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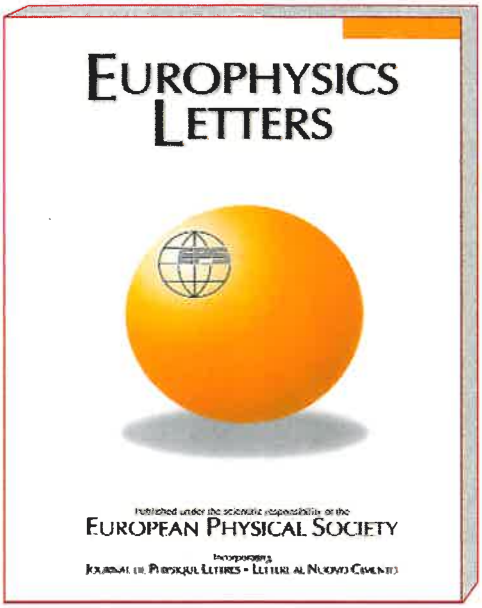

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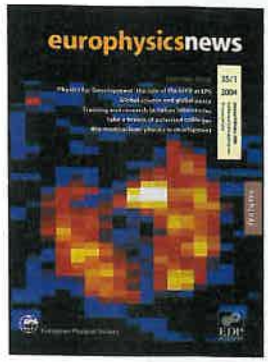

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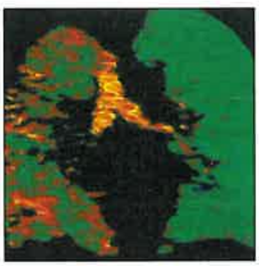

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Physics for Development: the role of the IGPD at EPS

Majed Chergui, Ecole Polytechnique Fédérale de Lausanne, Lausanne-Dorigny, Switzerland

When looking through the scientific literature, most of us will agree that not much happens in physics in developing countries. Yet, as physicists we all agree that physics can address a large number of problems that developing countries have to face and find cheap and easy solutions to many of them, e.g. production of solar energy, monitoring of urban and rural pollution, medical applications, water purification, etc.

The problems encountered in physics research and training in developing countries are acute. While they may vary from country to country, they obey more or less the same rules: serious lack of funding, which worsens with the economic situation, political instability, wars, isolation of scientists, lack of public awareness, lack of institutional frameworks for research, difficult or no access to scientific publications, etc. The list is too long and we leave it to the collection of articles of this special issue to discuss the situation more in depth and to go into details in some characteristic examples. Yet at the same time, what is being and has been achieved is impressive and deserves admiration, given the local difficulties physicists have to face. In parallel, and despite the many individual initiatives by European scientists to develop links with colleagues from developing countries, it is fair to say that there is no initiative or policy by European countries, let alone the EU, to strengthen the research potential of developing countries, except for very few exceptions (see article by Furlan). Most of the North-South collaborations in Physics rely more on personal contacts (article by Svanberg and Svanberg and by Kwato Njock), which is fine but far from sufficient.

> what is being achieved is impressive and deserves admiration, given the local difficulties physicists have to face.

While the awareness of the EPS for Physics for Development dates back to 1981 when H. Van Regemorter founded the Interdivisional Group of Physics for Development (IGPD) at the European Physical Society (see article by Lillethun and Suzor-Weiner), the importance of pursuing the effort and making it more significant is crucial at present. In August 2002, a symposium on Physics and Development was organised during the General EPS conference in Budapest, which brought together physicists from Latin America, Africa and the Arab world (unfortunately the South and South-East Asian participants cancelled their attendance) to discuss the situation with European physicists. The present mini-special edition stems in parts from the discussion that then took place.

Strengthening the research potential in Physics of developing countries is the IGPD main focus, despite its very limited funds. Three axes are being pursued, in order of priority: a) funding for advanced schools and workshops in Physics in developing countries, with particular emphasis on participation by citizens from developing countries both at the level of lecturers and students; b) funding of the bi-annual Southern European School, which encourages strong participation by students from developing countries (see article by Lillethun and Suzor-Weiner); c) travel grants for short-term training in European laboratories.

In addition, the IGPD aims at becoming a forum for exchange of information and for establishing both South-South and South-North contacts. Along with the efforts of individuals and other organizations both in the industrialized and developing countries (see below for a list of useful organisations), we feel committed to the strengthening of physics research and teaching in developing countries. At a time when physics has become highly international and when European laboratories have more and more doctoral students from developing countries, leaving more than 80% of the world out of the game is counterproductive and unsafe. The European physics community should grasp the importance and urgency of this issue.

Useful Links

Institutions concerned with research in developing countries

The Abdus Salam International Centre for Theoretical Physics, Trieste (ICTP)
http://www.ictp.trieste.it/

The Abdus Salam International Centre for Theoretical Physics, Trieste Link for publications
http://library.ictp.trieste.it/

African Academy of Sciences (AAS)
http://www.aasciences.org/

Agence Universitaire de la Francophonie (AUF)
http://www.auf.org/

The Alexander von Humboldt Foundation (Germany)
http://www.avh.de/

Arab Science and Technology Foundation (ASTF)
http://www.astf.net

Association of Asian-pacific physical societies (AAPPS)
http://www.aapps.org/

German Academic Exchange Service (DAAD)
http://www.daad.org/

Initiative on Science and Technology for Sustainability (ISTS)
http://www.sustainabilityscience.org/ists

International Council of Scientific Unions (ICSU)
http://www.icsu.org

Palestinian European Academic Cooperation in Education (PEACE PROGRAMME)
http://www.unesco.org/general/eng/programmes/peace-palestine/

Public Library of Science
http://www.publiclibraryofscience.org/

Third World Academy of Sciences (TWAS)
http://www.twas.org/

World Conference on Science (UNESCO)
http://www.unesco.org/science/wcs

Henri van Regemorter: genesis of the IGPD

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Our colleague and friend Henri Van Regemorter, a French CNRS fellow attached to the Paris Observatory (Meudon, France) passed away last November. An active member of EPS since its beginning, his main contribution to the EPS action is the co-foundation in 1984 of the Interdivisional Group Physics for Development (IGPD), successively chaired by E. Lillethun (Norway), L. Hasselgreen (Sweden), A. Suzor-Weiner (France) and presently by M. Chergui (Switzerland). Two of these chairpersons describe the contribution of Henri to the IGPD action.

The beginning
by E. Lillethun

I met Henri first in Istanbul, in September 1981, where he was chairing a meeting of the Advisory Committee on Physics and Society, following a seminar on "Physics in Developing Countries in Europe," the first attempt of EPS to discuss the peculiar difficulties of training and research in some Southern European countries. We kept contact now and then, and met again at a conference in Trieste, in 1984, together with Prof. M. Tomak, from Turkey. During the same week there was a workshop for mathematics and physics teachers/researchers from Africa. Both Henri and I were interested in sitting in, listening to their discussions.

The participants returned again and again to the questions: "Why do we have to get to Europe to meet each other?" and "How can we build up our strength at home in Africa? Coming to conferences, workshops, courses in Europe is interesting, but when we come back home we are isolated and without any infrastructure needed for continued research. We have hardly one periodical and very little experimental equipment."

These questions struck a chord with both Henri and me, and we started discussing how we, European physicists, could help our colleagues from developing countries. Of course, the ICTP in Trieste was already doing a wonderful job, but we thought that EPS could bring something specific, not in terms of budget but of solidarity. Together with M. Tomak we discussed possible methods for starting an EPS committee to help the physicists and mathematicians in developing countries. Henri had been the President of a French "Committee for Scientific and Technical Cooperation with Vietnam" from about 1975, and therefore had experience of the needs and ways to help.

Henri, Mehmet and I went back to our universities and worked on the proposal for creating the IGPD which was approved by the EPS Executive Committee in October 1984, and by the Council of EPS on 23 March 1985. Soon a board was elected, and met about once a year, often in Paris where Henri was very helpful in providing free meeting rooms and cheap accommodation!

The first action of IGPD was to organize in 1988 a "Workshop for Planning of Network Projects in Materials Science and Solar Energy," in Nairobi (Kenya). Henri was one of the most active members of the International Programme Committee, and he formulated the Declaration from the workshop.

In 1988 I started a project for cooperation between a Norwegian university group and Makerere University in Kampala, Uganda. My IGPD archive since 1988 has therefore become less organised, but I can still describe the implementation of another idea of Henri, the series of "Southern Europe Schools of Physics."

The Southern Europe School of Physics
by E. Lillethun and A. Suzor-Weinor

Henri came with the idea that EPS should organize physics schools in Southern Europe, considered at the time a developing region, to train young physicists locally. He wanted the level to be high but adapted to the needs of the audience, and the school to be hosted by a local institute or university which would benefit from the contact with physics professors from all Europe, and young researchers from other European developing countries.

The pioneer school was run by G. Delgado, presently in the EPS Executive Committee, on "Dynamical Processes in Molecular Physics" in Spain, in 1991. Schools have been held in various domains of physics, at different universities or physics centres, every two or three years depending on funding opportunities. A school on lasers was organized in 1995 by S. Fotakis and the Laser Center in Heraklion (Crete). The next was on solar cells in Portici (Italy), organized by I. Solomon in 1998, and more recently we had an excellent school on medical physics in the University of Algarve (Portugal), organized in 2001 by Prof. M. Abreu, still a member of the IGPD board.

Although organized by various colleagues and under various chairs of IGPD, these schools were closely followed by Henri who always insisted on their training sessions, and on adapting the level to the young attendees. Many came from Eastern countries, making interesting connections between Eastern and Southern Europe. More researchers from Northern Africa also obtained grants to attend.

From Southern Europe to South of Europe
by A. Suzor-Weinor

When Henri, my former thesis advisor, proposed my name as a possible chairperson of IGPD in 1994 I was tempted by the challenge but did not know EPS, except for the ECAMP conference in my research domain. I was soon able to work effectively due to constant help from G. Thomas, the EPS Secretary General and a good friend of Henri, and generous support from J. Lewis, the EPS treasurer. I found EPS very receptive to the specific problems of physics in developing countries, both in Europe and outside, and I established fruitful connections with the Action Committee for Physics and Society and the IG for Physics and Education. A task force was created in 1996 dealing with the specific problems of young researchers in the former Eastern block. The IGPD could then look further south, to strengthen the links of EPS and European physicists with colleagues in the third world. The actions went from supporting attendees from North Africa to our Southern Europe schools, to organizing a workshop on "Spectroscopy and Applications" in Dakar (Senegal) in 2001, with the support of UNESCO and in collaboration with APS. Henri had strong connections with physicists in Dakar (such as Prof. A. Wague) and he helped in the selection of participants and teachers. Besides the scientific information, this workshop established some sustained collaborations between African and European teams.

Throughout the years, Henri's impact for opening EPS to support physics and physicists in difficult environments, inside or outside Europe, was constant, effective, and an example to younger colleagues.

Bio-medical laser physics in development

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Optics, spectroscopy and laser applications are suitable high-tech fields for the promotion of physical research in developing countries, since the associated technology is affordable and connects to real-world applications. This is particularly true for diode laser-based research. A developmental programme, mostly for African universities, was pursued from the Lund University with support from the International Programme in Physical Sciences (IPPS), Uppsala and the Abdus Salaam International Centre for Theoretical Physics (ICTP) in Trieste. Our experience started with lecturing at the ICTP and at schools and conferences in Africa. Two 1-month workshops were arranged in Lund focusing on diode laser spectroscopy and applications; the first one in 1996 and the second one in 2001. In both workshops equipment was integrated in Lund and each group could bring a full set-up back to the home university, to be used in advanced teaching and research. Thus, in the 1996 smaller workshop, participants from Cape Coast (Ghana), Dakar (Senegal), Khartoum (Sudan) and Nairobi (Kenya) built experimental set-ups, primarily for diode laser spectroscopy on rubidium vapour. Resonance cells with separated Rb^{85} and Rb^{87} isotopes were used, and ground state hyperfine structure, isotopic shifts and Doppler broadening of free atoms could be studied. Using saturation spectroscopy even Doppler-free signals could be observed, and upper-state hyperfine structure be studied. As a follow-up of the workshop, a Lund graduate student, Peter Kauranen, toured the four African sites and helped to bring the equipment into high performance at each location.

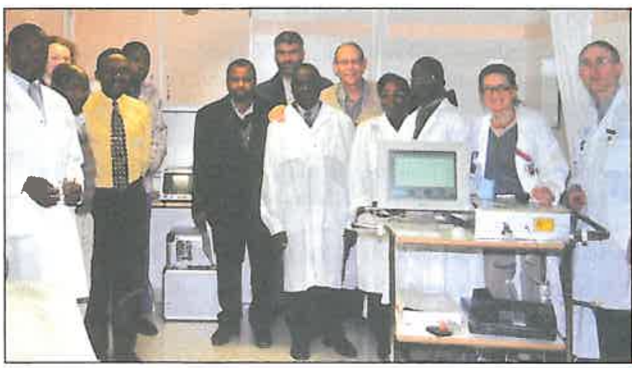
The Lund Workshop "Laser Spectroscopy in Development"

The 2001 spring workshop had participants from the same sites but also from three additional universities, in Harare (Zimbabwe), Tunis (Tunisia) and Quito (Equador). The groups were generally composed by a senior researcher and a student from each location, working together on their own equipment. Lund graduate students Sara Pålsson, Mikael Sjöholm and Gabriel Somesfalean assisted in the workshop. Practical laboratory work was combined with extensive lecturing on relevant topics, and study visits to different Lund research laboratories and to the Lund University Hospital. The main focus of the workshop was to build a compact fibre-optics fluorosensor, based on a Nichia violet diode laser and an integrated spectrometer. A prototype had previously been developed in Lund and successfully applied to vegetation monitoring and skin cancer detection. The Lund group has a long experience in both these fields, which have relevance also to developing countries. The fact, that the hardware for these cutting-edge technology devices costs only 10,000 Euro, including a powerful lap-top computer for experiment control and data collection, made it a very realistic project. The six instruments are now being used in different research projects at the home universities. E.g., a controlled fluorescence study of the growth development of different species of cowpea was recently performed by the group in Cape Coast.

