International Union of Pure and Applied Physics

IUPAP Newsletter

President: **Bruce McKellar** • Editor-in-Chief: **Kok Khoo Phua** • Editors: **Maitri Bobba; Sun Han**

SEPTEMBER 2015

Message from the President

The mission of IUPAP is to assist in the worldwide development of physics, to foster international cooperation in physics, and to help in the application of physics toward solving problems of concern to humanity. One of the most important things we can all do to achieve this mission is the mentoring of young physicists, thus ensuring the continued health and development of our subject. As a contribution to this mentoring, IUPAP, through its Commissions, awards Young Scientist Prizes. This issue of our Newsletter highlights the Young Scientists who have received Prizes this year. I hope that you will find their stories as inspiring as I have. Calls for nominations for the 2016 Prizes will appear on the IUPAP website at http://iupap.org/young-scientist-prize/award-announcements/ early next year. I encourage all of you to nominate one of the young physicists you are mentoring for the next IUPAP Young Scientist Prize in your field.

Bruce McKellar

First C&CC Meeting – April 24 – 27, 2015 – ICTP Trieste, Italy

group photo of IUPAP Council members and Commission Chairs

The first meeting of the new (2015-2017) IUPAP Executive Council and Commission Chairs (C&CC) was held at the Abdus Salaam International Center for Theoretical Physics (ICTP) in Trieste, Italy on April 25 and 26, 2015. At the welcome address to the council and commission chairs, the Director of ICTP explained the role of ICTP as a successful model of international collaboration for scientific research and education. Research at ICTP now covers a wide range of topics: high energy, cosmology and astrophysics, condensed matter and statistical physics, mathematics, applied physics, earth system physics as well as new areas like renewable energies, quantitative biology and high performance computing. Since its inception in 1964, ICTP has trained and developed many scientists, particularly from developing countries.

IUPAP does much of its work through its 23 commissions and associated commissions based on their expertise in a particular field in Physics. These commissions promote the objectives of the Union within their areas and provide advice to IUPAP on the activities and needs of subfields of physics that they represent. This C&CC meeting provided an opportunity for the new Chairs of Commissions and representatives of associated commissions to get to know each other, and to learn more about the workings

IUPAP Secretary General , Professor Phua Kok Khoo presented his report

of IUPAP. You can find out more about them from the electronic version of this newsletter (http://iupap.org/newsletter/).

The earlier sessions of the C&CC meeting were devoted to several discussions related to resolutions arising from the last General Assembly in November 2014 in Singapore. In particular, it was decided that K.K. Phua, Sandro Scandolo and Deborah Kane would form a sub-committee to produce a report on how to revise the statutes to include associated organizations which can assist IUPAP with its missions. Moreover, it was also decided that there should be an IUPAP prize for outstanding contributions to the improvement of physics research and/or education in one or more developing countries.

K.K. Phua also gave a brief status report on the relocation of the IUPAP office from London to Singapore. Commission matters related to the sponsorship, endorsement and approval of conferences, commission reports and so forth were discussed and debated. It was pointed out that there is a need for the previous Chair of a Commission to stay as an observer for one year after the completion of their term to facilitate and mentor the new Chair. On the second day of the meeting, financial matters related to the approved budget for 2015 and matters arising from membership dues were discussed. Bruce McKellar informed the council and commission chairs that the IUPAP website would be transferred from its current site in London (hosted by IOP, UK) to Singapore. During the initial stage, some teething problems are expected. The IUPAP newsletter was also circulated.

Detailed minutes of the meeting are available on the IUPAP website (http://iupap.org/about-us/executive-council/executive-council-minutes/).

As stated in the statutes, the IUPAP aims (i) to assist in the world development of physics to foster international collaboration in physics and to help in the application of physics towards solving problems of concern to humanity, and (ii) to sponsor international meetings thereby fostering communications and publications, encouraging research and education, fostering the free circulation of scientists, promoting international agreements on symbols, units and nomenclature as well as cooperating with other organizations on disciplinary and interdisciplinary problems. It is important that the commissions contribute to these missions and there was a brief session on how commissions could do so.

The meeting closed with Joe Niemela delivering a fascinating report on the progress and activities of the International Year of Light.

