Symposium 1

European Research Infrastructure (Neutron, Muon and Photon Sources, Low-Energy Ion Accelerators)

Convener:

Y. Petroff
Lawrence Berkeley National Laboratory, USA

X-RAY SCIENCE AT THE EUROPEAN SYNCHROTRON RADIATION: RECENT RESULTS AND FUTURE CHALLENGES

F. Sette *
ESRF

Third generation synchrotron radiation sources are presently reaching their full maturity. Their impact is very widespread, and many areas of science and technology are strongly benefiting from them. Fundamental research problems are regularly addressed, and typical examples are provided by: I) High pressure research, where equation of state, physical properties and new materials are investigated at very exotic conditions, ii) Highly correlated systems, which are studied with novel polarization dependent scattering and spectroscopy techniques, iii) time resolved studies, addressing microscopic processes in the sub-nanosecond range, iv) The extraordinary revolution in biology, which is fostered by the exploding field of structural studies of proteins. The present contribution will illustrate few examples in this respect. Moreover sometime will be devoted to new challenging possibilities, as the fields that may become available in the future thanks to expected instrumental achievements from new storage ring, extreme x-ray focusing, and exotic samples and sample environments.

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SCIENCE WITH VUV AND SOFT X-RAY SYNCHROTRON LIGHT SOURCES

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The development of « third-generation » synchrotron light sources of VUV and soft x-ray radiation has been particularly intense in Europe, but also in the US and in the Far East. These sources provide photon beams characterized by high brilliance, high degree of spatial coherence and also tunable polarization properties. They are particularly important in the determination of the electronic properties of matter, with techniques such as photoelectron spectroscopy, photoabsorption, resonant x-ray scattering and imaging. An important extension of the powerful photoemission techniques for the investigation of electronic states is obtained by the achievement of spatial resolution, from the sub-μm to the ~10nm scale, either by focusing the photon beam with suitable optical elements, or by imaging the photoelectrons by electron optics devices. These techniques have found applications as diverse as the study of catalytic action, the imaging of domains in magnetic nanostructures (exploiting the polarization properties), or the study of growth and deposition processes. The polarization properties are also useful in the study of magnetic and strongly correlated systems by absorption and/or resonant scattering techniques. The emergence of new techniques such as inelastic VUV scattering is also discussed.

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ANTIBIOTICS TARGETING RIBOSOMES

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Resistance to antibiotics is a major problem in modern therapeutics. Antibiotics are small chemical agents (m.w. 600-800 Dalton), designed to eliminate bacteria. Over 40% of the useful antibiotics interfere with translation of the genetic code into proteins; a fundamental life process, which, in rapidly growing bacterial cells consumes up to 80% of the cell's energy. Most of these antibiotics target the ribosomes, the universal cellular organelles catalyzing this process. Ribosomes are giant nucleoprotein complexes (m.w. 2.3 mega-Dalton in prokaryotes and 4.5 mega-Dalton in mammalian), built of two independent subunits that associate upon the initiation of protein biosynthesis. The larger subunit creates the peptide bonds and provides the path for emerging proteins and the smaller controls the fidelity, the initiation and the termination of the biosynthetic process.

We identified bacterial sources suitable to serve as pathogen models and used their ribosomes for crystallographic studies with bright synchrotron radiation. These led to the localization of clinically relevant antibiotics that were found to inhibit ribosome function by interfering with substrate binding, hindering the progression of nascent proteins or limiting ribosomal mobility. All bind primarily to ribosomal RNA and do not cause major conformational changes. Understanding their modes of action provide powerful tools for rational drug design.

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ESS: A QUANTUM LEAP IN RESEARCH OPPORTUNITIES

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Tremendous progress in neutron scattering research capabilities has been achieved over the past half century primarily by the development of the performance of the instrumentation, both in terms of new concepts and approaches and advances in components, such as detectors. Over the same period of time the brightness of neutron sources only increased by a modest amount. ESS will offer an unprecedented jump of some two orders of magnitude in a crucial source performance parameter, the instantaneous peak flux during the pulses compared to the leading continuous or pulsed neutron sources existing today, while in terms of time average flux it will equal the most powerful continuous sources. The pulsed character allows for a more efficient use of the total number of neutrons produced, and this efficiency differs from one application to another. The goal of the ESS project is to combine the vastly enhanced, unique source quality with the most advanced instrumentation concepts and techniques to achieve a quantum leap in neutron scattering research opportunities well beyond what could be achieved by concentrating only on enhancing the source performance or only trying to further develop instrumentation. The results of the combined effort as characterised by the sensitivity of observing small signals.(which is the main limitation in the use neutron scattering techniques in general) are found to amount to as much as three orders of magnitude in some unique core applications and more than two orders of magnitude in the majority of neutron scattering work. To achieve this huge step forward, well comparable to the progress expected from the realisation of large free electron laser in X-ray research, we need to vigorously advance neutron scattering instrumentation techniques together with the source performance. Extensive experience accumulated over the past 5 decades of using continuous reactor source and nearly 3 decades of progress with pulsed spallation. sources provides a solid and sophisticated basis for this effort. The utilisation of innovative concepts will further enhance the efficiency of using source power in the actual experiments. Examples include enhancement of the efficiency of extracting and transporting neutrons from the source to the sample by advanced neutron optical means, or sophisticated so called multiplexing techniques, which allow us to optimise the efficiency gains by the pulsed character of the source simultaneously for a large number of instruments with very different characteristics. As a result ESS will not only surpass all other neutron sources (existing or being built) by its higher neutron brightness achieved by more proton beam energy per pulse, but it will enhance this advantage by the more efficient use of the neutrons produced.

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MUON BEAM RESEARCH IN CONDENSED MATTER SCIENCE: ACHIEVEMENTS AND PROSPECTS

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The overriding strength of μSR, a generic acronym for muon spin relaxation, rotation and resonance techniques, is that it is a uniquely sensitive probe of extremely small magnetic fields and the distribution and dynamics of such magnetic fields within a sample, both in zero and applied magnetic field. Indeed the sensitivity of μSR is such that fields generated by nuclear moments are easily measured, whilst the dynamical response (10^{-12}-10^{-4} s) serves to bridge the gap that separates, for example, neutron spin echo methods from the bulk measurements of magnetization and susceptibility. The field dynamics measured by the muon can be related either to intrinsic internal field fluctuations, or to the apparent fluctuations caused by a muon diffusing through a lattice. The latter case is often of key interest, as the muon itself behaves like a light isotope of hydrogen (M_μ=1/9amu) and therefore can be used to probe hydrogen-like diffusion processes.

The unique sensitivity of μSR has secured its role as an indispensable and increasingly important tool in the armory of the condensed matter scientist. Over the last decade the extremely successful and often pioneering exploration of phenomena as diverse as spin glass dynamics, spin fluctuations in itinerant electron systems, magnetic ordering in ultra-small moment systems, critical dynamics, flux distribution in superconductors, hydrogen mobility, passivation in semiconductors, muonium formation and dynamics in proteins and, more recently surface and near surface effects, has provided a testimony both to the wide applicability of muon beam techniques and to the breadth of the muon beam user community.

Europe is particularly fortunate to host two major world-class muon facilities, namely PSI in Switzerland and ISIS in the UK. In this presentation I will briefly revue the impact of the muon beam research performed at these facilities, and also extrapolate beyond existing facilities and capabilities to what the proposed European Spallation Source might be able to offer muon spectroscopists in the future.

