europhysicsnews

THE MAGAZINE OF THE EUROPEAN PHYSICAL SOCIETY

45/2
2014

Volume 45 • number 2
European Union countries price:
100€ per year (VAT not included)

The evolution of IBM Research
Mobility and payload
Fantastic plastic makes the quantum leap
100 years of Philips Research
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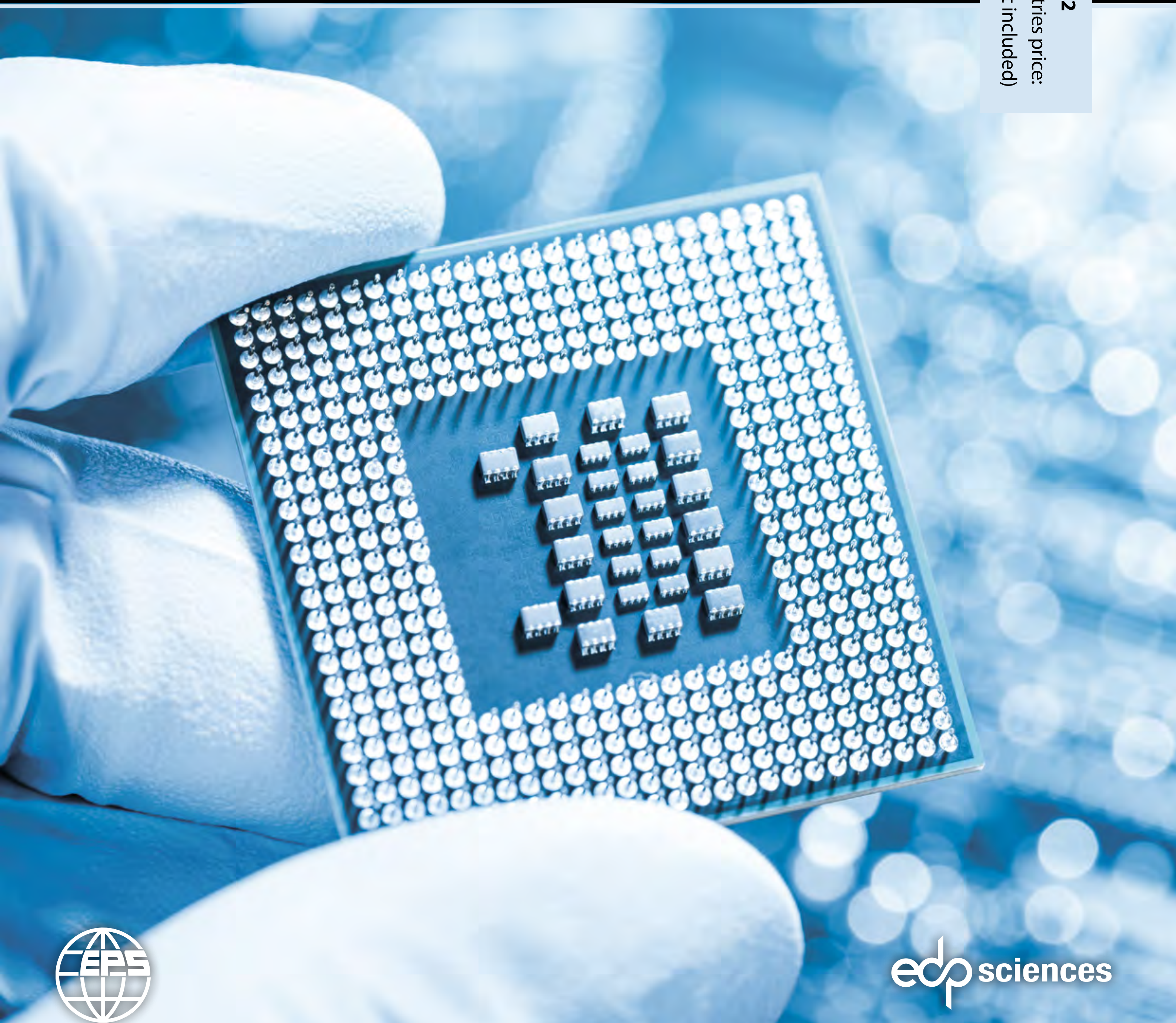

europhysicsnews

Cover picture: eectronic technician with glowes holding chip. © iStockPhoto

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The evolution of IBM Research

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Plastic makes the quantum leap

▲ PAGE 27

100 years of Philips Research

[EDITORIAL]

Hello EPN

In the EPN 44/6 Editorial Claude Sébenne, the former EPN Editor, said goodbye to the journal, after a long and very distinguished term of service. I must thank him for his advice and help in the transition. Now it is my turn to take the responsibility as the new Editor of EPN. All the interested people were given an inkling about my scientific areas of interest and my involvements with EPS in the January issue of e-EPS. Let me now present here some reflections on EPN.

The EPS has gone through many changes from its creation in September 1968. The parallel evolution of the European Union creating new opportunities for the development of the European Science and Technology, together with the increasing number of its Member States has imposed additional tasks to EPS as well. The EPS must not only deal with the interests and expectations of the Individual Members and the Member Societies, its natural constituency, but also with the new opportunities put forward by the European Union through their administrative structures in Brussels.

EPN as the EPS magazine, not a research journal, has to cover many areas of a quite varied nature. One of EPN's tasks is to disseminate useful information to the large number of physicists in Europe. It must communicate to the various categories of EPS members the most important developments and the new areas of interest in physics research and education. It must also distribute information on EPS activities, European events and so forth. Being a bi-monthly publication covering all of these tasks in a timely manner is not possible. This was addressed by the birth of the monthly web-newsletter, e-EPS, in 2011.

The current EPN format has a quite balanced set of interests with a wide variety of subjects in the Features, Opinions and Letters, giving it a more lively and interactive form. The final aim of all the people involved in this task is to offer a very good quality publication, able to get readers interested in the topics of every issue and eager to go through them.

Sometimes, it is necessary to step back and have a look to the human team doing this. You can see this in the "europhysicsnews.org" web-page. It shows the structure of the team formed by the Editor, the Science Editor and the Editorial Advisory Board. The EPS Secretary General is the EPN Executive Editor. The wizardry needed to give an attractive look to the magazine is performed by the EPS graphic designer, X. de Araujo. It is quite clear that every issue requires a lot of work and enthusiasm on the part of a small team of volunteers.

EPN as the EPS magazine, not a research journal, has to cover many areas of a quite varied nature

Looking back to the EPN 36/4 Editorial (July/August 2005), introducing Claude Sébenne as EPN Editor, one sees that the structure and the size of the team doing EPN are essentially unchanged. One must acknowledge that this structure has proved to be robust enough to brave many circumstances during the past years and to arrive to the attractive format of the present EPN issues. It has to be stressed also that all this has been done without incurring any substantial budget increases.

We must remember that EPN being the magazine of the EPS is subject to the EPS governance and to the decisions coming from it.

There is always enough room for improvements following a careful analysis of all the factors involved. This has been done in the past by former Editors and I will do my best, together with all the people involved in doing EPN, to make it a publication worthy of the attention and interest of the EPS members and to further the mission and aims of the EPS. ■

■ **Victor R. Velasco**
EPN Editor

europhysicsnews
2014 • Volume 45 • number 2

Europhysics news is the magazine of the European physics community. It is owned by the European Physical Society and produced in cooperation with EDP Sciences. The staff of EDP Sciences are involved in the production of the magazine and are not responsible for editorial content. Most contributors to Europhysics news are volunteers and their work is greatly appreciated by the Editor and the Editorial Advisory Board.

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General instructions to authors can be found at: **www.eps.org/publications**

Editor: Victor R. Velasco (SP)
Email: vrvr@icmm.csic.es

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

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

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

Director of Publication: Jean-Marc Quilbé

EPS Secretariat

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

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

EDP Sciences

Chief Executive Officer: Jean-Marc Quilbé

Publishing Director: Agnès Henri
Email: agnes.henri@edpsciences.org

Production: Thierry Coville

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

Address: EDP Sciences
17 avenue du Hoggar • BP 112 • PA de Courtabœuf
F-91944 Les Ulis Cedex A • France
Tel: +33 169 18 75 75 • **fax:** +33 169 28 84 91

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Individual Members of the European Physical Society receive Europhysics news free of charge.

Members of EPS National Member Societies receive Europhysics news through their society, except members of the Institute of Physics in the United Kingdom and the German Physical Society who have access to an e-version at www.europhysicsnews.org. The following are 2013 print version subscription prices available through EDP Sciences (Prices include postal delivery cost).

Institutions - European Union countries: 100 € (VAT not included, 20 %). **Rest of the world:** 119 €

Student - European Union countries: 47.50 € (VAT not included, 20 %). **Rest of the world:** 57 €

Contact: EPN Europhysics News • BP 95 • 92244 Malakoff Cedex • **info@route66-agence.com** or visit **www.edpsciences.org**

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

Printer: Fabrègue • Saint-Yrieix-la-Perche, France

Dépôt légal: March 2014

EPS HISTORIC SITES

Niels Bohr Institute

Blegdamsvej 17, Copenhagen, Denmark

The European Physical Society has declared the Niels Bohr Institute as a Historical Site with great international importance for developments in physics and research on 3 December 2013. The Niels Bohr Institute in Copenhagen was established in 1921 for the physicist and Nobel laureate, Niels Bohr, who in 1913 created the groundbreaking atomic model that formed the basis for our understanding of how the world is constructed, and later as the basis for quantum mechanics, which has revolutionized technological development.

Across the world organizations declare UNESCO sites, buildings and monuments as the cultural or natural heritage of mankind. Since science is a fundamental part of our culture, the European Physical Society, EPS, has – like the American Physical Society – declared particularly important sites as 'Historic Sites' for science.

The Niels Bohr Institute in Copenhagen has been selected on this basis: "This is where the foundation of atomic physics and modern physics were created in a creative scientific environment inspired by Niels Bohr in the 1920s and 30s."

▲ From the left: Nils O. Andersen, Jørgen Schou, Jakob Bohr, Ove Poulsen, John Dudley, Ian Bearden, Robert Feidenhans'l, Peter Sigmund

International environment

For years, Niels Bohr worked in humble conditions at the University of Copenhagen, but in 1921 he got his very own Institute of Theoretical Physics. It was a brand new building on Blegdamsvej 17 and was the setting for Bohr's work for the rest of his life.

Niels Bohr created a fundamental change in thinking in physics. Niels Bohr's pioneering atomic model has formed the basis for our understanding of how the world is constructed and for quantum mechanics, which has revolutionized technological development.

Niels Bohr created a fundamental change in thinking in physics and at the same time he managed to create an international environment that attracted some of the best scientists from around the world. Many foreign researchers visited Copenhagen, where they exchanged views and ideas with each other and with Niels Bohr. Several of them were later awarded the Nobel Prize for their work.

The Niels Bohr Institute at Blegdamsvej in Copenhagen has been the setting of no fewer than four Nobel laureates. Niels Bohr won the Nobel Prize in 1922 for his pioneering model of the atom, George de Hevesy received the Nobel Prize in 1943 for his pioneering work in nuclear medicine, and in 1975 Aage Bohr and Ben Mottelson received the Nobel Prize for their model of the structure of the atomic nucleus.

Atomic model basis for technological development

Niels Bohr's pioneering atomic model has formed the basis for our understanding of how the world is constructed and for quantum mechanics, which has revolutionized technological development.

All of the things that we surround ourselves with and find very natural and indispensible are based on quantum mechanics. It centers around all of the electronics found in modern appliances, computers, mobile phones, communication devices, CD players, flat panel displays, lasers and special nuclear medicine scanners for the diagnosis and treatment of diseases. One analysis shows that over 30 percent of the western world's GDP can be traced back to Niels Bohr's articles from 1913.

The selection of the Niels Bohr Institute as a Historic Site was celebrated at an event on 3 December in the historic Auditorium A, where the President of the European Physical Society, John Dudley, attended.

A plaque was placed on the building with the inscription: "This is where the foundation of atomic physics and modern physics were created in a creative scientific environment inspired by Niels Bohr in the 1920s and 30s." ■

Robert Feidenhans'l,
Niels Bohr Institute,
University of Copenhagen

▶ Flemming Besenbacher and John Dudley

◀ Jens Jørgen Gaardhøje

The pictures were taken in the historical Auditorium A, where quantum mechanics was discussed and developed in the 20's and 30's.

EPS HISTORIC SITES

The Cathedral

Kamień Pomorski, Westpomerania, Poland

Sharply - 268 years after the discovery - on the 11th of October 2013, another "EPS Historic Site" plaque was placed in Kamień Pomorski, Westpomerania, Poland. The statement was as follows: "*The Cathedral of Kamień Pomorski*. Here the physicist Ewald Georg Jürgen von Kleist, Dean of the Cathedral, devised on 11 October 1745 the "Kleist Bottle". This was the prototype of a capacitor. The "Kleist Bottle" became known as the "Leiden Jar", after it had been independently re-invented in the Dutch university town of Leiden."

Ewald Georg von Kleist (10 June 1700 – 10 December 1748) was a German jurist, Lutheran cleric, a physicist, and a member of the prestigious von Kleist family, which dates to contemporary. He studied jurisprudence at the University of Leipzig and then at the University of Leiden, where he possibly started his interest in electricity under the influence of Willem 's Gravesande. While he was working as the dean of the cathedral in the years 1722-1747, he also used to perform experiments with electric current. The device he produced was a glass jar filled with water and covered with an insulating cap with a copper wire through which could connect water with a friction machine or with a piece of silk charged by rubbing. The inner walls of the jar became electrified after the connection was set. In order to enlarge the capacity, a silver foil was applied on both sides of the jar.

▾ Left to right: M. Kolwas, K. Chałasińska-Macukow, M. Dąbrowski in front of the Kleist Palace near the Kamień Pomorski cathedral.

Ewald Von Kleist made his discovery on 11 October 1745 and he reported it in a letter which included a picture of the experiment dated on 4 November to Dr. Johannes Nathan Lieberkühn from Berlin as well as on 9 December 1745 to Prof. Johann Gottlob Krüger from Halle, who copied Kleist's letter in his book "Gesichte der Erde in den Allerälsten Zeiten". Daniel Gralath – then the Mayor of Gdańsk – successfully repeated Kleist experiment on the 5 March 1746 which he reported in his book "History of electricity". Gralath first used the name "Kleist bottle", but such a name has not been widespread in Europe because of an independent discovery (published on 4 January 1746) by Gravesande's graduate student Pieter van Musschenbroek of Leiden. Two years after the discovery - on 25 August 1747 – Ewald von Kleist was nominated the president of the royal court of justice in Koszalin (Köslin), Westpomerania, where he died soon afterward. "Kleist bottle", known as "Leiden jar" became an attraction in the royal manors all over Europe. One day in Palais de Versailles, as many as 240 King's guards made a chain instead of a wire. They instantaneously jumped up once electrified which became a big fun for the audience.