IUPAP COMMISSION AND AFFILIATE COMMISSION CHAIRS 2014-2017

IUPAP body is divided into 23 commissions and associated commissions based on their expertise in a particular field in Physics. These commissions promote the objectives of the Union within their areas and provide advice to IUPAP on the activities and needs of subfields of physics that they represent.

IUPAP Commission Chairs

C1: The Commission on Policy and Finance

Chair: Bruce McKellar
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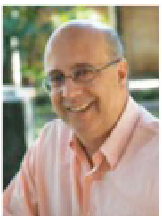

C2: The Commission on Symbols, Units, Nomenclature, Atomic Masses and Fundamental Constants

Chair: Vanderlei Salvador Bagnato (2014) (2011)
Instituto de Fisica de São Paulo
Universidade de São Paulo
Av. Trabalhador Sao Carlense, 400
São Carlos SP 13566 – 590
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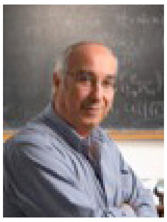

C3: The Commission on Statistical Physics

Chair: Itamar Procaccia (2014) (2011) (2008)
The Weizmann Institute of Science
Rehovot 76100
Israel
Tel: +972 8 934 3810
Fax: +972 8 934 4123
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C4: The Commission on Astroparticle Physics

Chair: Karl-Heinz Kampert (2011) (2008)
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C5: The Commission on Low Temperature Physics

Chair: John Saunders (2014) (2011) (2008)
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Fax: +44 (0) 1784 472794
Email: j.saunders@rhul.ac.uk

C6: The Commission on Biological Physics

Chair: Aihua Xie (2014) (2011)
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145 Physical Science II
Stillwater, Oklahoma 74078-3072, USA
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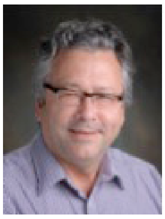

C8: The Commission on Semiconductors

Chair: Michael Thewalt (2014) (2011)
Department of Physics
Simon Fraser University
8888 University Drive
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Fax: +1 778 782 3592
Email: thewalt@sfu.ca

C9: The Commission on Magnetism

Chair: Xiaofeng Jin (2014) (2011)
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Shanghai 200433
China
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Fax: +86 21 5566 4480
Email: xfjin@fudan.edu.cn

C10: The Commission on Structure and Dynamics of Condensed Matter

Chair: J. Raynien Kwo (2014) (2011)
Department of Physics,
National Tsing Hua University
101 Guang-fu Rd.
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Taiwan 30013
Phone: 03-574-2800
E-mail : raynien@phys.nthu.edu.tw

C11: The Commission on Particles and Fields

Chair: Juan Fuster
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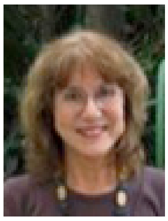

C12: The Commission on Nuclear Physics

Chair: Alinka Lépine-Szily
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Travessa R da Rua do Matão, 187
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Email: alinka@if.usp.br

C13: The Commission on Physics for Development

Chair: Sandro Scandolo
The Abdus Salam International Centre for theoretical physics
Strada Costiera 11 – 34151 Trieste
Italy
Tel: +39 40 2240209
Email: scandolo@ictp.it

C14: The Commission on Physics Education

Chair: Hideo Nitta
Tokyo Gakugei University,
4-1-1 Nukuimachi, Koganei,
Tokyo 184-8501
Japan

C15: The Commission on Atomic, Molecular, and Optical Physics

Chair: Toshiyuki Azuma
Atomic, Molecular & Optical Physics Laboratory
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Tel: +81 48 4621614
Email: toshiyuki-azuma@riken.jp

C16: The Commission on Plasma Physics

Chair: Lin-Ni Hau
Institute of Space Science and Department of Physics
National Central University, Taiwan (R.O.C.)
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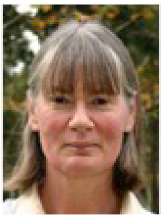
Taiwan Tel: +886 3 4227151857200
Email: lnhau@jupiter.ss.ncu.edu.tw



C17: The Commission on Laser Physics and Photonics

Chair: Deb Kane
Dept. of Physics and Astronomy
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Sydney, Australia
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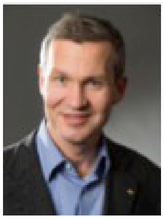
Email: deb.kane(at)mq.edu.au