▲ **Fig. 2:** Participants from Senegal, A. Konte and A. Wagué, build and integrate a diode laser based fluorosensor during the 2001 workshop at Lund University. Conferring with them is K. Wangai.

The 2001 workshop also dealt with high-resolution diode laser spectroscopy on free atomic and molecular gases. The Harare group got their own rubidium spectrometer, similar to the ones already in place at the other African sites and this project provided a good update for all. A special grant for the Zimbabwean university from SIDA/SAREC also allowed the integration of an instrumentation for Gas in Scattering Media Absorption Spectroscopy (GASMAS). The first paper on this new technique, where free gas, e.g., molecular oxygen, present in pores in scattering media is studied, had actually been published only 3 months before the 2001 workshop. The equipment is again affordable and allows studies of gas and gas diffusion in natural and synthetic materials such as wood, fruits, polystyrene foam, ceramics etc. A Ghanese graduate student, Benjamin Anderson, stayed 6 months in Lund working with GASMAS. After some time back in Ghana he went on a 4-week research visit to Harare and performed very successful GASMAS experiments together with the local Zimbabwean team on their GASMAS equipment.

The experience from the diode laser spectroscopy project has been described in a recent EPN article, where also the GASMAS principles are presented. The present article focuses on some recent developments in biomedical applications, in particular on the introduction of medical fluorescence diagnostics and photodynamic therapy (PDT) of cancer tumours in Dakar (Senegal). This field is particularly suited for cross-disciplinary interaction between physicists and physicians, and again, the techniques are affordable.



◀ **Fig. 1:** A group from the 2001 workshop in Lund photographed together at the Oncology Department of the Lund University Hospital for a training session with laser based fluorosensors. From left to right M. Diop, S. Pålsson, A. Abdalla, K. Kaduki, A. Konte, K. Dzinavatonga, J. Nejmedinne, A. Wagué, S. Svanberg, N. Ndlovu, M. Mathuthu, K. Svanberg and N. Bendsoe.

features

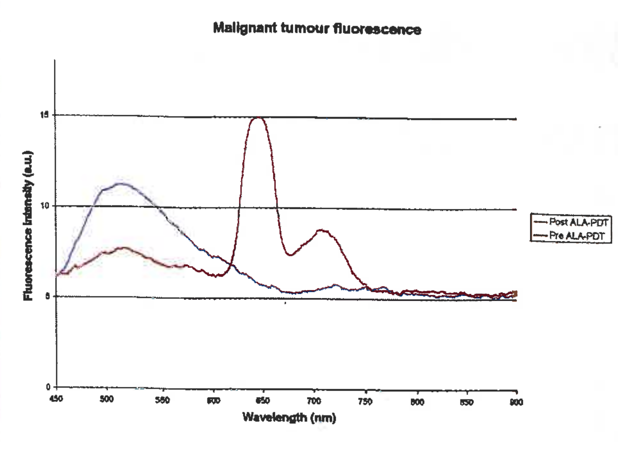
Fluorescence Diagnostics and Photodynamic Therapy

Certain organic molecules have a combination of interesting medical properties: they accumulate in cancer tumours, they mark the presence of a tumour by strong and specific laser-induced fluorescence, and upon tissue irradiation with red light, they mediate the conversion of ground-state molecular oxygen into toxic singlet oxygen. A selective release of this agent in tumour cells leads to specific necrosis and tumour eradication. The Lund group has been working in this field for almost 20 years. During recent year, the introduction of δ-amino levulinic acid (ALA) for PDT has greatly facilitated the application of the techniques. In contrast to most other sensitizers, which are suitable only for intravenous administration, ALA can be given orally, or applied topically as a cream on skin lesions. ALA enters the natural human haem cycle, where the tumour sensitizer Protoporphyrin IX is formed as an intermediate state before the red blood pigment is formed by iron incorporation in a final step. Enzymatic differences lead to the selective production of the strongly fluorescent and photodynamically active protoporphyrin in tumours.

During the International Commission on Optics Conference on Sustainable Development, Dakar, in April 2000, a lecture on the topic was given and there was also an opportunity to visit the Ear-Nose-Throat Clinic in Dakar and together with Prof. Malick Diop discuss the possibility to use PDT in Africa. The 2001 Lund workshop had fluorescence diagnostics and PDT as important aspects, with Dr. Diop and also Dr. Ntkomo Ndlovu, Radiation Therapy Unit, Harare, present together with their local physicist partners. Figure 1 shows part of the school participants together with the local hosts during a training session at the Lund University Oncological Department, where practical aquaintance with the medical laser techniques was obtained. Figure 2 illustrates the integration in Lund of a diode-based fluorosensor by the Dakar group. It is similar to the one described in the paper listed at the end of this article.

In January 2003 Lund researchers went to Dakar with the double purpose of lecturing at the Preparatory School on Biophotonics, arranged by the Cheik Anta Diop University, and to introduce medical fluorescence diagnostics and PDT in work with patients at the Oto-Rhino-Laryngology and Dermatology departments of the Artiside le Dantec University Hospital. The Lund team brought a PDT treatment illumination source based on red light emitting diodes, ALA powder and relevant disposables. The laser fluorosensor shown in Figure 2 was already in place! Three patient were treated in a demonstration session, where the Dakar physicists and physicians collaborated. In Figure 3, Prof. Diop and one of the authors prepare the treatment of an aggressive basal cell carcinoma in a Mauritanian patient. Laser-induced fluorescence recordings on a further Dakar patient taken with by the local physicists using their fluorosensor, are shown in Figure 4. The sharp Protoporphyrin peaks at 635 and 705 nm obtained on tumour tissue are shown. The completion of the PDT session using light-emitting diode light peaking at 635 nm, is evidenced from the total bleaching of the sensitizer in the irradiated region.

▲ **Fig. 3:** Prof. Malick Diop and Katarina Svanberg prepare the PDT treatment in Dakar of a Mauritanian "Blue-men" tribe member, suffering from an aggressive basal cell carcinoma.



▲ **Fig. 4:** Selective uptake of Protoporphyrin IX in a malignant tumour prior to PDT (red curve), and complete photobleaching of the sensitizer in the tumour after treatment (blue curve) as evidenced with the compact Dakar fluorosensor being integrated in Figure 2. (Courtesy: A.S. Ndao and A. Wagué, Dakar.)

The different topics introduced at the African sites—high-resolution laser spectroscopy of free atoms, molecular gas monitoring in natural scattering media, environmental and medical laser-induced fluorescence, and finally, photodynamic therapy of malignant tumours, are all based on the use of diode lasers. The cutting edge technology, while being affordable, provides applications which make a lot of sense also to local governments, and can thus hopefully well serve in the promotion of the physical and medical sciences in developing countries.

Further reading

S. Svanberg Laser Spectroscopy in Development *EPN* March/April 2002 pages 52-53

S. Svanberg "Atomic and Molecular Spectroscopy - Basic Aspects and Practical Applications," Springer Verlag, Heidelberg, 3rd edn. 2001

U. Gustafsson, S. Pålsson, and S. Svanberg Compact Fibre-optic Fluorosensor using a Continuous-wave Violet Diode Laser, *Rev. Sci. Instr.* **71** (2000) 3004

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K. Svanberg, I. Wang, S. Colleen, I. Idvall, C. Ingvar, R. Rydell, D. Jocham, H. Diddens, S. Bown, G. Gregory, S. Montán, S. Andersson-Engels and S. Svanberg, Clinical Multi-Colour Fluorescence Imaging of Malignant Tumours - Initial Experience, *Acta Radiologica* **39** (1998) 2

M. Sjöholm, G. Somesfalean, S. Andersson-Engels and S. Svanberg Analysis of Gas Dispersed in Scattering Solids and Liquids, *Optics Letters* **26** (2001) 16

Global science and global peace

Ahmed Zewail,
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In the past five years, the scientific community worldwide has published about 3.5 million research papers. Europe's share is 37 percent. The U.S. share is 34 percent. The Asia/Pacific share is 22 percent. Other parts of the globe—representing 70 to 80 percent of the world's population living largely in developing countries—have contributed less than 7 percent of these scientific articles.

What difference does this disparity in academic output make? Should only universities and research centers be concerned? Perhaps not. Consider this interesting correlation. The U.S. contribution to the world's annual economic output is between 30 and 40 percent, comparable to its share of scientific output on a global scale. Europe's annual economic output registers a similar percentage and, like the U.S., its economic output tracks its output of scientific contributions. And where there is prosperity and scientific achievement, there is often democracy. It is unlikely that these correlations are coincidental.

If we are aware of these trends and understand the problems that stand in the way of progress, why does the developing world continue to have such difficulties building scientific capacity and putting science to work to improve its economic well-being? And, what can the "haves" and "have-nots" do to change the current situation that threatens global peace and progress?

A renaissance in thinking is needed. The developing and developed worlds each shoulder responsibilities in efforts to build societies that are enlightened by science education and benefit from the revolutionary economical developments of science and technology. As someone who has citizenship in both worlds, with roots in an ancient civilization that was highly "developed", but is now considered "developing", and who currently lives and practices in a developed nation, I perhaps can speak to these questions from both perspectives.

For the developing world, the first and foremost priority should be for it to get its own house in order. It should not simply wait for the developed world to help, or accuse people there of engaging in conspiracy theories. Yes, international politics play a significant role, but people's will is a stronger force, provided the force is coherent and not dispersed by internal politics.

Specifically, the developing world must create new systems of education that eradicate illiteracy and emphasize rational thinking. The objective is to build a new workforce equipped with 21st century tools of education and skills and with a belief in ethics and teamwork. Women must be included in the educational process not only because they deserve to be given an opportunity to succeed, but because societies cannot progress without them. Clearly, this may not be possible on a grand scale in a short time, but the foundation must be established properly and in a timely manner.

Developing countries, moreover, should implement a merit-based system that rewards excellence. Science in much of the developing world relies too much on seniority and puts decision-making into too few hands. The result is a snail-paced environment in a fast-paced world. The developing world is rich in human and material resources. But to take advantage of these invaluable resources, strategies have to be developed to nurture and reward the achievements of scientists and scholars so that the best among them are encouraged to stay at home and pursue work that their countries so desperately need.

> No country can develop centers of excellence unless it creates the right milieu for researchers.

Such long-standing problems have to be addressed in an honest and clear way. Leadership should be the reward for competence; centers of excellence for science and technology should be for fostering creativity. No country can develop centers of excellence unless it creates the right milieu for researchers. That means identifying and investing in talent and putting in place a merit-based system that minimizes bureaucracy and maximizes freedom and flexibility. The benefits to the country and the world are enormous. Besides the obvious benefits of science and technology, the power of knowledge enhances national pride, limits the brain drain, and leads the country into economic prosperity and effective participation in globalization.

Cheap labour may have worked for developing countries in the past but it will not work in the 21st century. How can the developing world embrace such economy-transforming technologies as microcomputing, genetic engineering, and information technologies without a strong foundation in science and education? Does the developing world always have to wait decades or centuries before participating in global science and technology? Cannot the new society be a part of the modern world without losing cultural and religious identities? Despite all the political and economic problems, progress is still possible. But change from within is the first ingredient.

For the developed world, the concerns are of similar magnitude but of a different nature. The developed world carries important responsibilities in its efforts to promote the scientific capacity and technological advancement in the developing world. First and foremost it must reform its international aid programs, investing less money on military hardware and instruction and more on scientific education, technology training, and partnerships. The amount of money spent on a few fighter planes could fund many of these programs throughout the developing world, helping in what must be our ultimate goal—global education, peace, and prosperity.

International aid programs, moreover, should be drained of politics to ensure money is available for productive initiatives between developed and developing countries, helping to boost

features

science and technology in the developing world. As important, we need visionary leaders who understand the problems of the have-nots and are deeply committed to political and economic fairness.

What will wealthy countries receive in return for the help they give to the have-nots? The first reward lies in the moral dimension. The psychological value derived from being a generous global neighbor should not be underestimated. Even on a personal level, most of us do try to help one another and all major religions encourage and legitimize helping the needy. It is also difficult to ignore that the prosperity of the developed world is in part due to natural and human resources from the developing world and its markets.

The second reason for helping is to maintain bridges of continuity between civilizations. By looking back in time and by thinking about the future, one can see that reciprocity between civilizations has been a natural and necessary component for scientific advancement. Islamic civilization gave a great deal to Europe, especially during the Dark Ages. The Arab and Islamic civilizations, which at one time were the world's foremost economic and scientific powers, were major contributors to the European Renaissance. Today it is the Muslim world that is in need of help and it is appropriate that the United States, Europe, Japan, and other developed nations should in turn lend a hand as a modest gesture to the changing fortunes of history.

> The Arab and Islamic civilizations,... at one time were the world's foremost economic and scientific powers

Finally, there is a more practical, self-centered consideration based on the time-tested importance of having an adequate insurance policy. In the United States, we pay a great deal for insurance to protect our families against the high cost of medical care, to protect our houses against fire and theft, and to protect our cars against accidents. Similarly, the developed world needs to invest in an insurance policy to help it live in a safer and more secure world.

The choice for the haves is clear—to help in a genuine and sincere manner. Neither hegemony nor shields and missiles will provide adequate security in a world with 4.8 billion people classified as developing or underdeveloped. The choice for the have-nots is also clear—to first get their house in order and build the confidence for a transition to a developed-world status. The developed and developing worlds can achieve their objectives by participating as partners in a dialogue for the sake of global peace and stability. Such a dialogue among civilizations and cultures should not be confused with slogans theorizing about conflicts between religions or cultures.

