Abstracts

Antiferromagnetism

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Ferromagnetism has been known for millenia, and has underpinned many technologies for centuries. The possibilitty of antiferromagnetism has only been noted in the last century. I show that far from being a footnote in condensed matter physics, antiferromagnetism is at the frontier of physics and is beginning to display genuine technological relevance.

Note from the IPS20004 Committee:

Professor Aeppli is the Quain Professor of Physics and Head of the Condensed Matter and Materials Physics Group at UCL, and the Director of the London Centre for Nanotechnology. Prior to taking up these posts in the autumn of 2002, he was a Senior Research Scientist for NEC (Princeton), a Distinguished Member of Technical Staff at Bell Laboratories, a Research Assistant at MIT, and an industrial co-op student at IBM. He obtained a B.Sc. in Mathematics and Ph.D., M.Sc. & B.Sc in Electrical Engineering from MIT. Honours include the IUPAP Magnetism Prize/Neel Medal(2003), Fellow of Riso National Laboratory(2002), Royal Society Wolfson Research Merit Award(2002), Mildner Lecturer, Department of Electronic & Electrical Engineering, UCL(2002), Fellow of the American Physical Society(1997), Fellow of the Japan Society for the Promotion of Science(1996). In addition, he has been a member and chairman of many panels, sponsored by the USDOE, American Physical Society, EPSRC, and National Research Council(US), among others. His main research interests are quantum information processing, nanotechnology (including especially its manifestations in the life sciences) and particle and X-ray beam-based probes of condensed matter. We have just heard that he has been awarded the Buckley Prize of the APS this year.

Challenging demonstrations in the physics classroom

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(Submitted by Eli Raz, Physics Dept., Ort Braude College, Karmiel, eliraz@braude.ac.il)

We consider the role of classroom demonstrations in improving students understanding of physics lectures and suggest criteria to decide whether a given demonstration will be pedagogically useful. In the light of these considerations, we performed two series of related experiments before groups of high-school students. We shall perform one of them with active participation from the audience. We shall also show some challenging demonstrations performed in the final stages of the Israeli Physics Olympiad for high-school students.

Calculated I-E characteristic of HTS tape and coil exposed to inhomogeneous magnetic field

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(Submitted by Yossi Adanny, Bar-Ilan University, Department of Physics, adanny@mail.biu.ac.il)

HTS wires, employed in high current coils are exposed to strong inhomogeneous magnetic field changing over the superconducting tapes broad face. Under these conditions, the current density distribution would be controlled by the local characteristic of the tape (defects, structure etc.) and by the magnetic field distribution over the tape. However, strong dependence of the critical current density on the magnetic field along with strong anisotropy of Bi_2Sr_2 $Ca_2Cu_3O_8 - \delta$ tape make the prediction of the current density, electric and magnetic field distributions a complex problem.
In this work we introduce a model which enables us predict the I-V curves of superconducting tapes and coils exposed to inhomogeneous magnetic fields. Based on empirical I-V experiments of a single tape, under different values and orientations of an applied homogeneous magnetic field, the local current and electric and magnetic fields distributions are calculated for the inhomogeneous external magnetic field case.
I-V curves of a flat pancake coil, which results from this model, are compared to the measured I-V curves. This model predicts, for the first time, the full curve of the current-voltage characteristics of tapes and coils exposed to inhomogeneous magnetic fields. The field component, parallel to the tapes broad surface, is shown to strongly affect the tape characteristics and the weakest coils point, in terms of critical current density distribution.

Study of the electric field in HTS tape caused by perpendicular AC magnetic field

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(Submitted by Vlad Roitberg, Bar-Ilan University, Department of Physics, roitbev@mail.biu.ac.il)

In a previous work [1] we studied the influence of AC magnetic fields on voltage-currents (V-I) characteristics of high temperature superconducting (HTS) multifilament BSCCO-2223 tapes. It was found that AC magnetic fields perpendicular to the ab plane (the wide surface of the tape) cause a linear decrease of the critical current (IC) with amplitude of the AC magnetic field. The degradation of IC in AC field was explained by the geometrical model according to which the transport current flow is confined to the central zone of the tape where AC field does not penetrate. For deeper understanding of the observed phenomena we carried out a study of the time dependence of the electric field during the cycle of AC field. At the same time we expanded the frequency range to low frequencies down to 1 Hz. The main results of the work are as following. 1. The time modulation of the electric field E in the HTS tape carrying transport DC current has the double frequency relating to AC magnetic field. 2. In field amplitudes less than 70 G the electric field modulation decreases with increasing frequency in opposite to its well-pronounced increase in higher AC field amplitudes. Above 70 G, the electric field increases with increasing the frequency of the external magnetic field. The wave forms of the electric field are different in both amplitudes ranges. 3. E-I curves of the tape in low amplitudes are frequency independent and coincide with E-I curves in DC field with intensity equal to the AC field amplitude. 4. In high AC field amplitudes, a strong dependence of the E-I curves on frequency is observed in the frequency range of 1-40 Hz and no dependence is observed in higher frequencies. Our results suggest that a combination of the geometrical model with flux creep concepts is necessary for a better understanding of the electric field behavoior in our measurement conditions.

[1]. I-V curves of BSCCO tape carrying DC current exposed to perpendicular and parallel AC fields. A. Friedman, Y. Wolfus, F. Kopansky, I. Soshnikov, V.Roitberg, S. Asulay, B. Kalisky, Y.Yeshurun. Paper 4MM07, presented to ASC2004 IEEE Transactions on Applied Superconductivity, in press, 2004

How is the diamagnetic effect (DME) relevant to stellar surface phenomena?

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The interaction of plasmas with ambient (geometrically) diverging magnetic fields, combined with gravity, give rise to speed filters. Closed magnetic structures appear as "cold" spots or "hot" coronae. Open field structures promote stellar winds. In addition, with Dielectronic Recombination, chemical abundances interpreted as peculiar. The current numerical simulations examine some of these effects.

On the evolution of gravitationally unstable protoplanetary disks

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Planets form in disks of gas and dust. There is a general consensus that during the early evolution of these disks mass must be transported inward while angular momentum must be transferred outward, a situation anticipated by consideration of the solar system. In this work, the position is adopted that involve a simultaneous formation of a star and planets around it through a gravitational Jeans-type instability in a protostellar disk of dust and gas. It is shown analytically that in gravitationally unstable, spatially inhomogeneous disks differential rotation can effectively transfer angular momentum outward to the outer parts of the system, as mass flows inward to the growing star through gravitational torques.
The gravitational instability results in a turbulence of the protoplanetary disk. An expression is derived for the viscosity coefficient due to disk turbulence.
Three-dimensional N-body experiments that simulate the nonlinear development of gravitational instabilities are also used to test the validities of the theory.
The advantages of the disk instability model are that (1) the instability process itself is quite fast, and could form planets in 1000 yr, (2) in gravitationally unstable, nonaxisymmetric disks differential rotation can simultaneously transfer the angular momentum outward and mass inward through gravitational torques, and (3) such a model obviates the requirements for turbulent viscosity, frequently appealed to as a physical mechanism for outward transfer of angular momentum. The present work has precedents in earlier studies of gravity disturbances in galactic disks and Saturn's ring disk (Lin and Shu 1966; Lin et al. 1969; Shu 1970; Lin and Lau 1979; Griv et al. 1999, 2001, 2002, 2003; Griv and Gedalin 2003, 2004).
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Time machines, Gödel's universe and Mach's principle

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General relativity (GR) allows world lines in the form of closed time-like (CTL) curves which, in principle, enable "time machines" that can travel to the past. A variety of such machines were proposed, employing exotic entities such as rotating black holes, cosmic strings, super-dense rotating cylinders and wormholes which are kept traversable by negative energy (Casimir vacuum). However it was shown for almost all these proposals that the putative time travel to the past is either technically impossible, or can not be detected by an external observer. On the base of those works Hawking [1] assumed that there is a general principle in physics, which prevents travels to the past, as well as other violations of causality, unless they are utterly unobservable by an external observer. Quantum mechanics might guarantee this "chronology protection conjecture" (CPC) by expelling causality violating events from the quantum phase space [2]. The CPC seems not to apply to global time machines which encompass the entire universe, such as Gödel's rigidly rotating universe [3]. According to GR a CTL world-line can be achieved in Gödel's universe simply by sending a high speed spaceship over a sufficiently large orbit. Gödel's model was carefully checked and, unlike other time machines, it apparently represents a plausible mechanism for traveling to the past. According to the microwave background radiation probes COBE and WMAP, as well as other sorts of measurements, our universe is not rotating, or at least the upper limit of its angular velocity is far lower than what needed for Gödel's time machine. However, a rotating universe is a possible solution of Einstein's field equations and the violation of causality in such a universe poses an intriguing paradox. It can be argued that the only way out of the paradox is to assume that the rotation of the universe as a whole is meaningless in much the same way as the translation motion of the universe. A by-product of this assumption would be the clarification of the long-standing debate over the validity of Mach's Principle.

[1] S. W. Hawking, Phys. Rev. D 46, 603 (1992). [2] M. J. Cassidy and S. W. Hawking, Phys. Rev. D 57, 2372 (1998). [3] K. Gödel, Rev. Mod. Phys. 21, 447 (1949).

Cosmological applications of gravitational lensing

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I studied gravitational lenses an their use for probing cosmological parameters and the nature of dark matter. Using astronomical databases such as FIRST, APM and SDSS, and additional optical observations, I have conducted several searches for large separation lensed quasars (Ofek et al. 2001;2002). Currently, I am conducting two others surveys for large separation lensed quasars in the USNO-B1 catalog, and among quasars in the SDSS catalog. The number statistics inferred from these ongoing searches will be compared with ray tracing simulations through N-body simulations, taking into account all the observational details. I have been monitoring a sample of about 30 lensed quasars using the Wise Observatory 1m telescope and I have measured the time delay of HE1104-1805 (Ofek & Maoz 2003). For two additional lensed systems resolvable from the Wise observatory, I have already obtained tight constraints on possible time delays. I used lensing statistics to constrain the mass and number evolution, and zero-redshift velocity dispersion, of early type galaxies (Ofek, Rix & Maoz 2003). I am also interested in Gamma Ray Bursts and their connection to supernovae. I have taken part in global campaigns of GRB afterglow followup (Galama et al. 1999; Price et al. 2001, 2003), and observational effort directed at GRB030329 (Lipkin, Ofek, Gal-Yam et al. 2004) which produced the best sampled light curve of a GRB afterglow. In Levinson, Ofek, Waxman, Gal-Yam 2002, we conducted, for the first time, a detailed comparison between point sources in the FIRST and NVSS radio catalogs. This survey allowed us to select orphan afterglow candidates and other radio transients and used them to put a lower limit on the beaming factor of GRBs.

Space climate manifestatin in earth prices - from medieval England up to modern USA

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In this study we continue to search for possible manifestations of space weather influence on prices of agricultural products and consumables. We note that the connection between solar activity and prices is based on the causal chain that includes several nonlinear transition elements. These non-linear elements are characterized by threshold sensitivity to external parameters and lead to very inhomogeneous local sensitivity of the price to space weather conditions. It is noted that soft type models are the most adequate for description of this class of connections. Two main observational effects suitable for testing causal connections of this type of sensitivity are considered: burst-like price reactions on changes in solar activity and price asymmetry for selected phases of the sunspot cycle. The connection, discovered earlier for wheat prices of Medieval England, is examined in this work on the basis of another 700-year data set of consumable prices in England. Using the same technique as in the previous part of our work (Pistilnik and Yom Din 2004) we show that statistical parameters of the interval distributions for price bursts of consumables basket and for sunspot minimum states are similar one to another, like it was reported earlier for wheat price bursts. Possible sources of these consistencies between three different multiyear samples are discussed. For search of possible manifestations of the space weather - wheat market connection in modern time, we analyze dynamics of wheat prices in the USA in the twentieth century. We show that the wheat prices revealed a maximum/minimum price asymmetry consistent with the phases of the sunspot cycle. We discuss possible explanations of this observed asymmetry, unexpected under conditions of globalization of the modern wheat market.

Polymer dynamics of biological molecules

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The measurements of monomer dynamics within polymer coils will be presented. The combination of specific fluorescent labeling and Fluorescence Correlation spectroscopy technique allows to measure mean-square monomer displacement as a function of time in a wide range of time and length scales. The monomer dynamics in three types of polymers will be presented: flexible coils (single-stranded DNA), semi-flexible coils (double-stranded DNA) and stiff polymers (actin filaments). The monomer motion in single-stranded DNA obeys the predictions of Zimm theory, the monomer kinetics in double-stranded DNA is close to Rouse model predictions, while the dynamics of actin filaments is consistent with the current models of the dynamics of stiff polymers.

DNA in nanopore

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1. Recent experimental results on nanopore unzipping of DNA hairpins are analyzed using a simple 2 (and a half) state model. 2. The electrostatics of DNA and small ions in a nanopore is studied using molecular dynamics simulations.

RNA dynamics in live cells

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(Submitted by Golding Ido, Department of Molecular Biology, Princeton University, Princeton, NJ 08544, igolding@princeton.edu)

We describe a method for tracking individual mRNA molecules in live E. coli cells. The method enables us to follow the life history of messenger RNA molecules, and quantify their dynamics, including: the kinetics and stochasticity of induction; chain elongation rate; "spring constant" while tethered to the DNA template; sub-diffusion when freely moving in the cell. We compare the measured parameters to known biophysical parameters of the E. coli system.

Cell-free genetic networks

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Cell-free expression systems offer an alternative to in vivo protein synthesis. A general approach is presented for designing artificial cell-free networks using simple activation and repression cascades. Advantages and limitations of the approach are discussed towards integration within materials.

Polymer tumbling statistics in shear flow

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Understanding of the orientation and temporal behavior of polymers in simple shear flow with small random component is important problem for biological (micro manipulation of DNAs in micro channels) as well as for physical (boundary layer dynamics in turbulence in a pipe) needs. The behavior of molecules in a simple shear flow with only thermal fluctuations was considered. For the first time orientation angle dynamics and statistics as well as tumbling times statistics were investigated experimentally. We obtained probability distribution functions (PDF) for those quantities and found universal behavior of the PDFs slope and scaling with Wi in the deterministic region as predicted by theory.

Single polymer dynamics: Coil-sretch transition in a random flow

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Understanding of the single polymer dynamics in a random 3D flow is important physical and industrial problem especially in the understanding of the turbulent drag reduction effect. Recently discovered elastic turbulence allowed us to get a random flow in a small tank. For the first time we studied statistics of polymer stretching in such flow that showed sharp increase in polymer extension (comparing to that which occurs in a simple shear flow) signaling the occurrence of the coil-stretch transition. The quantitative verification of the transition criterion showed rather close agreement with the theoretical value.

Vesicles orientation and dynamics in shear flow

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The dynamics of giant unilamellar vesicles in an external shear flow is investigated experimentally. Fluorescent microscopy and microfluidics techniques are used for precise measurements and control of the dynamical and geometrical parameters of the vesicles. Stationary inclination angle with respect to the flow direction is measured as a function of the vesicle shape parameter. We found scaling of the angle fluctuations in presence of thermal noise with dimensionless parameter, which is proportional to inverse shear. Evidence of shape evolution of the vesicles under the flow stresses is observed. We compare our results with existing theories and numerical simulations.

Structuring carbon forms by energetic species: Amorphous, nanotubes and crystalline

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Energetic species in different forms play a major role in current thin film technology. The evolution of such films via energetic particle bombardment is a shallow implantation (subplantation) process1-3. The stopping of the energetic species in the bombarded target advances through three stages: (i) collisional stage in which the species are stopped by the target via atomic displacements, ionization and phonon excitations, (ii) the thermal relaxation stage in which the excess energy is dissipated in the target, (iii) the long term relaxation stage in which long term processes (diffusion, chemical reactions) take place. The final evolution of the structure is determined by the equilibrium between subsurface trapping at the final site and detrapping processes. Carbon is an excellent model system to study the structuring of materials by energetic species due to the host of possible configurations it forms. By properly altering the energy and temperature it is possible to form: (i) amorphous carbon films with a local configuration and properties ranging between those of graphite (sp2 hybridization) and diamond (sp3), (ii) ordered graphitic films including carbon multiwall tubes4, (iii) nanocrystalline diamond5,6. The processes leading to the different carbon structures will be highlighted through experimental data and molecular dynamic simulations.

1 Y. Lifshitz, S.R. Kasi and J.W. Rabalais, "Subplantation Model for Film Growth From Hyperthermal Species: Application to Diamond", Phys. Rev. Lett., 62, 1290, 1989. 2 Y. Lifshitz, G.D. Lempert, E. Grossman, "Substantiation of Subplantation Model for Diamondlike Film Growth from by Atomic Force Microscopy", Phys. Rev. Lett., 72 (17), 2753, 1994. 3 S. Uhlmann, Th. Frauenheim, Y. Lifshitz, Molecular Dynamics Study of the Fundamental Processes Involved in Subplantation of Diamondlike Carbon, Phys. Rev. Lett., 81(3), 641, 1998. 4 H.Y. Peng, N. Wang, Y.F. Zheng, Y. Lifshitz, J. Kulik, R.Q. Zhang C. S. Lee and S.T. Lee, Smallest Diameter Carbon Nanotubes, Appl. Phys. Lett., 77(18), 2831, 2000. 5 Y. Lifshitz, Th. Köhler, Th. Frauenheim, I. Guzmann, A. Hoffman, R.Q. Zhang, X.T. Zhou, S.T. Lee, The mechanism of diamond nucleation from energetic species, Science, 297, 1531, 2002. 6 Y. Lifshitz, X. M. Meng, S.T. Lee, R. Akhveldiany and A. Hoffman, Visualization of Diamond Nucleation and Growth from Energetic Species, Phys. Rev. Lett., 93(5), 56101, 2004.

Carbon nanotubes embedded in polymer nanofibers

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The electrospinning process was used successfully to embed Multi-walled carbon nanotubes (MWCNTs) and single-walled carbon nanotubes (SWCNTs) in a matrix of poly(ethylene oxide) (PEO) forming composite nanofibers. Initial dispersion of SWCNTs in water was achieved by the use of an amphphilic alternating copolymer of styrene and sodium maleate. MWNT dispersion was achieved by ionic and nonionic surfactants. The distribution and conformation of the nanotubes in the nanofibers were studied by transmission electron microscopy (TEM). Oxygen plasma etching was used to expose the nanotubes within the nanofibers to facilitate direct observation. Nanotube alignment within the nanofibers was shown to depend strongly on the quality of the initial dispersions. Well-dispersed and separated nanotubes were embedded in a straight and aligned form while entangled non-separated nanotubes were incorporated as dense aggregates. X-ray diffraction demonstrated a high degree of orientation of the PEO crystals in the electrospun nanofibers with embedded SWCNTs, whereas incorporation of MWCNTs had a detrimental effect on the polymer orientation. Composite polymer nanofibers containing dispersed phases of nanometric TiO2 particles and MWCNTs were also prepared electrospinning. In this case, the polymer matrix was poly(acrylonitrile) (PAN). The morphology and possible applications of these composite nanofibers will be discussed.

Nano-acrobatics: How to measure nanotube-polymer adhesion

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Some of our recent experimental and theoretical results regarding materials mechanics at the nanoscale will be briefly reviewed. The main theme includes carbon nanotubes and nanotube-based composite materials. Carbon nanotubes hold great promises as a possible reinforcing phase in composite materials of a new kind. Such developments still present, however, enormous practical challenges, in particular when attempting to probe the properties of individual nanotubes, for which most studies consist of computer simulations. We report promising results regarding polymer-nanotube wetting and interfacial adhesion. The potential use of nanotubes as sensors in composite matrices is also briefly outlined.

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3. A.H. Barber, S. Cohen, H.D. Wagner, "Measurement of carbon nanotube-polymer interfacial strength", Applied Physics Letters, 82 (23) (2003), 4140-4142.
4. A. H. Barber, S. Cohen, H.D. Wagner, Static and dynamic wetting measurements of single carbon nanotubes, Physical Review Letters, 92 (18) (2004), 1861031-1861034.

Implanting very low energy atomic ions into surface adsorbed cage molecules: the formation/emission of $Cs@C_{60}^{+}$.