C18: The Commission on Mathematical Physics

Chair : Manfred Salmhofer
Institute for Theoretical Physics
University of Heidelberg
Philosophenweg 19
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Germany
Tel: +49 6221 549433
Email: M.Salmhofer@thphys.uni-heidelberg.de

C19: The Commission on Astrophysics

Chair: Grazina Tautvaisiene
Institute of Theoretical Physics and Astronomy
Vilnius Univ.
Gostauto 12, Vilnius LT-01108, Lithuania
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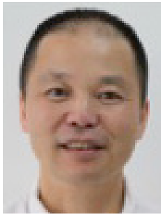

C20: The Commission on Computational Physics

Chair: Hai-Qing Lin
Beijing Computational Science Research Center
3 He-Qing Road
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Beijing 100084
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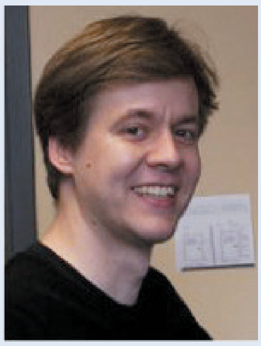
YOUNG SCIENTIST AWARDS

The Young Scientist Prize is granted by IUPAP Commissions. Successful candidates have up to 8 years of research experience following Ph.D. (excluding career interruptions). Each commission can give up to three awards over three years (these can be one per year or all three awarded together). The award consists of a certificate, medal and a monetary award. A presentation will take place at an international conference sponsored through the commission.

COMMISSION ON ASTROPARTICLE PHYSICS (C4)

Dr. Julia Tjus, University of Gothenburg, Sweden

Julia Tjus was awarded the 2015 IUPAP Young Scientist Prize in Astroparticle Physics for her outstanding work connecting phenomenology and experiment in neutrino astronomy. After studying physics in Oerebro (Sweden) and Wuppertal (Germany), Julia finished her PhD in 2007 in Dortmund (Germany). After taking a postdoctoral position at University of Gothenburg, Sweden, she became Junior Professor at Bochum, Germany, in 2009 and then full professor on plasma astroparticle physics in 2013. Since 2012, she is a member of the Young Academy of the Berlin-Brandenburg Academy of Sciences and Humanities as well as the German National Academy of Sciences Leopoldina. Her research activities cover physics for active galaxies and gamma-ray-bursts as potential cosmic accelerators. She is a member of the IceCue, HESS, and CTA collaborations.



Dr. Claudio Kopper, University of Erlangen, Germany

Claudio Kopper was awarded the 2015 IUPAP Young Scientist Prize in Astroparticle Physics for his outstanding contribution to the analysis of the IceCube Neutrino-Telescope data, leading to the first-ever observation of high-energy cosmic neutrinos. Claudio received his PhD from the University of Erlangen, Germany, in 2010. As a graduate student, he worked on optimizing the layout of the planned KM3NeT neutrino telescope. After receiving his PhD, Claudio went to the National Institute for Subatomic Physics in Amsterdam, to help finalize the design of KM3NeT and to provide major contributions to its Technical Design Report. In 2011, he became the John Bahcall Fellow at University of Wisconsin, Madison, where he joined the IceCube project and developed novel techniques that improved the sensitivity in detecting signals from high energy neutrinos. Since 2014, he has been a professor at the University of Alberta.

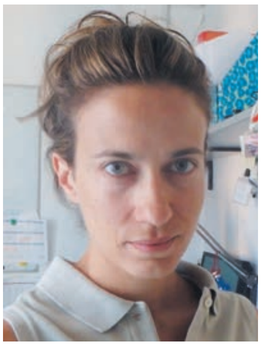
COMMISSION ON ATOMIC, MOLECULAR AND OPTICAL PHYSICS (C15)

Dr Gretchen K Campbell, a Fellow, Joint Quantum Institute, National Institute of Standards and Technology and University of Maryland, Gaithersburg, MD

The 2015 IUPAP Young Scientist prize for the Commission on Atomic, Molecular and Optical Physics (C15) was awarded to Dr Gretchen K Campbell, for her outstanding contributions in toroidal Bose-Einstein condensates and its application to "atomtronic" circuits. She received her Ph.D. in Physics (87Rb Bose-Einstein Condensates in Optical Lattices) in 2007 from MIT, Boston under the supervision of W. Ketterle and D. Pritchard. After taking a postdoctoral position in Prof. Jun Ye's group at JILA/NIST, Boulder, she moved to JQI, NIST/Univ. of Maryland as a group leader of the Laser Cooling and Trapping group.