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ION BEAM ANALYSIS TODAY AND TOMORROW

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Ion Beam Analysis (IBA) is a general name of wide group of analytical methods, based on the observation and analysis of various particles emerging from the investigated sample under MeV energy ion impact. The most widespread IBA techniques are:

	name	*observed particle*
RBS	Rutherford Backscattering Spectrometry	elastically scattered ions
ERDA	Elastic Recoil Detection Analysis	elastically recoiled target atoms
NRA	Nuclear Reaction Analysis	nuclear reaction products (p, á, γ...)
PIXE	Proton Induced X-ray Emission	characteristic X-rays

RBS, the first IBA method, was introduced for thin film analysis in the field of semiconductor technology in the early 1960's. Since then, new IBA methods are continuously developed and applied in various fields of application. Today it is routine to determine the depth distribution of almost all the elements and isotopes in the first few ìm of the sample with sensitivities of a few tenths or hundreds of at% and with a depth resolution of a few nm (near to surface). The lateral size of the investigated spot in most cases is a few mm^2, but in microbeam facilities the beam size can be reduced to few $ìm^2$. IBA is not sensitive to chemistry, gives reliable information only on the elements existing in the sample.

To remain competitive with other surface sensitive analitical methods unique features of IBA have to be developed. In the years past some remarkable results have been achieved. The sensitivity of the method can be extremely good using coincidence detection methods (e.g. H detection with ERDA using H ions) or AMS (Accelerator mass spectrometry). Atomic scale depth resolution can be achieved using magnetic or electrostatic spectrometers. Application of time of flight energy determination forecasts also significant improvements. The lateral resolution of few hundred keV Focussed Ion Beam devices, applying electrostatic focusing, is now being to reach the few nm scale. The impurity lattice localisation by channelling with sub-angstrom spatial resolution still remains an attractive feature. New IBA setups using compact accelerators of 1 MeV energy are now available in the market.

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Symposium 2

Education

Convener:

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SCHOOL PROJECTS AT THE PHYSICS FRONTLINE

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One of our great challenges today is to make physics at school level more interesting and to increase the science literacy in general. It is also important to show that physics is an evolving subject where there is still a lot to discover. Our projects at the physics frontline have an important role to play in this process and as a source of inspiration for continued studies.

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EUPEN'S ONGOING CONTRIBUTION TO EUROPEAN PHYSICS EDUCATION

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The 'European Physics Education Network' (EUPEN) is a Consortium of more than hundred and twenty Physics departments/faculties from universities and technical universities in more than twenty-five countries across Europe. The EUPEN Consortium was established in 1996 and executed its activities as a Thematic Network (TN) under the same acronym, with funds by the European Commission (E.C.) via the DG XXII, and presently via the DG EAC, in the frame of the ERASMUS action of the SOCRATES programme. The EUPEN Consortium promotes and contributes to physics education in Europe, mainly by offering a yearly forum for discussion on subjects of common interest to physics departments /faculties, e.g. this year's EUPEN General Forum EGF2002 in Varna (BG) on 6 and 7 September 2002. During the period 1996/2000 the project focused on a comparative study of physics first-degree programmes, on physics doctoral studies, on ICT and associated kills in physics studies all at member institutions and also on physics teacher training in five countries, with dissemination of the results mainly during the academic year 1999/2000. During the period 2000/2006 in phase II of the SOCRATES programme, the EUPEN scheme is updating the previous comparability survey with an emphasis on the new degree courses in the light of the Bologna Declaration. During the last two academic years EUPEN contributed in a synergetic way to the 'Tuning educational structures in Europe' project by searching for convergence of the studies in a European dimension. We hope to continue this Bologna process in the follow-up 'Tuning 2' part, directed towards C/EE countries. With the management help of ENQA (European Network of Quality Agencies) together with the 'Danmarks Evalueringsinstitut' in København (DK) and the financial support of the Directorate General Education and Culture (DG EAC) of the E.C. a 'Pilot Scheme on European Higher Education Quality Evaluation' will be established. Quality assessment would be performed by an 'International Peer Review Committee' in volunteering universities of the EUPEN Network, leading to an Assessment Report to be presented at the Berlin 2003 Summit of the Ministers, who signed the Bologna Declaration and the Prague Communiqué.

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PHYSICS IN A SMALL COUNTRY

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The beginning of physics education at a university level in Macedonia is in 1946. The graduates from the University are the main source of physics teachers, researchers and physicists following other careers. An overview will be given of the educational system including the contents of physics in school curricula, the most common methods used by teachers and recently adopted changes. Two recently finished TEMPUS projects closely related to the general education, concentrated on continuous education of physics teachers, use of computers, provision of modern equipment and modernisation of the university syllabus for future physics teachers. It is hoped they will help to counter the trends of diminished interest for studying physics.

Already 45 years, an important activity of the Society of Physicists of Macedonia is the organisation of physics competitions for elementary and secondary school pupils. Comparison is made between the achievement of pupils at the International Physics Olympiads and those reported in the Third International Science and Mathematics Study.

At the end the pedagogical content of some gravitational billiards is discussed, namely the approach to equipartition and deterministic diffusion, including a novel type of Poincare surface sections containing arcs besides the usual closed curves corresponding to quasiperiodic motion. (The latter part is a joint work with Lasko Basnarkov.)

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TEACHING PHYSICS AT A DISTANCE: CHALLENGES AND SOLUTIONS

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The Open University is the largest university in the UK. Its 200 000 students are mainly mature students, studying part-time and at a distance. The remoteness of the students, and their wide range of prior qualifications, backgrounds and educational objectives present a number of teaching challenges, especially in an experimentally based subject such as physics.

This talk will review some of those pedagogic challenges and critically examine some of the responses that have been used to overcome them over the past thirty years of Open University teaching. Particular emphasis will be given to the way the responses have evolved as educational technology has developed, especially in the areas of practical work, assessment, multimedia activities and the widening of participation.

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PHYSICS COMPETITIONS - A WAY TO PROMOTE THE DISCIPLINE IN SCHOOLS

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One way to making young people interested in physics can be to arrange international competitions, like the Olympiad which is concerned with individual performances. This event has a very long tradition and there are laureates who have later become famous physicists. The International Young Physicists' Tournament (IYPT) is a team competition, also held annually, but with a rather different profile. This year's competition was held in Odessa, Ukraine, with 20 teams from 18 countries participating. A report will be given on the general terms of this very interesting type of event as well as on the results from Odessa.

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NEW TYPES OF PHYSICS COMPETITIONS FOR SECONDARY SCHOOL STUDENTS

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International physics competitions play an important role in the education of highly talented secondary school students opening new possibilities to extend their knowledge in physics and other sciences. There are many ways of educating gifted students in and outside the school. International competitions prove the individual abilities of students and their capability to work in a team. The results are in connection with the educational and scientific level of the participating countries. There are many types of competitions, here we present only two of them. The International Conference of Young Scientistst (ICYS) and the International Young Physicists' Tournament (IYPT) are new forms of competitions. On the poster some of the problems of the IYPT will be presented together with the short description of the training method the Hungarian students for the competition. Two successful secondary school students are ready to show a short presentation about their own scientific investigation. This kind of work acts as a bridge between university and secondary school.

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Symposium 3

Physics in Biology

Convener:

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COUPLING MICROTUBULE DEPOLYMERIZATION TO ATP HYDROLYSIS BY THE KIN I KINESIN MCAK

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MCAK belongs to the Kin I subfamily of kinesin-related proteins, a unique group of motor proteins that are not motile but instead catalyze microtubule depolymerization. We have used a combination of stopped-flow, ATPase and single-molecule assays to probe the kinetics of the MCAK-microtubule interaction and to understand how this interaction is coupled to ATP hydrolysis.

In the presence of ATP, MCAK depolymerizes microtubules from both ends with a maximum total rate of 1 μm/min. For the stable GMP-CPP microtubules used in these experiments, this corresponds to the dissociation of 30 tubulin dimers per second per microtubule, a 100-fold acceleration over the basal depolymerization rate. Thus MCAK is a catalyst. The saturation of both the depolymerization rate and the physical binding indicates that there is one high affinity MCAK binding site (K_d = 1 nM) per protofilament end, and that each MCAK removes up to 30/28 ≅ 1 tubulin dimer per second from a protofilament end (each microtubule has 14 protofilaments and two ends).