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We demonstrate the formation of an endo-complex via a collision of energetic ions with molecular overlayers on a surface. An incoming atomic ion is encapsulated inside a very large molecule or cluster by implanting the primary ion into the target species, which then recovers its original structure or rearrange itself around the implanted ion in some stable configuration. Here we describe an experiment resulting in the formation and ejection of an endo-complex, within a single collision. We study the formation and emission of endohedral fullerenes,$Cs@C_{60}^{+}$ and $Cs@C_{70}^{+}$, following a single collision of Cs^{+} ion with a sub-monolayer of C_{60} (steady state coverage) on gold and silicon surfaces and with a sub-monolayer of C_{70} on gold [1,2]. A continuous low energy (E_0=35-220 eV) Cs^{+} ion beam hit the C_{60} covered surface and the collisional formation and ejection of the endohedral $Cs@C_{60}^{+}$ complex, within a single Cs^{+}/C_{60} collision was observed and characterized. Several experimental observations clearly demonstrate the single collision nature of the combined atom penetration /endo-complex ejection event. The fullerene molecule is actually being picked up off the surface by the penetrating Cs^{+} ion. The evidence for the trapping of the Cs^{+} ion inside the fullerene cage is given both by the appearance of the $Cs@C_{(60-2n)}^{+}$ ($n = 1-5$) sequence and its termination at $Cs@C_{50}^{+}$. Kinetic Energy Distributions (KEDs) of the outgoing $Cs@C_{60}^{+}$ were measured for two different Cs^{+} impact energies under field-free conditions [3]. The most striking observation is the near independence of the KEDs on the impact energy. Both KEDs peak around 1.2 eV with similar line shapes. A simple model for the formation/ejection/fragmentation dynamics of the endohedral complex is proposed and is found to be in good agreement with the experimental results [3].

[1] A. Kaplan, A. Bekkerman, B. Tsipinyuk and E.Kolodney, J. Chem. Phys. 117 (2002) 3484-3491
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Dramatic distortion of 4d Giant resonance by the Fullerenes C60 shell

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It is demonstrated that in Xe@C60 the 4d10 Giant resonance is impressively distorted as compared to the case of an isolated Xe atom. The reflection of photoelectron waves by the C60 leads to profound oscillations in the photoionization cross section so as the Xe Giant resonance is substituted by four powerful oscillations. Accordingly modified are the angular anisotropy parameters, both dipole and non-dipole. It is essential that the C60 shell being approximated by an infinitely thin real potential, leaves the sum rule for 4d electrons almost not affected, but noticeably modifies the dipole polarizability of the 4d shell. In contrast to Xe@C60, the Giant resonance in is almost not modified by C60 shell, since it is manifested by fast photoelectrons that penetrate the C60 shell without prominent distortion. This work was supported by Binational Science Foundation, grant 2002064 and Israeli Science foundation, grant 174/03.

Hydrogen in nano-diamond films

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(Submitted by Alon Hoffman, Technion, Chemistry Department, choffman@tx.technion.ac.il)

The distribution, content and bonding of hydrogen in nano-crystalline carbon films possessing a prevailing diamond character the films are investigated by secondary ion mass spectroscopy (SIMS), high resolution electron energy loss spectroscopy (HREELS) and Raman spectroscopy. The films were deposited by DC glow discharge chemical vapor deposition from a methane:hydrogen mixture. Following the formation of a thin oriented precursor graphitic film, diamond nucleation occurs and a nano-diamond film grows. The hydrogen content in the precursor oriented graphitic film is $\sim$ 5 at %. Concurrently with the nucleation and growth of nano-diamond a considerable increase of the hydrogen concentration in the films occurs reaching a value of 15-20 at %. This is accompanied by appearance of $\sim$ 1150 cm-1 and $\sim$ 1450 cm-1 Raman peaks, attributed to distinctive bonding of hydrogen in nanodiamond films. In this work the origin of the Raman peaks was investigated by means of isotopic shift on the films deposited from deuterized and C13 gas mixtures. The HREELS revealed a broad band associated with CH vibration centered at 362 meV. Concurrently with film evolution the full width half maximum of this band broadens from 33 to 42 meV and it shifts from 362 meV to 367 meV. From EELS measurements it was determined that the hydrogen plasma at the conditions applied for nano-diamond growth disrupts the crystalline structure of diamond resulting in an amorphous surface layer. In this work we further corroborate the role of hydrogen as bonding and displacing agent during diamond nucleation and nano-diamond growth as was recently proposed by us [Y. Lifshitz, X. M. Meng, S.T. Lee, R. Akhvlediani, A. Hoffman, Phys. Rev. Lett. 2004 (93) 056101].

Granular segregation: Simulating the expected and the unexpected

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Studies of granular media continue to produce surprising results that are unique to this class of matter. A particularly prominent feature of granular mixtures is the tendency to segregate into their individual components when externally driven in various ways, an effect that is not without consequences for industrial processing. This talk describes the computer simulation of several different modes of segregation in flowing, rotating and vibrating granular media, in some cases reproducing known behavior, in others predicting effects that have yet to be observed experimentally. The talk will be accompanied by computer demonstrations of these effects.

Computer simulations of the damage due to the passage of a heavy fast ion through diamond

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We present tight-binding molecular dynamics simulations of the structural modifications that result from the "thermal spike" that occurs during the passage of a heavy fast ion through a thin diamond or amorphous carbon layer, and the subsequent regrowth upon cooling. The thermal spike and cooling down are simulated by locally heating and then quenching a small region of carbon, surrounded either by diamond or by a mostly sp^3 bonded amorphous carbon network. For the case of the thermal spike in diamond we find that if the "temperature" (kinetic energy of the atoms) at the center of the thermal spike is high enough, an amorphous carbon region containing a large fraction of threefold coordinated C atoms (sp^2 bonded) remains within the diamond network after cooling. The structure of this amorphous layer depends very strongly on the "temperature" of heating and on the dimensions of the thermal spike. Scaling is found between curves of the dependence of the percentage of sp^2 bonded atoms in the region of the thermal spike on the heating "temperature" for different volumes. Justification of the validity of the tight-binding approximation for these simulations will also be given.

Residual strength of randomly perforated plates

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In an extensive series of about 60 experiments, variable number of holes (of about $0.8cm$ linear size) were drilled into a square aluminum plate (of $10cm$ length and about $0.5cm$ thickness) with the aim of measuring in a different set of experiments the residual strength of the perforated plates. This was done by pulling at an edge of the plate (in a tensile-testing configuration) until the plate came apart. The applied force needed to achieve this was associated with the residual strength S_r of the plate.
It was found that S_r approached zero at perforation area densities ρ that corresponded to the percolation limit ρ_c in two dimensions. Near this limit, the observed strength (expectedly) underwent significant statistical fluctuations. This focused our attention to the different geometrical arrangements of the holes in the various plates (those having the same ρ) . We have also utilized a numerical algorithm[1] to simulate the time development of the individual perforated plate, as the edge-displacement was increased. The experimental rupture path has been successfully reconstructed in all configurations. Good overall correlation ($r^2 \approx 0.99$) was found between the calculated and measured values of $S_r(\rho)$.
Detailed examination has also shown that when the pulling force is applied, the first (and decisive) rupture in the already perforated plate occurs at a "neck", namely, where the material is at its smallest width. We have theoretically investigated the anticipated outcome of pulling, when there are more than one necks of the same width. Based on a simplified model, the theory indicates that the geometry that leads to an efficient channelling of the stress applied at the edges to the neck is the one that promotes the rupture at the neck.

References

[1] MSC Dytran (MSC Software Corporation, Santa Ana, Ca. 92707, USA)

Brownian simulations and uni-directional flux in diffusion

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(Submitted by Amit Singer, Department of Applied Mathematics, Tel Aviv University, amits@post.tau.ac.il)

The prediction of ionic currents in protein channels of biological membranes is one of the central problems of computational molecular biophysics. Existing continuum descriptions of ionic permeation fail to capture the rich phenomenology of the permeation process, so it is therefore necessary to resort to particle simulations. Brownian dynamics simulations require the connection of a small discrete simulation volume to large baths that are maintained at fixed concentrations and voltages. The continuum baths are connected to the simulation through interfaces, located in the baths sufficiently far from the channel. Average boundary concentrations have to be maintained at their values in the baths by injecting and removing particles at the interfaces. The particles injected into the simulation volume represent a unidirectional diffusion flux, while the outgoing particles represent the unidirectional flux in the opposite direction. The classical diffusion equation defines net diffusion flux, but not unidirectional fluxes. The stochastic formulation of classical diffusion in terms of the Wiener process leads to a Wiener path integral, which can split the net flux into unidirectional fluxes. These unidirectional fluxes are infinite, though the net flux is finite and agrees with classical theory. We find that the infinite unidirectional flux is an artifact caused by replacing the Langevin dynamics with its Smoluchowski approximation, which is classical diffusion. The Smoluchowski approximation fails on time scales shorter than the relaxation time $1/\gamma$ of the Langevin equation. We find that the probability of Brownian trajectories that cross an interface in one direction in unit time Δt equals that of the probability of the corresponding Langevin trajectories if $\gamma\Delta t = 2$. That is, we find the unidirectional flux (source strength) needed to maintain average boundary concentrations in a manner consistent with the physics of Brownian particles. This unidirectional flux is proportional to the concentration and inversely proportional to $\sqrt{\Delta t}$ to leading order. We develop a BD simulation that maintains fixed average boundary concentrations in a manner consistent with the actual physics of the interface and without creating spurious boundary layers.

Spontaneous superconducting islands

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(Submitted by Jorge Berger, Ort-Braude College, phr76jb@tx.technion.ac.il)

We study a clean superconductor in the Hall configuration, in the framework of a purely dissipative time-dependent Ginzburg–Landau model. We find situations in which the order parameter differs significantly from zero in a set of islands that appear to form a periodic structure. When the pattern of islands becomes irregular, it moves in or against the direction of the current and a Hall voltage is found. Tiny differences in the initial state may reverse the sign of the Hall voltage. When the average Hall voltage vanishes, the local Hall voltage does not necessarily vanish. We examine the influence that several boundary conditions at the electrodes have on these effects.

Shape variation of the two-electron photoionization spectrum with photon energy growth

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(Submitted by Evgeny Liverts, Racah Institute of Physics, The Hebrew University, Jerusalem 91904, Israel, liverts@phys.huji.ac.il)

We trace the evolution of the shape of the two-electron photoionization spectrum with photon energy growth using quite a precise two-electron wave functions, obtained by Correlation Function Hyperspherical Harmonic Method. We obtain the values of ω_1 and ω_2 at which the spectrum curve changes its shape. At $\omega = \omega_1$ the **U**-shape changes to **W**-shape. At $\omega = \omega_2$ the central **W** peak splits into two. We consider ground states of the helium atom and of helium-like ions with the nuclear charge Z, the negative ion of hydrogen H^- and the excited n^1S states of helium. The limiting laws for $Z \gg 1$ and $n \gg 1$ are obtained. The analysis is carried out without calculations of the particular energy distributions themselves.
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Atomistic simulation of separation of hydrogen and hydrocarbons in carbon nanotubes

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(Submitted by Tali Mutat, Technion, talimu@tx.technion.ac.il)

As an important research direction in nano-science and nano-technology, carbon nanotubes have aroused great interest, due to their unique structure and stability. We are studying the transport and separation of hydrogen and hydrocarbons mixtures, which is of considerable research interest in the chemical and pharmaceutical industries. Computational methods, such as Molecular Dynamics or Monte Carlo simulation, have been widely applied to determine the nature of the diffusion of molecules inside carbon nanotubes.
Transport phenomena in carbon nanotubes depend on the pore size, the pore network structure, the molecule dimensions, the temperature of the gas mixture and the interaction between the transported mixture and the tube. The solid tube is modeled using the Brenner (Bond-Order) potential energy which can model intermolecular chemical bonding in a variety of small hydrocarbons as well as graphite. I will present a Molecular Dynamics simulation of diffusion of methane molecules inside carbon nanotube, and find obtain the apparent diffusivity values.

Path integral Monte Carlo study of phonons and vacancies in the bcc phase of ^{4}He

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(Submitted by Slava Sorkin, Technion - Israel Institute of Technology, phsorkin@techunix.technion.ac.il)

Anharmonic effects become significant for all crystals at high enough temperatures, but for the quantum crystals they are important even at zero temperature. Self consistent phonon theory is the standard method for evaluating the dynamics of quantum solids. As an alternative to this perturbation method, we use quantum Monte Carlo simulations to study the dynamics of atoms in solid ^{4}He.
We estimate both the one-phonon and total dynamic structure factor for solid ^{4}He in the bcc phase at the finite temperature T = 1.6 K. A path integral Monte Carlo simulation is performed to compute the imaginary-time intermediate scattering function from which the dynamic structure factor is extracted by thr maximum entropy method. The longitudinal and transversal phonon branches are calculated along the main crystalline directions ([001],[011] and [111]).
In addition we use the path integral Monte Carlo method to determine the energy of formation of single vacancies at T = 1.6 K. We present data on the relaxation of the neighboring atoms around vacancy and on the correlation between vacancies. Following the path of the vacancy during our simulation we observe the delocalization of vacancies in ^{4}He.

A numerical model based on variational principle for airfoil and wing aerodynamics

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Over the last few years, finite element algorithms for solution of the Euler flow equations have gained increased popularity. The objective of the current research is to develop a new method to solve the Euler flow equations numerically using a variational technique for airfoil and wing aerodynamics. A new formulation of Eularian variational principle satisfying the Kutta condition is suggested, and a numerical implementation is presented. The proposed method can obtain improved solution, especially for complicated geometries. A computer code named FLUIDEX was developed to analyze barotropic fluid dynamics. The solution of the flow problem is obtained by using numerical algorithm to find the extremum value of an Action i.e. by a variational principle. Predictions of the FLUIDEX numerical model were analyzed for particular cases of potential flow (compressible and incompressible). The results were successfully compared against exact analytical solutions for potential flow test problems. The proposed method obtains fast and stable solutions without the need to integrate the equations in time and space, and thus enables a considerable reduction of the time and cost of the solution.

Molecular dynamics simulation of granular segregation in a rotating cylinder

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Discrete-particle simulation methods have been used to study segregation in a rotating horizontal cylinder partly filled with a mixture of two different types of grains. Radial segregation is observed to occur under a wide range of circumstances, with the small particles concentrated in the inner region of the bulk parallel to the cylinder axis. Axial segregation is also found to appear under suitable conditions, in which the particles separate into a series of bands perpendicular to the axis. The system exhibits time-dependent behavior that can include rapid initial formation of the radial core, which then gradually vanishes as the axial bands develop; this corresponds to behavior that is observed experimentally. A variety of parameter settings have been examined in order to determine how the details of the model influence the segregation process.

Physiological and clinical applications of the photoplethysmographic signal variability

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Photoplethysmography (PPG) records the cardiac induced changes in tissue blood volume by light transmission measurements. The baseline and the amplitude of the PPG signal, measured in the finger, show very-low-frequency (VLF) spontaneous fluctuations, which are mediated by the sympathetic nervous system. The VLF fluctuations of the amplitude of the PPG signal and the inverse of its baseline (a parameter which is related to blood volume) show significant negative correlation with the VLF spontaneous fluctuations of the systolic and diastolic blood pressure, measured by Finapres (mean correlation coefficient 0.67-0.83). In most examinations the VLF fluctuations of the heart period negatively correlated with blood pressure VLF fluctuations, but for some examination the correlation was positive. We also examined the correlation of the baseline and the amplitude PPG fluctuations between right and left. The PPG signal was simultaneously measured in the two index fingers and the two second toes of diabetic patients and non-diabetic subjects. The VLF fluctuations in the baseline showed high right-left correlation both for fingers and toes (mean 0.93) for the non-diabetic subjects, and significantly lower correlation (0.78 and 0.84, respectively) for the diabetic patients. Similar results were obtained for the amplitude VLF fluctuations. Since sympathetic neuropathy is one of the diabetic complications, the lower right-left correlation for some diabetic patients probably indicates sympathetic neuropathy. The right-left correlation coefficients of the PPG fluctuations provide simple and convenient means for assessing the adequacy of the sympathetic nervous system function.

Ventilation of the Alveolar layer: A model of airways elastic response to changes in the pleural pressure and the potential effect on blood O_2 saturation.

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The main roll of the human lung is to conduct O_2 and CO_2, to and from the alveolar layer, the location of gas-exchange with the blood in the pulmonary cycle. Hence, the efficiency of respiration depends mainly on the ventilation of the alveolar layer and on the conditions for diffusion across the alveoli wall. Both these conditions vary within a single respiration cycle and between cycles. During each cycle, the ventilation of the lung relays mainly on the elastic inflation and relaxation of the airways in response to changes in the pleural pressure. The resulting ventilation of the alveolar layer as well as the momentary distribution of volume and O_2 partial pressure within the alveolar layer all depend on the morphology of the bronchial tree, namely the specific elastic properties of the airways and their resistance to flow.

We present a model of lung elastic response to changes in the pleural pressure, based on minimal energy formalism. This model provides a unique description of gas flow and mixing within the lung during respiration depending on lung morphology and respiration pattern. Namely concluded from this model are the momentary ventilation and distribution of gas within the alveolar layer. Given this and a simplified description of O_2 diffusion from the alveolar layer into the pulmonary capillaries, a quantative evaluation of Hb O_2 saturation level in the blood is obtained. This is presented as an assessment for lung efficiency depending on the respiration pattern. The model incorporates a simplified binary tree description of the bronchial tree with additional parameters for describing distribution of elastic fibers within the airways wall. The potential energy of an airway when inflated from its initial volume 'Vi' to a final volume 'Vf', given an external pleural pressure 'Pp' is calculated. Minimizing this energy per each airway ills the steady state volume of the average airway in each generation as a function of Pp. The basic model considers a bronchial tree with non-resistive to flow, such resistance may be added later using a similar formalism. Using this approach we were able to estimate the Pressure-Volume curve of a specific lung and to investigate the dependence of this curve on local lung morphology.

The cardiac muscle molecular motor and related clinical implications

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Cardiac muscle mechanical function is generated by the sarcomeres, the intracellular contractile elements, and is determined by the interaction between the actin myosin filaments, and the creation of the cross-bridges (Xbs). The Xbs are linear motor units which convert biochemical to mechanical energy, generate force and contract the sarcomere, hence the muscle, by filament sliding and sarcomere shortening. It is important to note that the head of the myosin is 19nm long and 5nm thick, much smaller than any human-made nano-motor. The isolated myosin head creates a unitary force of about 2pN and a stroke step of 5nm. Each cubic mm of muscle tissue contains 401012 motor units. It is obviously interesting to know how does muscle regulates this huge number of motor units and what are the mechanisms that yield the outstanding efficiency of around 70Motility assays and isolated fibers studies elucidate the underlying molecular mechanisms, and establish the basis for the analytical description of energy conversion in the cardiac muscle. The data support the hypothesis that Xb dynamics is determined by two distinctive kinetics: a fast physical one, which relates to Xb attachment-detachment, and a slow one, which relates to the biochemical reactions of nucleotide binding and dissociation. In general, the study enhances our understanding of the mechanisms of motion in the biological world. It links basic molecular studies to the biophysics of the whole muscle and cardiac contraction. It allows differentiating between normal and pathological hearts and has significant implications for future development of therapeutic modalities and an important research avenue into molecular and genetic engineering.

Novel procedure for perfusion evaluation based on contrast echo

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Current uses of Ultrasonic Contrast agents in Echocardiography are usually limited to “Left Ventricular Opacification”. In this procedure, the Left Ventricular (LV) cavity is filled with the highly reflective Contrast agent, which improves the visualization of the LV wall-motion. In addition, the feasibility of measuring LV local Myocardial perfusion using contract Echocardiography has been proven in numerous papers. The method measures the time-dependency of Contrast agent's concentration within the Myocardium based on the fact, that the local Contrast agent concentration is linearly correlated to the gray-level in the Echocardiographic image. However, while having the potential to reduce the need for exploratory Angiography (an invasive procedure), and even partially replace SPECT (Single Photon Emission Computerized Tomography) imaging, this method is rarely used clinically. Its main flaw is its lengthy data acquisition protocol (usually over 30 [sec]), which requires that the imaging plane does not change for the entire period of time. Furthermore, the data analysis usually requires extensive human intervention. The lecture presents a novel procedure for data acquisition and analysis, supplying quantitative evaluation of the local perfusion within the entire cardiac muscle based on the data acquired during a single heartbeat. The imaging is performed only after the concentration of the Contrast agent within the Myocardium has reached steady state. Our technique has been tested on six cine-loops of five different patients. The results show high correlation between the calculated perfusion and the clinical evaluation of segmental contractility, based on Echocardiographic imaging (the mean calculated perfusion level for normo-kinetic tissue is 52 +/- 24 [%], while the mean perfusion level for hypo-kinetic and a-kinetic tissue is 20 +/- 20 [%]).