At its core, we should nurture a dialogue between the haves and have-nots. What is needed is visionary leadership, economic progress, and perspectives that rely on rational thinking. And if we truly believe in fostering democracies around the globe, science is the best vehicle for engendering that democracy. Global science unites citizens of the world through one common language and empowers them with the critical thinking needed to overcome dogmas and misconceptions. Only with knowledge and rationality can we hope for a genuine global peace.

The status of physics teaching and research in Palestine

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More than ten years ago, one of us (YIS) listened, at the International Center for Theoretical Physics in Trieste, Italy, to a distinguished African mathematician lecture about "the future of mathematics in Africa". The lecturer started by saying, in almost as many words, that he could describe the future of mathematics in Africa by a single word: "bleak", and that we, his audience, could go home immediately. Unfortunately, the same thing can be said today about physics in Palestine. Strangely enough, physics in Palestine suffers from pretty much the same symptoms that are prevalent in other developing countries when you expected it to be uniquely bad. Let us illustrate:

Money, or rather lack of it, is issue number one! The problems start at the school level. Schoolteachers are not well paid, their schools can not afford to have adequately equipped labs, and they teach outdated curricula to often very large classes. As a consequence, a high-school physics-teaching job is not what most bright young men and women would like to consider training for. All bright young kids (their parents acquiescing) would like to become doctors, engineers, or lawyers, to the detriment of those professions in a shambled economy that seems to barely sustain a corrupt clan of politicians who, mostly without college degrees and hence ignorant of the role of education in development, have naturally opted for preserving the status quo in schools, colleges and universities.

Palestinian colleges and universities, (there are eight of them in the West Bank and two in Gaza with a total student population of a little more than 70,000) grew during, or should we say in spite of, the Israeli occupation. With conditions here slightly better for teaching, physicists aspire to realize their potential in another demanding sphere: research. Unfortunately, lack of the necessary infrastructure and funding to do research puts to rest the research careers of most scientists in a developing nation, rather prematurely. At our institution, for example, we can confidently assert that no money is set aside to doing research in physics in the overall annual budget. Worse yet, the institution stopped paying for journal subscriptions a long time ago (e.g., we stopped getting the Physical Reviews in 1992). We don't have any hope of getting publication charges paid by the institution (one of us was advised at a certain point in time by a highly-ranking official to avoid publishing in journals that require such charges, and recommended a few, rather obscure, alternatives!). Talk about building research laboratories with institutional funds is a luxury.

At institutions like ours, a semi-paradox prevails. Faculty members are required to produce, admittedly little, publishable research work in order to be promoted to the higher professorial ranks. To help them in the process, the institutions contribute next to nothing. If they are to do any meaningful research, they often do it on top of heavy teaching responsibilities. For example, requests of a twenty-five percent release from teaching, by one of us, have all been turned down at the beginning of every one of the past few years.

So, how do scientists in a developing nation survive professionally? Well, the few that do, manage at the expense of their sleep, the time they are expected to spend with their families, and at times using part of what they earn as salaries that are little to live on, and often too late to come in full! With regard to funding research projects, the lucky/competent ones maintain contact with their colleagues in (mostly) Europe and North America. With almost no support from their institutions, these individuals manage to make short summer visits to their colleagues, allowing them the luxury of working in modern labs and/or using state-of-the-art computing facilities.

The "less fortunate" follow a more modest path. They stay at home, produce work that is often not publishable in the "good" journals and publish it locally, to be seen by very few, if at all, outside their home institutions. At some places, this is considered work good enough to be used for promotional purposes. Speaking of promotion, we are certain that, in most cases, it hardly adds a thing to the scientist's fortunes, apart from the (often hollow) change of title. Unfortunately, many use this as an argument to defend their lack of enthusiasm to do any meaningful research work.

The Oslo accords

However, Palestinians are still unique among peoples of the developing nations: most of their country is still under the yoke of Israeli occupation. Reeling from years of direct rule in which the closure of institutions of higher learning used to be one of the favorite pastimes of the Israeli military, Palestinian academics found themselves face to face with the mirage of the Oslo agreements and the subsequent devastation of the second Intifada. The Oslo accords brought an era which witnessed the migration of academics, including physicists, to assume political positions with the self-rule "government", dwindling resources, and chronic financial difficulties. Attempts to create scientific institutions like a Palestinian Physical Society and a National Research Council, although partially successful, resulted immediately in the turning of those institutions into inept, politically oriented, bodies with no track record of achievement. Research infrastructure simply does not exist. No infrastructure exists for experimental research, and even support for theoretical science is meager. The communications revolution arrived in a somewhat hyped bang in Palestine, but academic research has yet to benefit from it. The attempt to establish an academic network faltered due to political haggling and even the establishment of a Palestinian 'internet top level domain' was mired in years of controversy in which the academics played no role, but stood to suffer from its consequences. Inter-university collaboration is absent, and something as simple as a West Bank wide 'inter-library loan system' does not exist.

No infrastructure exists for experimental research, and even support for theoretical science is meager.

The worst was yet to come. The recent re-occupation of the West Bank brought severe travel restrictions, turning simple trips like the one from nearby Ramallah to Birzeit University, easily made in ten civilized minutes under normal conditions, into a horrendous life-threatening 40-60 minute adventure. Worse yet, in order to travel abroad, and therefore benefit from the opportunities briefly alluded to above, one is required to obtain all kinds of permits from three different authorities: Palestinian, Israeli and Jordanian, and that is on top of the usually restrictive regulations of the European countries and the US. Getting those permits and making the arduous trip to take a flight from Amman, Jordan, can easily strain the pocket book, not to mention nerves, of the most resourceful scientist. At present, Israeli airports, like many roads and exits in the West Bank and the Gaza strip, are off limits to Palestinians, including academics. Attempting to buy equipment and consumables is a nightmare, given the fact that the regular mail system is rarely allowed to work, as part of the measures of collective punishment the Israelis have been imposing.

Some international funds are available, at least in theory, mostly from Europe. Some of those have been lending support to projects that came as a result of the peace process. The benefits for basic science, however, have been minimal, because most funds seem to have been earmarked for projects with direct societal involvement. We hear, in this context, that the tri-lateral projects involving European, Israeli and Palestinian scientists have either been blocked for political reasons (like at Birzeit University) or have produced minimal Palestinian contribution. Even when funds are made available, the travel restrictions, poor infrastructure, and inability to buy equipment and materials are usually enough to degrade the project.

Young faculty members can also benefit from a host of European, Arab, and sometimes US research opportunities. Again, more of these are available for the humanities than for physics and the other basic sciences. Administrative ineptitude, however, has made most of those opportunities part of the corrupt system.

A 'tribal system of rules'

Some sort of a 'tribal system of rules' characteristic of this part of the world finds its way into academia. When adhered to, rules are often applied selectively. Selective appointments to administrative positions are almost always made that discourage dissent and free expression of ideas and certainly whistle blowing. Consider, for example, how administrators handle issues like fellowships, prizes and the funding of short visits abroad. By the time the announcement for one of these filters down to the faculty, administrators would have diverted it to benefit their clients or the deadline for such an announcement would have already passed. Fortunately, many prestigious funding agencies do not follow that path. The German Academic Exchange Program (DAAD) and the Alexander von Humboldt Foundation are but two of the examples that stand out in offering their services directly to the scientists and based on merit. We both owe survival of our research careers, in large measure, to these agencies.

In summary, we tend to believe that problems stemming from the socio-political developments do exist and are pretty bad. But, most of the troubles facing research and teaching of physics in Palestine have their roots in the lack of adequate funding, the absence of real, mostly material, incentives, in addition to negative competition and the lack of visionary administration. Unfortunately, the government has not been able to do much to improve the working and living conditions of the school teachers. Neither have the universities been able to lift themselves from their chronic financial troubles. Programs continue to shrink (the physics major has recently been scrapped at Birzeit University) and physicists, like many others in academia, keep looking for foreign aid to help them survive professionally. What is needed is a real effort aimed at building a local research infrastructure (labs, libraries, computing facilities, and so on) and initiatives to forge strong collaborations with scientists in the developed nations.

Nuclear, atomic and molecular physics and sustainable development: an issue within CEPAMOQ

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The perception of the relationship between scientific research and sustainable development in Cameroon is determined by a number of misconceptions and prejudices. The idea of development itself in our collective representations refers almost exclusively to economic data. In this context, to talk about nuclear, atomic and molecular physics and sustainable development is surprising, all the more given that the former suffers from a negative perception associated with the military use of nuclear energy. Above all, it is perceived as an academic discipline or an exclusively theoretical research topic influenced by fashion. It is argued that our technological and structural weakness, make it difficult to render this type of research applicable, which in addition is considered as essentially cut off from our real concerns and unable to lead to any transformation of our daily lives.

These misconceptions partly result from the lack of communication and of popularisation of scientific research in developing countries and in Cameroon in particular, calling for the promotion of scientific popularisation tools. This situation accounts for the false ideas on scientific research, both at the level of its quality and its relationship with development. The area of nuclear, atomic and molecular physics does not, obviously, limit itself exclusively to theoretical research. It is at the turning point of numerous development problems, for instance the outcome of modern applications of nuclear and optical technologies, which are bearers of sustainable development.

These problems, little known to the public, are at the core of the research activities of Centre for Atomic Molecular Physics and Quantum Optics (CEPAMOQ) created within the Faculty of Science of the University of Douala on December 17, 1999 by the Cameroon Minister of Higher Education. The missions of this Centre, which has a regional character, and is affiliated to the Abdus Salam International Centre for Theoretical Physics (Trieste), consist, among other things, of high-level doctoral training, but also of carrying out on the one hand theoretical research in the area of nuclear, atomic and molecular physics and, on the other hand, applied research likely to contribute to the solution of development problems (in its own domain) and thus rendering this research directly applicable. The Centre is also in charge of developing scientific and technical co-operation with African and international researchers in its domains of competence, through South-South and North-South exchange and research programmes, scientific meetings and co-operation with national and international organisations.

The Centre offers postgraduate training which lasts 4 to 5 years, organised in three phases: the first phase (2 years) takes place at CEPAMOQ. It is finalised by a Master's degree (DEA: Diplôme d'Etudes Approfondies in Physics of Matter and Radiation) at the end of the first year. Initiation into research continues during the second year, comprising advanced courses, seminars and research visits to one of the national laboratories or research groups working with the Centre. The second phase (12 to 18 months) takes place in a research laboratory in a country with advanced technology, in association with CEPAMOQ. The research student remains enrolled at CEPAMOQ. The third phase which lasts (12 to 18 months) takes place at the Centre. It is a period set aside for the completion and finalisation of research work followed by the defence of the doctoral thesis.

Since its creation, CEPAMOQ has trained, after a selection procedure by the Cameroon Ministry of Higher Education, two groups of thirteen students, one in 1999-2000 and one in 2001-02.

> misconceptions partly result from the lack of communication and of popularisation of scientific research in developing countries

Research is planned and organised according to the competencies of researchers of the Centre, regional needs and collaborations with our foreign partners. Research activities effectively started in 2001, with the thesis admission of the first batch of students. It is conducted by six permanent lecturer-researchers (University of Douala), eight lecturers-researchers from other state universities in Cameroon as associate researchers, external collaborators from partner institutions in industrialized and developing countries. The goal is the training of experts in radiation-matter interaction in view of radiological control of the environment and the professional milieus, and the study of atmospheric pollutants, in interaction with other disciplines (medicine, biology, climatology, etc.). Research is divided into the three following areas.

Optics and Applications

This area comprises four lecturers-researchers and five doctoral students. Research focuses on the fluorescence of tropical plants, excimer lasers (from the characterisation of beams to final applications), spectral structure and molecular concentration considered as atmospheric pollutants: organic (HCOOH) and inorganic (HCl, HF, HOBr, HNO_3 acids), nitrogenous compounds (NOx) and sulphur compounds (OCS, H_2S et SO_2), carbon dioxide (CO_2), and hydrocarbons (C_2H_2, C_2H_4, etc.), and their effects on climate change. It is important to stress that Cameroon, an essentially agricultural country, faces serious problems from atmospheric pollution. In the Douala region, this pollution results from many factors: imported industrial waste, massively imported second hand vehicles, soil fertilisation, and heavy deforestation, volcanic emanations from Mount Cameroon, and the degassing of crater lakes (Nyos, Monoun), which contain an enormous carbonic gas pocket that regenerates continuously and sends huge quantities of carbonic gas into the atmosphere.

Dosimetry and Radiation Protection

This area comprises four lecturers-researchers and four doctoral students. Research developed in this sector stems from the effective relaunching in 2001 of nuclear activities in Cameroon: the rehabilitation of CATEN (National Centre for Nuclear Technology

Application), the remobilization of professionals in this domain within the framework of technical co-operation projects with the IAEA and the AFRA Programme, and the creation on 31 October 2002 of the National Agency for Radiation Protection. This stresses the importance that the Cameroon Government attaches to peaceful applications of nuclear energy in the priority sectors of development in order to fight poverty. The work in progress or in preparation at CEPAMOQ is on radiotherapy (quality control of conformational treatment and IMR, dosimetric calculations using the Monte-Carlo method around radioactive grains), radiology (evaluation of doses of X-rays delivered by helicoidal scanners), nuclear instrumentation and spectrometry (mounting of a gamma detection set up and measuring of radioactivity of environmental samples) and the management of radioactive waste.

Atoms and molecules

Six lecturers-researchers and six doctoral students are involved in this area. Research of a theoretical nature is oriented towards fundamental studies of atomic physics (life times of heavy radioactive ions including highly ionised lanthanides, atoms in intense laser fields, electron-atom scattering), molecular physics (dissociative recombination of molecular ions, molecules in intense laser field), cluster physics (stability of highly charged metallic clusters).