Campbell pioneered the study of ring-shaped Bose condensates of atomic gases and created the first closed-circuit atomtronic devices. She performed the ground-breaking experiments that incorporated a "circuit element" (a weak-link) into a closed loop of condensate. After these milestone experiments, she achieved enormous progress in this new research field. The similarities and differences between Campbell's atomtronic circuits and the equivalent electric circuits have brought new insights into superfluidity and the controversial nature of critical velocities and the mechanisms for dissipation.

COMMISSION ON PLASMA PHYSICS (C16)



Dr. Livia Lancia, Université of Rome

After her Bachelor's degree, Dr. L. Lancia received her Master in « Scienze per l'Ingeneria » from University of Rome, La Sapienza in 2006. For both her Bachelor's and Master's degrees, she obtained the highest final mark 110/110. She then performed her PhD work in the field of laser plasma interaction, which was awarded in 2010 as a joint PhD between the University of Rome, La Sapienza and the Ecole Polytehnique, Palaiseau (France). The thesis title was « Study of non-linear effects on laser propagation and electron transport in plasmas". After a postdoctoral position at the University of Rome, La Sapienza, she is now a Researcher - Teacher at the same University. She also conducts research as Principal Investigator at the Laboratoire d'Utilisation des Lasers Intenses, LULI, France. In conjunction with her research activities, she teaches Physics at the University of Rome.

Dr. Lancia's laudation reads : "For experimental contributions to our understanding of laser-matter interaction phenomena, including Brillouin amplification of laser beams and magnetic fields self-generation in plasmas"

Dr. Christian Theiler, The Centre de Recherches en Physique des Plasmas (CRPP)

Dr. Christian Theiler received his master degree in physics from the Eidgenössische Technische Hochschule Zürich ETHZ in Zurich (CH). He then joined the Centre de Recherches en Physique des Plasmas (CRPP) of the Ecole Polytechnique Fédérale de Lausanne (EPFL in Lauasanne, CH) for his PhD thesis, which he obtained in 2011. His thesis, "Basic Investigation of Turbulent Structures and Blobs of Relevance for Magnetic Fusion Plasmas", was a Special Distinction among the Best Thesis of the EPFL. He then moved to the Plasma Science and Fusion Center of the Massachusetts Institute of Technology for his postdoctoral years (2012-2014). During this period, he was also granted a Swiss National Science fellowship as an advanced postdoctoral fellow. In 2014, he won one of the EUROfusion postdoctoral fellowships and returned to the CRPP. Besides his research activities on the CRPP tokamak TCV, he also participated in the preparation of the first massive open online course MOOC on plasma physics.

Dr. Theiler's laudation reads: "For pioneering work on the physics of the edge of magnetically confined plasmas and its influence on fusion performance and on the interaction between the plasma and the surrounding material walls.

COMMISSION ON LASER PHYSICS AND PHOTONICS (C17)

Dr Mark Thompson, Centre for Quantum Photonics, University of Bristol, United Kingdom.

Dr Mark Thompson is awarded the prize "for his contributions to the new and emerging field of quantum photonics, and particularly for his pioneering work in integrated quantum photonic circuits." He did his Master of Physics at the University of Sheffield, United Kingdom, finishing in 2000. He completed his PhD in 2007 at the University of Cambridge, UK, in the Department of Electrical Engineering. Subsequently he held postdoctoral fellow positions at the University of Cambridge, University of Bristol, UK; and Toshiba Corporation, Japan. He was appointed as a lecturer in the School of Physics, University of Bristol, UK, in 2010 and is now a Reader in Quantum Photonics and Director of the Quantum Engineering Centre for Doctoral Training.

Dr Robert Fickler, Institute for Quantum Optics and Quantum Information, University of Vienna, Austria.

Dr Fiickler moved very recently to a postdoctoral fellowship at the Centre for Quantum Photonics, University of Ottawa, Canada. Robert Fickler is awarded the prize "for his groundbreaking contributions to the entanglement of complex structures of photons, which have opened up new avenues for quantum communication". He completed his Bachelor's and Master's degrees (in Physics) at the University of Ulm, Germany, finishing in 2009. He completed his PhD in 2014 at the University of Vienna in the Institute for Quantum Optics and Quantum Information. His thesis, titled "Entanglement of Complex Structures of Photons", received a Doc.Award. Until recently, he has been working as a postdoctoral fellow, continuing in the group of Professor Anton Zeilinger in Vienna.

