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COLLEGE on
PHYSICS OF NANO-DEVICES

10 - 21 July 2006

Miramare - Trieste, Italy

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BOOK OF ABSTRACTS

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CONTENTS

PREFACE

This Summer College will review the state of the art in the experiment and theory of quantum nano-systems and nano-structured materials.

Lecture courses will encompass:

(a) Luttinger liquid in quantum wires, Kondo effect, transport and dynamical properties of quantum dots, issues of phase coherence and de-coherence in qubits;
(b) new materials and systems, such as ultra-thin graphite films, nano-mechanical/electro-mechanical systems;
(c) mesoscopic electromagnetics, optics of quantum dots and microcavity lasers, Bose-Einstein condensation of excitons;
(d) coherent manipulation of cold atomic gases, atoms trapped in optical lattices.

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Programme

Week 1 (10-14 July, 2006)

	10 (M)	11 (Tu)	12 (W)	13 (Th)	14 (F)	15/16
9:00	registration	**Shekhter 1**	**Ivanov 1**	**Cheianov 1**	**Efros 1**	
10:00	opening (10:15-10:30)	**Shekhter 2**	**Ivanov 2**	**Cheianov 2**	**Efros 2**	
11:00	10:30 **MacDonald 1**	coffee	coffee	coffee	coffee	
11:30	**MacDonald 2**	**MacDonald 3**	**Imamoglu 3**	**Shekhter 3**	**Ivanov 3**	
12:30	lunch	lunch	lunch	lunch	lunch	
14:00	registration	discussions	discussions	poster talks	discussions	
16:30	coffee	coffee	coffee		coffee	free days
17:00	**Imamoglu 1**	**Ardavan 1**	**Roukes 1**	posters	**Kastner 1**	
18:00	**Imamoglu 2**	**Ardavan 2**	**Roukes 2**		**Kastner 2**	
19:00	dinner	dinner	dinner	dinner	conference dinner (bus at 19:15)	
20:30						

Week 2 (17-21 July, 2006)

	17 (M)	18 (Tu)	19 (W)	20 (Th)	21 (F)	22 (Sat)
9:00	**Lerner 1**	**Loss 1**	**Littlewood 1**	**Shlyapnikov 1**	**Altshuler 1**	departure
10:00	**Lerner 2**	**Loss 2**	**Littlewood 2**	**Shlyapnikov 2**	**Altshuler 2**	
11:00	coffee	coffee	coffee	coffee	coffee	
11:30	**Cheianov 3**	**Cheianov 4**	**Langedijk 1**	**Lerner 3**	**Shlyapnikov 3**	
12:30	lunch	lunch	lunch	lunch	lunch	
14:00	discussions	discussions	discussions	discussions	discussions	
16:30	coffee	coffee	coffee	coffee	coffee	
17:00	**Falko 1**	**Turberfield 1**	**Geim 1**	**Lagendijk 2**	**Marcus 1**	
18:00	**Falko 2**	**Turberfield 2**	**Geim 2**	**Lagendijk 3**	**Marcus 2**	
19:00	dinner	dinner	dinner	dinner	closing reception	
20:30						

Lecture: 50 mins, plus 5 mins questions, and 5-mins break between two lectures in a pair.
On 10 July, the first lecture by A. MacDonald starts at 10:30.

On 13 July, 14:00-17:00, attendees will give short talks (3mins, 2 slides) advertising their posters.

The conference dinner will take place on 14 July, in the agriturismo Mezzaluna near Sistiana. Bus departs from Adriatico at 19:15. The conf. dinner fee, 25Euro/person should be payable upon registration.

Lectures

B. Altshuler (Columbia U, NY) - (1&2) *Adiabatic and non-adiabatic dynamics of quantum condensates*

A. Ardavan (Oxford) - (1) *An introduction to magnetic resonance in quantum information processing*
(2) *Endohedral fullerenes and electron spin resonance quantum information processing*

V. Cheianov (Lancaster) - (1-3) *Kondo effect, Luttinger liquid and bosonisation technique*
(4) *Friedel oscillations in graphene*

A. Efros (Utah) - (1&2) *Optical properties of materials with negative refraction: Perfect lenses and cloaking*

V. Falko (Lancaster) - (1&2) *Quantum transport of chiral electrons in graphene*

A. Geim (Manchester) - (1&2) *Physics of graphene*

A. Imamoglu (Zurich) - (1) *Quantum optics with quantum dots: elementary properties, photon correlation measurements, single photon sources*
(2) *Cavity-QED with quantum dots in photonic crystal cavities*
(3) *Quantum dot spin manipulation*

A. Ivanov (Cardiff) - *Statistically-degenerate indirect excitons in coupled quantum wells*
(1) *Thermalization and optical decay*
(2) *Diffusion and photoluminescence rings*
(3) *In-plane traps and extremely low temperatures*

M. Kastner (MIT, Boston) - (1) *Introduction to the physics of semiconductor quantum dots*
(2) *Electron correlations in single-electron transistors*

A. Lagendijk (Twente) - (1) *Photonic crystals: without and with imperfections*
(2) *Multiple light scattering in mesoscopic and nano-systems*
(3) *Quantum optics and multiple scattering*

I. Lerner (Birmingham) - (1-3) *Decoherence and relaxation in qubits: a challenge for experimentalists, a puzzle for theorists*

P. Littlewood (Cambridge) (1&2) *Excitonic and polaritonic condensates*

D. Loss (Basel) - (1&2) *Spin qubits and spin decoherence in single and double quantum dots*

A. MacDonald (Austin) (1-3) *Introduction to Spintronics*

C.Marcus (Harvard) - (1&2) *Mesoscopic quantum dots and spin qubits*

M. Roukes (Caltech) - (1&2) *Physics, engineering & applications of nano-electro-mechanical systems and quantum electro-mechanical systems*

R. Shekhter (Chalmers) - (1-3) *Theory of electromechanical shuttles*

G. Shlyapnikov (Orsay) - (1) *Strongly interacting Fermi gases. From few-body to many-body physics*
(2) *Strongly interacting mixtures of heavy and light fermions*
(3) *Supersolid states in quantum gases*

A. Turberfield (Oxford) - (1) *Nanofabrication by biomolecular self-assembly*
(2) *Self-assembled nanomachines*

ABSTRACTS OF POSTERS

(in alphabetical order of presenting author)

Name: David Abergel.

Title: Electron - Optical Phonon Interaction in Semiconductor Quantum Wells Mediated by Spin-orbit Coupling.

Abstract: We introduce a new mechanism of coupling between optical phonons and electrons in semiconductor quantum wells. When one sublattice of the semiconductor crystal is displaced with respect to the other, the inversion symmetry of the semiconductor is broken and a spin-orbit coupling is induced. We perform symmetry analysis of this spin-orbit assisted electron-phonon coupling in zinc-blende semiconductors and study its influence on the mixing of the cyclotron resonance with optical phonons. We analyse the fine structure of the cyclotron resonance due to such coupling in the regime of a strong magnetic field and show that it strongly depends on the quantum well filling factor and the spin polarisation of the electron gas. We predict the shape and form of the anticrossings for those pairs of resonances which exhibit non-zero coupling and provide an explanation for those resonances which are not coupled in terms of the quantum numbers of the system.

Density-functional theory of interacting electrons in "short" quantum wires

S.H. Abedinpour, M. Polini, G. Xianlong, and M. P. Tosi
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Motivated by the experimental evidence of electron localization in cleaved edge overgrowth quantum wires [O.M. Auslaender *et al.*, Science **308,** 88 (2005)], we present a density-functional study of strongly correlated electron liquids confined by power-law external potentials into a "short" portion of a thin wire. The theory employs the quasi-one-dimensional (Q*1D*) homogeneous electron liquid as the reference system and transfers the appropriate Q*1D* ground-state correlations to the confined inhomogeneous liquid *via* a suitable local-density approximation to the exchange and correlation energy functional. We first show that this local-density approximation describes accurately "liquid-like" phases and then point out its failure in describing the emergence of "Wigner molecules". We finally discuss how this limitation can be overcome by adding an infinitesimal spin symmetry breaking term to the Hamiltonian and using an exchange-correlation functional of the local-spin densities.

Mesoscopic anisotropic magnetoconductance fluctuations in ferromagnets

S. Adam, M. Kindermann, S. Rahav and P. W. Brouwer

The conductance of a ferromagnetic particle depends on the relative orientation of the magnetization with respect to the direction of current flow. This phenomenon is known as "anisotropic magnetoresistance". Quantum interference leads to an additional, random dependence of the conductance on the magnetization direction. These "anisotropic magnetoresistance fluctuations" are caused by spin-orbit scattering, which couples the electron motion to the exchange field in the ferromagnet. We report a calculation of the dependence of the conductance autocorrelation function on the rotation angle of the magnetization direction.

College on Physics of Nano-Devices

Polaron states in self-assembled quantum dot molecules

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In realistic semiconductor quantum dots the optical phonon emission is a powerful source of relaxation. It has been shown that the polaron formation in these systems is a crucial process in relation with the energy loss processes. Furthermore, it offers a theoretical explanation to the experimental results in quantum dots [1]. Recently have been grown quantum dots molecules in which can be observed interesting behaviour relating with the coupling mechanism of quantum dots [2].

We focus on the polaron formation and its lifetime in these artificial molecules set up of two coupled quantum dots. In particular, we investigate the optical transitions in self-assembled InAs/GaAs quantum dot molecules with varying the quantum coupling parameter. We calculate the coupling between the electron and the LO-phonon states by using the Fröhlich Hamiltonian, from which we determine the polaron states as well as the energies of the dipolar electric transitions.

We study the dependence on the polaron formation with the coupling between the dots. Since polaron formation strongly modifies the optical spectra due to the appearance of several anticrossings in the excited states, we present a study of the parameter ranges in which the polaron presence is relevant for the behaviour of the molecule. In addition we calculate the polaron decay time through irreversible emission of acoustic phonons for several coupling magnitudes.

References:

[1] V. Preisler, T. Grande, R. Ferreira, L. A. de Vaulchier, Y. Guldner, F.J. Teran, M. Potemski, and A. Lemaitre Phys. Rev. **B 73**, 075320 (2006)

[2] E.A. Stinaff, M. Scheibner, A.S. Bracker, I.V. Ponomarev, V.L. Korenev, M.E. Ware, M.F. Doty, T.L. Reinecke, and D. Gammon, Science **311**, 636 (2006).

HOT ELECTRON ENERGY RELAXATION IN QUANTUM WIRES: ROLE OF PHONON CONFINEMENT AND NON-EQUILIBRIUM PHONON POPULATION

A.L. Asatryan, A.L. Vartanian, A.A. Kirakosyan
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Modern technologies in micro- and nanoelectronics allow different semiconductor device structures of very small sizes and various geometries to be created. In particular, high-speed field effect GaAs transistors with one-dimensional electron gas, or in other words, quantum wire transistors [1, 2] have been created and actively investigated. It is supposed that on the basis of these transistors a new generation of high-speed GaAs ultra large-scale integration circuits can be produced.

It has been also proposed by Ben Yu-Kuang Hu and S.Das Sarma [3] the quasi-one-dimensional version of the tunneling hot-electron transistor amplifier which has been fabricated successfully in three and two dimensions. It has been shown that it may be possible to obtain a device with large and sudden onset of negative differential resistance.