The interest triggered by CEPAMOQ is demonstrated today by the number of cooperations which have been initiated, and fruitfully implemented. At the national level, CEPAMOQ constitutes the research focal point in nuclear, atomic and molecular physics for lecturers from the five state universities of Cameroon with a scientific nature. Contacts have been established with national Institutions capable of benefiting from our activities: the General Hospitals of Yaounde and Douala, the Institute of Geological and Mining Research (IRGM), the National Committee on Climate Change, the Permanent Secretariat of Environment (Ministry of Environment and Forests), the National Programme for Agricultural Research and Popularisation, the Department of Civil Protection (Ministry of Territorial Administration) and the Mount Cameroon Observatory based at the IRGM.

At the African level, CEPAMOQ already welcomes foreign students and collaboration has started with the Physics Department of the Marien Ngouabi University (Brazzaville, Congo), the Lasers Atoms Laboratory of the Cheikh Anta Diop University (Dakar, Senegal), the Atomic Molecular Spectroscopy and Applications Laboratory of the University of Tunis-El Manar (Tunisia), and the Medical University of Southern Africa (South Africa).

Out of the African continent, CEPAMOQ has singled out itself through research and training missions in European and North-american universities and institutions (e.g. Université Paris-Sud, CEA-Saclay, Université de la Méditérranée in France, Université Catholique de Louvain in Belgium, Division of Applied Physics of the ENEA Centre at Frascati and the Abdus Salam ICTP centre in Italy, and the Université de Laval in Canada). Support has been provided by the partner institutions, their Embassies, ICTP and the AUF (Agence Universitaire Francophone).

Chosen to host the 7th LAM (African Laser Atomic Molecular and Optical Science Network) conference, CEPAMOQ hopes to establish its position within the network by succeeding in the organisation of this event planed for December 2004 at the University of Douala.

All these achievements give us hope and and make us ambitious, given the interest we have aroused both from local and international partners. Hence the necessity of supporting this dynamic trend in its success.

"Unless it has its own scientists and technicians, no country can call itself free. This involves the whole problem of scientific and technical training from secondary education to fundamental research..."

René Maheu, UNESCO Director General (1965)

The ICTP TRIL Programme: Training and Research in Italian Laboratories

G. Furlan,
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The International Centre For Theoretical Physics (ICTP) in Trieste set up in 1983 a fellowship scheme indicated as Programme for Training and Research in Italian Laboratories (TRIL). The main motivation was the increasing demand from many developing countries scientists to have an advanced experimental counterpart to the theoretical research and lecture-based training offered at the Trieste Centre.[1]

A more farsighted view was to favour, through direct contacts and side-by-side research, the regular development of collaborations between the Italian scientific community and individuals, groups, and institutions in developing countries, enlarging substantially the line of action of the ICTP. The main objective remains to strengthen a permanent elite which, being aware of the needs of their own country and cognisant of the frontiers of science and technology, may properly influence the decision-makers' choices.

The specific purpose of the TRIL Programme is to offer scientists from developing countries who have participated in the ICTP scientific activities (conferences, workshops, schools), the opportunity of widening their experience by getting actively involved, in different branches of physical sciences, with the research work of laboratories at Italian universities and at public and private research centres. This includes academic studies as well as practical applications and industrial projects. In general, stays in the laboratory last several months (mostly one year and longer), but shorter visits are also envisaged.

The fields covered, which reflect current activities held at the ICTP, can be broadly classified as[2]:

- Physics of Condensed Matter
- Physics and Energy
- Physics and Technology
- Earth and Environmental Sciences
- Physics of the Living State
- Miscellaneous (Instrumentation, Topics at the interface with other sciences i.e. Chemistry, Biology, Mathematics)

Grants in a specific area are announced by a poster which contains a list of the Italian Laboratories agreeable to host scientists from developing countries together with a short presentation of the research activity carried out in each of them.

The selection is done jointly with the Italian laboratory indicated by the candidate as a priority in his application and is based mostly on scientific merit and on the matching of the candidate's expertise to the research lines pursued in the laboratory.

Achievements

The TRIL Programme represents no doubt one of the most successful and fruitful activities of the centre. Since 1983, in this framework 981 scientists (for a total of 1428 grants and 13,198 person-months) from developing countries have been offered many interesting opportunities to participate in side-by-side high level research, mostly experimental, working in active Italian teams with advanced equipment and experiencing an international atmosphere (see table 1).

▼ Table 1:

Grants awarded	1428
Grants of less than 3 months	366
Grants of more than 3 months	1062
Fellows	981*
Person-months	13198
Laboratories involved	339
Publications submitted	2773**
Countries involved	73

* Several fellows were awarded more than one grant.
** Results obtained from the 1348 grants terminated.

It can also be interesting to have a geographical distribution of grants and fellows. This is presented in table 2 which shows the figures relevant to the ten countries which have till now better profited by TRIL.

▼ Table 2:

Country	Applications	Grants	Fellows
China	1596	272	208
India	1288	271	185
Argentina	220	91	64
Nigeria	502	68	40
Brazil	88	41	37
Cuba	139	59	37
Egypt	360	40	26
Turkey	156	33	23
Poland	263	30	23
Romania	129	38	20

More than 330 Italian laboratories have until now contributed to TRIL without any charge for the assistance offered to the fellow. Universities are the most numerous host institutions because of their historical ability of dealing with different problems and interesting solutions. On the other hand laboratories of public and private research institutions—CNR, ENEA, INFN[3] and several others—often dispose of equipment which is better geared to a specific research and the presence of foreign visitors can be a valid solution to temporary personnel problems. The stay in Italy also represents a rewarding cultural and human experience, even more if the fellow is accompanied by his family members.

As a measure of the success one can mention the often significant contribution offered by the fellow to the research activity of the laboratory, the good standard of the reports published, the fact that frequently a TRIL fellowship, considered a guarantee of academic excellence, has been instrumental for the scientists to progress in his academic carrier (to the rank of Full Professor, Vice Chancellor, High Ministerial Official, even Minister). Another positive aspect is represented by the ever increasing interest and participation of the Italian scientific institutions which continue to offer the possibility of a high level scientific collaboration and often contribute financially to the costs of the grant, sometimes through specific agreements (in 2002 the financial contribution from those sources constituted more than half of the TRIL budget!).

> The TRIL Programme represents one of the most successful and fruitful activities of the centre.

Developments

The visit of an individual scientist has in many cases constituted the seed for a more extended collaboration, which sometimes involves the institutions. One can quote the fruitful, almost regular collaboration between Italian Laboratories and corresponding institutions in India, China, Cuba, Argentina, Morocco, Nigeria. This side of the programme, i.e. the "follow-up" stage, represents one of the main objectives of the TRIL and needs continued attention and support. Many return visits have been supported but in order to make the "follow up" action more effective, the creation of a TRIL Associate Scheme was recently advocated. Paralleling the original ICTP-Associate Programme, the TRIL Associates are entitled to pay regular visits to the laboratory of their first stage, 3 visits in 5 years, 2-3 months each time, to complete and update original research projects.

Twenty years later, the above description confirms that the TRIL Programme can be considered a very valuable component of the action of the ICTP (and of the Italian Government) to strengthen a scientific-technological elite in the developing world, in the broader framework of the relations between the North and the South. A natural development of TRIL is a series of "more," more topics to be included, more fellowships, more collaborations etc. But also more industrialized countries supporting our endeavour: partners from Europe are welcome any time! Will our physicists' community be willing to set up a TREL (E for Europe) Programme?

Footnotes

1 For a more complete description of the motivations, achievements, programmes of the Abdus Salam ICTP see "The Constant yet Ever-Changing Abdus Salam International Centre for Theoretical Physics", Juan G. Roederer, Physics Today, v. 54, n. 9, September 2001, pp. 31-36.

2 Purposely Experimental Particle Physics was not initially considered as a field of primary interest to developing countries.

3 CNR; National Research Council
ENEA: National Body for Energy and Environment
INFN: National Institute for Nuclear Physics

Physics in the developing world

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The developing world includes various types of countries differing in their economic status and educational facilities. There are some that are economically poor and have very few scientists in them; there are some developing countries economically poor, but with a high percentage of educated personnel, including scientists; and there are some that are economically rich but without advanced educational and scientific institutions. The commonality amongst all these countries is the absence of a proper institutional framework and infrastructure for science although the magnitude of the deficiency varies widely. Let me briefly give a description of the kind of scenario we have today.

All the developing countries today suffer from the absence of good scientific institutions and universities. There are no developing countries today, with the exception of a few countries, such as India, China and Brazil, that have universities even somewhat comparable to those in the advanced countries. The educational institutions in most have minimal or no laboratory facilities. Scientists who are motivated to carry out good teaching and research are generally in short supply. This is particularly true of the least developed countries (LDCs). In fact, in a large number of these countries, there is almost no research or higher education opportunities in physics and other science subjects. Many of them do not have post-graduate programmes. Even in those countries which have Master's degree programmes, the conditions are poor.

The least developing countries (LDCs) require special attention. There are 49 LDCs and most of them are in Africa. The situation in these countries is so desperate and depressing that we need to initiate a major international programme for the rejuvenation and reconstruction of institutions devoted to science and science education. I have visited some of the laboratories in the LDCs and found that even among their premier universities many of them do not have facilities comparable to those in some of the good high schools in the advanced countries. Some of the bright students there who want to take post-graduate courses and carry out research projects have no opportunities, unless they go to some other country which provides suitable encouragement. A young person from one of the LDCs was telling me recently that it is not possible to think of any experimental problem to work on within the available facilities. It is therefore necessary to initiate a programme of action which will involve not only education and re-education of teachers by providing travel fellowships and establishing exchange programmes, but also to provide optimal experimental facilities by establishing national or regional centres in these countries. The Third World Academy of Sciences has initiated a special programme which includes some of these elements. Recently, a research grant scheme has been initiated to support a few good scientists in the LDC countries, so that they are able to carry out research there. Such grants may help them to stay in these countries and not migrate to countries with scientific opportunities.

Whatever programmes we start for the developing countries in physics and other subjects will have to ensure that we concentrate on science education and capacity building as well as on steps to minimize brain-drain. Special programmes will have to be initiated to help female students and teachers to take up physics and other science subjects in these countries.

In order for new initiatives to be effective, one should promote not only North-South cooperation but also South-South cooperation. South-South cooperation has the additional advantage in that young people will be working in countries with somewhat comparable situations but with better facilities. This would help them to plan careers in the countries of their origin. A list of Centres of Excellence in developing countries is available from TWAS. These Centres should be utilized for South-South cooperation.

In conclusion, the state of science in most of the developing countries, except for some of the leading ones, is so backward that there is much that we can do.

Feedback from Framework 6 proposals

Europhysics News is undertaking a survey to assess the level of involvement of its readers in Framework 6 and to compile a short report on the experiences of people who submitted proposals during the first year of the programme. Sean McCarthy of Hyperion Ltd. will analyse the replies and present the results in a future edition of EPN. This information will be valuable to EPN readers in the planning of future research proposals.

1. Did you submit a proposal to Framework 6?
2. If you did not submit a proposal, then what were your reasons?
3. What was the most difficult part of the proposal to write?
4. Did you participate as a partner or as the coordinator of the proposal?
5. How much effort (in person days) was involved in participating in the proposal?
6. Have you any recommendation you would like to make to the European Commission regarding proposal writing for Framework 6 (and future Framework programmes)?

Please email your replies to sean.mccarthy@hyperion.ie. Participation of EPN readers will be greatly appreciated.

Take a breath of polarized noble gas

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Isn't that title just a piece of nonsense designed to catch your attention? Why should you breathe in the inert noble gas knowing that you need oxygen instead? Maybe an aging singer could mix some helium to his breath when his voice does not meet the high notes anymore. Of course, divers exchange nitrogen with helium since even under pressure it hardly dissolves in the blood and hence averts the danger of bubbling and embolism when the pressure is released. But do not mix it up with a xenon bottle! You would quickly lose your consciousness, since xenon penetrates into the blood and further into the brain with anaesthetizing effect. The real trick, however, is breathing spin-polarized noble gas! Why?

Almost a decade ago, a Princeton-StonyBrook collaboration published a seminal paper in NATURE [1] in which they showed for the first time a magnetic resonance image (MRI) of excised mouse lungs filled with spin-polarized ^{129}Xe (Fig. 1 left). The image was not formed as usual from the MRI signal of the protons in the tissue but from the pre-polarized xenon nuclei serving as a contrast agent, so to say. The decisive novelty in MRI was the use of spins which had been pre-polarized beforehand to a so-called hyperpolarization far beyond thermal equilibrium. In contrast the usual MRI signal derives from the Boltzmann polarization P_B of nuclear spins, which is established in the magnetic field B_0 of the tomograph within a so-called longitudinal relaxation time T_1 of order 1s to the thermal equilibrium value of

$$P_B = \frac{n^+ - n^-}{n^+ + n^-} = \tanh\left(\frac{\mu_I B_0}{kT}\right) \qquad (1)$$

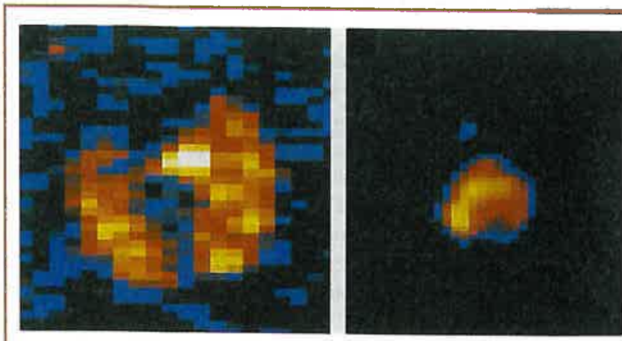
where n^+ and n^- denote the number of spins oriented parallel and anti-parallel to B_0, respectively. In a typical tomograph field of $B_0 = 1.5$ T the protons at body temperature reach a polarization of only $P_B \approx 5\ 10^{-6}$. Therefore, MRI is, first of all, a fight for signal to noise ratio. This is virtually lost if, in addition to the low P_B, the spin density is lowered from condensed matter level to that of a gaseous medium. Hence, the air filled spaces of the lungs, for instance, could not be imaged by NMR methods. Indeed the lung tissue itself hardly yields any signal since it is very porous and lacking in protons (Fig. 1 right).