The main celebration of von Kleist discovery was conducted by Mr. Bronisław Karpiński, the mayor of Kamień Pomorski, while the plaque was uncovered jointly by the representative of the EPS (and a former President) Prof. Maciej Kolwas, the President-elect of the Polish Physical Society (term of office 2014-2017) Prof. Katarzyna Chałasińska-Macukow and the Chair of Szczecin Branch of the Polish Physical Society

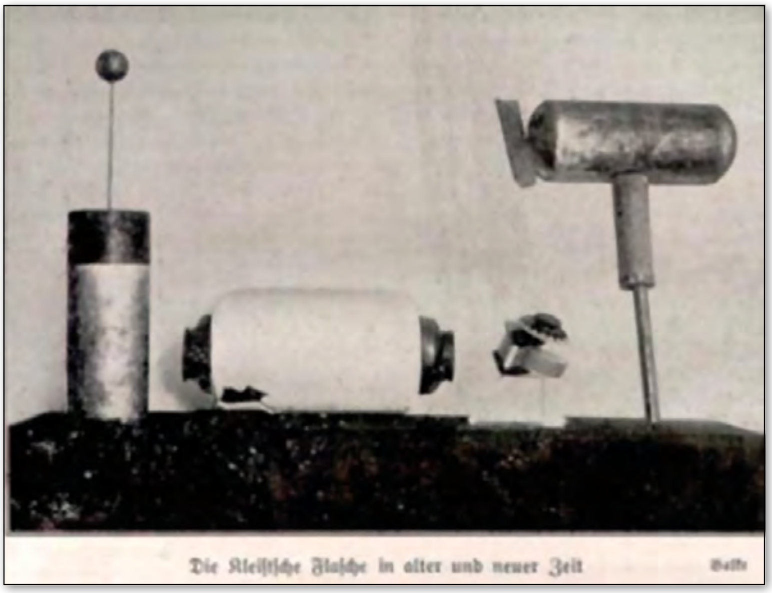
▴ The memorizing plaque devoted to Ewald von Kleist discovery.

Prof. Mariusz Dąbrowski. Among the invited guests were the president of the Berlin Physical Society Prof. Michael Müller-Preussker, the representative of the German Physical Society Prof. Gebhard von Oppen, and the representative of the von Kleist family - Mr. Sigurd von Kleist. The guests could listen to the organ concert in the cathedral, watch an interactive exhibition devoted to energy and electricity at the Museum of the History of Kamień Pomorski, as well as to attend a special town-hall session devoted to the physical, historical and social aspects of the discovery entitled "Ewald von Kleist - a discoverer of a capacitor and a citizen of Kamień Pomorski". Last but not least, part of the celebration was the two-day conference entitled "Ewald von Kleist contribution and its consequences to the development of science" held in the University of Szczecin conference center in Pobierowo near Kamień Pomorski. The conference had sessions devoted to history, contemporaneity, and philosophy of physics, problems with energy generation in contemporary world, as well as problems related to physics teaching. A special book devoted to the discovery and to the conference topics is planned to be issued in 2014.

It is unfortunate that the original Kleist bottle which survived for over 250 years was lost after the death of the previous dean of the cathedral in 2008. Police investigation is being held, but there have not been any results yet. Anybody can help? ■

■ **Mariusz P. Dąbrowski ,**
Institute of Physics
University of Szczecin, Poland

▾ Photo of the original Kleist bottle kept for over 250 years in the cathedral, lost in 2008 .



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Participation fee: € 900,00 (for attendance, board, lodging and Lecture Notes)

GENERAL INFORMATION

A) – The School is intended for PhD students and young post-docs. The number of students at the Course is limited to about 70. Students are requested to attend all lectures.

B) – Whoever may be interested in attending the Course and is not entitled - for his age or other reasons - to be considered a student, may follow the Course as observer. Registration fee charged to observers is Euro 500,00. Observers should provide for their board and lodging; if required, the School may take care of their hotel accommodation.

C) – Applicants will be informed of the decision on their admittance within 6 weeks from the beginning of the Course.

D) – Owing to the limited number of places available in the lecture hall, it will not be possible to allow any person not selected by the Committee of the School to follow the Course.

E) – Students are requested to arrive at Varenna the day preceding the opening of the Course: Wednesday, 16 July. Accommodation for the students will be provided in rooms with 2 beds in hotels at Varenna.

F) – Fees should be paid by students and observers following the instruction and within the date indicated in the letter of admittance.

G) – Scholarships may be granted to deserving students who need financial help. Such requests must be specified in the application and justified in the recommendation letter. Some of the Scholarships will be granted to EPS and/or SIF Members.

H) – Students should avoid being accompanied by relatives. In view of the holiday season local accommodation is very limited. Quite exceptionally the School could see to the accommodation of members of students' families in local hotels. Hotel expenditure for students' relatives will be payable separately and directly to the hotel management.

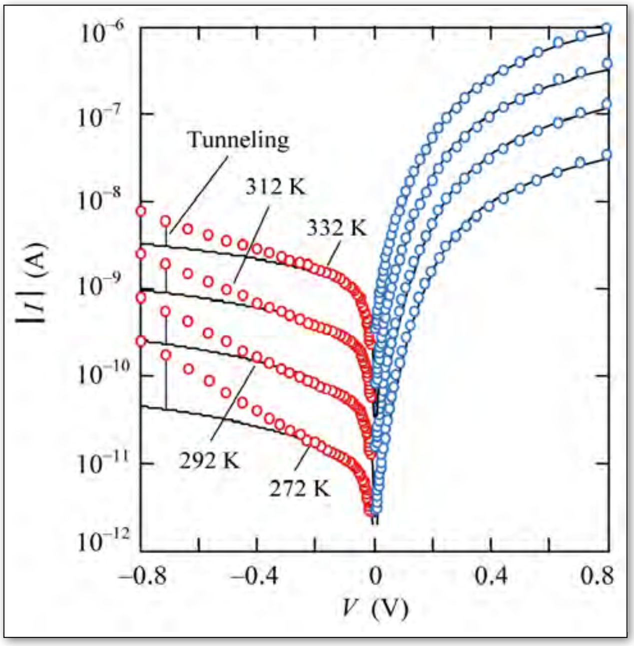
General Organization: Società Italiana di Fisica – Via Saragozza 12 – 40123 Bologna, Italy – Tel. ++39-051-331554 – Fax ++39-051-581340 – sif@sif.it – www.sif.it

Highlights from European journals

CONDENSED MATTER

Graphite/CdMnTe Schottky diodes and their electrical characteristics

CdTe is a basic material for X- and γ-ray detectors, which are widely used in various areas. However, the leakage current in these devices at room temperature is too large, which precludes a high energy resolution in the measured spectra. In the 1990s, $Cd_{1-x}Zn_xTe$ alloy with a wider band gap was proposed as a solution, but hopes pinned on it were not fully fulfilled. The search for new materials for the detectors continues and $Cd_{1-x}Mn_xTe$ is considered a promising material.



▴ Comparison of the calculation results (solid lines) with the measured I-V curves (circles) of the graphite/CdMnTe diode at different temperatures.

The main obstacle hindering the application of $Cd_{1-x}Mn_xTe$ in the detectors is the lack of $Cd_{1-x}Mn_xTe$-based diodes. In this paper we show that Schottky diodes fabricated by the deposition of colloidal graphite have good rectifying properties and low reverse currents. Their *I-V* curves are described analytically in terms of the generation-recombination theory based on the Shockley-Read-Hall statistics. It is shown that tunneling is responsible for the increase of the leakage currents at higher voltages and ways of its elimination are proposed. ■

■ **L.A. Kosyachenko**, **R. Yatskiv**, **N.S. Yurtsenyuk**, **O.L. Maslyanchuk** and **J. Grym**, 'Graphite/CdMnTe Schottky diodes and their electrical characteristics', *Semicond. Sci. Technol.* **29**, 015006 (2014)

HISTORY

Einstein's conversion from a static to an expanding universe

Albert Einstein accepted the modern cosmological view that the universe is expanding, only long after several of his contemporaries had demonstrated it with astrophysical observations.

Until 1931, physicist Albert Einstein believed that the universe was static, in line with his 1917 model. Now, the author explains how Einstein changed his mind and adopted the notion of an expanding universe following many encounters with some of the most influential astrophysicists of his generation.

He then fiercely resisted the view that the universe was expanding. For example, in 1922, Alexander Friedman showed that Einstein's equations were viable for dynamical worlds. And, in 1927, Georges Lemaître, concluded that the universe was expanding by combining general relativity with astronomical observations.

▾ Einstein and Lemaître photographed around 1933. Credit: Archives Lemaître, Université Catholique, Louvain.

It is only by April 1931 that Einstein finally adopted a model of an expanding universe. In 1932 he teamed up with Willem de Sitter, to propose an eternally expanding universe. This became the cosmological model generally accepted until the middle of the 1990s. ■

∎ **H. Nussbaumer**,
'Einstein's conversion from his static to an expanding universe', *Eur. Phys. J. H* **39**, 37 (2014)

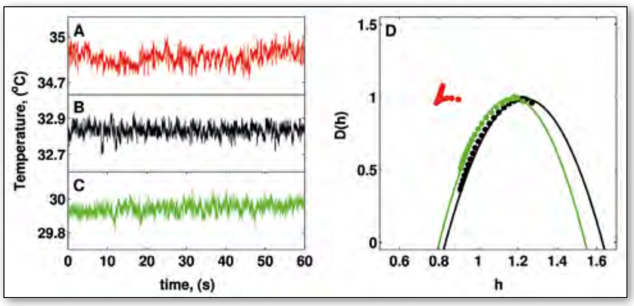
BIOPHYSICS

Multifractal analysis of breast cancer IR thermograms

Breast cancer is a common type of cancer among women and despite recent advances in the medical field there are still some inherent limitations in current screening techniques. The radiological interpretation of X-ray mammograms often leads to over-diagnoses and to unnecessary traumatic and painful biopsies. In this paper, the authors propose a computer-aided multifractal analysis of dynamic infrared imaging as an efficient method for preliminary screening in asymptomatic women, in order to identify those with a higher risk of breast cancer. Using a wavelet-based multi-scale method to analyze the temporal fluctuations of breast skin temperature, collected both from patients with breast cancer, and from healthy volunteers, they show that the multifractal complexity of temperature fluctuations observed in intact breasts is lost in mammary glands with a malignant tumor. Besides potential clinical application, these results underline the informative content of physiological changes that may precede anatomical alterations in breast cancer development. ■

∎ **E. Gerasimova**, **B. Audit**, **S.-G. Roux**, **A. Khalil**, **F. Argoul**, **O. Naimark** and **A. Arneodo**,
'Multifractal analysis of dynamic infrared imaging of breast cancer', *EPL* **104**, 68001 (2013).

▾ Multifractal analysis of temperature time-series (A-C) of the cancerous (red) and intact (black) breasts of a patient, and of a healthy volunteer breast (green). D(h) singularity spectra (D): the multifractal wide spectrum of healthy breasts reduces to a single point (monofractality) in the presence of a tumor.

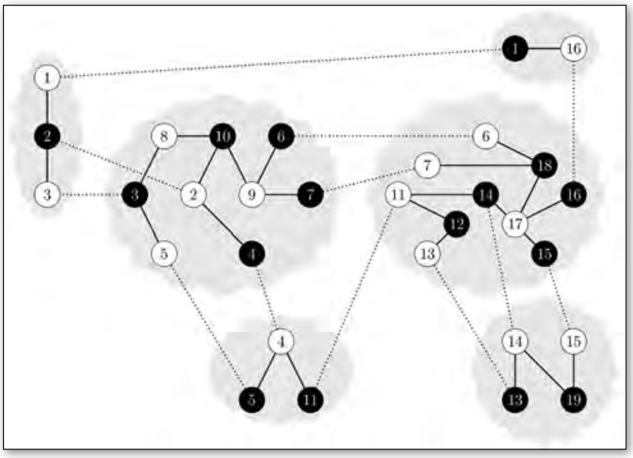


MATERIAL SCIENCE

Optimising custody is child's play for physicists

Ensuring that parents in recomposed families see their children regularly is a complex network problem that models developed to study materials may help to solve.

As a diversion from his normal duties as a theoretical physicist, one of the authors set out to find a suitable weekend for both partners in his recomposed family to see all their children at the same time. This resulted in a study showing that solving this problem equates to minimizing the energy in a material model.



▴ A graph depicting the children's custody problem, where grey nodes represent couples. Credit: Gomberoff *et al.*

The authors assume that people in the network, who are connected, as current or ex-partners, are willing to cooperate and communicate. They attempt to verify whether all parents could see all of their children together every other weekend. The answer is that it is not possible.

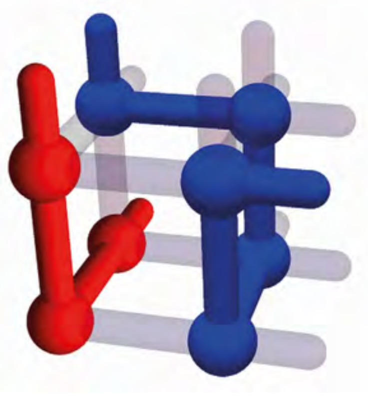
However, authors found an algorithm to maximise the number of parents spending time with their own children and those of their current partners. It was akin to minimizing the energy of a particular magnetic material called a spin glass. ■

∎ **A. Gomberoff**, **V. Muñoz** and **P.P. Romagnoli**,
'The physics of custody', *Eur. Phys. J. B* **87**, 37 (2014)

MATHEMATICAL PHYSICS

Hamiltonian walks and applications to protein folding

Hamiltonian walks on lattices are model systems for compact polymers such as proteins. The authors present a new enumeration algorithm that exactly counts the number of Hamiltonian walks on the 4×4×4 cube, which before was out of reach by



▲ Elementary 2×2×2 building block of 4×4×4 Hamiltonian walks.

several orders of magnitude of computing power. In addition, the authors present a new related Monte Carlo algorithm for counting the number of Hamiltonian walks, up to the 7×7×7 cube. The exact enumeration algorithm proved to be very fast, taking only several hours on a single PC. The number of Hamiltonian walks on the 4×4×4 cube was found to be 27,747,833,510,015,886.

The number of Hamiltonian walks grows faster with system size than previously anticipated. The authors attribute this to severe surface corrections. These effects could only be shown using the new Monte Carlo algorithm, which greatly extended the range of system sizes, compared to previous results.