Changes in plasma during treatment of leukemia using advanced FTIR-microspectroscopy

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FTIR spectroscopy has been gaining wide recognition as a technique suitable for medical diagnostics due to its rapid, sensitive and reagent free nature. Blood plasma analysis by FTIR spectroscopy has been used to monitor levels of metabolites during disease and recovery conditions. In the present work, we describe the analysis of plasma of patients undergoing treatment for leukemia and the changes in spectral features that help to monitor the developments and response to treatment. A group of healthy volunteers was used as a control group. Cluster analysis of the spectral data in the region 900-1185 cm-1, 1352-1479 cm-1, 1479-1597 cm-1 corresponding to glucose/phosphates, lipids and proteins showed that the plasma from healthy people were always different from that of the patients. Thus, it was clear that within the treatment period, the plasma was not comparable to those from the group of healthy people, and though clinically the persons had responded to treatments resulting in recovery from leukemia (decrease in blasts counts), their body physiology/metabolism was yet to return to normal. The work is a preliminary effort towards identifying a methodology for monitoring effect of treatment profiles in patients undergoing chemotherapy.

Shaping thin sheets and the geometry of wavy leaves

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Gauss's famous theorem (theorema egregium) establishes the connection between intrinsic metric properties of a surface and its possible shapes in space. This link provides a powerful mechanism, not yet studied, for the generation of complex three dimensional shapes from thin elastic sheets, by prescribing curved metrics on them. For example the edge of a torn plastic sheet is composed of an organized cascade of waves. The waves are similar in shape but differ greatly in scale, leading to the formation of a fractal edge as an equilibrium configuration. We show that the tearing process prescribes a hyperbolic metric near the edge of the sheet. This metric should be satisfied in order to reduce the stretching energy, but the limitations on the embedding of such a metric in Euclidean space "force" the sheet to wrinkle. We use environmentally responsive gels to form "engineered sheets" – sheets that adopts a prescribed metric upon induction by environmental conditions. With this system we can study the shaping mechanism in a large variety of metrics. We suggest that some complex shapes of leaves and flowers might result from this buckling instability that links between simple growth and complex configuration. The complexity, in this case, results from elasticity and not from complex growth processes, as commonly accepted.

Inertial waves induce segregation of suspended particles in a rotating fluid

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A dilute suspension of particles in an almost inviscid fluid that fills a rotating horizontal cylinder has recently been observed to segregate into well-defined periodic vertical bands. We present the results of an extensive experimental investigation into the main features of this phenomenon, including the dependence of the periodic spacing between bands on the tube length and a previously unreported phenomenon of oscillations betwen two interleaving band patterns. A theoretical approach to the banding mechanism, assuming very small Ekman and Rossby numbers, is presented whereby the gravity-induced motion of the suspended particles excites inertial waves, whose flow pattern leads to the observed axial segregation. The flow pattern has been visualized. The experimental results agree well with the theory with no adjustable parameters. We shall discuss some effects of viscosity and non-linearity which were neglected in the theory.

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Unexpected nonlinear effects and critical coupling in NbN superconducting microwave resonators

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In this work, we have designed and fabricated several NbN superconducting stripline microwave resonators sputtered on sapphire substrates. The low temperature response exhibits strong and unexpected nonlinear effects, including sharp jumps as the frequency or power are varied, frequency hysteresis loops changing direction as the input power is varied, and others. Contrary to some other superconducting resonators, a simple model of a one-dimensional Duffing resonator cannot account for the experimental results. Whereas the physical origin of the unusual nonlinear response of our samples remains an open question, our intensive experimental study of these effects under varying conditions provides some important insight. We consider a hypothesis according to which Josephson junctions forming weak links between the grains of the NbN are responsible for the observed behavior. We show that most of the experimental results are qualitatively consistent with such hypothesis. While revealing the underlying physics remains an outstanding challenge for future research, the utilization of the unusual nonlinear response for some novel applications is already demonstrated in the present work. In particular we operate the resonator as an intermodulation amplifier and find that the gain can be as high as 15 dB. To the best of our knowledge, intermodulation gain greater than unity has not been reported before in the scientific literature. In another application we demonstrate for the first time that the coupling between the resonator and its feed line can be made amplitude dependent. This novel mechanism allows us to tune the resonator into critical coupling conditions.

Experimental control of spatio-temporal chaos in parametrically excited surface waves

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The study of parametrically driven surface waves has been of much recent interest. In particular, recent experiments where the system is driven by two commensurate frequencies has revealed a number of interesting nonlinear states. Among these is an "unlocked" state, which is excited in the near vicinity of the system's first bifurcation, and exhibits highly disordered behavior in both space and time. Our current research is focused on both the characterization and control of this state. We find that this disordered state can be stabilized and a rapid switching to spatially ordered patterns can be accomplished by the addition of a small amplitude 3rd frequency excitation. The spatial symmetry of the selected pattern is governed by the temporal symmetry of the third frequency used.

Detachment fronts and the onset of a dynamic friction

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Though studied for hundreds of years by names as distinct as Leonardo da Vinci, Coulomb, and Hertz many aspects in the study of solid friction remain as fresh today as they were was five hundred years ago. One such aspect is the onset of slip. First described by Coulomb and Amontons as the transition from static to dynamic friction, the onset of frictional slip is central to fields as diverse as physics tribology, mechanics of earthquakes and fracture. We perform real-time measurements of the net contact area between two blocks of like material at the onset of frictional slip. We show that the process of interface detachment, which immediately precedes the inception of frictional sliding, is governed by three different types of detachment fronts. These crack-like detachment fronts differ by both their propagation velocities and by the amount of net contact surface reduction caused by their passage. Two of these, which propagate at Sub-Rayleigh and intersonic velocities, have been the subject of intensive recent interest. The most rapid fronts, propagating at intersonic velocities, generate a negligible reduction in contact area across the interface. Sub-Rayleigh fronts are crack-like modes which propagate at velocities up to the Rayleigh wave speed, VR, and give rise to an approximate 10% reduction in net contact area. We show that a new third type of front, which propagates an order of magnitude more slowly and and give rise to an approximate 20% reduction in net contact area is the dominant mechanism for interface detachment. No over all sliding occurs until either of the slower two fronts traverses the entire interface.

Diverging intermodulation gain in a nanomechanical duffing resonator

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Nanoelectromechanical (NEM) resonators are promising devices for applications such as sensing and signal processing. Nonlinear effects are of great importance for NEM devices. The relatively small forces needed for driving a NEM resonator into a nonlinear regime is usually easily accessible. Thus, a variety of useful applications such as frequency synchronization, frequency mixing and conversion, and parametric amplification, can be implemented by applying modest driving forces.
In this work we investigate the intermodulation gain near the onset of Duffing instability in a NEM resonator. The resonator is driven by an applied force composed of an intense pump with frequency f and a relatively small signal with frequency $f + df$. Due to nonlinear mixing, the resonator's response has an idler component with frequency $f - df$, which is being measured. Theoretical analysis predicts that the intermodulation gain near the onset of Duffing instability (infinite slope in the frequency response) diverges in the limit $df \to 0$ [1]. NEM resonators are fabricated using bulk-nano-machining process and their dynamics is characterized using a scanning electron microscope. In our experiments we study the dependence of the mechanical intermodulation gain on a variety of parameters. Our preliminary results show a partial qualitative agreement with theory.

[1] B. Yurke and E. Buks, unpublished.

Structure of random flows of a dilute polymer solution

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We investigate experimentally the structure and global features of random flows of a dilute polymer solution in a regime of elastic turbulence. By combined measurements of the flow resistance and time-resolved measurements, we provide a rather complete flow characterization as a function of the control parameter, the Weissenberg number (Wi). We investigate experimentally the statistics of the random flow by measuring Finite Time Lyapunov Exponents (FTLE's) as a function of the control parameter. The FTLE's are compared with Eulerian velocity correlation times and mean velocity gradients. The Lagrangian frame intermittency is captured by measurements of Generalized Finite Time Lyapunov Exponents (GFTLE's). The validity of the Taylor frozen flow hypothesis (TH) is studied by measuring the velocity coherence between pairs of points displaced both in time and space. The breakdown of the TH is further discussed in both the context of strong velocity fluctuations and long range spatial correlations which are a result of flow smoothness and lack of scale separation. A correction based on a different choice of the advection velocity is tested.

Chaos and mixing in micro-flows of a dilute polymer solution

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We present an experimental investigation of random micro- flow fields of a dilute polymer solution in a regime of elastic turbulence. Systematic investigation of micro-flows has shown that, when elastic stresses overcome the viscous ones (Wi¿1), the micro-flow becomes quite irregular and evolves (as Wi is further increased) towards a fully developed chaotic regime. Although the typical size of the elongated polymer molecules is likely to become comparable to the diameter of the micro-channel, most of the main features of elastic turbulence in macroscopic systems are observed: fast growth of flow resistance, randomly varying and strongly fluctuating velocity fields, fast and monotonous decay of Eulerian velocity correlations. We next show that such flows are an ideal realization of the Batchelor regime of mixing. The decay of a passive scalar in such random micro-flow was studied and a good agreement with recent theories was found.

Type specification of stability islands and chaotic stickiness

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A detailed characterization of stability islands in area-preserving maps is introduced on the basis of the resonance partition of phase space and it is used to define chaotic stickiness in these maps. It is shown that a general island can be characterized by a well-defined quasiregularity *"type"*, specifying the sequence of resonances visited by the island. In particular, a "tangle" island lies entirely not just within the turnstile lobe of a resonance but also within the *turnstile overlap* of two resonances. Chaotic stickiness to a given island is then defined as the coincidence of the type of a chaotic orbit with that of the island in some time interval. First aspects of stickiness, based on this definition, are studied in some detail and are illustrated in the case of an accelerator-mode island of the standard map.

Statistical physics and phase diagram of passive mode locking in lasers

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An important branch of laser physics deals with the formation of extremely short pulses, whose duration can be as short as 3 fs, i.e. two light cycle periods, by the action of a *saturable absorber*, a dissipative optical element which becomes more transparent for high intensity light. Until recently this has been the method of choice for the creation the shortest available optical signals. In an exciting new development, pulses created by passive mode locking are used to create even shorter pulses at extreme UV frequencies.

By its very nature the saturable absorber makes the continuous wave (CW) operation of a laser intrinsically unstable. However, it is experimentally well-known that there is threshold power requirement for the 'self-starting' of passive mode locking. This discrepancy has been an outstanding open question for more than three decades.

In a series of recent works [1, 2, 3, 4, 5] it has been recognized that the inevitable presence of *noise* in the laser gain mechanism must be taken into account in the study of mode locking. Ostentatiously weak, the noise action is enhanced by the large ratio of the intracavity length to the pulse width, and may compete with the absorptive nonlinearity, stabilizing CW and inhibiting mode locking.

The stochastic dynamics of the laser was mapped to an effective problem in equilibrium statistical mechanics with all its available powerful tools, where the noise power plays the role of temperature. It was shown that mode locking is in a precise sense a first order phase transition from the disordered CW state to the ordered pulsed operation, bearing similarity to liquid gas system. In the simplest cases thermodynamics depends on the dimensionless parameter γ, the product of the coefficient of saturable absorption and the intracavity power squared divided by the noise power. Furthermore, the statistical problem is solvable by mean-field-like methods, and explicit simple expressions are found for the mode locking threshold and the pulse power as a function of γ.

The system exhibits unusually strong hysteresis, and is characterized by the existence of a metastable disordered state for arbitrarily low positive temperature. The theory thus explains the self-starting problem. More recently we have been able to calculate activation rates and the corresponding lifetime of the metastable states.

The present approach has many ramifications and diverse applications, several of which were studied or are being studied at the moment. When the saturable absorber is characterized by an oscillatory transmissivity, mode locking into multi-pulse configuration occur as a cascade of first order phase transitions. Experiments in such systems were performed showing remarkable agreement with theoretical predictions. External driving may be applied to the system by feeding externally generated pulse. A rich phase diagram is then obtained displaying several phases and critical phenomena.

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Design and robustness of delayed feedback controllers for discrete systems

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We study a matrix form of time-delay feedback control in the context of discrete time maps of high dimension. In almost all cases where standard proportional feedback control methods can achieve control, time-delay feedback controllers containing only static elements can be designed to achieve identical linear stability properties. Analysis of an example involving a ring of coupled maps that can be controlled at only two sites demonstrates that the time-delay controller equivalent to a standard optimal controller can be equally robust in the presence of noise, except at special points in parameter space where the uncontrolled system has a mode with Floquet multiplier exactly equal to 1. Numerical simulations confirm the results of the analysis.

Numerical tools for the study of defect dynamics in quasiperiodic structures

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We have developed a set of numerical tools for the quantitative study of defect dynamics in quasiperiodic structures, with the intention of addressing in the near future some of the open questions regarding the dynamics of dislocations in quasicrystals. We intend to apply these tools to study dislocation motion in the dynamical equation of Lifshitz and Petrich [1] whose steady-state solutions are quasiperiodic, exhibiting dodecagonal (12-fold) rotational symmetry.

Here we demonstrate our ability to inject an arbitrary set of dislocations—parametrized by the homotopy group of the D-torus (here D=4)—and quantitatively follow the positions of these dislocations as the equation evolves in time. We measure dislocation velocities as a function of applied stress and shear, as well as the phonon and phason strains that accompany this motion as the system evolves in time.

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Vibrational excitation of molecules by chirped laser radiation in ladder-climbing and autoresonance regimes

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Vibrational excitation of molecules or dissociation without ionization is of great importance for initiation and improved efficiency of certain chemical reactions. Therefore, since the emergence of lasers, a long standing goal was to excite and control molecular dissociation or molecular vibrations by laser radiation. Direct excitation of high vibrational levels in a molecule by a monochromatic radiation is inefficient, due to the small value of the transition dipole moment between the initial and final states. An alternative is to create a cascading transition from the initial to the final state through a series of intermediate levels by using a chirped light pulse having a continuously varying frequency. This method is usually referred to as a vibrational ladder climbing (LC).The dynamic autoresonance (AR) is a method to excite a classical oscillatory, nonlinear system to high energies and control the excited state by changing the driving frequency. This method is general and has been applied in many fields of physics. It has been identified that in both the AR and the LC, the external driving force (due to the laser radiation) should exceed some threshold in order to excite the nonlinear system efficiently. This threshold is in general a function of the chirp rate and the physical properties of the system, such as the dipole moment and the nonlinearity coefficient. Here we will discuss the similarities and differences between the LC and the AR regimes. We shall introduce two parameters P1 and P2, fully characterizing the domains of ladder-climbing and autoresonance in the parameter space. We will show that there is a smooth transition from the LC to the AR regions in the P1-P2 plane. Finally, we shall describe an experiment conducted in our laboratory to demonstrate these methods in application to Hydrogen-fluoride molecules.

Phase synchronization decay of fixational eye movements

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When we view a stationary scene, our eyes perform extremely small autonomic movements. These fixational eye movements are produced involuntarily and are characterized by three different movements: (i) high-frequency small amplitude tremor, (ii) slow drift, and (iii) fast microsaccades. In general, it is thought that these movements serve to counteract visual system adaptation by generating small random displacements of the retinal image in stationary viewing.

We investigated the dynamic behavior of fixational eye movements using the phase synchronization decay method. This method detects weak phase synchronization between records that seem to be uncorrelated and thus are likely to be from coupled systems. We calculate the synchronization index versus the time delay between the records. The synchronization index quantifies the sharpness of the peak of the histogram of the phase differences between the two signals.

We tested all the six possibilities of synchronization between eyes components: two eyes horizontal; two eyes vertical; Right eye horizontal and left eye vertical; Right eye vertical and left eye horizontal; Right eye horizontal and vertical; Left eye horizontal and vertical. Our results show that only two combinations are synchronized: Right eye horizontal and left eye horizontal, and right eye vertical and left eye vertical. We noticed that there are significant differences in synchronization between horizontal and vertical components - we found that vertical components are more synchronized than horizontal.

Spatio-temporal investigation of ultrasound scattering by a flow: A characterization tool in turbulence

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A measurement tool has been developed based on multi-channel sampling of coherent ultrasound pulses that travel through a flow. An array of acoustic detectors is placed on the wall of the liquid cell in the forward beam. Using a wave construction method similar to the Huygens principle in optics we retrieve the scattering wave induced by the flow, projected to the far field. Consequently, the vorticity of a single vortex flow is extracted, as well as the energy and enstrophy of a turbulent flow. Additionaly, by plotting the spatio-temporal map of phase shift fluctuations one can deduce about the average advection velocity.

A new theoretical estimate for the westward propagation speed of planetary waves

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Recent observations, made by the radar altimeter aboard the Topex/Poseidon satellite demonstrate a slower westward propagation speed than predicted by the classical theory of planetary waves developed 65 years ago by Carl-Gustav Rossby. Some of factors contributing to the shortcoming of the classical theory are the simplification of the spherical geometry by a local planar one and the assumption of near non-divergence of the flow. In the talk I'll review the effect of each of the simplifying assumptions that lead to the planar theory and develop how linear wave dynamics can be transformed into a linear, Sturm-Liouville, eigenvalue problem that has the form of Schrudinger equation with a quadratic potential. Standard WKB method can be employed to obtain higher order solutions of the eigenvalue problem. The resulting phase speeds in the new theory are always higher (in absolute value) than in the classical theory, which is consistent with the Topex/Poseidon observations.

Investigating Paleolithic flint tools with cosmogenic ^{10}Be

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Based on the measurement of concentrations of *in-situ*-produced cosmogenic ^{10}Be nuclides, we present a new approach to the study of Paleolithic and Neolihic flint tools. The *in-situ* buildup of ^{10}Be in a flint matrix is related to the exposure time of the flint to cosmic rays. Although this exposure history can be complex, the ^{10}Be content of flint assemblages can show whether the raw material used to manufacture the tool was obtained from surface collection and/or shallow mining as opposed to sediments two or more meters below the surface. The development of mining to acquire the best raw materials for producing stone tools represents a breakthrough in human technological and intellectual development. Flint artifact assemblages from two Palaeolithic caves in Israel, Tabun and Qesem, were analyzed and we show that these assemblages have different concentrations of ^{10}Be, indicating different raw material procurement strategies.In Tabun cave the flint artifacts from Lower Layer E (Acheulo-Yabrudian, around 400,000–200,000 yr ago) contain very small amounts of ^{10}Be, which is consistent with flint procured from sediments two or more meters deep. Artifacts from above and below Tabun Lower Layer E show a more complex distribution, as do artifacts from all layers of Qesem cave (Acheulo-Yabrudian). This is probably due to the fact that there the flint was surface collected and/or mined from shallow (less than 2 m) depths.

Ab-initio calculation of inelastic reactions in light nuclei

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In the last few years we have witnessed a tremendous progress in ab-initio calculation of light nuclei. This progress results from both the improvement in computational power and the development of new and powerful theoretical techniques. These techniques allow comparison of experimental results with predictions which depend only on the nuclear force model. In this talk I shall present recent theoretical developments in this field, and review the challenges presented by the available experimental data.

Loosely bound three-body nuclear systems in the J-matrix approach

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Extension of the oscillator-basis J-matrix formalism on the case of true A-body scattering [1] is discussed. The approach links the quantum scattering theory formalism with traditional variational methods of nuclear theory based on the wave function expansion in the harmonic oscillator function series. The hyperspherical harmonics method [2] is used for the description of A-body democratic $A \to A$ decay channels, which are the only channels allowed for in an asymptotic region.
The formalism is applied to the light weakly bound ^{11}Li and ^{6}He nuclei within three-body cluster models $^{9}\mathrm{Li} + n + n$ and $\alpha + n + n$ [3]. It should be noted that none of the two-body subsystems of these neutron halo nuclei has a bound state.
The J-matrix formalism is used not only for the calculation of the three-body continuum spectrum wave functions but also for the calculation of the S-matrix poles associated with the ^{11}Li and ^{6}He ground states to improve the description of the binding energies and ground state properties as well as low-energy electromagnetic excitations. The effect of the phase equivalent transformation of the $n-\alpha$ interaction on the properties of the ^{6}He nucleus is examined.