Optical pumping

Only a radical increase in the spin polarization to far beyond P_B can help us to perform MRI on a gaseous medium. Polarizing beyond P_B succeeds with so-called dynamical methods. In essence, they transfer polarization from one system to the other, for instance from electrons to protons as in the case of the well known polarized proton targets. A particularly elegant solution well suited to gases is Alfred Kastler's method of optical pumping (OP) which won him the Nobel Prize in 1966. It transfers polarization from photons to atoms by resonant absorption of circularly polarized light. Grosso modo, the atomic system gains 1 $\hbar$ of angular momentum per absorbed photon. Not a bad bargain! Bowever, things do not work that easily. Only a few atomic species are well suited to optical pumping, namely alkalis and helium. Molecules are excluded since they lose their polarization in gas kinetic collisions, as do atoms in other than spherical S-states. Moreover, an atomic vapour is already becoming optically thick for a strong resonance line at a column density of order 10^{10} atoms/cm^2. At a normal density of $3 \cdot 10^{19}$/cm^3, the light would neither get in nor out. This explains why it is only for thin vapours that OP is a well established and widely used art, culminating nowadays in the spectacular experiments involving the cooling and manipulating of atoms by lasers. Polarizing large quantities of gas by OP is in a different category, however. It only succeeds by indirect means and only for noble gases. The light is absorbed by a thin medium whose polarization is then transferred to the dense noble gas by spin exchange mechanisms during gas kinetic collisions. Polarizing the whole ensemble takes up time, ranging from seconds to hours, during which the dense gas must not lose its polarization, either by gas kinetic or by wall collisions. Only noble gases can fulfil this demand with helium being better than xenon, strictly following the ranking of nobility. There are two methods in this game, already known since the early sixties. It is only in recent years that they have reached their quantitative goal after extensive R&D work.

We begin with the so-called rubidium spin exchange method (RbSE), discovered at Princeton in 1960 and pursued there ever since. Here, the unpaired spin of the valence electron of Rb is polarized by OP via the strong resonance line at 795 nm connecting the $5s^2S_{1/2}$ ground state to the $5p^2P_{1/2}$ excited states (left of Fig. 2). Rb electron spins then transfer their polarization through magnetic hyperfine coupling to the nuclear spins of a noble gas which is admixed at much higher density up to several bars. Due to the weakness of hyperfine coupling, this kind of spin exchange is a rare process occurring with a probability of order 10^{-4} for xenon and 10^{-7} for helium during a gas kinetic encounter of the partner atoms. As a result, it takes from minutes for ^{129}Xe up to many hours for ^{3}He before the noble gas attains its equilibrium nuclear polarization.

The other method can be traced back to the early sixties when a group from Rice University published the result of their experiment on metastable exchange optical pumping (MEOP) which exclusively applies to the species ^{3}He. In MEOP metastable ^{3}He atoms are produced in the $1s2s^3S_1$ state at a relative population of 10^{-6} in a low pressure plasma at about 1 mbar. These metastable atoms are then polarized by OP at $\lambda = 1083$ nm connecting to the $1s2p^3P_0$ state (right of Fig. 2). With a powerful laser source it takes only a fraction of a microsecond to polarize this metastable state.



▲ Fig. 1: Left: The pioneering MRI of hyperpolarized ^{129}Xe injected into excised mouse lungs.
Right: Proton MRI of the same subject showing only the tissue of the heart in the centre, but no proton signal from the lungs [1].

Fortunately, this characteristic pumping time τ_{OP} matches fairly well to the metastable exchange time σ_{ex} within which the metastable excitation energy is transferred to the next atom, leaving the former in the atomic ground state with a polarized nucleus. The next atom is then ready for pumping, thus forming a fast catalytic chain of successive energy transfers and pumping action. Within a few seconds the ^{3}He plasma attains a nuclear polarization of about 50 % and saturates in the range of 80 %. MEOP owes its rapidity to the very large metastable exchange cross section ($\sigma_{ex} \approx 10^{-15}$ cm^2) which is driven by the dominant electrostatic rather than by the weak hyperfine interaction.

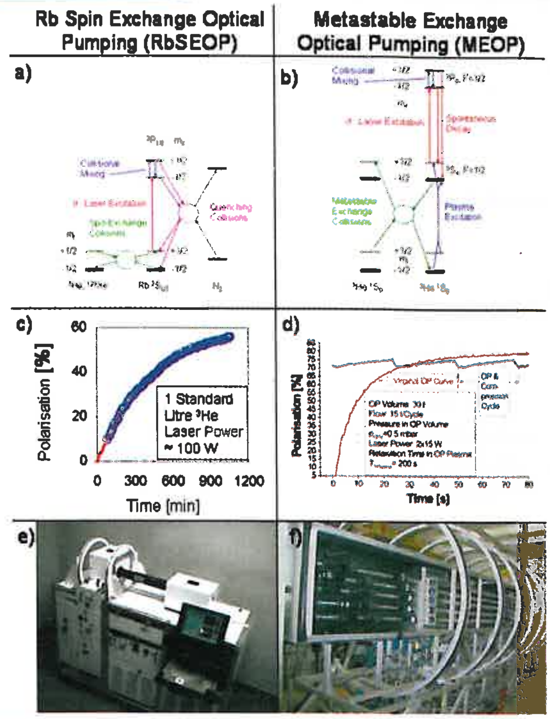
In Europe, Kastler's and Brossel's laboratory in Paris devoted its experimental and theoretical activity from the beginning in the fifties to the foundations of the physics of OP, including both indirect methods of noble gas pumping. In particular it has a strong tradition in studies of MEOP which lead to a complete theory of the pumping and exchange dynamics [2] and to the development of suitable laser sources.

Polarizing and handling larger quantities of noble gas

The motivation for polarizing ^{3}He in large quantities did not come from MRI but from particle and nuclear physics where there was a need for a polarized neutron target or at least a substitute for it. As such, polarized ^{3}He serves best since the spin and magnetic moment of the nucleus stem almost entirely from the single neutron. A SLAC-Princeton-collaboration realized a successful high pressure target polarized on-line by the RbSE method. It served to measure the polarized neutron structure function in deep inelastic electron scattering [3]. A Mainz-Paris-Collaboration realized the first dense MEOP target which led to the measurement of the electric form factor of the neutron in quasi-elastic electron scattering [4]. Another motivation was to realize a broadband spin filter for neutron beams, based on the huge spin dependent absorption cross section of ^{3}He [5] (see also W. Heil at the International Workshop HELION02, Oppenheim, Germany (2002), [6]). These experiments needed quantities of order 1 standard litre and a polarization of order 40 to 50 %. Readers should note that these numbers match quite well to what is needed for performing MRI of a human lung. That is why this technique could be applied so quickly once the idea was born. All the necessary R&D work had been carried out beforehand for the purposes of fundamental physics research. This is yet another example proving that fundamental research is a most fruitful source of innovation.

High production rates at high polarization could only be achieved through the advent of powerful pumping lasers at the required infrared wave lengths. In particular, RbSE scales rather strictly with the laser power available. A low SE cross section requires high Rb density in order to reach satisfactory exchange rates for the spins of the noble gas. Nowadays, one works under conditions where the Rb vapour has an optical thickness of order of 1000 absorption lengths. Hence, it takes of order 100 W for the laser beam to break through this wall by saturated absorption. Arrays of diode lasers can now provide this power routinely at reasonable cost. At the same time any fluorescence light must be totally suppressed by quenching the Rb excitation by a high dosage of admixed nitrogen (Fig. 2a). Rb SE polarization units now yield routinely production rates of order 0.1 standard l/h, reaching degrees of polarization in the range of 30 % to 50 % at maximum (see also G. Cates in [6]). ^{129}Xe can be polarized at considerably larger yields but to a somewhat smaller degree, usually.

In MEOP the He plasma yields only an optically thin layer of metastables, hence the laser beam is used to irradiate a whole battery of long plasma tubes (Fig. 2f). At an intensity of about



▲ Fig. 2: Polarizing noble gases by RbSEOP (left) and MEOP (right). a) and b) show the respective pumping schemes, c) and d) up-polarization curves for ^{3}He, e) and f) the respective polarizers, namely the first commercial one (by Amersham Health) following RbSE and a MEOP laboratory setup at Mainz [5], now fabricated by IC-Automation.

1 W/cm^2 the OP cycle is speeded up to its saturation limit of about 10^{-7} s, the natural lifetime of the upper P-state. The scaled-up MEOP spin factory at Mainz yields about 5 standard l/h at $P = 50$ %, rising beyond 70 % at reduced flow (Fig. 2d). However, it is necessary to compress polarized ^{3}He from less than 1 mbar in the OP plasma to at least atmospheric pressure at which it has to be inhaled, e.g. It took the Mainz group more than a decade of research to develop step by step a satisfactory solution such that no polarization is lost during compression (see also E. W. Otten [6]). Note that relaxation predominantly occurs during wall collisions, hence scales with the surface to volume ratio and that this ratio really explodes at large compression factors in a piston for example.

Today, both possible methods in the game have reached satisfactory physical and technical standards: RBSE with a compact set-up (Fig. 2c) for modest production rates fulfils the demands of a single research or clinical unit, MEOP with an elaborate apparatus for large-scale production capable of serving many users. The latter statement provokes the question of whether the polarization can survive shipping to a client. For ^{3}He the answer is "yes" but the "how" is not trivial! In the early days of MEOP, one had already found that polarized ^{3}He bottled in nonmagnetic vessels such as those made from glass or metals, relaxes quite slowly. Obviously, surface relaxation of a gas scales with adsorption time and energy. These are smallest for He leaving its spin least chance to flip in an encounter with a paramagnetic centre. Any knowledge beyond these qualitative statements is empirical, gained mostly by trial and error. Anyway, carefully cleaned and baked bulbs from special glass nowadays reach T_1 values of order 100 h for ^{3}He, completely satisfactory for storage and shipment. To that end the bulb is housed in a μ-metal box providing a small homogeneous holding field. Within the framework of an EU research project on polarized helium imaging of lungs (PHIL) [7], the delicate medium is now routinely delivered from the Mainz physics institute to scanners in clinics at Copenhagen, Mainz and Sheffield. The shorter relaxation time of ^{129}Xe, on the other hand still requires on-site polarization.

MR imaging with hyperpolarized gases

Once the idea of using hyperpolarized gases for MRI was published [1] and sufficient quantities could be provided, its implementation into existing MRI techniques was realized very rapidly. The reason for this is readily found in the brilliant standards of signal processing, in the high flexibility, and in the wide diversification of this well established technology. Still, it is interesting for a physicist to know *how* it is done. It was said already that the basic capital of optically pumped gases lies in their extreme hyperpolarization which exceeds the Boltzmann value P_B (eq. 1) by five orders of magnitude and hence even overcompensates the loss in spin density as compared to protons in tissue. At $P = 50$ % and diluted in the air of the lungs ^{3}He still offers a nuclear magnetization $\boldsymbol{M}$ much stronger than that stemming from protons in tissue. But once this hyperpolarization is used up by exciting magnetic resonance, it is gone forever, whereas P_B of the protons recovers within seconds and is then ready for the next NMR pulse. Usual MRI sequences need of order 100 MR pulses at different field gradients to produce an image of decent resolution. Hence, one has to observe economy with the hyperpolarized spins and use only part of them for each MR pulse. Let us adjust for instance the MR pulse such that $\boldsymbol{M}$ flips from its static orientation along $\boldsymbol{B}_0$ by an angle of say $\vartheta = 6°$ towards the transverse plane, then we have already a transverse component of $M_\perp=|\boldsymbol{M}| \sin 6° = 0.1\, M$ precessing after the pulse at the Larmor frequency

$$\nu_L = \gamma B \tag{2}$$

around $\boldsymbol{B}$ and causing an induction signal in the antenna coil. It is already 10 % of the maximum signal achieved with a 90° flip. But the remaining longitudinal magnetization $M = |\boldsymbol{M}| \cos 6° = 0.995\, M$ has dropped only by 0.5 % and hence can easily feed another 100 MR pulses as required. Summarizing, ^{3}He MRI can count on a signal strength comparable to that of proton MRI.

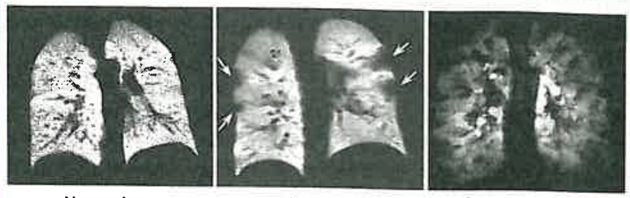
Each MR pulse is followed by applying a series of field gradients $\nabla_i B$ over the sample which encode the position of its spins with a particular frequency shift

$$\Delta\nu_i(\boldsymbol{r}) = \gamma(\nabla_i B\cdot \boldsymbol{r}). \tag{3}$$

The antenna then receives an integral signal from the whole sample

$$S_i \propto e^{i2\pi\gamma B_0 t} \int_{Sample} M(\boldsymbol{r}) e^{i2\pi\gamma(\nabla_i B\cdot \boldsymbol{r})} d\tau \tag{4}$$

that is a Fourier transform of the magnetization. The series of signals S_i can then be retransformed back into the sought for $M(\boldsymbol{r})$. That is all we need in principle. In reality there are many additional tricks in the game which are standard in modern MRI. Usually, one already applies a gradient during the MR pulse, say in the z-direction; this selects a certain slice in the xy-plane to be imaged. The thinner the slice the better the resolution, but at the cost of the

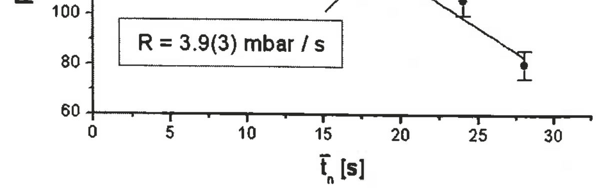


▲ Fig. 3: Left and middle: ^{3}He images of the lungs of two young, healthy probands. The arrows on the smoker's lungs point to ventilation defects at the lung edges. Also the blood vessels in the centre do not contribute to the ^{3}He signal. The imaged slices are 1 cm and 2 cm thick, respectively [8]. Right: Severe smoker's emphysema of a 49 years old patient, showing ventilation defects all over. The image stems from the first ^{3}He survey of lung diseases [9].

signal strength. During free precession one first applies a gradient, for example in the x-direction and reverses its sign later waiting for the so-called spin echo at which the spins are coherently rephased. During the echo another field gradient is applied in the y-direction. In this way one can extract from the time and frequency distribution of the echo the x- and y-distribution of $M(\boldsymbol{r})$ in the slice simultaneously. Fig. 3 from the Mainz Clinics shows some ^{3}He-MRI slices of human lungs with an in-plane resolution of 256 • 256 pixels [8,9].

