outcomes of the next year must be to identify more of us within the community of physicists who will accept the lesson of Charles Townes, and who will take up the challenges ahead. ■

John Dudley
President of the EPS



▸ Charles Townes and James Gordon with their second MASER device, 1955. In the background T.C. Wang stands beside the first maser. Via www.aip.org.

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EPS HISTORIC SITES

The laboratory of Georgi Nadjakov

Sofia, Bulgaria

The laboratory is neither big nor sophisticated. An ordinary room at the Institute of Solid State Physics (ISSP) of the Bulgarian Academy of Sciences (BAS), which gathers some of the equipment, lab reports and belongings of Georgi Nadjakov, arranged in manner people that had the privilege to work with him still remember.

The instruments might evoke smiles on the faces of young Bulgarian physicists, spending most of their time in big laboratories abroad. The modest collection, however, bears evidence of a scrupulous work, good planning, and careful account for details – all that makes an inspired experimentalist. The systematic studies led Nadjakov, among other things, to the discovery of the photoelectrets – permanent electrets obtained by simultaneously applying an electric field and light. The significance of this new state of matter is sufficient to uphold the EPS decision to put Nadjakov laboratory on the European map of important places for the history of physics. This is yet another recognition for a researcher who, according to his own memoirs, as a young fellow was on the brink to jump into the Seine! Why? In 1925 Georgi earned a fellowship from Sofia University to study abroad. With no specific subject or recommendation, he decided to apply to Paul Langevin's Lab with his own research agenda involving the internal photo effect. In Paris he was shocked to find that even the students knew more than he himself and were working with far more advanced equipment than that in Sofia, where he had been an assistant professor for five years!

Catching up while being on a short mission is never easy, but Georgi had been in this plight before. Returning from the battle fields of WWI, where as a volunteer he fought the French (now his teachers!) he graduated with his Physics class, taking all exams in only two years. The studies in Paris made Nadjakov a world-class experimentalist and defined his future research subjects, including the electrets.

Nadjakov's breakthrough on photoelectrets would not come, however until 1937, a clear proof of the care and effort he put into validating the discovery. Atypically, the paper was published in Bulgarian, in the Annals of Sofia University, followed by two short reports in *Comptes rendus de l'Académie des Sciences à Paris*, 1937 (presented by Paul Langevin) and

▲ Prof. Cifarelli and Academician Petrov pose for a picture in front of Georgi Nadjakov's memorial plaque.

in *Physikalische Zeitschrift*, 1938. It quickly brought him the first foreign recognition: he became a corresponding member of the Göttingen Academy of Sciences in 1940.

More important was his pivotal role in putting Bulgaria on the map of world science. Before WWII, he founded and was the first chair of the Department of Experimental Physics, founded the first research institute at Sofia University (1938) and was among the founders of the first engineering school in the country (1942). After WWII Nadjakov served as the Rector of Sofia University for two consecutive terms.

In 1945 Nadjakov was elected a member of BAS. He was instrumental for building and organizing the Institute of Physics at BAS, a seed for its evolution from a learned society to a blend of learned society and national research center. Nadjakov became the first, founding director of the institute. Under his governance, which extended up to 1972, the institute built the first nuclear reactor in Bulgaria (1961) and a Cosmic ray observatory on the summit of Rila mountain (1962). All other physics institutes spun off later. One of them, the Institute of Solid State Physics (ISSP) bears his name today.

Nadjakov's career spanned controversial times for Bulgaria, both ideologically and politically. He dealt with this by offering science and when this was not enough, by offering … more science. Moreover, photoelectrets and photoconductivity proved all important for the invention of the photocopier and vacuum-less TV. Thus, Nadjakov had a crucial contribution to the free spreading of information and knowledge in the world, a perfect answer to counter narrow-minded ideologies. This makes him perhaps more than anyone else, a man of the belated, twentieth century Bulgarian Enlightenment.

The ceremony was both inspiring and lovely. The announcement was made by Prof. Luisa Cifarelli, Chair of EPS Historic Sites Committee and a former President of EPS. She and the director of ISSP, Academician Alexander Petrov, unveiled the memorial plaque of Georgi Nadjakov. Among the honorable guests was Academician Nikola Sabotinov, former president of the BAS, who highlighted the importance of the event and stressed the impact of Nadjakov's discoveries on other branches of technology, such as memory devices, X-ray dosimetry, *etc.* The ceremony was followed by a small symposium, in which colleagues of Nadjakov presented his work and told stories from their collaborations. At the end, Dr. Elka Nadjakova, daughter of Georgi Nadjakov, shared memories of the meetings of her father with notable physicists of the 20th century: Joliot Curie, Langevin, Ioffe and others. ■

Oleg Yordanov and Alexander Petrov,
Bulgarian Academy of Sciences

▼ Part of the exposition in Nadjakov's Lab – Historic site No. 17 of EPS.

International Year of Light 2015
Opening Ceremony

The Opening Ceremony of the International Year of Light and Light-based Technologies 2015 was held on 19-20 January 2015 at UNESCO HQ in Paris, France. This two-day event gathered over 1,000 participants comprising international diplomats and decision-makers, Nobel laureates, CEOs, and science and industry leaders from across the globe.

The United Nations General Assembly adopted the resolution A/RES/68/221 in December 2013 declaring 2015 as the International Year of Light. The purpose is to raise awareness of how optical technologies promote sustainable development and provide solutions to worldwide challenges in energy, education, agriculture, communications and health. With UNESCO as lead agency, IYL 2015 programmes and activities promote improved public and political understanding of the central role of light in the modern world while also celebrating noteworthy anniversaries in 2015, from the first studies of optics 1,000 years ago to discoveries in optical communications that power the Internet today. The IYL Global Secretariat is located at the Abdus Salam International Centre of Theoretical Physics (ICTP), in Trieste, Italy.

Light is important for all life on earth, and human beings have always been fascinated by it. The Opening Ceremony presented many of the activities of national and international scope that will raise awareness of the importance of light and light-based technologies in m any key areas such as efficient lighting, sustainable energy, transportation, communications and healthcare.

During the two-day ceremony, keynote lectures, symposia, and round-table discussions covered areas of basic science, innovative lighting solutions for society, light pollution, emerging trends in photonics, the Einstein Centenary, the role of light-based technologies in addressing global challenges, light in art and culture, the history of science, and science policy.

▲1. UNESCO Fontenoy building illuminated by "Light is Here".

▲2. 1001 Inventions and the World of Ibn Al-Haytham exposition

▶3. Ngāti Rānana London Maori Club.

▼1. The main hall.

▼2. William Phillips during his lecture.

▶3. Einstein's Light performance by Joshua Bell and Marija Stroke.

Recent advances in the science of light and photonics, as well as contributions to society were addressed during the Plenary Lectures delivered by Nobel Laureates, **Ahmed Zewail**, **Steven Chu**, **Zhores Alferov**, **William Phillips** and **Serge Haroche**.

John Dudley, President of the European Physical Society and chair of the IYL Global Steering Committee, pointed out the importance of the IYL 2015 to the optics and photonics community as a means to communicate the importance of the technologies in everyone's lives. *"We only get one chance"*, he said *"It is nice to celebrate but we need to get to work as well"*.

The program also featured several cultural and musical interludes: violinist

Joshua Bell performed "Einstein's Light" and the exterior of the UNESCO Fontenoy building was illuminated by a display entitled "Light is Here", designed and installed by Finnish light artist **Kari Kola**. The installation transformed all three faces of the building to recreate the Aurora Borealis. Other events included the performance of the Maori founding myth Te Ao Mārama (From Darkness to the World of Light) by dance troupe **Ngāti Rānana London Maori Club** (New Zealand).

In an inspiring session on Light Solutions, three presenters, **Illac Diaz**, **Martin Aufmuth** and **Linda Wamune**, described highly successful programs that are making huge improvements in quality of life in several areas of the world.

Future of Light panelists **Sune Svanberg**, **Alain Aspect**, **Bernard Kress** and **Brian Wilson** discussed future applications of light in healthcare, computing, wearable technologies and research.

A roundtable discussion on science policy moderated by **Jose Mariano Gago**, Portugal's former Minister of Science, Technology and Innovation, emphasized the role of science as a tool for development.

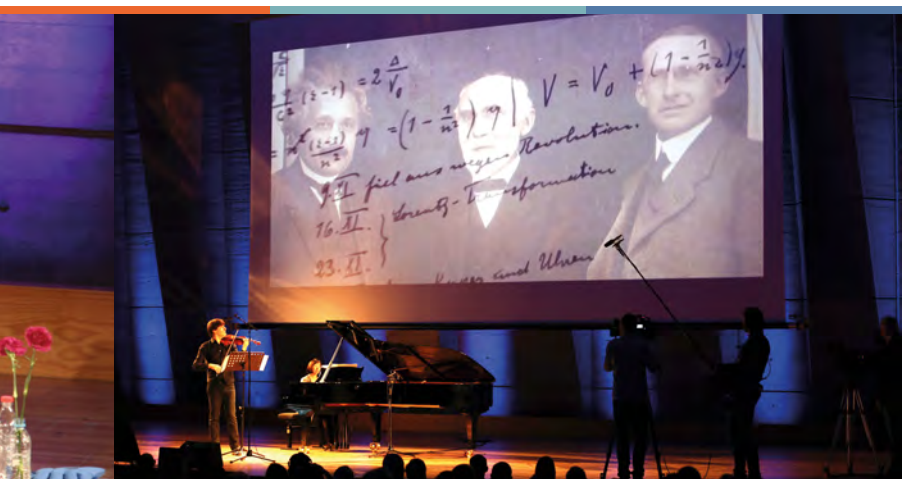
Professor Gago encouraged nations to cooperate and improve the dialog about science policy at an international level. Science, he said, *"can be a source of peace or a source of conflict, a source of war or a source of development. It must rely on knowledge and trust."*

Naledi Pandor, South African Minister of Science and Technology, pointed out that Africa is often forgotten by the rest of the world, saying that the continent is often excluded from initiatives that are nominally "global." She declared: *"The continent needs to raise its profile with well-crafted science policy, building human capital in a wide range of disciplines, and making sure researchers have academic freedom and the infrastructure to work."*

Ana María Cetto noted that international cooperation can be a catalyst, stressing that countries need to build their own internal capacity, "whatever comes from outside may help, but it does not replace what countries do themselves."

Maciej Nalecz, UNESCO Director of the Division of Science Policy and Capacity-Building closed the IYL 2015 Opening Ceremony pointing that this is the beginning of a year full of activities.

David Lee
Secretary General of the EPS



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Open nominations
EPS - Quantum Electronics and Optics Division

The Quantum Electronics and Optics Division (QEOD) of the European Physical Society (EPS) is soliciting nominations for the biennial Quantum Electronics and Optics Prizes, Fresnel Prizes and Thesis Prizes, which will be presented at the 2015 Edition of the CLEO/Europe-EQEC Conference in Munich, Germany, between 21st and 25th June 2015.

Nominations are to be received online by March 20th, 2015 at the latest.

EPS Quantum Electronics & Optics Prizes

Two Quantum Electronics & Optics prizes are awarded for outstanding contributions to quantum electronics and optics. There is one prize for fundamental aspects and another one for applied aspects. Each Prize winner will receive a medal and 5000 euros.

Fresnel Prizes 2015

Two EPS-QEOD prizes will be awarded for outstanding contributions to quantum electronics and optics made by young scientists before the age of 35 (as of December 31st, 2015). There is one prize for fundamental aspects and one prize for applied aspects. The prize winners will each receive a medal and 2000 euros.

EPS-QEOD Thesis Prizes 2015 (with OPFocus)

Four EPS/QEOD prizes will reward excellence in PhD research and scientific communication in quantum electronics and optics related to a PhD thesis defended in the period June 2013 - June 2015. This prize is awarded in collaboration with Optics and Photonics Focus (www.opfocus.org), the online photonics and optics journal cosponsored by EPS-QEOD and OSA. These prizes will be awarded for fundamental and for applied aspects. The prize winners are each to receive a diploma and 1000 euros.

Online Submission

All material must be prepared in English and combined into either a single consolidated PDF file or a ZIP archive.

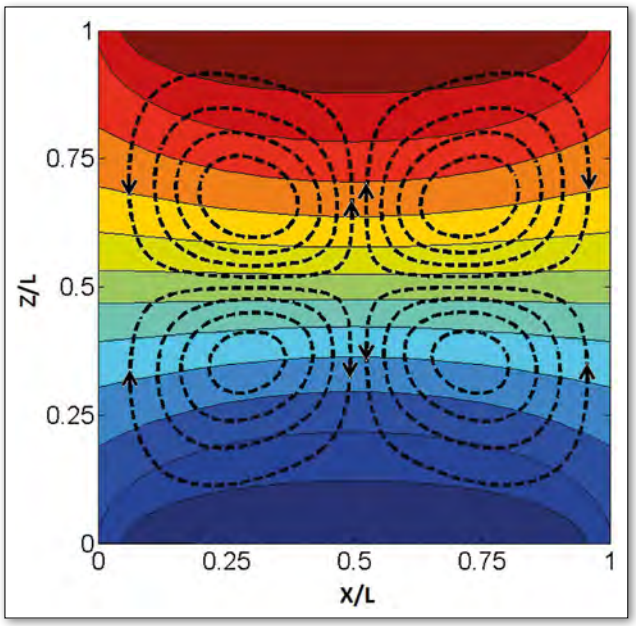
Please use the link below to access the submission site: http://qeod.epsdivisions.org/QEOD%20Prizes/european-physical-society-quantum-electronics-and-optics-division-prizes-2015 ■

Highlights from European journals

LIQUID PHYSICS

Thermodiffusion in weightlessness

Zero gravity experiments on the International Space Station shed some light on thermodiffusion effects, relevant to the oil and gas industry and global warming prevention processes



▲ Flow pattern 2 minutes after the start of vibrations. Credit: Y. Gaponenko *et al.*

Thermodiffusion, also called the Soret effect, is a mechanism by which an imposed temperature difference establishes a concentration difference within a mixture. Two recent studies provide a better understanding of such effects. They build on recent experimental results from the IVIDIL—Influence Vibration on Diffusion in Liquids—research project performed on the International Space Station under microgravity to avoid motion in the liquids.

In the first study, using a mathematical model the authors set out to identify how vibrations applied to a binary liquid mixture change the temperature and concentration fields over a long time scale. Their findings—if extended to ternary mixtures—have implications for models used to evaluate the economic value of oil reservoirs.

