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This celebratory 10th anniversary collection showcases, via a series of summaries written by the original authors themselves, a selection of just some of the article highlights published in NJP since 1998 from across physics. Identified by my colleagues on the Editorial Board, and NJP publishing staff on the basis of a range of criteria including referee endorsements, readership and citation levels, and simple broad appeal, the work compiled here provides a real flavour of the diversity, breadth and quality of NJP’s content so far.

On behalf of the whole journal I thank all of the authors featured inside for publishing with NJP, and for contributing to what I think is a very special anniversary compilation. I hope that you as readers enjoy it too!

Eberhard Bodenschatz
Editor-in-Chief
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Decoherence-free states for quantum computing

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Quantum information processing rests on our ability to manipulate the state of a quantum system in a controlled way. However, quantum systems do not exist independent of their environment. Uncontrollable interactions with the environment might lead to dissipation and the irreversible loss of information. An important step towards the practical realisation of quantum computing was therefore the identification of a large set of states, which do not couple to the environment. These became known as decoherence-free states.

In this paper we give a detailed description of the decoherence-free states of a system consisting of N atoms trapped inside an optical cavity. Moreover, we proposed how to manipulate these states very efficiently with the help of weak laser pulses. Normally, local interactions like these cannot create entanglement between atomic qubits. However, we could show that the presence of relatively large spontaneous decay rates renders the behaviour of the system dramatically. It suppresses the population of non decoherence-free states so that the laser driving transfers the system in general into an entangled state. This shows that one can actually use dissipation to perform quantum computational tasks.

Since the publication of our manuscript, many quantum computing schemes have been proposed in which dissipation and measurements are an integral part in generating and manipulating stable qubits. Our work mainly focuses on the design of simpler, more robust and scalable quantum computing architectures based on the use of environment-induced measurements, which are readily available.

Rotation of the universe, time travel and quantum gyroscopes

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In the last phase of his life the mathematician Kurt Gödel was the single close friend of Albert Einstein. He had shaken the world of mathematics with his incompleteness theorems. Stimulated by discussions with Einstein during their numerous walks, Gödel found in 1949 an exact cosmological solution of Einstein’s field equations of gravitation with closed world lines. Therefore, general relativity does not exclude time travel and one could in principle go back into one’s own past — a world without time.

The Gödel metric corresponds to a universe with a rotating matter distribution. In our paper we summarize various concepts of rotation starting from Newtonian mechanics and general relativity, and discuss experiments to measure the rotation of the universe using the Sagnac effect. Here the rotation manifests itself in a phase shift between two counter propagating light or matter waves. Unfortunately, the phase shift predicted by the Gödel metric is 10 orders smaller than the one due to the Lense Thirring effect which is at the limit of the state of today’s gyroscopes. The use of entangled photons or atoms might increase the accuracy of these devices. In this way our paper addresses this use of quantum mechanics to create rotation sensors to test general relativity.

Quantum cryptography: from basic physics to real world applications

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Quantum physics is well known for being counter-intuitive or even bizarre. Now, during the last decade it has been widely realized that it can also be useful for practical applications. Quantum cryptography, or more exactly quantum key distribution (QKD), is the first application of quantum physics at the individual quanta level. It takes advantage of the Heisenberg
uncertainty relations or, equivalently, of the no-cloning theorem to provide an absolutely secure communication scheme. In 2002 we demonstrated a turn-key QKD system on several long distance optical cables outside the laboratory with a real physical distance between Alice (the emitter) and Bob (the receiver). Some cables were terrestrial, some under Lake Geneva and some aerial. The latter was possibly the most significant, since the stability of qubits encoded in single photons is then especially critical. The system proved to be so robust and simple that it was used in the first commercial products.

Since 2002 many subsequent demonstrations of various QKD schemes have been reported, but only very few over long distances outside the lab with a real physical distance; and almost none in aerial cables. Today, almost every country has its QKD research lab and several working systems have been developed, both by large companies (mostly Japanese) and by small start-up companies.

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Entanglement on the move

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‘Dynamics and manipulation of entanglement in coupled harmonic systems with many degrees of freedom’ M B Plenio et al 2004 New Journal of Physics 6 36

Tap your clothes-line at one end and you will see that the perturbation is propagated along its length. Tap it in the middle and you will see perturbations travel in opposite directions. In the first case you have transmitted a signal, in the second case you have created correlations between different parts of your clothes line. Indeed, when you observe a perturbation a distance d to the left of the center then there will also be one the same distance d to the right of the center. In both cases the system, our clothes line, is, for small amplitudes, harmonic and one may replace it by a chain of harmonic oscillators coupled by springs. The featured work examines questions of this type, and much more, at the quantum mechanical level. You may of course propagate quantum states along the harmonic chain (this was discovered here independently of related work in spin systems) and by creating localized perturbations in a coupled chain of harmonic oscillators you can, for example, create quantum mechanical correlations, i.e. entanglement between distant parts in a chain. This is intuitive from the classical analogues, but you can do more. By changing global properties of the chain, e.g. the coupling strengths, you will again be able to generate dynamics leading to entanglement between different parts of the chain. This is interesting for various reasons. Firstly, the quantum information propagation and entanglement generation does not need much detailed experimental control and may thus be relatively easy to implement. The propagation may also be made perfect either by tuning the coupling strengths in the chain or other tricks [see M B Plenio and F Semião 2005 New J. Phys. 7 73]. Finally, studying the dynamics of quantum-many-body systems is interesting as it involves not just ground state properties but those of excited states as well [see M Hartmann, M Reuter and M B Plenio 2006 New J. Phys. 8 94]. The featured work has led to a whole range of follow-up activity by the authors as well as many colleagues in this area.
Cosmology and Gravitation

Gravity, geometry and the quantum

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‘Gravity and the quantum’ A Ashtekar 2005 New Journal of Physics 7 198

This article appeared in a focus issue celebrating the 100th anniversary of Einstein’s miraculous year and was therefore addressed to non-experts. It began with a historical account of how quantum gravity developed and then discussed a background independent, non-perturbative approach called loop quantum gravity (LQG). In LQG, not only is the space–time geometry dynamical as in general relativity but it is quantum mechanical. Its fundamental excitations are one-dimensional, rather like polymers. Basic geometrical quantities such as areas of surfaces and volumes of regions are represented by non-commuting operators with discrete eigenvalues. The familiar Riemannian geometry of general relativity emerges only in a semi-classical, coarse-grained approximation. In ordinary situations effects of quantum geometry are completely negligible. However, in extreme conditions, such as those near black holes and the big-bang, these effects dominate and can then resolve seemingly unsurmountable difficulties, making fundamental physics coherent. For example, the quanta of geometry that make up a black hole horizon are sufficiently numerous to account for its huge entropy. Secondly, if the space–time curvature approaches the Planck scale, a new repulsive force emerges, rises sharply and overwhelms the familiar gravitational attraction. In the last couple of years, several cosmological models were studied in detail where this force resolves the big-bang singularity. The resulting quantum space–times are much larger than what Einstein had us believe. This opens up new paradigms in cosmology and black hole physics which are being investigated vigorously.

Spacetime in string theory

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‘Spacetime in string theory’ G T Horowitz 2005 New Journal of Physics 7 201

Strings interact by splitting and joining.

Our view of space and time changed dramatically with Einstein's general theory of relativity. It is expected that a quantum theory of gravity — such as string theory — will result in another dramatic change. This article summarizes the current status of spacetime in string theory. Since the theory is not yet fully developed, the final picture is not yet clear. However, we already know that the properties of space and time in string theory are radically different from general relativity. Not only does string theory predict extra spatial dimensions, two spacetimes which are physically different in general relativity can be completely equivalent in string theory. In some cases, space and time emerge ‘holographically’ from a more fundamental dual theory.