It is known that in polar semiconductor materials, the electron LO-phonon Fröhlich coupling is significantly stronger than the electron acoustic-phonon coupling. The most efficient energy relaxation process for the hot-electron gas, except at very low temperature, is therefore to emit LO phonons. The understanding of this energy relaxation process is of great technological importance since actual electronic devices work mostly under high-field hot-electron conditions. In addition, acting as nonradiative relaxation mechanisms the emission and absorption of phonons have a strong impact on the optical properties of semiconductors.

In order to obtain a realistic estimate for the energy-loss rate due to LO-phonon interaction from a hot electron gas in quantum wire structures, the effect of the confinement of phonon mode should be taken into account, particularly in narrower wires. Phonon confinement causes changes in the selection rules for transitions involving subband electrons and also affects the magnitude of the electron-phonon interaction matrix element, consequently modifying the hot-electron energy relaxation rate compared with the bulk-phonon case. In the present work we study the interface and confined LO-phonon caused electron energy-loss rate (ELR) in quantum wires (QWRs) within the frame of dielectric continuum model. We present a comparative analysis of the confined and interface phonons as well as intrasubband and intersubband transition contribution to electron ELR for the $GaAs/Al_xGa_{1-x}As$ and $Cd_xZn_{1-x}Se/ZnSe$ QWRs.

Under the application of a high electric field, the power supplied to the carriers by the electric field generates phonons. Thus the phonon distribution is perturbed, and non-equilibrium or hot phonons are produced if the phonon lifetime is not too small. Our calculations show that the consideration of hot phonon bottleneck effect is slowing down the cooling rate of hot electrons.

This work was supported by the Armenian State Program “Semiconductor Nanoelectronics” and by the Armenian National Science and Education Fund (Grant No.05-PS-nano-0811-228.).

1. D.Jovanovic, J.P.Leburton, IEEE Electron Device Lett. **14**, 7 (1993).
2. S.K.Islam, F.C.Jain, Solid State Electron. **39**, 615 (1996).
3. Ben Yu-Kuang Hu, S.Das Sarma, Phys.Rev.B **48**, 5469 (1993).

Physics of carrier-transport mechanisms for theoretical modeling of nanometer AlGaN/GaN Heterostructure field effect transistors

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Abstract:

The continuous downsizing of transistors geometries is motivated by the need for higher packing density and device speed together with low supply voltage operation for low-power, ultra-large scale integrated circuits.

Full functionality in HFETs with deca-nanometer (between 10 and 100 nm) metallurgical gate lengths has been achieved leading to mass production of devices, and HFETs below 10-nm gate lengths have been established. Because of their extremely small geometries, the design, fabrication and analysis of these HFETs involves the careful consideration and prediction of phenomena that require the understanding of device physics at the sub-micrometer and nano-scales [1, 2].

On the other hand, the AlxGa1-xN alloy and associated AlxGa1-xN/GaN heterostructures are the subject of intense research interest because of the great potential for the fabrication of high electron mobility transistors (HEMTs) and for future applications in industries requiring high power and/or high temperature microwave field-effect transistors [3,4,5].

The charge-transport mechanisms and theoretical foundations for describing the functioning of small AlGaN/GaN heterostructure based field effect transistors are surveyed. Various models of nano-HFET devices incorporating quantum-mechanical phenomena and velocity overshoot effect, based on the drift-diffusion, hydrodynamical and scattering approaches are discussed [6].

1. G. Curatola, G. Iannaccone, Computational Materials Science 28, 342–352, (2003)
2. S.M. Sze, Physics of Semiconductor Devices, John Wiley, New York, 1981.
3. A. Asgari, M. Kalafi, and L. Faraone, J. Appl. Phys. **95**, 1185 (2004).
4. A. Asgari, M. Kalafi, and L. Faraone, Physica E **25**, 431 (2005).
5. A. Asgari, M. Kalafi, and L. Faraone, Physica E **28**, 491 (2005).
6. R. Yahyazadeh, A. Asgari, M. Kalafi, "The effects of Depletion layer on Negative Differential Conductivity in AlGaN/GaN High Electron Mobility Transistor", (To be published in Physica E).

Shot noise and strong feedback effects in nanoelectromechanical systems

Steven D. Bennett and Aashish A. Clerk

McGill University

Quantum nanoelectromechanical systems have attracted much attention recently, offering potential for applications as well as insight into fundamental physics. Using a quantum noise approach, we study theoretically a nanomechanical oscillator coupled to a superconducting single-electron transistor (SSET). Incoherent Cooper pair tunneling processes in the SSET can lead to a negative damping instability, where the oscillator's amplitude increases as it absorbs energy from the SSET [1]. In this regime, the motion of the oscillator becomes large enough that it strongly influences Cooper pair tunneling in the SSET, which in turn strongly influences the oscillator motion. This interplay leads to interesting feedback effects and cooperative phenomena reminiscent of laser physics; in our system, the SSET plays the role of population-inverted atoms while the oscillator plays the role of cavity electromagnetic field modes. We describe the inherent non-linearity of this regime using effective, energy-dependent damping and temperature. We then calculate the current noise in the SSET, and find a significant enhancement of the noise in the regime of negative damping. The current noise is of particular interest because it can be directly measured, and current experiments are probing this regime [2].

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[1] A. A. Clerk and S. D. Bennett, NJP **7**, 238 (2005).

[2] K. Schwab *et al.* (in preparation).

First Principles Calculations on various hexagonally shaped Si nanowires

Cüneyt Berkdemir [a1] and Oğuz Gülseren[b2]

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Abstract:

In the past years, a variety of carbon and silicon nanostructures have extensively been studied by using first principle calculations to understand their geometric and electronic properties in nanoscale. These studies have been in part fueled by the discovery of carbon nanotubes (CNTs) in the early 1990s and shown a novel way to produce new nanostructures. Among them, silicon-based nanowires (SiNWs) have attracted considerable attention due to their technologically important applications in device components for future nanoelectronic and especially optoelectronic devices. The main interest arises from the combination of opto-electronic properties of III-V semiconductors with the existing silicon-based technology. It has been suggested that the SiNWs thinner than 100nm in diameter because of their fascinating quantum properties may be used in quantum-wire high-speed field effect transistors and light-emitting devices with extremely low power consumption. However, the particular advantages of SiNWs are still a great challenge so far.

The goal of this study is to investigate the geometric structures and electronic properties of various hexagonally shaped silicon nanowires by using plane wave pseudopotential calculations based on the density functional theory. The stability of the nanowire made from staggered and eclipsed hexagons is checked by including various transition metal atoms to the inner core of the nanowire. Results are obtained by both generalized gradient (GG) and local density (LD) approximations, and conjugate gradient (CG) method is used for wave function optimization. Electronic and transport properties are discussed based on these first principles calculations.

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Controllable Metallic Quantum Dot

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We explore the transport properties of a metallic quantum dot (QD) with fine control over the dot-lead coupling. The ability to study I-V characteristics and the Coulomb-blockade peaks at different coupling regimes has a great significance in studying dynamical situations in which the "orthodox" picture of transport fails and new phenomenon appears, known as "charge sensing". This phenomenon results in asymmetric Coulomb-blockade peaks as well as saw-tooth or domelike structures. A common explanation for this phenomenon is based on the presence of traps which contribute additional charging to the system.

Recently, various transport properties of strongly coupled nanoscopic semiconducting systems have been investigated. However, from the basic science point of view, metallic quantum dots have been studied only within the Coulomb blockade regime which is characterized by a weak tunnel coupling between quantum dots and leads. We find it very challenging to explore the metallic dot in this regime since it is characterized by a very high density of states and high charging energy, unlike semiconductor quantum dots. Studying a metallic dot in the strong coupling regime may be possible only if one could control the number of channels and study the transport through a metallic QD in which one state is much more strongly coupled to the leads than the others.

We use a new technique to fabricate metallic quantum dots in which we can span the entire range from closed to open dots and study the effect of interactions between the energy levels on the conductance spectrum. Our experimental setup combines e-beam lithography and AFM nanomanipulation to place a small metallic dot between two leads. In order to achieve fine control over the dot-lead coupling we use an electrochemical deposition process by which we grow metal on the electrodes with extremely fine (atomic-scale) control thus scan the entire regime of an isolated island to an open quantum system. The process is stopped at different degrees of couplings and the transport properties are measured. The most interesting case is that of large coupling in which the widths of some levels are larger than the level spacing and a very nontrivial regime of QD is expected.

Probing Spin Precession by Noise Spectroscopy

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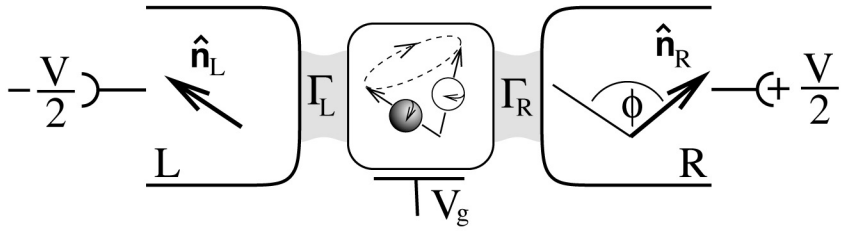
We discuss the possibility to observe the precession of an electron spin via its imprint on the frequency dependent noise of an easier measurable quantity. In this way, a noise measurement can be used as unorthodox electron-spin resonance experiment. To illustrate this point, we review the following two systems:

Transport through a quantum-dot spin valve



A quantum-dot spin valve is a non-magnetic single-level quantum dot, which is contacted by two ferromagnetic leads. Further an external magnetic field can be applied. Via magnetoresistance, the electrical transport through the device is governed by the spin on the quantum dot. While the time-averaged current is sensitive to the time-averaged accumulated non-equilibrium dot spin, the time-resolved dynamics of the dot spin is provided by the power spectrum of the current noise. Single spin precession in the magnetic field generates a resonance in the current-noise spectra at the Larmor frequency [1]. A measurement of the current-current correlation function can supply similar kind of informations as a single spin cw-ESR experiment could access.

Faraday-rotation fluctuation spectroscopy

In materials with spin-orbit coupling such as semiconductors, also the optical detection of spin precession is possible. Via the Faraday effect, the spin fluctuations in a sample leads to a fluctuation of the polarization plane of a transmitted laser. With the power spectrum of the recorded Faraday-rotation fluctuations, the Larmor frequency as well as the spin life time of the electrons can be determined [2,3]. Furthermore, we propose [4] to apply an oscillating magnetic field to avoid line broadening due to structural or chemical inhomogeneities in the sample (not hyperfine interaction), and thereby to increase the precision of the spin-coherence time T_2 measurement. This way, the Faraday-rotation fluctuation spectroscopy resembles an ESR-pulse experiment, without pulses.

[1] M. Braun, J. König, and J. Martinek cond-mat/0601366. [2] M. Oestreich, M. Römer, R. J. Haug, and D. Hägele, Phys. Rev. Lett. **95**, 216603 (2005). [3] S. A. Crooker, D. G. Rickel, A. V. Balatsky, and D. L. Smith, Nature **431**, 49 (2004). [4] M. Braun and J. König, cond-mat/0601607.