The second paper uses numerical models to study the establishment of the concentration field near the critical region, where diffusion strongly diminishes. Surprisingly, the authors demonstrate that the component separation through the Soret effect is saturated and not infinite, and is reached surprisingly rapidly. The findings of this study may help determine whether the Soret effect could lead to a very large accumulation of sulfur dioxide and hydrogen sulphide capable of creating a leak in the cap-rock of a reservoir, during the process of capturing CO_2 and reinjecting it in supercritical state in such a reservoir. ■

■ **Y. Gaponenko**, **A. Mialdun** and **V. Shevtsova**, 'Experimental and numerical analysis of mass transfer in a binary mixture with Soret effect in the presence of weak convection', *Eur. Phys. J. E* **37**, 90 (2014)

■ **J.C. Legros**, **Yu. Gaponenko**, **T. Lyubimova** and **V. Shevtsova**, 'Soret separation in a binary liquid mixture near its critical temperature', *Eur. Phys. J. E* **37**, 89 (2014)

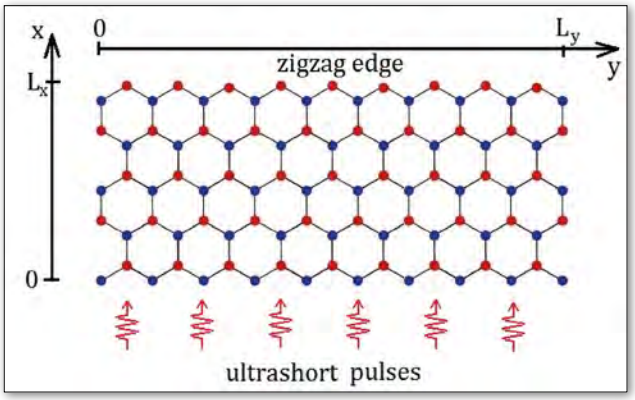
MATERIAL SCIENCE

On-demand conductivity for graphene nanoribbons

Physicists have, for the first time, explored in detail the time evolution of the conductivity, as well as other quantum-level electron transport characteristics, of a graphene device subjected to periodic ultra-short pulses. To date, the majority of graphene studies have considered the dependency of transport properties on the characteristics of the external pulses, such as field strength, period or frequency. These results may help to develop graphene-based electronic devices that only become conductors when an external ultra-short pulse is applied, and are otherwise insulators.

Specifically, they found that applying external driving force leads to enhancement of electronic transitions within valence and conduction bands. This study thus demonstrates that such

▼ Sketch of a kicked zigzag graphene nanoribbon. Credit: D. Babajanov *et al.*



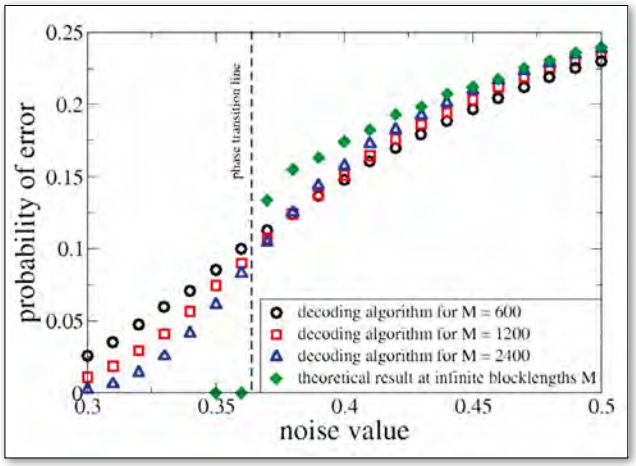
transitions allow a dramatic increase in conductivity within a short time, making it possible to tune the electronic properties using short external pulses. ■

▪ **D. Babajanov**, **D.U. Matrasulov** and **R. Egger**, 'Particle Transport in Graphene Nanoribbon Driven by Ultrashort Pulses', *Eur. Phys. J. B* **87**, 258 (2014)

MATHEMATICAL PHYSICS

Small worlds to analyze **error-correcting codes** on memory channels

Low-density parity-check (LDPC) codes invented by Robert Gallager are error-correcting schemes that form the basis of today's most promising communication systems. Their performance not only approaches Shannon's theoretical bound, but they are based on computationally efficient encoding/decoding schemes.



▲ Probability of error vs. channel noise.

While the literature behind LDPC codes is vast, it is based mostly on LDPC codes on channels without memory, *i.e.* channel noise acts independently on every bit. Memory in the channel noise is however a practical fact: *e.g.* the noise in wireless communication due to a moving source.

We have shown that decoding algorithms for LDPC codes on channels with memory can be analyzed using statistical mechanics. Memory introduces an extra set of degrees of freedom and the decoding problem becomes equivalent to studying phase transitions on `small-world' networks. In this mapping the ferromagnetic-paramagnetic transitions represents the transition from success to failure of reliable communication. Using replicated transfer matrices we derived the corresponding density evolution equations which determine the decoding performance at infinite block lengths (see figure). The theoretically derived critical values agree well with the practical implementation of the decoding algorithm. The phase diagram shows that the presence of memory can lead to superior decoding performance. ■

▪ **I. Neri** and **N. S. Skantzos**, 'On the equivalence of Ising models on 'small-world' networks and LDPC codes on channels with memory, *J. Phys. A: Math. Theor.* **47**, 385002 (2014)

PLASMA PHYSICS

Plasma: Casimir and Yukawa mesons

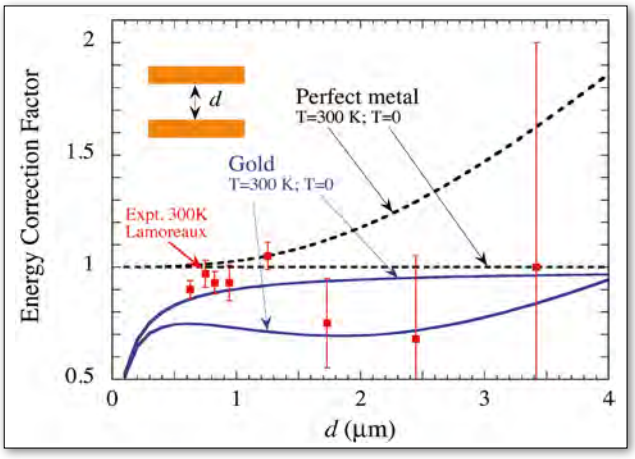
The Casimir electromagnetic fluctuation forces across plasmas are analogous to so-called weak nuclear interaction forces, as new findings show.

A new theoretical work establishes a long-sought-after connection between nuclear particles and electromagnetic theories. Its findings suggests that there is an equivalence between generalised Casimir forces and what are referred to as weak nuclear interactions between protons and neutrons. The Casimir forces are due to the quantisation of electromagnetic fluctuations in vacuum, while the weak nuclear interactions are mediated by subatomic scale particles, originally called mesons by Yukawa. These results have been found by the authors.

The authors extended the formulae for the Casimir force between these ideal metal plates to include interactions across a plasma and temperature, explicitly. The new formulae that emerge show that long-range electromagnetic fluctuations are qualitatively different from those across a vacuum. They also shed some new light on measurements of Casimir forces between metal plates, an issue that has long puzzled physicists. ■

▪ **B. W. Ninham**, **M. Boström**, **C. Persson**, **I. Brevik**, **S. Y. Buhmann** and **B. E. Sernelius**, 'Casimir Forces in a Plasma: Possible Connections to Yukawa Potentials', *Eur. Phys. J. D* **68**, 328 (2014)

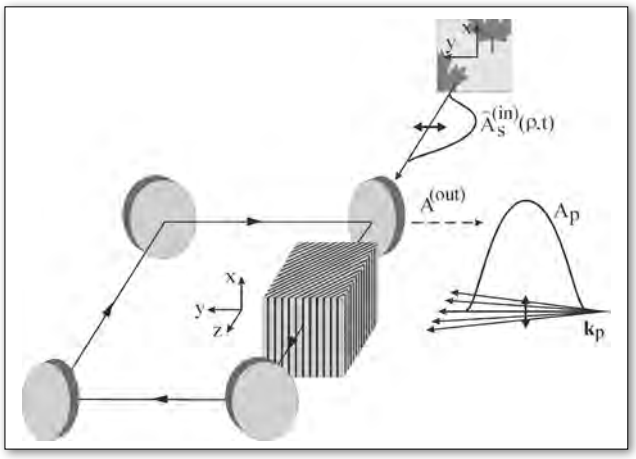
▼ Energy correction factor for two gold plates in the absence of any intervening plasma. Credit: Ninham *et al.*



QUANTUM PHYSICS

Quantum holograms as atomic scale memory keepsake

A new theoretical study demonstrates for the first time that quantum holograms could be a candidate for becoming quantum information memory.



▲ Set up of the experiment showing the orthogonal side illumination. Credit: A. N. Vetlugin *et al.*

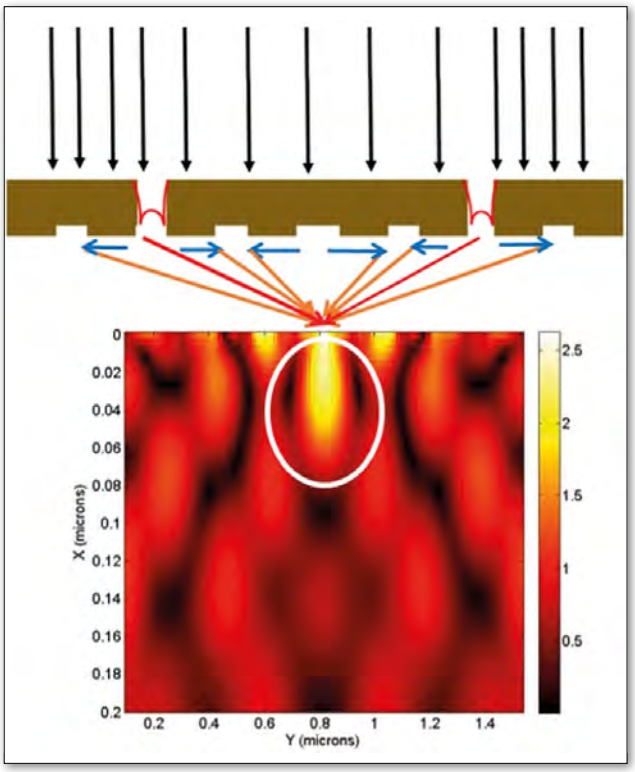
The authors have developed a theoretical model of quantum memory for light, adapting the concept of a hologram to a quantum system. They demonstrate for the first time, that it is theoretically possible to retrieve, on demand, a given portion of the stored quantised light signal of a holographic image—set in a given direction in a given position in time sequence. This is done by shaping the control field boh in space and time. Ultimately, scientists aim to introduce into quantum holograms the ability not only to store quantum signals but also to perform transformations of their quantum states; an approach useful for quantum communication and computation. ■

▪ **A. N. Vetlugin** and **I. V. Sokolov**, 'Addressable parallel cavity-based quantum memory', *Eur. Phys. J. D* **68**, 269 (2014)

OPTICS

Super-focusing of light with a plasmonic super lens

The diffraction barrier, which states that the FWHM of a focal spot cannot be lower than λ/2, has hampered investigators from visualizing nanoscale processes. Since the discovery of Extraordinary Optical Transmission and Surface Plasmon Polaritons, hope was renewed in building devices that can potentially break the formidable diffraction barrier. However, they were either unsuccessful or too complicated. This imposed the question: can these devices be made simple enough to be translated into the real world?



▲ Novel plasmonic device and super-focusing in the deep UV at a wavelength of 186.716 nm with FWHM of 64 nm.

The authors, working on a novel design of a plasmonic super lens, show that the answer to this question is "Yes". In their contribution, they have proposed a plasmonic super lens that was shown to reach a FWHM of λ/3 consistently at various wavelengths ranging from the visible to the ultraviolet. The super lens also acts as a super-antenna that is capable of beaming the light in a small pencil beam with subwavelength width over a long distance allowing it to be used as an optical nano-tweezer. ■

▪ **M. El Maklizi**, **M. Hendawy** and **M. A. Swillam**, 'Super-focusing of visible and UV light using a meta surface', *J. Opt.* **16**, 105007 (2014)

LIQUID PHYSICS

Drops hop from hydrophilic surfaces

The impact of liquid droplets on solid surfaces is ubiquitous in many natural and industrial settings. It is now well known that drops can bounce on super-hydrophobic surfaces such as the leaf of a lotus plant or a patterned engineered surface, coated to repel water. Furthermore, it is commonly thought that when impacting hydrophilic substrates, for instance a glass window, drops will splash or spread but never bounce. Here, this

assumption is shown to be incorrect - drops do in fact bounce on smooth and defect-free hydrophilic substrates such as very clean glass, silicon wafers, or the surface of cleaved mica.

And they do so by never actually contacting the surface.

▲ A mm-scale oil drop rebounds and oscillates atop a nm-thin air film before wetting the mica surface beneath.

Direct experimental evidence supports a surprising mechanism for drop rebound. If the velocity of the drop is relatively low, on impact it spreads over a thin film of air, approaching to within 10 nanometres of the surface, but never truly contacting it; then the drop retracts and detaches from the surface. If, however, the impacting drop exceeds a threshold impact velocity, the nanometre-thick air film breaks down and liquid-solid contact initiates. ■

▪ **J. M. Kolinski**, **L. Mahadevan** and **S. M. Rubinstein**, 'Drops can bounce from perfectly hydrophilic surfaces', *EPL* **108**, 24001 (2014)

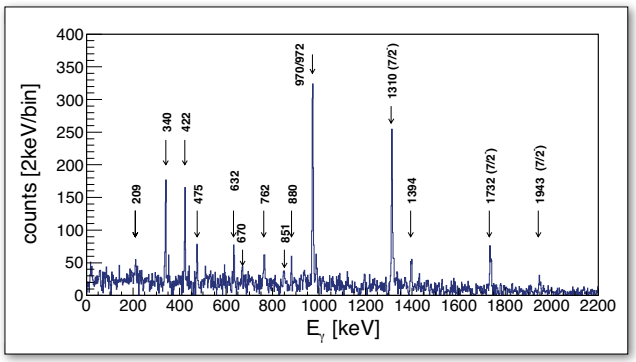
NUCLEAR PHYSICS

High-resolution measurement of two-proton stripping

To date, the two-nucleon pick-up and stripping counterparts of the (p,t) and (t,p) reactions, the (^{3}He,n) and (n,^{3}He) reactions, have been poorly investigated due to the difficulty in performing high-resolution measurements of fast-neutron energies. This experimental limitation has hindered a full understanding of the role of proton pairing in nuclei.