One consequence of this new view of space and time is the following. General relativity predicts that the topology of space (the way that it is connected) cannot change in a smooth way. If you try to construct a solution in which the topology changes, you encounter singularities — regions of infinite gravitational field or infinite spacetime curvature. This is not the case in string theory. Several examples are now known in which the topology of space changes smoothly without producing singularities. General relativity also predicts that gravitational collapse will result in a singularity where time ends. Cosmological models of expanding universes like our own, also must begin with a singularity (the big bang) where time begins. Whether this is also true in string theory is one of the main open questions in the field. It is currently a topic of active research.

Modified-source gravity suggests an alternative to dark energy

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‘Modified-source gravity and cosmological structure formation’ S M Carroll et al 2006 New Journal of Physics 8 232

The universe is accelerating, but we’re not sure why. The favored explanation is dark energy — a smooth, persistent form of energy density pervading every point in space. However, acceleration occurs over a huge length scale (the present Hubble radius, about ten billion light years), while experimental tests of General Relativity (GR) probe much smaller length scales. Thus, a reasonable question is whether cosmic acceleration might be a sign that gravity is deviating from GR on large scales.

Modifications of GR typically run afoul of experimental constraints because they introduce new degrees of freedom. The evolution of a homogeneous and isotropic universe, however, is described by the Friedmann equation — a part of Einstein’s equation in GR that is a constraint, rather than a dynamical equation of motion. We are therefore free to imagine modifying...
A dark future for dark energy?

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2 Department of Astronomy and Astrophysics, University of Chicago, IL, USA

The discovery of the acceleration of the Universe, using observations of distant supernovae established the existence of ‘dark energy’ associated with otherwise empty space as the dominant form of energy in the universe, and was one of the most exciting discoveries in cosmology in recent times. It has completely changed our picture of the current universe, and its future. The nature and origin of dark energy, however, remains a mystery. A key question thus becomes: how can we further cosmological observations address these deep mysteries? Our paper was an attempt to explore how observational uncertainties may combine with theoretical uncertainties to ultimately limit what we may be able to observationally infer in the near future about the nature of dark energy. In particular, the major theoretical question of interest is whether the dark energy is due to a cosmological constant, or some other form of exotic energy. The only way to distinguish this would be to look for time evolution in the dark energy density. However, without a good model for what this time evolution is, a comparison of theoretical expectations and observations becomes difficult. By examining what might be possible in future supernova surveys, we demonstrate that without significant improvements in our ability to measure the cosmic distance scale as a function of redshift we are unlikely to observationally resolve whether or not the dark energy is due to a cosmological constant.

From a cosmological constant using a future large scale supernova survey, here in the quantity sigma represents the luminosity magnitude uncertainty per supernova in such a survey and the value chosen reflects one such survey’s target value. Note that the present best fit for w is -1.2 < w < 0.8, and that allowing for a changing value of the equation of state means that the current uncertainty in w will not be greatly reduced by such a survey.

HIGH ENERGY PARTICLE PHYSICS

Watching for neutrinos with the SuperNova Early Warning System

K Scholberg (on behalf of the SNEWS international network)

Department of Physics, Duke University, NC, USA

Current SNEWS participants are the Super-Kamiokande experiment in Japan, the Large Volume Detector in Italy, the Super-Kamiokande Observatory in Canada (until 2006), the Large Volume Detector in Italy, the Super-Kamiokande detector in Japan, and the AMANDA/IceCube detectors at the South Pole. The Sudbury Neutrino Observatory participated until it completed operation in November 2006.
Neutrino physics has undergone a revolution in the last ten years or so. Experiments observing neutrinos produced inside the Sun, in the Earth’s atmosphere, in nuclear power plants, and in particle accelerators have finally established a phenomenon called neutrino oscillations, a quantum effect which occurs when neutrinos have mass. In the Standard Model of elementary particles neutrinos are massless. Hence, the discovery of neutrino oscillations has far-reaching consequences, since it is the first evidence for physics beyond the Standard Model and requires an extension of the model. Neutrino oscillations also have astrophysical implications since neutrinos provide an important probe of the interior of stars and the early Universe.

Our work describes the present status of neutrino oscillations through a global fit to world data. A concise determination of the parameters governing neutrino oscillations is obtained by the interplay of complementary information from various experiments. Neutrino mass splittings are determined by experiments where neutrinos are produced in nuclear reactors or particle accelerators, and observed in detectors located several hundreds of kilometres away from the neutrino source. In contrast, the mixing angles relevant for the leading oscillations are determined best by observations of natural neutrino sources like the Sun or the Earth’s atmosphere. We also explore in detail the bound on the last unknown mixing angle, which emerges from an interplay of global neutrino data. This mixing angle governs CP violation in neutrino oscillations to be probed in the next generation of experiments. Our work also scrutinizes the robustness of the oscillation interpretation of current neutrino data with respect to the possible existence of sterile neutrinos, solar magnetic fields, and non-standard neutrino interactions.

In amazingly prescient articles, Ken Greisen in the US and Vadim Zatsepin and Georgiy Kuzmin in the USSR predicted in 1966 that the cosmic-ray spectrum must end above energies of $10^{20}$ eV due to photohadronic loss interactions of the highest energy cosmic rays with photons of the cosmic microwave background. Only in the last year has this prediction been confirmed by the HiRes and Auger Observatories, meaning that ultra-high energy cosmic rays (UHECRs) originate from astrophysical sources. UHECRs detected with energies exceeding $10^{20}$ eV must originate within the Greisen–Zatsepin–Kuzmin (GZK) radius of order 100 Mpc.

This article examines gamma-ray bursts (GRBs) as the sources of UHECRs, an idea which has generated great interest since it was proposed in 1995. GRBs are the most luminous radiation sources of radiation in the universe during the brief time that they burst, are sources of energetic γ radiation, and are thought to be triggered by stellar core collapse to a black hole, and can occur within the GZK radius.

To test the hypothetical GRB origin of UHECRs, clues in the form of neutrinos, soon detectable with km-scale experiments such as IceCube, cascade γ rays observable with γ-ray telescopes, and fits to the UHECR spectrum, are reviewed. This article poses the main predictions that will soon be tested with the Gamma ray Large Area Space Telescope GLAST, scheduled for launch in 2008, IceCube, which reaches its design sensitivity early in the next decade, and the Auger Observatory in Argentina, already reporting major discoveries.
Neutrinos sent from CERN to the OPERA detector at the Gran Sasso Laboratory

A Ereditato (on behalf of the OPERA Collaboration)
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‘First events from the CNGS neutrino beam detected in the OPERA experiment’
R Acquafreda et al 2006 New Journal of Physics 8 303

Neutrino physics is a special research field, where one has to combine large mass detector targets, as required for the detection of these elusive particles, with the ambitious goal of performing precision measurements, as needed to obtain firm experimental conclusions. The CNGS project fulfills these conflicting requirements by featuring a νμ beam produced at CERN that, after a journey of 730 km and about 2.5 ms, reaches the large-mass and high-precision OPERA detector installed in one underground hall of the Gran Sasso Laboratory.

The experiment aims at the direct observation of νμ appearance from ντ→νμ oscillations, a process of great importance for particle physics. The observation of the interaction of νμ’s with the OPERA detector will clearly confirm the oscillation hypothesis for the first time in the so-called ‘appearance mode’, whereas disappearance of ‘oscillating’ neutrinos has already been observed by previous experiments. OPERA consists of a 1.3 kton neutrino target made of lead/graphicphotofilm sandwiches, and of electronic detectors. Photographic films provide a ‘microscopic’ image of the neutrino interaction point in order to identify the appearance of νμ over the most probable ντ events.

On 18 August 2006, the official start of the CNGS run produced the first νμ bunches to be observed by OPERA. At the end of this first short run OPERA observed 319 events, in good agreement with expectations. This paper reports on that first observation, to be followed by more events gathered in the 2008 run. The experiment will last a few more years with the goal of collecting of the order of 10-20 ‘unambiguous’ νμ interactions (and about 3000 ντ events).