Interface optical modes in finite lamellaire structure containing left handed material

D. Bria[a,b,c*], B. Djafari-Rouhani [b], N.Ouchani[a] and A. Nougaoui[a]

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The propagation of optical waves of transverse electric (TE) or transverse magnetic (TM) polarization in finite superlattices composed of alternating layers of right-handed (RHM) and left handed materials (LHM) is studied within a Green's function method. In the LHM material the dielectric permittivity and magnetic permeability are negative, frequency dependent and take the following forms[1,2]: $\varepsilon(\omega)=1-\frac{\omega_p^2}{\omega^2}$ and $\mu(\omega)=1-\frac{F\omega^2}{\omega^2-\omega_0^2}$. Localized modes induced by superlattice/subtrate interfaces are investigated theoretically. These modes appear as well-defined peaks of the density of states inside the minigaps of the superalttice. We show the possibility of the existence of interface modes, which are without analogue in the case of usual superlattices composed only of RHM.

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Modeling the memory effect on nanobiodevices

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Abstract - By using an artificial membrane that is a nano-structured material, we developed an experimental model in which it is possible to induce memory control. Many ion channels formed by proteins incorporated into a planar bilayer lipid membrane (BLM) are investigated by the voltage clamp technique using different step voltage stimuli. Each artificial membrane demonstrates a critical resting interval, Δt_c, between two successive voltage pulses, in which a predictable current response is produced when the second pulse is applied within this Δt_c and an unpredictable current response is produced when the second pulse is applied after the Δt_c. The behaviour of the voltage-gated ion channels may be interpreted as a transient gain, loss or resetting of memory, as revealed by a specific sequence of electrical pulses used for stimulation. In this sense, it is possible to induce memory control of the nanobiodevice in accordance with the experimental conditions imposed on it.

Memory in a Magnetic Nanoparticle System - Polydispersity and Interaction Effects

S. Chakraverty[1,1] , M. Bandyopadhyay[1], S. Chatterjee [2], S. Dattagupta[1], A. Frydman[3], S. Sengupta[1] and P. A. Sreeram[1]

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We report here a theory of relaxation of single domain magnetic nanoparticles, appropriate for analyzing measurements of Mössbauer spectra, magnetization response and hysteretic coercivity. Our special focus of attention in the theoretical formulation is the presence of dipolar interaction between the magnetic particles. We discuss in detail the effect of interaction as well as particle size-distribution on the measured relaxation spectra and irreversible, nonequilibrium magnetization response in field-cooled and zero-field-cooled situations. Some of the memory effects, similar to those seen in spin glass systems, may be put to important device applications by tuning the interaction and the particle size.

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Raman Spectra and Interface Modes of Germanium Layers in Silicon Nanocrystals

Wei Cheng[1,2], Shang-Fen Ren[2] and David T. Marx[2]

[1]Key laboratory in University for Radiation Beam Technology and Materials Modification, Institute of Nuclear Physics, Beijing Normal University, Beijing, 100875, P. R. China
[2]Department of Physics, Illinois State University, Normal, IL 61790-4560

Abstract:

Vibrational modes of 1, 3, and 5 layers of Ge atoms at the center of a spherical Si nanocrystal (NC) with 1147 atoms are calculated using the valence force field model. Raman intensities of this layered Si-Ge NC are calculated via a bond charge polarization approximation and compared with experiments in detail. The observed different Raman spectra for Ge thin films of a few monolayers deposited on Si substrates are explained. Properties of interface modes in this type of layered structures are discussed.

cond-mat//0603294

Scaling properties of the one-dimensional off-diagonal disorder

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[2] *Department of Physics, Damghan University of basic sciences, Damghan, IRAN**

(Dated: May 1, 2006)

Abstract

Validity of the single parameter scaling in one dimensional Anderson model with uncorrelated purely off-diagonal disorder is being studied. It is shown that at the vicinity of the band center, one parameter scaling is not only violated in a delocalized region with chiral symmetry, but also it is violated in a localized region with standard symmetry. It is shown that there is an additional length related to the integral density of states, which controls the scaling theory. The essential behavior of the scaling function in this model does not obey a universal form such as the studied models. A physical interpretation of the new length is the cross over length which separates regions with chiral symmetry from those that have standard symmetry.

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Keywords: localization,off-diagonal,single parameter scaling

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Coherent-incoherent transition in the sub-Ohmic spin-boson model

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We study the spin-boson model with a sub-Ohmic bath using a variational method. The transition from coherent dynamics to incoherent tunneling is found to be abrupt as a function of the coupling strength α and to exist for any power $0 < s < 1$, where the bath coupling is described by $J(\omega) \sim \alpha\omega^s$. We find non-monotonic temperature dependence of the two-level gap $\tilde{K}$, and a transition to an incoherent phase at a critical temperature T^*.

SU(4) versus SU(2) Kondo effect in double quantum dot

A. L. Chudnovskiy

The observation of the Kondo effect with orbitally degenerate levels provided the first demonstration of the strong influence of the orbital structure of the states in the dot and attached leads on the Kondo effect [1]. Further exploration of the interplay between spin and orbital degrees of freedom in the Kondo effect became possible in experiments with double dot systems. If the two dots are strongly electrostatically coupled [2, 3], then there are regions in the charging diagram of the double dot device, where there is no energy cost to transfer an electron between the two dots. In that regions, the two ground states of the double dot system with occupations of the two dots $(N_1 - 1, N_2 + 1)$ and (N_1, N_2) are degenerate. The two ground states build a two-dimensional Hilbert space which spans the representation of the $SU(2)$ group, hence a spin-like degree of freedom called pseudospin can be assigned to those two states. Quite analogously to and to a large extent independently of the well-known spin Kondo effect, the orbital fluctuations in transport through the double dot result in the development of the orbital, or pseudospin Kondo effect. Furthermore, at special values of Kondo couplings, the combined spin and pseudospin Kondo Hamiltonian possesses a $SU(4)$ symmetry with respect to rotations in the spin-pseudospin space. In that regime, the $SU(4)$ Kondo effect with greatly enhanced Kondo temperature has been predicted theoretically [4, 5].

The existence of the pseudospin Kondo effect crucially relies on the coupling of each quantum dot to its own electronic reservoir formed by the electron states in the attached leads. The separation of the reservoirs allows to define a pseudospin for the electrons in the leads in a natural way. For two sequentially coupled quantum dots [5] such a separation is given by geometry. In contrast, the realistic experimental geometry for two dots coupled *in parallel* to the leads does not introduce a separate reservoir for each dot *a priori* [2].

In this paper, we investigate the possibility and properties of spin and pseudospin Kondo effect in a double dot embedded in a parallel circuit with the attached leads if there is no separate electron reservoirs for each quantum dot. We introduce a measure of mixing between the two reservoirs that reflects the structure of tunnel matrix elements. We find that increasing the mixing between the reservoirs, the Kondo temperature gets slightly suppressed in the intermediate regime between the two symmetry points, the SU(4) one and the SU(2) one. The change in symmetry of the Kondo effect can be detected experimentally by applying an external Zeeman magnetic field in the plane of the double dot device. An external Zeeman field suppresses the Kondo effect in the spin sector. Therefore, whereas the $SU(2)$ Kondo effect is completely suppressed by the Zeemann field, the combined spin-pseudospin $SU(4)$ Kondo effect is only reduced to the $SU(2)$ Kondo effect in the pseudospin sector. We derive an expression for the Kondo temperature as a function of mixing between the reservoirs and of a Zeeman magnetic field in the whole range between the $SU(4)$ and $SU(2)$ regimes. Being the basic energy scale, the Kondo temperature determines all other experimentally observable properties related to the Kondo effect. Therefore, the calculated dependence of the Kondo temperature of Zeeman magnetic field and the mixing parameter can be seen in the measurements of the conductance through the double dot device. The obtained results can also be relevant to the experiments on Kondo effect in carbon nanotubes [6].

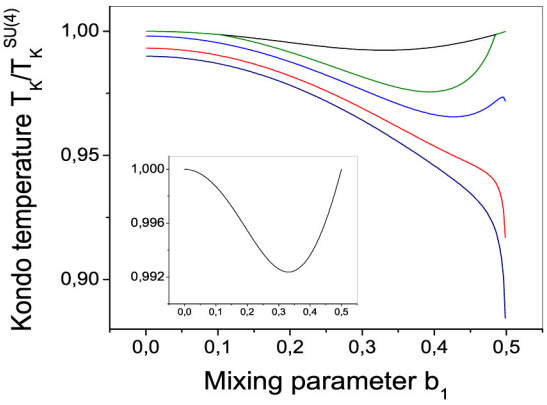

FIG. 1: Kondo temperature as a function of mixing between the electron reservoirs b_1 for different Zeeman fields h. Magnetic field increases from the highest to the lowest curve. From the highest to the lowest curve: $h/T_K^{SU(4)} = 1.0; 1.02; 1.06; 1.14; 1.29$. Inset: the dependence $T_k(b_1)$ at zero Zeeman field. The curves illustrate characteristic $T_K(b_1)$ dependencies.

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Phononless inelastic transport through a disordered array of quantum wires

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PACS 73.63.-b,72.10.Di,73.23.-b

It is a well established fact that the single-electron transport through a one-dimensional system with random scattering is suppressed at zero temperature and infinitesimally small applied voltage [1] due to the Anderson localization phenomenon. Namely, the constructive interference of initial and back-scattered waves enhances the return probability after scattering by an impurity potential. Eventually the constructive interference leads to the localization of the single particle wave function in a one-dimensional disordered system. A natural conclusion follows, that suppression of the coherence of the single particle propagation leads to delocalization and favors transport through the system. Indeed, at finite temperature electrons couple to thermally activated bosonic excitations in the environment (usually phonons), which results in the decoherence of the electron motion and in the thermally activated electron transport [2].

A basic theoretical question remains, whether the thermally activated transport can be induced by electron-electron interactions alone, that is without an external bath of bosonic excitations like phonons. The mechanism of a phononless thermally activated transport consists of dephasing of the electron wave function by electron-electron scattering that results from e-e interactions. In the case of decoherence by interactions, the role of bosonic bath is played by the electron-hole pairs, or charge fluctuations, that are excited thermally or in the result of electron-electron scattering.

In the present paper we investigate phononless thermally activated transport through a quasi-one-dimensional system formed by a parallel arrangement of conducting wires. Each wire has a finite length L and the transport direction is perpendicular to the wires. The considered model is special, because it combines two seemingly incompatible features: **i)** it is strongly disordered for single electron transport; **ii)** it is much weaker disordered for transport of charge-density fluctuations (plasmons). We show that charge-density fluctuations (plasmons) in the array can act as the agent promoting thermally activated transport, thus providing the possibility for phononless inelastic transport. As the result of generically strong plasmon-electron coupling in a quantum wire, the features of plasmon and phonon assisted transport are qualitatively different. We provide a qualitative explanation of plasmon assisted transport, identify the transport regimes, where the features of plasmon and phonon assisted transport are either similar or substantially different, and derive analytic expressions for the temperature dependence of the thermally activated resistance for a special model of a strongly correlated disordered array of quantum wires. We show that for a special kind of disorder introduced below the plasmon localization length can much exceed the single particle localization length. Our results apply to the regime, when the plasmon localization length exceeds the length of the array.