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The radon diffusion length in building materials: Measurement and impact on concentration indoors

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The radon (Rn222) gas, progeny of the natural uranium (238U) decay chain, is continuously produced in soil and in building materials derived from soil. Their porous structure allows radon penetration into the dwellings, from soil via the material or by emanation from the material itself. Radon progeny inhalation into the lungs leads to strong alpha particle damage of the tissue. The prolonged irradiation may result in lung cancer.
The diffusion length is the essential parameter determining the radon exhalation from the building material. This work presents a simple technique for determining the radon diffusion length in different building materials. A mathematical model describes the process of radon diffusion in a hermetically closed chamber, separated in two sections by a material sample. The derived relations allow evaluating the radon diffusion length in the material from measurements of the radon concentrations in the two sections. The radon concentration is measured by either passive (electret and activated charcoal) standard detectors or by a continuous radon monitor. Experimental results are presented for the diffusion lengths in ordinary building materials (concrete and gypsum) and in materials used for insulating the building from the soil (polyethylene and bitumen foils).
The measurement of the radon diffusion length in concrete and in the insulating material located underneath the basement slab allows optimizing the material thickness (about three times the diffusion length) to suppress radon penetration from the soil. Reliable measurements of the radon diffusion length in ordinary building materials (massive concrete and building blocks) allows estimating, already at design stage, the expected exhalation rate from the walls, the radon concentration in the air and finally the annual radiation dose to the population, as required by a recent Israeli standard.

A new determination of the $S_{34}(0)$-factor from new precision cross section measurements

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The ^{3}He(^{4}He,γ)^{7}Be reaction is one of the remaining major sources of uncertainty in determining the high energy solar neutrino flux [1] and also plays an important role in understanding the abundances of primordial ^{7}Li [2] and of nuclei of mass $\geq$12. From the compilation of existing data [3], a significant scatter can be seen, resulting in a considerable uncertainty on the adopted astrophysical $S_{34}(0)$ factor [4]. However, almost no attempt was made towards more accurate measurements nearly for two decades. We carried out recently a precision measurement of this cross section at energies around $E_{c.m.}$= 360 - 950 keV at Weizmann Institute of Science using a ^{3}He (^{4}He) beam from the 3 MV Van de Graaff accelerator, a ^{4}He (^{3}He) gas cell and a Ni window typically of 1 μm thickness. The gas cell, including an electron suppressor, is in electric contact with a Cu stopper and serves as a Faraday cup to determine the number of impinging beam particles. We also monitor on-line the elastically scattered beam from the Ni window, using a Si surface barrier detector placed at 44.7° to the beam direction. The catcher distance from the Ni foil and the target gas pressure are adjusted and monitored to obtain an optimum target thickness at a given energy. The cross section is determined by measuring the ensuing ^{7}Be (478 keV γ) activity on a Cu catcher using a similar Ge detector setup as was used for the precision determination of the ^{7}Be target strength for an earlier S_{17} measurement [5]. Representative theoretical [2,6,7] fits to the present data yield an extrapolated value of $S_{34}(0)$=0.53(2)(1) keV-b. The errors in brackets are from the experimental and theoretical uncertainties. The compatibility of previous data sets to our results and the implications of an improved $S_{34}(0)$ value to high energy solar neutrino flux and to the Big-Bang nucleosynthesis will be discussed.

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Study of the supernova nucleosynthesis ^{40}Ca(α, γ))^{44}Ti reaction

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Understanding of the nucleosynthesis of ^{44}Ti in the supernova environment stands out as particularly important in the view of the half-life (59.2 yrs) of the nuclide and the direct observation of its radioactivity by γ-ray astronomy in young supernova remnants. We have pursed the laboratory measurement of the yield of the production reaction ^{40}Ca (α, γ) ^{44}Ti in the range of incident energy E_{cm}= 0.5-1.1 MeV/nucleon, important for supernova nucleosynthesis. In our technique, we bombard a ^{4}He gas target with a ^{40}Ca beam and implant ^{44}Ti forward-recoiling ions into a catcher. Implanted ions are chemically extracted together with a ^{nat}Ti carrier of known amount (n_c) and the isotopic abundance r=^{44}Ti/Ti (in the 10^{-13} range) is determined by accelerator mass spectrometry (AMS), yielding the total number of produced nuclei in the target through the relation $n(^{44}\text{Ti})=n_c r$. In our experiment, a ^{40}Ca^{8+} beam, free of isobaric ^{40}Ar contamination, was obtained from the Koffler 14UD Pelletron Tandem Accelerator at the Weizmann Institute. the He (99.999%) gas target and a water-cooled high-purity Cu catcher are contained in an electrically insulated and secondary-electron suppressed chamber acting as a Faraday cup for the beam charge integration, using a 1.55 mg/cm^2 Ni foil as a pressure window. The average intensity of the incident ^{40}Ca beam (E_{lab}= 72 MeV) was 15 pnA and the total charge accumulated over a period of three weeks was 11.3 pmC. In order to dissipate the beam power absorbed in the foil, the beam was magnetically steered so that its spot on the pressure foil described a periodic spiral trajectory at constant velocity with an external radius matching the acceptance of the target chamber and that of the catcher. The thickness of the ^{4}He gas target (110 Torr, 23 cm) was selected to integrate the reaction yield from E_{cm}= 4.2 MeV (after the pressure foil) down to E_{cm}= 1.7 MeV (E_x=9.3-6.8 MeV). After activation, a 10 μm-thick layer was etched off the Cu catcher in a HNO_3 solution containing the 3 mg Ti carrier and Ti ions were separated from Cu and from Ca impurities by ion-exchange techniques. The measured total yield n_{44}=(4.9$\pm$0.4)$\times 10^7$ of ^{44}Ti produced in the activation corresponds to an overall resonance strength $\Sigma(\omega\gamma)_i$ between 24 and 60 eV depending on the resonance energies. This resonance strength is considerably larger than observed in previous prompt-γ measurements. The implication of this result in supernova nucleosynthesis will be studied.

Physical model for the calibration of activated charcoal radon detectors

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Radon (222Rn) is one of the ubiquitous pollutants of the indoor air. It penetrates dwellings from soil or by emanation from the walls. Prolonged exposure to the alpha radiation of its progeny may result in lung cancer. In Israel, the Ministry of the Environment limits its concentration to less than 200 Bq m3 and imposes regulations on the testing procedures.
Radon detection by passive adsorption into activated charcoal (AC) has evolved from the earliest improvised WWII gas mask filter to the present EPA standard diffusion barrier canisters and liquid scintillation vials. Radon atoms from the air are trapped by Van der Waals forces onto the huge pore surface of the charcoal. After the exposure, the AC is closed and the radon activity is measured by gamma or beta spectrometry. The radon concentration is measured as the ratio between the detector activity and a calibration constant, known as the effective volume, determined in a radon calibration chamber. Due to its simplicity, the AC detector has survived the competition of the more accurate electrostatic (electret), ionization chamber or solid-state detectors, and is still a widely used method for short-range radon tests.
However, the physical processes involved in the radon detection are not trivial. Due to radon decay the detector is not a true integrator. Its response to a variable radon concentration is different from the mean value. In addition, the competition between the adsorption and desorption of radon atoms and water molecules lead to a non-linear response. The calibration constant is a function of exposure time, temperature and humidity. Due to statistical fluctuations of the radon collection, a precise calibration requires averaging between 5-10 detectors. A systematic calibration over the standard 2-7 days exposure time and the ranges of humidity (30-80
In this work we propose a model that describes in more detail the physical processes governing the diffusion barrier AC 3 inch detector. The calibration constant is predicted as a function of four physical parameters which may be measured independently: maximal effective volume, relative humidity and the radon and water desorption rates. They are specific detector parameters and may be measured as a function of temperature. The predicted calibration constant is in good agreement with direct measurements in standard radon chambers.

Bulk excitations in Bose-Einstein condensates

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After a general theoretical and experimental review of weak Bogoliubov excitations in this novel superfluid (including some measurements of dephasing and decoherence), I'll discuss some of our more recent results and ideas about strong excitations. Some interesting symmetries of the three-wave mixing process (of momentum excitation wavepackets) will be presented. Namely, the mapping of the problem to an angular momentum basis. Next I'll show how a strong, moving optical lattice leads to a measured splitting in the excitation spectrum. Many of the dephasing effects present for weak excitations will be shown to be strongly suppressed. Also a remarkable change in the collisional decay of the system is observed, and explained by collisions between Bloch states. This intriguing dynamics may be simulated by stochastic evolution of the non-linear Schrodinger equation.

Brillouin-zone spectroscopy of nonlinear photonic lattices

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We present a novel, real-time, experimental technique for linear and nonlinear Brillouin zone spectroscopy of photonic lattices. The method relies on excitation with random-phase (partially-incoherent) waves and far-field visualization of the spatial spectrum of the light exiting the lattice. Our method allows for the characterization of the underlying lattice structure, while mapping out the borders of the extended Brillouin zones and marking the areas of normal and anomalous dispersion within them. Specifically, for photonic lattices with defects (e.g., photonic crystal fibers), our technique enables far-field visualization of the defect mode (guided mode) overlaid on the extended Brillouin zone structure of the lattice. The technique is general and can be used for photonic crystal fibers as well as for periodic structures in areas beyond optics.

Modulational instability and spontaneous pattern formation with incoherent white light

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One of the most fundamental phenomena in nonlinear dynamics is the spontaneous formation of ordered structures, known as pattern formation or modulational instability (MI). Essentially, MI is a process in which a spatially homogeneous state of a nonlinear system is becoming unstable and small spatial perturbations with a specific periodicity are enhanced through the nonlinearity, until diffraction, dispersion or diffusion counterbalances the effect and a regular pattern is formed. In optics, MI has been reported in many materials with diverse nonlinearities; however, until recently, pattern formation in nonlinear optical systems was studied with fully coherent light. Several years ago a new concept was introduced, when spontaneous pattern formation was predicted [1] and demonstrated [2] to occur with quasi-monochromatic spatially incoherent beams. Here we report the first experimental observation of pattern formation with incoherent white light [3]. We demonstrate that spatially and temporally incoherent beam, emanating from an incandescent light bulb and propagating in nonlinear medium, spontaneously break up to produce an ordered structure of 10-micron-thick filaments. We show that in this process, where all colors interact with each other, the whole temporal spectrum is collectively becoming unstable at a common threshold value of the nonlinearity and all wavelengths (temporal frequencies) “lock” to a single periodic pattern. Furthermore, we show that the spectrum of the pattern self-adjusts as the beam propagates in the nonlinear medium so that the contrast of the pattern is higher at shorter wavelengths, as predicted by our theoretical model [4].

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Polarization measurement by use of discrete space-variant subwavelength dielectric gratings

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Polarization measurement has been widely used for a large range of applications such as ellipsometry, bio-imaging, imaging polarimetry and optical communications. A commonly used method is measuring of the time-dependent signal once the beam is transmitted through a photoelastic modulator or a rotating quarter-wave plate followed by an analyzer. The polarization state of the beam can be derived by Fourier analysis of the detected signal. This method, however, requires a sequence of consecutive measurements, thus making it impractical for real-time polarization measurement in an application such as adaptive polarization-mode dispersion compensation in optical communications.
Recently, we developed a novel method for real-time polarization measurement by use of a discrete space-variant subwavelength dielectric grating (DSG) [1,2]. The formation of the grating is done by discrete orientation of the local subwavelength grooves. The complete polarization analysis of the incident beam is determined by spatial Fourier transform of the near-field intensity distribution transmitted through the DSG followed by a subwavelength metal polarizer. We realized the gratings for CO2 laser radiation at a wavelength of 10.6 micron on GaAs substrate utilizing advanced photolithographic and etching techniques [1-5]. We experimentally demonstrated the ability of our method to measure the polarization state for fully and partially polarized light.
Unlike other methods based on Fourier analysis, no active elements are required. It is possible to integrate our polarimeter on a two-dimensional detector array for lab-on chip applications to achieve a high-throughput and low-cost commercial polarimeter for biosensing. Currently we are investigating the possibility of using far-field measurement of the beam emerging from a DSG for polarization measurement.

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Dynamic magnetic imaging based on femtosecond pulsed laser

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(Submitted by Liat Szapiro, Tel-Aviv university, szapiro@post.tau.ac.il)

In recent years there has been growing interest in the response of magnetic materials, and itinerant ferromagnets in particular, to short-pulse laser excitation. The nature of the optically-excited, nonequilibrium condition and the reasons for the remarkably fast changes of magnetic contrast that accompany its evolution have been the subject of much debate. In contrast with the extensive efforts to understand this ultrafast optically-induced demagnetization, there has been little interest in magnetization reversal in response to short-pulse laser excitation of the same ferromagnets. We present an imaging system that can follow changes in the magnetic domain structure of the sample across the hysteresis loop with femtosecond temporal resolution, and in particular shows the local magnetization rotation. The imaging system, based on illumination by a femtosecond pulse, opens the way to a detailed, spatially and temporally-resolved study of demagnetization and magnetization reversal in ferromagnetic thin films, in response to short-pulse laser excitation.

Super and sub-Poissonian photon statistics for single molecule spectroscopy

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Single atoms in the process of resonance fluorescence exhibit well known effects of photon anti-bunching and related sub-Poissonian photon statistics. These behaviors indicate that photon emission events from a single source are correlated. In recent years sub-Poissonian statistics was observed for single molecules embedded in condensed phase environements. Due to different types of interactions between the molecule and its environment, sub-Poissonian statistics of single molecules is very different than that found for simple atomic systems. In our talk we will investigate the relation between spectral diffusion, and single molecule photon statistics. Transitions between quantum (sub-Poissonian) and classical (super-Poissonian) behaviors is found, as well as a transition between a fast modulation limit (motional narrowing limit) and a slow modulation limit. In particular we obtain an exact expression for Mandel's Q parameter for a single molecule undergoing a Kubo-Anderson spectral diffusion process and interacting with a cw laser field. A Lower bound on Q is found. We show that there exists an optimal Rabi frequency on which the quantum fluctuations become strongest. Comparison to experiment is made.

Propagation-invariant vectorial Bessel beams by use of subwavelength quantized Pancharatnam-Berry phase optics

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Propagation-invariant scalar fields have been extensively studied both theoretically and experimentally, since they were proposed by Durnin et al. These fields were employed in applications such as optical tweezers and for transport and guiding of microspheres. Although there has recently been considerable theoretical interest in propagation-invariant vectorial beams, experimental studies of such beams have remained somewhat limited. One of the most interesting types of propagation-invariant vectorial beam is the linearly polarized axially symmetric beam (LPASB) [1]. Recently, we introduced and experimentally demonstrated propagation-invariant vectorial Bessel beams with linearly polarized axial symmetry based on quantized Pancharatnam-Berry phase optical elements (QPBOEs) [2] and an axicon. QPBOEs utilize the geometric phase that accompanies space-variant polarization manipulations to achieve a desired phase modification [3]. To test our approach we formed QPBOEs with different polarization orders as computer-generated space-variant subwavelength gratings upon GaAs wafers for use with 10.6 micron laser radiation. The resultant beams were also transmitted through a polarizer that produced a unique propagation-invariant scalar beam. This beam has a propeller-shaped intensity pattern that can be rotated by simple rotation of the polarizer. We therefore have demonstrated the formation of a vectorial Bessel beam by using simple, lightweight thin elements and exploited that beam to perform a controlled rotation of a propeller-shaped intensity pattern that can be suitable for optical tweezers.

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Coherent addition of single mode and multimode laser beam distributions

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We present a unique approach for coherently adding various transverse field distributions of separate laser channels within a laser cavity. This includes the coherent addition of Gaussian channels, of single high-order mode channels, and even of spatially incoherent multimode channels. With this approach, self phase locking and coherent addition is achieved by use of intra-cavity interferometric combiners, so as to obtain a compact, stable and practical configuration. To verify our approach, we performed experiments with a pulsed Nd:YAG laser setup, in free running and Q-switched operation. We experimentally demonstrated coherent addition of 2 and 4 intra-cavity Gaussian channels, obtaining 92

Spectral-ballistic-imaging with sub-picosecond temporal resolution

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Spectral Ballistic Imaging (SPEBI) [1] was used to measure the impulse response of a two-layer optically turbid system with sub-picosecond resolution. The SPEBI technique emulated the illumination and detection of an optically diffuse medium with a sub-picosecond pulse. The optical target consisted of a reflecting surface concealed behind diffusive paper. Although the distance between the two layers was as small as 0.5mm, we were able, due to the high temporal resolution, to distinguish between the reflection from the turbid paper, which is slightly broadened and symmetric, and the reflection from the reflector, which displays the characteristic asymmetric temporal broadening of a light pulse passing through a diffusive medium (in this case, a round-trip through the paper). The SPEBI technique allowed us to measure the pulse spreading with high resolution, clearly showing the quasi-ballistic and snake photons as well as the diffuse components. The SPEBI technique is totally equivalent to other imaging methods, which utilize actual sub-picosecond pulses. However, with the SPEBI technique no complicated or expensive equipment is necessary since the measurements are done in the frequency regime. Our experiments and analysis show that in many cases it can yield superior experimental results over any other temporal method.

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Nonlinear optics with intensity waves

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Modulated light beams are ubiquitous in both linear and nonlinear optics. Investigations of nonlinear effects, however, have for the most part focused on the interaction of the light electromagnetic field wave, with little formal attention given to the modulated light envelope, which is essentially a wave of light intensity. This is not the case, for example, in the field of light scattering in turbid media, where the formal treatment of this intensity wave has lead to the development of a new paradigm for characterizing these media.
We present a theoretical and experimental study of the behavior of intensity waves in nonlinear media, which has lead to a new understanding of the interaction between counter-propagating intensity waves in third-order stimulated scattering. Various new effects have emerged, which are reminiscent of interactions among light field waves in second-order parametric wave-mixing. This is exemplified by a new type of phase mismatch between the intensity waves, which causes suppression of the intensity waves amplitude, and is characterized by an unusually sharp singularity. In addition, an oscillatory dependence of the intensity waves amplitude and phase on this phase-mismatch is predicted. Our initial experimental investigations show good agreement with theory, and point to new applications in sensing and optical processing.

Topological phase in carpentry

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(Submitted by Stephen G. Lipson, Technion, Physics Dept., sglipson@physics.technion.ac.il)

I was faced with the problem of constructing a wooden banister for a quasi-spiral staircase. After failing to steam-bend the wood successfully (1), I decided to construct it from interlocking curved sections. The problem was to calculate the angles at which the successive pieces had to be cut in order to achieve the correct angle of rise and radius of curvature. I discovered that the problem can be solved elegantly by the use of the topological phase (Berry's phase)(2) and is in fact analogous to the transport of light along an optical fibre wound in a helical form (3, 4). One first draws the required banister as a locus on the Poincaré sphere, and then divides into sections as required. The joint angles are then determined by the solid angle subtended by each section at the centre of the sphere. The theory and experimental results will be presented, together with practical tips for anyone interested in repeating this experience.

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"Superluminal" phenomena can be attributed to instantaneous tunneling of excitations in near field

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(Submitted by Mark Perel'man, Racah Institute of Physics, mark_perelman@mail.ru)

Recent new observations of superluminal transmission of photons afresh raised the discussions of problem of their reality and significance. The possibilities and conditions of such transferring are examined by the covariant theory of dispersion relations and are resulted into the THEOREM: Superluminal transfer of excitations (jumps) through the linear passive substance can been effected nothing but by the instantaneous tunneling of virtual particles on distances of order of half wavelength corresponding to energy, which is lacking to the nearest stable (resonance) state. The nonlocality of electromagnetic field must be describable via the 4-potential A_μ, whereas electric and magnetic fields remain unconnected in the near zone. (The proof of its preliminary version in: M.E.Perel'man: gen-physics/ 0309123.) The experimental data can be interpreted on this base as the sequential processes of scattering of single photons. Their temporal distributions are estimated with taking into account durations of scattering: in optically thin media the usual statistical description is invalid and interpretation via the theory of scattering is required. So in the most known experiments of M.D.Stenner, D.L.Gauthier, M.A.Neifeld. Nature, 425, 695 (2003) the pulse (389 THz) on the entrance of gas cell of $L = 40$ cm length is $J(t, x = 0; \omega) = J_0 I(t) I(\omega)$. The measured group refraction index $n_g = -19$ and the duration of formation $\tau = -27$ ns, therefore the free path length is of order $l = 40$ cm and the probability of single scattering $p(\omega) = exp(-L/l) = 0.37$. Thereby for photons, which undergo not more than one scattering the intensity on the outlet $J(t, x = L; \omega) = J\prime I(\omega)\{pI(L/c - |\tau|) + (1 - p)I(L/c)\}$, i.e. the outlet must be represented by the sum of two Gaussians, initial and advanced. As the non-shifted peak must be twice bigger than advanced, the center of their envelope will be displaced into the side of speed c or even to c/n. And it possibly predefined the conclusions of Stenner e.a. But this experiment does not prove the absence of superluminal phenomena: its results can be explained by the differences between advancing of superluminal part of light pulse and regular speed of other part only: the problem of superluminal phenomena is not exhausted yet.