A magnetic butterfly made of ultracold atoms

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‘Creation of effective magnetic fields in optical lattices: the Hofstadter butterfly for cold neutral atoms’ D Jaksch et al 2003 New Journal of Physics 5 56

Condensed matter systems in magnetic fields have been the subject of intense research over the past few decades. Several unexpected effects were discovered in the course of these studies like fractional quantum Hall effects which clearly indicated strong quantum correlations. For charged particles moving on a lattice in very large magnetic fields Hofstaedter predicted fractal energy spectra reminiscent of a butterfly (see figure (a)). This magnetic butterfly has so far escaped direct observation due to the high magnetic fields required.

This work proposed the creation of huge artificial magnetic fields for neutral ultracold atoms moving on a two dimensional optical lattice by irradiating them with lasers. The lasers drive atom hopping between lattice sites simultaneously imprinting a phase on their wave function. By judiciously choosing the laser setup these phases mimic a magnetic field (see figure (b)) and break time reversal symmetry normally associated with conservative optical lattice potentials. The number of flux quanta α penetrating each lattice plaquette can easily be varied between 0 < α < 1. A value α of order one corresponds to unattainably large magnetic fields in customary condensed matter systems and enables Hofstaedter’s butterfly to be studied with ultracold atoms.

This proposal has stimulated numerous studies on properties of ultracold atomic lattice gases in magnetic fields investigating e.g. the influence of two particle interactions and extensions to non-abelian gauge potentials. In contrast to rotating a lattice for simulating a magnetic field it does not suffer from the requirement to balance centrifugal terms by trapping potentials which proves experimentally difficult. The method provides another invaluable tool for engineering ultracold atom systems.

“New Journal of Physics has been able to offer incredibly fast publication for my papers, while keeping a very high standard for peer-review. This is a real asset of the journal.”

Stefan W Hell, Max Planck Institute for Biophysical Chemistry, Goettingen, Germany
In this work we described the experimental observation of different regimes in an array of Josephson junctions realized with Bose–Einstein condensates trapped in a one dimensional optical lattice. The transition occurs between a superfluid and an insulator regime and is accompanied by a loss of coherence through the array even though each condensate in the array is still described by a coherent state. The experimental findings have been compared with the prediction of a 1D theoretical model based on a discrete nonlinear Schrödinger equation (DNLSE). This model is found to qualitatively describe the different stable regions but fails to quantitatively describe the system close to the transition where a full 3D simulation of the Gross–Pitaevskii equation is needed.

The paper follows in a series of theoretical and experimental works that successfully established the parallel between the dynamics of Bose–Einstein condensates in 1D optical lattices and the widely used DNLSE. Such an equation is common to a large class of discrete non-linear systems, including polarons, optical fibers, waveguides, and biological molecules, and the established parallel helped in opening a new interdisciplinary route.

In the last five years many other Hamiltonians common to many physical systems have been reproduced using quantum degenerate gases in optical potentials thus rediscovering Feynman’s ideas suggesting that an ideal system with a ‘quantum logic’ can be used to study open problems in quantum physics. The upsurge of interest of the scientific community has been remarkable, and some perspectives disclosed by trapped-atom labs’ have been already explored: the observation of the superfluid–Mott insulator quantum phase transition and the analysis of the Tonks–Girardeau regime in strongly interacting bosons were relevant achievements for condensed matter physicists.

In the trap + optical lattice. A dipole oscillation is excited by a sudden displacement Δz of the magnetic trap along the lattice axis (horizontal in figure) below (left column) and above (right column) the critical displacement. While the images in the left column show a nice oscillation, for the images on the right the center-of-mass dynamics is blocked and the density distribution shows the appearance of more complex structures.

Absorption images of the expanded condensate after different evolution times in the harmonic trap + optical lattice. A dipole oscillation is excited by a sudden displacement Δz of the magnetic trap along the lattice axis (horizontal in figure) below (left column) and above (right column) the critical displacement. While the images in the left column show a nice oscillation, for the images on the right the center-of-mass dynamics is blocked and the density distribution shows the appearance of more complex structures.

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Magnetic traps are one commonly used way. Combined with new cooling techniques, they lead to the achievement of Bose–Einstein condensation in 1995. At that time, the magnetic trap was no more than a bottle with immaterial walls. It took another four years until our group and others had developed a miniaturized version that now gives us not only more precise control over the atoms, but also completely new ways of manipulation. For example (and that is what this article is about) cold atoms and Bose–Einstein condensates can now be transported over millimetre distances, can be split into two and even recombined — all without destroying the delicate ensembles of atoms. To achieve this goal, our group introduced what is now known as ‘atom chips’ or ‘chip traps’. The idea is to generate the magnetic fields not with macroscopic coils located far away from the atom cloud, but with microscopic, lithographically fabricated, current-carrying wires on a substrate. This resembles a micro-electronic chip, hence the name. Atom chips have since been used to study atom–surface interactions in a new regime, to realize atom interferometers and, most recently, to observe cavity quantum electrodynamics effects with BECs.

This paper reported the experimental demonstration of a new method to produce cold and trapped atoms which should be widely applicable to most of the periodic table. While the standard method to control atomic motion has been laser cooling, this approach only works for a small set of atoms in the periodic table that have a closed two-level transition that is accessible with a tunable laser. The starting point for the current work is the supersonic beam of noble-gas atoms, a source that provides a high flux of atoms that is very cold in the co-moving frame but also very fast. These atoms are emitted in bunches as a valve is opened for a short time. Other atoms or molecules can be introduced into the flow by seeding or entrainment near the output of the nozzle. A series of magnetic field coils is timed with the firing of the valve, and slows the atoms by making them climb a magnetic hill and then removing the hill before they have time to roll off. The group will apply these methods to trapping of atomic hydrogen isotopes for precision spectroscopy, and tests of the fundamental physics of the beta decay of tritium.

Interference patterns made with white light are coloured, because the conditions for phase matching for different wavelengths are satisfied at different places in the field. This has been known for centuries, but it was surprising to discover that the colours are most intense where interference is destructive, and that the pattern of colours in an image is universal if the points of perfect destructive interference for each of the contributing wavelengths are well separated. The pattern (see figure) consists of red, orange and blue rings — no green — in a characteristic arrangement with a precise mathematical description. It seems paradoxical that the universal colours are concealed in the darkest parts of the pattern. But they can be dramatically revealed by the ‘chromoscope’ — an image-processing algorithm computer to intensify the dark parts of images while preserving the colours. Universality means that the colours occur in many situations, for example random waves and near caustics, and can be generated by appropriately created diffraction gratings. The colours predicted theoretically were soon observed (see J Leach and M J Padgett 2003 Observation of chromatic effects near a white-light vortex New J. Phys. 5 154).

Optics and Imaging

Colours of darkness

M V Berry
H H Wills Physics Laboratory, University of Bristol, UK

‘Exploring the colours of dark light’ M V Berry 2002 New Journal of Physics 4 74
‘Coloured phase singularities’ M V Berry 2002 New Journal of Physics 4 66

Universal colours and light intensity of white light near an isolated interference zero.

“I have been very impressed with New Journal of Physics, and have published several papers there. The editorial process, referee system, and post-publication handling have all been excellent. This is clearly an up-and-coming journal that is getting more prestigious.”

Mark G Raizen, University of Texas at Austin, USA
Abbe’s discovery of the diffraction barrier about 130 years ago has lead to the notion that a light microscope cannot resolve spatial structures that are closer than about half of the wavelength of light. Near-field optical microscopy overcomes this limit by scanning with a subdiffraction sized tip, but this technique is difficult to operate and is limited to imaging surfaces. Stimulated emission depletion (STED) microscopy is the first far-field fluorescence microscopy modality which, although still relying on regular lenses and visible light, radically overcomes the limiting role of diffraction. In fact, the resolution \( \Delta r \) of a STED microscope follows a new law given by:

\[
\Delta r \approx \frac{\lambda}{2n \sin \alpha \sqrt{1 + \zeta}}
\]

where \( \lambda \) and \( n \sin \alpha \) are the wavelength of light and the numerical aperture of the lens, respectively. The equation differs from Abbe’s resolution law by the square-root term in the denominator, where \( \zeta \gg 1 \) defines the magnitude of STED. Evidently, letting \( \zeta \to \infty \) implies that the resolution can be improved down to the molecular scale.