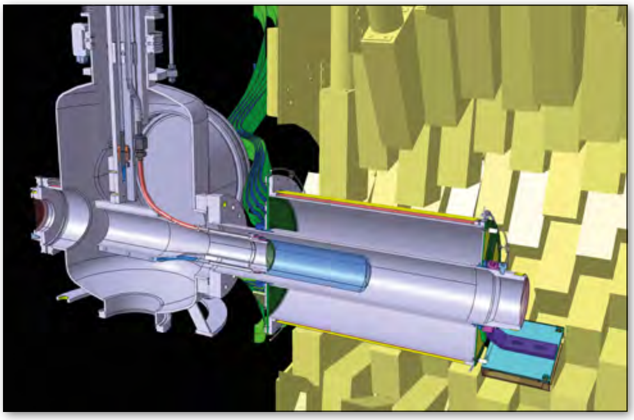
Finally, the paper discusses the uniqueness of ground states in the HP model for protein folding. It provides a bound on the uniqueness, and gives an intuitive picture for the uniqueness in the thermodynamic limit. ■

■ **R.D. Schram** and **H. Schiessel**,
'Exact enumeration of Hamiltonian walks on the 4×4×4 cube and applications to protein folding', *J. Phys. A: Math. Theor.* **46**, 485001 (2013)

NUCLEAR PHYSICS

MINOS: a vertex tracker for in-beam spectroscopy of exotic nuclei

MINOS is a new apparatus dedicated to in-beam nuclear structure experiments with low-intensity exotic beams at energies above 150 MeV/nucleon. It is intended to provide increased luminosity compared to standard solid-target experiments in hydrogen-induced studies, while simultaneously improving experimental resolution. This work exposes the concept of the device developed at the CEA in France and reviews in detail the associated recent technical advances. MINOS is composed of a thick finger-shaped liquid hydrogen target, from 50 to 200 mm thick, combined with a compact time projection chamber serving as a vertex tracker, the first of its kind in low-energy nuclear physics. This innovative setup offers access to the first spectroscopy of a new range of very exotic nuclei beyond our current reach. An exciting program on the search for new 2_1^+ states in neutron-rich even-even nuclei, spectroscopy of unbound oxygen nuclei



▲ View of the MINOS device inside the DALI2 gamma array at the RIKEN Radioactive Isotope Beam Factory.

and di-neutron correlations in Borromean nuclei will be performed with MINOS at the RIKEN Radioactive Isotope Beam Factory in Japan over the next few years. MINOS is funded by the European Research Council. ■

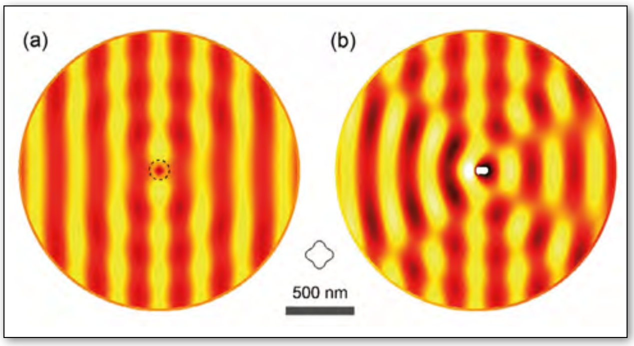
■ **A. Obertelli *et al.***,
'MINOS: A vertex tracker coupled to a thick liquid-hydrogen target for in-beam spectroscopy of exotic nuclei', *Eur. Phys. J. A* **50**, 8 (2014)

OPTICS

Quasi-effective medium theory for multi-shell systems

Maxwell–Garnett theory is the most widely used effective medium theory for the determination of the permittivity/permeability of nano-composite materials. However, it places a serious restriction on the physical dimensions of the constituents, that is, the feature sizes must be smaller than the incident wavelength. Thus, its applicability is limited to the quasi-static regime. An alternative theory has now been proposed by the authors which uses mode-dependent quasi-effective impedances to allow exact calculations of the far field scattering/extinction of complex multi-shell structures regardless of the object physical dimensions.

▼ Object-independent cloaking.



To demonstrate the physical insights that are to be gained based on this quasi-effective medium theory the authors have studied two practical examples: (i) they consider the problem of surface plasmon hybridization in concentric multi-shell particles, and (ii) they have applied the theory to design an object-independent cloak which consists of an arbitrary shaped object enclosed by a set of concentric shells. The most significant advantages of this new theory are its simplicity, ease of implementation and the important insights the theory provides into the optical properties of complex systems. ■

■ **D. A. Genov** and **P. C. Mundru**,
'Quasi-effective medium theory for multi-layered magneto-dielectric structures', *J. Opt.* **16**, 015101 (2014)

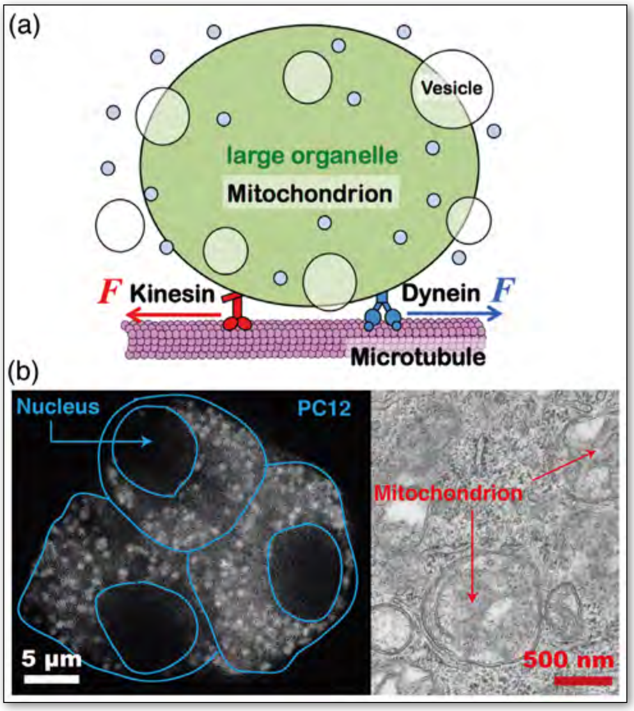
BIOPHYSICS

Elucidating biological **cells' transport mechanisms**

A new study focuses on the motion of motor proteins in living cells, applying a physicist's tool called non-equilibrium statistical mechanics used to study diffusion.

Using an ingenious setup, the authors have, for the first time, calculated the force of molecular motors – called kinesin and dynein – acting on the inner components of biological cells, called mitochondria. These findings could contribute to elucidating the transport mechanism in biological cells by multiple motors.

▾ Image of mitochondria observed by transmission electron microscopy. Credit: K. Hayashi *et al.*



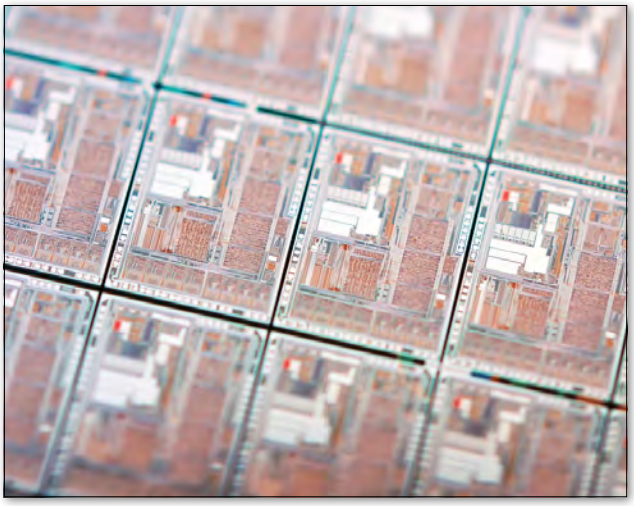
The authors compared evaluations of the diffusion coefficient obtained via the so-called Einstein relation – which stems from non-equilibrium statistical mechanics – applied to both mitochondria and the random motion of beads artificially incorporated into a cell. They found that the medium's viscosity obtained using the beads, was slightly lower than that obtained using the mitochondria motion. This means that physical laws such as the Einstein relation are not sufficient to fully describe the mitochondria's motion, which is subjected to complex biological processes. ■

■ **K. Hayashi**, **C.G. Pack**, **M.K. Sato**, **K. Mouri**, **K. Kaizu**, **K. Takahashi** and **Y. Okada**,
'Viscosity and drag force involved in organelle transport: Investigation of the fluctuation dissipation theorem', *Eur. Phys. J. E* **36**, 136 (2013)

QUANTUM PHYSICS

Sharpening the focus in **quantum photolithography**

A new protocol, exploiting the quantum properties of materials, makes it possible to improve the accuracy of photolithography by addressing its physical limitations due to diffraction.



▴ Photolithography is used to etch circuits onto microelectronic devices. Credit: Tambako the Jaguar/Flickr

Photolithography uses light beams to design thin geometric patterns on the substrates of semiconductors used in microelectronic devices. This is achieved using a chemical reaction on a light-sensitive chemical, called photoresist. The trouble is that the phenomenon of light diffraction does not permit highly accurate patterns. Now, the author has developed a quantum lithography protocol designed to improve the resolution of this technology. The author establishes the formula for the probability of a single, and no longer multiple, photon transition from a bound state of a quantum system to a state of continuous spectrum, using the so-called Markov approximation. This makes it possible to select the exposure time and the beam's intensity to obtain a narrow stripe in the photoresist on the substrate. ■

G. P. Miroshnichenko,
'Quantum lithography on bound-free transitions',
Eur. Phys. J. D **67**, 257 (2013)

APPLIED PHYSICS

Carbon dating uncovers **forged Cubist painting**

Physicists use carbon dating to confirm alleged Fernand Léger painting was definitely a fake, thus corroborating the doubts about its authenticity previously expressed by art historians.

For the first time, it has been possible to identify a fake painting by relying on the anomalous behaviour of the concentration of ^{14}C in the atmosphere after 1955 to date its canvas. These findings were recently obtained by the authors.

Previously, art historians called upon scientists to compare the alleged Léger painting from the Peggy Gugenheim Collection (PGC), in Venice, Italy, with an authentic painting of the 'Contrastes de formes' series belonging to the Solomon Guggenheim Foundation (SGF) in New York, USA. They showed that the canvas fibres and the paint pigments differed, evidence was inconclusive. Using accelerator mass spectrometry, the authors definitely proved that the canvas sample contains a level of radioactive carbon found in 1959, years after Léger's death in 1955. ■

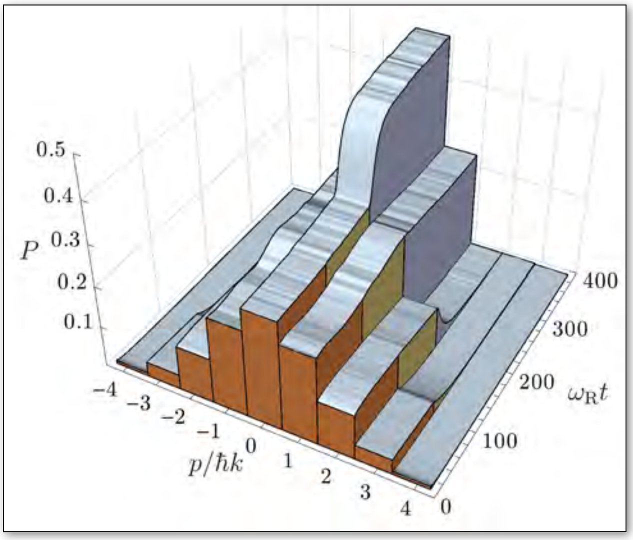
▾ The alleged Contraste de formes, an oil on canvas from the Peggy Guggenheim Collection, Venice, was proven to be a fake. Credit: Caforio *et al.*

L. Caforio *et al.*,
'Discovering forgeries of modern art by the ^{14}C Bomb Peak', *Eur. Phys. J. Plus* **129**, 6 (2014)

QUANTUM PHYSICS

Subrecoil cavity cooling towards degeneration

Cavity assisted cooling has become a valuable tool to implement cavity-QED with ultra cold quantum gases, trapped ions and optomechanical elements. Injecting a red-detuned laser extracts kinetic energy from the particles to create cavity photons, which leak out of the resonator, carrying away energy and effectively cooling the system. In contrast to conventional laser cooling, this method works without resonant excitation and spontaneous emission, eliminating photon re-absorption and making it applicable to a wide class of polarizable particles with final temperatures only limited by the cavity line-width.



▴ Single-particle momentum distribution for bosons in a ring cavity. The initially broad distribution is cavity-cooled to $|p| = 0, \pm 1\hbar k$ momentum states.

We present a detailed numerical analysis of the cooling dynamics involving a cavity with energy uncertainty below the recoil energy. Motivated by a recent Hamburg experiment demonstrating targeted cooling on the subrecoil scale, we embrace a tailored sequence of laser pulses transferring the particles from a thermal state towards the ground state reaching subrecoil kinetic energies. The few particle simulations give encouraging prospects to implement condensation of a quantum gas via cavity cooling and exhibit genuine quantum correlations distinguishing fermions and bosons.

A broad momentum distribution is cooled to generate a large ground state population. Each step of a laser pulse sequence with optimized detunings transfers specific momentum states irreversibly towards lower momenta. ■

■ **R.M. Sandner**, **W. Niedenzu** and **H. Ritsch**
'Subrecoil cavity towards degeneration: a numerical study', *EPL* **104**, 43001 (2013)

PLASMA PHYSICS

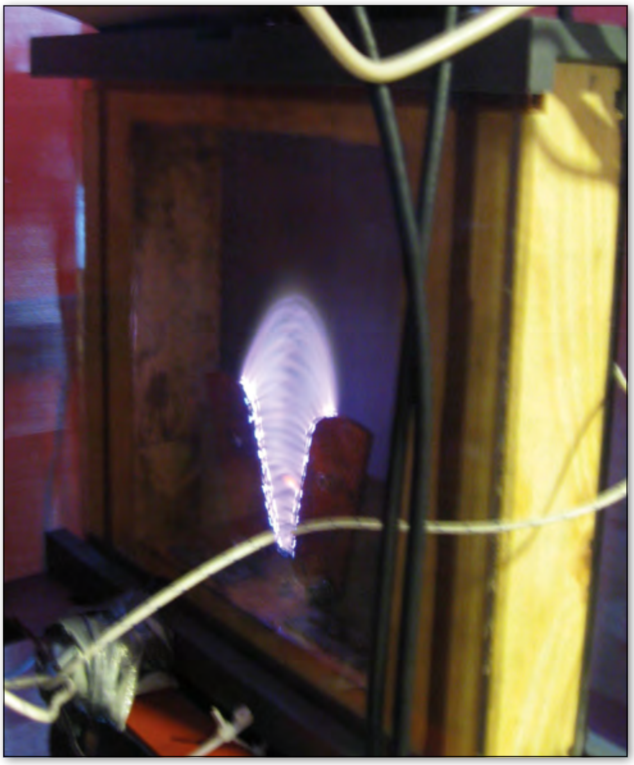
How hypergravity impacts **electric arcs**

A new study focused on electric discharge behaviour under intense gravitational forces shows that its dynamic changes as gravity increases.

Arc discharges are common in everyday conditions like welding or in lightning storms. But in altered gravity, not as much is known about their behaviour. For the first time, the authors studied the behaviour of a special type of arc discharge, so-called glide arc, in varying hypergravity conditions, up to 18 G. In this work they demonstrate how the plasma channel of this glide arc discharge moves due to external forces of buoyancy in varying gravity conditions. These results could have implications for improved safety precautions in manned space flights and in the design of ion thrusters used for spacecraft propulsion.

The authors performed measurements on atmospheric pressure glide arc helium plasma under the forces of hypergravity.