In the present work, this experimental constraint is addressed by detecting the γ-ray decay of populated excited states in an array of escape-suppressed HPGe detectors in coincidence with neutron detectors placed near $\theta_{lab} = 0°$. High selectivity is obtained and a rejection factor of the order of 1 in 10^3 of unwanted reaction channels is demonstrated. The population strength of excited states is deduced with an energy resolution better than 3 keV. This allows the proton occupancy of excited states to be measured.

▼ Spectrum of γ-rays populated in the direct two-proton ^{59}Co(^{3}He,n)^{61}Cu stripping reaction. The L = 0 transitions strongly populate $J^\pi = 7/2^-$ 2p-1h proton states in 61Cu.



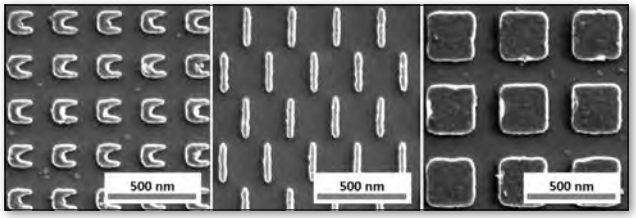
We use the ^{59}Co(^{3}He,n)^{61}Cu reaction at E_{lab} = 22.5 MeV to populate 2p-1h proton states across the $Z = 28$ closed shell. Discrepancies with large-basis shell-model calculations suggest that proton occupancies of the $f_{7/2}$ shell are not currently well reproduced. ■

▪ **P. Papka (+13 co-authors)**, 'High-resolution two-proton stripping to 2p-1h 7/2- states via the ^{59}Co(^{3}He,nγ)^{61}Cu reaction', *Eur. Phys. J. A* **50**, 158 (2014)

OPTICS

Coupling plasmonic materials to semiconductor gain

Optical antennas, metallic structures with plasmonic resonances at optical frequencies, allow one to convert freely propagating light into highly localized modes. This strongly enhances light-matter interactions, increasing nonlinear effects and altering the emission of light from nearby active materials. Due to the nano-scale size of the metal structure and the localized light around it, the array of antennas must be placed within nanometers of active material in order to interact. For semiconductor gain materials, such as a quantum well, this distance is limited by surface effects which degrade optical emission.



▲ SEM images of split-ring, wire and square antenna arrays.

Looking for other ways to improve the interaction we have studied the effect of the antenna shape on the interaction. Using time- and frequency-resolved differential transmission measurements, arrays of different shaped antennas coupled to the same quantum well are studied and compared to theory. This experiment shows the unexpected result that all antenna shapes create a similar response. This is attributed to the fact that antenna shapes with larger dipole moment do not provide the same amount of localization of the optical mode creating a weaker electro-magnetic field at the location of the quantum well. ■

▪ **M. Gehl (+9 co-authors)**, 'Spectroscopic studies of resonant coupling of silver optical antenna arrays to a near-surface quantum well', *J. Opt.* **16**, 114016 (2014)

MATHEMATICAL PHYSICS

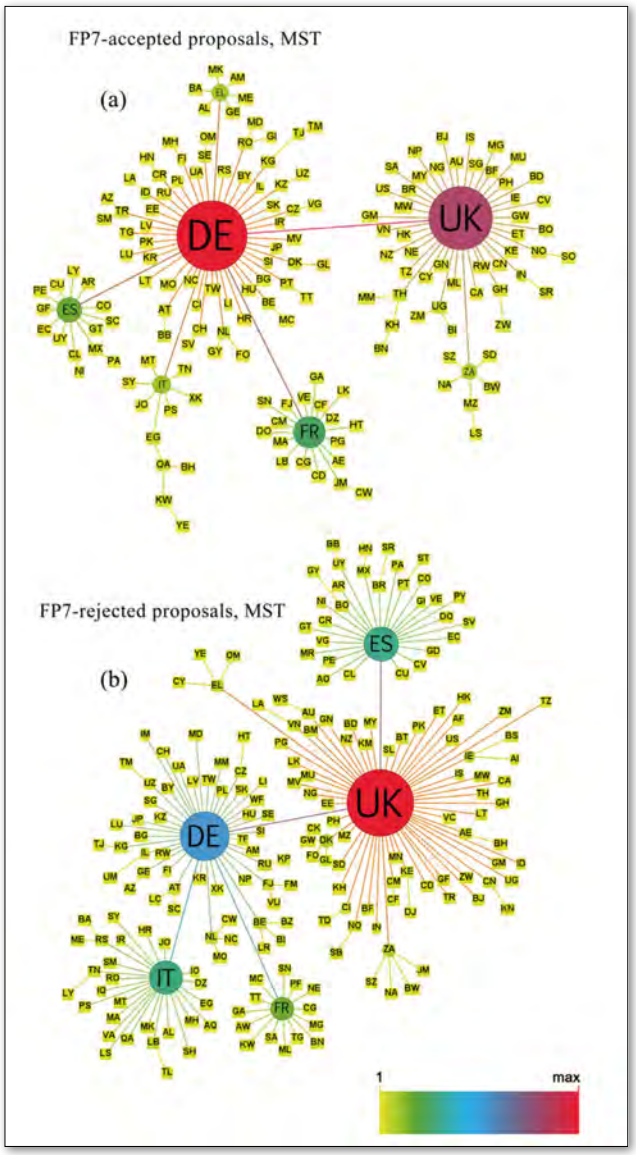
Winner and losers of the EU funding challenge

Successfully attracting EU funding could depend on the nature of the research consortium.

The European Union has a well-oiled funding mechanism in the form of grants given to research consortia. Understanding which type of consortium work receives funding could help future applicants. And it could also bring further transparency on how public funds are spent. Now, the authors have brought valuable insights into the structure of research consortia that are most likely to attract EU funding.

They found that a proposal from a partnership made up of small-scale institutes is more likely to be rejected. The authors also found that large-scale institutes favour collaborations with small-scale ones, in both successful and unsuccessful research consortia. This means they are different from other social networks of similar interactions. Finally, the team also revealed that in both network types the same five countries are the most influential ones: France, Germany, the UK, Spain and Italy. ■

▼ A representative Minimum Spanning Tree of the network of countries involved in the FP7 accepted proposals, which captures the backbone of interactions between the countries. Credit: M.Tsouchnika *et al.*



▮ **M. Tsouchnika** and **P. Argyrakis**, 'Network of participants in European Research: accepted vs. rejected proposals', *Eur. Phys. J. B* **87**, 292 (2014)

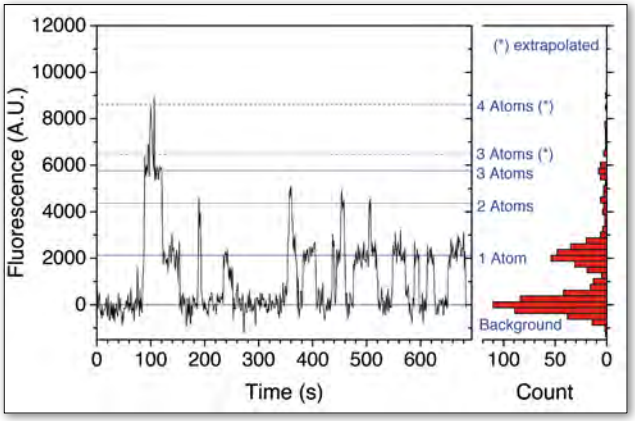
ATOMIC AND MOLECULAR PHYSICS

All-optical production and trapping of metastable noble-gas atoms

The determination of isotope ratios of noble gases has many applications *e.g.* in physics, nuclear arms control and earth sciences. In many cases, low concentrations of wanted noble gas isotopes (*e.g.* Kr and Ar in air or groundwater samples) make single atom detection necessary to achieve an adequate precision of measurement. As an important step into this direction, we demonstrate operation of an Atom Trap Trace Analysis (ATTA) setup based on a magneto-optical trap (MOT) for metastable Kr atoms excited by all-optical means. Compared to other state-of-the-art techniques for preparing metastable noble gas atoms, all-optical production is capable of overcoming limitations regarding minimal sample volume and avoiding cross-contamination. In addition, it allows for a compact and reliable setup. We identify optimal parameters of our experimental setup by employing the most abundant isotope Kr-84, and demonstrate single atom detection within a 3D MOT. ■

▮ **M. Kohler (+ 7 co-authors)**, 'All-optical production and trapping of metastable noble-gas atoms down to the single-atom regime', *EPL* **108**, 13001 (2014)

▼ Fluorescence of up to four trapped Kr-84 atoms as a function of time.



By H.C.W. Beijerinck,
Emeritus Professor of Physics - Eindhoven University of Technology - the Netherlands - DOI: 10.1051/epn/2015101

The DNA of physics

In cell culture, the physical environment plays an important role: "Everything is everywhere, but the environment selects"[1]. The education of physicists can be viewed within this framework. The Petri dish for the reproduction of physicists is a university research group. The full professor is its DNA. The selection process of new professors – new DNA – is a determining step in creating the right culture.

A passion for teaching comes first. High-quality research comes next as an essential tool for training students. Then, keeping an open mind for the outside world where 95% of our students work. Next, 'soft' skills determine for at least 50% if a career will be successful. Finally, integration in (inter) national physical societies and local culture is also required. In short, a healthy 'cell culture' is essential.

Although these requirements seem obvious, many of them are forgotten in the rat race for research funding. University should retrace its steps to honor excellent teaching, not with extra money but with respect by your peers. Effective feedback loops at the departmental level are essential for keeping track of the primary goal: stimulating talented young people to satisfy their curiosity.

Research is an excellent tool for challenging students. Erasmus grants for travel and local networks for internships at the national level prepare for the student's career. Soft skills are learnt both on the fly and in workshops. It is sufficient to grasp the flavor of these skills: the workplace will further hone them. Each employer should invest in its employees, for creating employer loyalty and stimulating team building.

Society

Employers look for self-propelled physicists that can tackle new problems. Specific experience is not too important. Success in a job is determined by universal problem-solving skills, rapid assimilation of new information, and 'soft' skills like reporting and communication. A research group is the ideal training ground.

What about the image of physics? Presenting science as a medication - this is good for you - has no impact. Outreach programmes that feed natural curiosity are more successful: street performances; a physics circus; engaging teenagers in their passions like music; showing that science makes life more rewarding: these work. But this is too large a task for the physics community to handle by itself. Fortunately, there are good examples outside academia [2, 3].

University: quo vadis?

The root cause of failure in 'cell culture' lies in the extreme focus of groups on research as the first and only output of universities. The Hirsch index is the metric for a successful career. Management only supports this simplification. Getting the focus back on the core business of a university – students – is the road to go. This is not a plea for separating research and teaching. It is a plea for rebalancing the education of physics students.

The participation of women is lagging behind in physics. By contrast, biomedical technology and the fields of medical physicists, clinical IT specialists, and medical engineers engage 50% women. What we learn from these numbers is that the 'colour' of science plays an important role. Science with a human face is clearly attractive. Energy transition, ecology, and climate change also have this potential.

Improving the image of physics [4] cannot be achieved by using band-aid. The root cause lies in its DNA and the environment. ■

References

[1] M.W. Beijerinck and L.G.M. Baas Becking, en.wikipedia.org.

[2] www.jet-net.nl (Dutch).

[3] www.platformbetatechniek.nl (Dutch).

[4] Topic of VI Forum on Physics and Society, Belgrade (2014), EPN, to be published.

THE ACOUSTICS OF A CONCERT HALL

AS A LINEAR PROBLEM

Tapio Lokki and Jukka Pätynen – DOI: 10.1051/epn/2015102
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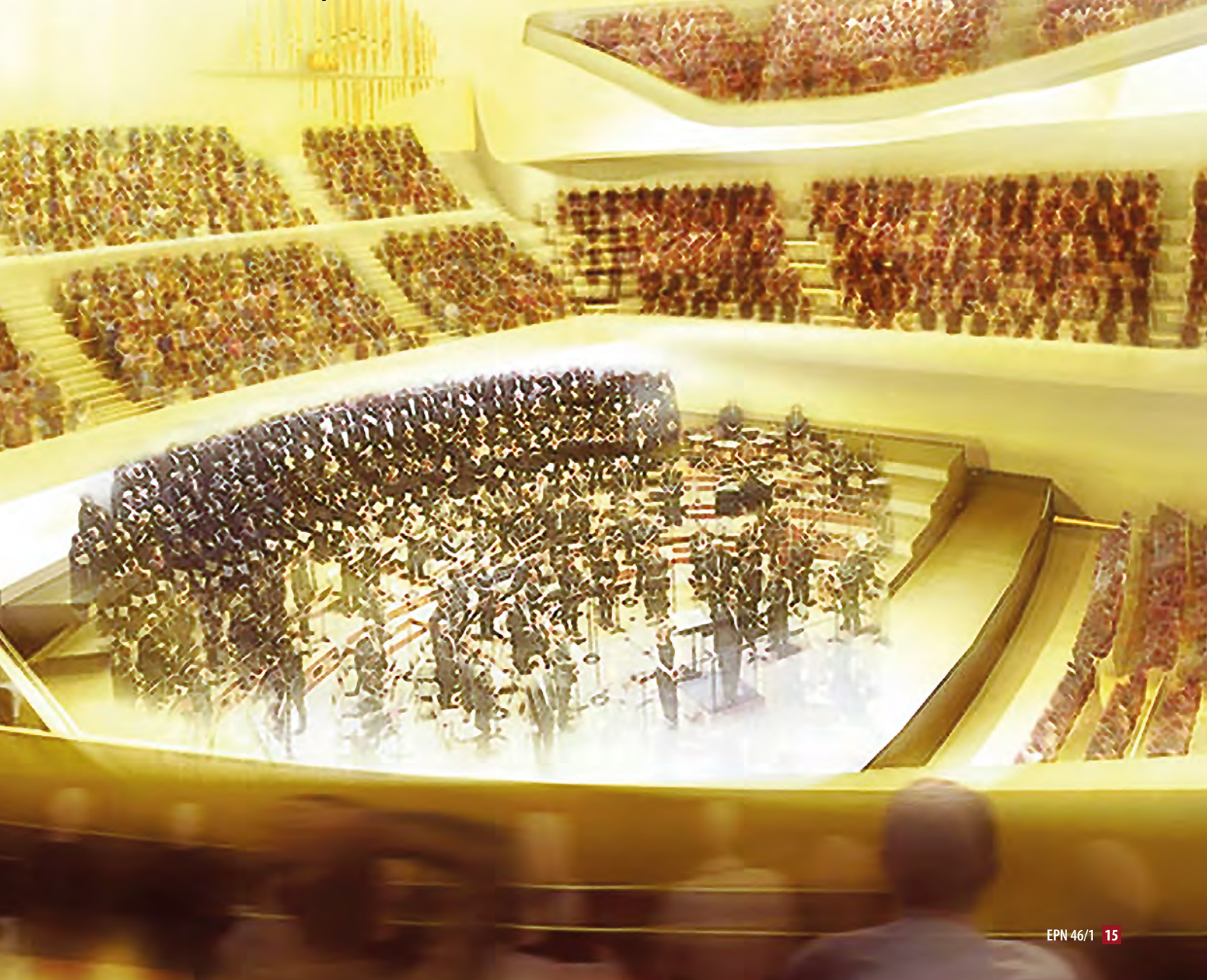
The main purpose of a concert hall is to convey sound from musicians to listeners and to reverberate the music for more pleasant experience in the audience area. This process is linear and can be represented with impulse responses. However, by studying measured and simulated impulse responses for decades, researchers have not been able to exhaustively explain the success and reputation of certain concert halls.