The emerging power of STED-microscopy is exemplified by revealing the spatial order of densely packed biological and non-biological nanopatterns. Unlike confocal microscopy, which is the best-resolving standard used in the far-field, STED microscopy resolves fluorescent nanoparticles that are of 40 nm diameter (\( \lambda / 15 \)) as well as nanosized aggregates of a neuronal protein in a cell membrane. Similarly, images of colloidal nanoparticles demonstrate the potential of STED-microscopy for colloidal physics. Finally, STED microscopy records images of protein distributions in a cell with regular lenses and visible light that feature a resolution that is about twice the size of an antibody (20 nm).

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**QUANTUM OPTICS AND LASERS**

### Generation of photon number states

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*Generation of photon number states* E Waks et al 2006 New Journal of Physics 8 4

Photon number states play an important role in quantum optics. These states exhibit effects such as photon anti-bunching and negativity of the Wigner function that contradict classical electromagnetic theory. They also have important applications in the areas of optical telecommunication, quantum information processing, and interferometry. In this work, we prepared photon number states containing up to four photons using a unique photon counter called the visible light photon counter (VLPC). Unlike conventional photon counters that cannot distinguish between one and more than one simultaneous photons, the VLPC puts out a voltage pulse whose height is proportional to the number of detected photons.

In order to generate number states, we used the number counting capability of the VLPC in conjunction the non-linear optical process of parametric down-conversion. Parametric down-conversion creates a twin pair of number correlated beams. By measuring the correct number of photons in one arm of the twin beams, we prepared the other arm in the appropriate number state. These number states were verified by detection with a second VLPC. This work could open up the door to a broad range of new experiments in quantum optics and quantum information processing.

**New prospects for attoscience**

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*Route to intense single attosecond pulses* G D Tsakiris et al 2006 New Journal of Physics 8 19

A reflected pulse, rich in harmonic content results by focusing a few-cycle pulse of red laser light (half oscillation period: 1.25 femtosecond = 1250 attoseconds) into a solid target. Appropriate filtering gives rise to a single attosecond pulse.

Recent innovations in laser technology have paved the road to the generation of flashes of light that can freeze the ultrafast motion of electrons inside atoms and molecules initiating thus the era of attoscience. These ultra-short pulses enable us to see the miniscule, or freeze in time the fleeting dynamical processes of the microcosm. Unfortunately, the low flux of the current attosecond sources limits the scope of applications of attosecond technology to a small fraction of what would potentially be feasible for advancing a wide range of fields in science and technology. Making the most of the full potential of attosecond technology, calls for attosecond pulses being intense enough to be simultaneously used as a ‘starter gun’ for triggering microscopic motion and as a ‘hyperfast-shutter camera’ for probing the unfolding processes. To this end, one needs to seek a new attosecond source exhibiting much higher efficiency. Our article investigated the possibility of exploiting the relativistic interaction of an intense laser pulse with an overdense plasma towards this objective and concluded that it constitutes a promising approach. Realization of a source based on this process using laser systems envisioned for the near future will spark a revolution in exploring the microcosm, by permitting — for the very first time — imaging of the position of both basic ingredients of matter — nuclei and electrons — with sub-atomic resolution simultaneously in space and time. This technical capability will have far-reaching impact, from physics and chemistry through biology and medicine to future information technologies.

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“One key to New Journal of Physics’ considerable success and editorial quality is its highly engaged Editorial Board of professional scientists. Each offers significant expertise and, taken collectively, ensures coverage across the widest possible range of physics research.”

William P Halperin, Regional Editor for North America
Improved fidelity of triggered entangled photons from single quantum dots

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‘Improved fidelity of triggered entangled photons from single quantum dots’
R J Young et al 2006 New Journal of Physics 8 29

Entangled photon pairs have interconnected properties, such that measuring one photon changes the other. This unusual property makes entangled light a key resource for new applications in quantum information.

One example is the quantum repeater, which could extend the distance that quantum communication can operate over. At present the most widely used techniques for generating entangled photons are nonlinear optical processes that produce a probabilistic number of pairs per excitation cycle. The scaling of quantum information applications requires a source for which single entangled pairs are generated in a regular stream. We have produced a semiconductor device which acts as a triggered source of entangled photons. It is based upon a two-photon cascade in a single quantum dot. Prior to this work experiments indicated that an energetic splitting of the intermediate exciton state in the cascade provided ‘which-path’ information destroying the entanglement. By controlling the growth conditions for the dot, we have removed the exciton splitting and thus now generate entangled photon pairs. The fidelity of the total source emission (without background subtraction) to the ideal entangled state is ~70%, nine standard deviations in excess of the classical limit, proving that the source generates entangled pairs. Thus the ideal entangled state is achieved in the coherent quantum opticians have powerful capabilities that confirm the increasingly complex procedures, confirming the increasingly powerful capabilities that quantum opticians have achieved in the coherent control of the quantum states of light and matter, and their interface.

A first step towards entanglement connection of matter systems

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‘Towards experimental entanglement connection with atomic ensembles in the single excitation regime’
J Laurat et al 2007 New Journal of Physics 9 207

Entanglement, one of the most striking features of quantum mechanics, leads to strong correlations between the various components of a system, regardless of the distance separating them. Entanglement distribution enables quantum protocols, such as quantum cryptography, where the security is guaranteed by the laws of physics, or quantum teleportation, where a quantum state is faithfully transferred from one place to another. One property of entanglement is also that it can be swapped from one pair of systems to another. The creation of entanglement for two pairs of physical systems and the subsequent joint measurement of one system from each pair (called Bell measurement) projects the remaining systems into an entangled state. Beyond its fundamental interest, entanglement connection is also a key element in quantum information science, where it is crucial for quantum repeaters, which would extend the range of quantum communication to long distances.

The reported experiment demonstrates an essential step towards entanglement connection of matter systems, namely the transfer of quantum coherence between two atomic systems that have never interacted. It involves two pairs of atomic ensembles separated by 3 metres. The ensembles are clouds of cold cesium atoms. With real-time control of the quantum states, entanglement is generated on each pair, and stored in the atoms. Next, a Bell measurement is performed between two ensembles belonging to different pairs to project them into an entangled state. Finally, the transfer of coherence is verified by way of an interference measurement.

A successful entanglement transfer still requires large improvements of current setups. Multiplexing of atomic ensembles, photon-number resolving detection, and improved memory time are directions currently explored. Beyond quantum communication, this experiment incorporates many complex procedures, confirming the increasingly powerful capabilities that quantum opticians have achieved in the coherent control of the quantum states of light and matter, and their interface.

“The progress New Journal of Physics has made over the last ten years is exciting to see and provides a real indication that the editorial activity we carry out towards expanding our authorship and readership is working.”

Tim Smith, Publisher, New Journal of Physics
The upper atmosphere of Jupiter — a region known as the thermosphere — contains hydrogen gas. Some of this gas is ionized as it absorbs energy from sunlight — this forms the ionosphere. The auroral rings or ovals surrounding Jupiter’s magnetic poles receive a continual ‘rain’ of energetic charged particles which heats and ionizes the hydrogen, causing beautiful displays of light similar to the Earth’s northern and southern lights. But is this auroral heating able to explain the high (up to 1000 K) temperatures of the thermosphere of Jupiter? (Sunlight alone cannot heat Jupiter’s atmosphere to these levels.) We attempted to answer this question by using a computer model of Jupiter’s thermosphere and ionosphere regions. The results were surprising — instead of a constant outflow of energy from the auroral regions to the rest of the planet, it was found that the wind systems on Jupiter tend to be controlled by the planet’s rapid rotation (period 10 hours) and giant size (10 Earth radii = 1 Jupiter radius). Hydrogen flowing into the auroral ovals is slowed down in its rotation by the ‘auroral rain’. The resulting balance between centrifugal force (very strong at Jupiter), gravity and pressure forces then acts to accelerate this hot gas towards the poles, confining it to high latitudes. At higher altitudes, the flow of gas looks very different but cannot carry the enormous heat energy required.