COMMISSION ON MATHEMATICAL PHYSICS (C18)

Dr Roland Bauerschmidt, Post-Doctoral Researcher Harvard University

Roland Bauerschmidt has been awarded the IUPAP Young Scientist Prize in Mathematical Physics 2015-2017 for his work on self-avoiding random walks in 4 dimensions and the development of supersymmetric renormalization group techniques for their study.

Born in Hannover, Germany, Roland Bauerschmidt studied in Bonn, Germany, and Zurich, Switzerland, and received his B.Sc. and M.Sc. in Physics from ETH Zurich. His Ph.D. in Mathematics (2013) was from the University of British Columbia, Vancouver, Canada. He spent 2013-2014 at the Institute for Advanced Study, Princeton, before moving to Harvard University, where he is currently a postdoctoral Researcher. In 2016, he will return to the University of British Columbia as Assistant Professor of Mathematics.

Bauerschmidt has mastered, developed and extended a renormalization group program initiated by David Brydges and Gordon Slade, and made important contribution to this area. In a strikingly original paper, he provided a simple new way to understand the finite range decompositions of Gaussian fields that underpin the renormalization group approach.
His work on the structural stability of non-hyperbolic dynamical systems is
an essential ingredient in the application of the renormalization group method.

Bauerschmidt's work sheds new light on fundamental aspects of statistical physics, such as the behaviour of the self-avoiding random walk in four dimensions, quantum friction, and random matrix theory.

Dr. Joseph Ben Geloun, Humboldt Fellow at the Albert Einstein Institute in Golm, Germany

Joseph Ben Geloun has been awarded the IUPAP Young Scientist Prize in Mathematical Physics 2015-2017 for his pioneering work on the renormalization of tensor field theories and his discovery of their generic asymptotic freedom.

Joseph Ben Geloun was born 1976 in St. Louis, Sénégal. After graduating from Cheikh Anta Diop University in Dakar, Sénégal,
he received his PhD in 2007 from Université Nationale du Bénin.
After taking a visitor's and postdoctoral positions at Université Paris-Sud, France, and University of Stellenbosch, South Africa, he held a postdoctoral position at the Perimeter Institute for Theoretical Physics, Waterloo, Canada, from 2010 to 2013.

After his PhD, Ben Geloun entered research on quantum gravity. In just a few years, he became a major expert in the field. His most striking results concern a new class of non-local renormalizable quantum field theories, called tensor field theories, whose perturbative expansion sums over random geometries weighted by a discretized Einstein-Hilbert action. In his classification of these models, he discovered an unexpected property, namely their generic ultraviolet asymptotic freedom.

He has also started to direct the research work of younger scientists such as Dine Ousmane Samary and Remy Avohou. Now a Humboldt Fellow at the Albert Einstein Institute in Golm, Germany, Ben Geloun is becoming a role model for the next generation of young African scientists.

Dr. Nicolas Rougerie, CNRS researcher at Laboratoire de Physique et Modélisation des Milieux Condensés, Grenoble

Nicolas Rougerie has been awarded the IUPAP Young Scientist Prize in Mathematical Physics 2015-2017 for his exceptional contributions to the theory of cold quantum gases, in particular, the proof of the appearance of a giant vortex and vortex circles in rapidly rotating Bose gases.

Nicolas Rougerie was born in 1985 in Versailles, France, and received his PhD in Mathematics from Université Pierre et Marie Curie, Paris, in 2010. He subsequently became a postdoctoral associate at Université de Cergy-Pontoise. In 2011, he was awarded a permanent CNRS researcher position in mathematics, at Laboratoire de Physique et Modélisation des Milieux Condensés, Grenoble (the only CNRS position in mathematical physics awarded in all of France in that year).

Already Nicolas' PhD thesis contains seminal results on giant vortices and vortex circles, and he published two important papers on these topics in 2011. This work was pushed further in a series of papers written together with Michele Correggi, Florian Pinsker and Jakob Yngvason, which appeared in 2011-2013. Further important contributions include the quantum Hall regime of rapidly rotating Bose gases (joint with Sylvia Serfaty and Jakob Yngvason), a new approach to the mean-field limit in quantum many-body physics, based on a quantum version of de Finetti's theorem (joint with Mathieu Lewin and Phan-Tanh Nam). He has furthermore published work on polarons in quantum crystals, on higher dimensional Coulomb gases and on the average field approximation for extended anyons.