◂P. 17: Big hall of the Philharmonie de Paris. Architect: Jean Nouvel. 3D rendering. © Philharmonie de Paris – Didier Ghislain

The acoustics of concert halls have been measured, studied, and interpreted with impulse responses for over 100 years [1]. This is a well–justified approach, as the behaviour of sound in a room is a linear system. The sound emitted by a source propagates with the speed of sound to all directions and bounces from the walls dozens of times while reaching the receiver, which is a microphone in the case of acoustic measurements. Thus, the response to an impulse (for instance a popping balloon or a start pistol) covers all possible sound propagation paths and describes the room acoustics between the chosen source and receiver positions. In addition, an impulse response measurement is relatively easy to carry out. One just needs an impulsive sound source on stage (using a loudspeaker) and one omnidirectional microphone, which captures the impulse response at a certain location. Moreover, using several source and receiver positions provides the average characteristics of the acoustics of a particular hall.

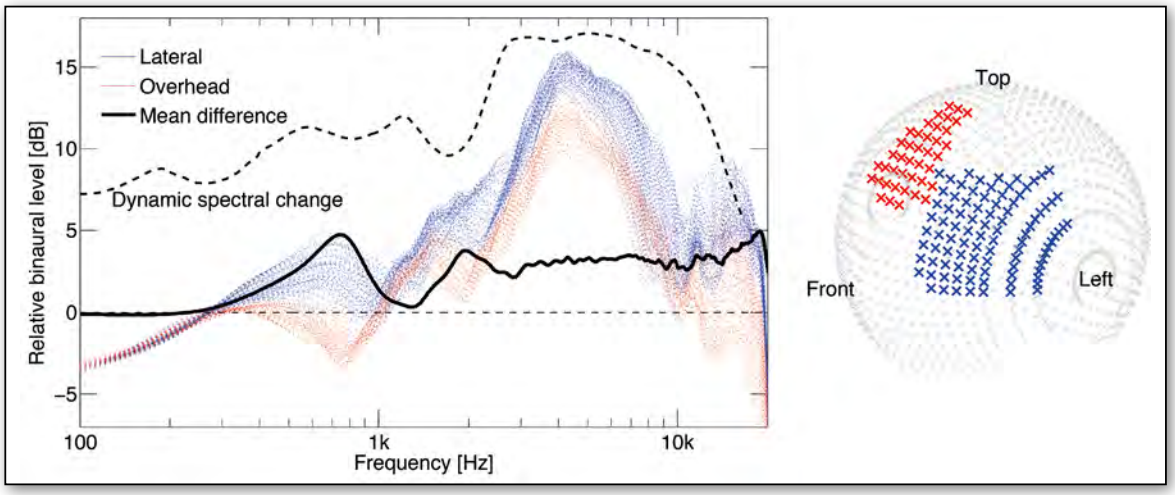
Prominent features

The concept of the impulse response offers a nice way to objectively describe the acoustics of a concert hall. To overcome the analysis of complex signals of the acoustic response, researchers have invented dozens of parameters that aim to describe the prominent features of an impulse response. The most commonly applied parameters have been included in the ISO3382-1:2009 standard. For example, this standard defines the reverberation time, *i.e.*, the time of a 60 dB linear decay of sound energy, or strength, which is the linear amplification of sound relative to sound pressure level at 10 m in the free field. The objective metrics such as these have become the de-facto standard to compare and characterize the acoustic conditions in different concert halls. Consequently, the acousticians designing concert halls try to predict these parameters using scale and computer models to guarantee the acoustical success of the new concert hall. However, experience has shown that tuning the parameters to their optimal range does not necessarily result in a successful concert hall. This has rendered concert hall acoustics somewhat mysterious for many researchers and designers.

Orchestra simulator

Our research team at Aalto University has worked since 2008 towards a better understanding of the acoustics of concert halls. We have applied psychometric methodologies borrowed from the food and wine industry to reveal which features of sound people pay attention to when listening to music in concert halls, and what kind of halls they like [2]. We have taken great care to minimize the uncontrollable variables in the music samples that we present to our subjects to compare and evaluate. For example, to keep the source constant, we have invented a symphony orchestra simulator, an array of 34 loudspeakers on stage [Fig. 1 and Ref. 2] playing anechoic (echo-free) symphony music [3]. In addition, to keep the recording system constant, room acoustics is captured via "spatial impulse responses" [4]. In other words, the measured spatial impulse responses are decoded for spatial sound reproduction system before convolution with anechoic music in order to obtain as natural sounding spatial sound reproduction as possible in laboratory conditions. When subjects then sit in our laboratory surrounded by 24 loudspeakers listening to music, they can switch recordings between different seats and concert halls allowing us to discover interesting results.

▸ FIG. 1: The symphony orchestra simulator on the stage of Vienna Musikverein. © Jukka Pätynen



◂**FIG. 2:** The dashed line shows the difference in power spectrum of a symphony orchestra between *forte* and *piano* playing dynamics. The coloured curves illustrate the binaural magnitude spectrum for sound entering to the ear canal from different directions, which are indicated on the right. Finally, the thick black line is the mean difference for lateral (blue) and overhead (red) directions.

One of the most intriguing results is that some concert halls seem to expand the dynamics of music. It is clearly heard that a full orchestra crescendo from pianissimo to fortissimo is much more powerful and larger in halls which have the classical rectangular geometry, *e.g.*, the Vienna Musikverein or the Berlin Konzerthaus. But, wait a minute! This should not be possible as the acoustics of the hall is linear and measured with linear impulse responses. How can such a linear conveyor of sound compress or expand the dynamics of music? It is well known that human hearing has non-linearities, but this cannot alone explain compression and expansion of music in a concert hall.

Rigorous literature studies do not bring much light to this problem. There are some hints that such a phenomenon has been noted earlier on certain occasions. Beranek [5, p. 509] describes the effect without any explication as "listening is enhanced immeasurably by the dynamic response of the concert hall". Moreover, Marshall and Barron [6] discuss the spatial responsiveness of concert halls, *i.e.*, the widening of sound sources, by writing "a hall seems to respond to crescendi in the music [...] the effect may be perceived non-linearly." But again, no scientific explanation is provided for the apparent change in the musical dynamics.

Spectrum of the orchestra

Enhancement of dynamic expression is not evident from examination of either the hall or human (spatial) hearing alone. But these two are missing the third part of the basic source-medium-receiver communication system: music. What if we include the influence of the excitation signal, *i.e.*, the symphony orchestra, to this communication system? What has not been understood earlier in the context of concert hall acoustics research is that the spectrum of the orchestra changes strongly as a function of played dynamics. Thus, the excitation is non-linear. In a concert, we have the interaction of three simultaneous factors: non-linear excitation (musical instruments); linear sound conveyor (a concert hall); non-linear spatial hearing (human). When the interaction between these three is investigated as a complete communication system, it is hardly surprising that musical dynamics can be perceived differently in different concert halls, as the system contains two non-linear components. Let us explain the main reason for these non-linearities.

Figure 2 summarizes the non-linearities of the orchestra music and the directional spectral changes in the sound entering to the human ear due to the geometry of head and ears. When all musicians in an orchestra are playing, the average difference between piano and fortissimo dynamics is less than 10 dB at low frequencies, around 10 dB at mid frequencies, but over 15 dB above 2 kHz. For some individual instruments, such as a trumpet or a trombone, the difference at high frequencies can be over 40 dB! And these brass instruments seldom play in pianissimo passages, but they enter the ensemble in majestic fortissimos. To conclude, when an orchestra plays loud they excite much more high frequencies than mid and low frequencies. If a concert hall attenuates these high frequencies (due to relatively large absorptive surfaces, for instance), the extra energy of high frequencies in fortissimos is not delivered to the listeners' ears. Moreover, the human spatial hearing has a direction-dependent sensitivity, which works in concert with the hall geometry.

> **"A full orchestra crescendo from pianissimo to fortissimo is much more powerful in halls which have the classical rectangular geometry"**

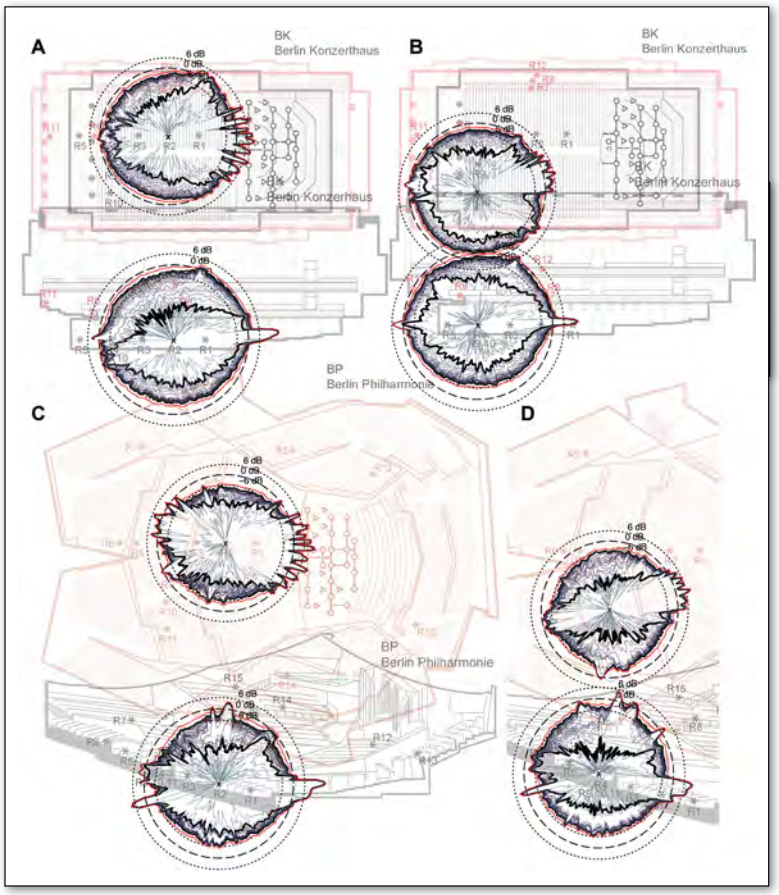
Sound propagation

Now, we need to look at how sound propagates in a hall from the source to the receiver. Listeners in the audience first receive the direct sound from the stage, and then the sound reflected from the walls and the ceiling. The directions of the first reflections are important because the geometry of the human head modifies the sound entering the ear canals. When the sound arrives to the

listener from the side or lateral frontal directions (blue curves in Fig. 2), the high frequencies are amplified more than for the sound reflected from the ceiling (red curves) before reaching the human head. Even though in Fig. 2 the mean difference is only a few decibels, this difference is notably in the same frequency region where the loud orchestra music has more energy than the quietly played music (dashed curve). In summary, when walls and ceiling of a concert hall attenuate high frequencies as little as possible and when the first early reflections are bounces from the sidewalls, the change of the spectrum of orchestral music makes the largest perceived crescendo [7]. Furthermore, auditory masking also plays a role here, but due to its complexity we leave it out in this context.

Figure 3 visualizes the measured spatial sound energy distribution as a function of time at two seats in the Berlin Konzerthaus (BK, rectangular hall) and in the Berlin Philharmonie (BP, audience surrounding the stage). At both seats in BK the early sound energy following the direct sound reaches the listeners from the side or front lateral directions. In addition, the ceiling reflection is not very strong, and arrives much later in time. Therefore, the early sound energy after the direct sound comes from the optimal directions for amplifying the high frequencies as much as possible (see blue curves in Fig. 2). Moreover, there are several of those lateral reflections. In contrast, in BP such early lateral reflections do not exist, but the ceiling reflections are considerably more dominant. Again, as shown in Fig. 2, those reflections emphasize less the high frequencies, which are disproportionally excited more when the orchestra plays loud. This results in weaker fortissimos and reduced dynamics to the audience. To conclude, the rectangular halls provide more reflections that support the high frequencies, which carry the power of loud playing. Thus, it is no wonder why nearly all world-renowned concert halls are rectangular with parallel sidewalls and side balconies.

The acoustics of a concert hall is a great example of research that needs multi-disciplinary understanding of music, room acoustics and human perception. Extensive research has been carried out over several decades without a comprehensive understanding of all involved components of the system. Finally, we have the technology to make rigorous studies on individual components together and this has allowed us to connect the dots and see the bigger picture clearly. Does the research in your field really understand the complete picture - could there be a non-linear component hiding somewhere, making measurements hard to interpret? ■



▼ **FIG. 3:** Spatiotemporal visualizations of sound energy on two equivalent seats in two concert halls (Berlin Konzerthaus, BK, and Berlin Philharmonie, BP). The curves indicate the forward-cumulative wide-band energy at time instants of $t = 5, 10, 20...200$ ms. The thick black curve shows the early energy accumulated from the initial direct sound up to 30 ms. The outermost red curve is the spatial energy distribution of the full room impulse response including the late reverberation tail.