Thus, the search for the mysterious ‘extra heat’ continues, but we have learned much about the influence of giant planets’ aurorae on their wind systems, and how this compares with the situation for the Earth.

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**Experimental on plasma turbulence**

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‘Large-scale fluctuation structures in plasma turbulence’ O Gruilke et al 2002
New Journal of Physics 4 67

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Global model profiles of ionization and velocity in the co-rotating frame for the northern polar region. **Left panel:** Colour contours of H$_3^+$ density over a 0.1 µbar pressure surface (location of the auroral ion peak). Arrow heads indicate the direction of horizontal ion velocity, and arrow lengths represent speed, according to the mixed linear/log velocity scale bar shown. Bold meridian (vertically downward in plot) is zero of longitude (contains subsolar point).

**Right panel:** As for the left panel, with arrows now representing the neutral horizontal wind velocity. The spherical coordinate grid in the plots has a spacing of 5° in latitude and 10° in longitude.

Turbulence in plasmas can be observed in both laboratory experiments and in nuclear fusion devices. The latter are based on magnetic confinement of a hot plasma in toroidal, sheared magnetic field geometries. Turbulent transport leads to significant losses of particles and energy.

Of key importance to the understanding of turbulence is the transition from linear to non-linear plasma dynamics. In dedicated laboratory experiments it could be demonstrated that such a transition is characterized by a sequence of different dynamical states, as evident in reconstructed dynamical phase space diagrams. Such a transition route is known as the Ruelle–Takens–Newhouse scenario, which was previously observed in ordinary fluids. In the fully developed turbulent state, plasma fluctuations are dominated by large-scale spatio-temporal structures with a finite lifetime. They are identified as propagating vortices with a rotating velocity field.

The investigation of the vortex dynamics is done by high-resolution measurements in space and time. The statistical reconstruction of the spatio-temporal vortex dynamics reveals that in linear and curved magnetic field geometry, the life time of the turbulent vortices is longer than their typical rotation time, which characterizes them as so-called coherent structures. In sheared toroidal magnetic field geometry, vortices seem to have a much smaller life time. Generally speaking, the propagation of vortex structures is dominated by the mean background plasma rotation, which is determined by the self-consistent electric field.

These findings imply that turbulent plasma transport is caused by vortex rotation that passively convects plasma density in the radial direction, thereby contributing strongly to the intermittent character of cross-field transport.
Cold plasma: a practical decontamination/sterilization technology

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‘Plasma interaction with microbes’ M Laroussi et al 2003 New Journal of Physics 5 41

Non-equilibrium low temperature plasmas, such as the one shown in the photograph, have recently attracted a lot of interest because of their relatively simple and practical designs and the range of applications for which they can be used. Amongst the novel applications, their use in the biomedical field is of particular focus. Ongoing multidisciplinary works on wound healing, the surface modification of biocompatible materials, and the sterilization of reusable heat-sensitive medical instruments are showing promising results. This paper shows a clear correlation between the theoretically predicted electrostatic tension caused by charging effects of bacterial cells submerged in a plasma and experimental observation of morphological changes of these cells. Scanning electron microscopy shows that cells exhibiting ‘rough’ surface texture (such as some gram-negative bacteria) experience loss of integrity of their cell wall/membrane after exposure to a plasma. This is attributed to an outward electrostatic stress that overcomes the tensile strength of the outer membrane and causes its rupture. Subsequently, the cell loses its cytoplasm, ultimately leading to its demise. Therefore it is concluded that charging effects can be one of the mechanisms whereby nonthermal plasmas inactivate bacteria.

Photograph of a nonthermal atmospheric pressure plasma used to destroy bacteria (photo courtesy of M Laroussi, Old Dominion University, Norfolk, VA, USA).

For the last ten years, New Journal of Physics has been dedicated to serving the whole physics community by publishing free-to-read, cutting-edge research of the highest quality.”

Eberhard Bodenschatz, Editor-in-Chief
**Broken parity superconductors take a spin**

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‘Spin susceptibility in superconductors without inversion symmetry’ P A Frigeri et al 2004 New Journal of Physics 6 115

Inversion symmetry, coupled with Pauli’s exclusion principle, plays a central role in determining how electrons pair when they become superconducting. Even parity is linked with spin singlet and odd parity with spin triplet pairing. What happens when inversion symmetry is removed? Cooper pairs become a mixture of spin-singlet and spin-triplet. Can this be seen experimentally? This is the question that is addressed in this paper and the answer is yes: it requires a measurement of the spin response to a magnetic field. Such a spin susceptibility measurement depends crucially on a single electron spin-orbit coupling characteristic to systems without inversion symmetry. In such non-centrosymmetric superconductors (NSC) the spin-susceptibility becomes essentially universal, behaving qualitatively the same for all types of superconducting interactions. While this behavior is masked by antiferromagnetism in the NSC CePt$_3$Si, recent experiments on CeRhSi$_3$ and CeIrSi$_3$ are completely compatible with this prediction.

**Exotic properties of hard materials caused by soft electrons**

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‘Open questions in CMR manganites, relevance of clustered states and analogies with other compounds including the cuprates’ E Dagotto 2005 New Journal of Physics 7 67

The properties of several metallic materials can be accurately described using a so-called one electron approximation, where the Coulombic forces between electrons are neglected. However, there are many other compounds where this assumption is not valid and new paradigms are needed for their theoretical understanding. The study of these materials led to the current vast interest in the area of research called ‘strongly correlated electrons’ (SCE) [see E Dagotto 2005 Science 309 257 and references therein]. These compounds have rich phase diagrams, with several competing states that can have drastically different properties (metals, Mott insulators, superconductors, ferro- and antiferro-magnets, heavy fermions, multiferroics, etc). The close proximity in the phase diagrams of these states suggests that their energies are similar. Moreover, experimentally it has been observed that SCE materials often present inhomogeneous states (regularly organized, as in stripes, or randomly distributed, as in cluster glasses) and also giant responses to small external fields (as in the so-called colossal magnetoresistance effect).

Recent theoretical investigations, as reported in this article suggest that all these effects are related: phase competition causes both the inhomogeneous states and the giant responses. The main idea is sketched in the figure. In the absence of sources of disorder or strain, ‘clean’ SCE materials should often present first-order transitions separating two competing states (phase I and phase II in the figure). However, a variety of perturbations (such as disorder introduced by chemical doping) smear the first-order transition into a region with ‘mixed’ characteristics, where electrons behave in several respects as soft matter. Theory has shown that this mixed regime is spatially inhomogeneous and, moreover, it presents nonlinear responses to particular perturbations (such as magnetic fields in Mn oxides). The scenario described in the figure is very general and should apply to a variety of materials. Once considered exotic and puzzling properties, theoretical studies suggest that inhomogeneous states and giant nonlinearities in SCE materials should actually be vastly more general than previously anticipated. Extensions to the underdoped regime of high temperature superconductors have been proposed [see G Alvarez et al 2005 Phys. Rev. B 71 014514] and novel applications of these effects may emerge in the growing field of oxide multilayers [see S Yunoki et al 2007 Phys. Rev. B 76 064532 and references therein].