There are a few more features of hyperpolarized gas MRI which play specific roles. The gain in imaging time compared to ordinary MRI is of importance. It results from the fact that one does not need to wait for the recovery of the Boltzmann polarization (taking about 1 s) in between consecutive MR pulses. This plays a role in lung imaging, since one cannot hold one's breath for much longer than ≈ 20 s. Regarding short imaging times, ultrafast sequences have been developed which show a 3-dimensional movie of the breathing process with an apparent time resolution of 20 ms. One may find such impressive movies on the website of the group at Charlottesville [10]; see also [11].

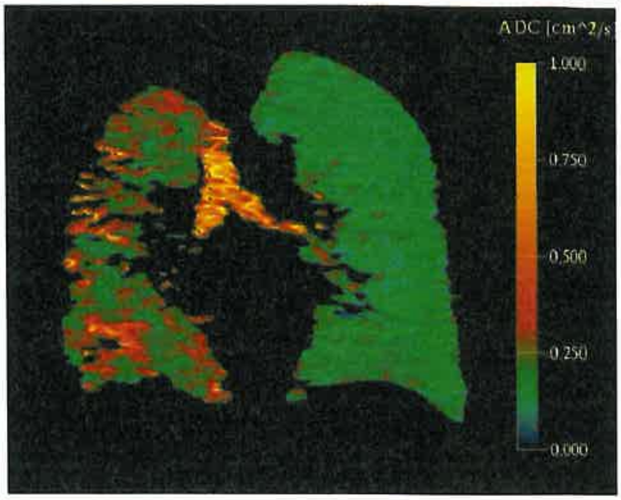
There is yet another reason not to stretch hyperpolarized MRI over much more than about 15 s - this is the relaxation time of ^{3}He



▲ Fig. 4: Decrease of O_2 in the lungs of an anaesthetized pig during breathhold, determined from the O_2-dependent relaxation rate of hyperpolarized ^{3}He. The signal is averaged over a region of about 12x12x100 mm^3 [12].

in the presence of the oxygen in the lungs. The reason for this relaxation effect is the strong dipolar coupling to the paramagnetic oxygen molecules. Hence, the hyperpolarization just fades away during the period when the breath is held. A physicist, however, is trained to look always at both sides of the coin. Here, he easily recognizes on the other side a chance to image the actual oxygen concentration in the lungs and moreover, how it drops during the holding of breath due to oxygen uptake which is the principal lung function. One does so by precisely measuring the time evolution of P in consecutive images (Fig. 4) [12].

It is not only the longitudinal relaxation time T_1 that counts, since the transverse T_2 characterizes the decay of the coherence of the free Larmor precession and hence of the induction signal. In the field gradient of the tomograph this dephasing happens necessarily for the entire spin ensemble with a time $T_2 \approx 1/\Delta\nu$ according eq. 3. This is a reversible process as long as the spins do not move and the gradient is under control. This fact denotes the origin of Hahn's famous spin echo technique which has been known for 50 years. However, the coherence decays irreversibly when the atoms diffuse at random through the gradient. For ^{3}He the diffusion coefficient in air is about 0.8 cm^2/s, orders of magnitude larger than for protons in tissue or water. For this reason too, gas MRI has to be speeded up. The imaging gradient must not last longer than a couple of milliseconds. Again, let us have a look at the other side of the coin. The gradient sequence may be tailored such that the signal strength and hence the image are just weighted with the local diffusion coefficient (Fig. 5 from W. Schreiber in [6], see also M. Salerno in [6]). Within the trachea, the large bronchial tubes and also within the wide caverns of sick lung tissue one observes the free diffusion coefficient. In healthy lung tissue however, diffusion is apparently reduced by a factor 3 to 4 due to the small scale of its fractal structure. This fine structure also causes a kind of random field gradient through the susceptibility difference between lung tissue and the air spaces. This gradient scales with B_0 and leads to uncomfortably short coherence times at high field. Since hyperpolarization does not depend on B_0 one may take the chance to scale it down. An Orsay-Paris collaboration has explored low field ^{3}He MRI down to 0.1 T and observed the various benefits of enhanced coherence times [13].



▲ **Fig. 5:** Mapping of the apparent diffusion coefficient of ^{3}He in the lungs of a patient suffering from fibrosis (left wing). It varies from 0.2 cm^2/s in still functioning tissue to 0.8 cm^2/s in wide caverns (see the colour code at the right). The black regions are not ventilated. The wing on the right has been transplanted and is well functioning.

^{129}Xe versus ^{3}He

For ^{129}Xe the signal situation is not as favourable as for ^{3}He. The nuclear magnetic moment is three times smaller and the natural isotopic abundance is 29 %. Unless the very expensive enriched isotope is used, the magnetization drops by an order of magnitude as compared to ^{3}He. That is a serious handicap for Xe but not a prohibitive one and may be easier to carry in a couple of years from now when MRI techniques may have progressed to even better signal to noise ratios. If in the long run a high clinical demand for this technique develops one will have to discuss the question of gas supply. At present, the ^{3}He market is fed only from the debris of tritium decay since ^{3}He abundance in natural helium is only 1.4 ppm. A dedicated ^{3}He production will then be necessary which seems to be conceivable at reasonable terms. Xenon, on the other hand, is available from our atmosphere at any quantity desired. For economic reasons one would in any case recover the precious enriched ^{129}Xe as well as ^{3}He from the exhaled air; this is easily done. Satisfactory ^{3}He supply provided, hyperpolarized MRI of the lungs will probably stay with that isotope because it reaches by far the higher magnetization and is lacking any toxic side effect. Xenon also carries this latter handicap. Although its anaesthetic action is moderate for a single intake of breath, doctors prefer to avoid any toxicity associated with a treatment as far as possible.

Looking at ^{129}Xe only as a competitor to the use of ^{3}He would underestimate its role in MRI. Contrary to He it finds its chances explicitly through its strong surface interaction and solubility. This goes along with large characteristic chemical shifts of order 10^{-4} of its Larmor frequency, thus revealing its local host. Thus a group at Ann Arbor has identified ^{129}Xe in arterial and venous blood and also at different sites in the brain [14]. This opens, if not a widely applicable diagnostic tool, a very interesting research area, inaccessible to ^{3}He MRI. Therefore, hyperpolarized ^{129}Xe is also the preferred substance in a wide range of NMR studies at surfaces, in porous media etc. (see also K. Ruppert, S. Swanson, P. Blümler [6]).

The medical case

The images shown above in the context of MRI technology partly concern lungs already suffering from various diseases. Their effect on the images is apparently quite drastic and has never been shown before in this clarity and detail by any other diagnostic tool. The standard method for ventilation imaging is so far scintigraphy from inhaled radioactive gas, for instance ^{81}Kr or air loaded with ^{99}Tc aerosols. However, the in-plane resolution is poor, in the range of several cm only, and the depth is integrated up over the full lung. Hence, scintigraphy indicates an average regional ventilation. In order for a lung to function, it also needs to be perfused by blood. This has to be checked in addition by a separate perfusion scan obtained by some other radiological method. Oxygen-sensitive ^{3}He MRI can check this principal lung function in a single scan directly to the point. But what looks close to perfect already in the animal experiment (Fig. 4) needs some further development to yield precise results also for spontaneously breathing humans. Anyway, one is clearly en route from simple morphological to the more informative functional imaging at which doctors finally aim. In this sense also, the inhalation/exhalation movie is clearly functional imaging, because it answers the decisive question for any asthma or emphysema patient of how fast the gas is transported within the lungs. The static ventilation scan performed at the holding of breath yields superior spatial resolution in all three dimensions and clearly localizes any ventilation defect. Of great value is also the image of the diffusion coefficient since it measures the dimensions of the open structures down to the sub-millimetre scale of the alveolae. Hence, it discriminates between the finely structured healthy lung tissue with a high surface to volume ratio from inefficient blown-up cavities of a diseased lung (Fig. 5). Still, one has to remember that gas MRI has only access to ventilated air spaces. Neither non-ventilated open spaces nor the tissue itself contribute to the signal. Diseased tissue that may spread over the lung like cancer or fibrosis must still be diagnosed by other radiological means such as computer tomography (CT). The EU network PHIL [7] which has gathered European groups interested in ^{3}He MRI has confined its clinical aims to a systematic survey over about 200 emphysema patients in Denmark (Copenhagen), England (Sheffield) and Germany (Mainz). This large sample will form the base for establishing a reliable and differentiated ^{3}He MR diagnosis of this, frequently encountered, serious disease. The survey is observing a fixed protocol of ^{3}He procedures comprising static and fast ventilation scans, a diffusion scan and in some cases an oxygen-sensitive scan. It is accompanied by complementary traditional diagnostic means on the same sample for comparison.

Conclusion and outlook

The physics of manipulating spins via OP and NMR seems to remain forever fresh due to a high rate of methodological innovations opening new fields of application in fundamental and applied science. Polarizing large quantities of noble gases to a high degree was a demand of particle and neutron physics in the case of ^{3}He and an aim of surface physics in the case of ^{129}Xe. Then the potential of these polarized gases for MRI was discovered, in particular for imaging the air spaces in the lungs. This stimulated a new wave in radiology. Today, we count around 20 groups in the US and Europe who are actively pursuing research in this field. Approval of MR lung tomography for ^{3}He as a contrast agent is being sought on both continents and will probably soon pass the final Phase III. The further fate of the method, its clinical success, will then not lie predominantly in the hands of scientists anymore. However, they will have to assist industry and clinicians in the coming phase with extensive R&D in order to optimize the methods and to realise the ultimate potential of the technique. The need for improved diagnostic tools is obviously there: Lung diseases are about number four in killing people and quite often after many years of painful suffering. Early diagnosis could help to prevent this fate.

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Czochralski's contribution: 50 years on

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This article commemorates Jan Czochralski's contribution fifty years after he passed away and was buried in his home town, Kcynia, roughly mid-way between Warsaw (Poland) and Berlin (Germany).

The seminal work published by Czochralski in *Zeitschrift für physikalische Chemie*, received for publication on August of 19th, 1916, but published two years later [1], was an example, rarely met in our days of conciseness and concreteness in presenting research results. On three pages the author reports on his new finding: that a method of pulling metallic monocrystals had been discovered, and had been applied for testing three metals of interest: *Sn*, *Pb*, and *Zn*. This earned him much praise, and in consequence, he is still recognized as one of the fathers of todays semiconductor technology [2] although his method was thoroughly elaborated only for the above metals. It should be noted that Jan Czochralski invented his method during his stay and work in Berlin for the AEG (Allgemeine Elektrizitäts-Gesellschaft) company (Fig. 1) using the AEG lab facilities. He also benefitted from collaboration with a German physicist W. v. Mollendorff [3] and developed much of his knowledge on the crystallography of metals during this time.

In order to augment his activity in metal science and technology he moved from Berlin to Frankfurt on Main, where he worked intensively on metallurgical methods to obtain new alloys, as well as on metal based composites, leading to the production of bearings (metal *B*) [2], and on *Al*-based wires and contacts in electrotechnics. He also became interested in the durability of materials. However, with his German coworkers, his main focus was on the principles of the metallurgical processes, such as: the role of defects, additives, and specifically of dislocations, in efficiently yielding pure metals and alloys; stress-strain aspects; characteristics of recrystallisation; phase equilibria and transitions associated with their appearances, etc. It is also to be noted that during his time in Frankfurt he proposed in one of his papers "Radiotechnics in Service of Metal Science" in 1925 [4] a kind of radiomicroscope, serving to detect non-metallic inclusions in the outer layer (surface) of a metallic sample. This can in some way be

▲ **Fig. 1:** Young Jan Czochralski (beginner), first from left, in an AEG lab in Berlin 1907 (courtesy of Z. Czochralska).

anticipated as a possible prototype of the scanning microscope, with the AFM (atomic force microscopy) included. In the year 1929 he accepted the invitation of the Polish State President, Ignacy Mościcki, himself quite a recognised chemist, and moved to Warsaw, where a Warsaw University of Technology professorship in chemistry had been offered to him. Since it was likely that Czochralski had no matriculation, this was only formally possible after the university presented to him the prestigious title of *doctor honoris causa*. In Warsaw he also became interested in X-ray methods in service of metal structure research, though it is not clear whether he had any Röntgen device at his disposal while working in Warsaw [2].

▲ Fig. 2: The mature Jan Czochralski (professor), second from left, in a Warsaw University of Technology lab in the nineteen thirties (courtesy of Z. Czochralska); Polish State President, I. Mościcki – first from right.