Control of millimeter wave propagation by tailoring the dispersive properties of the medium

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We have developed a space - frequency model for the propagation of a high frequency signal in an arbitrary dispersive medium. The model can be solved analytically under certain conditions for a Gaussian pulse, revealing the conditions under which pulse compression or expansion occurs. It can also be shown that under appropriate conditions the delay time of the pulse can be stretched almost indefinitely. By studying a Gaussian pulse propagating in air described by the standard dispersion model of Liebe [1] we were able to show that even in a substance as trivial as standard atmospheric air some of the effects that we predict are pronounced especially for carrier frequencies in the vicinity of the 60 GHz O_2 absorption line. In this case the calculations were carried both analytically and numerically. We further discuss how materials and wave-guides might be tailored for a certain pulse characteristics in order to achieve an a priori-defined amount of compression and delay.

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Simulated annealing in adaptive optics for imaging the eye retina

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Adaptive optics is a method designed to correct deformed images in real time. Once the distorted wavefront is known, a deformable mirror is used to compensate the aberrations and return the wavefront to a plane wave. This study concentrates on methods that omit wave front sensing from the reconstruction process. Such methods use stochastic algorithms to find the extremum of a certain sharpness function, thereby correcting the image without any information on the wavefront. Theoretical work [1] has shown that the optical problem can be mapped onto a model for crystal roughening. The main algorithm applied is simulated annealing. We present a first hardware realization of this algorithm in an adaptive optics system designed to image the retina of the human eye.

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Regulating photon mass in classical 5D gauge theory

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(Submitted by Martin Land, Hadassah College, Jerusalem, martin@multinet.net.il)

Off-shell electrodynamics, the local gauge theory associated with a covariant symplectic mechanics developed by Stueckelberg, describes instantaneous interactions between spacetime events, mediated by five massive gauge fields. Event evolution in this formalism is parameterized by an independent, monotonically increasing, Poincare-invariant parameter, and not by the proper time of the motion, and so one is led to a dynamical theory in which mass conservation is demoted from the status of an a priori constraint to that of a Noether current conserved for a certain class of interactions. While the total mass-energy of particles and fields is conserved, particles and photons may, in general, exchange mass. In the equilibrium limit, photons are pushed onto the Maxwell zero-mass shell, but during interaction, photons may acquire any mass, even pushing particle trajectories far into the spacelike region. We discuss a higher derivative correction to the photon kinetic term, which regulates the photon mass while preserving gauge invariance and Poincare covariance of the original theory. We discuss an information-theoretic interpretation of this mechanism, and demonstrate that the resulting quantum field theory is made super-renormalizable.

Current trends in string theory

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I will present an overview of some of the recent developments in string theory, with an emphasis on the role string theory has played in understanding the quantum nature of black holes.

Dark matter/energy from a varying Newton constant

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(Submitted by Aharon Davidson, Ben Gurion University,
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In a spontaneously generated General Relativity, let the reciprocal Newton 'constant' be a Brans-Dicke scalar field damped oscillating towards its constant VEV. We show, at the limit where the matter Lagrangian is switched off (in particular, no dust is explicitly introduced), that the corresponding cosmological evolution averagely resembles, in the Jordan frame, the familiar dark radiation $\rightarrow$ dark matter $\rightarrow$ dark energy domination sequence. The fingerprints of such a theory are fine ripples, hopefully testable, in the FRW scale factor; they die away at the General Relativity limit. The possibility that the Brans-Dicke scalar also serves as the inflaton is favorably examined.

Model building with a dynamical volume element in gravity, particle theory and theories of extended object

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The Volume Element of Space Time can be considered as a geometrical object which can be independent of the metric. The use in the action of a volume element which is metric independent leads to the appearance of a measure of integration which is metric independent. This can be applied to all known generally coordinate invariant theories, we will discuss three very important cases: 1. 4-D theories describing gravity and matter fields, 2. Parametrization invariant theories of extended objects and 3. Higher dimensional theories including gravity and matter fields. In case 1, a large number of new effects appear: (i) spontaneous breaking of scale invariance associated to integration of degrees of freedom related to the measure, (ii) under normal particle physics laboratory conditions fermions split into three families, but when matter is highly diluted, neutrinos increase their mass and become suitable candidates for dark matter, (iii) cosmic coincidence between dark energy and dark matter is natural, (iv) quintessence scenarios with automatic decoupling of the quintessence scalar to ordinary matter, but not dark matter are obtained (2) For theories of extended objects, the use of a measure of integration independent of the metric leads to (i) dynamical tension, (ii) string models of non abelian confinement (iii) The possibility of new Weyl invariant light-like branes (WILL branes). These WILL branes dynamically adjust themselves to sit at black hole horizons and in the context of higher dimensional theories can provide examples of massless 4-D particles with nontrivial Kaluza Klein quantum numbers, (3) In brane and Kaluza Klein scenarinos, the use of a measure independent of the metric makes it possible to construct naturally models where only the extra dimensions get curved and the 4-D observable space-time remain flat.

A dialogue of multipoles: Matched asymptotic expansion for caged black holes

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No analytic solution is known to date for a black hole in a compact dimension. We develop an analytic perturbation theory where the small parameter is the size of the black hole relative to the size of the compact dimension. We set up a general procedure for an arbitrary order in the perturbation series based on an asymptotic matched expansion between two coordinate patches: the near horizon zone and the asymptotic zone. The procedure is ordinary perturbation expansion in each zone, where additionally some boundary data comes from the other zone, and so the procedure alternates between the zones. It can be viewed as a dialogue of multipoles where the black hole changes its shape (mass multipoles) in response to the field (multipoles) created by its periodic "mirrors", and that in turn changes its field and so on.

Beam dynamics at the compact linear collider (CLIC) study

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The CLIC study aims at the design of a multi-TeV, high luminosity electron-positron linear collider, as a facility for the post-LHC era. The beams are accelerated using high-frequency (30 GHz) RF-structures, operating at high accelerating gradients. This reduces the total length of the machine and, in consequence, the total cost. The generation of the RF power for the acceleration is based on the Two Beam Acceleration (TBA) scheme, where the power is extracted from a separate high-intensity low-energy electron beam. The latter is produced by a dedicated accelerator complex, the Drive Beam Accelerator (DBA). CLIC Test Facility (CTF3) is an ongoing project at CERN, the European laboratory for Particle Physics. It is a model of the CLIC power generation scheme, e.g. the DBA, which can also serve as a test bed for various CLIC-technology-related topics. The CTF3 project aims at being a proof of feasibility for the whole CLIC power generation scheme. This presentation will introduce the design of the CLIC machine and the CTF3 complex, and will show some present topics related to the beam-dynamics study for CLIC and CTF3.

Search for heavy long lived charged super-symmetric particles with the ATLAS experiment

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(Submitted by Shikma Bressler, Technion, sshikma@tx.technion.ac.il)

ATLAS is one of two large experiments being built at the LHC collider. The LHCs properties, specifically its 14TeV center of mass energy and 40MHz bunch crossing frequency, will allow exploring theories beyond the standard model. This is among ATLASs main goals.
One such theory is the Super-Symmetry. There are many different super symmetric models and many of them predict the existence of long lived heavy charged particles. A case in point is GMSB where the stau is the NLSP and couples weakly to the gravitino. These particles will live long enough to pass the muon spectrometer. A unique signature of such particles would be a velocity significantly lower than the speed of light.
In ATLAS, in order to piece the events correctly, great emphasis is placed on beam crossing identification (BCID). This assumes that the particles that leave signals in the detector travel nearly at the speed of light (b=1), an incorrect assumption in the case of the heavy charged slepton. Here we are faced with a situation where the signal will arrive with different BCID from different parts of the detector. Signals have to be matched correctly from different beam crossings (BC), but first we have to ensure that the signals from the different BCs are collected and read out, otherwise we may lose completely the possibility to analyze this signal.
The problems of bunch crossing identification for slow charged particles are described. An algorithm for measuring the mass of slow particles is presented.

Measurements of the Standard Model Higgs parameters at ATLAS

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(Submitted by Lidija Zivkovic, Weizmann Institute of Science, lidiaz@wisemail.weizmann.ac.il)

Once the Higgs boson is discovered the focus will be shifted to uncovering its properties. Precision measurements of these parameters allow a deeper understanding of the electroweak symmetry-breaking mechanism. This presentation summarizes the latest results on the measurement of the Higgs boson mass, total width, production rates, couplings to bosons and fermions, and spin. With an integrated luminosity of 300 fb^{-1}, ATLAS can measure various properties of the Higgs boson with high precision.
The mass of the Higgs boson can be determined with an error of $0.1\% - 1\%$, the width of the Higgs boson with an error of $10\% - 20\%$, the production rates with $10\% - 20\%$, the relative branching ratios with $15\% - 45\%$, and the relative coupling ratios with $10\% - 20\%$.
For $m_H > 200$ (230) GeV a Spin-0 CP-odd and a Spin-1 (CP-even and CP-odd) Higgs boson can be ruled out at 2σ (5σ) level with an integrated luminosity of 100 fb^{-1}.

Low mass electron pair production in heavy ion collisions using the PHENIX detector.

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Lepton pair production is considered as a powerful tool in the search for the QGP in heavy ion collisions. Dileptons can be emitted during the entire lifetime of the collision and interacting only electromagnetically they escape the interaction region almost freely carrying information directly to the detector. In the low mass region ($m_{e^+e^-} \leq 1\ GeV/c^2$) dileptons can provide information about possible in-medium modifications of the light vector mesons properties which are important signals of the chiral symmetry restoration.
The PHENIX experiment is one of the four experiments at the Relativistic Heavy Ion Collider (RHIC) at BNL, USA. The PHENIX central-arm spectrometers are capable to identify electrons at mid-rapidity in a wide momentum range and perform the measurements of the light vector mesons, ρ, ω and ϕ, and the low-mass pair continuum. However, a huge combinatorial background from γ conversions and π^0 Dalitz decays makes such measurements extremely difficult at the high multiplicities of RHIC. The first PHENIX results show that even with a large single electron p_t cut of 300 MeV/c, the ϕ meson measurement has a signal to background ratio, S/B, of about 1/20 and at lower invariant masses $m_{e^+e^-} \approx 400$ MeV/c^2, S/B$\sim$1/300 as expected from Monte Carlo studies.
An upgrade of the PHENIX detector is planned to reject the background electrons from γ conversions and Dalitz decays improving the S/B by almost two orders of magnitude. The main element of the upgrade is an additional detector which is almost blind to all particles except for electrons, i.e. Hadron Blind Detector (HBD). It consists of a windowless Cherenkov radiator, operated with pure CF_4, a triple Gas Electron Multiplier (GEM) detector element with a reflective CsI photocathode and pad readout.
The results of a detailed R&D program, the object of which is to demonstrate the feasibility of the proposed Hadron Blind Detector configuration, will be presented.

Study of supersymmetry mass spectrum in R-Parity violating model

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The ATLAS detector operating at the Large Hadron Collider, during the first months of its operation, can already reveal the first indications for supersymmetric signals. R-Parity symmetry is usually assumed without any fundamental or experimental justification, just in order to suppress the R-Parity violating terms that appear in the most general superpotential and can give rise to e.g. proton decay. If one keeps RPV couplings, one should also include them in the Renormalization Group Equations (RGE). This results in a modified mass spectrum of the super particles. Some consequences of the modified mass spectrum are shown. Among them, LSP identity change, opening of new decay channels, re-analysis of some RPV processes in ATLAS, and new interpretations of LEP limits regarding MSSM Higgs and anomalous fermion pair production.

Measurement of high-Q2 deep inelastic scattering cross sections with longitudinally polarised positron beam at HERA

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The first measurements of the cross sections for neutral and charged current deep inelastic scattering in e^+p collisions with longitudinally polarised positron beams are presented. The total e^+p charged current cross section is presented at positive and negative values of longitudinal polarisation. In addition, the neutral and charged current single differential cross sections are presented. The measurements are based on data of integrated luminosity 40 pb^{-1} collected with the ZEUS detector between Oct. 2003 and Aug. 2004.

Polarized positrons in a high-energy linear-collider

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The High-Energy Physics community is preparing itself for a new high energy e+e- International Linear Collider (ILC). In this connection the question whether the two beams should be longitudinal polarized is still an open issue. From past experience it is known that polarizing the electron beam was found to be very useful. Here the advantages of having also the positron beam polarized will be discussed. Assuming a positive answer to this topic, a method to obtain this polarization build-up will be outlined, including its current R&D efforts through the DESY-SLAC E-166 project.

Relativity and symmetry

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The Theory of Relativity is based on two postulates, usually: Principle of Relativity and constant velocity of light c. The new approach is based on the Generalized Principle of Relativity and the Symmetry following from it is proposed. This approach permits linear transformations between uniformly accelerated systems to be derived by using proper velocity-time description of events. The transformations preserve an interval. The formula of acceleration addition is obtained. The most interestingly that existence of an invariant maximal acceleration is predicted. Accuracy of this method is verified for relativistic space-time transformations of inertial systems.

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Instrumentation of the forward region for the ILC detector project

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(Submitted by Ronen Ingbir, Tel Aviv University, ronen@alzt.tau.ac.il)

There is a consensus in the High Energy Physics community that the future of experimental accelerator based physics lies in an e+e- linear collider (LC) of 500 GeV to 1 TeV center of mass energy, with a program complementary to that of the Large Hadron Collider. In this presentation a short overview will be given on the International Linear Collider (ILC) and detector project and more in particular the FCAL collaboration activities and intermediate results in designing the forward instrumentation for this global project. The Tel-Aviv experimental group is one of the members of the FCAL collaboration specializing in the luminosity detector R&D.

Possibility of estimation of bare coupling of grand unification via theory of dispersion relations

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All processes of point particle elastic scatterings on the fixed point-like force center of any nature of coupling can be kinematically subdivided onto two classes: (proper) processes, at which complete energy throughout is not lesser kinetical one: $E > K$, and (improper) processes, at some interval of which potential energy become bigger complete energy (tunneling, backward scattering, etc.). The projector of proper processes, expressed via the Heaviside unit operator, $P = \theta(E - K)$, extracts from the general response functions (scattering amplitudes F) parts that describe all these processes: $f(E, p, ...) = \theta(E - K)F(E, p, ...)$. Its Fourier transformation leads to the dispersion relations in (t,r)-representation, which can be infinitely iterated and is represented in form of the Neumann series for the integral Fredholm equation. At this calculation the unique numerical constant $\alpha_0 = 2(2\pi)^{-5/2} \approx 1/50$ for (3+1) metrics is appeared, which does not depend from nature of coupling and therefore can be considered as the constant of decomposition of complete amplitude over number of interactions. Precisely this value, independent from dynamics, can be considered as the universal bare coupling. Via the Gell-Mann - Low relations it results in the GUT energy $M = 10^{18}$ GeV with consistent magnitudes of all running couplings and reasonable values of electron and nucleon masses as dynamical fields objects. Moreover it allows the consideration of some problems of black holes also.

Laboratory, non-LTE, transient plasmas - spectroscopic measurements of non Maxwellian electron energy distribution

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The energy distribution of free electrons in laboratory or astrophysical plasmas often deviates from Maxwellian distribution. Though the spectroscopic determination of such distributions is much more challenging than that of an electron temperature in a case of equilibrium, they both rely on similar techniques. From a spectroscopic viewpoint, a good electron temperature diagnostic is obtained by finding intensity ratios of spectral lines emitted from a common ion that are sensitive to the electron temperature but insensitive to other plasma parameters. Even though the energies of the upper levels of the transitions are largely separated (to achieve the temperature or energy sensitivity), the lines need to be close in wavelength to enable a reliable measurement of the intensity ratio. Such line pairs are difficult to find and measure. Obviously, for inferring a non Maxwellian distribution function one needs to use several line ratios, each sensitive to a different electron energy range. To add to the complexity, non Maxwellian plasmas are commonly of a transient nature, thus the investigation of the time dependent energy distribution requires measuring the evolution of the line intensities simultaneously. Unlike in astrophysics, in the laboratory there are many cases where the plasma homogeneity and emitting volume are well known, so the population of the transition upper levels can be obtained directly from the measured absolute line intensities. This helps to determine the plasma properties and opens the possibility to measure non Maxwellian energy distribution using spectral lines of *various* ions. Example of such a measurement is presented for a case of a current-carrying plasma. Comparison of the evolution of measured line intensities to a time-dependent collisional radiative model shows a significant deviation from a Maxwellian distribution due to the interaction of the plasma with the strong magnetic field generated by the current flowing through the plasma. It is found that the electron energy distribution consists of a bulk population with a temperature that rises from 5 eV to a few tens of eV and a hot electron beam fraction that rises from a few percent with an energy of ~100 eV up to ~50% with an energy of several hundreds eV.

Hall MHD - waves and instabilities in inhomogeneous low density plasmas

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The effect of the Hall electromotive force on plasma dynamics is considered through linear analysis of the magnetohydrodynamic (MHD) equations within the framework of a two-fluid model in which the Hall term is taken into account in Faraday's law (Hall MHD), for low density weakly inhomogeneous magnetized plasmas. It is shown that the Hall MHD model is relevant to a wide range of applications both in the laboratory as well as for space plasmas. Analysis of the local dispersion relation reveals that each of the Whistler waves, the Alfven waves as well as the ion cyclotron acoustic waves and the magnetoacoustic waves, split into two branches due to spatial gradients of the plasma density. In the case of waves propagating perpendicularly to the external magnetic field the fast branch is a quasi-Whistler mode that exhibits one of the most pronounced and observable effects associated with the non-diffusive penetration of a magnetic field into weakly inhomogeneous plasma. The slower branch is a quasi-electrostatic mode that is shown to give rise to inhomogeneity-driven instability in the case of slab geometry. For near parallel propagation it is shown that instability occurs when the density gradient generated slow and fast branches of two different stable waves merge into a single unstable mode. The threshold conditions under which unstable waves appear and the appropriate growth rates are derived. Two applications are investigated. In the first one, the stability of a cylindrically-symmetric z-pinch is investigated. It is shown that unlike the acceleration-driven Hall instability in slab geometry, axially-symmetric imploding plasmas become unstable due to the curvature of the magnetic-field lines. Implications of such instabilities on the z-pinch properties are discussed. In addition, the stability of rotating disks is investigated. It is shown that unlike the well known incompressible magneto-rotational instability, small-scale Hall instabilities that are accompanied by density fluctuations arise due to the plasma inhomogeneity.

Comparison of underwater wire discharges generated by nanosecond and microsecond current generators

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Underwater wire electrical discharges (UWED) generated by pulsed high-current nanosecond and microsecond generators can be considered as sources of non-ideal plasma. In our experiments with UWED we used microsecond ($T_{1/4}$ = 2us, Imax=100kA, $dI/dt = 5 \times 10^{10}$A/s, W=3.3 kJ) and nanosecond ($T_{1/4}$ = $60ns, Imax = 80kA, dI/dt = 2 \times 10^{12} A/s, W = 0.6$ kJ) generators. The parameters of the generated SW were obtained using different pressure gauges and shadow photography with fast frame and streak cameras. The discharge channel plasma parameters were obtained by the analysis of the evolution of the discharge channel and pressure waves generated in water combined with equation of state of wire material. Also, time resolved spectroscopic data of the discharge plasma light emission was obtained for determination of the discharge plasma parameters. An attempt to receive total energy balance was made. Performances of nanosecond and microsecond UWED are compared.