▼ Glide arc discharge under normal gravity conditions. Credit: J. Sperka *et al.*



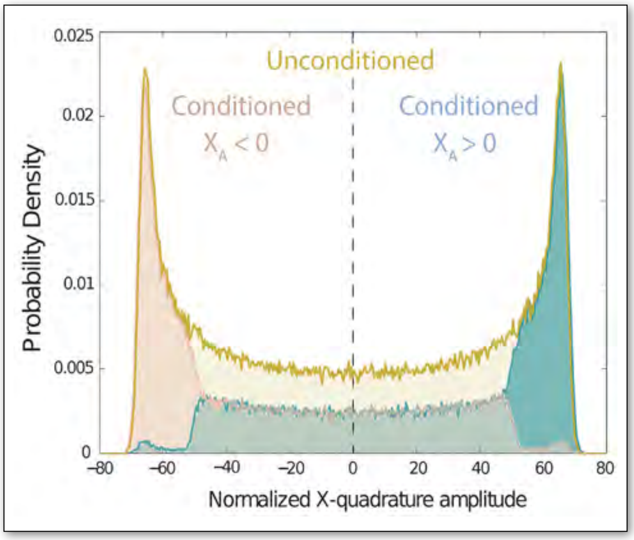
They established a model showing that gravity strongly influences the glide arc discharge. These effects stem from thermal buoyancy, which increases with gravity, they conclude. ■

■ **J. Sperka**, **P.Souček**, **J. J.W.A. Van Loon**, **A. Dowson**, **C. Schwarz**, **J. Krause**, **G. Kroesen** and **V.Kudrle**,
'Hypergravity Effects on Glide Arc Plasma', *Eur. Phys. J. D* **67**, 261 (2013)

QUANTUM PHYSICS

Finding and verifying **quantumness in "classical" states**

Separable states were previously treated as "classical" states due to the lack of entanglement. Recently, quantum discord was proposed as a general quantification of quantumness that is able to reveal nonclassical correlations beyond entanglement. This measure suggests that for bipartite Gaussian states, quantum correlations are nonzero for all but product states. This implies that even a non-entangled bipartite state prepared by splitting a thermal state on beamsplitter could display nonzero quantumness. To examine such nonclassical correlations, experimental methods to verify the presence of discord are of particular interest.



▲ Changes in conditional marginal distributions as signature of discord.

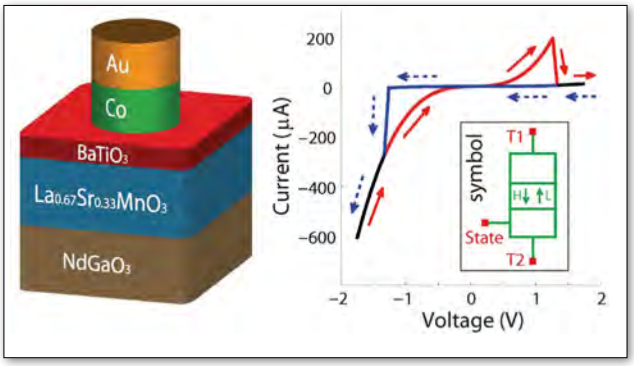
In this paper, the authors demonstrated a simple yet efficient technique for certifying quantum discord in continuous variable states. By checking the difference between conditioned marginal distributions, such as peak separation, the authors were able to reveal discord in bipartite Gaussian states and a certain class of non-Gaussian states. Hence, the presence of informational contents greater than that attributed to classical correlations in these separable states was verified. With some prior knowledge about the bipartite states, the proposed method could detect quantum correlations with minimal resources, thus serves as an indispensable tool for the testing of quantumness. ■

▮ **S. Hosseini**, **S. Rahimi-Keshari**, **J.Y. Haw**, **S.M. Assad**, **H.M. Chrzanoswki**, **J. Janousek**, **T. Symul**, **T.C. Ralph** and **P.K. Lam**,
'Experimental verification of quantum discord in continuous-variable states', *J. Phys. B: At. Mol. Opt. Phys.* **47**, 025503 (2014)

CONDENSED MATTER

Ferroelectric tunnel junction for memory and logic design

Ferroelectric tunnel junction (FTJ) is an emerging nonvolatile binary data storage device. Unlike conventional tunnel junctions, FTJ is switched via a pure electronic mechanism, and it exhibits higher OFF/ON resistance ratio and larger resistance-area product. Considering great potential of FTJ as next generation memory, the authors aimed to develop the first compact model of FTJ for associated circuits design and simulation.



▴ The structure of $Co/BaTiO_3/La_{0.67}Sr_{0.33}MnO_3$ FTJ and DC simulation curves with proposed model.

They presented a SPICE-compatible model of $Co/BaTiO_3/La_{0.67}Sr_{0.33}MnO_3$ FTJ through investigating a variety of physical theories including Brinkman model, JKD semi-empirical scaling law, KAI model, and Merz's law. These theories quantitatively explain the experimental data of tunnel resistance and switching process, and hence verify the accuracy of proposed model. This model has been programmed with Verilog-A language and integrated on Cadence platform. With the proposed model, the authors researched the reading reliability and power dissipation of FTJ based on CMOS 40nm technology node. Simulation results demonstrated the advantages of FTJ over magnetic tunnel junction (MTJ) in high reliability and ultralow power.

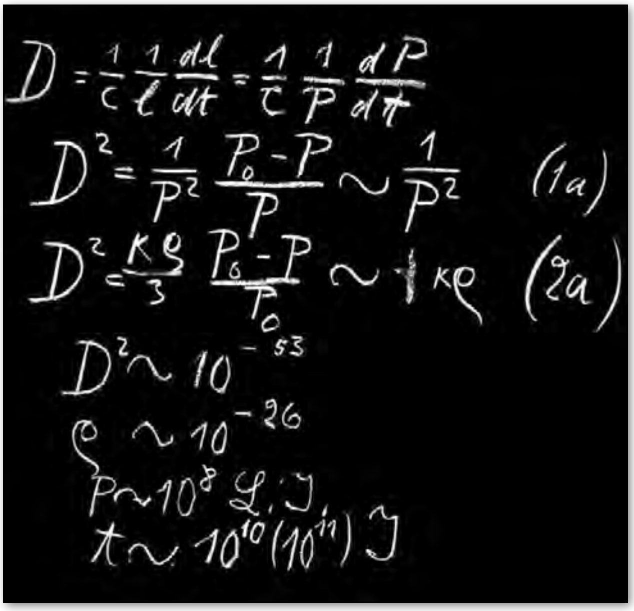
The authors have added this model into the open source device library SPINLIB to allow IC designers to simulate FTJ-based circuits efficiently. ■

▮ **Z.H. Wang**, **W.S. Zhao**, **W. Kang**, **A. Bouchenak-Khelladi**, **Y. Zhang**, **J.-O. Klein**, **D. Ravelosona** and **C. Chappert**,
'A physics-based compact model of ferroelectric tunnel junction for memory and logic design', *J. Phys. D: Appl. Phys.* **47**, 045001 (2014)

HISTORY

Einstein's forgotten model of the universe

New insights into Einstein's view of the cosmos from the translation and study of one of his least known papers.



▴ An image of the blackboard used in Einstein's 2nd Rhodes lecture at Oxford in April 1931. Credit: Museum of the History of Science, University of Oxford, UK.

This work provides the first English translation and an analysis of one of Albert Einstein's little-known papers, "On the cosmological problem of the general theory of relativity." Published in 1931, it features a forgotten model of the universe, while refuting Einstein's own earlier static model of 1917. In this paper, Einstein introduces a cosmic model in which the universe undergoes an expansion followed by a contraction. This interpretation contrasts with the monotonically expanding universe of the widely known Einstein-de Sitter model of 1932.

The authors provide insights into Einstein's view of cosmology. At that time, the first pieces of evidence for an expanding universe emerged, among others, stemming from Hubble's observations of the expanding universe. In this paper, the authors also discuss Einstein's view of issues such as the curvature of space and the timespan of the expansion, while also uncovering some anomalies in Einstein's calculations.

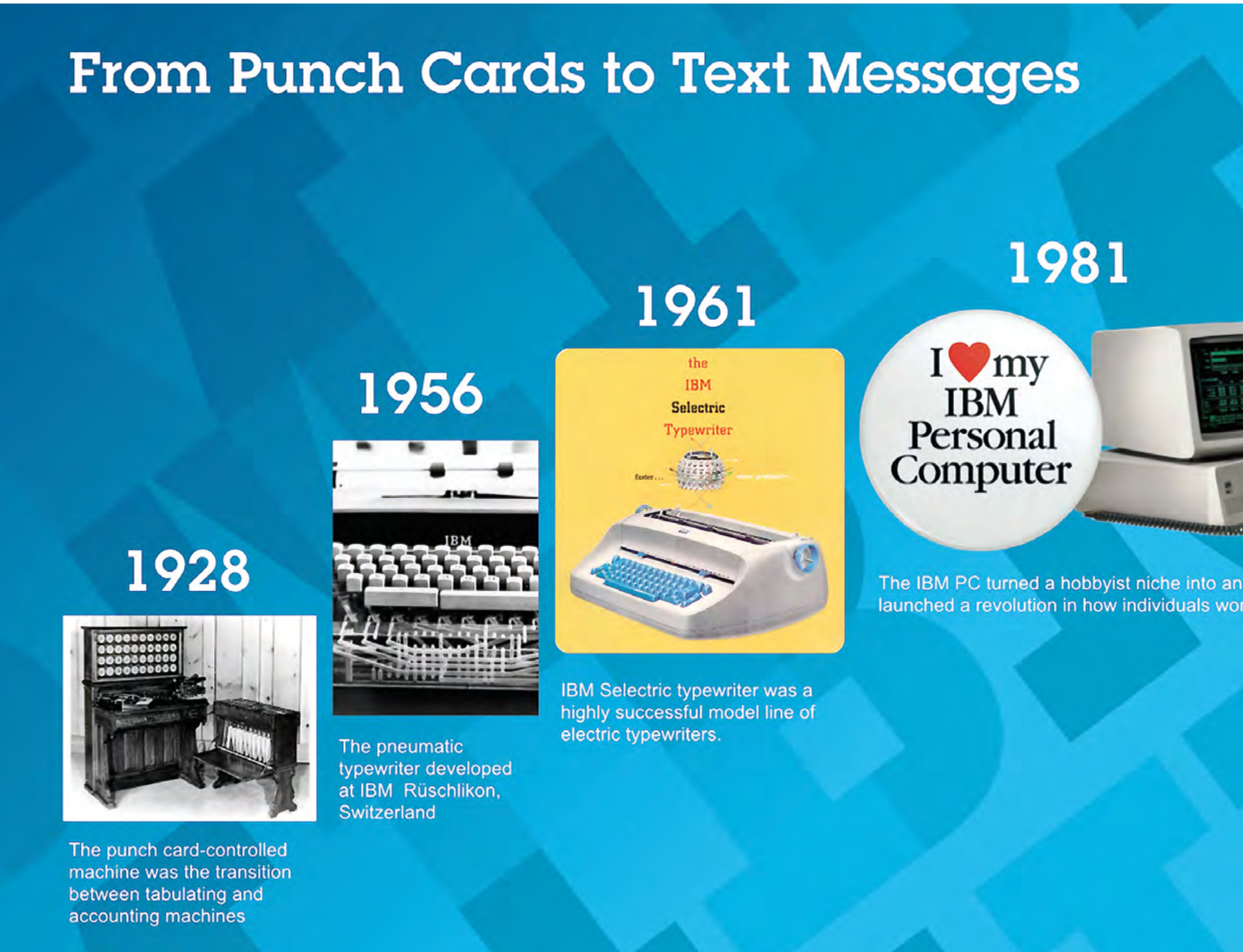
▮ **C. O'Raifeartaigh** and **B. McCann**,
"Einstein's cosmic model of 1931 revisited",
Eur. Phys. J. H **39**, 63 (2014)

THE EVOLUTION OF IBM RESEARCH

LOOKING BACK AT 50 YEARS OF SCIENTIFIC ACHIEVEMENTS AND INNOVATIONS

Chris Sciacca and Christophe Rossel – IBM Research – Zurich, Switzerland – DOI: 10.1051/epn/2014201

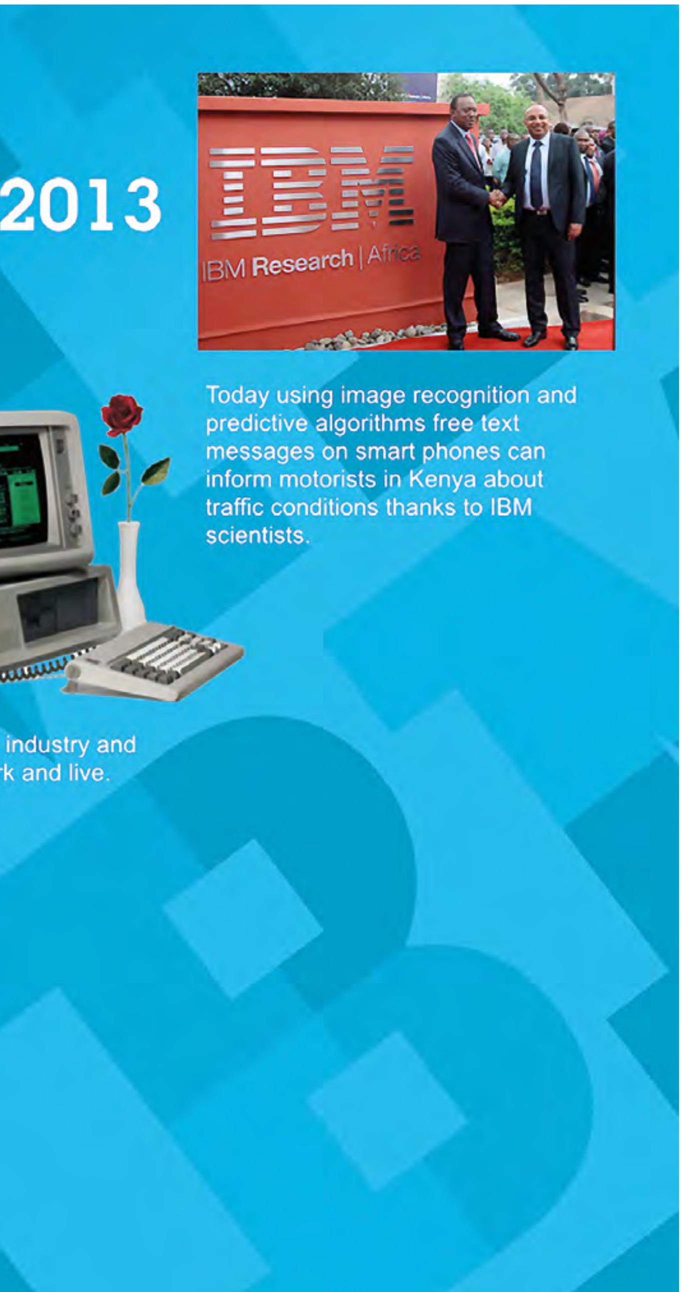
By the mid-1950s IBM had established laboratories in New York City and in San Jose, California, with San Jose being the first one apart from headquarters. This provided considerable freedom to the scientists and with its success IBM executives gained the confidence they needed to look beyond the United States for a third lab. The choice wasn't easy, but Switzerland was eventually selected based on the same blend of talent, skills and academia that IBM uses today — most recently for its decision to open new labs in Ireland, Brazil and Australia.