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Effects of the Electrode Structure on the Transport Properties of Ge_7 Cluster

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Abstract:

We have systematically studied the electrical transport properties of Ge_7 cluster, which is coupled to two kinds of Ag(100) and Ag(110) atomic electrodes with finite cross sections. About the equilibrium properties under zero bias, our results exhibit that the conductance of Ge_7 cluster, which is contacted with Ag(100) electrode, takes the value of 3.76Go(quantum conductance unit) in the case of the equilibrium cluster-electrode contact distance. However, the equilibrium conductance for the Ag(110) electrode, which is also in case of the equilibrium contact distance, is only 2.92Go. The difference between these two cases of electrodes is close to 1Go. We elucidate that this conductance difference is due to the variation in the number of bands crossing the Fermi level in these two kinds of electrodes. In the Ag(100) electrode, there are five bands crossing the Fermi level. However, there is only four bands crossing the Fermi level in the Ag(110) electrode. More bands crossing the Fermi level induce more eigenchannels contributing to the equilibrium conductance. The equilibrium conductance of Ge_7 cluster under some other contact distances for these two kinds of electrodes is also calculated. Our results also show that the conductance in the case of Ag(100) is always bigger than that in the case of Ag(110).

Title: **Tunneling of fractionally charged quasi-particle through an insulator.**

Co-author(s): Sourin Das and Yuval Gefen

Short abstract:

We consider tunneling of fractionally charged quasi-particles (Q.P.) through a large barrier in a Fractional Quantum Hall droplet in a multiply connected geometry. Global constraint for Q.P. tunneling does not arise in the context of multiply connected geometry. We employ RG technique to analyze the problem in the vicinity of weak tunneling, regime.

Melting transition in mesoscopic superconducting high Tc samples

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We are studying the melting transition of the vortex ensemble that has been observed in High Temperature superconductors, in particular we are interested in the bulk properties of this system when the sample size is reduced to the mesoscopic domain. In this work we will present the fabrication of $Bi_2Sr_2CaCu_2O_8$ samples of mesoscopic size, magnetic decoration on these samples and magnetic measurements by high-Q micro-oscillators (MEMs).

Multiphase Fluid Modelling at the Microscale: Liquid-Liquid Slug Flow Hydrodynamic

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Introduction: Phenomena at microscale can be counterintuitive due to the difference in physical behaviour between microscopic and macroscopic systems. Microfluidics applications serve as interface between the macro- and nano-world. Microscale systems offer many advantages such as minimal substances consumption, complex chemical waveforms, and significantly reduced analysis or experiment time, e.g. an important concept recently introduced was μTAS, the Micro Total Analysis System (for details, Manz, 1990). The absence of inertial and turbulent effects in microfluidics devices, due to the low ratio between the inertial forces and the viscous forces offers new horizons for new physical, chemical and biological applications. Also the short length scales gives high surface-to-volume ratios, small diffusion distances and easy temperature profiling along the dimensions. Other significant forces are the surface tension of the fluid and the wetting properties. Drops or slugs and their application in micro and nano-scales are a very important field in present science. In medical applications for example: cell-based assays (Pihl, 2005), models for capillary blood vessels for red cells infected with malaria (Shelby, 2003), drug delivery targeted at specific sites in the body for a less invasive chemotherapy, miniature biosamples preparations on fully automated biochips, for DNA sampling and other genomic applications. On Chemical applications it has been used in two-phase chemical reactions (Tice, 2004; Hodges, 2004; Harries et. al., 2003; Burns and Ramshaw, 2001 and 2002,) elucidation and optimisation of nitration reaction (Dumman et. al., 2003), fast or dangerous reactions, solvent extraction and separation and so on. These microscales reduce the problem of scale-up for large scale production by simply numbering-up.

Motivation: Mathematical models describing the movement of drops, or in general, multiphase flows are not always able to predict or quantify properly all the important particularities of this complex system. Hence a deeper knowledge of the physical problem: hydrodynamics transport and chemical kinetics is mandatory. This task requires vigorous modelling techniques; therefore we initiate the hydrodynamic study of drops/slug movement in capillaries. Accordingly, we focused in the application of a slug flow microreactor model, to match the necessities and behaviour described in (Kashid et. al., 2005 and 2006), see Figure 1. We identified some key issues in slug flows; in this abstract the focus is on internal circulation within the slugs.

Methods: The hydrodynamic flow pattern of a slug flow and the evolution of complex interfaces was performed using in-house developed, open-source, CFD code FEATFLOW (free surface modelling, levelset approach). This code uses an implementation of surface tension effects in interfacial flow combining two techniques: the continuum surface force (CSF) method and a finite element discretization together with the Laplace-Beltrami operator (Hysing, 2006), (Hysing and Turek, 2005), (Turek and Becker,1999) .

Results The computational domain is a rectangular section with a height as from the capillary internal diameter of 1 *mm* and a length of 100 *mm*. A region of the mesh and the initial configuration of the slugs shape are given in Figure 2. The boundary conditions are such as in the experimental conditions: Pouisselle parabolic profile at the inlet and atmospheric pressure at the outlet. Calculated hydrodynamic flow conditions are also presented in the mentioned figure.

Conclusions & Outlook: The presented numerical results show good agreement with expected physical behaviour and experimental measurements. It is expected to couple more complicated physical phenomena to fit several applications as mentioned in the **Introduction** section.

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Figures:

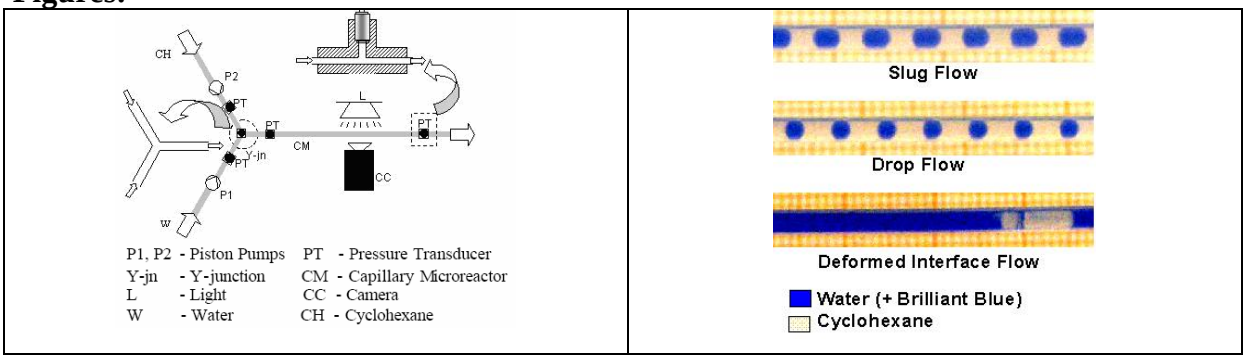

Figure 1. Experimental setup

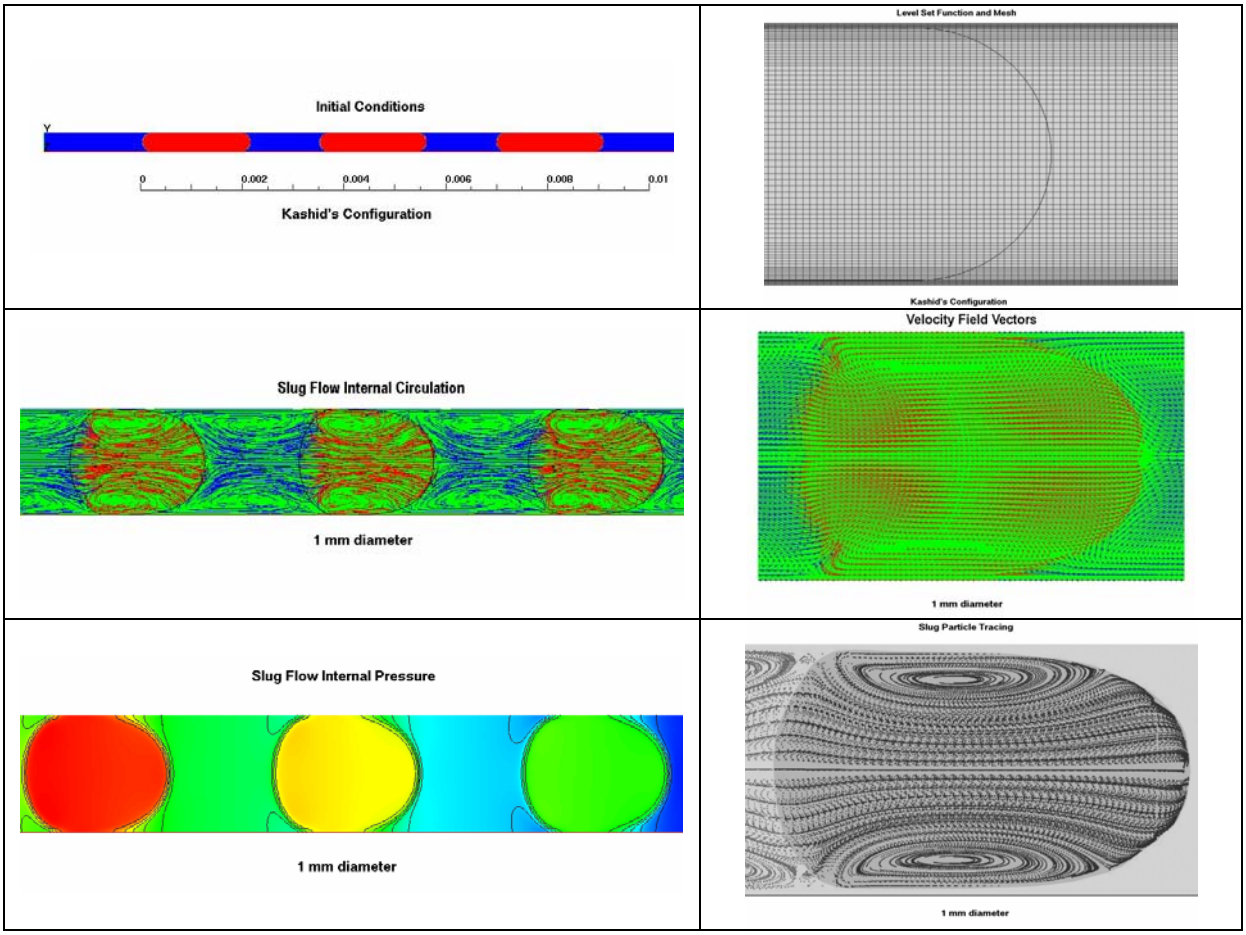

Figure 2. Modelling Initial Conditions, and Numerical Results for the Hydrodynamics of three slugs.

"Dynamical effects of the anisotropy, due to Spin – Orbit coupling, on the operation of the $(swap)^{\alpha}$ quantum gate"

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The electronic spin has been proposed as one of the two level systems that can be a good candidate for the construction of the qubit. It has been also proposed that the exchange coupling between two electronic spins can be used to control and manipulate de states of the two qubit space. This control over the exchange coupling, when used as a dynamical variable, can be made to produce specific two qubit operations, call quantum gates, which are the key elements of quantum computation[1]. The CNOT gate is particularly important, because is universal, i.e., any quantum circuit can be created using this gate (two qubit operations) and operation over each of the spins (single qubit rotations).