Equilibrium orientation of an ellipsoidal particle inside a dielectric medium with a finite electric conductivity in the external electric field

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The dynamics of solid or liquid particles in a host medium under the action of an external electric field is of theoretical and technological interest. Technological application include manipulation of microparticles in biotechnology and genetic engineering, nanotechnology, and non contact measurements of physical properties of particles. Interaction of an external electric field with an inclusion embedded into a host medium is important for understanding the mechanisms of the electric breakdown of dielectrics, in atmospheric physics and aerosol dynamics. We studied the stability of the orientation of an ellipsoidal dielectric particle immersed into a host dielectric medium under the action of the external electric field. It was assumed that the particle and the host medium have a finite electric conductivity. We showed that in a medium with a finite electric conductivity, a torque acting at the particle in a stationary electric field can change the orientation of a particle even when the direction of the field is fixed. Thus, if initially the particle was in a state of a stable equilibrium, then after some time the initial orientation of the particle loses its stability. Our analysis shows that there exist two time intervals, T_1 and T_2 , such that during time T_1 the stable orientation of the particle is the same as for the case of an ideal dielectric. During time interval T_2 , where $T = T_1 + T_2$ is a period of the external electric field, the direction of stable orientation is normal to that for the case of an ideal dielectric.

Plasma steady-state with neutral depletion

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In low temperature weakly-ionized plasmas the electron temperature is usually determined by particle balance while the plasma density is determined by energy balance. When the power deposited in the plasma is large enough so that neutrals are depleted, the electron temperature and the plasma density are coupled. We calculate analytically the plasma steady-state for a substantial neutral depletion. A case is presented in which, surprisingly, the plasma density QTRitdecreases when the power deposited in the plasma QTRitincreases. Implications to our Helicon plasma source are discussed.

Post-breakdown shock waves in water caused by low current arc discharge

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(Submitted by Evgeny Gidalevich, gidal@eng.tau.ac.il)

Post-breakdown plasma and liquid motion from a submerged arc discharge is described theoretically based on arbitrary discontinuity propagation. It was found that the primary mechanism for heat energy transport was radiation. The radiative coefficient of thermoconductivity was calculated by determining the radiation transfer for thin plasma layers. With an initial discharge current of magnitude $I = 10$ A, voltage $V_s = 10^3$ V, and temperatures $T = 4 \times 10^5$ K and 6×10^5 K, a shock wave was calculated to be initially generated in the liquid surrounding the arc channel, but after $t = 30$ ns, and 50 μs, respectively, the liquid velocity became subsonic. A Mach number, defined as the ratio of the shock front velocity to the speed of sound in the undisturbed water, is about $M = 3$. Pressure in the shock wave is $\sim 10^5$ atm. The relaxation length of the shock wave is approximately 500 μm.

Intraband and interband absorption of femtosecond laser pulses in copper

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We investigate optical properties of pure copper irradiated by a femtosecond laser pulse. Self-absorption of 50-fs laser pulses at 800 nm and 400 nm wavelengths (below and above the interband absorption threshold, respectively) is studied for peak laser intensities up to $10^{15} W cm^{-2}$. Theoretical description of laser interaction with copper target is developed, solving numerically the energy balance equations for electron and ion subsystems together with Maxwell equations for laser radiation field inside the target. The theory accounts for both intraband and interband absorption mechanisms. We describe in detail the changes in electron structure and distribution function with an increase in electron temperature, as well as the ensuing changes in thermodynamic properties, collision frequencies, optical and transport coefficients. We predict a change in electron properties from metallic to plasma-like as a result of ionization of localized d-states and the onset of charge disorder in the lattice at $Te > 7$ eV. Experimental work on self-absorption of femtosecond laser pulses in copper targets at 800 nm and 400 nm wavelengths is ongoing.

Spatial resolution of conditions in a tokamak through X-ray lines with a new technique.

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This paper deals with a basic problem of diagnostics in tokamaks. The functions describing the change of density, ion temperature and degree of ionization in tokamaks, along a cross section of the torus, perpendicular to the main axis, behave like step functions and not like bell-shaped functions of any kind. In order to investigate the reason for this astonishing behavior it is of importance to investigate the experimental conditions of the plasma with full spatial resolution, including possible turbulences of the plasma at the changes of direction in the step functions. This may be possible through the use of double reflections in single crystal in X-ray spectroscopy. With this technique each spectral line will yield such spatial resolution, including change of wave lengths at the place of eventual turbulences. This may be investigated on the tokamak at M.I.T. which yields lines of an intensity greater by two orders of magnitude than the intensity obtained from other tokomaks.

Plasma heating of asymmetric anodes in a hot refractory anode vacuum arcs

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In a Hot Refractory Anode Vacuum Arc (HRAVA), the anode is heated by heat flux from the interelectrode plasma. A thermal model of an asymmetric graphite anode is presented and the heat flux as function of the arc time is determined.
The method is based on 3-D numerical solutions of the heat conduction equation using the measured anode temperature distribution. The model takes in account the time-dependent thermal coefficients of the anode material and the Stefan-Boltzmann radiation from anode surfaces. A cylindrical graphite anode with radius R_a=32 mm and arc currents I=175 and 225 A are considered. The front surface of the asymmetric anodes is inclined so that the maximal (apex) and minimal (anti-apex) anode lengths (L1, L2) were: (30, 25), and (30, 20) mm, whereas the length of the symmetrical anode was 30 mm. The anode temperatures were measured by three thermocouples placed near the apex, anti-apex and the rear anode surface for an 18 mm gap. The heat flux was determined by fitting the calculated temperatures at the thermocouple locations to the measurements.
The numerical results show that the heat flux can be approximated by $q_{in}^{asym}(x,t)= q_{in}^{sym}(t)(1+k_{as}x/R_a)$ where the x-coordinate axis is parallel to the rear anode surface and starts from the anode axis, with positive and negative values in the apex and anti-apex directions respectively, k_{as} is a coefficient of asymmetry for the heat flux, $q_{in}^{sym}(t)$ is the previously determined incoming heat flux for a symmetric anode, in the form $q_{in}^{sym}(t)=q_{ss}+q_0\ e^{-t/\tau}$ where q_{ss} the steady-state heat flux, $q_{ss}+q_0$ is the initial heating flux (i.e. at t=0), and τ is the characteristic time when the anode plume reaches the cathode and is obtained from visual observation.
The heat flux may be characterized by an effective anode potential U_{eff}, defined as the ratio between the net input power to the anode surface and the arc current. U_{eff} decreased from 10.5 V at t=0 to 7 V in steady-state for I=175A, L2=20mm. U_{eff} slightly increased with arc current (up to 11 V at t=0 and 7.5V at steady state for I=225A). k_{as} increased for more asymmetric anodes from 0.15 to 0.2 for anodes with L2=25 and 20 mm respectively, with I=175 A. The calculated temperature distribution is asymmetric on the asymmetric anode surface, with the maximum (T_{max}) shifted from the anode axis in the apex direction. For the symmetric anode, the maximum was at the anode axis, and the temperature decreased slightly in radial direction. The temperatures T_{max} are 1975 and 2000K for anodes with L2=30 and 20mm, respectively (I=175A). The difference between the maximal and minimal surface temperatures increased from 50 K for symmetric anode up to 150 K for an asymmetric anode (L2=20 mm) for I=175A.

Dependence of the fast waves-plasma interactions in pre-heated spherical tokamaks on the antenna location and poloidal extension

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In the magnetically confined fusion devices, externally launched e.m. waves are used, e.g., for heating, non-inductive current drive and turbulent transport suppression barriers. In view of the complexity of these processes, it is desirable to assist the planning of the actual experiments by reliable theoretical (computational) studies.
This work aims to (i) assess the effect of antenna position and extension on the fast waves-plasma interactions in pre-heated spherical tokamaks and consequently, (ii) to further the physical understanding as well as to determine optimal conditions in order to achieve the imposed goals.
Thus, using as a study case the spherical tokamak START, we considered the following antenna positions and extensions: (a) low field side location and $\pm\pi/4$ poloidal extension; (b) above and below middle-plane locations (two separate sections) and extending (each) $\pi/2$; (c) (hypothetical) circular, 2π-extension.
We solved the full wave equations in order to consistently determine the global e.m. field for Alfvénic modes in inhomogeneous, non-uniformly magnetized, resistive, small aspect ratio tokamak plasma in the presence of externally launched fast waves. The "global" approach consists of simultaneous treatment of the plasma-vacuum-external rf source-vacuum-metal wall configuration with the appropriate consideration of wave propagation, transmission, absorption and mode conversion; in this, no simplifying approximations or small parameter extension are used.
Illustrative results of these investigations will be presented and discussed.

Parameters of the plasma produced at the ferroelectric surface by different driving pulses

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Spectroscopic investigations of properties of the plasma produced by a ferroelectric plasma source are presented. The plasma electron density, electron and ion temperature, and density of desorbed neutrals near the ferroelectric surface were determined from spectral line intensities and profiles analysis. Tree different methods of the plasma formation were tested and results are compared. Maximal plasma density up to 10^15 cm^{-3} is achieved when electrons attached to the ferroelectric surface by the driving electric field are released from the surface owing to driving pulse sharp decay and ionize heavy atoms desorbed from the ceramic. A mechanism controlling the density of the surface plasma is suggested. This mechanism is related to surface density of the bounded polarization charges which in it turn depends on the driving electric field and ferroelectric sample properties.

Optimization of a low-pressure hollow anode electrical discharge for generation of high-current electron beams

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We report results on the optimization of the design of a high-current hollow anode electrical discharge electron beam source triggered by a ferroelectric surface discharge. For the ferroelectric sample we used a BaTi solid solution with a large dielectric constant $\epsilon = 1600$. Three different electric schemes for ignition and sustaining of the hollow anode discharge were investigated. The studied hollow anode designs allow reliable ignition and sustaining of the discharge with current amplitude of up to 1.2 kA and pulse duration of up to 20 μs, with and without gas flooding. It was found that the rise time of the discharge current monotonically decreases from ~ 10 μs to ~ 7.5 μs with the increase of the background pressure from 4 Pa to 7 Pa. Generation of high-current electron beams was demonstrated under an accelerating voltage of up to 300 kV and ~ 400 ns pulse duration. It was shown that the use of an optimal resistor which supplies an auto-bias potential to the hollow-anode output grid eliminates almost entirely the plasma pre-filling of the accelerating gap prior to the application of the accelerating pulse. In addition, it was found that within a certain range of time delays (12.5 μs - 15.5 μs) of the application of the accelerating pulse with respect to the beginning of the hollow anode discharge, the amplitude of the diode current remains practically unchanged in spite of a considerable decrease in the amplitude of the discharge current.

Laser ignited ablative capillary discharges for guiding of ultra high laser intensities

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Plasma channels provide a convenient medium for optical guiding in a laser wakefield accelerator. Capillary discharges are simple to construct and operate, and offer the possibility of external fine tuning of the plasma parameters. In this report, generation of plasma channels with narrow and deep axial minimum in electron density profile will be reviewed. Channels with the temperature 2 4 eV and the electron density 5x10^{17} 2x10^{18} cm^{-3} were produced by a low-current (200 A) discharge with laser ignition via polyethylene and plexiglas capillaries of 0.3 mm diameter and 15 mm long. The diameter of the obtained hollow plasma channels at half-minimum of electron density was approximately 15% of the capillary diameter, and the relative profile depth was as much as 70% of the axial electron density. The ignition of the capillary discharge was obtained using auxiliary 10 mJ, 10 nsec Nd-YAG laser. This triggering is characterized by both low delay and jitter times. Time-resolved radial profiles of the electron density were measured from Stark broadening of the H_α line. Temporal evolution of the axial distribution of plasma density inside the capillary and in the near-outlet region of the plasma jet was estimated as well.

The width of profiles was significantly (3 to 4 times) less than that of previously reported profiles of a slow ablative capillary discharge. Such narrow plasma channels can provide the possibility to achieve significant electron acceleration using less intense ultrashort laser pulses.

Backward wave excitation and generation of oscillations in distributed gain media and free-electron lasers in the absence of feedback

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Quantum and free-electron lasers (FELs) are based on distributed interactions between electromagnetic radiation and gain media. In an amplifier configuration, a forward wave is amplified while propagating in a polarized medium. Formulating a coupled mode theory for excitation of both forward and backward waves, we identify conditions for phase matching, leading to efficient excitation of backward wave without any mechanism of feedback or resonator assembly. The excitations of incident and reflected waves are described by a set of coupled differential equations expressed in the frequency domain. The induced polarization is given in terms of an electronic susceptibility tensor. In quantum lasers the interaction is described by two first order differential equations, while in high-gain free-electron lasers, the differential equations are of the third order each. Analytical solutions of reflectance and transmittance for both quantum lasers and FELs are presented. It is found that when the solutions become infinite, the device operates as an oscillator, producing radiation at the output with no field at its input, entirely without any localized or distributed feedback.

Ferroinductor coupled discharge

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An inductively coupled discharge was obtained at low gas pressure. Unlike an ordinary inductively coupled discharge with an inductor-like rf antenna we used a magnetic core with a primary winding (ferroinductor). In this way we increased the electric field and eliminated the magnetic field of the winding. Gas breakdown was obtained at a pressure as low as 10^{-4} Torr, the discharge plasma ionization rate reached almost 100% and the maximum plasma density was about 10^{13} cm^{-3}. The high inductance of the ferroinductor allowed us to work even with single pulses. The efficiency of such a discharge as a plasma source could reach 90%, which makes this kind of discharge attractive for many applications.

Impedance characteristics of LF driven ferroinductor coupled discharge

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We present impedance characteristics of a LF inductively coupled discharge where instead of an inductor-like rf antenna we used a ferromagnetic core with a primary winding (ferroinductor). A dense ($>10^{12}$ cm^{-3}), highly ionized (30-40%) plasma was obtained in this ferroinductor at gas pressures as low as 10^{-4} Torr. In a wide frequency range the core and winding losses were found to be low compared to the LF power delivered to the plasma. The driving frequency could be very low compared to typical inductively coupled discharges. The input impedance was found to be almost purely active (cosϕ 0.9), and it was possible to achieve various input resistances (e.g. 50 Ohm in the whole investigated range of frequencies, powers and pressures, which made unnecessary any matching box between the LF driver and the ferroinductor coupled plasma device. Such a combination of properties makes this kind of discharge attractive for many applications.

Study of coherence limits and chirp control in long pulse FEL oscillator

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We report experimental studies of the spectral line width and chirp characteristics of the mm-wave RF radiation of Israeli Electrostatic Accelerator FEL (EA-FEL), along with theory and numerical simulations. The simulations matching the experimental data were carried out using space-frequency model. EA-FELs have the capacity to generate long pulses of tens microseconds and more, that in principle can be elongated indefinitely (CW operation). Since a cold beam FEL is by nature a “homogeneously broadened laser”, EA-FEL can operate, unlike other kinds of FELs, at a single longitudinal mode (single frequency). This allows the generation of very coherent radiation. The current status of the Israeli Tandem Electrostatic Accelerator FEL (EA-FEL), which is based on an electrostatic Van de Graaff accelerator, allows the generation of pulses of tens microseconds duration. It has been operated recently past saturation, and produced single mode coherent radiation of record narrow inherent relative line width $\Delta f/f = 10^{-6}$ at frequencies near 100 GHz. A clear frequency chirp is observed during pulses of tens of microseconds (0.3 –0.5 MHz/μs). This is essentially a drifting frequency pulling effect associated with the accelerator voltage drop during the pulse. Additionally, aperiodic oscillation relaxation was experimentally measured and compared with theory both numerically, and analytically in general framework of non-harmonic oscillations. Possibilities of chirp applications and power boosting are also discussed.

ABCD matrix method: A case study

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A general approach for phase-space characterization of an electron beam from physical measurements is presented. The theory is based on the paraxial beam tracing approach, employing ABCD transfer matrix. Relations between the beam radius and its angular spread at each plane along the beam line are derived, enabling calculations of beam emittance from its spot dimensions. The theory can be applied in electron beam transport systems, in which fluorescent screens serve as the only means for beam diagnostics. Optimization procedure was carried out in order to obtain a beam waist at a required position.

Spot-to-beam procedure

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We describe the interactive spot-to-beam MATHEMATICA procedure for a) approximating the spot image at the screen (and beam at screen position) as an ellipse, b) getting five parameters of the elliptic beam (two diameters, center coordinates, and orientation angle). The basic idea is to "map" the *reference* holes at the diagnostic screen onto the XY plane normal to the beam propagation direction (Z-axis). All distortions of the image, e.g., due to camera-screen disposition can be, in principle, taken into account. With the non-linear LSM fitting, the "curved" coordinate system of the holes at image is transferred to the Cartesian "Laboratory" coordinate system (C.S.) at XY plane. Then the fitting ellipse is found in the C.S., by solving the system of N linear equations for 5 unknown parameters of beam ellipse, where N>5 is a number of the sample points on edge (boundary) of the spot image. Examples of the real measurements in the Israeli Electrostatic Accelerator FEL (EAFEL) are demonstrated. The accuracy of the beam diameter values is ≈.5 mm depending on picture quality and the operator's experience (and patience!). The procedure is to be used in routine measurements of EAFEL to improve the electron beam transport.

Implementing phase gates with cold collisions in an optical lattice

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Quantum information processing with cold atoms in optical lattices relies on the ability to entangle nearest neighbor atoms in an efficient controlled way. The basic idea of realizing for example phase gates with a two particle system in an external potential is: The external potential initially localizes the particles far enough apart so that they may be considered independent. The external potential then changes in time so that wave function overlap gives rise to correlations due to particle-particle interaction. The external potential is finally restored to its initial shape, so that the two particles no longer interact, but are prepared in some new correlated state.
In this work optimal-control techniques and a fast-approach scheme are used for implementing such a collisional control phase gate in a model of cold atoms in an optical lattice, significantly reducing the gate time as compared to adiabatic evolution while maintaining high fidelity. New objective functionals are given for which minimal paths are obtained when the evolution is equivalent to a control-phase gate up to single-atom Rabbi shifts. Theoretical issues of fidelity and adiabaticity are discussed.

On lattices, learning with errors, cryptography, and quantum

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Our main result is a reduction from worst-case lattice problems such as SVP and SIVP to a certain learning problem. This learning problem is a natural extension of the 'learning from parity with error' problem to higher moduli. It can also be viewed as the problem of decoding from a random linear code. This, we believe, gives a strong indication that these problems are hard. Our reduction, however, is quantum. Hence, an efficient solution to the learning problem implies a *quantum* algorithm for SVP and SIVP. A main open question is whether this reduction can be made classical.
Using the main result, we obtain a public-key cryptosystem whose hardness is based on the worst-case quantum hardness of SVP and SIVP. Previous lattice-based public-key cryptosystems such as the one by Ajtai and Dwork were only based on unique-SVP, a special case of SVP. The new cryptosystem is much more efficient than previous cryptosystems: the public key is of size $\tilde{O}(n^2)$ and encrypting a message increases its size by $\tilde{O}(n)$ (in previous cryptosystems these values are $\tilde{O}(n^4)$ and $\tilde{O}(n^2)$, respectively).

A general framework for unambiguous detection of quantum states

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The problem of detecting information stored in the state of a quantum system is a fundamental problem in quantum information theory. Several approaches have emerged to distinguishing between a collection of non-orthogonal quantum states. We consider the problem of unambiguous detection where we seek a measurement that with a certain probability returns an inconclusive result, but such that if the measurement returns an answer, then the answer is correct with probability 1.
We begin by considering unambiguous discrimination between a set of linearly independent pure quantum states. We show that the design of the optimal measurement that minimizes the probability of an inconclusive result can be formulated as a semidefinite programming problem. Based on this formulation, we develop a set of necessary and sufficient conditions for an optimal quantum measurement. We show that the optimal measurement can be computed very efficiently in polynomial time by exploiting the many well-known algorithms for solving semidefinite programs, which are guaranteed to converge to the global optimum.
Using the general conditions for optimality, we derive necessary and sufficient conditions so that the measurement that results in an equal probability of an inconclusive result for each one of the quantum states is optimal. We refer to this measurement as the equal-probability measurement (EPM). We then show that for any state set, the prior probabilities of the states can be chosen such that the EPM is optimal. Finally, we consider state sets with strong symmetry properties and equal prior probabilities for which the EPM is optimal.
We next develop a general framework for unambiguous state discrimination between a collection of mixed quantum states, which can be applied to any number of states with arbitrary prior probabilities. In particular, we derive a set of necessary and sufficient conditions for an optimal measurement that minimizes the probability of an inconclusive result, by exploiting principles of duality theory in vector space optimization.