**Measurement of the upper critical field of optimally-doped YBa$_2$Cu$_3$O$_7$ in megagauss fields**

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High $T_c$ superconductors possess not only a high critical temperature $T_c$ but also a very high upper critical magnetic field $B_{c2}$. This is one of the reasons why they have attracted so much interest as promising materials for a vast range of novel applications, such as superconducting wires or magnetic levitation. As the critical field exceeds 100 Tesla in the case of optimally doped YBa$_2$Cu$_3$O$_7$ ($YBCO$, $T_c$ ~90 K), it has not been an easy task to study its high field properties across the critical field.
Dimensionally constrained D’yakonov Perel’ spin relaxation in n-InGaAs channels: transition from 2D to 1D

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‘Dimensionally constrained D’yakonov–Perel’ spin relaxation in n-InGaAs channels: transition from 2D to 1D’ A W Holleitner et al 2007 New Journal of Physics 9 342

In the emerging field of spintronics, it is important to explore carrier spin relaxation mechanisms in nanostructures as a function of dimensionality. In two and three dimensions, elementary rotations do not commute, with significant impact on the spin dynamics if the spin precession is induced by spin–orbit coupling. Spin–orbit coupling creates a randomizing momentum-dependent effective magnetic field; the corresponding relaxation process is known as the D’yakonov-Perel’ mechanism. In an ideal one-dimensional system, however, all spin rotations are limited to a single axis, and the D’yakonov-Perel’ spin relaxation is suppressed. The experimental work reported in this article demonstrates a progressive slowing of the D’yakonov-Perel’ spin relaxation in the regime approaching the one-dimensional limit. The experiments were performed on narrow channels of semiconductor heterostructures, containing InGaAs quantum wells, in which the spin–orbit interactions are dominated by structural inversion asymmetry. Such solid-state systems have been proposed as candidates for spintronic devices, including spin transistors, due to their potential scalability and compatibility with existing semiconductor technology.

Transmission of radio frequency (RF) signal through a sample of YBCO as a function of magnetic field at different temperatures. The magnetic field where the transmission reaches the normal state level is marked by arrows. The top figure shows the schematic illustration of electromagnetic flux compression for generating very high magnetic fields and the device for measuring the RF transmission at the centre of the field.

(a) Scanning electron micrograph of dry-etched InGaAs channels, which are patterned along the four crystallographic directions [100], [110], [010] and [-110]. (b) Micrographs of channels along the cleaving direction [110]. The crystallographic direction of the channels is [100] and [010]. (c) Spin relaxation time \( T_2^\* \) as a function of the channel width. Open and filled squares represent data of channels along [100] and [110], while the dotted line depicts the spin relaxation time of the unstructured quantum well.

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The recent advances in high magnetic field technology have enabled us to carry out various high precision experiments in the megagauss range well above 100 Tesla. In this study we observed for the first time a clear transition from the superconducting state to the normal state in optimally doped YBCO in a wide temperature range, employing very high pulsed magnetic fields up to 600 Tesla generated by electromagnetic flux compression. For measuring the conductivity in the very short pulsed fields, we developed a contactless radio frequency transmission technique. It was revealed that for magnetic field parallel to the CuO$_2$ plane \( B \| \text{CuO}_2 \), the transition field is 250 Tesla at 5 K, and gradually decreases as the temperature is increased, towards zero at \( T_c \). The entire phase diagram on the temperature–magnetic field plane was constructed for both \( B \| \text{CuO}_2 \) and \( B \perp \text{CuO}_2 \). A good fit of the experimental phase diagram to the conventional theory (WHH theory) was obtained only when we took account of a large spin–orbit interaction effect, indicating the importance of the spin effect.

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Nicolas Gisin, University of Geneva, Switzerland

My experience with New Journal of Physics has been really positive. In addition to enjoying professional handling of the peer-review process, my articles have, importantly, been highly visible to my community and beyond.”
This paper describes well-controlled nanoprocesses of carbon nanotubes which have been developed for fabricating nanotube probes and nanotube tweezers that operate in a scanning probe microscope (SPM). The first crucial process is to prepare a nanotube array, called a nanotube cartridge, in which arc-discharge-produced multiwall nanotubes were aligned at the knife-edge using ac electrophoresis.

The second important process is to transfer a nanotube from the nanotube cartridge onto a conventional SPM tip under scanning electron microscopy (SEM) observation. The advantages of the nanotube probes have been clarified for the observation of biological and nonbiological samples. The nanotube tweezers have demonstrated their motion in SEM and the operation for carrying nanomaterials in SPM.

The electron ablation process of the tip of nanotubes to adjust their length and the current-induced sharpening process of the tip of nanotubes have also been developed. For the sharpening process, the free end of a nanotube protruding from the cartridge was attached to a metal-coated SPM tip and a current in the saturation regime was applied to the nanotube. The current decreased stepwise with time, corresponding to the sequential destruction of individual nanotube layers from the outer. The nanotube was finally cut at the middle, and its tip was sharpened to have an inner layer. It has been shown that the maximum current in each layer during the stepwise decrease depends on its circumference rather than the cross section of the nanotube, and the force for extracting the inner layer with ~5 nm diameter is ~4 nN.

Illustration and SEM images of nanotube tweezers. (a) Tweezers formed on a Si cantilever with electrode wires, (b) open state at the applied voltage of 0 V and (c) closed state at ~4.5 V.

Raman spectroscopy has become one of the most valuable tools for carbon nanotube sample characterization, addressing aspects like purity, quality, metallicity, length, diameter, chirality and environment. This work overviews the basic theoretical concepts and experimental characteristics for each Raman feature of carbon nanotube samples. The radial breathing modes give the tube diameters in a sample. The graphite-like G band strongly depends on doping (chemical or applied voltage) and is different for metallic and semiconducting nanotubes. The disorder-induced D band indicates the presence of carbonaceous impurities and defects in the nanotube crystalline structure, and it is a probe for covalent functionalization. The G’ band (D band overtone) is highly sensitive to the electronic structure and can be used to probe small interactions. Many other disorder-induced, combination and overtone modes enrich the spectra and provide routes for new studies. Raman spectroscopy can be performed on all types of samples, including carbon nanotubes in bundles, in solution, dispersed in different matrices (e.g. polymers), isolated on different substrates or suspended over trenches. It is a non-destructive and non-invasive tool and can be used for in situ characterization of tubes in conjunction with other experiments/devices, including under operation and extreme conditions.

As a referee I can only congratulate New Journal of Physics for leading the way yet again; it is a great feeling to get a £100 discount on the article charge as an acknowledgement of the time spent on the review process. I've acted as a referee for many journals, and this is the first time I feel so good about it!

Sebastien Guenneau, University of Liverpool, UK
VHF, UHF, and microwave frequency nanomechanical resonators

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VHF, UHF and microwave frequency nanomechanical resonators X M H Huang et al 2005 New Journal of Physics 7 247

Doubly-clamped beam nanoresonators based upon nanoelectromechanical systems (NEMS) with operating frequencies up to the microwave L-band have been achieved, through the development of improved materials and novel detection techniques. This milestone in NEMS enables a broad range of applications including next-generation high resolution sensors and actuators, and high speed signal processing components. However, the first microwave NEMS resonators exhibit decreasing quality factors as the device frequency is increased. This could significantly restrict the range of applications for this developing technology. In this invited paper, after outlining the fabrication and measurement of these NEMS devices, we discuss our initial attempts to address this important problem and our efforts to improve measurement techniques at these frequencies.

Dissipation arising from clamping losses in NEMS devices is found to increase as the aspect ratio of these doubly-clamped beams is reduced. We have demonstrated that the SiC free-free beam nanomechanical resonators offer significant improvement in quality factor compared to a doubly-clamped beam design operating at similar frequencies.

By examining devices made from SiC wafers with different roughness, a strong correlation between surface roughness and quality factor is established from experiments. Furthermore, eddy current damping inherent to the widely-used magnetomotive transduction scheme is experimentally measured using a top-down nanofabricated SiC nanowire device.

This dissipation effect becomes particularly important for large aspect ratio beam resonators. Further work towards understanding dissipation mechanisms and improving the quality factors of ultrahigh and microwave frequency resonators is crucial for the wide spectrum of potential applications promised by these devices.