The short delay between the mixing of MCAK with microtubules and the initiation of depolymerization indicates that MCAK reaches these binding sites very quickly: the apparent second-order association rate constant (k_{on}) is 50 $\mu M^{-1} \cdot s^{-1}$, more than 10-times greater the fastest, diffusion-limited protein-protein association rates. Several lines of evidence support a model in which MCAK first binds to the microtubule lattice, then diffuses along the lattice until it finds its binding site at the microtubule end.

Knowledge of the on-rate (k_{on}) and the dissociation constant (K_d) allow one to calculate the dissociation rate: $k_{off} = k_{on} \cdot K_d = 0.05\ s^{-1}$. Because this is 20 times smaller than the rate at which an individual MCAK removes tubulin dimers from a protofilament end (1 s^{-1}), these findings suggest that each MCAK remains at the end of a protofilament for for an average of 20 s, during which time it removes 20 tubulin dimers. Thus MCAK is processive.

The catalytic activity of MCAK requires ATP. Consistent with this, MCAK has an ATPase activity which is stimulated by microtubule ends. In the absence of tubulin or microtubules the ATPase rate is 0.014 s^{-1}; in the presence of unpolymerized tubulin the ATPase rate is 0.15 s^{-1}; and in the presence of microtubule ends, the ATPase rate is 5 s^{-1}. Unexpectedly, we found that five ATPs are required to remove each tubulin dimer from a GMP-CPP-microtubule, suggesting that the efficiency of tubulin removal is quite low (only 20%).

Our results provide insight into how an ATP hydrolysis cycle has been modified from one that powers a motor to one that powers a depolymerase.

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EXPLORING THE RUGGED CONFORMATIONAL ENERGY LANDSCAPE OF PROTEINS

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Proteins are complex biological molecules with intriguing physical properties. At physiological temperatures, the intricately folded polypeptide chain of a protein is in a state of incessant thermal motion and fluctuates among a large number of slightly different conformations with similar free energies. These so-called conformational substates can be represented by local minima in a rugged energy landscape, and the dynamics can be described by thermally activated crossing of energy barriers with widely differing heights. Due to the complex topography of the energy landscape, motional time scales span more than 15 orders of magnitude, from fast bond vibrations (subpicosecond time scales) to slow, local and global unfolding events (time scales of milliseconds and longer). Protein motions on subnanosecond time scales have been studied extensively both with experiments and computer simulations. Our knowledge of nanosecond to millisecond protein motions still remains fragmented. These time scales are particularly important, however, as most proteins rely on rare thermal fluctuations to conformationally excited substates to carry out their biological functions.

To explore the energy landscape of proteins, a few model systems have been studied in great detail, including heme proteins and bacterial reaction centers. Structural and spectroscopic studies over wide ranges of external parameters (temperature, pressure, pH, cosolvents) have given insight into the general features of the energy landscape. We have developed techniques to prepare and characterize non-equilibrium conformational states, most importantly by laser excitation, and transitions between these states have been studied using spectroscopic techniques as well as x-ray crystallography.

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THE ROLE OF ENVIRONMENTAL FLUCTUATIONS IN THE FUNCTION OF PROTON PUMPS

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Anions at moderate and high concentrations (above 50-100 mM) control the aggregation state of proteins, as well as their structure and dynamics in a correlated manner ("Hofmeister-effects"). Although the exact action mechanism is not fully understood, many experts agree that the effects are mediated by the altered structure of water in the presence of anions. Chaotropic ions ("water structure breakers") generally tend to loosen protein structures, while kosmotrops ("water structure makers") usually stabilize them. We have recently introduced a general concept for the interpretation of Hofmeister-effects based on salt-induced changes in protein free energy flucuations, that can formally account for a row of phenomena. The question how environmental fluctuations can control protein dynamics will be discussed on the basis of experiments carried out on the simplest proton pumping protein, bacteriorhodopsin.

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ACTIVE DETECTION OF SOUND IN THE INNER EAR

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The performance of our senses is remarkable – and none more so than hearing. Our ears are able to capture whispers that impart no more energy per cycle than the thermal motion; at the same time, they can respond to loud noises that carry fourteen orders of magnitude more energy; and, of course, they can analyse frequencies that differ by a few percent. Key to this performance is a process of active amplification within the inner ear. Recent theoretical work suggests that the amplifier consists of a set of nonlinear dynamical systems which are regulated by a feedback system that maintains them at the threshold of an oscillatory instability. Poised on the verge of vibrating at a characteristic frequency, each oscillator is especially sensitive to periodic perturbation at that frequency. This active method of signal detection is ideally suited to the ears needs, providing exquisite sensitivity, wide dynamic range and frequency selectivity. However, its intrinsic nonlinearity causes tones of different frequency to interfere with one another in the cochlea. This interference appears to be at the origin of many psychophysical phenomena such as auditory illusions and the distinction between consonance and dissonance.

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MICRO TO NANOSCALE MACHINERY TO UNRAVEL THE CODE OF LIFE

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Although the human genome has now been “sequenced”, at some level, it is misleading to think that we now understand how the genome is expressed and how the cell functions. The key word here is ``epigenetics" . Epigenetics refers to the non-genomic information that a cell passes on to its progeny. This ``information" can vary from methylation of the DNA bases to the occupancy of the promoter and repressor sites on the DNA that control gene expression. In our lab, we are trying to do it all: select rare cells, extract the genomic material, fractionate the genomic DNA and scan the DNA for the occupancy of the epigentic control sites. I’ll discuss where we stand on these projects, most of which involve micro and nanofabrication techniques.

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Symposium 4

Physics of Conjugated Polymers and their Applications

Convener:

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CHARACTERIZATION OF THE CHARGE TRANSPORT AND ENERGY TRANSFER PROCESSES IN ORGANIC SEMICONDUCTORS

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Energy transfer and electron transfer are found to be key processes in the working mechanisms of devices based on organic semiconductors. Here, we provide a theoretical description of the energy and electron transfer phenomena that take place in a variety of organic materials. Materials under study include single crystals of conjugated oligomers (such as oligoacenes, oligothienylenes, and their derivatives), discotic liquid crystals (based on triphenylenes and derivatives), conjugated polymers, and donor-acceptor oligomer wires.

We first focus on the characterization of the charge (electron and hole) transport processes. The intrinsic electron and hole mobilities of well-ordered and disordered materials are discussed on the basis of Marcus theory and extensions thereof.

A second topic concerns the relative efficiencies of *interchain* versus *intrachain* energy transfer processes and the dependence on distance of the transfer mechanism (superexchange vs. hopping). Here, we will discuss this issue in the framework of a theoretical approach based on an improved Förster model applied to polyindenofluorene.

Finally, we model the mechanisms of photoinduced charge transfer from a π-electron donating group to a π-electron-acceptor moiety separated by a bridge of increasing size made of *p*-phenylenevinylene oligomers. It is found that while superexchange is the dominant mechanism for short bridges, incoherent transfer through hopping along the phenylene vinylene segment takes over in longer chains (for *ca*. three phenylenevinylene repeat units).

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PHOTOELECTRON SPECTROSCOPY OF CONJUGATED POLYMERS

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Conjugated polymers have been studied by photoelectron spectroscopy and other related surface science techniques for over two decades. In the past few years, however, several advances have been made in classical techniques. Some aspects of X-ray and ultraviolet photoelectron spectroscopy (XPS and UPS), as applied to conjugated polymers, will be hi-lighted. New results on high quality conjugated polymers will be presented.