About the authors

Prof. Tapio Lokki and Dr. Jukka Pätynen work at the Aalto University School of Science, Finland. Prof Lokki's multi-disciplinary Virtual Acoustics team has successfully applied sensory evaluation methods to reveal the secrets of concert hall acoustics. The team has invented novel measurement and visualization techniques for room acoustics research and developed listening test methodology to study human auditory perception.
The main funding sources of the team are European Research Council and Academy of Finland.

References:

[1] W. Sabine, "Reverberation: Introduction," *American Architect* (1900) [Reprinted in W. C. Sabine, Collected Papers on Acoustics (Harvard University Press, London, 1922), pp. 3–68]

[2] T. Lokki, "Tasting music like wine: Sensory evaluation of concert halls," *Physics Today* **67(1)**, 27(2014)

[3] J. Pätynen, V. Pulkki, and T. Lokki, "Anechoic recording system for symphony orchestra," *Acta Acustica united with Acustica* **94(6)**, 856 (2008)

[4] S. Tervo, J. Pätynen, A. Kuusinen, and T. Lokki, "Spatial Decomposition Method for Room Impulse Responses," *Journal of the Audio Engineering Society* **61(1)**, 17 (2013).

[5] L. Beranek, *Concert Halls and Opera Houses: Music, Acoustics, and Architecture* (Springer, New York, 2004)

[6] A. H. Marshall and M. Barron, "Spatial responsiveness in concert halls and the origins of spatial impression," *Applied Acoustics* **62**, 91 (2001)

[7] J. Pätynen, S. Tervo, P. W. Robinson, and T. Lokki, "Concert halls with strong lateral reflections enhance musical dynamics," *Proceedings of the National Academy of Sciences of the United States of America (PNAS)* **111(12)**, 4409 (2014)

▲ Cartoon by W. Drenckhan, coauthored by D. Weaire and R. Piazza

ON HOUSE RENOVATION AND COAUTHORING: TRICKS OF THE TRADE TO BOOST YOUR H-INDEX

Roberto Piazza – Department CMIC 'Giulio Natta' – Politecnico di Milano – Italy – DOI: 10.1051/epn/2015103

Suppose that your house needs some restoration, and that you call a master mason asking for an estimate. If the mason replies at once that he will quote 1000 € for himself, plus 500 € for each helper apprentice, you will likely be puzzled, if not annoyed. Surely you have good reasons to complain, reasoning that the job you ask for should be remunerated with a fixed amount, irrespective of the number of labourers involved. Yet, this is not a criterion that we usually apply when evaluating the CV of an applicant for an academic position or for a grant.

We may examine the number of papers the applicant has written, where they have been published, or how many citations they have obtained. More recently, we would surely check the Hirsch h-index [2,3], or exploit more sophisticated indicators. Rarely do we look for the extent of coauthoring: a good paper is a good paper and, in terms of the applicant prestige, it is often regarded to be equally valuable regardless of whether it is signed by one, five, or two hundred coauthors. Possibly, if the applicant is the first author, who presumably did the hard job, or the last one, usually the lab "master mason", you may grant her or him an additional bonus. But that's all. After all, recovering quantitative information of this kind from search services like ISI or Scopus, even something simple as the average number of coauthors per paper, is not immediate (just try!).

Suppose, however, that the mason refutes your argument by claiming that the more people do the job, the better it comes out. You may be skeptical, but you will not easily come out with general abstract arguments in favour or against such a claim. Like a cosmologist who

has a single Universe to investigate, you have just this house to test, and relying on repetitive trials is out of question. In the scientific community, however, grounding discussions about coauthoring are not uncommon. Some colleagues argue that, yes, discouraging excessive coauthoring is probably sensible, but that a penalty consisting in simply dividing the citations of a given paper by the number N of authors is probably excessive. So they suggest using various sublinear forms of rescaling, such as dividing by $\sqrt{N}$, usually on the basis of some kind of *a priori* reasoning. Some others (mostly experimentalists), counter that being able to build up a collaboration network is a virtue that should be acknowledged, hence no scaling should be applied if N is, say, smaller than 5 or 10. When questioned, several high-energy experimental physicists even let the matter drop at once, branding talks of this kind as absurd. The fact is, in contrast to the former case, we *do* have a sensible, albeit not perfect way to quantify how much coauthoring impacts on the recognition of a publication by looking at the total number of citations it has received after some years. Faithful to the experimentalist's motto "In God we trust, all others must show data", let us then try and get some figures [1].

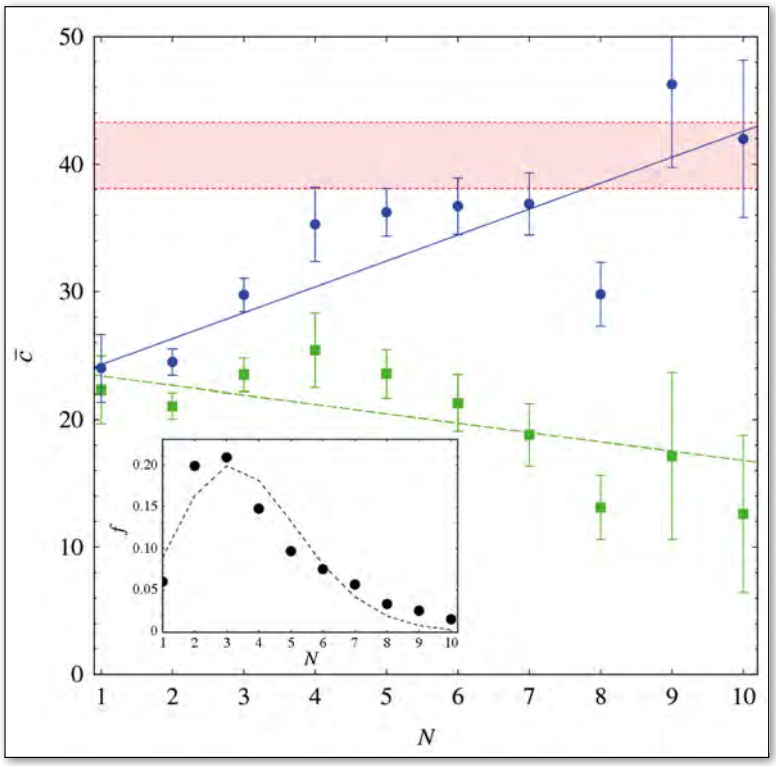
Coauthoring and citations.

Since I am addressing an audience of physicists, I shall focus on Physical Review Letters (PRL), still a reference journal for our community. I have considered the number of citations obtained in the first 6 years, according to ISI Web of Knowledge (WoK), by all manuscripts published in Physical Review Letters in 2007, which amounts to about 3700 records, including comments, but not replies and corrections. I sorted these papers in groups on the basis of the number of authors, and evaluated the average and standard deviation of the number of citations c for each group. A first striking evidence from the results, shown in Figure 1, is that c grows by a mere factor of two when N increases from 1 to 10, namely, just a little more than 8 % for each additional author. Equally surprising is that, as clearly evidenced by the purple band in Figure 1, very large collaborations do not seem to yield, on the average, a much greater impact on the scientific community. In other words, if we "reward" each author just on the basis on the total number of citations he/she has obtained, we are likely to make a big gift to those masons used to work in large groups.

Nevertheless, a moderate increase with N of the "acknowledged value" of a publication seems to be present. At least, if we neglect self-citations. Quantifying the latter for each single record is hard, and the WoK is surely not of great help. Just to get a rough figure, I then simply considered the average fraction of self-citations for those authors (about 150) of the 5% most cited papers who have got an ISI Author Identifier, which turns out to be 0.07 ± 0.01. If we then assume that each of the coauthors contributes to the total number of a citations of a given paper with 7% of self-citations, we may subtract this "spurious" contribution by substituting $c \rightarrow (1\text{-}0.07N)c$. This is of course questionable, since several papers have been probably cited by more than one coauthor, hence the contribution of self-citations is likely to be overestimated. Yet, the result is rather impressive, for the net data obtained this way (squares in Figure 1) even show a slight apparent *decrease* with N. We may conclude that the scientific impact of a paper is roughly independent of N.

Coauthoring and excellence.

Yet, the fact that a multi-authored article is *on the average* not cited more than a paper originating from a single small group may not be the real issue. Perhaps, young scientists (but also experienced group leaders) long for collaborations because they believe this gives more chances to a publication of entering the restricted heaven of *excellent*, outstanding papers. Besides, the story may not be the same for different research areas in physics, an aspect which is not captured by a crude analysis of the total number of citations. Once again, let's have a look at real data. Things are relatively easy if one considers only those papers that are awarded a little "gold cup" in the WoK because, according to the Essential Science Indicators (ESI), they score within the 1% more cited papers, in a given year, within a subfield of a discipline. Hence, I have considered *all* papers published by PRL within the past decade (2004-2013) that should be regarded as "excellent" according to the ESI. Let us first discuss the results obtained for those



▼ FIG 1: Average number of citations $\bar{c}$ versus the number N of authors at the end of 2012 for the manuscripts published in PRL in 2007 with $N \leq 10$ (blue dots). The full line is a linear fit with slope (0.08 ± 0.02) N. The purple band shows the number of citations (within $\pm 1\sigma$) of the papers with $N>10$, which are about 8 % of the total. When self-citations are tentatively removed by rescaling $\bar{c}$ by a factor $(1+0.07N)^{-1}$, the corrected data point (green squares) show no significant change, or even a slight decrease, with N. Data are obtained from a set of about 3400 records, with the distribution shown in the inset, and compared with a Poisson distribution having the same mean (dotted line).

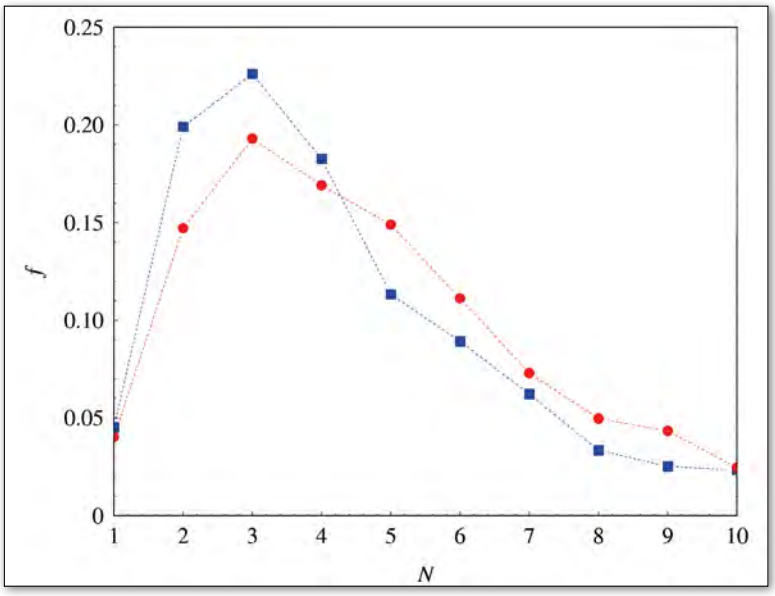
papers with $N \leq 10$, which amount to about 1900 articles over a total of more than 38000 papers published by PRL in the decade. Their relative frequency distribution as a function of the number of authors, shown in Figure 2 with red dots, is of course far from being uniform, just because such is the total number of submitted and published papers (see the inset in Figure 1). To compare consistently with the latter, I have considered an equal number of papers, selected by merely sorting them, for each year, in terms of publication date. Which means, basically, at random. The results I obtained are shown by the blue squares in Figure 2. Although statistically significant differences *can* be spotted, so that increasing the number of authors seems to give a slightly larger chances of making a very successful paper, these are minimal: for instance, the average number of authors in the distribution of excellent papers (about 4.5) is very close to the value obtained for the distribution of randomly selected PRL papers (about 4.1). PRL articles with $N > 10$ account for about 16% of the ESI selected papers, whereas they amount to only 10% of the total number of published papers. Sticking to our analogy, if the master mason summons a large group of apprentices - say, 100 - the chance they make a superior job increases by 60-70% with respect to the case of the master working alone: remember, however, that we pay *fifty* times more. Summing up, I am prone to conclude that the "merit" of a scientific publication, as judged by the number of citations it obtains, or by its chance of "scoring at the top", does not substantially depend on N. Hence, in the absence of further information on the role played by each author (of the kind provided for instance by several biological or medical journals), credit should be shared in equal parts by all coauthors.

Does quality require quantity?

In bibliometric assessments, taking into account the former "profit sharing" considerations in detail is not trivial [4]. A crude but reasonable approach is simply rescaling the total number of the citations of a scientist by the *average* number of authors of her/his papers, or, in the case of the h-index, by the average number of authors of her/his h most cited papers [5,6]. (A more sophisticated approach has been taken by Hirsch himself [7], who introduced a so-called "$\hbar$-index", roughly defined as follows: one of your papers contributes to your ħ-index if it contributes also to the $\hbar$-index of *all* your co-authors.)

A further excursus on the h-index is, however, appropriate. Because it is so easy to evaluate, but more so because of its statistical robustness, the Hirsch index has rapidly ascended the throne of bibliometrics as a single number summarizing the success of a scientist: I myself must confess of having been a fan, almost a zealot of this brilliant, straightforward approach since it was originally proposed. Yet, how much additional information does the h-index *really* convey? We may reasonably expect h to scale with $\sqrt{c}$ (at least, $\sqrt{c}$ is obviously an upper bound for h). But is there any relation between h and the total number of papers an author has published? To this aim, I have considered the 10% most cited papers published in PRL in 2012, examining (manually) the individual citation reports of all those authors, 470 in total, who appear to have an ISI Author Identifier. As can be reasonably expected, if n_p is the total number of papers an author publishes, the ratio h/n_p (which we may regard as a kind of "success ratio") rapidly decreases with n_p. Actually, Figure 3 shows that h is quite well fitted by a linear dependence on $\sqrt{n_p}$, except for $n_p \geqslant 400$, where some saturation may occur. What is really surprising is the very limited dispersion of the data around the mean. As a matter of fact, the ratio of the actual h-index for each individual author to the value $\bar{h}(n_p)$ obtained from the fit has an approximately Gaussian distribution, with a standard deviation σ=0.23.