Electromechanical resonances measured from a typical pair of UHF nanomechanical resonators using a balanced-bridge detection scheme with magnetomotive transduction. Resonances are detected as the B field is swept from 1 to 8 Tesla. The noise floor of detection is measured to be ~0.14, corresponding to a ~7.1 K noise temperature. This arises from a combination of cryoamp noise, and the Johnson noise from the metallic resistors on the resonator beams. (inset) Data from both the 590 MHz and the 712 MHz devices show the resonance peak amplitude is a quadratic function of the B field, as expected. A Lorentzian fit to the de-embedded data traces give Q ~ 1700 for the 590MHz resonance and Q ~ 900 for the 712 MHz peak.

SURFACE SCIENCE AND THIN FILMS

Does one-dimensional adatom and cluster diffusion of Pt on the Pt(110)-(1 x 2) surface lead to one-dimensional ripening?

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Does one-dimensional (1D) adatom and cluster diffusion of Pt on the Pt(110)-(1 x 2) surface lead to 1D ripening? T R Linderoth et al 2005 New Journal of Physics 7 13

Growth of crystals by vapor deposition of atoms onto solid surfaces is one of the most fundamental areas of surface science and much effort has been directed at elucidating underlying microscopic processes such as diffusion of adatoms on surfaces, nucleation and growth of adatom clusters, and cluster decay and ripening.

An ideal technique for this task is scanning tunnelling microscopy (STM) which provides direct real space images of surfaces at atomic resolution. By STM it is uniquely possible to zoom in on atomic scale details of the growth process and follow dynamic phenomena by STM-movies.

The Pt(110) surface is an interesting model system for fundamental growth studies since it forms a so-called missing row reconstruction in which every second close-packed atomic row is removed, resulting in a highly anisotropic surface morphology with one-dimensional (1D) troughs.

In a series of papers we had characterized the diffusion of adatoms and clusters on this surface from experiments as illustrated in the figure. The results showed that the diffusing species were confined to the missing row troughs making the mass transport in this system entirely 1D.

In the featured publication, we therefore investigated if this surface constitutes a 1D model system to explore later stage growth, such as island decay and ripening, allowing comparison with the well-known 2D case. A surprise was in store, however, since new unanticipated processes were shown to set in at higher adatom coverage providing mass transport between the troughs. The work later inspired further theoretical studies.
A spin-density-wave (SDW) is a sinusoidal modulation of the magnetization in an antiferromagnet, as visualized in figure (a), for example, in chromium. What determines the SDW wavelength? For 40 years it has been thought that electronic transitions in momentum ($k$-) space drive the SDW, but the relationship between real- and $k$-space has never been experimentally tested in Cr. The angle-resolved photoemission results in figure (b) show a cut through the Cr Fermi surface, that is, the allowed $k$-space states near the Fermi level $E_F$ in a thick Cr(110) film. Two possible transitions between parallel or nested sections of the Fermi surface stabilize the SDW by modifying the generalized magnetic susceptibility of the material. The resulting nesting is incommensurate by a factor $\delta = 0.05 \pm 0.005$, in agreement with the SDW incommensurability determined with neutron and x-ray scattering. This finding confirms the conventional SDW theory for bulk Cr.

Structured metal films allow for terahertz pulse shaping using surface plasmon-polaritons

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‘Excitation and scattering of surface plasmon-polaritons on structured metal films and their application to pulse shaping and enhanced transmission’
A Agrawal et al 2005 New Journal of Physics 7 249

Free-space broadband terahertz radiation is efficiently coupled to surface plasmon-polariton waves on a metal film containing concentric annular grooves around a subwavelength aperture. The shape of the THz pulse exiting the aperture depends on the geometry and location of individual grooves.

Surface plasmon-polaritons (SPPs), which are composed of electromagnetic waves coupled to a collective excitation of electrons at a metal-dielectric, have elicited renewed attention in recent years. Much of this interest arises from the possibility of subwavelength field localization, creating opportunities for applications in a range of nanophotonics applications. In this article, we demonstrated a novel approach for THz pulse shaping by modifying the coupling and scattering characteristics of SPP waves propagating along structured metal films. The technique relies on appropriately varying the cross-sectional parameters and location of each individual groove fabricated into a metal film allowing for the generation of arbitrarily complex THz pulse shapes. This ability to alter the spectral and temporal properties of THz pulses using structured metal films is expected to be important for applications in THz communications and coherent control. Based on this approach, we have recently demonstrated a simple, flexible approach to couple freely propagating broadband THz radiation to shaped THz pulses on a cylindrical metal wire waveguide.

We are currently extending this work to develop surface plasmon based waveguide devices. Although a number of other approaches are actively being pursued in this research direction, plasmonic waveguides offer several attractive features, including the possibility for a simplified device topology, subwavelength field localization, and low-loss transmission of THz radiation. At a time when THz technology is still maturing, this ability to manipulate radiation at a sub-wavelength scale and over a wide spectral range holds great promise for the development of frequency selective devices for THz optoelectronic applications.

Magnetic periodicities in Cr(110) films

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‘Electron states and the spin density wave phase diagram in Cr(110) films’
E Rotenberg et al 2005 New Journal of Physics 7 114

The actual SDW periodicity can be determined directly in our experiments by looking at ‘backfolded’ or replica bands seen at binding energies away from $E_F$ (figure (c)). Moreover, the SDW incommensurability $\delta_{\text{SDW}}$ can be determined directly from the splitting of these replica bands. Surprisingly, we find that the measured SDW wavelength does not always match the wavelength determined by the Fermi surfaces, that is, $\delta_{\text{SDW}} \neq \delta_F$. $\delta_{\text{SDW}}$ goes smoothly to zero as the film thickness is reduced. We have recently shown that a competition between nesting of 3D bulk states and 2D surface states can explain these unusual results.
Catastrophic rhythm disturbances of the heart, such as ventricular fibrillation (VF), are the major cause of death in the United States. Although there currently is some controversy concerning the exact mechanism for fibrillation, all hypotheses invoke wave break and conduction block, secondary to spatial heterogeneity of electrical properties in the ventricle. One hypothesis, the restitution hypothesis, proposes that the spatial heterogeneity required for the induction and maintenance of fibrillation can arise dynamically. Dynamically-induced heterogeneity has been characterized extensively under the condition of constant rapid pacing. However, it is unlikely that this scenario applies directly to the clinical situation, where the induction of VF often is associated with the interruption of normal cardiac rhythm by several premature beats. Therefore, we have been investigating the effects of small numbers of premature stimuli as they relate to the development of VF. These studies began with a coupled maps lattice 1D cable model, and a theoretical analysis of a similar model. The main result from this paper is that certain sequences of premature stimuli were found to induce spatial heterogeneity and conduction block in the 1D cable model. Experimental tests of this idea have thus far been consistent with the theoretical predictions (see figure). Further elucidation of the mechanism for dynamically-induced heterogeneity and subsequent wave break is likely to lead to new, more effective methods for preventing or treating VF.

The interactions between polymers and surfaces govern the properties of man-made as well as natural composite materials such as bone, wood, paper, enforced plastics, or any kind of polymer coatings on surfaces. Bio-compatible materials or self-cleaning surfaces are determined by these interactions but also such phenomena as lubrication or bio-fouling. At the same time these technologically and economically extremely relevant systems pose most interesting questions for basic research. Basically it boils down to the question, what happens when a flexible 1D-object meets a rigid 2D-object.