To perform a CNOT operation is necessary to do single rotation over each of the two electronic spins and to be able to realize the $(SWAP)^{1/2}$, which is obtained naturally by the two coupled electronic spins system.

By considering the effect of the spin-orbit coupling on the two spin system, it has been found that an anisotropic term will appear in the two spin Hamiltonian. This new term will be about 1% to 10% of the total energy of the system[4]. In particular, the effect of this new term will have important consequences on the operation $(SWAP)^{1/2}$ gate. It has been demonstrated that the error added by the anisotropic term, to produce the CNOT gate, can be "rotated out" by careful selection of the form of the exchange variable J[2,3]

Recently it has been proposed that a more general two qubit quantum gate, $(SWAP)^{\alpha}$, could be used in place of the CNOT[5]. It was demonstrated also that $(SWAP)^{\alpha}$ is universal[5], and equally efficient, in the number of gates used, as the CNOT gate. This gate has the effect of adding a phase equal to the value of α to the state that describes the system. The different values of α are obtain by careful choosing of the form of J.

In this work, we study the effect that the anisotropic term will have on the $(SWAP)^{\alpha}$ gate operation.

By selecting the area of the exchange J over a period of time to produce the required gate operation, we have calculated dynamical properties of the probability of the two spin states, magnetization, entanglement (concurrence) and fidelity of the required quantum gate to determine the effect of the anisotropic term in the operation of the $(SWAP)^{\alpha}$ gate.

By calculating the fidelity of the quantum gate, we found that only for values of $\alpha=1$, the error produced by the anisotropy could be corrected. This result appears to point out that a small error in the operation would be always present, and would be of the second order in the anisotropic amplitude, so that it can be manageable for small values of the anisotropy.

Time dependent properties of entanglement of the two spin state through the concurrence are also calculated and a general analytical expression describing this property in terms of the magnetization, and observable, was found.

It was also shown that the right magnetization of the spins in the states of the $(SWAP)^{\alpha}$ gate is not a sufficient property to determine the successes of the system in constructing the necessary quantum gate, but a careful analysis of the fidelity must be done in the quantum gate construction.

We thank support from DGAPA, through the project 1N114403 and CONACYT through the project 43673-F.

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Poposal of a novel light-addressable potentiometric sensor using two-photon-induced photocurrent in nano-poroussilicon heterostructure.

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Abstract:

Conventional light-addressable potentiometric sensor, LAPS, wroks with single photon absorption utilizing photons having energy higher than the band gap, which can not ensure highest spatial resolution. Instead, two-photon absorption (TPA) can be utilized where the photon energy is less than the band gap and electron-hole pair (EHP) generation in bulk can be avoided as the Si is transparent at that wavelength. But the TPA cross section for conventional silicon is very low and the capacitive photocurrent is very small to be used efficiently in LAPS. Due to the higher TPA-cross section porous silicon (p-Si) heterostructure as the LAPS sensor has been proposed in this study. The focusing of pulsed laser through a hemispherical silicon solid-immersion-lens (h-SIL) is also proposed. Using femtosecond laser pulse of 1530nm with focusing by h-SIL it is possible to make two-photon absorption near the depletion region. As a result the electron-hole pair will be generated near the depletion region and before diffusing appreciably laterally it will be possible to get them separated in the depletion layer. Including all the mechanism of enhancing the photocurrent and focusing the pulsed laser, this study proposes a novel LAPS that is expected to provide a spatial resolution better than 150nm.

Growth and characterization of Mn-catalyzed GaAs nanowires by MBE

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The unique properties of semiconductor nanowires are likely to play an important role in a whole series of emerging technologies.[1,2] Most of the methods to produce high densities of nanowires, while minimizing structural defects, involve catalyst-assisted growth. In such procedures metal catalyst particles induce and dictate one-dimensional semiconductor growth through a vapor-liquid-solid process[3]. A metal particle is generally found at the top of the final semiconductor nanowire and the lateral dimension of the nanowire is determined by the particle size. Several authors have argued that the use of a metal catalyst may cause contamination and change in the physical properties of the nanowires.[3]

Another emerging field of semiconductor research - spintronics - promises to make profitable use of diluted magnetic semiconductors. In these materials, the magnetic properties arise from spin-exchange interactions between the magnetic impurity ions and free holes[4]. In order to exploit GaAs technology, one of the most investigated material system is GaAs:Mn. The combination of these two research fields could lead to 1D spintronic devices.

In this work we report the fabrication and the structural properties of III-V nanowires grown by molecular beam epitaxy using Mn growth catalysts. The use of Mn is intended to exploit the Mn diffusion into GaAs to obtain diluted magnetic semiconducting nanowires.

The growth of III-V nanowires (NWs) by solid-state molecular beam epitaxy. GaAs and InAs NWs have been fabricated using both Mn as growth catalysts. In particular, one of our intents is to investigate whether Mn diffuses into the NWs during the growth, with the explicit intent to dope the NWs with manganese as a first step towards the attainment of dilute ferromagnetic semiconducting NW.

The growth of GaAs and InAs NWs has been successfully obtained on a number of substrates. The use of substrates gives rise to the fabrication of a large number of nanowires with both catalysts. Fig. 1 shows the scanning electron microscopy image of a typical GaAs NW yield obtained on SiO_2 (catalyst Mn). Together with the nanowires a number of quasi 2D structures, a kind of nanoleaves, has been also obtained. The growth temperature range useful for tha growth of GaAs NWs is 520-620 °C. InAs NWs are instead obtained at a lower temperature. A SEM picture of InAs NWs is reported in Fig. 1.

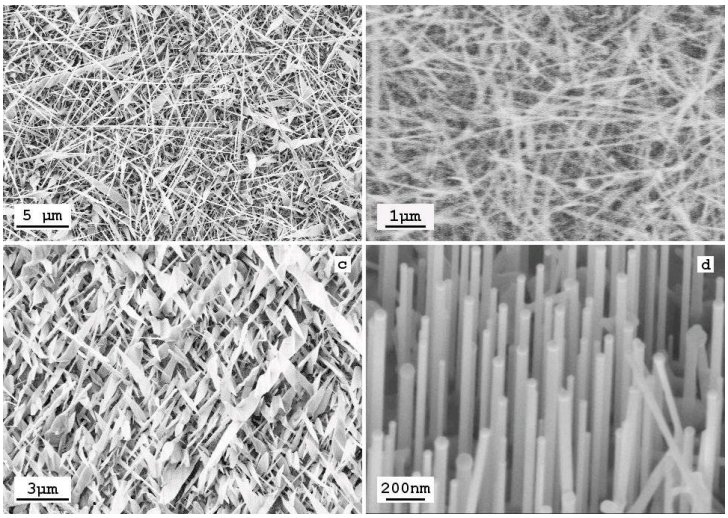
The growth process and the crystalline structure of the nanowires have been investigated by transmission electron microscopy. In case of Mn-induced wires, the image analysis is made more difficult by the tip oxidation that occurs when the specimens are taken out of the growth chamber. The amount of crystalline material at the top of the wire that can be identified with α-Mn has an apparent diameter smaller than the corresponding wire (Fig. 2). This feature suggests the possibility of a sizeable Mn diffusion into the wires. Mn diffusion is confirmed by extended X-ray absorption fine structure measurements (not reported in this abstract), that show that about 50% of the Mn atoms revealed by the measurements is bound to As, while the rest is bound to oxygen.

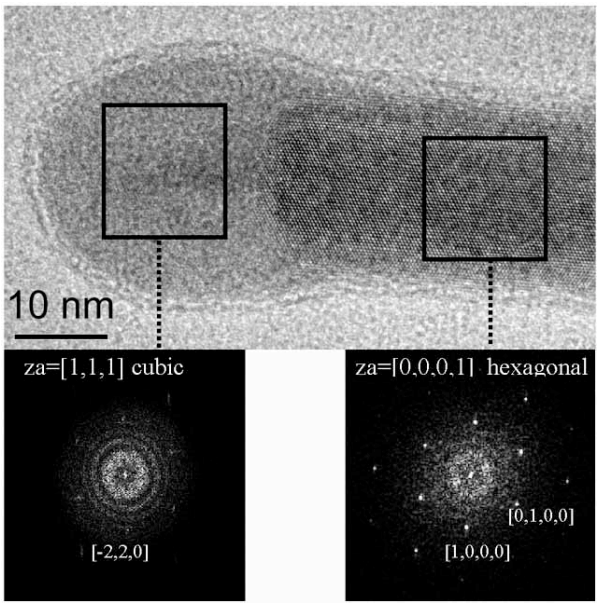
Photoluminescence measurements have been performed on both as-grown samples as well as on NWs transferred onto a different substrate. Fig. 3 shows the emission spectrum at 10 K taken on *as-grown* Mn-catalyzed GaAs NWs fabricated at 580°C. The PL spectrum, does not resemble the luminescence of epitaxial GaAs, and is composed of a main peak at 1.522 eV and a number of weaker peaks located at lower energy superimposed on a broad background. The peak at 1.522 eV is located 7 meV above the free-exciton recombination in zincblende (ZB)-GaAs. We emphasize that this peak is observed in all Mn-catalyzed wires, irrespective of the growth temperature.

We suggest that the peak at 1.522 eV originates from e-h recombination in wurtzite zones of the nanowires, clearly observed in TEM experiments[5]. It is known that the band gap of a wurtzite semiconductor is always larger than in its corresponding ZB structure. If our suggestion is correct this would be the first evidence of luminescence from wurtzite GaAs.

Only limited information can be gained by the number and energy position of the other peaks. They are also reproducible from sample to sample and in different regions of the samples. Their intensity relative to the main peak at 1.522 eV decreases with increasing excitation intensity and the peaks eventually merge into a broad tail.

Fig. 1 SEM images of (a) Mn-catalyzed GaAs nanowires grown on SiO_2; (b) Mn-catalyzed InAs nanowires grown on SiO_2; (c) Mn-catalyzed GaAs nanowires and nanoleaves grown on oxidized GaAs; (d) oriented Au-catalyzed GaAs nanowires grown on GaAs(111)B.





Fig(2) HRTEM image of the tip of a Mn-catalyzed GaAs NW. The insets are the FFT obtained from the marked relevant regions of the ananowire. The FFT from the body indicates wurzite GaAs whereas the FFT from the crystalline region of the tip is due to a α-Mn phase

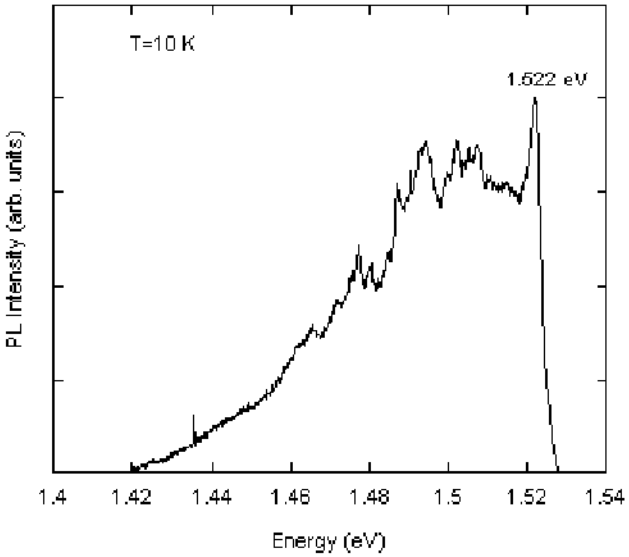


Fig. 3. Photoluminescence spectrum at 10 of a typical GaAs NWs sample.