The Computing-Tabulating-Recording Company (C-T-R), the precursor to IBM, was founded on 16 June 1911. It was initially a merger of three manufacturing businesses, which were eventually molded into the $100 billion innovator in technology, science, management and culture known as IBM.

With the success of C-T-R after World War I came increased competition. With growing alarm Thomas Watson Sr., the president of C-T-R, watched his tabulators falling behind competing products. This was particularly vexing because he knew the tabulating business was critical to the company's future, since scales and coffee grinders wouldn't make C-T-R a globally renown company.

Very much like today, T. Watson Sr. saw that big companies were experimenting with tabulating machines to help run railroads, handle accounting at department stores, and keep track of manufacturing and distribution for factories. He realized that collecting, sorting and disseminating information was going to be a big business, requiring investment in research and development.



He began hiring the country's top engineers, led by one of world's most prolific inventors at the time: James Wares Bryce. Bryce was given the task to invent and build the best tabulating, sorting and keypunch machines.

With more strategic moves T. Watson Sr. put the company back on a sustainable growth track and C-T-R was rebranded as International Business Machines (IBM) on 14 February 1924.

A new division is born

By the mid-1940s IBM was really taking off. Between 1940 and 1945 the company grew from 12,000 employees and $45 million in revenue to 18,000 employees and $138 million in revenue. This success gave Watson the confidence to open the first pure science corporate research lab in the USA in February 1945. He did this in New York City, in partnership with Columbia University, as he believed that for a successful research lab direct access to the best talents was paramount (Fig.1).

With his humble initial steps Watson Sr. set the basis for what was to become *IBM Research*, two words which are today synonymous with leading-edge science and innovation.

In 1956 IBM officially created an independent research division incorporating the small labs at Columbia University in NY City with labs in Poughkeepsie (NY) and San Jose (Ca). These labs combined with a small, but ambitious new lab in Europe, were the first steps towards its global R&D map.

Switzerland wasn't IBM's first option for a European research lab. London and Amsterdam were also on the short list, but it was Zurich's openness and dense talent pool which made the city the obvious choice.

How to build a research center

Ambros Speiser, a young Swiss electrical engineer from ETH Zurich, became the first director of IBM Research – Zurich in that summer of 1956. He faced immense challenges ranging from finding a suitable location to attract talented scientists to employ.

As he tells it in the *IEEE Annals of the History of Computing:* "There was no established pattern to follow – an industrial laboratory, separate from production facilities, did not exist in Switzerland."

He eventually rented space in the Pelikan building, a German manufacturer of writing instruments, in Adliswil, 20 minutes outside of Zurich. The location gave employees access to the city by bus, but, more importantly, access to the talents at his *Alma mater* the University of Zurich and the "Polytechnikum" (ETHZ).

▲ **FIG. 1: (a)** The Watson Scientific Computing Laboratory in New York (1940s). **(b)** Students in class at the Watson Scientific Computing Laboratory

▼ **FIG. 2: (a)** Aerial view of IBM Research - Zurich in 1963 when the lab first opened in Rüschlikon… **(b)** and today after the construction of the BRNC Nanotech center.

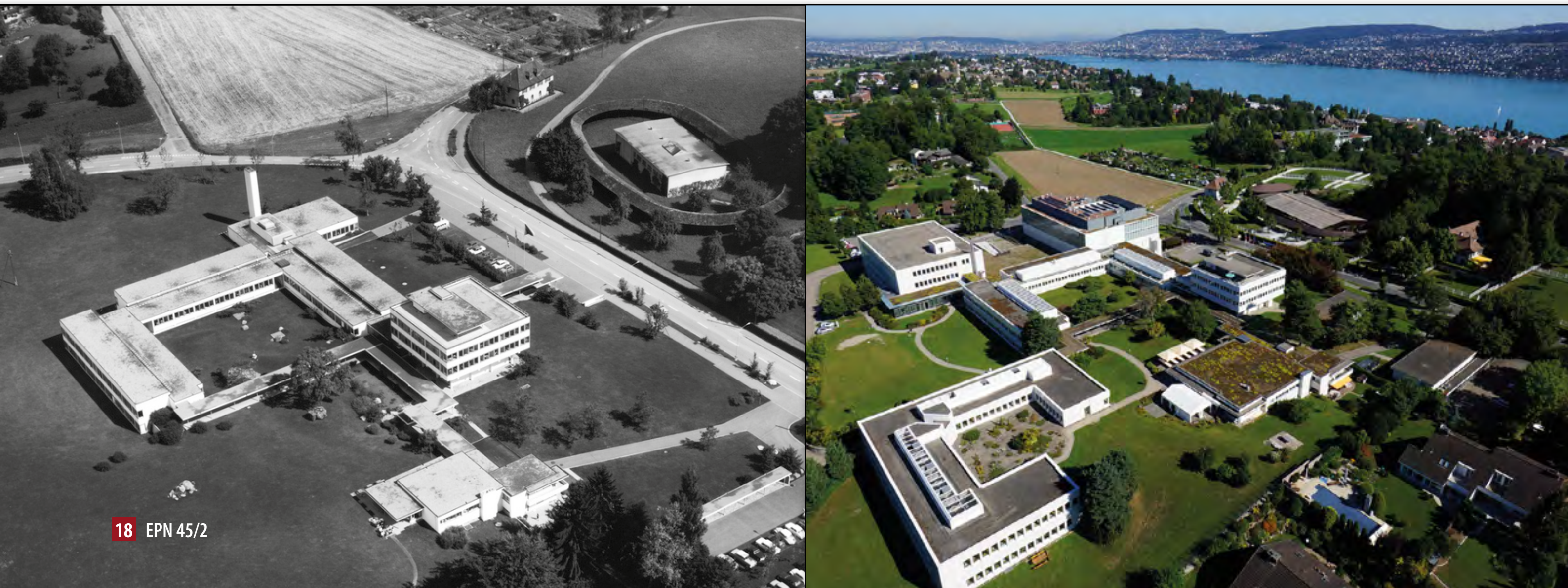
While initially focusing on electrical engineering for computer hardware, Speiser wanted the Zurich Lab (ZRL) to have a clear differentiation compared to the US labs. With the support of IBM management he took a new direction towards solid-state physics as the basis for electronic devices of the future. He soon added a mathematics department and quickly the lab outgrew its modest space in Adliswil.

With the approval of then IBM CEO Thomas Watson Jr., son of the founder, Speiser purchased a 10 acre site in Rüschlikon, close to Zurich, to build a new laboratory with its own facilities (Fig. 2a). The official inauguration with several hundred guests took place on 23 May 1963. Several demonstrations were organized on that day (Fig. 3).

The world is our lab

From 1945 up until the 1990s IBM Research was funded primarily by headquarters and by the hardware and software divisions. The scientists had their own research agenda with some occasional technology transfer, but this was not the norm.

This slowly began to change in the 1980s. In this period IBM was already looking at how effective research was and tried to influence the direction in which it had to develop. IBM started joint programs between research and the product divisions with a shared agenda. They created collaborative teams to accelerate the transfer of research results. One notable result from this collaboration was the now iconic red TrackPoint found on millions of ThinkPad keyboards to help users navigate. Some of the great accomplishments at ZRL are summarized in Fig. 4. Two of them provided the Zurich Lab with the highest scientific honor, namely the Nobel Prize in Physics in 1986 for the scanning tunneling microscope (STM) and in 1987 for high-temperature superconductivity. Scanning probe microscopy remains a dedicated area of focus at the lab as IBM scientists continue to look at novel materials and designs for the ultimate switch in the next generations of transistors (Fig. 5)



After the tremendous success of the 1980s, not only financially with the invention of the personal computer, but also with outstanding scientific discoveries, IBM found itself entering the next decade in a truly difficult situation.

IBM's near-death experience was caused by its failure to recognize that the 40-year old mainframe computing model was out of touch with the needs of clients. Start-up firms like Sun Microsystems pounced on the opportunity impacting everyone from sales to research.

To preserve their research activities, scientists in Zurich became more proactive in working on actual customer problems — a completely unheard-of concept at the time. The idea was to interact with clients, gain insight into their challenges and find solutions. It turned out to be a great success and in 2000 the Zurich Lab opened up a dedicated facility called the Industry Solutions Lab (ISL), with the goal of hosting and interacting with clients on a daily basis.

The idea was eventually rolled out to other labs and today similar environments exist around the world, with the latest recently opening in Almaden, California, called the Accelerated Discovery Lab.

The strategy to connect IBM scientists with clients to solve the world's grand challenges gave birth to the phrase *"The world is now our lab."*

IBM Research Today

With 3,000 scientists across 12 labs on six continents and a $6 billion R&D budget, IBM Research today is a major driver of innovation for both IBM and its clients.

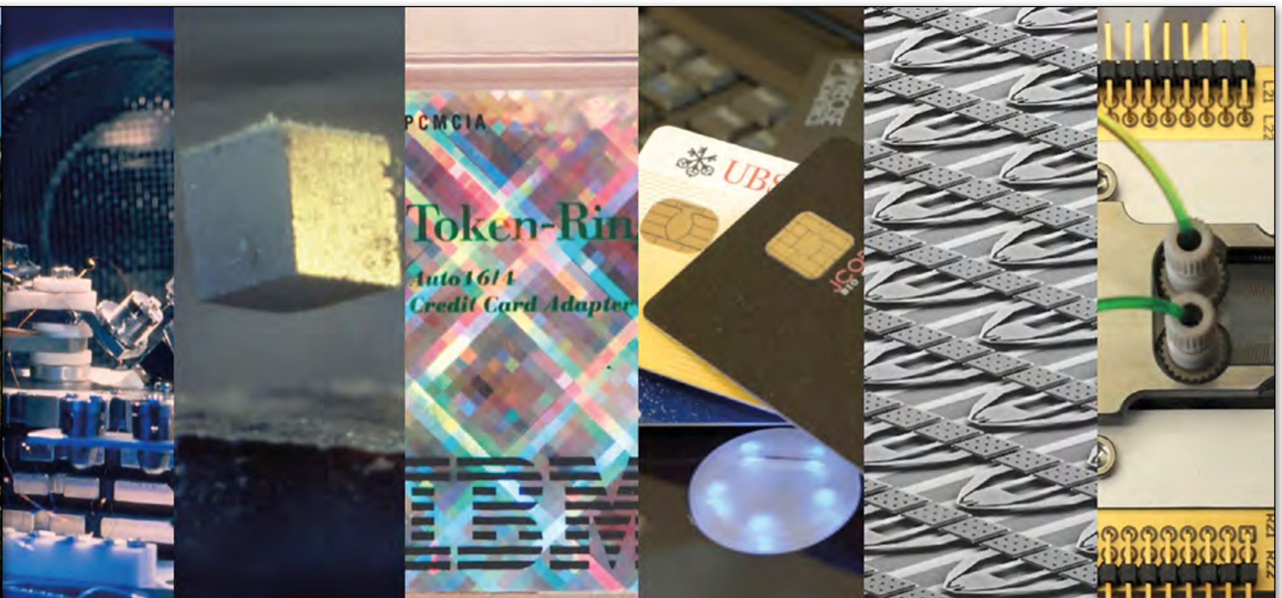
In October 2013 IBM opened the doors to the first commercial technology research facility in Africa. The new lab based in Nairobi, Kenya, is located at the Catholic University of Eastern Africa. It will conduct applied and far-reaching exploratory research into the grand challenges of the African continent including energy, water, transportation, agriculture, healthcare, financial inclusion and public safety.

▲ **FIG. 3:** Two IBM scientists (Kenneth Niebuhr and Robert Green) demonstrated for the first time the transmission of voice and other audio information by a light beam generated by an injection laser at the opening of the new IBM Research lab in Rüschlikon (May 22, 1963).

The Zurich Lab has also been expanding most recently with the addition of the Binnig and Rohrer Nanotechnology Center (BRNC), named after the two IBM Nobel Laureates (Fig. 2b). This $90 million exploratory research facility includes a state-of-the-art cleanroom combined with six innovative noise-free labs. In such rooms, dedicated to advanced nanotechnology studies, all external perturbations (vibrations, electro-magnetic fields, *etc.*) are reduced to an unprecedented low level, whereas temperature and humidity are stabilized with highest precision.

The BRNC is also used in an open collaboration by researchers from ETH Zurich and the Swiss Federal Laboratories for Materials Science and Technology (EMPA).

Outside of the nano-world IBM scientists are working on some of the important challenges of our society today as part of IBM's vision called Smarter Planet (Fig. 6). The vision is based on the realization that the world's systems and industries are becoming more instrumented, interconnected and intelligent, and that leaders and citizens can take advantage of this state of affairs to improve the way the world works.



◂ **FIG. 4:** Some of the major accomplishments at IBM ZRL include the discovery of the STM/AFM, of high-temperature superconductivity, the development of the Token-Ring, the smart card operating system, the Millipede for storage, and liquid chip cooling.

For example, scientists in Zurich are building an affordable photovoltaic system capable of concentrating solar radiation 2,000 times and converting 80 percent of the incoming radiation into useful energy. The system can also provide desalinated water and cool air in sunny, remote locations where both are often in short supply.

“With 3,000 scientists across 12 labs on six continents and a $6 billion R&D budget, IBM Research today is a major driver of innovation”

Another team is collaborating with a consortium of scientists in the Netherlands and South Africa on extremely fast, but low-power exascale computer systems aimed at developing advanced technologies for handling the Big Data that will be produced by the Square Kilometer Array (SKA), the world’s largest and most sensitive radio telescope that consortium will build. And scientists across several of IBM’s labs are using big data analytics and weather modeling technology to predict output of individual wind turbines and estimate the amount of generated renewable energy. This level of insight will enable utilities to improve the much-strained energy grid.

While much has changed at IBM Research – Zurich, the essence of collaboration and the spirit of innovation and excellence that Speiser envisioned remains true to this day.

About the authors

Christophe Rossel received his PhD in physics from the University of Geneva in 1981. After 4 years as research scientist at UCSD, La Jolla (CA) he joined IBM Research - Zurich in 1987. His fields of expertise in condensed matter physics are superconductivity and magnetism, and more recently transport and structural properties of advanced functional materials for CMOS and beyond CMOS technology. Fellow of the EPS and IOP, he was also president of the Swiss Physical Society (2008-12).

Christopher Sciacca is the communications manager for IBM Research in Europe. He is a citizen of both the United States and Cyprus and in his free time he enjoys skiing, squash, photography, traveling and practicing his German. Christopher has a Bachelors of Science in Advertising degree from the New York Institute of Technology. Connect with him at about.me/cps .