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ORGANIC SPINTRONICS: A NEW PERSPECTIVE FOR ORGANIC SEMICONDUCTORS

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We explore a new approach to Spintronics by using organic semiconductors as active transport materials in combination with novel spin polarised (SP) electrodes made of a $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) thin film which is a ferromagnetic metal at RT. Sexithienyl is deposited by UHV deposition. At zero magnetic field the LSMO electrodes are randomly oriented, while in magnetic field the SP are parallel. By inserting a 3.4 kOe magnetic field we observe indeed a 30% drop of the resistance (MR) for a channel length L of 140 nm. By increasing L the MR drops to 7-10% at 200nm and eventually vanishes at 300nm. The room temperature spin transfer coherence length is estimated to be about 200-300nm. This is the first evidence of spin coherent injection and transfer in organic semiconductors (1). Preliminary results of LSMO electrodes in a OLED configuration show efficient charge injection and electroluminescence opening the possibility to control the recombination spin statistics and improving the efficiency.

1)V. Dediu et. al., Sol. St. Commun., 122, (2002), 181; USA patent n°: 6.325.914.

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POLYMER ELECTRONICS

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Conjugated polymers now provide a class of processible, film-forming semiconductors and metals. We have worked on the development of the semiconductor physics of these materials by using them as the active components in a range of semiconductor devices. Polymer light-emitting diodes show particular promise, providing full colour range (red, green and blue), efficiency (above 20 lumen/W for green emitters). I will also discuss progress made on their application to displays, with integration with active-matrix TFT drive, and with patterned deposition using ink-jet printing techniques.

Polymer LED efficiency is considered to be controlled by ratio of singlet to triplet excitons formed by electron-hole capture, since the exchange energy for these strongly-bound excitons is large (> 0.7 eV), so that only singlet excitons can produce raditiative emission. The spin-independent ratio of 1:3 would limit efficiency to 25%, and this is found in organic LEDs made with molecular semiconductors. However, several experiments now reported for polymers indicate a higher ratio, of nearer 50% singlets, and indicate therefore spin-dependent electron-hole capture. Reasons for this behaviour will be discussed.

Polymer-polymer heterojunctions can be exploited both in LEDs and also in polymer photovoltaic cells. An important approach which can be exploited with solution-processed polymers is the formation of de-mixed polymer blends formed with electron- and hole-accepting polymers, and we have recently studied the process of demixing in such systems. I will discuss conditions required for photo-induced charge transfer (as required for photovoltaic diode operation) or for energy transfer (as required for LEDs), and consider evidence for localisation of excitons at the heterojunction in this regime.

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APPLICATION OF CONJUGATED POLYMERS – WE ARE JUST AT THE BEGINNING

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Conjugated polymers are at the basis of "Polymer Electronics", an emerging, very promising, technological area, which may pave the way to many new applications and products. The unique features of conjugated polymers, like ease of processing, extreme robustness, good mechanical properties enabling the manufacturing of flexible products, in addition to the opportunities provided by "molecular engineering" enabling tailor-made functionality, form the cornerstones of Polymer Electronics.

The use of electroluminescent semiconductive polymers for emissive displays is already becoming an established technology. Philips just has launched the first commercial products, incorporating monochrome PolyLED^{TM} displays. Polymer light-emitting diode based displays indeed are the first polymer electronics products to have reached the market. It is expected that the thin emissive displays, which can be realized with this new technology, will conquer an important place in the display market.

The use of polymer transistors in ICs and in transponders, and as pixel switches for displays is still in its infancy. Applications have been demonstrated in a research environment, but significant effort is still required to address production issues and to demonstrate business opportunities. The present state of affairs is comparable to that at the beginning of the rise of the silicon-based IC industry, some 40 years ago. The application of polymers for low-cost electronic products, like labels and barcodes and for electronic paper, will lead to a family of very interesting new products, which will definitely change the electronics industry.

New options of polymer electronics, e.g. their possible application for photovoltaics (e.g., in organic solar cells) and as sensors, and for solid-state storage, are just beginning to be explored.

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Symposium 5

Quantum Gases

Convener:

N.J. Mason
University College London, Great Britain

Co-convener:

E. Hinds
University of Sussex, Great Britain

STUDIES OF PENNING IONIZING COLLISIONS IN BOSE-EINSTEIN CONDENSATES

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The observation of Bose-Einstein condensation of metastable helium (He*) [1,2] constituted a pleasant surprise for experimentalists and a remarkable vindication for theorists [3]. Success hinged, among other things, on a strong suppression of Penning ionization in the (spin-polarized) magnetic trap. Too high a rate of ionization would have prevented the accumulation of a sufficiently high density of atoms.

The ionization rate is not completely suppressed however, and when the atomic density gets high enough, a cold, magnetically trapped sample of He* does produces a detectable flux of ions, and this signal can even be used as a signature of BEC. An example is shown in the figure.

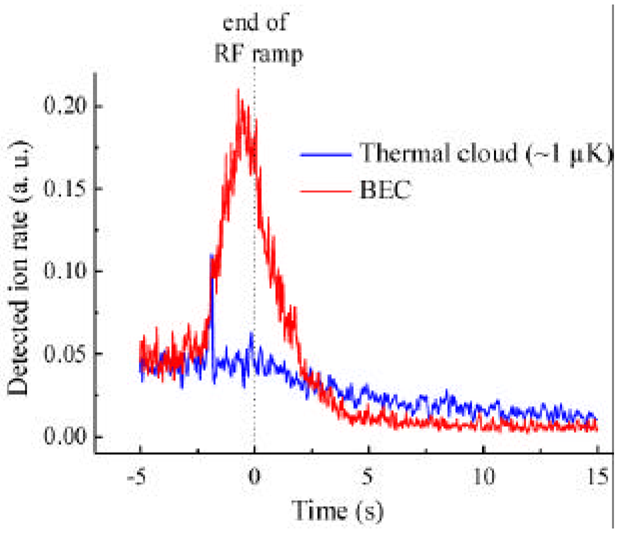

Figure : Ion production from a cold cloud of He atoms during and after the evaporation ramp. The production of a condensate is accompanied by an abrupt increase in the ion production rate. The condensate apparently decays significantly faster than a thermal cloud just above the transition temperature.*

After a brief review of some of the general issues surrounding BEC in metastable gases, this talk will discuss our efforts to understand the origins of the ionization signals. Are the ions produced by two body or three body collisions or something else? Are they responsible for the decay of the condensate seen in the figure? Can we use the ions signal to quantitatively study the dynamics of the condensate: its growth, its decay, and its response to perturbations. We have partial answers to these questions but more work needs to be done.

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FERMI-BOSE AND BOSE-BOSE QUANTUM DEGENERATE K-RB MIXTURES

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We present the experimental investigation on binary atomic mixtures composed by ^{87}Rb and isotopes of potassium. The atomic samples are simultaneously trapped and cooled in a double magneto-optical apparatus and then transferred in a magnetic trap, where potassium atoms are sympathetically cooled by means of thermal exchange with evaporatively cooled rubidium atoms [1]. The interspecies interaction properties of the pairs ^{40}K –^{87}Rb and ^{40}K – ^{87}Rb are favorable for the formation of Fermi-Bose and Bose-Bose quantum degenerate gases, respectively [2].

We indeed produce Rb Bose-Einstein condensates immersed in a Fermi sea of ^{40}K atoms, at a temperature $T \leq 0.3T_F$ [3]. The peculiar attractive interaction of this mixture is promising for the study of sympathetic cooling deep into the degenerate regime.

We also produce binary Bose-Einstein condensates of ^{40}K and Rb atoms, and we evidence their superluid behavior in the dynamics in the magnetic trap [4]. The large repulsive interaction makes this system interesting for the study of immiscible superfluids.

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FORMATION OF ULTRACOLD MOLECULES VIA PHOTOASSOCIATION OF LASE-COOLED ATOMS

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Whereas direct laser cooling of molecules is difficult, recent experiments have produced a large number of ultracold (T < 100 μK) Cs_2 [1], K_2 [2], and Rb_2 [3] molecules by photoassociation of ultracold atoms in a magneto-optical trap. In a photoassociation reaction [4], two ground state alkali atoms *A(ns)* absorb a photon slightly red-detuned from the frequency of the resonance line, forming a molecule in a vibrational level *n* of an excited potential curve correlated to the first (*ns* + *np*) dissociation limit. This excited molecule usually decays back into a pair of cold atoms. The stabilization into a bound level of the ground electronic state requires a favourable transition moment between the excited- and ground-state vibrational wave functions.