It is interesting to note that his research activity peaked in the years 1936 and 1937 (15 papers in 1936 is the best 'quantitative' result), and thereafter decreased slowly toward the years 1939 and 1940 when probably his last paper on research results on *Al* in Poland appeared [2]. (The total number of his papers is estimated to number about one hundred [2].)

In the beginning of the fifties, shortly before he died, Jan Czochralski moved to Kcynia and until the end of his life he devoted his activity in two main directions: he conducted, as dr. Wojciechowski (the "commercial" surname taken unofficially from one of his daughters, Leonia, after she married), his small chemical enterprise *Bion*, that was in fact a pharmacy and drugstore; and he tried to work out a Polish version of his *Moderne Metallkunde in Theorie und Praxis* (English: Modern Metal Science in Theory and Practice), published in 1924 by the Julius Springer Publishing Company in Berlin, see [2] for details. (There appeared even in 1950 a first draft of that translation, with some extensions and changes, but it disappeared, most probably because of too strong invigilation of Czochralski by the Polish secret police under unknown circumstances.)

The main reason for such a division of his mostly scientific activity and also for a certain slowing down was the following: the Warsaw University of Technology's highest council (*Senat*) suspended him in December 1945 from his professorial duties, strongly referring to certain unproven suspicions that Czochralski had operated against Polish interests from the beginning of World War II [2]. That biased decision was not changed after the war ended and lasted until his death. Although many of us over many years have been taught the way that the semiconductor monocrystals are pulled from the melt by using Czochralski's or, as abbreviated, the *CZ* method, and at the same time being aware that the method has been readapted and technically expanded by other authors to be the method suitable for semiconductors, we are still surprised to learn from Scheel [5] that recently obtained semiconductor crystals are pulled by another method due to Teal and Little [6]. For an explanation of why Teal and Little's method can be termed an adaptation of *CZ* method, see [7].

There is no doubt that Jan Czochralski was a personality, satisfying criteria of open-mindedness quite far exceeding his specialised activities. Two examples support this viewpoint. There exists a paper witnessing his activity as a geochemist [8]. While a chemistry professor in Warsaw he was kindly asked by the local authorities of Kcynia to resolve a "burning" problem: Are there any underground resources of natural oil in Kcynia, and in its surroundings (Pałuki region), or is there something else behind it? His answer after investigation was: There are no underground oil resources there, and the fluid that wets the nearby grounds comes from long-existing storage places for fuel, tar, lubricants and other, mostly liquid, materials, where the barrels containing them, neither tight nor free of corrosion, have systematically polluted all the surroundings by creating over many years sewage areas of high pollution. There is also information that points to Czochralski's wide-ranging activity in the field of ecology. Firstly, because in a renowned *McGraw-Hill* dictionary there appeared a notion that the Czochralski process was roughly equivalent to the term '*antropopression*', well known in ecology [9]. But until now, it has not been proved in a satisfactory way that he coined that term.

Czochralski died in 1953 at the age of 68, up until the end of his life being constantly watched by the Polish secret police, following some denunciations by a few people, unfortunately those coming also from the circle of his university colleagues. Fortunately, none of which have ever been proved [2].

To sum up: Jan Czochralski contributed quite substantially to many aspects of, what we now call, applied physics and chemical technology as well as of materials science. For example, his theory of recrystallization, though being particularly (and first) proposed for *Sn* [10], deserves recognition. He also contributed much to interdisciplinary research. It is worth noting that formally since the year 1986 [2], a systematic revival of Czochralski's reputation can be observed, at least in Poland. After the political changes in Poland had come about (around 1990), one may observe a visible revalidation of Czochralski's work and a better reception of his well-spread life style, mostly that during World War II, when he had to decide on how to live between Polish and German, historically different, standpoints, and under the critical conditions of the War.

For further reading see: www.unipress.waw.pl/emrs/ and http://www.ptwk.org.pl/ where some recent events organised in Poland have been chosen.

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features

Most readers enjoy having a better understanding of physical phenomena in everyday life, and being able to explain them to the layman. This has some extra relevance in view of the upcoming World Year of Physics 2005. This "Physics in daily life…" column is aimed at doing just that. Since it will span a wide variety of phenomena, most of which are outside the research expertise of the author, he welcomes comments, additions or corrections, especially from readers who happen to be more familiar with the topic. email: Hermans@Physics.LeidenUniv.nl

Physics in daily life: Moving around efficiently

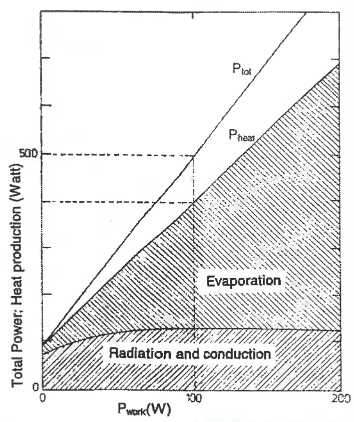
L.J.F. Hermans, Leiden University, The Netherlands

Ever considered the efficiency of a human being moving from A to B? Not by using our car or a plane, but just our muscles. Not burning oil, but food.

Many physicists will shout immediately: a bike! Use a bicycle! It is because we all know from experience that using wheels gets us around roughly 5 times as fast with the same effort as going by foot. But just how efficient is a bike ride? First, we have to examine the human engine. The power we produce is easily estimated from climbing stairs. If we want to do that on a more or less continuous basis, one step per second is a reasonable guess. Assuming a step height of 15 cm and a mass of 70 kg, this yields a power of roughly 100 W. Mountain climbers will find the assumed vertical speed quite realistic, since it takes us about 500 m high in an hour, and that is pretty tough.

Riding our bike is pretty much like climbing the stairs: same muscles, same pace. In other words: we propel our bike with about 100 W of power. But that is not the whole story. The efficiency of our muscles comes into play. With this type of activity, the efficiency is not so bad (a lot better than, e.g., weight lifting). We may reach 25%. The total energy consumption needed for riding is therefore around 400 W.

What does that tell us about the overall transport efficiency? How does this compare with other vehicles? Now it's time to make a small conversion. If we translate

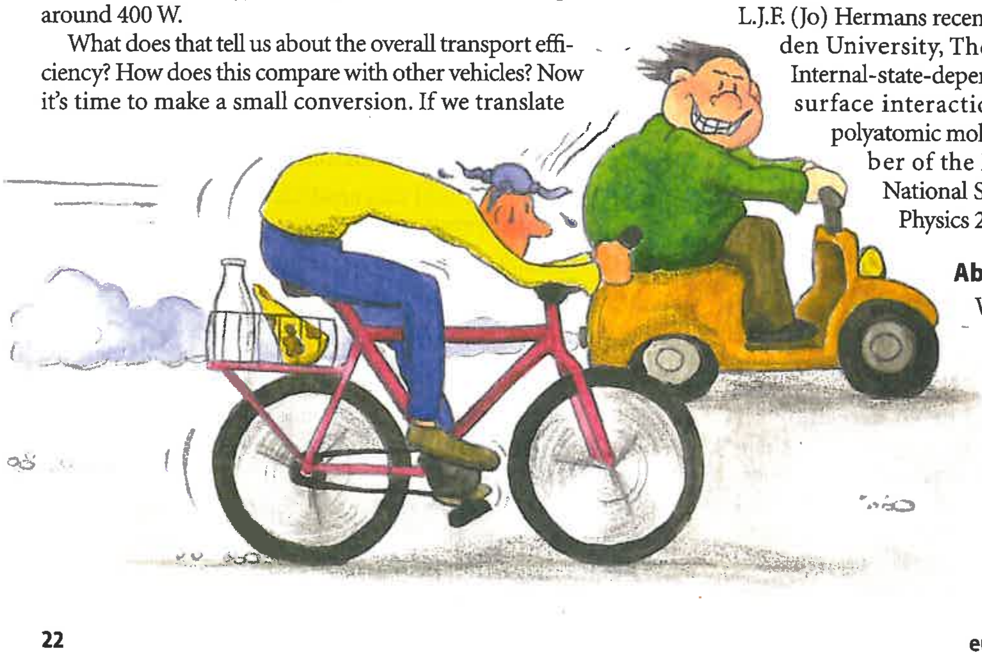


◄ **Erratum:** This figure, omitted from the first Physics in daily life column, "The human engine: How to keep it cool," [EPN 34/4, page 153] demonstrates schematically that each 100 W of released heat that has to be compensated by evaporation requires a glass of water (0.18 l) per hour.

400 W continuously in terms of oil consumption per day, we find pretty much exactly one litre per day, given that the heat of combustion of most types of oil and gasoline is about 35 MJ per litre. In other words: if, for the sake of the argument, we ride 24 hours continuously, without getting off our bike, we have used the equivalent of 1 litre of gasoline in keeping moving. How far will that get us? That, of course, depends on the type of bike, the shape of the rider, and other parameters. If we take 20 km/h as a fair estimate, the 24 hours of pedalling will get us as far as 480 km. In other words: a cyclist averages about 500 km per litre.

That's not bad, compared to our car, or even a motorbike. So, we should all ride our bike if we want to conserve energy? Careful, there is a catch here. We have been moving on food, not oil. And it takes a lot more energy to get our food on the table than its energy content may suggest. A glass of milk, for example, takes roughly 0,1 litre of oil, a kg of cheese roughly 1 litre. It's because the cow has to be milked, the milk has to be cooled, transported, heated, bottled, cooled again, transported again, etcetera. Same (or worse) for the cheese. Etcetera.

Conclusion: Riding our bike is fun. It's healthy. It keeps us in shape. And if we have to slim down anyway, it conserves energy. Otherwise—I hate to admit it: a light motorbike, if not ridden too fast, might beat them all.



About the author

L.J.F. (Jo) Hermans recently retired as professor of Physics at Leiden University, The Netherlands. Main research topics: Internal-state-dependence of intermolecular and molecule-surface interactions, and nuclear spin conversion in polyatomic molecules. In the 1990s he served as a member of the EPS council. Presently he chairs the National Steering Committe for the World Year of Physics 2005.

About the illustrator

Wiebke Drenckhan (26) is currently doing her PhD in the "Physics of Foams" in Trinity College Dublin, Ireland. She has studied and worked in Germany, USA, New Zealand and France, being largely supported by the German National Merit Foundation. Additionally to taking a scientific approach to the world, she likes to capture its oddities in cartoons.

noticeboard

Conseps has started

The European Commission has accepted to finance the project piloted by the EPS for the Consortium of Physics Schools (Conseps). Three well known schools (Varenna, Bad Honnef, and Les Houches) have agreed to co-ordinate the information and the topics of each of their schools. The content of the courses will, where practical also be available to the physics community. A web site, a brochure, and an electronic archive are currently under construction.

New EPS building on schedule

EPS' new office building is currently under construction. In spite of the inclement weather, the building remains on schedule. The building is co-financed by the French Government, The Region of Alsace, the city of Mulhouse and the Université d'Haute Alsace. Though cut back from the initial project from 400 to 350 m2, the building promises to be reflect the prestige of the EPS.

HAL operational

The Hyper Article on Line (HAL) is a new service for the physics community developed by the CNRS laboratory and the Centre pour la Communicatgion de Science Directe that provides an interface for authors to upload their scientific articles onto the CCSD article database. Articles in mathematics, physics, computer science are instantly and automatically driven to "arXiv" base (now located in Cornell University - former Los Alamos). In addition to the search options on arXiv, thanks a specialized interface using metadata given by the authors, HAL enables more precise search options. Authors are encouraged to use the HAL interface. For more information, see http://hal.ccsd.cnrs.fr/.

EPS 13 under way

The programme for EPS 13, "Beyond Einstein: Physics for the 21st Century" is currently being developed. Scheduled for July 11-14 2005 at the University of Bern (CH), EPS 13 will be a high point in the World Year of Physics (WYP2005) and the celebration of the centennial of Einstein's annus mirabilis 1905. The Conference will also inaugurate the new format of the EPS General Conferences and be comprised of three separate conferences, each highlighting the impact of Einstein's contributions to physics: Photons, Lasers and Quantum Statistics, organised by AMPD, CMD, QEOD; Relativity, Matter and Cosmology organised by HEPPD, JAD, NPD, PPD together with ESA, ESO and CERN; Brownian Motion, Complex Systems and Physics in Biology, organised by EPD, PLSD, SNPD and the Liquid and Macromolecular Phys. Sections of CMD.

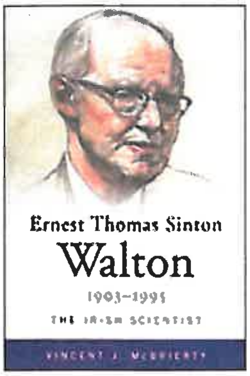
Max Auwärter Award 2004

The Max Auwärter Foundation in Balzers, Principality of Liechtenstein, offers bi-annually the Max Auwärter Award for students and young scientists at universities, vocational colleges and other research institutions, who have published as single author relevant work in the field of surface physics, surface chemistry and organic or inorganic thin films. The award includes a citation and a prize-money of EURO 10.000 (euro ten thousand) and may be split between several candidates.
Applications or proposals for the Max Auwärter Award 2004 should be submitted with four copies of the publication to be considered and the curriculum vitae of the proposed recipient describing his/her previous scientific activities by April 30, 2004 to:

Prof. Hannspeter Winter
Institut für Allgemeine Physik, Technische Universität Wien
A-1040 Wien, Wiedner Hauptstraße 8-10/134
Fax: +43 1 58801-13499
email: winter@iap.tuwien.ac.at

A jury appointed by the Foundation Council will decide finally and indisputably about the awarding of the prize. Presentation of the Max Auwärter Award 2004 is scheduled for September 2004 in Austria.