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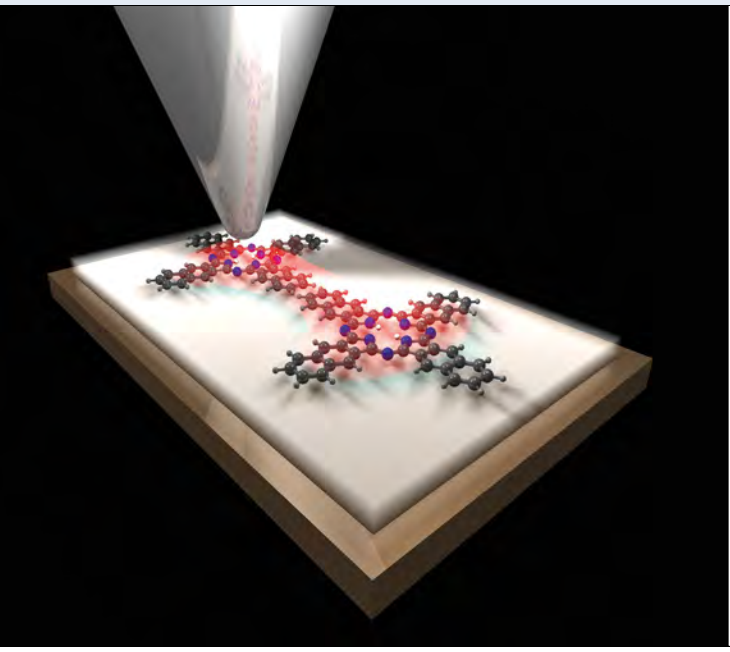
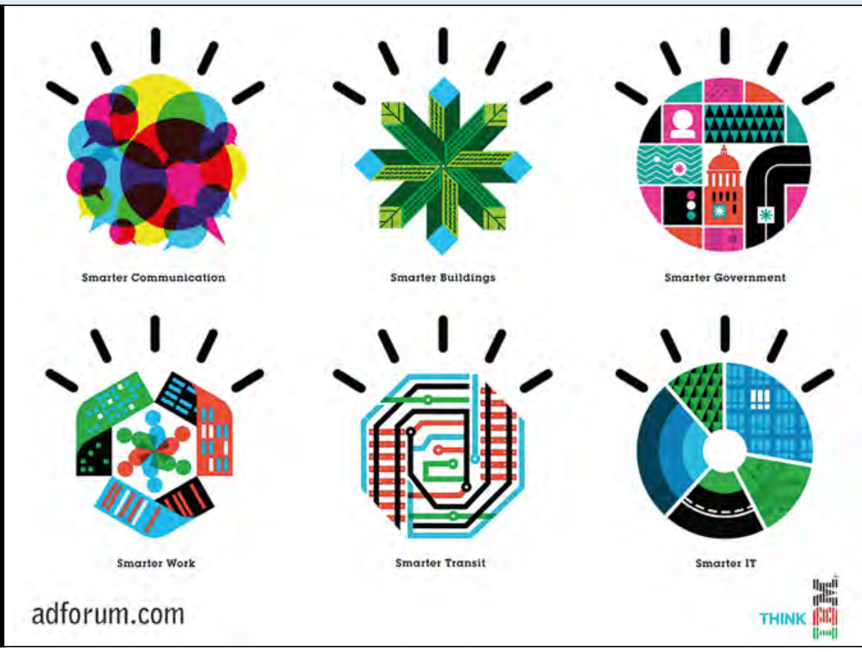
[1] IBM Research Laboratory Zurich: The Early Years, Ambros P. Speiser, *IEEE Annals of the History of Computing* **20-1**, 15 (1998) http://dl.acm.org/citation.cfm?id=612719

[2] IBM 100 Icons of Progress: ibm.com/ibm/history/ibm100/us/en/icons/

▼**FIG. 5:** Schematic 3D image of a molecular “logic gate” consisting of naphthalocyanine molecules, as probed by a low-temperature STM. By a voltage pulse the two hydrogen atoms (in white at the center of the molecule) change position and electrically switch the entire molecule from “on” to “off”, representing a rudimentary molecular logic-gate (F. Mohn, L. Gross, N. Moll & G. Meyer, *Nature Nanotechnology* 7, 227 (2012)).

▼**FIG. 6:** In the span of a century, IBM has evolved from a small business that made scales, time clocks and tabulating machines to a globally integrated enterprise with more than 400,000 employees and a strong vision for the future. *Smarter Planet* is IBM’s latest “big bet” on the future, where Research is strongly involved in finding solutions for everyday work and personal lives.





by L.J.F. (Jo) Hermans
Leiden University, The Netherlands - Hermans@Physics.LeidenUniv.nl - DOI: 10.1051/epn/2014202

Mobility and payload

When moving around, our energy efficiency is heavily influenced by the ratio of the mass being transported to the mass of the vehicle which does the transporting. Professionals call it the 'Payload Fraction'. Let us call it the PF for simplicity. When we mount our bicycle, we are extremely lucky: the PF is much larger than 1. For a typical cyclist (assumed to be not particularly heavy) we find the PF to be around 5. Cars are nowhere near such high value. If driven by a single person, we find a PF around 0.05, and for a full car around 0.25. Can this compete with trains? That depends: typically trains have a PF of 0.10 to 0.20 while light-weight trains can reach a PF of more than 0.35 if people are willing to stand.

But the really interesting case is the airplane. The reason is the energy source. Whereas electric trains do not have to carry their fuel, planes do. And this makes quite a difference. Remember the traditional rule of thumb: irrespective of the type, planes used to consume 10 cm^3 of fuel per seat per second, or 36 litres per hour. With recent improvements in efficiency, let us assume that 25 litres per seat and per hour is a fair number. For short flights of an hour or so, this does not represent a tremendous extra weight per passenger, and hardly influences the payload. However, for long-distance flights this is a different story. Take a flight from Paris to Cape Town, or from Amsterdam to San Francisco. These take more than 10 hours, so the fuel per passenger that the plane has to carry is around 250 litres at take-off. This is several times the mass of the passenger, so it has a pretty devastating impact on the payload. The first lesson we learn is that short flights have a much better PF than long ones. Planes like the Embraer 190 and the Fokker 100, designed for short distances, achieve PF values of 0.35 (for maximum payload and maximum take-off weight). Not bad if we compare it to a car.

Now what about long distances? Let us look at a real case: the big, double-decker Airbus 380 which is designed for long-haul distances. Its 'operational empty weight' is some 270 tons. The maximum amount of fuel it can load is 250 tons. This is in line with the above rule of thumb if we consider that the number of passengers is around 700 (it varies from 550 to 850, depending on seating arrangement) and realise that some extra fuel should be taken on board for take-off and landing. So, refuelling the empty aircraft practically doubles its weight! The result is that the PF for maximum take-off weight is 0.21 only. Other long-haul planes like the much smaller Boeing 787 Dreamliner have the same value.

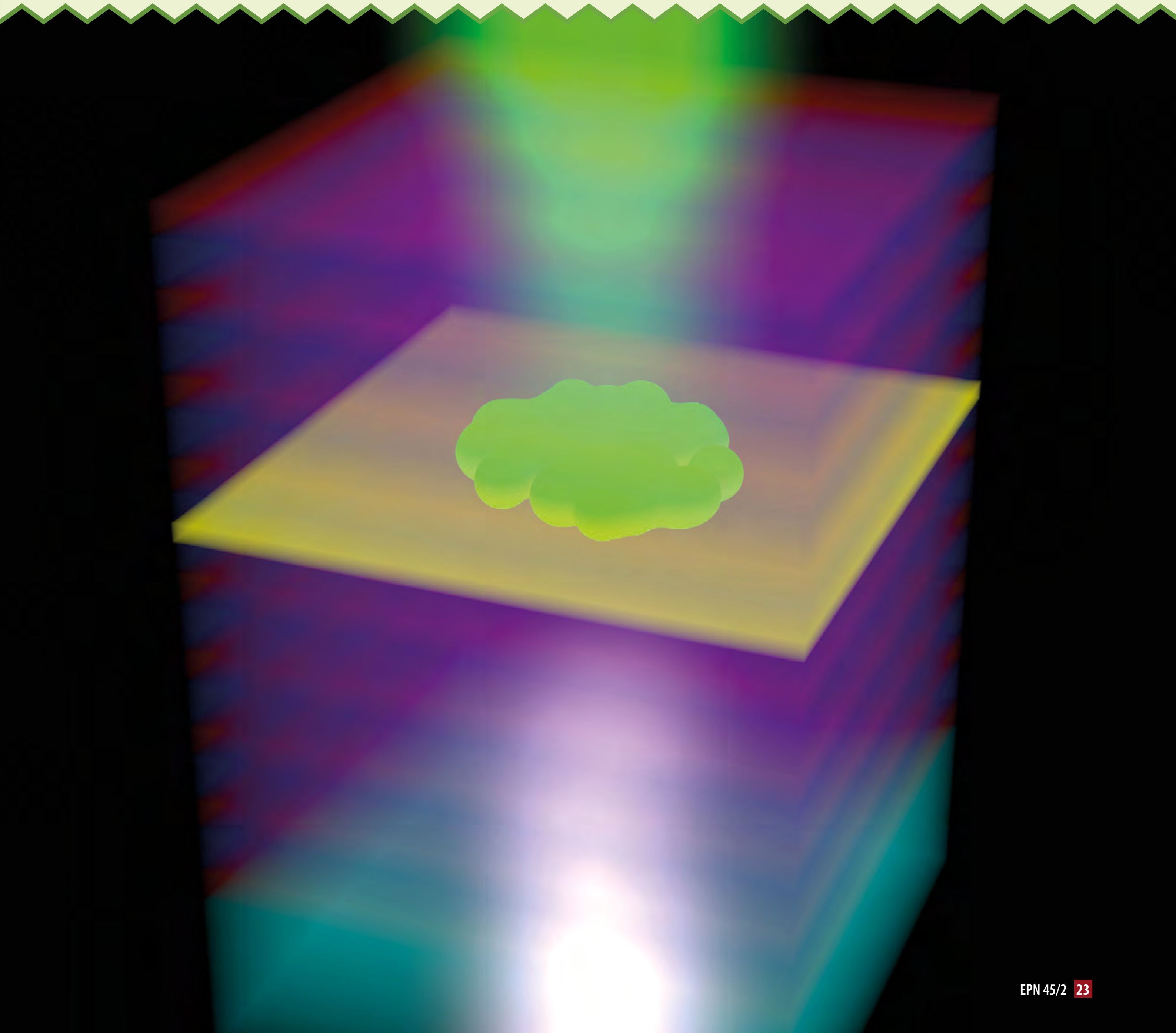
Now one would be tempted to think that the heavy fuel load of long-range, four-engine planes like the Airbus 380 or the Boeing 747 explains why they climb so slowly after takeoff, if you compare it with two-engine planes. Wrong. The real reason is that safety rules require that an aircraft must be able to continue its take-off even if one engine goes dead. This means that, if everything works properly, four-engine planes have a 33% power surplus, whereas two-engine planes have a full 100% surplus.

So it's not always the physicist who determines the behaviour of an aircraft, nor the technician. Sometime it's our safety. ■

FANTASTIC PLASTIC MAKES THE QUANTUM LEAP

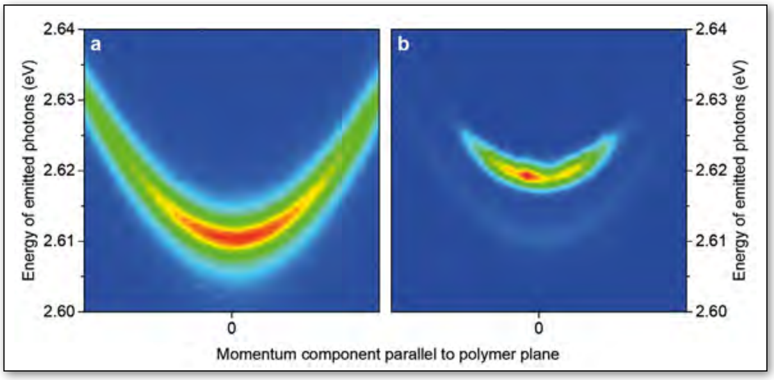
Thilo Stöferle and Rainer F. Mahrt – IBM Research – Zurich, Switzerland – DOI: 10.1051/epn/2014203

A Bose-Einstein condensate is an intriguing state of matter where extensive collective coherence leads to macroscopic quantum phenomena. It has now been demonstrated using a thin plastic film at room temperature. This provides a new, simple route to experimentally study many-body quantum physics and opens the door for device applications.



◂ **Previous page:** a polymer layer (yellow) is sandwiched between two Bragg mirrors (red and blue oxide layers). When excited with an ultraviolet laser from below, polaritons are created (green). The laser-like light emitted to the top is a signature of the Bose-Einstein condensate.

In the 1920s Satyendranath Bose and Albert Einstein predicted the existence of a new state of matter near the absolute zero temperature. At this low temperature, particles do not behave like point-like billiard balls anymore but acquire significant spatial extension as their de Broglie wavelength increases with decreasing temperature. At sufficiently high density, the wavefunctions of particles whose behaviour in the ensemble follows the so-called Bose-Einstein statistics, start to overlap and accumulate in the lowest energy state. Thereby they lose their individual character and instead form a macroscopic "super-particle", the Bose-Einstein condensate (BEC).



▴ **FIG. 1:** Dispersion relation of the polymer film within the microcavity, where the false colors represent the emitted intensity. **(a)** Below the critical polariton density, a parabola with Boltzmann-like intensity distribution in energy and momentum is observed. **(b)** Above the condensation threshold, the polariton BEC shows up as a separate, narrow peak in the center. The intensity is 100 times higher which requires a corresponding adaptation of the false-color scale.

Looking into nature's quantum kitchen

While it was soon realized that there is an intricate relationship with the phenomena of superfluidity in liquid helium and superconductivity, it took physicists 70 years to create such a state of matter in the laboratory. In 1995, Eric A. Cornell and Carl E. Wieman from JILA in Boulder [1], and Wolfgang Ketterle from MIT in Boston [2] achieved Bose-Einstein condensation in dilute alkali gases at temperatures below a few micro Kelvin, for which they were later awarded the Nobel prize. This breakthrough paved the way for an ongoing, long series of fundamental studies of genuine quantum effects and phases, exploiting the unprecedented possibilities to control, manipulate and investigate this special quantum many-body state. A truly fascinating and appealing aspect of all these experiments is that one can literally really see quantum mechanics "at work".

Shortly after the first BEC, Atac Imamoğlu and co-workers predicted that similar phenomena should be observable also in solid state systems [3]. Here the condensing bosons would be quasi-particles (so-called polaritons) created by strong coupling between bound electron-hole pairs (excitons) and photons in an optical microcavity (see BOX). In contrast to alkali atoms, their number is not conserved as they can readily be created by pumping with a laser and destroyed by recombination of electron-hole pairs or photons leaking out of the cavity. Therefore it is different from Bose and Einstein's original model because the driven and dissipative nature of polaritons intrinsically prohibits thermal equilibrium with the environment. A compelling advantage, however, is that the effective mass of these polaritons is on the order of 10^{10} times less than the mass of alkali atoms, which boosts the critical temperature for BEC above room temperature. Furthermore, photons leaking out from the cavity transport all the necessary information about the polariton state to the outside world where they can easily be measured with a spectrograph or imaged by a camera.