We shall report upon the efficiency of various schemes to obtain stabilization, making use of double-well potentials [1,3], tunneling effect [5], transfer to a Rydberg state [6] and resonant coupling [7].

Good agreement is obtained between theory and experiment. The present accuracy of experimental spectra is of the order of 10^{-3} cm^{-1}, well beyond the achievements of the best *ab initio* calculations. The uncertainty on short range potentials can be bypassed by use of asymptotic methods, such as Le Roy Bernstein formula [8] or generalized Lu Fano plots [9]. Such methods rely upon the analogy between a photoassociated molecule and a Rydberg atom. Parameters such as generalized quantum defects or reduced coupling are fitted to the photoassociation spectra [10]. Generalized MQDT is a powerful theoretical method to analyze the data, and scaling laws can be derived to predict rates of formation of molecules [11,12].

Work in progress is focussing on the formation of molecules within a condensate. Going beyond the alkali dimers, and making trimers or larger molecules is a challenge.

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TAMING THE WILD ATOM

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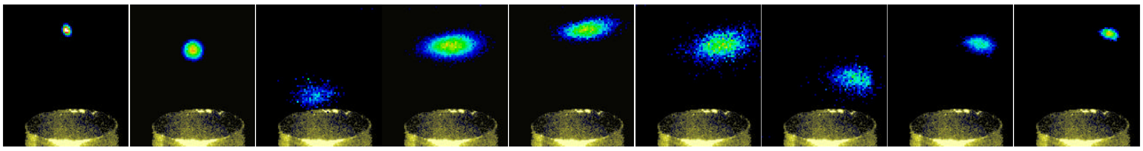
Clouds of cold atoms, collected and refrigerated by laser light, can be cooled to the lowest temperatures in the universe. This has created the new field of atom optics where cold atoms are manipulated, much as photons are controlled in traditional optics using mirrors, lenses, and waveguides. I will show some of the first movies of atom clouds being manipulated.



From the viewpoint of basic science these clouds are a fantastic new tool for studying the quantum physics of gases close to absolute zero.

It is now becoming possible to confine and manipulate atoms in extremely small structures, for example in tubes a millionth of a metre across. Atoms flowing in such tubes could provide the basis for a new technology similar to electronics but based on the flow and interaction of neutral atoms rather than on electricity in wires. I will describe how atom "chips" are being realised and how they might be used to construct revolutionary devices such as a quantum computer, which will be able to solve problems previously considered impossible.

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ROTATING BOSE-EINSTEIN CONDENSATES AND QUANTUM VORTICES

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Coherence and superfluidity are hallmark properties of quantum fluids and encompass a whole class of fundamental phenomena. One striking consequence of superfluidity is the response of a quantum fluid to a rotating perturbation. In contrast to a normal fluid, the thermodynamically stable state of a superfluid involves no circulation, unless the frequency of the perturbation is larger than some critical frequency. In this talk I will describe recent experiments, showing how a quantized vortex can be obtained in a rubidium condensate by setting the trap confining the atoms into rotation above this critical frequency. I will show how a regular vortex lattice is generated for a notably larger rotation frequency, and I will discuss the vortex nucleation dynamics in these systems.

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Symposium 6

Computational Physics: Interdisciplinary Applications

Convener:
D. Stauffer, Universität zu Köln, Germany

PHYSICS IN MEDICAL IMAGING

R.E. Ansorge*
University of Cambridge

Advanced medical imaging techniques, such as Magnetic Resonance Imaging (MRI) and Positron Emission Tomography (PET), are leading to dramatic improvements in both medical research and clinical practice. These methods depend on instrumentation originally developed for physics research. For example, the initial work on PET scanners was done at CERN. There is considerable scope for collaborative research between physicists and medical researchers for further development of this instrumentation. This paper presents a brief review of PET and MRI and discusses some current research challenges. A particular feature of 3D medical imaging modalities is that they typically generate very large data sets, which present mathematical and computational challenges, for both image reconstruction and image analysis. Parallel computing methods have an important role to play in this analysis. Beowulf systems, consisting of clusters in inexpensive PCs, are an ideal tool for many such medical imaging problems. Effective visualisation of 3D medical data sets is another area where rapid progress can be expected.

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FRACTURE AND FRAGMENTATION OF DISORDERED SOLIDS

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The response of a heterogeneous solid, such as concrete or fiber reinforced composites, to an external load strongly depends on the way the load is applied. Under a constant or a quasistatically increasing load disordered materials display a non-linear macroscopic behavior followed by sudden microscopic movements due to the formation and propagation of microfractures, which can also result in a break-up of the specimen into two pieces.

When a disordered solid is subjected to a high stress for a very short time the solid breaks up into many smaller pieces in a dynamic way. Fragmentation, i.~e.\ the breaking of particulate materials into smaller pieces is a ubiquitous process that underlies many natural phenomena and industrial processes. The most striking observation about fragmentation is that the size distribution of fragments shows a power law behavior independent on the microscopic interactions and on the relevant length scales.

Most of the theoretical investigations in these fields rely on large scale computer simulations of lattice and fiber bundle models. We present recent developments on the computational modeling of fracture and fragmentation phenomena of disordered solids. We study the creep response of solids to a constant external load in the framework of fiber bundle models. It is shown that increasing the external load on the specimen a transition takes place from a partially failed state of infinite lifetime to a state where global failure occurs at a finite time. The creeping system evolves into a macroscopic stationary state accompanied by the emergence of a power law distribution of interevent times of the microscopic breakings indicating self organized criticallity in creep.

We develop a two-dimensional dynamical model of breakable disordered solids and elaborate the impact fracture and fragmentation of solids at low imparted energy. Simulating collisions of two solid discs we show that, depending on the imparted energy, the outcome of a collision process can be classified into two states: a damaged and a fragmented state with a sharp transition in between. We give numerical evidence that the transition point between the damaged and fragmented states behaves as a critical point.

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HOW TO CONVINCE OTHERS – SIMULATIONS OF SZNAJD MODELS

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The Sznajd model in less than a year has found several followers. An isolated person does not convince others; a group of people sharing the same opinions influences the neighbours much more easily. Thus on a square lattice, with variables +1 (Democrats) and –1 (Republicans) on every lattice site, a pair (or plaquette) of neighbours convinces its six (eight) nearest neighbours of its own opinion if and only if all members of the pair (plaquette) share the same opinion. The generalization to many possible states is used to explain the distribution of votes among candidates in Brazilian local elections.

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Symposium 7

High-Energy Accelerators and the Future of High-Energy Physics

Convener:

A. Wagner
DESY, Hamburg, Germany

THEORETICAL PERSPECTIVES OF PARTICLE PHYSICS

W. Buchmuller*
DESY, Hamburg, Germany

The symmetries of the standard model of particle physics point towards a unified theory of all particles and interactions. This leads to the quest for supersymmetry and to the prediction of baryon- and lepton-number nonconservation, with important implications for particle physics and cosmology.

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WHAT HAVE EXPERIMENTS TAUGHT US?

L. Rolandi*
CERN

Recent results from neutrino oscillation experiments and cp-violation experiments are discussed together with a summary of the main successes achieved in the last years at the large colliders: LEP, HERA and TEVATRON.

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THE SCIENTIFIC ROADMAP OF PARTICLE PHYSICS IN THE COMING 20 YEARS

B. Foster[*]
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The Large Hadron Collider, currently under construction at CERN, should be completed in 2007. It is likely to revolutionise our understanding of particle physics. There is an unprecedented world-wide consensus that the next major project in particle physics, which will complement and extend the research that can be done at the LHC, is the construction of a linear electron-positron collider with an energy of at least 400-500 GeV. My talk will explain why this is the case and put it in the context of other current or planned facilities. I will also discuss what other developments will be important in the longer-term future to ensure that progress in understanding the fundamental constituents of matter can continue.