In simple words, this means the following: tell me the total number of papers you have published, and I'll predict your h-index within 20-30 % accuracy. More seriously, this result cast doubts on the amount of novel information the h-index carries *per se*, besides a simple reshuffling of basic information about the total scientific productivity of an author. Notice that even more refined bibliometric parameters like the "contemporary h-index" [8], which suitably takes into account the total duration and trend of the scientific production of an author, would not perform much better. (In fact, provided that these



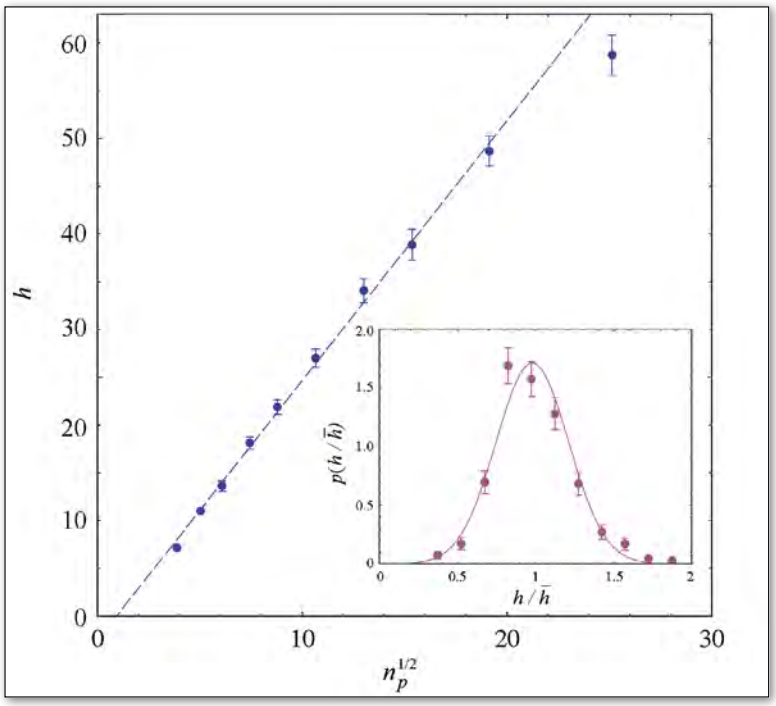
▲ FIG 2: Frequency distribution versus the number N of coauthors of the papers published in PRL in the decade 2004-2013 considered as "outstanding" according to the Essential Science Indicators (red dots), compared with the distribution of an equal number of published papers, randomly selected according to the publication date (blue squares).

> **The merit of a scientific publication, as judged by the number of citations it obtains, does not substantially depend on the number of authors**

general observations are confirmed by testing a much larger and varied sample besides the selected one I have considered, a more meaningful bibliometric parameter would actually be the fractional *deviation* $\delta h = h/\bar{h}(n_p)$-1). The observed correlation between h and n_p together with the basic independence of the value of a scientific paper on N, could be particularly deleterious for the community of experimental high-energy or nuclear physicists, whose h-indices, besides being typically larger than the average, have a distribution with a quite smaller relative standard deviation $\sigma h/\bar{h}$ [1]. Hence these authors form a rather homogeneous group in term of their overall "scientific success", which of course makes it harder to discriminate among different scientists on the bases of the h-index.

To conclude, I am surely not claiming the little evidence I dug out to be conclusive or comprehensive: this little *divertissement* should not be taken too seriously, for any sound conclusions must be corroborated by a much more extensive and rigorous statistical analysis, which could easily be performed by appropriate organizations such as ISI or Scopus. My aim has simply been to try and shift the discussion about the impact of coauthoring from abstract reasoning to real data analysis. Nevertheless, the former observations surely lead me to two considerations. First, in the future I would not like to take part in committees where hiring or funding of young scientists is made only on bibliometric bases, renouncing to the pleasure of interviewing, even shortly, the candidates. Second, I came to believe that no bibliometric approach to hiring and promoting, however refined, will ever ensure a real improvement of our academic institutions, unless there are ultimate motivations *to long* for scientific quality. And, at least within some national communities, this should not be necessarily taken for granted. ■

▼ FIG 3: Hirsch index h as a function of the square root of the number of published papers n_p, for a set of 470 scientists co-authoring the 10% top cited papers published by PRL in 2012. The quantity $\bar{h}$ is derived from n_p according to the fit $\bar{h}(n_p) = (2.72\pm0.05)\, n_p^{1/2}$-(2.5±0.5). The inset shows the frequency distribution of the quantity $h/\bar{h}(n_p)$ for the whole set of investigated authors and fitted with a Gaussian with standard deviation σ=0.23.



Acknowledgements

The original version of this paper [1] has been prepared while I was in Cambridge as a visiting professor: I thank Pietro Cicuta for having given me the chance to work in such a stimulating environment. I also took pleasure from discussing these issues with several colleagues, and in particular with Wilson Poon, a scientist well on the right (in both senses) side of the Gaussian in Figure 3. I am finally extremely grateful to Wiebke Drenckhan, who, besides bringing Ref. [1] to the attention of EPN, contributed to this paper with the splendid opening cartoon.

About the author

Roberto Piazza is full professor of Condensed Matter Physics in Politecnico of Milan, after having got his PhD from the University of Pavia and having worked as a research associate at the University of Pittsburgh. He has also being invited professor at the École Normale Supérieure in Lyon and Leverhulme visiting professor at the Cavendish Lab in Cambridge.
His research has been mostly devoted to the experimental investigation of soft matter systems ranging from colloidal suspensions to surfactant and protein solutions. Currently, he is Section Editor for liquids, soft matter, and biological physics of the Journal of Physics Condensed Matter.

References

[1] A preliminary version of this paper, containing some additional technical details, can be freely download from the arXiv:1307.5647 [physics.soc-ph].

[2] J. E. Hirsch, An index to quantify an individual's scientific research output, *Proc. Natl. Acad. Sci. U.S.A.* **102**,16569 (2005).

[3] P. Ball, Index aims for fair ranking of scientists, *Nature* **436**, 900 (2005).

[4] As a matter of fact, rescaling by the number of authors of each single publication is automatically feasible using software like "Publish or Perish". Provided of course you fully trust the Google Scholar database on which this programme is based: just a matter of taste.

[5] P, D. Batista, M. G. Campiteli, O. Kinouchi, Is it possible to compare researchers with different scientific interests?, *Scientometrics* **68**, 179 (2006)

[6] Several drawbacks of this simple approach can be eliminated by introducing a "fractional count" of the papers, see M. Schreiber, A modification of the h-index: The hm-index accounts for multi-authored manuscripts, *Journal of Informetrics* **2**, 211 (2008)

[7] J. E. Hirsch, An index to quantify an individual's scientific research output that takes into account the effect of multiple coauthorship, *Scientometrics* **85**, 741 (2010)

[8] A. Sidiropoulos, D. Katsaros, and Y. Manolopoulos, Generalized Hirsch h-index for disclosing latent facts in citation networks, *Scientometrics* **72**, 253 (2007)

THE EUROPEAN SCIENCE FOUNDATION; DEATH OR MID-LIFE CRISIS?

Martin Hynes – Chief Executive – The European Science Foundation – Strasbourg, France – DOI: 10.1051/epn/2015104

It was a 40th birthday party with a difference [1]: to celebrate a lively and eventful past (Figs. 1, 2), but with no clearly-defined future. However, what might have been a wistful event turned into a surprisingly lively one. It applauded the achievement of researchers and the great benefits of European collaboration in science. A commemorative booklet was published for the event and a number of associated events held. Highlights from the past were celebrated; but what does the future hold?

With 40 years' experience in all areas of research, the European Science Foundation (ESF) was originally set up to act as a coordinating body for Europe's main research funding and research performing organisations. But as the research landscape evolved, so did ESF's role in supporting scientific endeavours.

Some members began to express frustration that the organisation had grown too large and distant from its original mission. At a time of national financial crisis in most countries, members wishing to downsize their international payments considered the future of the association. Indeed, when a vote was held in May 2011, the result was very close to a formal decision to dissolve the organisation directly.

At the same time, some European Heads of Research Councils (EuroHORCS) and ESF members decided to establish a separate body in Brussels with the mission to act as the policy body for elaboration of common positions. The resulting *Science Europe* was designed to be slim and agile, supported by strong Scientific Committees [2] and acting primarily in a policy role; the intention was to not reproduce the funding instruments and tools of ESF.

Developing this focus, members decided that the combined budget for both ESF and *Science Europe* should not exceed the peak of funding allocated in the 2011 general budget for ESF alone. Clearly, this implied a strong downward trajectory on ESF financial resources — a reduction of Euro 15.4 Million in member contributions for 2015 compared to 2010 (Fig. 3).

Adapting to these budget cuts, and in accordance with the members' wishes, ESF is winding down its traditional networking activities to reach completion by the end of 2015. Its policy activities have been transferred to *Science Europe*, and staff numbers dramatically reduced.

However, ESF has the experience and agility to develop solutions and services to face challenges and turn them into opportunities.

▾ **FIG. 1:** ESF Chief Executive, Mr. Martin Hynes and President, Professor Pär Omling, during the 40th anniversary celebrations in Strasbourg, May 15-16, 2014.

A new trajectory

A number of strategies for a new mission for ESF have been assessed. At the 2014 Assembly, the members agreed to allow business planning to proceed with a go/no-go deadline of end May 2015. If the business planning is accepted at that time, the existing association will not be dissolved.

With a new approach to working as a service provider rather than a wholly member-funded organisation, ESF is supporting the future of a globally competitive European Research Area by concentrating on activities designed to support and sustain the funding and conduct of scientific research across Europe. The aim remains to promote scientific developments through collaborative actions, but with the emphasis shifting to helping research funding organisations carry out their decision making processes. It is probable that members will decide to change the name and trading style.

The essential core of evidence-based support to scientific decision making will centre on: Peer Review [3], Evaluation [4], Expert Hosting, and Project Management.

Peer Review

ESF's European Peer Review Guide [5] (2011), issued on behalf of its members, and created from an in-depth analysis of peer review processes implemented by the leading European public research funding organisations, gave rise to considerable interest in good practice in this activity. ESF has been requested to carry out project work for many Member Organisations as well as other not-for-profit organisations. The work with the AXA Research Fund has proved particularly fruitful in delivering effective views of scientific excellence and in expanding the capabilities of both organisations. Further examples are listed on the ESF website at www.esf.org/serving-science/peer-review/experience-and-references.html.

Evaluation

Similarly, evaluation services spring from a long-term dialogue with members on appropriate structures and methodologies. In 2012, ESF conducted a detailed review of scientific evaluation practices across European research organisations and issued a Member Organisation Forum report entitled *Evaluation in Research and Research Funding Organisations: European Practices* [6]. Recent projects include organisational evaluation and reports on the Research Council of Lithuania [7] and the Hungarian Scientific Research Fund (OTKA) [8].

Specialised approach and practice

ESF can provide expert reviews for specific competitive calls or full-scale call management, covering all aspects including planning and coordination of specialised peer

▲ FIG. 2: ESF's 40th anniversary celebrations.

review and research evaluation assignments. With its highly regarded and experienced reviewers, ESF is able to provide outstanding scientific peer review support to institutes or organisations implementing competitive calls across all scientific domains. The process ensures that research proposals and applications are assessed for scientific quality, validity, significance and originality. The collective achievements of a funding programme can subsequently be evaluated to assess the overall effectiveness, outcomes and impact of the programme, while identifying improvements or policy implications for the future.

ESF is positioned as a benchmark peer review and evaluation provider at the European and international level.

Expert Hosting

For many years, ESF has hosted Expert Boards and Committees [9] with strong knowledge and experience of influencing ministerial and other high-level forums at the European and international level. These boards and committees have the expertise and authority to wield influence with decision makers and funding agencies. The Expert Boards and Committees develop the strategic approach to their domains in close collaboration with national authorities in member nations or European-wide agencies and research entities. They are composed of high-level independent researchers or research managers, nominated by their stakeholders to provide targeted expert advice in areas of science, policy, infrastructure, environment and society in Europe.

The 2011 Statutory Review of the Expert Boards and Committees [10], chaired by Professor Martin C.E. Huber, made a number of important recommendations regarding the future of these bodies - concluding *"that all Boards and Committees provide scientific services in the European or even global framework that are indispensable for Europe's scientific landscape"*. The report observed on the possible hosting in future under the aegis of Science Europe.

Following further review and discussion, Science Europe concurred that the Boards and Committees were of value within their domains and that there was potential benefit to collaborating with these interdisciplinary groups. However, it felt that Science Europe would not be the appropriate platform from which to operate. For the successor to ESF, the maintenance of this platform and collaboration is of central importance.

> **"ESF has the experience and agility to develop solutions and services to face challenges and turn them into opportunities"**

Project Management

ESF can call on unrivalled experience managing both individual research projects and larger programmes at the international level. ESF has managed a considerable number of scientific projects funded by the European Commission and Member Organisations, supporting and collaborating with national institutions.

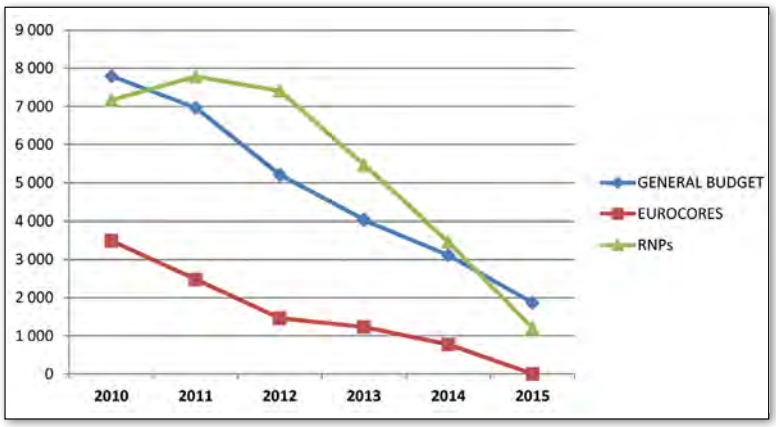
The COST Programme (European Cooperation in Science and Technology) was the largest at €250 Million during the duration of Framework Programme 7. In the frame of the ESF disengagement from the management of COST activities, a new legal entity, the COST Association, has now contracted with the EC under the new H2020 Framework Programme.

Having designed and implemented numerous collaborative programmes, including the Research Networking Programmes (RNPs) and EUROCORES (EUROpean COllaborative RESearch) scheme, ESF has enabled research teams in different European countries to collaborate in areas where European-wide scale and scope with cross-border cooperation were essential. Another example is its coordinator role in the FET Flagship project, Graphene.