From dilute gases at a few micro Kelvin to semiconductors crystals at room temperature

In 2006, the groups of Benoît Deveaud-Plédran in Lausanne and Le Si Dang in Grenoble jointly demonstrated the first polariton BEC in CdTe quantum wells at -268°C [4]. In the following years, other groups reported polariton BECs at room temperature, using GaN or ZnO structures. The delicate and defect-free growth of these semiconductor crystals and quantum wells is very challenging and only mastered by a handful of laboratories world-wide. However, the quest for materials with relaxed requirements on the quality and better suitability for application in devices is opposed by the fundamental difficulty to realize a very ordered phase such as the BEC in disordered materials.

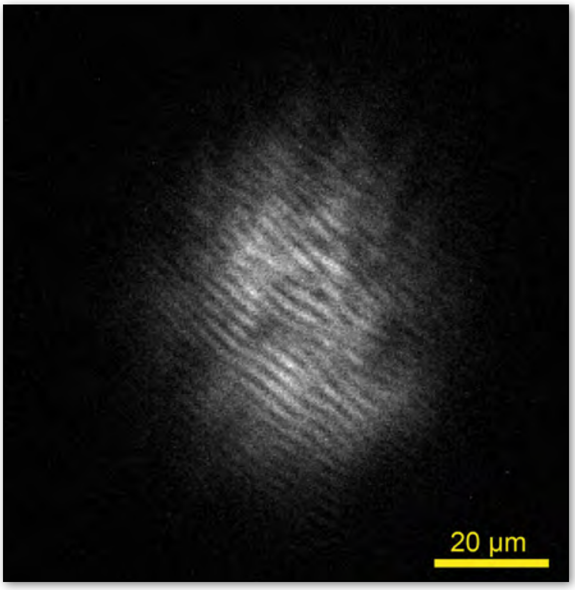
Very recently, our group at IBM Research – Zurich used an amorphous 35 nm-thin polymer film embedded in an optical microcavity to achieve polariton BEC [5] (see Intro Illustration). The special luminescent polymer, which was developed about 20 years ago at the Max-Planck Institute for Polymer Research in Mainz for organic light emitting diodes (OLED), features a rigid backbone to reduce intrinsic disorder and enhance its optical properties.

Can something as ordered as a Bose-Einstein condensate be created in something as disordered as a polymer film?

By exciting the polymer film with picosecond laser pulses at a wavelength of 400 nm, the transition from a normal phase to BEC shows up in the polariton dispersion (Fig. 1). The spectrum and angular distribution of the light coming from the microcavity allows to directly map out the dispersion relation and the occupation of the polariton states as a function of energy and momentum. At low pump intensity, the parabolic shape of the polariton dispersion is observed, where the intensity distribution reflects a Boltzmann distribution in energy and momentum – as expected for a thermalized ensemble of polaritons. When the intensity of the pump laser and therefore the polariton density is increased, suddenly a new peak appears which is much narrower in energy and momentum than the parabolic polariton dispersion. This is a key signature of the polariton BEC. Owing to the stimulated scattering mechanism responsible for the population of the BEC state, its intensity grows strongly super-linear with excitation power. It is slightly shifted to higher energy compared to the polariton parabola because of the repulsive Coulomb interaction in the dense ensemble of electron-hole pairs.

The most striking feature of a BEC is the emergence of long-range phase coherence where the wavefunctions of the condensing bosons are synchronized over macroscopic distances. This can be directly probed by sending the photons from the microcavity through a Michelson interferometer and recombining the light from the two interferometer arms on a camera. If the polaritons were coherent, they should interfere constructively and destructively and therefore form a fringe pattern. We observe such interference patterns over almost the whole pumped area which is several tens of micrometers in diameter (Fig. 2). Furthermore, certain characteristic patterns such as fork-like structures are indicative of the presence of vortex-like excitations in the condensate. As the total duration of this pulsed-driven BEC is currently on the order of a few picoseconds only, the observations are dominated by the "birth phase" of the condensate where vortices are expected to be quite ubiquitous [6]. Actually, this is a consequence of the so-called Kibble-Zurek mechanism that is a general feature of sudden phase transitions, and which was also at play in the formation of matter in the early universe.

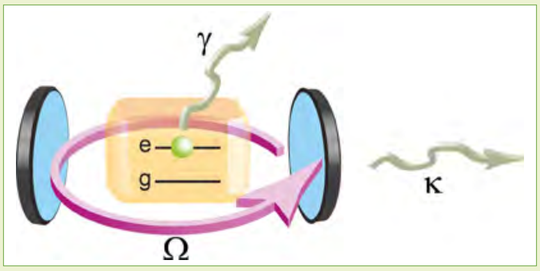
Nearly two decades after the first atomic gas condensate just above absolute zero, we now have arrived at (non-equilibrium) BEC at room temperature in a plastic film. But apart from beautiful textbook-like quantum mechanical experiments, what is it good for in terms of applications? Most recently, atomic gas BECs have been used for "quantum simulations" of other physical systems, which are hardly experimentally accessible or even not theoretically tractable [7]. For the solid-state polariton BEC, opto-electronic applications come within reach. Here the promise is to use the coherent laser-like light from the polariton BEC as micro-laser that does not require the energy-intensive creation of population inversion in the gain medium like in conventional lasers. The first electrically pumped polariton laser based on semiconductor quantum wells has just been demonstrated at a few degrees above absolute zero [8]. With the polymer-based BEC, however, electrical driving will be much more difficult, given the low charge mobility in the material, and will certainly require another quantum leap. Nevertheless, even optically driven polariton BECs are expected to provide deeper insight into fascinating quantum effects, especially simulating non-equilibrium phenomena on very fast timescales. And this has just become radically easier than ever before, something that Bose and Einstein probably would not have dreamed of almost 90 years ago.



◂ **FIG. 2:** The interference pattern is a hallmark of the long spatial coherence length of the BEC. Non-parallel fringes are a consequence of excitations in the condensate.

BOX: EXCITON-POLARITONS

The optical activity of semiconductors, organics and most other materials originates from electron-hole pairs that can be formed by absorption of light or electrical excitation and can emit light by recombination. In the simplest approximation, this can be described as a two-level system with ground state (no exciton) and excited state (exciton has been formed). Placing such a material into a resonator that is tuned to the transition energy between the two states gives rise to new eigenstates of the coupled system, given that the interaction rate Ω between the cavity photon and the exciton is larger than the spontaneous emission rate γ and the leakage rate κ from the cavity. The resulting quasi-particles composed of half-exciton and half-photon are called exciton-polaritons and inherit the bosonic character from their constituents.



About the authors

Thilo Stöferle received his PhD from ETH Zurich in 2005 for the investigation of Bose-Einstein condensates and degenerate Fermi gases in optical lattices. In 2006 he joined IBM Research – Zurich where he is working on highly efficient nanoscale components for integrated optical communication.

Rainer F. Mahrt received his PhD in 1991 and his habilitation in 1997 in Physical Chemistry from Marburg University. He was appointed a group-leader position at the Max-Planck Institute in 1999. In 2001 he joined IBM Research – Zurich. Current research interests are optics of organic/inorganic hybrid systems in photonic band gap structures.

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[Letter to the Editor]

by A. Bettini

Università di Padova - Italy

About "scientific consensus on climate change"

It has been with great astonishment that I found published on the 44/6 issue of EPN, a journal of a scientific Society, the article "Scientific consensus on climate change".

Climate change is a complex physical phenomenon or better a set of physical phenomena that are being scientifically studied, including their possible anthropic causes. It is also a highly politically sensitive issue. As scientists we should, I think, keep the two aspects well separated.

On the contrary, the article published by EPN pretends to prove the existence of human-caused global warming, "by consensus". The point here is not whether the theory of human caused global warming is true or not, but the means that is used to proof that. Consensus rather than experiment. "Consensus can be measured; if it is large enough it proofs the theory".

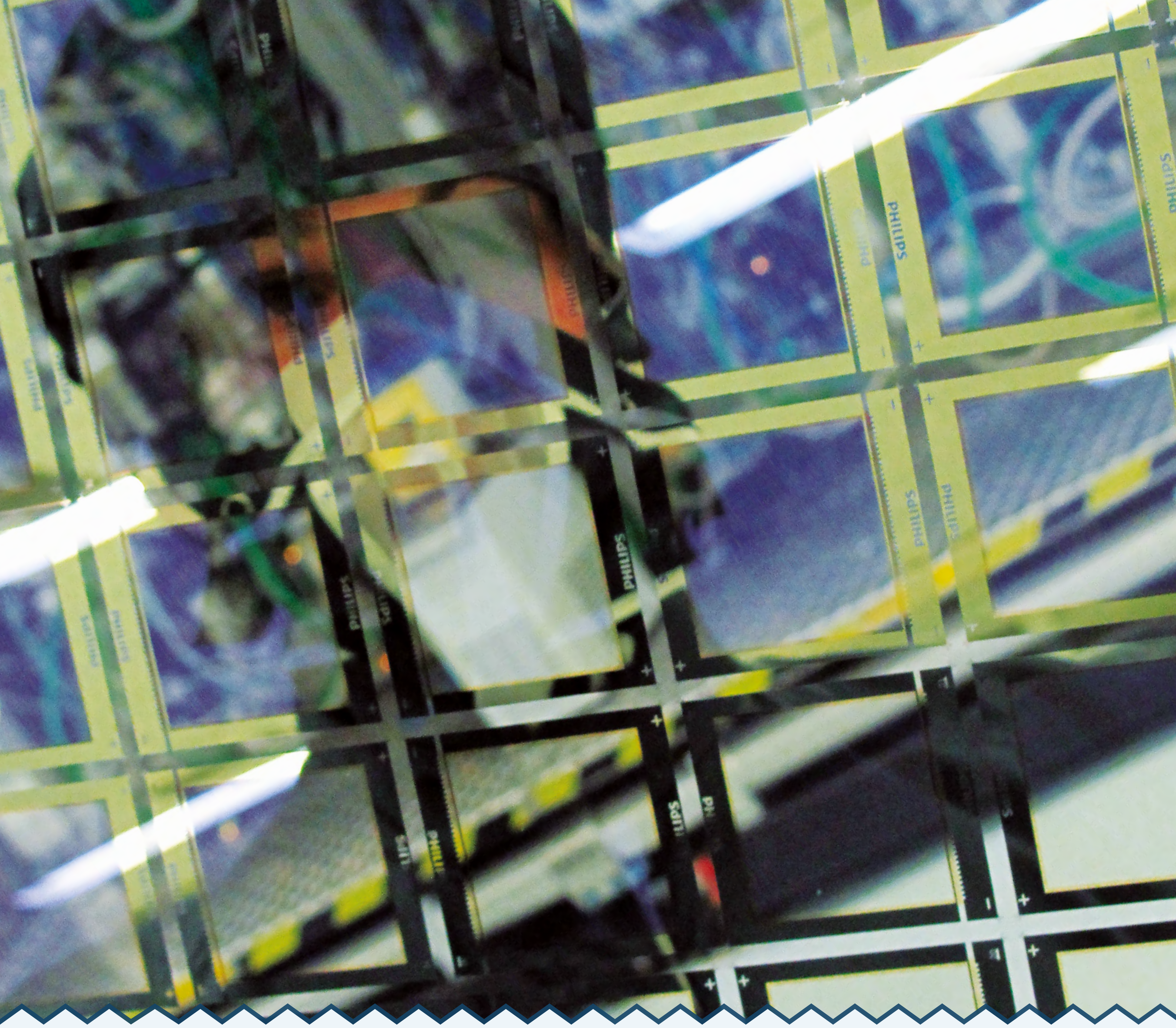
This is an extremely dangerous behaviour. Consensus is the instrument of democracy. Science is not democracy; it rests on the Galilei scientific method. Abandoning that will bring us back to the Middle Ages. It is astonishing to find this view in a Journal of a scientific society.

I would like to ask you to publish my letter.

Thanks for your attention. ■

The Editor responds

Europhysics News offers its readers a forum to publish articles which are interesting to a wide readership and which satisfy accepted scientific standards. The Feature by John Cook meets both criteria. Prof. Bettini claims that the author uses consensus to prove the existence of human-caused global warming, but this is not the case. What the author does show is that there is a much larger consensus among climate scientists than the public thinks. The quote "Consensus can be measured; if it is large enough it proofs the theory" does not appear in the article. ■



100 YEARS OF PHILIPS RESEARCH

Dirk van Delft – Museum Boerhaave – PO Box 11280 – 2301 EG Leiden – the Netherlands
dirkvandelft@museumboerhaave.nl – DOI: 10.1051/epn/2014204

On Thursday 23 October 1913, a Dutch newspaper published the following advertisement: Hiring: *A capable young scientist with a doctorate in physics. Must be a good experimenter. Letters containing information on age, life history and references may be submitted to Philips in Eindhoven.* Two days later, a candidate applied: Gilles Holst. At that time, Holst was working in Leiden as an assistant to Heike Kamerlingh Onnes, a recent Nobel Prize winner.

In this position, he had played an important role in the 1911 discovery of superconductivity in the Leiden cryogenic laboratory [1]. The 27-year-old Holst was invited for an interview with Gerard Philips, who had begun producing incandescent light bulbs in a vacant factory on Emmasingel in Eindhoven – which is now the location of the Philips Museum.

The two men quickly reached an agreement and, on 2 January 1914, Holst started to work on the fourth floor of the Philips factory building in Eindhoven. He was excited. In a letter to Adriaan Fokker, a colleague and a friend, he wrote, 'I will be furnishing an entire laboratory, and I will be doing all types of measurements that will tell us the formula of the incandescent light bulb'. Known as the *NatLab, this Natuurkundig Laboratorium* (physics laboratory) would gain international fame and serve Philips exceptionally well.

From Copying to Inventing

From 1891 on, Philips had been able to fend off the competition by taking over and adapting innovations that had been developed elsewhere (for example in the research laboratory of General Electric, founded in 1900). Launching original new ideas was not a part of the strategy. This put the company in a technologically vulnerable position. The re-introduction of a patent law in the Netherlands made the matter even more urgent.

Holst's first challenge was to become familiar with the half-watt lamp, which Philips had copied from General Electric and brought into production shortly before his arrival in Eindhoven. In addition to research, Holst's duties included testing, monitoring and troubleshooting. One stubborn problem involved the tendency of the inside of the light bulb to turn black due to the vaporisation of the filament.

The 1920 appointment of the German physicist Gustav Hertz was a signal that research was being conducted in Eindhoven at an academic level. The development of radio tubes and X-ray tubes only served to reinforce this signal. The *NatLab* generated new products and contributed to the progress of Philips. The people around Holst had to be excellent scientists. In his *NatLab* he therefore provided an academic climate that made people feel that they were working in a high-level scientific environment. Holst encouraged publication in scientific journals, which reflected well on Philips, the *NatLab* and the individual researcher. He also organised colloquiums with renowned physicists, who informed the staff members of *NatLab* about new developments on the scientific front. Paul Ehrenfest, a professor of theoretical physics, made dozens of appearances in Eindhoven, accompanied by speakers from his own colloquium in Leiden.