Detection of vacuum entanglement in a linear ion trap

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Recently, the entanglement properties the ground state (vacuum) have been investigated in several bosonic and fermionic systems. I will first discuss shortly the reasons for this effort, and then show that the entanglement properties in many of these systems, can be analyzed using the mode-wise decomposition theorem.
I will then proceed to suggest a scheme to actually detect vacuum entanglement in a system of trapped ions, which is connected with a previously suggested gedanken-experiment for detecting vacuum entanglement in quantum field theory. I will show that the entanglement between single ions or groups of ions can be swapped to the internal levels of two ions by sending laser pulses that couple the internal and motional degrees of freedom. Interestingly, this allows to entangle two ions without actually doing gates. A proof of principle of the effect can be realized with two trapped ions and is feasible with current technology.

Spin state read-out by quantum jump technique for the purpose of quantum computing

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Semiconductor quantum dot (QD) based implementation schemes for quantum computation hold great promise, due to recent advances in nanostructure fabrication and characterization and to the possibility of integrating them into existing computational devices. Since the idea of utilizing the spin degrees of freedom of an excess electron confined to the QD as a qubit introduced in the the seminal paper of Loss and DiVincenzo [1], there have been numerous such proposals for quantum information processing (QIP) devices put forth. A necessary requirement from such QIP schemes is the ability to perform an accurate measurement of the spin state of a single QD confined electron, which is a great challenge.
We propose [2] an optical measurement scheme based on the quantum jump technique which utilizes the Pauli blocking effect in QDs,to read out the spin state of an electron confined to a QD. In an ideal case, i.e., no mixing of the heavy/light hole bands in the QD, shining a σ^+ polarized pulse on the QD one obtains due to the Pauli blocking effect the usual two-level situation: full fluorescence pattern from the spin up state, $|1\rangle$. No fluorescence is obtained from an initial spin down state, $|0\rangle$, since due to the Pauli principle the trion,$|x\rangle$, creation is blocked and therefore the spin down state is completely decoupled from the laser field.
A realistic QD will exhibit mixing of the heavy and light hole states, which invalidates the assumption of perfect Pauli blocking. Introducing mixing requires one to treat the full three-level lambda configuration. As opposed to the usual atomic lambda configuration, here one can not distinguish between the $|0\rangle\langle x|$ and $|1\rangle\langle x|$ transitions, since the two transitions are mediated through the same photon. We describe the complications arising due to this issue and present the equations of motion for this process. Numerical evidence is produced showing that even in the case of a typical mixing parameter of, $\varepsilon = 0.1$, our measurement technique can still be implemented achieving results which are accurate up to 0.1% in deducing from the fluorescence pattern, the initial electronic spin state. The case of limited photo detection efficiency is also investigated and we show that a high degree of accuracy can be achieved with state of the art photo-detectors.

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A toy-model for Born's propensity rules

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We develop a non-linear "toy-model" for the collapse of a wave-function superposition. A postulated master equation for the density matrix (ρ) contains terms quadratic in ρ, which drive towards collapse. A schematized random description of the environment leads to probabilities for quantum selections which are in accord with Born's propensity rules. The model has also a "factorization" version [1] which describes both the vanishing of non-diagonal elements of the density matrix ρ as well as the vanishing of non-selected diagonal elements.
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Detection of an ensemble mixed with unknown states

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We address the problem of distinguishing among a finite collection of quantum states, when the states are not entirely known. For completely specified states, necessary and sufficient conditions on a quantum measurement minimizing the probability of a detection error have been derived. In this work, we assume that each of the states in our collection is a mixture of a known state ρ_i^0 and an unknown state ρ_i^1, so that $\rho_i = q_i\rho_i^0 + (1 - q_i)\rho_i^1$ where $0 \leq q_i \leq 1$ are known. We investigate two criteria for optimality. The first is minimization of the *worst-case* probability of a detection error. For the second we assume a probability distribution for the unknown states, and seek minimization of the *expected* probability of a detection error.
We derive necessary and sufficient conditions for optimality under both criteria, and interpret them in light of the conditions in the nominal case. We also explore some special cases.

Experimental algorithmic cooling of spins — a novel polarization-enhancement method

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Algorithmic cooling is a promising new spin-cooling approach devised by Boykin, Mor, Rowchodhury, Vatan and Vrijen (PNAS, Vol. 99, p. 3388, 2002). This approach suggests data compression methods in open systems. It reduces the entropy of spins on long molecules to a point far beyond Shannon's bound on reversible entropy manipulations, thus increasing their polarization. The algorithm recursively employs two steps: The first is an adiabatic entropy compression of the *computation qubits* of the system. The second step is an isothermal heat transfer from the system to the environment through a set of *reset qubits* that reach thermal relaxation rapidly. Interestingly, the interaction with the environment, usually a most undesired interaction, is used here to our benefit, allowing a cooling mechanism, which is useful for initializing NMR systems in general and NMR quantum computers in particular.
A later work, "Algorithmic cooling of spins: a practicable method for increasing polarization" (e-print: quant-ph/0401135, to be published in IJQI) presented a much improved algorithm, yielding a significant spin-polarization increase already on small molecules.
To allow experimental algorithmic cooling, the thermalization time of the reset qubits must be much shorter than the thermalization time of the computation qubits. We investigated the effect of the paramagnetic material Chromium Acetylacetonate on the thermalization times of computation qubits (carbons) and reset qubit (hydrogen). We report here the accomplishment of an improved ratio of the thermalization times from $T_1(H)/T_1(C)$ of approximately 5 to around 15. The magnetic ions from the Chromium Acetylacetonate interact with the reset qubits, reducing their thermalization time, while their effect on the less exposed computation qubits is found to be weaker. An experimental demonstration of non-adiabatic cooling by thermalization in a nuclear magnetic resonance apparatus (based on using these magnetic ions) yielded cooling beyond Shannon's bound.

Indirect spin coupling between semiconductor quantum dots

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We have investigated theoretically an indirect exchange interaction between spins localized in two semiconductor quantum dots. The interaction is mediated by virtual delocalized carrier excitations in the host material and is analogous to the RKKY interaction between two magnetic impurities. The virtual excitations are driven by an interband off-resonance laser, thus making the interaction optically controllable. This exchange mechanism can be utilized for fast coupling between spins in quantum dots for gates in connection with quantum computation. The proposed scheme has both advantages of ultrafast optical control and very long spin coherence times which are maintained due to the virtual nature of the excitations.

The effective coupling between the two localized spins is obtained by calculating the exchange interaction between the localized and continuum electrons. We take into account the effects of hybridization of continuum and dot states and double occupancy in the dot. Applying a generalized canonical transformation to the Hamiltonian up to infinite order, we derive contributions to the exchange interaction arising from correlation and hybridization terms, which are added to the conventional Coulomb potential exchange.

The overall effect is modified by the Coulomb interactions between the intermediate virtual electrons and holes. We obtain the dependence of the coupling between two spins in quantum dots on the geometry of the quantum dots and the dimensionality of the system. Among the studied geometries, the largest couplings are found for lateral dots in a two-dimensional quantum well, and vertically stacked quantum dots in a quasi one-dimensional wire.

Cathodoluminescence study of excited states and spatial smearing effects in InAs/GaAs self-assembled quantum dots

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We have examined state-filling and thermal activation of carriers in buried InAs self-assembled quantum dots (SAQDs) with excitation-dependent cathodoluminescence (CL) imaging and spectroscopy. The InAs SAQDs were formed during molecular beam epitaxial growth of InAs on undoped planar GaAs (001). Emission from the excited states was obtained under high electron beam currents, revealing up to three QD excited states in CL spectroscopy. A suppressed relaxation from the first excited state to the ground state at very low excitation densities was observed, demonstrating the presence of a phonon-bottle neck. The dependence of the CL intensity of the ground and the first excited state transitions on excitation density was shown to be linear at all temperatures at low excitation density. This result can be understood by considering that carriers escape and are recaptured as excitons or correlated electron-hole pairs. At sufficiently high excitations, state filling and spatial smearing effects are observed together with a sublinear dependence of the CL intensity on electron beam current. A successive filling of the ground and excited states in adjacent groups of QDs that possess different size distributions is argued to be the cause of the spatial smearing. The intensities of the ground and excited state transitions were analyzed as a function of temperature and excitation to study the thermal activation and reemission of carriers. Thermal quenching of the CL intensity of the QD ground and first excited state transitions at low excitations in 230 to 300 K temperature range is attributed to dissociation and reemission of excitons from the QD states into the WL. At high excitations, significantly reduced activation energies of the ground and excited states are obtained, suggesting that thermal reemission of single holes from QD states into the GaAs barrier is responsible for the observed temperature dependence of the QD luminescence in 230 to 300 K temperature range.

Local probe investigation of the current paths in microcrystalline silicon

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The numerous studies of electrical transport in undoped hydrogenated microcrystalline silicon (μc-Si:H) failed so far to establish an agreement on where does the current flow in this heterogeneous system. Here we present a comprehensive local probe investigation, using conductance atomic force microscopy (C-AFM) and scanning tunneling microscopy (STM) that solves this intriguing question and sets up a self consistent picture of the conduction mechanisms and routes in this system. Our data clearly show that the current flows mainly along the disordered tissue that encapsulates the crystallite columns. The significance of our findings regarding the emerging field of percolation in semiconductor composites and the related photovoltaic applications will be discussed. Related preliminary results of local photoconductivity in granular CdS films will also be presented.

Correlations and entanglement of the polarization states of sequentially emitted single photons by semiconductor quantum dots

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We report on polarization sensitive, second order intensity correlation measurements [1] of photons emitted due to recombination cascades of quantum dot confined electron-hole pairs. We show that the cascaded emission from neutral quantum dots is strongly correlated, such that the emission from the confined two electron hole pair state (biexciton) and that from the one pair state (exciton) has the same linear polarization [2]. The cascaded emission from singly charged quantum dots, on the other hand, is markedly different and more interesting. We show, for the first time, that the cascaded emission from the charged biexciton state and that from the charge exciton state are oppositely circularly polarized.
The intermediate state in the radiative cascade of the charged quantum dot case (the charge exciton) has a half integer spin. Therefore, it is doubly degenerate (Krammers theorem). This is not the case for the intermediate neutral exciton state, where the total spin is an integer and the Krammers degeneracy is removed by the electron-hole ex-change interaction. As a consequence, the polarization states of the sequentially emit-ted photons from the charged quantum dots are entangled, as we demonstrate for the first time, using polarization sensitive, correlation measurements.

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Spin-charge separation in quantum wires

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Using momentum resolved tunneling between two clean parallel quantum wires in a AlGaAs/GaAs heterostructure we directly measure the dispersion of the quantum many-body modes in ballistic wires and follow their dependence on Coulomb interactions by varying the electron density. We find clear signatures of three excitation modes in the data: The anti-symmetric charge mode of the coupled wire system and two spin modes. The density dependence of the anti-symmetric charge mode agrees well with Luttinger-liquid theory. As the density of electrons is lowered, the Coulomb interaction is seen to become increasingly dominant leading to excitation velocities that are up to 2.5 times faster than the bare Fermi velocity, determined experimentally from the carrier density. The symmetric charge excitation, also expected from theory, is, however, not visible in the data. The observed spin velocities are found to be 25% slower than the bare Fermi velocities and depend linearly on carrier density. The dispersions are mapped down to a critical density at which spontaneous localization is observed. Some of the experimental findings concerning this phase will be discussed

Practical silicon light emitting devices fabricated by standard IC technology

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Research activities are described with regard to the development of a comprehensive approach for the practical realization of single crystal Silicon Light Emitting Devices (Si-LEDs). Several interesting suggestions for the fabrication of such devices were made in the literature but they were not adopted by the semiconductor industry because they involve non-standard fabrication schemes, requiring special production lines. Our work presents an alternative approach, proposed and realized in practice by us, permitting the fabrication of Si-LEDs using the standard conventional fully industrialized IC technology "as is" without any adaptation. It enables their fabrication in the same production lines of the presently existing IC industry. This means that Si-LEDs can now be fabricated simultaneously with other components, such as transistors, on the same silicon chip, using the same masks and processing procedures. The result is that the yield, reliability, and price of the above Si-LEDs are the same as the other Si devices integrated on the same chip. In this work some structural details of several practical Si-LED's designed by us, as well as experimental results describing their performance are presented. These Si-LED's were fabricated to our specifications utilizing standard CMOS/BiCMOS technology, a fact which comprises an achievement by itself. The structure of the Si-LED's, is designed according to specifications such as the required operating voltage, overall light output intensity, its dependence(linear, or non-linear) on the input signal (voltage or current), light generations location (bulk, or near-surface), the emission pattern and uniformity. Such structural design present a problem since the designer can not use any structural parameters (such as doping levels and junction depths for example) but only those which already exist in the production lines. Since the fabrication procedures in these lines are originally designed for processing of other devices and circuits (MOS structures, for example) the various procedures are already predetermined to utilize for example, specific junction depths, doping concentrations as well as other parameters. Accordingly, the design of the Si-LEDs by using the standard IC design rules, require an adaptive approach, due to the above imposed constrains. The gain is that such design approach enables integration with the other devices on the same chip to yield monolithic structures.

Low temperature growth of oxynitride thin films using plasma techniques

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The better insulation and reliability properties of Oxynitride (SiON) thin films, with respect to SiO_2 thin films, both which were grown by conventional (thermal) growth systems, makes the SiON films an attractive potential alternative as gate insulators in a variety of MOS devices. The growth temperature of Oxynitride films in these systems is around 900°C - 1000°C. This temperature result a severe limitation on the fabrication of future scaled down ULSI devices, featuring precise doping profile control and System On Glass (SOG) devices. This imposes an uncompromising demand for a drastic reduction in their growth temperature. However, lowering the growth temperature in the conventional systems is prohibitive since it results a severe unacceptable degradation of the insulating films electrical properties. Members of this group has previously reported the growth of thin insulating films grown by using microwave-excited high-density inert gas plasma mixed with other gas elements. SiO_2 and SiON films were grown at 400°C by this technique using Kr/O_2 and $Kr/O_2/N_2$ gas mixtures respectively, introduced into the plasma system. In this work we report the growth of oxynitride films at 400°C substrate temperature, by $Kr/O_2/NH_3$ mixture. The electrical properties of these SiON films were measured by fabricating MOS capacitors in which they have been used as insulators. The results were compared to those of identical MOS capacitors fabricated with SiO_2 insulators made either by the conventional thermal method at 1000°C or to those grown at 400°C using the above Kr/O_2 plasma. The experimental results, show that the electrical properties of the oxynitride films grown by this mixture, which contained only a small amount of NH_3 (0.5 %) in 96.5 %, Kr and 3% O_2 (pressure ratios), are superior to those of both above SiO_2 films. They exhibited lower leakage currents and higher breakdown fields. This was found to be the case for both thick (7 nm) SiON films, which operate in the Fowler-Nordheim (F-N) tunneling regime and for thin (3 nm) films which operate in the direct tunneling regime, demonstrating the potential of this approach.

Microwave-modulated photoluminescence of a 2D-electron gas in a magnetic field

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Novel microwave-induced effects have been recently revealed in a two dimensional electron gas (2DEG) subjected to a perpendicularly applied magnetic field B [1-4]. The underlying physics of the 2DEG interaction with microwaves (mw) is a heating of the 2D-electrons followed the resonant or nonresonant mw absorption [5].
We study the effects of mw-heating on the 2DEG-free hole photoluminescence (PL) in high quality, 25 nm wide GaAs/AlGaAs MDQW containing the 2DEG of variable density $(0.3-3)x10^{11}cm^{-2}$ under a perpendicularly applied magnetic field, $B < 7T$ and at $T_L = 2K$. The remarkable microwave-induced changes in PL spectra are observed with increasing B. At low B, the mw-modulated PL spectrum reveals a complicated line-shape with the strongest PL modifications occurring under condition of cyclotron-like resonance $B = B_R$ [1,4]. The electron and hole effective temperature are estimated from an analysis of the mw-modulated PL spectra, and these temperatures are found to be different. We explain such a difference by a spatial separation of the 2DEG and hole in the MDQW.
The mw-modulated PL intensity reveals new resonances at B values slight below the Landau level filling factors $\nu = 4, 2$ and 1. We study behavior of these new resonances on the mw-power and on the 2DEG density. The mechanism of the mw-absorption by the magnetized 2DEG and the origin of these new resonant bands are discussed. With further increasing B (at $\nu < 1$), the additional PL lines emerge in the spectrum [6]. The mw-modulated PL spectra of each line are different, and their line shape depends on filling factor. This allows us to investigate the nature of the 2DEG-hole radiative recombination mechanisms that result in the additional PL lines at $\nu < 1$.

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Recombination kinetics of photoexcitations in films of poly-phenylene-vinylene derivatives

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Photomodulation spectroscopy has been proven as an excellent tool to investigate the nature of the photoexcitation species in π-conjugated systems. The lifetime of the photoexcited species and their recombination mechanism may be extracted by following the photoinduced absorption (PIA) dependencies on the modulation frequency, ω, and intensity, I_L, of the laser pump excitation. Films of π-conjugated polymers are generally inhomogeneous. As a result, the recombination process is not characterized by a mechanism with a single lifetime, but rather a lifetime distribution determines the kinetics. In recent publications [1], we have outlined a general approach aiming at the characterization of the recombination kinetics of long lived photoexcitations in films of π-conjugated systems. This general approach is based on studying the PIA dependence on both ω and I_L on a wide dynamic range covering both near steady state and far away from steady state regimes. Using special analysis, it is then possible to sort out the recombination kinetics.
In this work we report on the recombination kinetics of triplet excitons and polarons in films of poly(2-methoxy-5-(2'-ethyl-hexyloxy)-1,4-phenylene vinylene) (MEH-PPV) and MEH-PPV/C_{60} mixtures, with a fixed molecular weight (MW), in the range $1-28\times10^5$ Dalton. We have found that in these films the recombination kinetics is not dominated by a single lifetime process, but rather may be better described as a "bimolecular dispersive" mechanism. In this mechanism, the underlying process is bimolecular, but there is a substantial lifetime (or recombination rate) distribution, resulting in characteristic sublinear dependencies of the photoexcitation density on the exciting laser intensity, $PIA \propto I_L^{\gamma}$, and modulation frequency, $PIA \propto \omega^{-\alpha}$ $(\alpha, \gamma < 1)$. We have measured, for both polarons and triplet excitons, the dependence of the sublinear exponents α and γ on the MW and film morphology. Using these dependencies, we are able to reassign and identify the polaron and triplet excitons bands in this system.

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Adiabatic quantum pumping and charge quantization

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Modern techniques for coherent manipulation of electrons at the nanoscale (electrostatic gating, surface acoustic waves) allow for studies of the adiabatic quantum pumping effect – a directed current induced by a slowly varying external perturbation. Scattering theory of pumping predicts transfer of an almost integer number of electrons per cycle if instantaneous transmission is determined by a sequence of resonances. We show that this quantization can be explained in terms of loading/unloading quasi-bound virtual states, and derive a tool for analyzing quantized pumping induced by a general potential. This theory is applied to a simple model of pumping due to surface acoustic waves. The results reproduce all the qualitative features observed in actual experiments.

Cathodoluminescence imaging and spectroscopy study of the thermal quenching of luminescence in AlN/Si

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Spatially and spectrally resolved cathodoluminescence (CL) measurements were performed for high-quality thin AlN films grown on Si(111). CL spectra for a sample temperature of 49 K exhibited a sharp peak at 5.960 eV, corresponding to the near-band-edge excitonic emission of AlN. Additional broader peaks related to deep-level oxygen impurities were seen at 3.040 eV and 3.430 eV. Excitation-dependent measurements were performed by varying the electron beam current from 30 pA to 10 nA revealing that the impurity-related emissions saturate at low-beam currents, while the near band-edge emission increases nearly linearly with beam current. Monochromatic CL imaging of the near-band edge emission exhibited a spotty emission pattern where defect-induced nonradiative recombination results in large spatial variations in the luminescence efficiency. Scanning electron microscopy revealed the presence of hexagonal-shaped V-defects on the surface. Cross-sectional transmission electron microscopy revealed the single crystal nature of the AlN film with threading dislocations propagating from the Si substrate interface to the AlN surface. Local CL spectroscopy was performed to assess temperature-dependent variations in the luminescence efficiency for regions of high- and low-defect densities. Temperature-dependent CL further revealed spatial variations in the activation energy, Ea, for the thermal quenching of the near-band edge luminescence. For regions of high- and low-luminescence efficiencies (i.e., bright and dark spots in the CL images), thermal activation energies of 29meV and 19meV, respectively, were measured. We propose a model that attempts to explain the local reduction in Ea with a corresponding local increase in the defect/dislocation density.