An example of providing key support for European decision making is the MERIL [11] project, initially supported with Commission funding but now being advanced with members' support. The Mapping of the European Research Infrastructure Landscape project is an online database of research infrastructures across all fields of research in Europe. The resulting web portal gives an easily searchable list of openly accessible research infrastructures in Europe that are of more than national relevance across all scientific domains: http://portal.meril.eu/converis-esf/publicweb/startpage?lang=1

ESF has particular expertise in the management of large, complex scientific programmes spanning different European countries and systems.

▾ **FIG. 3:** The annual contributions from ESF Members in k€. Note a reduction of 15.4 Million € in 2015 compared to 2010. EUROCORES is the EUROpean COllaborative RESearch scheme, and RNPs are the ESF Research Networking Programmes described at: http://www.esf.org/coordinating-research/research-networking-programmes.html



Membership

The November 2014 Assembly adopted amendments to the ESF statute that facilitate new types of membership in the organisation. Members can decide between taking part in the management and administration of the organisation, with voting rights and related responsibilities, or taking on a purely advisory role.

Full members are required to pay an annual contribution and, as a result, have access to ESF services at a preferential rate. Associate members are able to donate expertise and referees to help smaller countries develop their research programmes and smart specialist areas, thus assisting the development of science in the European Union. ■

About the Author

Martin Hynes qualified as an Engineer. He commenced his career with the Westinghouse Electronics and Controls Company, followed by 10 years at the National Metrology service and new NML facilities in Ireland. He devoted the past two decades to research policy and research support systems, *i.a.* as Director of the Irish Research Council for Science, Engineering and Technology, IRCSET. His work in promoting French / Irish research collaboration was acknowledged by the award of the *Chevalier des Palmes Académiques*. He also received an award from the President of Ireland for excellence in research support. He was appointed Chief Executive of ESF in November 2011. He is a Chartered Engineer and Fellow of the Institution of Engineers, and completed an MBA at University College Dublin.

References

[1] http://40years.esf.org/

[2] www.scienceeurope.org/scientific-committees/the-scientific-committees/

[3] www.esf.org/fileadmin/Public_documents/Publications/peer_review.pdf

[4] www.esf.org/fileadmin/Public_documents/Publications/evaluation.pdf

[5] www.esf.org/fileadmin/Public_documents/Publications/European_Peer_Review_Guide_01.pdf

[6] www.esf.org/fileadmin/Public_documents/Publications/mof_evaluation.pdf

[7] www.esf.org/fileadmin/Public_documents/Publications/RCL_evaluation.pdf

[8] www.esf.org/fileadmin/Public_documents/Publications/otka_evaluation_01.pdf

[9] www.esf.org/hosting-experts/expert-boards-and-committees.html

[10] www.esf.org/fileadmin/Public_documents/Publications/StatutoryReviewExpBoComm.pdf

[11] www.esf.org/serving-science/ec-contracts-coordination/meril-mapping-of-the-european-research-infrastructure-landscape.html

HEARING OVERCOMES UNCERTAINTY RELATION

AND MEASURES DURATION OF ULTRASHORT PULSES

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The human hearing sense is an astonishingly effective signal processor. Recent experiments [1, 2, 3] suggest that it is even capable of overcoming limitations implied by the time-frequency uncertainty relation. The latter, mostly known from quantum mechanics, requires that the product of uncertainties in time and frequency, $\Delta t \cdot \Delta f$, cannot be smaller than the limiting value $\Delta t \cdot \Delta f = (1/4\pi)$, which holds when the signal is a harmonically oscillating function with a Gaussian envelope.

The acoustic pressure of such a signal is $p(t)=p_0\exp(-t^2/2(\Delta t)^2)\cos(2\pi f_1 t)$, where f_1 is the underlying frequency. The spectrum of the signal is also Gaussian, $p(f)=p_0\exp(-(f-f_1)^2/2(\Delta f)^2)$ and the widths of the two Gaussian functions are inversely proportional to one another.

Whereas the theorem follows directly from properties of the Fourier transform, its significance both in quantum mechanics and in macroscopic physics is still debated. The problem resides in the meaning of words such as "width", "extent" or "uncertainty" in the theory of signal processing and in statistics. According to the standard quantum mechanical interpretation a sufficiently long measurement time is needed to achieve a prescribed precision in determination of the energy $E=hf$ of a stationary quantum state. Shortening the duration time of a pulse leads to broadening of its spectrum. Broadband properties of attosecond optical pulses are now investigated for applications in condensed matter studies [4]. Here we propose some simple acoustic tests that help to elucidate the extraordinary abilities of the human hearing when exposed to pulses of duration times comparable to or shorter than one oscillation cycle. This is what we call ultrashort pulses.

The ear is a frequency detector. In particular, a periodic acoustic signal of frequency f produces a sensation of pitch H (the tone height). A known tune, *i.e.*, a sequence of sounds of different pitches, is recognizable as long as the frequency ratios of the consecutive sounds are conserved. This impressive equivalence of pitch differences – called musical intervals – to frequency ratios implies that the pitch-frequency relation is strictly logarithmic. For example, in the conventions adopted by MIDI (Musical Instrument Digital Interface) the relation reads $H=69+12\log_2(f/440\text{Hz})$. The exact evolutional and physiological foundations of this relation are not well understood to the best of our knowledge.

Among all periodic signals the purely sinusoidal ones, called pure tones, are the closest counterparts of stationary quantum states. They are mostly exploited in what follows. The presence of higher harmonics, which does not affect the periodicity of the signal, results in changes in what is called timbre (tone colour) of the sound.

Sinusoidal signals with Gaussian envelopes

The test ep220_cos.mp4 [t1] is designed to allow the reader to appreciate the effect of a Gaussian envelope on the perceived pitch of a pure tone. The listener is provided with three sounds: i) a relatively long reference tone, ii) a cosine signal $\cos(2\pi f_1 t)$ wrapped in a Gaussian envelope $\exp(-t^2/2(\Delta t)^2)$ and iii) the envelope alone. The fundamental frequency is f_1=220Hz and the width Δt of the envelope decreases in the consecutive sequences in the range from 22.7 ms to 0.0227 ms. Detailed instructions for the test are supplied in Box 1.

The results obtained for three test persons (three of the authors) are shown in Fig. 1. All persons notice an increase in the perceived pitch f_p with decreasing envelope width Δt. The pitch of the sole envelope f_{EP} (Envelope Pitch) starts to be noticeable if Δt is less than about 1.13ms. The test persons report the two to be equal, $f_{EP}=f_p$, for extremely short pulses, Δt=0.159ms. We invite the reader to listen to the test ep220_cosRETRO.mp4 [t1] to appreciate the effect at a different aspect. The fact that the effective perceived pitch f_p of a short signal is higher than the pitch corresponding to the frequency f_1 of the underlying cosine indicates how our sense of hearing overcomes the uncertainty principle. The time needed to determine a higher frequency is, put simply, shorter. Now we have to find a mechanism to explain this rise in pitch. A hint is visible in Fig. 1 where a significant number of results concentrate around the frequency $f_p = 3\times f_1$, *i.e.*, that of the third harmonic. The signal seems, therefore, to be nonlinearly processed (distorted) prior to reaching the heart of the detector, *i.e.*, the basilar membrane of the cochlea. The nonlinear distortion may take place in the ear itself as well as outside. Another reason for the increase in the pitch, this time of purely linear origin, can be related to the broadening of the spectrum with decreasing duration, so that some higher frequencies, not necessarily harmonic, are also presented to the ear. In any case, the ratio f_p/f_1 is an estimate of the factor by which the uncertainty relation is "beaten" by our hearing organs. The factor is roughly constant in the region where the supposed third

BOX 1: TEST FOR THE EFFECT OF GAUSSIAN ENVELOPE ON THE PITCH OF A PURE TONE

In the test en220_cos.mp4 the listener is asked to determine the pitches of three consecutive sounds. The first reference sound is a long cosine signal so that its pitch is readily recognizable. The second sound is a cosine signal $\cos(2\pi f_1 t)$ wrapped in a Gaussian envelope $\exp(-t^2/2(\Delta t)^2)$. The width Δt of the Gaussian decreases in the consecutive sequences. The third sound is the Gaussian envelope alone. The signal underlying frequency is f_1=220Hz. The reference sound has a frequency $3\times f_1$ (third harmonic of the signal). The width Δt decreases with time of the experiment in the following manner: i) starting from $1000/F_s$=22.676 ms to $200/F_s$=4.535 ms by $50/F_s$=1.135 ms and: ii) from $199/F_s$= 4.533 ms to $1/F_s$=0.0227 ms by $1/F_s$ where F_s=44100 s^{-1} is the standard sampling rate in the *.wav format of sound files. The listener sees the number of the experimental sequence and the corresponding width of the envelope in ms on the screen. This allows one to trace curves analogous to Fig. 1. The test Env220_cosRETRO.mp4 contains the same sounds in order of decreasing Δt.

BOX 2: TEST FOR EFFECTIVE ENVELOPE PITCH OF A GAUSSIAN PULSE

The test eep.mp4 consists of pairs of sounds. The first sound is a cosine wave of frequency 660 s^{-1}, long enough to easily determine its pitch. The second sound is a pure Gaussian envelope $\exp(-t^2/2(\Delta t)^2)$. The maximum amplitudes of the signals are equal. The width Δt of the Gaussian decreases with the number of pairs in the manner analogous to Box 1 i) starting from $1000/F_s$ to $200/F_s$ by $50/F_s$ and ii) from $199/F_s$ to $1/F_s$ by $1/F_s$, where F_s=44100s^{-1} is the standard sampling rate The sequence number and the width in ms are visible on the screen. The listener is asked to attribute an interval to each pair of sounds heard. The corresponding frequency $f_{EP}(\sigma)$ should be calculated knowing the frequency ratios defining each interval (see, *e.g.*, http://en.wikipedia.org/wiki/List_of_pitch_intervals). Listeners with absolute pitch hearing may find the reference sound redundant. The listeners without knowledge of musical intervals may give their responses in terms of beginnings of known tunes. Multiple listening to the test may give more precise results. Sometimes subjects hesitate to attribute a perceived interval due to the approximate character of the Effective Envelope Pitch. The responses may also be different for subjects who are accustomed to different intervals than those used in European music. The file eepRETRO.mp4 presents the sequence in order of increasing Δt.

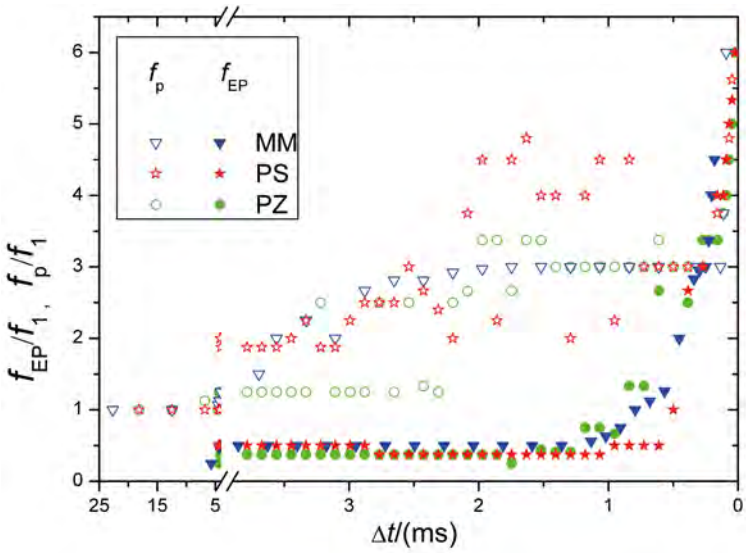
harmonic is generated and, at the same time, the pulse is too short to allow the fundamental frequency to be detected. A significant increase in the factor is visible for extremely short pulses. Noteworthy is that the "beating of the uncertainty principle" by more than a factor of ten, as reported in [2], concerns essentially quantities which are of a very different nature than the pulse's duration time Δt.

The shorter the sharper

An intriguing result of the test discussed above is that a certain pitch is attributed to a purely Gaussian pulse without any underlying periodic signal. The pulse must be very short for this to be the case, *i.e.*, Δt<1.5ms. One may realize that such pulses are in fact clicks or snaps. In other words: they are point-like events on the axis of time. The shape and the duration of such pulses are surely beyond the reach of human perception. Yet differences in what can be qualified as pitch or timbre offer the possibility to obtain insight into such properties. Let us have a closer look at the phenomenon.

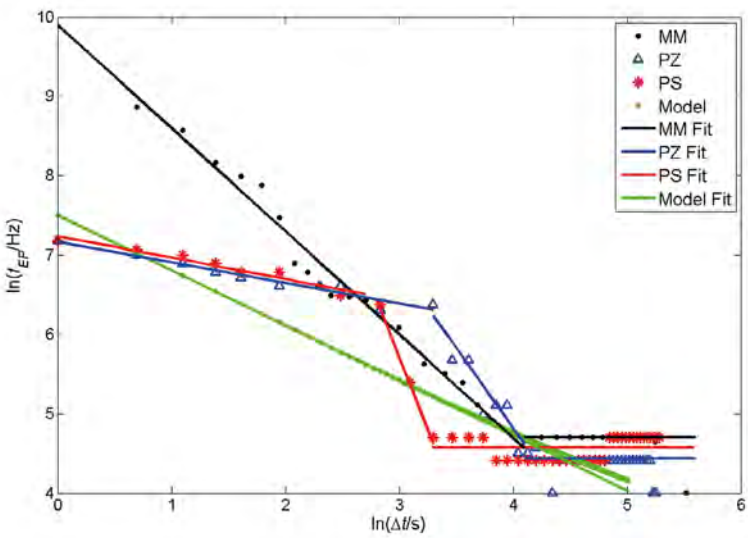
The dependence of the frequency f_{EP} (the perceived pitch of the envelope alone) on the pulse's width Δt can be studied with the test eep.mp4 [t2] described in Box 2. The listener is asked to determine the musical interval between a relatively long reference tone and the pulse. Knowing the intervals in terms of the frequency ratios one can trace the desired function $f_{EP}(\Delta t)$. It is clear that the shorter pulses appear sharper. The results obtained by the authors are represented in Fig. 2 as a log-log plot.