INTERNATIONAL COMMISSION ON MEDICAL PHYSICS, IOMP (AC4)

Dr. Guerda Massillon (2015), Instituto de Física, Universidad Nacional Autonoma de Mexico, México

Dr Guerda Massillon was born in Bassin-Bleu, a little town Northwest of Haiti, and moved to Port-au-Prince, the capital of Haiti to obtain a BSc in Physics from the Universite d'Etat d'Haiti in July 1996. She moved to Mexico City in 1998 where she earned an MSc in Medical Physics and a PhD from the Universidad Nacional Autonoma de Mexico (UNAM).

In February 2007, she was appointed by the Institute of Physics, UNAM as a Research Associate to work on dosimetric properties of materials exposed to high-ionization density radiation fields. Simultaneously, she was granted permission to undertake 2 years postdoctoral at the National Institute of Standards and Technology (NIST), Gaithersburg, MD USA where she led part of the research project: "Absorbed dose measurement for low-energy photon brachytherapy Sources" collaborating with Drs. Christopher G Soares, Michael G Mitch and Ronaldo Minniti. After her return to UNAM in 2010, she was promoted to Assistant Professor. Since then, she has been concentrating on two research projects: "Response of dosimetric materials exposed to low-energy photons" and "Reference dosimetry for small radiotherapy fields".

In 2011, Guerda Massillon was awarded as a Fellow of the InterAmerican Network of Academies of Sciences (IANAS) for her research and scholarly competence as well as her potential in helping to strengthen science and technology capacity in the Americas and cooperation between researchers and institutions in her field of study. In Mexico, she has been recognised as National Researcher Level II from the Mexican National System of Researchers (SNI) in January 2014.

Dr. Jan-Bernd Hövener (2014), Head of Hyperpolarization Research Freiburg, University Medical Center Freiburg, Germany

Dr. Jan-Bernd Hövener was born in Münster (Westfalen), Germany, and studied Physics and Business Informatics at the "Westfälische Willhlems Universität" in Münster. After receiving his Vordiplom (intermediate diploma) in 2001, he moved on to the University of Heidelberg. He spent two semesters at the "Université Nice Sophia Antipolis", France, where he took part in the "Maîtrise Physique" and "DESS biomedical", including subjects on fluid dynamics and statistical physics.

After returning to Heidelberg, he finished the final exams and carried out his diploma thesis with Prof. Bachert at German Cancer Research Center (DKFZ) titled "Development of a technique to determine non-invasively the total content of N-Acetly-L-Aspartate in the human brain in vivo". This was the starting point for a joint research project with Prof. Gass (Mannheim) and Prof. Gonen (New York). In the course of this project, Dr. Hövener spend several months followed by multiple visits as a visiting scientist in the lab of Prof. Gonen at New York University (NYU).

For his PhD, Dr. Hövener decided to join the hyperpolarization research group at the California Institute of Technology (CalTech, Prof. Weitekamp), and the Huntington Medical Research Institutes (HMRI, Profs. Bhattacharya and Ross), both in Pasadena, USA, for two years. Upon his return to Germany, he defended his thesis after total time of two years and seven months with the mark "magna cum laude" (very good) at the University of Heidelberg, Faculty of Physics and Astronomy.
During this time, he contributed essentially to the development and application of parahydrogen-based hyperpolarization of biomolecules, which is reflected by several manuscripts, conference contributions and awards.

In 2010, Dr. Hövener was admitted to the Academy of Excellence of the German Science Foundation (DFG). Supported by this award, Dr. Hövener was able to expand his group and to date has supervised more than ten students. He is teaching in Freiburg and has published more than 15 papers as well as numerous peer-reviewed or invited conference contributions.

His future potential and past accomplishments were recognized by the admission to the Emmy-Noether Program (ENP) of the DFG.

Plasma accelerators

R Bingham STFC, Rutherford Appleton Laboratory, Harwell Oxford, Didcot, Oxon. OX11 0QX, UK

Physics Department, John Anderson Building, University of Strathclyde, Glasgow, G4 0NG, UK.