Tunneling spectroscopy of gold-tipped CdSe nanorods

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Recently, Mokari et al. have demonstrated a selective growth of gold tips onto CdSe nanorods and tetrapods [1]. These novel nanostructures allow one to address experimentally the intriguing problem of the electronic properties of nanoscale metal-insulator contacts. We present here preliminary results, not all well understood yet, of spatially resolved tunneling spectroscopy measurements on gold-tipped CdSe nanorods. Spectra obtained on the gold tips, of diameters around 2.5-4 nm, exhibit a behavior typical of isolated metal nanoparticles and can be well modeled by the orthodox model for single electron tunneling effects. Spectra measured at the middle of the rods resemble those acquired on pure CdSe of similar size, with comparable energy gap (but somewhat smeared peak structure). Near the CdSe-gold interface, however, the tunneling spectra show a reduced gap and, surprisingly, a very pronounced negative differential resistance structure, with nearly equidistant peaks, develops. This structure may be due to a combination of resonant tunneling through a CdSe discrete state and charging of the gold tip, in a triple barrier tunnel junction system [2].

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Modeling of fluctuating reaction networks

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Various dynamical systems are organized as reaction networks, where the population size of one component affects the populations of all its neighbors. Such networks can be found in interstellar surface chemistry, cell biology, thin film growth and other systems. I cases where the populations of reactive species are large, the network can be modeled by rate equations which provide all reaction rates within mean field approximation. However, in small systems that are partitioned into sub-micron size, these populations strongly fluctuate. Under these conditions rate equations fail and the master equation is needed for modeling these reactions. However, the number of equations in the master equation grows exponentially with the number of reactive species, severely limiting its feasibility for complex networks.
Here we present a method which dramatically reduces the number of equations, thus enabling the incorporation of the master equation in complex reaction networks. The method is examplified in the context of reaction network on dust grains. Its applicability for genetic networks will be discussed.

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Spin model for inverse melting and inverse glass transition

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A spin model that displays inverse melting and inverse glass transition is presented and analyzed[1]. The model is a variation of the Blume-Capel model where strong degeneracy of the interacting states of an individual spin leads to entropic preference of the "ferromagnetic" phase, while lower energy associated with the non-interacting states yields a "paramagnetic" phase as temperature decreases. An infinite range model is solved analytically for constant paramagnetic exchange interaction, while for its random exchange, analogous results based on the replica symmetric solution are presented. The qualitative features of this model are shown to resemble a large class of inverse melting phenomena. First and second order transition regimes are identified and "normal" and "unnormal" transitions, in analogy to water anomaly, can be obtained by variations of the model. One step replica symmetry breaking confirms that the structure of the phase diagram found in replica symmetry is not altered when breaking it.

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Interface growth fluctuations and the correlation length

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Growth behavior of interfaces is usually described by a power-law of the growing interface width with time. This general scaling picture is an average behavior description, which may not be valid when only a finite number of interfaces is considered. In this work we study theoretically and experimentally the growth behavior of single interfaces and show that the particular growth function of the width always exhibits a non-monotonic, fluctuating behavior. This behavior results from competing mechanisms of normal growth and surface tension forces in the Quenched-noise Kardar-Parisi-Zhang (QKPZ) equation, and contains information on the growth process in this specific interface. We define a new measure of the interface width fluctuations in order to extract this information from experimental data. We analyze data of mercury droplets spreading on silver films, as well as data of water spreading on paper, in order to demonstrate the validity of our claim in a wide range of growing interfaces. The experimental results are compared to the numerical results of the QKPZ equation, for different cases of noise distributions.

Bogomol'nyi bound and screw dislocations in a mesoscopic smectic-A

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The de Gennes free energy functional of an infinite smectic-A liquid crystal at the dual point is shown to be topological and to depend only on the number of screw dislocations and the anisotropy. This result generalizes the existence of a Bogomol'nyi bound to an anisotropic system. The role of the boundary of a finite mesoscopic smectic is to provide a mechanism for the existence of thermodynamically stable screw dislocations. We obtain a closed expression for the corresponding free energy and a relation between the applied twist and the number of screw dislocations.

Long-range attraction between probe particles mediated by a driven fluid

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The effective interaction between two probe particles in a one-dimensional driven fluid is studied. This study is carried out using the asymmetric simple exclusion process, which serves as a standard model for stochastic driven systems. It is found that although the dynamics of the model is local, effective long-range interactions are induced between the probes. The probe particles may form one of three states: unbound, weakly bound, and strongly bound. In the unbound state the average distance between the probe particles grows diffusively as $\sqrt{t}$. In the weakly bound state, the steady-state distance distribution decays algebraically with a power-law $x^{-\sigma}$, where the exponent $1 < \sigma < 2$ varies continuously with the interaction parameters. The steady state average distance is infinite. The approach to steady state is sub-diffusive, whereby the average distance grows as t^{ν} with $\nu < 1/2$. In the strongly bound state the average distance decays algebraically in time to a finite value at steady state. In the steady-state, the distance distribution takes the form $x^{-\sigma}$, with $\sigma > 2$. The case of more than two probe particles may also be studied within this framework.

Scale-free networks emerging from weighted random graphs

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We suggest a simple mechanism for generating scale free networks with $\lambda = 2.5$. We start from a random graph with a well defined average degree $\langle k \rangle$ (an Erdös-Rényi graph) and with randomly and uniformly distributed weights associated with the links ("disorder"). All nodes which are connected by links having weights above a certain threshold are grouped into a single node. We show that this mechanism leads to a random Scale-Free network with $\lambda = 2.5$.
The procedure may be related to several real world networks and may explain the abundance of real world scale free networks. These results also enable us to gain useful insight regarding the structure of minimum spanning trees and optimal paths in random networks: We show that even for Erdös-Rényi graphs, the Minimum Spanning Tree has scale-free properties.

Electronic energy spectra and density of states on the square Fibonacci quasicrystal

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The electronic energy spectrum and density of states for an off-diagonal tight-binding hamiltonian on the square Fibonacci tiling [1] are studied by various methods. Hopping amplitudes are non-zero only for nearest neighbors and are taken to be 1 and t, arranged according to the edge lengths of the tiles as in the Fibonacci sequence. With these definitions the model is separable, thus its spectrum is the sum of two 1-dimensional spectra.
For nearly periodic and intermediate cases ($1 < t < 2$), the exact 1d spectrum is calculated and summed to obtain the 2d spectrum for approximants up to the 20th Fibonacci number. For higher values of t, as well as for larger approximants, Monte-Carlo integration is used to find the total bandwidth of the 2d spectrum. We intend to use the results of these calculations to find the exact nature of the transitions between different spectral behaviors [2], as well as the scaling of the total bandwidth as it becomes finite.

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Recurrence intervals between earthquakes strongly depend on history

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We study the statistics of the recurrence times between earthquakes above a certain magnitude M in California. We find that the distribution of the recurrence times strongly depends on the previous recurrence time τ_0. As a consequence, the conditional mean recurrence time $\hat{\tau}(\tau_0)$ between two events increases monotonically with τ_0. For τ_0 well below the average recurrence time $\overline{\tau}, \hat{\tau}(\tau_0)$ is smaller than $\overline{\tau}$, while for $\tau_0 > \overline{\tau}$, $\hat{\tau}(\tau_0)$ is greater than $\overline{\tau}$. Also the mean residual time until the next earthquake does not depend only on the elapsed time, but also strongly on τ_0. The larger τ_0 is, the larger is the mean residual time. The above features should be taken into account in any earthquake prognosis.

Phase transitions in charged Lamellar systems under osmotic pressure

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It is well known that lipids can self assemble into membranes, and form a lamellar phase. Experiments with charged lipids[1], have shown the existence of two lamellar phases – due to the interplay between hydration and electrostatics. The experimental system exhibits a phase transition between these two phases. We introduce a surface-ion interaction, and show that this kind of surface interaction may explain the transition. We investigated, both numerically and analytically, this transition.

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Effect of spontaneous curvature and twist rigidity on cyclization of fluctuating filaments

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We study the effect of spontaneous curvature and of twist rigidity on the probability of cyclization (loop formation) of short macromolecules. Using the Frenet algorithm, a continuous filament model simulation, we calculate the end-to-end distribution functions and the cyclization probability as a function of the filament length, for a range of spontaneous curvatures. We find that the spontaneous curvature has a dramatic effect on cyclization probability which can increase by several orders of magnitude. Particularly, the probability of cyclization is increasing in more then two order of magnitude. For randomly generated sequences (spontaneous curvature is treated as a random frozen variable, with only short-range correlations along the contour of the filament) cyclization is affected only by the average spontaneous curvature of filament. For filaments with spontaneous curvature cyclization is enhanced by increased twist rigidity which suppresses out-of-plane writhe fluctuations.

Polyelectrolytes adsorption: Chemical and electrostatic interactions

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Mean-field theory is used to model polyelectrolyte adsorption and the possibility of overcompensation of charged surfaces. For charged surfaces that are also chemically attractive, the overcharging is large in high salt conditions, amounting to $20-40\%$ of the bare surface charge. However, full charge inversion is not obtained in thermodynamical equilibrium for physical values of the parameters. The overcharging increases with addition of salt, but does not have a simple scaling form with the bare surface charge. Our results indicate that more evolved explanation is needed in order to understand polyelectrolyte multilayer built-up. For strong polymer-repulsive surfaces, we derive simple scaling laws for the polyelectrolyte adsorption and overcharging. We show that the overcharging scales linearly with the bare surface charge, but its magnitude is very small in comparison to the surface charge. In contrast with the attractive surface, here the overcharging is found to decrease substantially with addition of salt. In the intermediate range of weak repulsive surfaces, the behavior with addition of salt crosses over from increasing overcharging (at low ionic strength) to decreasing one (at high ionic strength). Our results for all types of surfaces are supported by full numerical solutions of the mean-field equations.

A "square-root" method for the density matrix in Lindblad processes

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The evolution of open systems, subject to both Hamiltonian and dissipative forces, is studied by writing the nm element of the time (t) dependent density matrix in the form $\rho_{nm}(t) = \frac{1}{A}\sum_{\alpha=1}^{A}[\gamma_n^\alpha(t)\gamma_m^{\alpha*}(t)]$. The so called "square root factors", the $\gamma(t)$'s, are non-square matrices and are averaged over A systems (α) of the ensemble. This square-root description is exact. Evolution equations are then postulated for the $\gamma(t)$ factors, such as to reduce to the Lindblad-type evolution equations for the diagonal terms in the density matrix. For the off-diagonal terms they differ from the Lindblad-equations.
When the method is tested on cases which have been previously treated by other methods, our results agree with them. Examples chosen are (i) molecular systems, such that are either periodically driven near level degeneracies, for which we calculate the decoherence occurring in multiple Landau-Zener transition, or else when undergoing descent around conical intersections in the potential surfaces, (ii) formal dissipative systems with Lindblad-type operators representing either a non-Markovian process or a two-state system coupled to bosons.
Attractive features of the present factorization method are complete positivity, the no higher than linear increase of the implementation effort with the number of states involved and the introduction of randomness only at the start of the process.
Keywords: Decoherence, Lindblad operators, Landau-Zener crossing, conical intersections, Non-Markovian processes
PACS number(s): 03.65.Bz

A study of YBCO junctions with magnetic or doped YBCO barriers

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Investigation of ramp type junctions with YBCO electrodes and YBFeCO, YBGaCO or SRO barriers will be described. Conductance spectra of junctions with the doped YBCO barriers yield information on the symmetry of the order parameter in the high temperature superconductors, as well as important physical parameters such as the Fermi velocity and the superconducting gap energy. Junctions with the itinerant ferromagnet SRO barrier show a switching effect in low magnetic fields, and possible cross Andreev scattering.

Spin waves in superconducting ferromagnets

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It is known that electromagnetic (EM) waves cannot penetrate into both superconductors and metals. On the other hand, wave propagation is possible in superconducting ferromagnets in form of spin waves, similar to what happens in insulating magnets. We consider excitation of spin waves in a superconducting ferromagnetic slab by an external EM radiation and calculate the surface impedance, which provides information on wave propagation inside the sample. We also find threshold frequencies at which the impedance has singularities and discuss their physical meaning. Our analysis shows striking differences between a superconducting ferromagnet and both normal ferromagnets (insulating and conducting), and a nonmagnetic superconductor. Hence experimental investigation of spin wave modes can be an effective probe of unusual magnetic properties of superconducting ferromagnets, including unconventional superconductors with broken time-reversal symmetry.

Theory of the magnetoresistance peak in thin superconducting films

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Recent studies of magnetonresistance in disordered superconducting (SC) thin films [1, 2] reveal a huge peak (about 5 orders of magnitude) in the resistance as a function of magnetic field. It is indeed expected that magnetic field destroys superconductivity, leading to an enhanced resistance. Yet, attenuation of the resistance at even larger magnetic field comes as a surprise. Here we propose a model which accounts for the experimental results in the entire range of magnetic fields. It is based on the formation of SC islands due to fluctuations in the SC order parameter amplitude [3, 4]. At strong magnetic fields these islands are small and thus are inaccessible to electrons due to large charging energy (or small tunneling amplitude, or both). As the island density grows with lowering the magnetic field, the area of the sample available for electron transport shrinks, leading to an enhanced resistance (exponentially high in the case of variable range hopping). Yet, as the island size increases with decreasing magnetic field, the charging energy becomes smaller and, at the same time, the resistance of the non-SC areas rises. At some value of the magnetic field resistance of the SC and the non-SC areas become equal, leading to a peak of the magnetoresistance. Eventually, at lower magnetic fields electrons prefer to tunnel into the SC islands and the resistance diminishes. At even lower magnetic field the islands percolate and the system becomes SC [5]. Numerical simulations together with analytic considerations show qualitative agreement with experiment. Numerous experimental features (such as disorder dependence of peak structure) are well explained within the above theory.

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Local magnetization measurements in single molecule magnets

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Single molecule magnets are molecules of a large spin, with strong easy-axis anisotropy. Below a blocking temperature of about 3 K, crystals of these molecules show hysteretic behavior when a magnetic field is applied parallel to the easy axis. The hysteretic curves are characterized by a series of steep steps associated with resonant tunneling of the magnetization. In this work, microscopic Hall sensor arrays were used to investigate the spatial profile of the hysteretic magnetization in a crystal of Mn12ac, as a function of a magnetic field applied along the easy axis of the crystal. We find the magnetization to be significantly non-uniform along the sample, with the non-uniformity being enhanced within the steps. Furthermore, it appears that different parts of the sample are at resonance at different values of the applied field, and that the internal magnetic field is spatially non-uniform. Finally we show that the degree of non-uniformity can be manipulated by sweeping the magnetic field back and forth through part of the resonance.

Non-equilibrium dynamics in electron glass

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Conductance fluctuations (CF) in Anderson localized indium oxide thin films were measured and analyzed. For large enough sample sizes, the power spectrum of the CF is found to be of the usual 1/f type and Gaussian. Non-Gaussian second spectrum is found occasionally for samples with lateral dimensions less then 50 microns. These results may be interpreted as an inherent feature of hopping conductivity with or without long-range interactions.

Evidence for a bulk complex order-parameter in $Y_{0.9}Ca_{0.1}Ba_2Cu_3O_{7-x}$ thin films

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We have measured the penetration depth of overdoped $Y_{0.9}Ca_{0.1}Ba_2Cu_3O_{7-x}$ (Ca-YBCO) thin films using two different methods. The change of the penetration depth as a function of temperature has been measured using the parallel plate resonator (PPR), while its absolute value was obtained from a quasi-optical transmission measurements. Both sets of measurements are compatible with an order parameter of the form: $\Delta_{dx^2-y^2} + i\delta_{d_{xy}}$ with $\Delta = 14.5 \pm 1.5$ meV and $\delta = 1.8$ meV, indicating a finite gap at low temperature. Below 15 K the drop of the scattering rate of uncondensed carriers becomes steeper in contrast to a flattening observed for optimally doped YBCO films. This decrease supports our results on the penetration depth temperature dependence. The findings are in agreement with tunneling measurements on similar Ca-YBCO thin films.

Reexamination of the vortex order-disorder phase transition line in $La_{1.85}Sr_{0.15}CuO_4$

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The significance of the second magnetization peak (SMP) in $La_{1-x}Sr_xCuO_4$ (LaSCO) crystals was reexamined following recent muon-spin rotation experiments [1] that showed an order-disorder vortex phase transition line remarkably different from that determined by the features of the SMP. We employed the Generalized Inversion Scheme [2] to determine the field and temperature dependence of the critical current density j_c and the collective pinning energy U_c in an optimally doped LaSCO. The results reveal no peak in j_c *vs.* field but a pronounced peak in U_c *vs.* field, clearly indicating that the SMP in this crystal has a dynamic origin. Analysis as a function of temperature shows that, unlike other high temperature superconductors such as $YBa_2Cu_3O_7$, $DyBa_2Cu_3O_{7-\delta}$ and $Nd_{1.85}Ce_{0.15}CuO_{4-\delta}$, which exhibit a single pinning mechanism over a wide temperature and magnetic field range, LaSCO crystals show a clear crossover from δl to δT_c pinning in the range of the SMP. This crossover is associated with a peak in U_c *vs.* temperature. Implications of the pinning mechanism crossover on the unique behavior of the second magnetization peak in LaSCO are discussed.

[1] U. Divakar *et al.*, Phys. Rev. Lett. **92**, 237004 (2004).
[2] R. Griessen *et al.*, Phys. Rev. Lett. **72**, 1910 (1994).

Suppression of the superconducting critical current of Nb in bilayers of Nb/$SrRuO_3$

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In bi-layers consisting of ferromagnetic and superconducting films, the ferromagnetic film in its domain state induces inhomogeneous distribution of magnetic fields in the superconducting film. When the ferromagnetic film has bubble magnetic domains in a labyrinth structure, it has been found that the pinning of the vortices increases; hence, the critical current of the superconducting film becomes larger. Here we study the effect of parallel ferromagnetic domain structure in Nb/$SrRuO_3$ on the critical current of Nb with current flowing perpendicularly to the domains and find that in this case the ferromagnetic domain structure decreases the critical current.

Transition-metal ordered double-perovskites: Half-metallic oxides with high Curie temperatures

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The interest in transition-metal double perovskites, $A_2BB'O_6$ (A-alkaline earth ions, B and B' - transition metal ions) has been driven by the discovery of low-field negative magnetoresistance exhibited up to room temperature (RT) by polycrystalline samples of some members of this family. Those members are regarded as half-metals, for which the Fermi level resides in a fully spin-polarized band. Their Curie temperatures are far above RT. When perfectly ordered, their magnetization is an integral number of Bohr magnetons/formula unit. Their zero-field conductivity (σ(T)) and magneto-conductivity (MC) may be dominated by spin-polarized inter-grain tunneling. The remarkable linearity of σ(T) from liquid He temperatures up to RT at least, found by us for various samples of sintered and granular Sr_2FeMoO_6, has motivated our study of additional members of this family. We report on selected results of our measurements of magnetization, thermopower, σ, MC and non-linear conductivity with high pulsed electric currents, carried out on polycrystalline samples of Sr_2FeMoO_6, Sr_2FeReO_6, Sr_2CrReO_6, Sr_2CrMoO_6, Sr_2CrWO_6 and $Sr_3Cr_2WO_9$.

Network models for a layered disordered superconductor

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We study new random matrix symmetry class which arise in models of non-interacting quasiparticles in disordered superconductors. Within the Altland-Zirnbauer classification scheme this is class C (with time reversal symmetry broken and spin rotation invariance intact). New results are presented pertaining to the 3d realization of class C, which, physically, corresponds to a layered superconductor.

A level coupled to a 1D interacting reservoir: A DMRG study

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The influence of interactions in a reservoir coupled to a level on the width of the filling as a function of the chemical potential and the position of the level is studied. The density matrix renormalization group (DMRG) method is used to calculate the ground state of a finite-size interacting reservoir, linked to a single state dot. The influence of the interactions in the lead as well as dot-lead interactions is considered. It is found that interactions in the reservoir result in a decrease in the resonance width, while the dot-lead interaction has an opposite effect. These effects are explained within the random phase approximation as an effective change in the inverse compressibility of the reservoir, while the dot-lead interactions renormalize the position of the level.

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