The incontestable straight-line behaviour indicates a power law $f_{EP}(\Delta t)\cong 1/\Delta t^{\alpha}$. It is interesting that the exponent α is almost identical for the two test persons who lack an absolute pitch hearing (α=0.271±0.031 for PS and α=0.260±0.023 for PZ) and much higher for the only test person who does have absolute pitch hearing

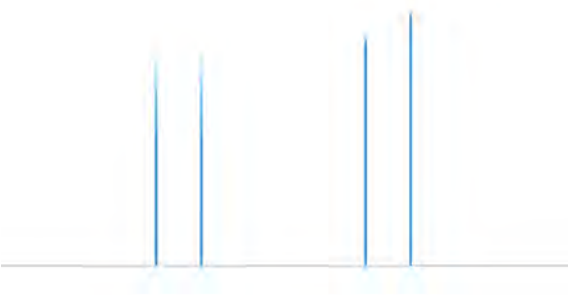


▲ **FIG. 1:** Effective pitch of a cosine signal with a Gaussian envelope and the pitch attributed to the envelope itself as a function of the pulse's duration Δt, for three different test persons (MM, PS and PZ). Here, f_1 is the frequency of the enveloped cosine signal, f_p the perceived pitch of the enveloped cosine signal and f_{EP} (the envelope pitch) the perceived pitch of the envelope itself.

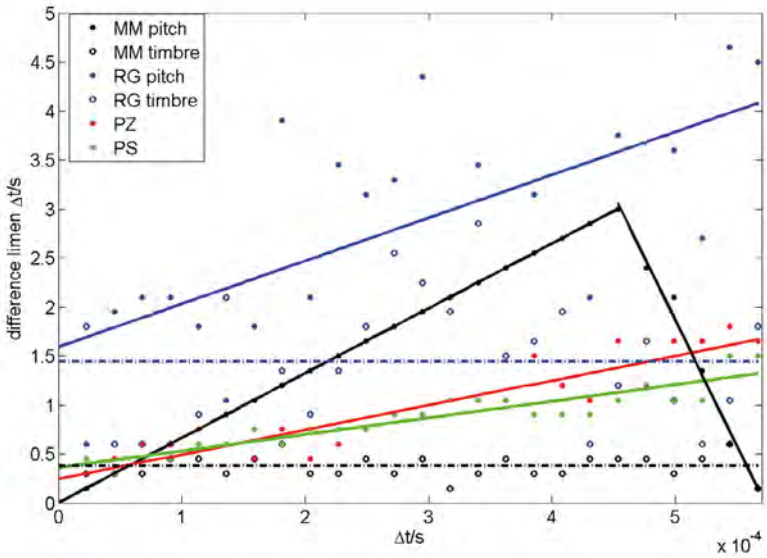
▼ **FIG. 2:** Pitch attributed to purely Gaussian pulses (envelopes only) as a function of duration Δt.



▼ FIG. 3: Assessment of the width of two narrow lines of equal area, using their height as a key.



▶ FIG. 4: Just noticeable difference in pulse width *vs.* pulse width as detected by the authors (MM, RG, PZ and PS). The lines represent linear fits.



(α=1.30±0.05 for MM). A plausible mechanism of the sensation of the envelope pitch is that the spectrum of the pulse is filtered by the ear in such a way that the maximum of the filtered spectrum shifts towards higher frequencies with increasing width Δf of the incoming spectrum, *i.e.*, with decreasing duration Δt. To model such a filter we adopted the idea of Helmholtz that an incoming signal excites a series of damped oscillators, each of which tuned to its own distinct *eigenfrequency*. The effective pitch corresponds to the oscillator that, when excited by the pulse, attains the highest amplitude. More details on the model can be found in [3]. The frequency of the most excited oscillator is also shown in Fig. 2. The power law is satisfied to great accuracy in the region studied, but the exponent is still different: α_{theory}=0.6939±0.0005.

Sensing submillisecond time intervals

It is clear that the increase in the effective pitch with decreasing duration Δt is most significant for the shortest pulses. This follows, of course, from the uncertainty principle for Gaussian envelopes: $\Delta f=1/(4\pi\Delta t)$. Therefore, paradoxically, changes in the duration are most easily discernible for the shortest pulses. A similar effect occurs in the assessment of the width of a line drawn on a paper as depicted in Fig. 3. It is not easy to detect a difference in width of the two vertical lines on the left hand side. The difference is, however, immediately clear if the area covered by each line, *i.e.*, the product of its width and length, is known to be constant, as is seen on the right-hand side.

A practical measurement of the duration of a Gaussian pulse with the use of its spectral properties raises the question of the discriminability – also known as the just noticeable difference – $d_l\Delta t$ (difference limen) of duration times. With the tests described in Box 3 [t3] the reader will find for herself/himself the smallest noticeable difference $d_l\Delta t$ as a function of Δt. The experience of the authors suggests that, when provided with two short purely Gaussian pulses of slightly different widths, some people distinguish two qualities: the effective pitch and the timbre. More precisely, if the duration times are very close, some subjects judge the pitches equal although they still notice a difference, which can be qualified as a difference in timbre. The results obtained by the authors indicate that the 'difference limen' associated with the effective pitch is fairly proportional to the duration of the pulse. Thus, it follows the Weber-Fechner law [5] stating that $d_l\Delta t/\Delta t=const$. In contrast, the difference limen as judged by the timbre

BOX 3: TEST FOR DISCRIMINATION LIMEN OF DURATION TIMES OF GAUSSIAN PULSES

The reader can check the discrimination limens for the width parameter Δt of Gaussian signals exp($-t^2/2(\Delta t)^2$) in the range $1F_s<\Delta t<25/F_s$, *i.e.*, 0.023ms<Δt<0.567ms, where F_s=44100s^{-1} is the standard sampling rate. There are 25 files here, each corresponding to the initial width parameter $\Delta t=NN/F_s$ where the integer number *NN* is indicated in the file name dlNN.mp4. Each file contains a series of pairs of sounds. The first sound has width parameter $\Delta t=NN/F_s$ and the second $(NN+n\cdot d\Delta t)/F_s$, where $d\Delta t=0.15/F_s$. The listener is asked to indicate the pair number n_l for which the sounds start to appear different. The corresponding difference $n_l\cdot d\Delta t/F_s=d_l\Delta t$ is an estimate of the discrimination limen sought. The Weber-Fechner law is satisfied if the discrimination limen is proportional to the initial width $\Delta t=NN/F_s$.

turns out almost independent of Δt, *i.e.*, $d_i \Delta t = const$. Two of us noticed just a difference without paying attention to the nature of the difference. The results were then just linear combinations of both behaviours as seen in Fig. 4. The values of the constants depend on the subject. The readers may try to trace their own curves.

In conclusion, simple acoustic tests are able to reveal mechanisms which make the ear overcome the uncertainty relation. The same mechanisms allow a human subject to distinguish the duration times of very short acoustic pulses provided that the shapes of the pulses are well defined. This phenomenon may be useful in designing devices aimed at measuring parameters of ultrashort pulses. ■

About the Authors

Marcin Majka, MSci (first from the left) and **Paweł Sobieszczyk**, MSci (first from the right) have graduated from the Cracow University of Technology (CUT). They are now PhD students at the H. Niewodniczański Institute of Nuclear Physics of Polish Academy of Sciences. They work under supervision of prof. **Piotr Zieliński** (second from the right) on various aspects of wave propagation, in particular of surface waves, in solids and fluids. **Robert Gębarowski** (second from the left), PhD at CUT specializes in atomic physics. He has an experience in studies of short pulses. The authors participate in teaching of various subjects including quantum physics, dynamics of fluids, applied acoustics and physiology of hearing. They are members of Polish Physical Society.

References

[1] T. D. Rossing and A. J. M. Houtsma, *J. Acoust. Soc. Am.* **79**, 1926 (1986)

[2] J. N. Oppenheim and M. O. Magnasco, *Phys. Rev. Lett.* **110**, 044301 (2013)

[3] M. Majka, P. Sobieszczyk, R. Gębarowski and P. Zieliński., arXiv:1404.6464 [physics.class-ph]

[4] E. Gustafsson, T. Ruchon, M. Swoboda, T. Remetter, E. Pourtal, R. López-Martens, Ph. Balcou, and A. L'Huillier, Broadband attosecond pulse shaping, *Optics Letters 32* **11**, 1353 (2007)

[5] S. Dehaene, *Trends in Cognitive Sciences* **7**, 145 (2003)

Links to tests

[t1] https://drive.google.com/folderview?id=0BwQPqgssghTtZDNwY2Z0NmgzRVE&usp=sharing

[t2] https://drive.google.com/folderview?id=0BwQPqgssghTtQkhHanZJd3hScDg&usp=sharing

[t3] https://drive.google.com/folderview?id=0BwQPqgssghTtZUdJOU9XX0pna00&usp=sharing

Opinion: International Years, Physics and Society

Gerardo Delgado is the Director of the Instituto de Física Fundamental, CSIC, Madrid, SPAIN

The International Year of Light and Light-based Technologies (IYL 2015) was officially launched few weeks ago with a two-day Opening Ceremony at UNESCO Headquarters in Paris, and it has also coincided with the tenth anniversary of the International Year of Physics 2005 (IYP2005). These two international years have been proposed by two presidents of the European Physical Society, in 2005 by the ex-president Martial Ducloy and 2015 by the current president John Dudley.

During 2015 a very impressive list of events, some of them at national level and others programmed at regional or international level, can be found in the web page of IYL2015. In the same vein, over 2005 all physical societies of the world had also made efforts to bring physics to society. All these contributed to increase the role of physics in the culture, and to enhance the role of physics at all education levels. Something similar will happen in IYL2015. The celebration of IYP2005 was a major step forward in the activities of many of the learned societies involved, although we may address questions such as: What is the situation ten years later? What we can expect from this new international year?

If we turn to the experience of IYP2005, several are legacies that remain for the society and for the different physical societies. In particular, in the case of Spain, as I was the president of the Spanish Royal Society of Physics (RSEF) and the coordinator in Spain of the International Year of Physics, at that time. I consider that a very important part of the success was based on the relationships with different private and public foundations in Spanish science, as well as some of the collaborations that began in this period with: the "Fundación Areces", the "Fundación BBVA", the "Fundación Española para la Ciencia y la Tecnología", (FECYT), the "Fundación Residencia de Estudiantes" in Madrid (recently nominated as EPS Historic Site). Thanks to the support of these foundations, we were able to organise several conferences and meetings about physics for all citizens.

An important activity during IYP2005, was the annual celebration of "Physics on Stage" programme. This initiative has been organised from the year 2000, and it was launched by the European Laboratory for Particle Physics (CERN), the European Space Agency (ESA) and the European Southern Observatory (ESO). This programme was adopted by many national physical societies. Since 2000 they had decided to organise it as a local Science Festival, in collaboration with several local science museums by selecting the participants for the European festival. In 2005 "Physics on Stage" was especially dedicated to the scientific contributions of Einstein, and to the international year of physics. Nowadays this programme was transformed in "Science on Stage", and I expect that several activities of this science festival will also be devoted to the IYL2015.

All these activities and many others at all levels of education centers, as well as several collaborations with television networks and with national and local newspapers were organised. What has been activated later on? First of all, Physics has certainly reached the general public. Definitely, the IYP2005 has also strengthened the physical societies and has made our presence in different social forums. Nevertheless in some countries, like Spain, it has not produced a long-term benefit in the number of students in Physics, neither an enhancement in research funding.

These two International Years have been proposed by two Presidents of the European Physical Society

I wish the greatest success to the IYL2015, continuing and reanimating the aims of IYP2005. ■

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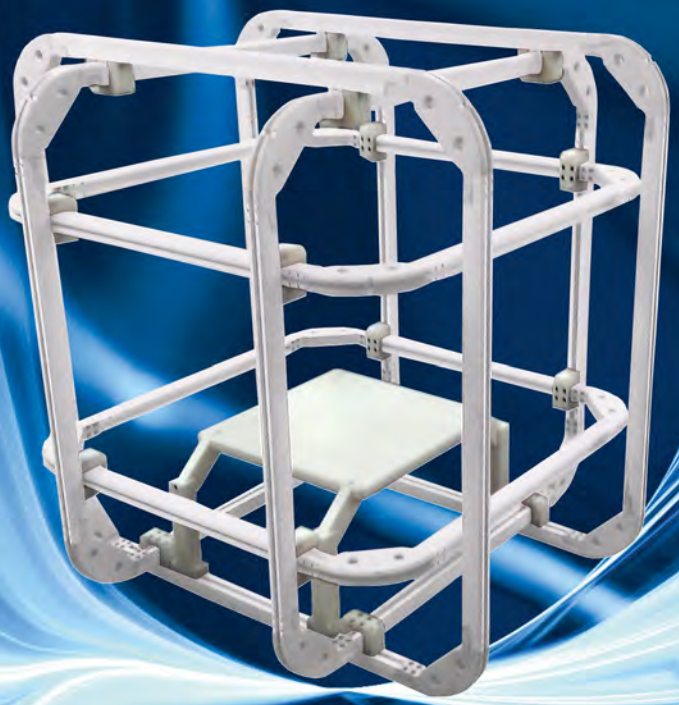

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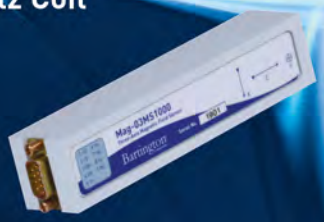

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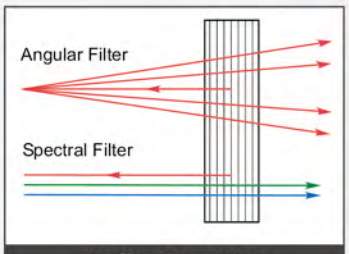

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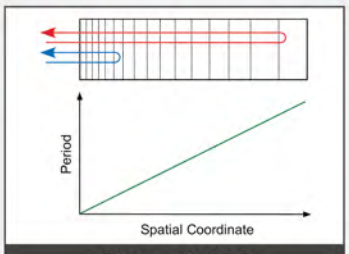

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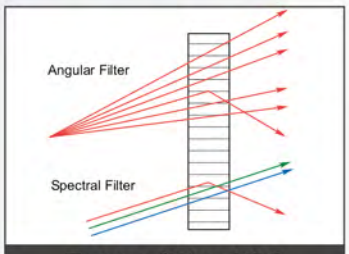

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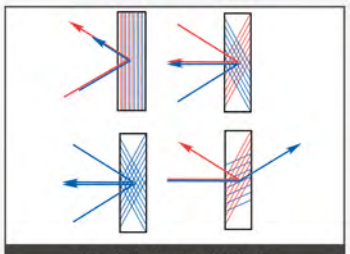

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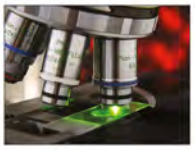


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