Enter Casimir

In 1946, Hendrik Casimir belonged to the triumvirate to succeed Holst, together with the engineer and inventor Herre Rinia and the chemist-physicist Evert Verweij.

▼ FIG. 1: Flexible 6-inch polyamide foil with a variety of components and electronic test circuits. The circuits still operate when the foil is sharply bent; 2013.

▶ FIG. 2: The Video 2000 was the technologically advanced showpiece that Philips expected to be its new 'money maker' in the area of consumer electronics. The miserable failure was due to several factors, including the relatively timid way in which the device had been brought to the market in 1979.

Casimir, a brilliant physicist who had worked with Niels Bohr and Wolfgang Pauli and who had a great future in academia before him, caused quite a sensation with this step. During the first years after the war, the *NatLab* clearly had more to offer talented scientists like Casimir than the university did. Pauli was not particularly amused to see one of his students, 'nicht ganz dumm' (*i.e.*, who was not entirely stupid), voluntarily descend to the nether regions of industrial research. From that time on, he would address Casimir ironically as 'Herr Direktor'. Nevertheless, Casimir remained loyal to Philips and repeatedly rejected offers of prestigious positions, including professorial appointments at Cambridge and Leiden, and a director's position at CERN, the European Organisation for Nuclear Research [2]. (Later, 1972-1976, he did become the second President of the EPS!)

While *NatLab* research under Holst had always been related to a concrete product, the opposite was the case during the Casimir era. In his vision, the *NatLab* served as a think tank to support the long-term policies of the product divisions with regard to their product portfolios. To this end, the *NatLab* conducted research that offered no direct prospects for application. This approach also called for *NatLab* research to be organised according to discipline (*i.e.*, by topic area). According to Casimir, a structure based on product divisions would be fatal to the innovative character, as that would raise the risk of introducing short-term thinking in the research.

The *NatLab* was always in search of new research areas. Nuclear physics, superconductivity, astrophysics – anything was possible. Topics on which sufficient knowledge already existed (*e.g.*, electric discharge in gases) were rejected. The fact that Philips earned good money on gas-discharge lamps did not matter. The Household Appliances division also received a raw deal due to the lack of possibilities for fundamental research. In 1960, Casimir complained about his inadequate opportunities for fundamental research. In many areas, the *NatLab* had made useful contributions, but they had yet to achieve any major breakthrough like the transistor developed by Bell Labs. It would nevertheless be quite wrong to assume that the fundamental research of the *NatLab* yielded only meagre results. Materials research on ferrite (magnets in loudspeakers) and research on the storage of hydrogen in a lanthanum-nickel compound (rechargeable batteries) were highly successful.

The two most remarkable successes from the Casimir period were the invention of the Plumbicon (a T.V. camera tube) and LOCOS (a process for manufacturing semi-conductors for the production of integrated circuits). Whether these breakthroughs would have occurred if the *NatLab* researchers had enjoyed less freedom remains an open question. The fact is that, during the period 1946-1972, Philips could afford to maintain a laboratory characterised by considerable

◂ **FIG. 3:** Gerard Philips (1858-1942), co-founder Philips, took the initiative to set up a Philips research laboratory, starting in 1914 with Gilles Holst as its first director.

▾ **FIG. 4:** 1931, Philips launched the Philora low-pressure sodium lamp. The name Philora is a combination of 'Philips' and 'aurora'. Highways, ports and classification yards proved particularly well suited for illuminating with Philora lighting.

▲ **FIG. 5:** 3D imaging research at Redhill, 1997. The British Philips Research facility was originally based at the Mullard Research Laboratories site. It has been based in Cambridge since 2008.

▶ **FIG. 6:** Hendrik Casimir explaining the model of the new location of Philips Research at Waalre (near Eindhoven). Construction started in 1959. Casimir would later become the second EPS president.

scientific freedom. Even if this freedom led to frustration in the contacts with product divisions, what would it matter, as long as the company as a whole was flourishing?

From Technology Push to Market Pull

After decades of economic prosperity, the tide started to turn at the end of the 1960s. This had repercussions for the *NatLab*. When Eduard Pannenborg succeeded Casimir in 1972, a new wind began to blow in Waalre, a town to the south of Eindhoven where a new *NatLab* had been built in the 1960s. Pannenborg saw greater advantage in 'market pull' than in the 'technology push' strategy according to which the initiative lay with the *NatLab* or the development laboratories of the product divisions. What now mattered was to listen to the market. Whereas Casimir encouraged the exploration of new areas of research, Pannenborg placed the priority on making optimum use of the existing science. In the Casimir era, there had always been fundamental questions that remain unanswered and offered an excuse to continue the research. Under Pannenborg's watch, subjects such as the Stirling engine, futurology and biology were abandoned because of lack of interest from the product divisions. Superconductivity suffered the same fate: decades of research and still no sign of any positive result.

In terms of its size, the *NatLab* had by now passed its peak. The new complex in Waalre had been designed for 3,000 employees, but this peaked at 2,600 at the end of the 1960s. As part of Centurion, the major cost-cutting exercise announced by Philips' boss Jan Timmer in 1990, the total research contingent (the *NatLab* and the laboratories abroad) had to be reduced from 4,000 to 3,300 employees. In 1989, the funding also changed. Previously, *NatLab* had always been allocated its budget (about 1% of Philips' annual turnover) directly 'from above', from the Executive Board. That very same Executive Board decided that the *NatLab* would henceforth have to secure two-thirds of its budget via contract research from the product divisions. The move was seen as a bitter defeat and the end of independence. However, what the move did achieve was to boost the mutual commitment between the *NatLab* and the product divisions, which had been sorely lacking with Casimir at the helm. When developing the electronics for a digital audio converter, which was important for the compact disc [3], the *NatLab* and the product divisions Audio and Elcoma (Electronic Components and Materials) worked together constructively.

NOTE

On view in Museum Boerhaave (Leiden, the Netherlands) until 26 October 2014: '100 YEARS OF INVENTIONS, Made by Philips Research', an exhibition celebrating the first centenary of Philips Research.
See www.museumboerhaave.nl/english

◂ **FIG. 7:** Molecular Beam Epitaxy for silicium devices; 1995.

▴ **FIG. 8:** A biosensor made by Philips Research with conventional chip manufacturing techniques, after which they are printed with proteins using the inkjet printer method; 2013.

Three focus areas

The modern-day Philips – and with it also Philips Research – focuses on three areas: *Healthcare*, *Consumer Lifestyle* and *Lighting*. No more CD players, computers or televisions, but MRI scanners, Senseo and LED lighting instead. The products may be different, but there is a startling continuity in the underlying technology. Philips Research has also retained its independence, on the proviso that a research success is only truly successful if it is also a commercial success. Philips Research (headquartered in Eindhoven, with locations in Bangalore, Briarcliff, Cambridge, Hamburg, Paris and Shanghai) employs around 1,500 staff after several cost-cutting exercises. Its research budget continues to be around 1% of Philips' total turnover (Research & Development for the whole of Philips was 7% of the annual turnover in 2012). The Waalre site has recently been updated and extended to become High Tech Campus Eindhoven, where Philips Research and other Philips divisions have since been joined by more than a hundred institutes and businesses working on technologies and products of the future.

Philips Research engages in what it calls 'open innovation', making its expertise available to third parties, and making use of the services of university laboratories or start-up companies across the world. Approximately 65% of Philips Research projects are carried out in alliance with universities, knowledge institutions or government bodies. Customers, suppliers or partners of Philips businesses are involved in around half of these projects.

Through all of this, Philips Research hopes to broaden its perspective and at the same time raise its profile as an attractive employer that gives talent room to grow. ■

About the author

Dirk van Delft is director of Museum Boerhaave, the Dutch museum for the history of science and medicine, and part-time professor 'Heritage of the Sciences' at Leiden University. In 2007 he published *Freezing Physics. Heike Kamerlingh Onnes and the Quest for Cold* (Edita, Amsterdam).

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Credit picture exhibition (in BOX): © Museum Boerhaave / Karen Polder

Opinion:
Is Open Access really good for science?

Anders Kastberg *is professor of physics at Université Nice Sophia Antipolis*

In EPN 44/4, Alex Bradshaw writes that we should "accept the challenge" of Open Access. In EPN 44/5, there is an article by Agnès Henri. Moreover, EPS has recently issued a statement on OA.

What seems clear with OA is that politicians have made their minds up. The slogan: "output from publicly funded research should be freely accessible" is tempting, and arguing against it implies political risks. If Bradshaw means that OA is going to happen, and we may as well start to adapt, I agree. However, it seems as if he wants us to embrace OA uncritically.

Henri has a point when writing that when parties submitting articles do not buy subscriptions, the current economic model will not be sustainable. Thus, green OA may not be compatible with subscription-based models.

The EPS statement is cautiously phrased. Instead of saying that we should "accept the challenge", it gives recommendations for OA. These are difficult to argue against, but EPS may create a catch-22 for OA. Like EPS, I find it important that one has the freedom to chose where to submit, but I cannot see how that can be compatible with models where revenue is created when articles are published.

What I miss is critical discussions about whether OA is really good for science, and for diffusion of knowledge. The standard "democracy argument" is that everyone should have access to research results funded by taxes. However, a majority of the general public will have no use of free access to specialised articles. I agree that there is a need to diffuse science better, but that is not solved by access to research journals. We do need better ways to diffuse knowledge, but such activities bring few career benefits, and I see few initiatives to address this. The suggestion that OA solves this problem may be counterproductive. In fact, I think this core argument for OA is fundamentally flawed.

Another objection to OA, rarely discussed, has to do with the raison d'être for science publishing. The purpose ought to be spreading of knowledge. A scientist's work expands the perimeter of knowledge, and publishing makes this accessible. Peer-review, gives quality control, and archiving makes the information available for overseeable future.

However, for many scientists today, the reason for submitting articles is not spreading of knowledge, but promoting one's career. Thus, journals are merely a quality control that facilitates indices and numerology for assessment, to the delight of policy makers.

Furthermore, the economics of publishing is claimed to be globally unchanged with OA, since it is the same community that both produces and reads the articles, with the publisher as intermediary. Thus, it does not make any difference, it is argued, if paying when writing or reading. This reasoning is at the heart of gold OA, illustrated in Henri's article, where the same researcher is both author and reader (with the general public no longer involved!).

Suppose the "author pays model" would be applied to other human activities. Can we imagine an economy where producers of groceries pay supermarkets for supplying goods, while consumers can pick up anything for free? A market where "supply" and "demand" take on different meanings?

The only way to make sense of models where we pay for authorship is that we accept that the demand comes from scientists wanting to improve performance indices.

Instead, the only way to make sense of models where we pay for authorship is that we accept that the demand comes from scientists wanting to improve performance indices. The suppliers are the journals. If someone reads the article is less important. Naively, I had wanted the researcher to be the supplier; the publisher an intermediary; and the reader representing demand. However, I do not think that is compatible with economic models where we pay for authorship, instead of readership.

This said, halting OA will be politically impossible. We shall have to accept that the purpose of scientific journals is no longer diffusion of knowledge. Then, we can "accept the challenge". And never mind if the emperor turns out to be naked. ■

COMING EPS EVENT

- **Advanced Materials at Demanding Applications,** *07-10 April 2014,* Glyndwr University, UK http://amda2014.iopconfs.org/home
- **MORE ON:** www.eps.org

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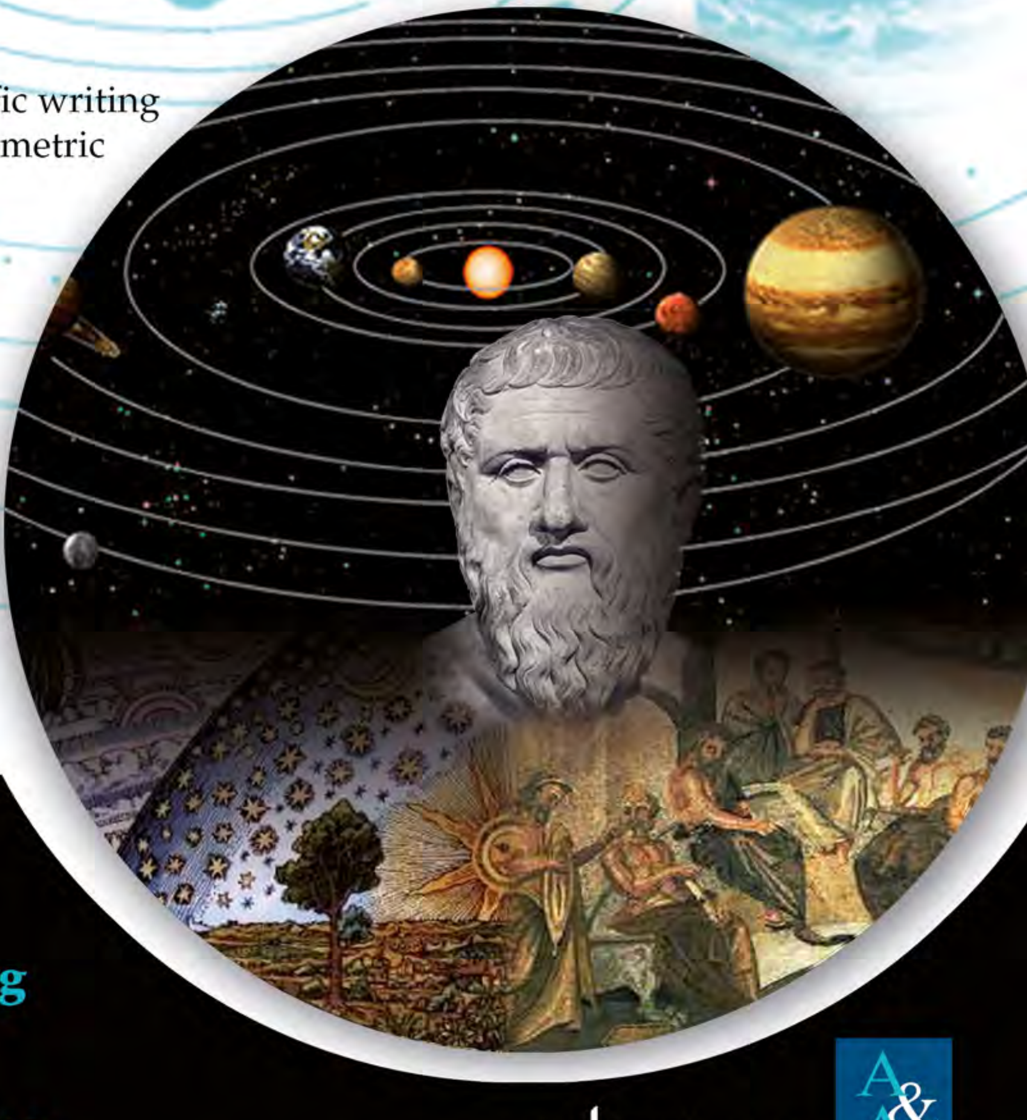
- Libraries, library services and librarians
- Policies of astronomical societies
- etc.



The School is open to PhD students and young postdocs

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