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Magic Melters Have Geometric Origin.

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Studies of finite temperature behavior of clusters have brought out many counterintuitive observations. For example, higher than bulk melting temperature in case of Sn and Ga, substantial variation in melting temperature as a function of size and the most intriguing one is drastic change in the characteristic of heat capacity with addition of just one atom. It has been observed that Ga_{31} has a well-defined peak in the heat capacity whereas heat capacity for Ga_{30} is flat and does not show any peak. Ga_{31} is termed as magic melters.

In this poster we demonstrate that magic melters have geometric origin. We have done isokinetic Born-Oppenheimer molecular dynamic simulations to compute the ionic specific heat of Ga_{30} and Ga_{31}. We have reproduce the experimental results and demonstrated that the drastic difference in the finite temperature behavior of these clusters is due to the subtle difference in their ground state geometries. Ga_{31} has relatively more symmetric ground state, with more number of bonds having equal strength. Indicators like root mean square bond length fluctuations, mean square displacements of individual atoms bring the differerence in these two clusters clearly. We also demonstrate that all these features are generic in small clusters and are observed in Al clusters as well.

Title: Spintronic analogue of the Stern-Gerlach device

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Abstract:

The Stern-Gerlach experiment, where spatial and spin degrees of freedom become intertwined, has been playing a fundamental role in the conceptual foundations of quantum mechanics. The recent development of spin electronics (spintronics) in low dimensional semiconductor structures offers a new way of manipulating spin degrees of freedom. Quantum rings made of semiconductor materials exhibiting Rashba-type [1] spin-orbit interaction have been shown to be especially important due to their remarkable spin transformation properties [2, 3, 4, 5, 6].

We consider three terminal rings and show [7] that they can be considered to a large extent a spintronic analogue of the Stern-Gerlach apparatus: The incoming electrons are forced to split into two different spatial parts by the geometrical construction of the semiconductor device. Due to spin sensitive quantum interference [8] and spin-orbit interaction, electrons that are initially in a totally unpolarized spin state become polarized at the outputs with different spin directions. Our model is based on an exact, analytic solution of the spin dependent transport problem and thus provides a clear physical picture of a process where fundamental polarization effects as well as nontrivial spatial-spin correlations appear. Calculating the spinor valued wave functions and the spin current densities along the ring, we show that the polarizing effect is due to the spatial interference of states carrying oppositely directed currents. By working in an appropriate basis we visualize that for the two basis states as inputs destructive interference takes place at different output junctions, resulting in the output of the completely polarized spin state corresponding to the basis state for which constructive interference takes place at the given junction.

Additionally, our treatment allows us to determine for which parameters the device is reflectionless, that is, perfect polarization takes place without losses.

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Title: Critical current and $0-\pi$ -transition in SFS junction.

Abstract: The critical current for a weak SFS junction with a ferromagnet doped by potential and magnetic impurities was found by solving the Eilenberger equation for the ferromagnet. The criteria for π -type behaviour in this junction was obtained. The diffusion approximation was shown to be incorrect for the case of magnetic impurities and a low transparency SF interface. In contrast to existing results where the only scale equals $\sqrt{D/I}$, this model has different coherent and oscillations-period lengths equal to $v_F\tau$ and v_F/I , respectively.

Carrier chirality and weak localisation in graphene

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The chiral nature of quasiparticles in graphene [1] recently revealed in the quantum Hall effect measurements [2] originates from its hexagonal lattice structure. It suppresses backscattering and, thus, can be expected to cause weak antilocalisation and a positive weak-field magnetoresistance [3]. However, this can be true only for purely potential scattering, while any violation of the hexagonal symmetry by static disorder in a realistic graphene sheet or by edges in a narrow wire tend to restore conventional negative magnetoresistance. We show this by evaluating the dependence of the magnetoresistance of graphene on relaxation rates associated with various possible ways of breaking the high original symmetry of the system.

The Fermi line for electrons in graphene consist of two tiny circles located close to the corners, $\mathbf{K}_\pm$ of the hexagonal Brillouin zone. The quasiparticle spectrum in these two valleys is described by the Hamiltonian $\hat{H}_1$ which operates in the space of 4-component wave functions, $\Phi = [\phi_{\mathbf{K}_+}(A), \phi_{\mathbf{K}_+}(B), \phi_{\mathbf{K}_-}(A), \phi_{\mathbf{K}_-}(B)]$ and governs electronic amplitudes on two sublattices (A and B) and in the valleys $\mathbf{K}_\pm$,

$$\begin{aligned} \hat{H}_1 &= v\left(\Pi_z\sigma_x p_x + \Pi_0\sigma_y p_y\right) + \hat{h}_{\rm w}, \\ \hat{h}_{\rm w} &= \mu\left[\Pi_z\sigma_y\left(p_x p_y + p_y p_x\right) - \Pi_0\sigma_x\left(p_x^2 - p_y^2\right)\right]. \end{aligned} \tag{1}$$

Here, we use a direct product of 'isospin' matrices $\sigma_0 \equiv \hat{1}, \sigma_{x,y,z}$ acting in the sublattice space and inter/intra-valley matrices $\Pi_0 \equiv \hat{1}, \Pi_{x,y,z}$ to highlight the difference between the form of $\hat{H}_1$ in the non-equivalent valleys.

We evaluate magnetoresistance, $\rho(B) - \rho(0) \equiv \Delta\rho(B)$ of graphene. Taking into account double spin degeneracy of carriers we present $\Delta\rho(B)$ as

$$\begin{aligned} \Delta\rho(B) = \frac{e^2\rho^2}{\pi h}\Bigg[F\Big(\frac{B}{B_\varphi}\Big) - F\Big(\frac{B}{B_\varphi + 2B_{\rm i}}\Big) \\ -2F\Big(\frac{B}{B_\varphi + B_{\rm i} + B_*}\Big)\Bigg], \\ F(z) = \ln z + \psi\Big(\frac{1}{2} + \frac{1}{z}\Big),\ B_{\varphi,{\rm i},*} = \frac{\hbar c}{4De}\tau^{-1}_{\varphi,{\rm i},*}. \end{aligned} \tag{2}$$

Here, ψ is digamma functions. When deriving Eq. (2), we assumed that electron mobility and diffusion coefficient, D in a monolayer of graphite are limited mainly by charged impurities in the underlying substrate. The role of other types of disorder is to break the symmetry of the system and to determine a finite intervalley scattering rate $\tau_{\rm i}^{-1}$. In particular, the relaxation rate $\tau_*^{-1} = \tau_{\rm w}^{-1} + 2\tau_{\rm z}^{-1}$ in Eq. (2) is generated by scattering from lattice defects locally distinguishing A and B sites (z) and by trigonal warping $\hat{h}_{\rm w}$ (w). Decoherence taken into account in Eq. (2) by the rate τ_φ^{-1} determines the curvature of magnetoresistance at $B \lesssim B_\varphi \equiv \hbar c/4De\tau_\varphi$. If $B_* \ll B_{\rm i}$ ($\tau_*^{-1} \ll \tau_{\rm i}^{-1}$), the magnetoresistance $\Delta\rho(B)$ changes sign: $\Delta\rho(B) < 0$ at $B < B_{\rm i} \equiv \hbar c/4De\tau_{\rm i}$ and $\Delta\rho(B) > 0$ at higher fields. For $B_* \gg B_{\rm i}$ ($\tau_*^{-1} \gg \tau_{\rm i}^{-1}$), the magnetoresistance is distinctly of a WL type, with almost no sign of anti-localisation up to the highest fields. Details of this work can be found in [4].

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Magnetization dynamics in a driven nanopillar

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We study magnetization dynamics in an ac-driven ferromagnetic/normal-metal/ferromagnetic tri-layer. We consider a geometry where the two magnetization moments are oriented perpendicular to each other, due to an external magnetic field. Assuming one layer remains static, the consequence of the spin-torque mechanism is a phase locked magnetization precession of the second layer. The precession depends resonantly on the driving frequency and the frequency set by the external magnetic field. We calculate the dependence of this resonance on system properties and find its signatures in the magnetoresistance.

Title:

Singular length dependence of critical current in SNS bridges

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Abstract:

We examine dependence of the critical Josephson current on the length L of the normal bridge N between two bulk superconductors. This dependence turns out to be non--analytic at small L. The non--analyticity originates from the contribution of extended quasiparticle states with energies well above the superconducting gap. This should be contrasted with the more familiar contribution to the Josephson current coming from Andreev bound states localized in the normal region at energies below the gap.

Electronic transport properties of NbC(C)-C nanocomposites

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The electronic transport properties of a composite system comprising zero dimensional superconducting NbC(C) nanocapsules and carbon nanofiber matrix were studied. DC susceptibility χ_{dc} measurements of the nanocomposite indicate that the critical temperature (T_C) of NbC nanocrystals is 10.7 K. The temperature dependence of electrical resistivity of the specimen pellet follows the Mott's $T^{-1/4}$ law in a temperature range between T_C of NbC and 300 K, owing to a strong degree of structural disorder in the carbon matrix. Below the T_C of NbC, when the change of its electrostatic energy ΔE is far greater than the thermal energy, an electron will be localized on an isolated NbC nanocrystal at very low temperatures, leading to "Coulomb Blockade." As a result, a collective behavior of the single-electron tunneling effect takes place in a three-dimensional granular superconductors' network composed of the NbC/carbon/NbC tunneling junctions. The superconducting gap of NbC crystals is not found in the current-voltage curves, due to the suppression of surface superconductivity through the contact between NbC and carbon shells. When a Nb_3Al block is used as an anode, Al_4C_3 nanorods are produced and NbC_x nanoparticles dose not show a superconductivity because of the attendant carbon vacancy sites.

Title: **Conductance through an array of quantum dots**

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We propose a simple approach to study the conductance through arrays of N interacting quantum dots, weakly coupled to metallic leads. Using a mapping to an effective site which describes the low-lying excitations and a slave-boson representation in the saddle-point approximation, we calculated the conductance through the system. Explicit results are presented for N=1 and for several arrays with N=3. For N=1 in the Kondo limit, the results are in very good agreement with previous results obtained with numerical renormalization group (NRG). In the case of a linear chain for odd N, when the parameters are such that electron-hole symmetry is induced, we obtain perfect conductance $G=2e^2/h$.