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CHALLENGES FOR ACCELERATORS

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The major facilities implied by the present Roadmap for Particle Physics are outlined. They comprise an electron-positron linear collider, advanced neutrino beams and a very large hadron collider. The possible upgrade options for the Large Hadron Collider (LHC) under construction are also briefly reviewed. The outline emphasizes the most critical issues. The present global effort and the medium-term plan for accelerator R&D addressing these issues are presented

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PARTICLE PHYSICS WITHOUT ACCELERATORS

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The first elementary particles not present in normal matter were discovered in the 1930's using cosmic rays in a period before the development of accelerators. Following 60 years during which the majority of knowledge in particle physics came from accelerator based experiments, non-accelerator experiments have begun again to make major discoveries.

In this presentation the experimental developments in non-accelerator particle physics of the past decade will be described together with planned future projects. The subjects covered will range from searches for proton decay; measurements of neutrino mass differences with neutrino oscillations; searches for dark matter and high-energy astronomy with cosmic rays, gamma rays and neutrinos.

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CHALLENGES OF GOING GLOBAL NEW PARADIGMS FOR PARTICLE PHYSICS?

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Particle Physics, astrophysics and cosmology have advanced in parallel to produce what could be called a standard model of the Universe, but recent observations have raised very fundamental questions about the early stages of the Universe and its fundamental composition in terms of matter and energy. It is generally accepted that the next generation of accelerators and detectors required to probe physics 'beyond the Standard Model' will require a changed paradigm, from national or regional facilities exploited internationally to inherently global projects, fundamentally different in their basic organizational concepts. Global projects are not new to science, but building a major new facility which will be open to researchers on a global scale is a new undertaking which poses questions which can only be addressed at governmental level.

The OECD Global Science Forum (GSF) established the High Energy Physics (HEP) Consultative Group (CG) in June 2000 to exchange views on the future direction of HEP, particularly as regards large facilities, examine the rationale behind programme priorities and strategies, look at common or generic issues and approaches, and identify and discuss relevant organization and managerial issues. It reported to the GSF in June 2002.

The report states that "the Group was impressed by the range and depth of the studies carried out by the world-wide HEP communities in setting out the scientific and programme priorities over the next decade and beyond, and by the degree of unanimity between the communities in all regions" and that "the Group found the scientific arguments presented by the communities to be compelling. "

A wide range of organisational and managerial issues associated with the creation of a major new international facility were studied. These are all areas where work will be required of the proposers of such projects and the participating governments. Specific issues highlighted in the discussion included: legal structure, financial arrangements, managerial structure, reporting and accountability, host nation and host laboratory. A key issue that is already exercising the communities is the mechanism whereby international negotiations on the next steps towards a linear collider can be started. The Group looked at the ways in which community driven initiatives offering different technological approaches to common scientific objectives might be reconciled to converge on a global consensus and, ultimately, funding decisions.
The conclusions of the report will be described, as will proposed follow-up activities, and possible implications for other areas of science will be mentioned.

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Symposium 8

Nanostructures

Convener:

L. Pavesi
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PHOTOLUMINESCENCE AND ELECTROLUMINESCENCE PROPERTIES OF UNDOPED AND Er-DOPED Si NANOCRYSTALS

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[(b)]*INFM and Physics Department, University of Catania, Catania, Italy*
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In the last decade a strong effort has been devoted towards the achievement of efficient light emission from silicon. Among the different approaches rare-earth doping and quantum confinement in Si nanostructures have shown great potentialities. In the present work the synthesis and properties of silicon nanocrystals (nc) will be presented. Si nc embedded in SiO_2 are obtained by thermal annealing of SiO_x films prepared by plasma enhanced chemical vapor deposition. Si nc exhibit a strong room temperature photoluminescence (PL); the PL signal is characterized by a weak temperature dependence and by a clear blue shift with decreasing the crystal size. Time-resolved PL measurements have been used to study the excitation and deexcitation properties of Si nc. Moreover we will show that optical gain and stimulated emission can be achieved from Si nc.

The characteristics of Si nc embedded within Si/SiO_2 Fabry-Perot microcavities are also investigated. Very narrow (up to $\Delta\lambda \sim 1.5$ nm) and intense luminescence peaks can be obtained at different wavelengths by properly setting the cavity resonance. The luminescence intensity of the on-axis emission is over an order of magnitude above that of reference samples and the emission is confined within a 30° cone from the sample normal.

The electroluminescence (EL) properties of Si nc are investigated, by fabricating MOS devices where the dielectric layer contains Si nc. It is shown that an efficient carrier injection and an intense room temperature electroluminescence signal can be achieved at low voltage (about 5 V). The influence of the Si nc size on the electrical and optical properties of these devices is also reported. Moreover, time-resolved EL measurements have been used to study the excitation and deexcitation properties of Si nc in the devices.

Finally, the interaction mechanisms between Si nc embedded in SiO_2 and Er ions will be discussed. When Si nc are doped with Er they absorb energy which is then preferentially transferred to the rare earth. The nanocrystals act as efficient sensitizers for Er which is excited much more efficiently than in pure SiO_2. Indeed, room temperature luminescence yields two orders of magnitude higher are observed for Er-doped SiO_2 in presence of Si nc than in pure SiO_2. Moreover, since Er is embedded within a SiO_2 matrix, the non-radiative decay channels limiting Er luminescence in Si are absent, and the luminescence yield results almost temperature independent. Also the characteristics of Fabry-Perot microcavities based on Er-doped Si nc will be presented.

These data will be presented and the future trends and applications discussed.

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NANOTECHNOLOGY FOR LIFE SCIENCES

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Nanotechnology offers new possibilities for research in the wide field of life sciences. It is expected that it will significantly contribute to the understanding of biological processes at a molecular level and enable us to improve medical diagnosis and therapy. Nanotechnology has various facets and at least three of them are relevant for life sciences: Nanosized materials, nanoanalytical methods and nanostructured surfaces. In the talk three projects with strong nanotechnological aspects are presented. First, the potential and limitation of nanoparticles for in vivo diagnosis are discussed. It can be concluded that the microdistribution of nanoparticles within a tumour tissue is the limiting factor for the intended image contrast in magnetic resonance imaging and that this process is only partly related to the particle size. Second, the power of atomic force spectroscopy for quantitative measurements of the antigen-antibody recognition is demonstrated. In analytical biochemistry, nanotechnology has opened the door to investigate single molecules and in this way has contributed to a comprehensive understanding of molecular processes. Third, a method to generate sufficient large areas of nanostructured surfaces is presented. Such surfaces are required to study how nanometer-sized structures influence the attachment and behaviour of various cells. The different techniques used in the three mentioned examples are incommensurable, but they all are found under the umbrella nanotechnology. They have in common that at least in one dimension the nanometer scale is important to tackle scientific problems.

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NON-LINEAR EFFECTS IN DIFFUSION ON NANOSCALE

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The continuum description of diffusion falls if the diffusion distance becomes comparable with the atomic spacing. But this condition is valid only if the diffusion coefficient, D, is independent of concentration. If D has an exponential dependence on the concentration c ($\log D = \log D(0) + mc$), in a binary ideal system for $m > 3$ the diffusional non-linearities result in a shift of the above validity limit (for $m = 7$ this can be one order of magnitude). Thus in multilayers with modulation length of several nm the continuum approach can not be valid. Due to this non-linearity the originally abrupt interface remains sharp and shifts keeping its shape. This was shown in amorphous Si-Ge multilayers and also for dissolution of Ni into single crystalline (111) copper substrate. Furthermore it was obtained both from simulations and experiments that the interface shifts *linearly* with t (instead of the parabolic law). The results of the simulations by deterministic kinetic equations and by Monte Carlo method will also be compared, as well as the sharpening of the initially wide interface in ideal solutions will also be predicted.