Particle accelerators have led to remarkable discoveries about the nature of fundamental particles providing the information that enabled scientists to develop and test the Standard Model of particle physics. The most recent milestone is the discovery of the Higgs boson using the Large Hadron Collider (LFHC) the 27km circumference 7 TeV proton accelerator at CERN Switzerland. On a different scale, accelerators have many applications in science and technology, material science, biology, medicine including cancer therapy, fusion research and industry. These machines accelerate electrons or ions to energies in the range of 10s of MeV to 10s of GeV. Electron beams with energies of several to 10s of GeV are used in generating intense x-rays in either synchrotrons or free electron lasers such as the Linear Collider Light Source LCLS at Stanford or the XFEL in Hamburg for a range of applications. Particle accelerators developed last century are approaching the energy frontier. Today at the terascale the machines needed are extremely large and costly, even the smaller scale lower energy accelerators are not small.

The size of a conventional accelerator is set by the technology used to accelerate the particle and the final energy required. In conventional accelerators radio frequency microwave cavities support the electric fields responsible for accelerating charged particles. In these accelerators, due to electrical breakdown of the walls, the electric field is limited to about 100MV/m. For more than 30 years plasma based particle accelerators driven by either lasers or particle beams have shown great promise, primarily due to the extremely large accelerating electric fields they can support, about a thousand times greater than conventional accelerators leading to the possibility of compact structures. These fields are supported by the collective motion of plasma electrons forming a space charge disturbance moving at a speed slightly below c, the speed of light in vacuum. This method of particle acceleration is commonly known as the plasma wakefield accelerator.

Plasma based accelerators are the brain child of the late John Dawson and his colleagues at the University of California, Los Angeles and is a topic that is being investigated worldwide with a great deal of success. Will they be a serious competitor and displace the conventional "dinosaur" variety? The impressive results that have so far been achieved show considerable promise for future plasma accelerators at the energy frontier as well as providing much smaller "table-top" ion and electron accelerators. Research on plasma based accelerators is based on the seminal work by the late John Dawson and collaborator Toshi Tajima [1]. The main advantage of a plasma based accelerator is that it can support accelerating electric fields many orders of magnitude greater than conventional devices that suffer from breakdown of the waveguide structure, the plasma is already "broken down". The collective electric field E supported by the plasma is determined by the electron density E~ n1/2, where n is the electron density, and is known as an electron plasma wave, the collective electric fields are created by a drive beam that can be either laser or charged particle beams. These electron plasma waves travel with a phase speed close to the speed of the drive beam. The electric field strength E of the electron plasma wave is approximately determined by the electron density, E~ n1/2 where n is the density in cm-3 , for example a plasma with density 1018 cm-3 can support a field of about 109 V/cm a 1000 times greater than an RF accelerator. This translates to a reduction in size of accelerator.

The original plasmaaccelerator schemes investigated in the 80s and 90s were based on a long-pulse laser. Short-pulse lasers did not exist because chirp pulse amplification had not yet been demonstrated in the optical regime, only in the microwave regime. Experiments used the beat-wave mechanism of Tajima and Dawson, where two laser beams with a frequency difference equal to the plasma frequency drive a large-amplitude plasma wave. Most laser-driven and particle-driven particle accelerator experiments today are in the so-called bubble or blowout regime where the pulse length of the laser or particle beam is of the order of the plasma wavelength, and are commonly known as the laser wakefield accelerator or beam driven plasma wakefield accelerators. In the laser wakefield accelerator the radiation pressure of a short, intense laser beam pushes plasma electrons forward and aside, creating a positively charged ion column. As the laser beam passes the displaced electrons snap back, due to the restoring force of the ions, and overshoot, setting up a plasma density modulation behind the laser pulse. Similar plasma wakefields are set up by relativistic, charged particle beams propagating through uniform plasma.