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Title: **Many-body and confinement effects on mirages in quantum corrals**

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In the quantum mirage experiment, confinement of surface electrons by an elliptical nanoscopic corral has been used to the project the Kondo effect from one focus of the ellipse to the other. Remarkably, the space map of the change in the differential conductance ($\Delta dI/dV$) at the Fermi energy, obtained with scanning tunnelling spectroscopy (STS), clearly resembles the density of the 42nd state of a hard-wall elliptical corral. In order to describe consistently the experiment, the effect of confinement as well as the many-body aspects must be included in any theoretical description. We first calculate the resonances inside the corral. To model a "soft" corral, we propose a confining potential of the form $W\delta(r-r_0)$. The many-body interactions are modelled with the single impurity Anderson model. Two different techniques, second order perturbation in the Coulomb repulsion U, and slave-bosons in the saddle-point approximation, have been used to handle the many-body problem. We calculate the resulting change in the differential-conductance $\Delta dI/dV$ as a function of the gate voltage and real-space position. The main features seen in the experiments are reproduced. By studying the the lineshape of $\Delta dI/dV$ as a function of the position inside the corral, we propose a means to experimentally discern the relative importance of bulk states, an issue that remains unclear yet. We also calculate spin-spin correlations.

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Kinetics of a Superconducting Charge Qubit in the Presence of a Quasiparticle

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We investigate the energy and phase relaxation of a superconducting qubit caused by a quasiparticle. In the considered model, the qubit is an isolated system consisting of a small "Cooper-pair box" (box) and a larger superconductor (reservoir) connected by a Josephson junction. If such system contains an odd number of electrons, then even at lowest temperatures a single quasiparticle is present in the qubit. The quasiparticle resides in the reservoir with an overwhelming probability, but its quick round-trips to the box lead to the relaxation of the qubit. We derive master equations governing the evolution of the qubit coherences and populations. The kinetics of the qubit can be characterized by two time scales - quasiparticle escape time from reservoir to the box Γ_{in}^{-1} and quasiparticle relaxation time τ. The former is determined by the normal-state conductance $g_{_T}$ of the Josephson junction and one-electron level spacing δ_r in the reservoir ($\Gamma_{in} \sim g_{_T}\delta_r$), and the latter is due to electron-phonon interaction. The phase coherence is damped on the time scale of Γ_{in}^{-1}. The qubit energy relaxation depends on the ratio of the two characteristic times, τ and Γ_{in}^{-1}, and also on the ratio of temperature T to the Josephson energy $E_{_J}$. In the limit $\Gamma_{in}\tau \gg 1$ and $T \ll E_{_J}$, the relaxation of the qubit populations occurs in two stages. In the first stage, $t \sim 1/g_{_T}\delta_r$, the initial population of the excited state changes only by a small amount $\sim (T/E_{_J})^{1/2}$. This quasi-stationary state relaxes to full equilibrium over a longer time scale $t \sim \tau(E_{_J}/T)^{1/2}$.

Inversion of magnetoresistance in spin-polarized tunneling devices

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Electron tunneling is a quantum phenomenon by which an electric current can flow between two electrodes despite being separated by an insulating layer. The story of spin polarized tunneling goes back to the early seventies when Meservey and Tedrow[1,2] proved that the electron tunneling from a ferromagnet into a superconductor is spin polarized and that the spin of the electron is conserved in tunneling. Magnetic tunnel junction (MTJ)[3] is a spin-polarized tunneling device in which two ferromagnetic metallic electrodes are separated by a very thin insulating layer. The junction resistance depends on the relative magnetic orientation of the electrodes, which can be manipulated by applying a small magnetic field. Usually, the conductance of the magnetic tunnel junction when the magnetic moments of the two layers are parallel is much higher than its conductance when the magnetic moments of the two layers are anti-parallel. This effect is called the Tunnel magnetoresistance (TMR). However there are a few interesting exceptions. Observation of inverse TMR (where the conductance in the antiparallel magnetic configuration is higher than that in the parallel configuration), has been instrumental in understanding some of the important aspects of spin polarized transport in MTJs. I will elaborate on the different important mechanisms, which can lead to inversion of TMR. For example, the inverse TMR observed in experiments by De Teresa et. al.[5] and Sharma et. al.[6] have proved that the transport properties of MTJ depend not only on the ferromagnetic metal electrodes but also on the insulator. The TMR depends on the specific bonding mechanism at the electrode-insulator interface and that the choice of the insulator dictates which band is to be selected for tunneling. Generally, in such cases, the inverse TMR can occur if the signs of spin polarization of the two electrode-insulator interfaces are opposite. Tsymbal et. al.[7] have proposd that there is a finite probability that resonant tunneling via localized impurity state, which is positioned asymmetrically inside the barrier can invert the effective spin polarization of one of the electrodes thus leading to inverse TMR. Recently, we have shown[8,9,10] that the superimposition of tunneling conduction (across insulating spacers) and ballistic channels through pinhole nanocontacts where the transmittivity is close to unity, can lead to inversion of magnetoresistance in MTJs. This mechanism will be given special emphasis.

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Quantum Interference and Negative Differential Conductance in Mettalic Single Wall Carbon Nanotubes

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We have investigated the quantum transport properties of defective, long, and metallic single wall nanotubes within the π-electron tight-binding model, describing the varying spatial Bloch's wave functions near the Fermi level at low bias regime. We have calculated the differential conductance for the sake of substitutional impurities over nanotubes. The scattering potential has been modeled by delta function potential. Our calculations show that defective nanotubes have atomic scales characteristics in their transport properties and the impurity conductance, G_{imp}, depends strongly on the atomic configuration including both their interdistance and symmetry of impurities. The forward electron wave is backscattered by impurities, and then quantum interference between forward and backward waves results oscillations in the DC over the source-drain voltage. Depending sensitively on symmetry and interdistance impurities; fast, slow, and no oscillations are shown for the armchair, metallic zigzag, and metallic chiral nanotubes, respectively. With atomic scale manipulation of impurities positions, in the certain range of the bias voltage, G_{imp} shows negative values due to suppression of the transport channel. It can be understood in terms of the band structure effect and quantum interference induced by impuritiesThe negative differential conductance is an unusual property that may lead to new atomic scale switches, resistors, amplifiers, and memory devices. This work presents an analytical-computational study of the effects of impurities in SWCNT systems and the dependence of the DC as a function of spatial configurations of impurities over the tube, diameter, and in special chirality of the tube.

QUANTUM DOTS ARRAYS

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The recent growth and the innovation of the nanotechnology have lead to the implementation of the quantum dots as tools of materials and devices development. Therefore, the study of the properties of quantum dots and their interactions is gaining interest in different fields as optical and optoelectronic devices [1], quantum computing [2], materials for cascade lasers [3], 3D imaging inside living organism [4], etc. The study of quantum dots supercrystals allows improves the tailoring of new materials with controllable properties.

Motivated by the experimental perspectives and the simulations of quantum dots arrays with different shapes [5-6], we first present the electronic energies and probability distributions of a conical quantum dot of GaAs with bottom radio 4nm, upper radio 2.14nm and height 4nm, embedded in a matrix of AlGaAs (Fig 1). In addition, we show the electronic structure of the supercrystal set up of conical quantum dots, by means of the tight-binding model sp3, following the traditional tight-binding calculations in crystals. Finally we compare our results with previous calculations made for spherical quantum dots.

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Figures:

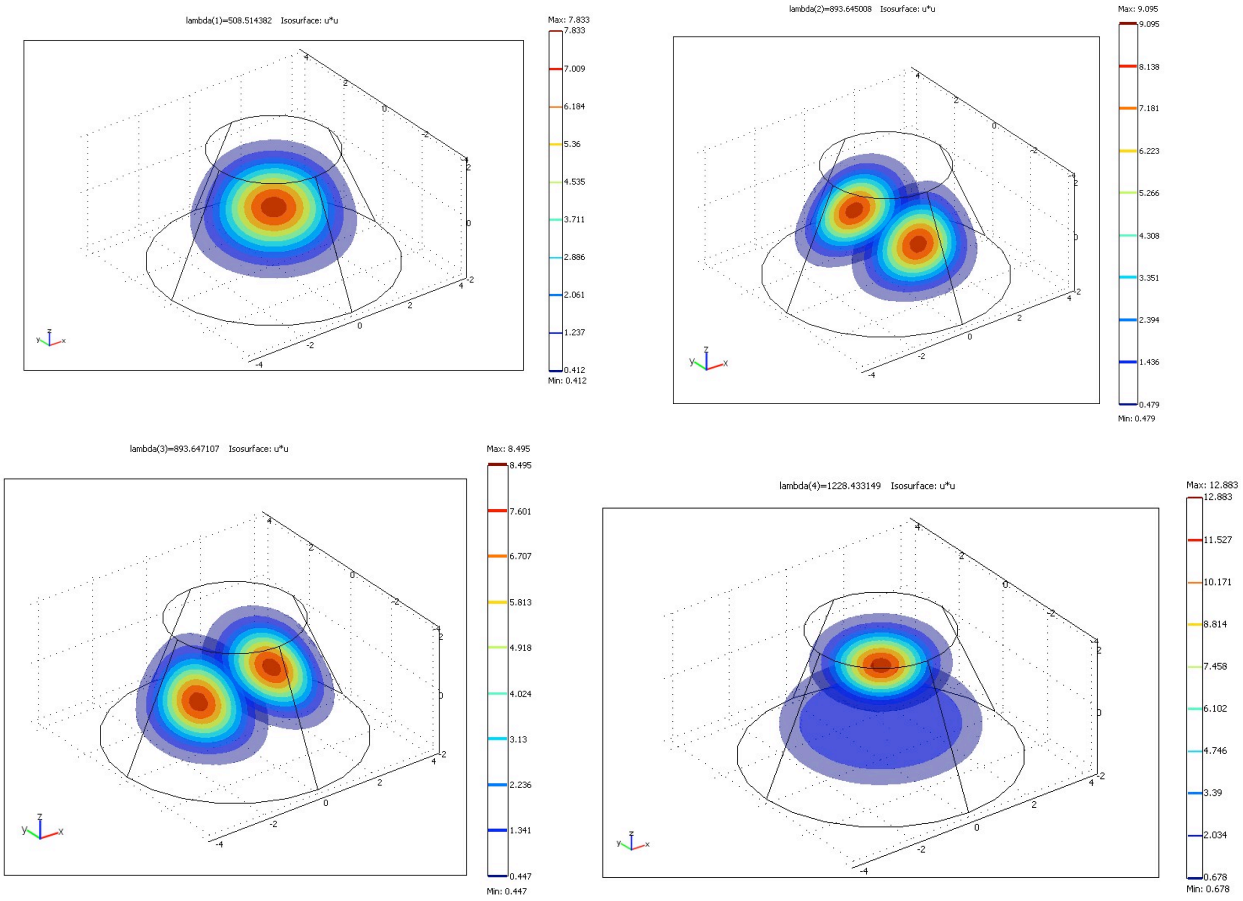

Figure 1. Probability densities and energies for a conical quantum dot.
Lambda=Energy [meV], uu = Probability density

How spin-orbit interaction can cause electronic shot noise

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The shot noise in the electrical current through a ballistic chaotic quantum dot with N-channel point contacts is suppressed for $N \to \infty$, because of the transition from stochastic scattering of quantum wave packets to deterministic dynamics of classical trajectories. The dynamics of the electron spin remains quantum mechanical in this transition, and can affect the electrical current via spin-orbit interaction. We explain how the role of the channel number N in determining the shot noise is taken over by the ratio $l_{\rm so}/\lambda_F$ of spin precession length $l_{\rm so}$ and Fermi wave length λ_F, and present computer simulations in a two-dimensional billiard geometry (Lyapunov exponent α, mean dwell time $\tau_{\rm dwell}$, point contact width W) to demonstrate the scaling $\propto (\lambda_F/l_{\rm so})^{1/\alpha\tau_{\rm dwell}}$ of the shot noise in the regime $\lambda_F \ll l_{\rm so} \ll W$.