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ULTRAFAST SPECTROSCOPY OF QUANTUM DOTS

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Present semiconductor technology provides artifical nanostructures based on colloidal semiconductor nanocrystals
or epitaxially grown self-organized islands.
We will give a survey about dephasing processes and ultrafast gain dynamics in both II-VI and III-V based semiconductor quantum dots. The experimemtal technigues
we use are femtosecond pump-probe and four-wave mixing spectroscopy in the infrared and visible spectral range. Applications of quantum dots in laser devices and
quantum optics will be discussed.

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Symposium 9

Quantum and Quantum-Optics Devices

Convener:

M. Ducloy
Université Paris Nord, Paris, France

Co-conveners:

G. Leuchs
Universität Erlangen-Nürnberg, Erlangen, Germany
J.-M. Raimond
Université Pierre et Marie Curie, Paris, France

QUANTUM COMPUTING AND NUCLEAR MAGNETIC RESONANCE

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Quantum information processing is the use of inherently quantum mechanical phenomena to perform information processing tasks that cannot be achieved using conventional classical information technologies. One famous example is quantum computing, which would permit calculations to be performed that are beyond the reach of any conceivable conventional computer. Initially it appeared that actually building a quantum computer would be extremely difficult, but in the last few years there has been an explosion of interest in the use of techniques adapted from conventional liquid state nuclear magnetic resonance (NMR) experiments to build small quantum computers. After a brief introduction to quantum computing I will review the current state of the art, describe some of the topics of current interest, and assess the long term contribution of NMR studies to the eventual implementation of practical quantum computers capable of solving real computational problems.

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ENTANGLING ATOMIC ENSEMBLES

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Two distant atomic ensembles of atoms at room temperature can be entangled by using laser light. In this talk I will review some of the methods to achieve this goal as well as some applications of the resulting entangled states. In particular, I will concentrate on the possibility of constructing quantum repeaters for quantum communication. Photonic channels appear to be very attractive for the physical implementation of quantum communication. However, due to losses and decoherence in the channel, the communication fidelity decreases exponentially with the channel length. I will describe a scheme that allows to implement robust quantum communication over long lossy channels using atomic ensembles.

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QUANTUM COMMUNICATION AT TELECOM WAVELENGTHS

N. Gisin*
Université de Geneve, Switzerland

Quantum communication at telecom wavelengths will be illustrated by the latest results on quantum cryptography (67 km), Bell tests (11 km) and quantum teleportation (2 km).

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OPTICAL CAVITY QUANTUM ELECTRODYNAMICS

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The radiation properties of atoms can be controlled by placing the atoms in an optical cavity. Most interesting is the regime of strong atom-cavity coupling, where (1) the finesse of the cavity is high, and (2) the volume of the cavity is small. In this case, an excited atom radiates mainly into the cavity, and the emitted photon is exchanged between the atom and the cavity many times. This allows one to perform experiments with single photons. Moreover, the intensity of a laser beam transmitted through the cavity depends on the presence of a single atom in the cavity. This makes possible to perform experiments with individual atoms. If (3) laser-cooled atoms are injected into a high-finesse small-volume cavity, it is possible to manipulate in real-time the motion of an atom by means of the light force established by just one photon in the cavity.

Conditions (1)-(3) could recently be met by combining techniques from laser physics with methods developed in atomic physics. In particular, single atoms from a dilute atomic gas cooled to micro-Kelvin temperatures could be injected into a micron-sized optical cavity with mirrors exhibiting losses of only a few parts per million. In this way, it is now possible to study with individual atoms the atomic motion in a quantized light field containing only a few photons on average [1,2], to trap a single atom in such a light field [3,4], to reconstruct the atom's trajectory [4,5], and to control the motion of the atom by means of opto-electronic feedback allowing one to extend the time the atom is stored inside the cavity [6]. Moreover, collective light forces govern the motion of an ensemble of atoms injected into the cavity [7]. Finally, an adiabatic passage technique was developed to generate on demand a bit stream of single-photon pulses from one-and-the-same atom [8,9]. The photon-generation scheme has two novel properties: First, no atomic excitation is required. Second, it is unitary and, hence, reversible. This opens up new perspectives for quantum information processing in a distributed network [10], with the atom-cavity system converting quantum information between stationary atoms and flying photons. Such a network combines modularity with scalability, two essential requirements of a future quantum computer.

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QUANTUM OPTICS WITH SINGLE NANO-OBJECTS

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A review several recent quantum optical experiments done with single quantum emitters will be present. I will first discuss the realizations of triggered single photon sources based on controlled single molecules fluorescence and then present the investigations of the intensity correlation function of single quantum dots which showed a strong photon antibunching

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OPERATION OF A SOLID-STATE QUANTUM BIT CIRCUIT

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We have designed, fabricated, and operated a superconducting electrical circuit implementing a quantum bit (qubit). Our circuit is based on the Cooper pair box, a device which combines charging and Josephson effects, and in which quantum coherence has already been demonstrated. Our circuit design however significatively improves over previous ones in that (i) it includes an efficient read-out system and (ii) the qubit can be decoupled from its measuring circuitry during preparation of a quantum state thus allowing for long coherence times.

We present experimental results demonstrating driven and free quantum coherent evolutions of the qubit. The experimental coherence time of superposed states corresponds to about 8000 oscillations at the transition frequency.

Our results open the way to integrated qubit circuits for quantum computing as several of these qubits can be coupled capacitively to build quantum gates and the long coherence time should allow implementing quantum error correction schemes in these gates.

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Symposium 10

Approaching the Dripline for Unstable Nuclei

Convener:

B. Jonson, Chalmers / GU, Göteborg, Sweden

EXOTIC NUCLEI AND RADIOACTIVE BEAMS AT LOW ENERGY

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Low-energy beams of exotic, radioactive nuclei are predominantly produced by the so-called ISOL method, where an intense driver beam impinges on thick targets and the wanted radioactive species are extracted, ionised and mass separated before delivered to the experimental set-up. In addition, post-acceleration of ISOL beams can provide for good quality beams of highest intensity ranging in energies from just above the Coulomb barrier towards more than 100 MeV/u.

The ISOLDE facility[1] at CERN is an ISOL facility that has been operational for 35 years, capable of delivering low-energy radioactive beams comprising more than 600 isotopes from ~70 elements. The experimental facilities are extensive and since late 2001 complemented by a post-accelerator for radioactive nuclei through the REX-ISOLDE project [2].

The low-energy beams allows for precision decay studies, laser spectroscopy and mass measurements of short-lived nuclei at, or approaching the neutron and proton drip-lines, and some recent examples from ISOLDE will be presented. With post-acceleration, low-energy reaction experiments can yield complementary information. Such experiments are underway using REX-ISOLDE.

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MULTI-PARTICLE EMISSION

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Modern segmented detectors for charged particles have significantly facilitated studies of multi-particle final states fed in low energy nuclear reactions or in beta-decay.

It is of particular interest to determine whether such processes proceed to the multi-particle final state by a single-stage instantaneous process or in a sequence of binary processes. Furthermore such studies can often yield spectroscopic information about nuclear states which is not accessible by other means.

Unbound nuclear states leading to multi-particle final states are fed in the beta-decays of several nuclei close to or at the drip-lines. For a small number of nuclei at the proton drip-line even the ground state might be unbound towards emission of two protons, which would exemplify the much searched for process of two-proton radioactivity. Experimental studies here are challenging due to the difficulty in producing these rare isotopes.

States in ^{12}C above 7.3 MeV are unbound towards breakup into final states of three -particles and therefore provide a more experimentally accessible research area for multi-particle breakup studies. Somewhat surprisingly open questions remain for the spectroscopic properties of states above the astrophysically important 0^+ state at 7.65 MeV. This region is of high interest not only for astrophysics, but also for models describing ^{12}C states as clusters of three -particles in either linear or triangular configurations. For the unnatural parity states conservation of parity forbids breakup sequentially via the narrow 0^+ ground state of ^{8}Be. This leaves only sequential decay via the broad 2^+ excited state or direct decay possible and in both cases strong correlations are predicted.