BOOK REVIEWS



E.T.S. Walton The Irish Scientist

Vincent J. McBrierty
Dublin Press, 2003, 98 pages
avail. from the Physics Dept, TCD, Dublin

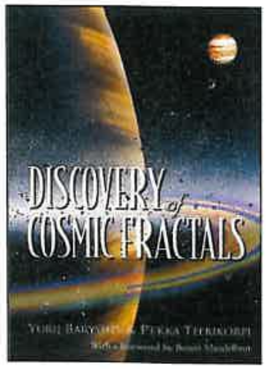
The names of Cockcroft and Walton are forever linked by their joint achievements in the *Annus Mirabilis* of nuclear physics, 1932. Working under Rutherford at the Cavendish Laboratory in Cambridge, they split the atom. Using cleverly designed high-voltage electronics producing 700kV, they were able to accelerate protons onto a lithium target and observe alpha particles resulting from the artificial disintegration of the lithium nucleus. Their work led to the award of the Nobel Prize for Physics in 1951. It also gave rise to the development of those big machines—the cyclotron, the synchrotron and others—that have extended enormously our knowledge of nuclear physics. The Large Hadron Collider, due to come on stream at CERN in 2007, is the logical extension of their pioneering work.

But what of the two men themselves? Who were they and what happened before and after 1932? October 2003 was the 100th anniversary of the birth of Walton and prompted Vincent McBrierty to write a short but delightful biography of him. Walton was the son of a Methodist minister and was born and educated in Northern Ireland, culminating in seven years spent as a boarder at the Methodist College in Belfast. The qualities of hard work, integrity, deep humanity and religious conviction learnt during his early years characterised his whole life. He developed an interest and talent for mathematics and science and was uncertain as to whether to attend Queens University Belfast or Trinity College Dublin to read physics, but chose the latter mainly because he won scholarships and awards that gave him greater financial independence.

In 1927, after a distinguished undergraduate career, Walton obtained an 1851 Exhibition Overseas Research Scholarship to work under Rutherford at Cambridge. After his dramatic discovery with Cockcroft, he stayed on at Cambridge for a further two years investigating artificial transmutations. By this time he had received his doctorate and his work had been widely recognised. He could probably have gone to several leading research institutes in America but instead he decided to return to TCD in 1934.

McBrierty has detailed the parlous state of TCD at that time. Not only was there a severe lack of money and facilities for research, there was also a very heavy teaching load, especially during WWII, when an enormous amount of teaching fell upon Walton's shoulders. He was an outstanding and inspirational teacher with a penchant for devising elegant experimental demonstrations. In 1946 he became the Erasmus Smith Professor of Natural and Experimental Philosophy at TCD, a post he was to hold until his retirement in 1974. He was thrust into the limelight by the award of the 1951 Nobel Prize for Physics, the only Nobel Prize awarded to an Irishman for science.

McBrierty has written a very readable account of his former colleague. In addition to discussing the life and work of Walton, he briefly describes the background of Irelands scientific heritage and that of TCD, which features such luminaries as Hamilton and Fitzgerald. But the personality of Walton remains in the foreground. He comes across as a person of great insight, integrity and humanity, an outstanding teacher and a brilliant scientist, a role model for us all.
Peter Ford, Physics Dept., University of Bath



Discovery of Cosmic Fractals

Yurij Baryshev & Pekka Teerikorpi
World Scientific Publishing, 2002
xxxi + 373 pages

Fractal objects appear ubiquitous in Nature. These self-similar structures are met in physics, biology, geography and many other disciplines, though under various designations like self-similarity, hierarchy, scaling invariance, fractals etc, which are often used as synonymous, but are not strictly equal constructs. With the rise of the scientific cosmology at the beginning of the last century, the concept of self-similarity reappeared in some astronomical circles, but it was only in the second half of the century that it entered the cosmological scene as a respectable, though not generally accepted model. When Mandelbrot introduced the concept of fractal in a rigorous manner in 1975, the paradigm of a hierarchically ordered cosmos gained its full cosmological significance.

Though there has been a fair number of review articles devoted to the question of the large-scale cosmic hierarchical ordering, this book by two astronomers is the first comprehensive and self-contained account of the development of the cosmological ideas which could be sorted out under the concept of fractality. Let us say rightway, the book is a splendid piece of a scholarly work. It is divided into two parts, the first dealing with the development of the notion of cosmos as a concept of the World in its totality. It appears almost exhaustive as regards the most relevant ideas and their proponents (though I wish the name of Anaxagoras, which appears several times, but not as the progenitor of the hierarchical cosmos paradigm, got a more prominent place) and I am pretty sure that even the most informed readers in the field will find facts and names they were not aware of. In this regard, this part might be well considered of an almost encyclopedian character.

The fractal cosmological paradigm is a matter of great controversy in the last decades and it makes an intellectual pleasure to follow the evidence and arguments for a general underlying principle, which orders material world from meso-physics to mega-cosmos (1-100 Mpc, so-called megafractals). The authors have made a readable blend of historical facts (many of them hardly known even by specialists), technical arguments (with brief mathematical support in footnotes) and epistemological comments, which gives the book a taste of self-sufficiency. Many people which contributed to the idea of hierarchical world appear unexpectedly (at least for me), like Emanuel Swedenborg, revealing the fact that the fractal idea was much more present in human mind than we are aware of that. The name of Benoit Mandelbrot appears, of course, frequently and the author of the very concept of fractal renders in the foreword an intimate account of the development of his ideas on the matter.

Richly illustrated by figures and photos, with a brief appendix and subject/author index, the book is aimed at the general academic readership, but I believe that those actively engaged in modern cosmology research will find many parts revealing and relevant to their work. To the former part of the readership the book will be an excellent introduction into cosmology in general, whereas I consider this monograph a must for the astronomers and cosmologists in particular.
Prof. Petar Grujic, Institute of Physics, Belgrade

Iya P. Ipatova obituary

Zh.I. Alferov, Vice-President of Russian Academy of Sciences
A.G. Zabrodskii, Director of the Ioffe Physical Technical Institute

On November 10, 2003 Iya Pavlovna Ipatova passed away due to a tragic accident.

A Ph.D. in physics and mathematics, she was an outstanding Russian specialist in solid state theory. A senior research associate at the Ioffe Physical Technical Institute, Russian Academy of Sciences, she was also a full professor at St. Petersburg Polytechnic University.

Ipatova made a valuable contribution to the theory of Raman scattering by free carriers in semiconductors. She demonstrated that the complex structure of the semiconductor band spectrum (multi- valley spectrum, valence band degeneration) results in a new mechanism of light scattering by single-electron excitations. She theoretically predicted a new mechanism of "gigantic" Raman scattering by spin-density fluctuation of holes, the mechanism which was later experimentally confirmed.

Ipatova's works dealing with the infra-red absorption and Raman scattering in semiconductors led to a new understanding of the anharmonic nature of broadening in spectral lines and the explanation of its temperature dependence. Her interpretation was based on the mechanism of line broadening by impurity local vibrations of dephasing nature. She also predicted the anomaly in the temperature dependence of the spectral line integral intensity in the impurity atoms, which were further revealed in the optical spectrum of U-centers in alkaline-haloids crystals.

Some of Ipatova's works were devoted to optical properties of disordered systems. Special mention should be made of her research on uniaxial solid solutions, whose optical properties are determined by local vibrations. The new concepts suggested in these works considerably upgraded the determination of parameters in new materials by absorption and light scattering. Six of her works were patented.

Ipatova made a pioneering contribution to the theory of surface phase transitions which leads to surface reconstruction. She succeeded in demonstrating that all the diversity of the observed surface phase transitions can be interpreted only in terms of the three-dimensional two-fold spatial symmetry groups, since the two-dimensional symmetry groups do not provide an adequate description of the experimental data obtained from these transitions.

Moreover Ipatova considerably contributed to the research into the instability of semiconductor solid solutions which are the basis of semiconductor opto– and microelectronics. Together with her young colleagues she predicted a new mechanism of spontaneous semiconductor super lattice formation, which was put into practice in designing a new type of modern laser diodes at the Ioffe Physical Technical Institute.

Ipatova's works were widely recognized both at home and abroad. Their number exceeds three hundred publications. Among them is the widely renown monograph "Lattice Dynamics In the Harmonic Approximation" co–authored with A.A. Maradudin, E.W. Montroll and G.H. Weiss.

Ipatova gave much of her time and energy to the education of young scientists at St. Petersburg Polytechnic University. A person of great vigor and resolve, she radically changed the conventional approach to teaching classical physics by creating an up–to-date course. This activity culminated in the two-volume edition of the textbook on general physics published in 2003 by the University Publishing House, as well as the new textbook "Solid State Quantum Theory" published in the USA (1996) and Russia (1999).

Ipatova was the life and soul, as well as the organizer, of numerous scientific conferences and schools held both at home and abroad. She was an outstanding member of the Russian and international physics community. For six years she was on the Commission of the International Union of Pure and Applied Physics (IUPAP) and for many years she was a member of the Board of the Condensed Matter Division of the European Physics Society.

Hard as was Ipatova's career in science, she always gave much support and consideration to women scientists. She was actively involved in establishing at the Ioffe Physical Technical Institute the organization "Women in Fundamental Science" which she chaired. A brilliant and talented researcher, she always had a galaxy of young talented physicists actively working under her guidance and supervision in the field of semiconductor theory. Honest, trustworthy and straightforward, she won the respect and recognition of her colleagues and students.

Iya P. Ipatova is a paragon of unselfish and faithful devotion to science. Her personality will be engraved in our memory forever.

Text translated into the English by E. Vlasova.

LETTERS TO EPN

Supercapacitors and cars don't mix easily

I was very disappointed by the paper about supercapacitors [Supercapicitors boost the fuel cell car] in the September/October 2003 issue of Europhysicsnews [EPN 34/5, page 176]. The scientific and technological level of that paper does not fit in such a high standard journal. Explaining that when a capacitor has lost half of its voltage, it has lost ¾ of its energy is really too elementary. Remember readers are supposed to be physicists.

The argument about using supercapacitors to boost the power of an electric car is at best naïve: can one imagine a car designer willing to add 100 kg of weight just to allow an extra power for 15 seconds? Every driver knows that after overtaking, one should not slow down too quickly, otherwise the car behind will hit you. You had better check you life insurance before boarding such a car!

Jean-Paul Hermann, Renault

Reply from the authors

It is indeed enough to have additional power for 15 seconds to be able to pass a car. As we considered the following explanation as too elementary for EPN, we did not include it into our article: To accelerate a car with a mass of 1000 kg e.g. from 60 to 100 km/h in about 5 seconds, you would need 50 kW additional power during these 5 seconds, i.e roughly a third of the available supercap-energy (remember that the fuel cell is working in parallel and covers all friction losses, so you need the supercap exclusively for accelerating). To drive on with 100 km/h after the acceleration phase, the fuel cell alone gives enough power and the supercap is not needed any more. A speed difference of 40 km/h is by far enough to pass another car and to avoid it hitting you from the back!

Fritz Gassmann, Rüdiger Kötz and Alexander Wokaun

The Faculty of Science of the University of Bern invites applications for a position of

Full Professor of Experimental High Energy Physics and Head of the Laboratory for High Energy Physics

opening March 1, 2006 at the Laboratory of High Energy Physics of the Physics Institute, University of Bern, Switzerland. Current research activities of the Laboratory include work at CERN especially on the ATLAS experiment at LHC, as well as the physics of neutrino oscillations (OPERA) and dark matter (ORPHEUS).

Candidates should have a proven first rate research record in experimental high energy physics. This may include participation in large experiments and the development of novel experimental techniques. She/he should also be prepared to participate actively in the teaching of physics at both the undergraduate and graduate level. As Head of the Laboratory, the successful candidate has overall responsibility for about 30 collaborators and will be a member of the Board of Directors of the Physics Institute.

The University of Bern especially encourages women to apply for this position. Letters of application, including a curriculum vitae, a list of publications, copies of the most important publications, and an outline of past and future research (all in English) should be sent before March 1, 2004 to Prof. G. Jaeger, Dean of the Faculty of Science, Sidlerstrasse 5, CH-3012 Bern, Switzerland.

Further information about the Laboratory can be found at http://www.lhep.unibe.ch and enquiries about this position can be made by contacting Prof. W. Benz, Physikalisches Institut, Sidlerstrasse 5, CH-3012 Bern, Switzerland, Phone: +41 31 631-4403, Fax: +41 31 631-4405,
e-mail: wbenz@phim.unibe.ch

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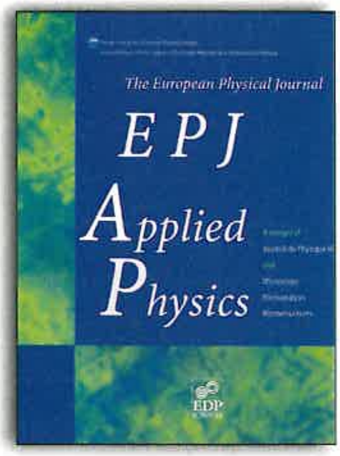

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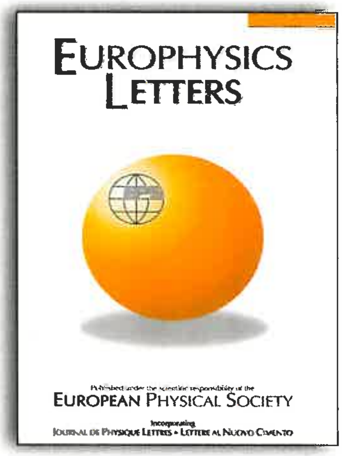

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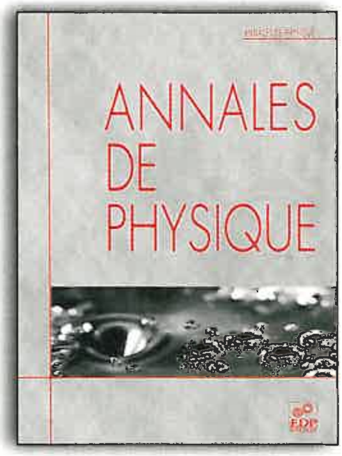

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