Up to now, both structure and dynamics of the polymer/solid interface were investigated in ensemble average. With the development of single molecule techniques, however, the interaction of individual polymers with selected surfaces became accessible. In this article we covalently attached individual polymers to the tip of an AFM cantilever and employed the cantilever as a ‘handle’ for this polymer. We brought this polymer in contact with different surfaces and allowed it to interact under various conditions. We studied the adhesion process and characterized the underlying physics by measuring the adhesion force as a function of the surface properties, which we adjusted using self-assembled monolayers with chosen chemistry. We were able to modulate the Coulomb-contribution to the adhesion forces and to tune the adhesion force of our model polymer poly-acrylic acid in a range between 40 and 85 pN. We furthermore discovered that despite the quasi-reversible adsorption of the polymers their lateral mobility may remain extremely high.

A polymer with a handle at a surface

The interactions between polymers and surfaces govern the properties of man-made as well as natural composite materials such as bone, wood, paper, enforced plastics, or any kind of polymer coatings on surfaces. Bio-compatible materials or self-cleaning surfaces are determined by these interactions but also such phenomena as lubrication or bio-fouling. At the same time these technologically and economically extremely relevant systems pose most interesting questions for basic research. Basically it boils down to the question, what happens when a flexible 1D-object meets a rigid 2D-object.

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Cell membranes both act as passive barriers that separate the inside and outside of the cell, and play an active role in physiological functions such as intercellular signaling and the transport of small molecules to and from the environment. Molecularly, the membrane is primarily composed of lipids, proteins and their surrounding water. Membrane function thus involves the interplay of these components. Molecular dynamics simulations have shown that this interplay evolves over sub-nanosecond timescales but experimental insights into the dynamics of these interactions have lagged. This lag is the result of the considerable challenge of investigating the single layer of molecules that compose the membrane with the required time resolution. In our article we overcome this challenge by using femtosecond laser spectroscopy to follow the evolution of a biomolecular system in real-time after a laser-pulse induced change (e.g. a temperature jump or vibrational excitation). The strength of our approach lies in probing the sample using an even-order nonlinear optical process that has inherent interfacial sensitivity but maintains the time resolution of simpler bulk techniques. Our study is the first surface-specific study of vibrational relaxation and energy transfer in lipid monolayers prepared over a water subphase. This model membrane allows us to easily control parameters such as surface pressure and lipid phase. Generally we find remarkably fast dynamics: heat transfer across the monolayer, for instance, occurs on picosecond timescales. This study demonstrates the potential of using ultrafast surface-specific spectroscopies to elucidate biomolecular dynamics in membranes on the timescale over which they occur.

Schematic of the experiment: a self-assembled monolayer of lipid molecules (with polar headgroups shown in yellow and apolar alkyl chains shown in grey) on water. Laser pulses at different wavelengths are incident on the lipid monolayer. One pulse triggers a temperature jump or vibrational excitation in the monolayer, and a delayed pair of pulses interrogates the transient changes in the monolayer, in a process where the sum-frequency of the incident pair (shown here as red and green) is generated (blue beam). This technique provides surface-specific information on model membrane relaxation processes.
Particle clustering in strong turbulence

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Reynolds number scaling of particle clustering in turbulent aerosols
L R Collins et al 2004 New Journal of Physics 6 119

For decades researchers have known that inertial particles cluster in turbulence due to a ‘centrifuge’ effect that causes them to be expelled from vortical regions of the flow and to collect in the high-strain regions between the vortices (see figure). This phenomenon, sometimes called ‘preferential concentration’, affects a broad range of aerosol processes. For example, it has been hypothesized to play a role in accelerating the development of clouds in the atmosphere, and in creating the conditions necessary for planets and solar systems to form from the initially homogeneous matter of the early Universe.

In 1997 Sundaram and Collins showed that particle collisions are enhanced by clustering by as much as 2 orders of magnitude, and they identified the radial distribution function (RDF) as the precise correction to the collision kernel for this effect. The RDF is known to be a strong function of the particle Stokes number, defined as St = τp/τE, where τp is the particle response time and τE is the time scale of the Kolmogorov eddies. However, its dependence on Reynolds number is less well understood. This dependence is crucial for applications such as atmospheric clouds and astrophysics, as they involve extremely large values of this parameter. The results from direct numerical simulations (DNS) showed the dependence of the RDF on Reynolds number over the range of the study to be weak, and furthermore the RDF appeared to approach an asymptote with increasing Reynolds number. Recent experimental measurements of the RDF in a turbulence box with particles are in quantitative agreement with these DNS, confirming the findings. This result stands in stark contrast to many other turbulence statistics, such as velocity derivatives and structure functions, which show power-law dependencies on Reynolds number over the range that has been studied. A physical explanation for the puzzling difference in the scaling of the RDF versus other velocity statistics remains elusive.

Taming thermal motion

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Does the second law of thermodynamics apply to small devices? This question, posed by Maxwell around 1870, has today become quite relevant since it is now possible — through the advances in nano and biotechnology — to measure, manipulate and even construct objects at a very small scale.

Smoluchowki and later Feynman showed on the basis of phenomenological arguments that an asymmetric device like the ‘ratchet and pawl’ (figure (a)) cannot rectify thermal fluctuations from a single heat bath, but can operate as a kind of Carnot engine when in contact with two heat baths. In this paper, we introduce the first microscopic model for which an exact analytic study of this question, posed by Maxwell around 1870, has today become quite relevant since it is now possible — through the advances in nano and biotechnology — to measure, manipulate and even construct objects at a very small scale.

For decades researchers have known that inertial particles cluster in turbulence due to a ‘centrifuge’ effect that causes them to be expelled from vortical regions of the flow and to collect in the high-strain regions between the vortices (see figure). This phenomenon, sometimes called ‘preferential concentration’, affects a broad range of aerosol processes. For example, it has been hypothesized to play a role in accelerating the development of clouds in the atmosphere, and in creating the conditions necessary for planets and solar systems to form from the initially homogeneous matter of the early Universe.

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Tectonic plates taken for a spin in the laboratory

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The surface of the solid Earth is tessellated with rigid tectonic plates that slowly drift, colliding in some places, spreading apart in others. Plate spreading occurs along the global mid-ocean ridge system on the sea floor. In the 1970s, ship-based surveys of the ridge system revealed small tectonic plates; these were termed microplates. Sea-floor microplates are characterized by spiral patterns of bathymetry that are suggestive of plate rotation about a vertical axis at a sluggish rate of about 20 degrees per million years. Impatient with such slow kinematics, we developed a wax analogue spreading ridge in the laboratory. In our experiments, a tray of wax is heated from below and cooled from above. Two skimmers embedded in the solid wax at the surface steadily diverge, causing spreading at a rift between the wax tectonic plates. Molten wax upwells at the rift, acrtes to
Swimming in curved space: the Baron and the cat

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'Swimming in curved space or the Baron and the cat' J E Avron et al 2006 New Journal of Physics 8 68

In empty Euclidean space conservation of linear momentum implies that a body at rest cannot move its own center of mass. Conservation of angular momentum does not imply similar restriction on rotations, a fact advantageously used by falling cats, because angular momentum cannot be used to define a ‘center of mass orientation’. As the notion of center of mass is intrinsically Euclidean and has no analog in curved space, the possibility is opened for Baron von Munchausen to displace himself, an observation made by Jack Wisdom his article ‘Swimming in spacetime: motion by cyclic changes in body shape’ (J Wisdom 2003 Science 299 1868–9).

In inhomogeneous spaces strictly rigid bodies are locked to positions where their geometry fits the geometry of the ambient space. Rigid body motion is possible in symmetric spaces, and swimming of deformable bodies then becomes a viable possibility. In these spaces Killing fields are natural generalizations of the notions of translations and rotations and a key result of the theory is that swimming (with zero momentum) is proportional to the curl of the corresponding Killing field.

For small swimmers that perform small strokes, we find an explicit formula for the distance covered in one stroke: it is proportional to the Riemann tensor at the location of the swimmer, certain (cubic) moments characterizing the stroke.

Movies of deforming triangles swimming on a ball and a torus can be viewed at http://physics.technion.ac.il/~avron.
New Journal of Physics is privileged to have received the support and guidance of the following people who have served as members of the Editorial Board and focus issue guest editors since 1998.

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