We have initiated a campaign to revisit the lowest unbound states in ^{12}C for such studies. First results from states fed in the beta-decay of ^{12}N will be discussed together with plans for future measurements.

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MASSES OF DRIPLINE NUCLEI

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Beside half-life and decay mode the mass is one of the gross properties of a nucleus. The mass, explored over large areas, helps the understanding of the nucleus considerably by revealing weaknesses in nuclear models, by uncovering nuclear fine structure effects as well as shell closures. At the dripline known or predicted mass differences help to find especially interesting decay modes as for instance the double proton decay.

Naturally, dripline nuclei have very short half-lives. This explains why direct mass determination techniques can only access a small fraction of these nuclei. However, accurate direct techniques as for instance Penning trap mass spectrometry together with reaction and decay energy measurements provide mass values for nuclei at the dripline and beyond. In some cases, as a result of recent improvements in Penning trap mass spectrometry especially at ISOLTRAP/CERN, it is even possible to measure with relative uncertainties as low as 10^{-7} in the direct vicinity of the dripline.

Examples for both approaches will be presented and range from the large area survey in the rare earth region to the near dripline measurements on neutron deficient argon, krypton and rubidium nuclei.

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EXOTIC NUCLEI AND RADIOACTIVE BEAMS AT HIGH ENERGY

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The study of reactions with high-energy secondary beams, which are produced in fragmentation processes of heavy ions and separated in-flight, allow the investigation of nuclear-structure properties of unstable short-lived nuclei far away from the beta-stability line. Phenomena not known for stable nuclei, e.g. the appearance of low-lying dipole excitation modes or the vanishing of shell closures, are observed. Experimental results from investigations of knockout reactions as well as kinematical complete measurements of inelastic electromagnetic scattering of light neutron-rich nuclei will be discussed.

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CLUSTERING IN NEUTRON-RICH NUCLEI

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Clustering in light alpha-conjugate nuclei is often a dominant structural mode where the clustering degree of freedom is liberated with increasing excitation energy until the point is reached at which the nucleus condenses into a collection of alpha-particles. The most exotic of these alpha-condensates are the predicted chain-states where the alpha-particles are linearly arranged. The experimental evidence for such structures is sparse, the α-α system (^{8}Be) is well documented, measurements of reduced widths and rotational behaviour of this nucleus verify the existence of the underlying cluster structure [1]. However, there is a lack of convincing evidence for the existence of chain-states in the 3α system. The 0^{+} (7.65 MeV) excited state is believed to be linked with an extended structure with an overlap with a bent chain structure, however the linear structure remains to be found [1]. It is possible that the lack of experimental evidence for such a structure reflects the instability against bending modes. Indeed calculations using the Molecular Orbit approach [2] predict the instability of 3α-chain. However, the same calculations indicate that the introduction of valence neutrons, particularly in the instance of ^{16}C, may stabilise these alpha-chains. The role of valence neutrons in such cluster systems is well documented in the beryllium isotopes where the neutrons occupy molecular orbits, covalent in nature [3]. For example, the α+n+α system (^{9}Be) is bound whereas ^{8}Be undergoes alpha-decay. It is possible that such a covalent bonding mechanism enhances the stability of other alpha-cluster structures.
The talk will present the latest developments in the study of molecular structures in beryllium and carbon isotopes, and examine the possibility that clustering is actually the dominant structural mode at the neutron drip-line, where neutrons exist in molecular type orbits, exchanged between the clusters.

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UNBOUND NUCLEI

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The study of exotic nuclei - far from the valley of β-stability - has become one of the main topics in modern nuclear structure physics.

Results of experimental investigations probing the single particle and cluster structure of light exotic nuclei are presented and consequences for nuclear models are drawn. Selected examples of experiments performed at GSI with relativistic secondary beams with energies between 0.2-1.5 GeV/nucleon are given, where cross sections, momentum distributions, angular and energy correlations after break-up reactions have been measured. Continuum spectroscopy provides a powerful tool to understand the intermediate, unbound systems in the exit channel as well as the ground state properties of the projectiles in the entrance channel of the break-up reactions.

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Symposium 11

Physics in Space

Convener:

J.P. Swings, Université de Liège, Belgium

Co-conveners:

M. Huber, ESA, Bern, Switzerland
J. Kuijpers, University of Nijmegen, The Netherlands

ASTEROSEISMOLOGY: FROM THE SUN TO STARS

C. Aerts*
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University of Leuven

In this overview talk we first of all introduce the relatively new research area termed asteroseismology and we present a basic introduction into the theory and observations of stellar oscillations. We set out the goals of asteroseismology, and the tools that have been developed to meet these goals.

Subsequently, we highlight the successes of seismic studies of the Sun (helioseismology) and of white dwarfs. Very recently, accurate seismic information has also become available for stars other than the Sun. We overview the current status of asteroseismic data and their analysis, and outline future projects in this area such as the development of asteroseismic space missions that will be launched in the near future. Finally, we highlight the impact the seismic studies of stars will have in other fields in astronomy.

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RECENT RESULTS FROM THE X-RAY SATELLITES CHANDRA AND XMM-NEWTON

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In this talk I review the results on Active Galactic Nuclei (AGN) research from the new generation of X-ray observatories *Chandra* and *XMM-Newton*. In particular, I discuss the progress on the Fe-K line diagnostics, new spectral features as well as new insights from high-resolution X-ray spectroscopy. In addition, I present the recent results on the cosmic X-ray background (XRB) from the Chandra and XMM-Newton Deep Surveys.

Previous Deep X-ray surveys have shown that the cosmic X-ray background, discovered by Riccardo Giacconi and colleagues in 1962, is largely due to the accretion onto supermassive black holes, integrated over the cosmic time. The *ROSAT* satellite has resolved about 70-80 % of the soft X-ray background into discrete sources, which are mainly X-ray and optically unobscured AGN (type-1, e.g., Quasars and Seyfert galaxies).

However, the charateristic hard spectrum of the XRB can be explained if most of the AGN are heavily absorbed (type-2). Deep surveys with *Chandra* and *XMM-Newton* in the Hubble Deep Field-North in the Chandra Deep Field-South and the Lockman Hole field have resolved most of the hard X-ray background into discrete sources.

The majority of these optically faint sources are intrinsically absorbed type-2 AGN, which are predicted by the population synthesis models for the X-ray background, based on the unified AGN schemes. Interestingly, a significant number of the long-sought class of high-luminosity, heavily obscured AGN (type-2 Quasars) at high redshift have been detected in deep Chandra and XMM-Newton fields.

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COSMIC MICROWAVE BACKGROUND MEASUREMENTS: STATUS AND FUTURE

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The anisotropies of the cosmic microwave background carry information about both the cosmological parameters and the early universe which cannot be obtained by other means in the near future. These observations constrain the early universe physics at energies not accessible by accelerators.

Due to fast progress in the detection techniques, the field of Cosmic Microwave Background anisotropies observations has been moving very fast in the last few years with ground based and balloon borne experiments. The observational situation and its cosmological implications will be described.

The satellite experiment Planck (to be launched in 2007) is the most ambitious project in this field. The European Space Agency leads this mission but the instruments are built by a large collaboration of Institutes in Europe and in the USA. The status and expected performances will be presented.

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Symposium 12

Physics for Development

Convener:

L. Wöste
Freie Universität, Berlin, Germany

PHYSICS FOR DEVELOPMENT (ROUND TABLE DISCUSSION)

Speakers:

Z.B. Lakhdar, Tunesia

J.L. Morán López, Mexico

A. Suzor-Weiner, France

L. Wöste, Germany

N. Hounkonnou, Benin

A. Baig, Pakistan

F. Piuzzi, France

E. Lillethun, Norway

B. Marticorena, Peru