Early experiments produced beams with large energy spread, but in 2004 three independent groups in three different countries demonstrated laser wakefield acceleration producing mono-energetic electron beams with good emittance using short-pulse lasers, and many groups worldwide now routinely produce electron beams at GeV energies using this scheme [2]. Similar plasma wakefields are set up by relativistic charged particle beams propagating through uniform plasma. In 2007 Chan Joshi's group at the University of California demonstrated acceleration of electrons in meter-long plasma columns using a SLAC charged particle beam as a driver. This resulted in particles near the back of the electron beam doubling their energy from 42GeV to 85GeV in a 1 metre long lithium plasma [3]. A remarkable result since it takes 3km of the SLAC linac to accelerate electrons to 42GeV. The plasma beam driven wakefield is incorporated into the latest round of experiments at SLAC, by a consortium now called the Facility for Advanced Accelerator Experimental Tests (FACET). Beam driven plasma wakefields also underpin the proton beam driven wakefield experiment, AWAKE, which will use the proton beam from CERN's Super Proton Synchotron and a 10 meter long plasm column to produce giga volt electrons.

Today most experiments are conducted in the bubble regime. The Berkeley Laboratory Laser Accelerator (BELLA) Centre at Lawrence Berkeley Laboratory, as well as many other laser plasma accelerator experiments around the globe including the lasers at the Rutherford Appleton Laboratory Central Laser Facility already demonstrated mono-energetic electron beams at the giga electron volt scale and planned experiments using lasers will demonstrate acceleration of electrons to 10 GeV. Recently FACET experiments demonstrated high efficiency in electron beam production where the energy transfer from the wakefield to the accelerated bunch exceeded 30% with a low energy spread [4].

Despite the successes of these experiments it is still necessary to improve beam quality, in particular low energy spread and low emittance, and beam focussing. Most of the experiments are guided by plasma simulations that require using HPC clusters. These simulations have already predicted that between 10-50GeV electron beams can be created in one stage of a plasma accelerator.

If plasma accelerators are to take over from conventional machines, a great deal of effort still needs to be put into efficient drivers. Suitable laser efficiency and pulse rate are looking likely with diode-pumped lasers or with fibre lasers, but effort has to be put into these schemes to meet the requirements necessary to drive a wakefield. For beam-driven systems, electron beams at 100 GeV and proton beams with tera-electron-volt energies are required. These exist at the LHC for protons and at FACET for electrons. For an e+e– system, a key challenge is positron acceleration and some groups are looking at positron acceleration in wakefields. Alternatively an e–e– collider or a photon (γ–γ) collider could be built, doing away with the need for positrons and so saving time and effort.

A number of other applications for plasma-based accelerators have been identified such as X-ray generators through betatron radiation, drivers for free-electron lasers, or low-energy proton machines. After more than 30 years it is time to develop the facilities that can answer some of the outstanding issues to demonstrate the full potential of high-energy plasma-based accelerators.

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[2] S P D Mangles et al, Nature 431, 535, 2004. C G R Geddes et al, ibid. 431, 538, 2004. J Faure et al, Ibid. 431, 3541, 2004.

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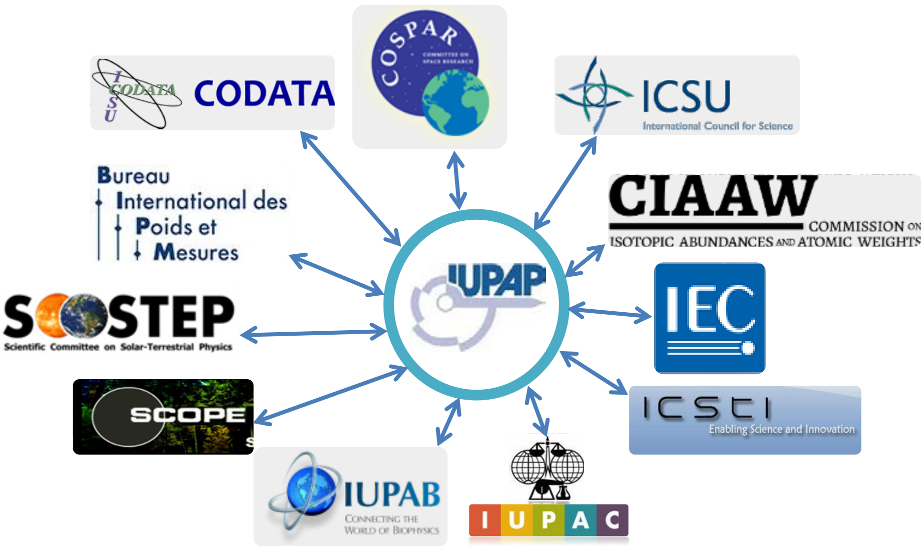

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