Adiabatic Pumping through Interacting Quantum Dots in the Coulomb Blockade Regime

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We investigate the electronic transport properties of an interacting quantum dot subjected to time dependent potentials in the Coulomb blockade regime. Using the Keldysh formalism, we derive an expression for the pumped current in terms of the Green's function of the dot in the adiabatic limit, i.e., when the time scale over which the pumping voltages vary is large compared to the lifetime of the electron inside the dot. We apply this formula to calculate the pumped charge per cycle and investigate possible applications to metrology.

ELECTRON DYNIMICS IN RECTANGULAR QUANTUM DOTS

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Quantum dots are a very expected system to be useful in the implementation of opto-electronic devices and quantum computation software. Fully discretized levels and long coherence times are their main features to technologic application.
We study the one-electron dynamic in a double quantum dot with rectangular confinement potential. We found the electronic levels of an asymmetric system varying with the ratio between the lengths of the dots. That ratio is showed to work as a tunability parameter to find anticrossing regions where high tunneling inhibits dephasing decoherence and only relaxation times are relevant for the temporal evolution of the system. We calculated relaxation times by finding decay rates for transitions between electronic levels by deformation potential electron-acoustic phonon and electron-electron interaction.
With those times, we evaluated the density matrix evolution of the system after a stimulating electric field short pulse. For some geometrical parameters, the electron-phonon and electron-electron life times are such that several complete oscillations of the populations and of the coherences are observed. So, our results show the viability of coherent radiation emission even at room temperature from this kind of quantum dots systems [1].

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Transverse electron focusing in 2DEGs: SPM imaging techniques and the effect of Rashba and Dresselhaus spin-orbit interactions.

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Transverse electron focusing in two-dimensional electron gases (2DEGs) in presence of strong spin-orbit coupling is revisited. The transverse focusing is related basically to the conductance between two contacts at the border of a 2DEG when a perpendicular magnetic field is applied. First we study the effect on the focusing signal of the electron's spin polarization angle. We find that the ratio between the Rashba and the Dresselhauss spin-orbit coupling strengths determines the angle of the spin polarization for which the spin separation is maximum. Finally we examine the potentiality of the system for being explored with scanning probe microscopy (SPM) imaging techniques. We show that hybrid edge states can be visualized and notably the outgoing flux can be polarized if the SPM probe is placed in specific positions, i.e. nano-mechanical induced polarization is achieved.

Spin Hall effect: Current induced spin polarization in two dimensional electron gases with Rashba spin-orbit coupling

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We study the spin polarization induced by a current flow in clean two dimensional electron gases with Rashba spin-orbit coupling. This *geometric* effect originates from special properties of the electron's scattering at the edges of the sample. In wide samples, the spin polarization has its largest value at low energies (close to the bottom of the band) and goes to zero at higher energies. In this case, the spin polarization is dominated by the presence of evanescent modes which have an explicit spin component outside the plane. In quantum wires, on the other hand, the spin polarization is dominated by interference effects induced by multiple scattering at the edges. Here, the spin polarization is quite sensitive to the value of the Fermi energy, especially close to the point where a new channel opens up. We analyzed different geometries and found that the spin polarization can be strongly enhanced.

Survival probability of a local excitation in a non-Markovian environment: Return effects and Survival Collapse.

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Nanosystems are never isolated, but they interact with the macroscopic world. In consequence the excitations have a survival probability $P_{00}(t)$ which typically decay according to the Fermi Golden Rule. However, this approximation neglects memory effects in the environment, which could be relevant. In this work we address effects that an electrode, considered as "environment", has on the excitations of a quantum dot. To simplify the treatment we consider a single state of the dot which is weakly coupled to an environment whose dynamics can be solved within a Hamiltonian model. Various works on models for nuclei, composite particles [1] and excited atoms in a free electromagnetic field [2], showed that the exponential decay has superimposed beats and does not hold for very short and very long times, compared with the lifetime of the system. In Ref. [3] we presented a model describing the evolution of a surface excitation in a semi-infinite spin chain, a model that is solved analytically and susceptible for an experimental test. Here, we present a general analysis showing the quantum nature of the deviations from the Fermi Golden Rule. We identify three time regimes in the decay of the survival probability $P_{00}(t)$:

1) For short times the decay is quadratic, as is expected when the coupling of the local state with the continuum is perturbative and for non-divergent Hamiltonian second moment. This lasts for a time proportional to the spectral density of the final states evaluated at the decaying state energy ε_0,

$$t_S \simeq \hbar\pi N_1(\varepsilon_0).$$

2) An intermediate regime characterized by an exponential behavior, the *self-consistent Fermi Golden Rule* (SC-FGR), where the rate Γ_0, the pre-exponential factor and the characteristic frequency $\varepsilon_0/\hbar$ are found self-consistently.

3) At long-times, $t > t_R$, the exponential decay of the *pure survival* probability is overrun by an inverse power law, which is identified with the *return* probability enabled by the slow quantum diffusion in the environment. We obtain

$$t_R \simeq \alpha\frac{\hbar}{\Gamma_0}\ln\left(\beta\frac{B}{4\Gamma_0}\right),$$

where B is the bandwidth and $\alpha, \beta \gtrsim 1$ are constants that depend on the dynamics of the environment. At this last cross-over time, quantum interference could lead to a dip in $P_{00}(t)$ of several orders of magnitude. This *survival collapse,* which last for a brief period $\hbar/B$, is identified with a destructive interference between the *pure survival* amplitude, i.e., the SC-FGR component, and the *return* amplitude, associated with high orders in a perturbation theory.

The identification of these regimes is very important to assess the validity of the Markovian approximation and to describe memory effects of the environment surrounding the nanodevices.

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Exciton-Phonon Interaction in CdSe Quantum Dots: Quantum Dot Size and Magnetic Field Effects.

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Abstract

We investigate theoretically the interaction between excitons and phonons in a cylindrical disk-like semiconductor quantum dot under an applied magnetic field. We first consider the interaction between CdSe quantum dot excitons and longitudinal optical (LO) phonons. Due to the intensity of the interaction in the strong coupling regime, a composite quasi-particle called exciton–polaron is formed. We focus on the effect of the disk size and the external magnetic field on the exciton–polaron modes. We calculate the quantum dot radius dependences of the exciton–polaron energy. We show that the exciton energy spectrum changes significantly when taking into account the interaction with LO phonons. The effect of the temperature on the integrated photoluminescence intensity is also investigated. We observe that at relatively high temperature the magnetic field and the quantum dot height have noticeable effects on the photoluminescence intensity.
We consider also the interaction between excitons and acoustic phonons, since the scattering of excitons by acoustic phonons in nanostructures such as quantum dots generally controls relaxation process to the lowest energy states, and is a basis for understanding optical properties and coherence effects in these systems. We calculate the scattering rate (SR) of excitons by acoustic phonons considering two scattering mechanisms, the standard deformation potential coupling and the piezoelectric coupling. We discuss the influence of the external applied magnetic field, and the quantum dot size on the SR. Our calculations show that the exciton–acoustic phonon SR depends significantly on these parameters, and using a modulated external magnetic field the interaction between exciton and acoustic phonon modes can be modified in a wide range.

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Synthesis and Raman spectra of Si-nanowires

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Randomly arrayed silicon nanowires (SiNWs) were synthesized by thermal evaporation of sulfur powders and silicon wafer; zinc sulfide and silicon; SiO powder. Orderly arrayed SiNWs were grown in the anodized aluminium oxide (AAO) template using the CVD method. The Raman spectra of the SiNWs were detected for the samples synthesized in different ways, and the temperature dependence of the Raman spectra of the samples was studied. Combining the structural analysis and Raman data of the samples, phonon confinement model and the anharmonic process were connected to the discussion of the Raman spectra.

Full Counting Statistics of an Aharonov-Bohm Interferometer with an embedded Quantum Dot

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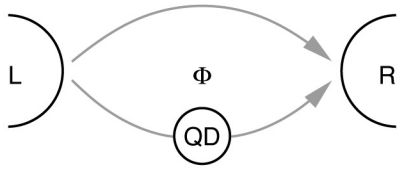
The electron's wave nature becomes apparent in Aharonov-Bohm interferometers, where constructive and destructive interference between two electron paths can be observed. The visibility of the Aharonov-Bohm signal provides information on the coherence of transport channels. Embedding of e.g. a quantum dot in one arm can lead to partial destruction of the coherence [1] and thus a reduction of the AB-signal. The occurence of this effect depends on the dot occupation.

Correlations of electron transport are reflected in shot noise and higher moments of the current distribution. These reveal infomation not contained in the average current. All moments can be conveniently extracted from the Cumulant Generating Function, whose calculation is the aim of Full Counting Statistics (FCS).

Originally developed for situations without interaction FCS has recently been extended to strongly interacting systems such as quantum dots. Treating the coupling to the leads perturbatively, it was found that non-Markovian effects cannot be neglected [2]. We expand this scheme to describe a quantum dot embedded in an Aharonov-Bohm geometry.



An Aharonov-Bohm Interferometer consisting of a single-level quantum dot tunnel coupled to two leads, with a parallel transport channel, also given by a tunnel contact.

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Quantum computers with coupled quantum dots

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Abstract

In recent years, theoretical design schemes for quantum computers (QCs) - a very special and important type of nano-devices, have attracted enormous intention. In this poster, we study two schemes of quantum computers with a coupled semiconductor quantum dots system: spin (electron)-based and photon-based quantum computers, which are considered as most promising design-models for QCs on the "top-down" road of nanotechnology. The most important physical values on both schemes are the exchange interactions on the double quantum dots systems: the exchange coupling J (the difference between the spin singlet and triplet energy of electrons) in the case of spin-based QCs, and the Forster coupling V_F between interacting excitons in the case of photon-based QCs, respectively. Different working principles of spin-based QCs: analog, digital, and pseudo-digital was discussed, and we show that the proposed by us good-analog working condition for quantum computing may reduce operation error rates in comparison with ordinary analog cases. For photon-based QCs, considering the Morse effective potential for exciton-exciton interaction, we obtain an analytical expression for inter dots Forster coupling V_F depend on inter-dot separation d. Our calculated results do not have singularity at any value of d, and could be applied also for the more practical case of smaller inter-dot separation.

Notable structural enhancement effect of field emission from nano-multilayer semiconductor films

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Field emission (FE) materials have important applications in vacuum microelectronic devices, such as FE display and microwave amplifier, and hence become one of the hottest materials.

Based on the quantum self-consistent consideration, we present a quantitative model to investigate the structural enhancement effect of field emission from nano-multilayer semiconductor films. Calculated results show that FE characteristics can be remarkably improved only by structure modulation. Furthermore, it concludes that field emission could be greatly enhanced with a quantum well (QW) formed in the multilayer film structures which on one hand, accumulated electrons by confine energy levels and on the other hand, lowered the effective surface potential. And it also means the structure effect on improving the FE characteristics may be mainly due to two possibilities: the change in the band structure and the reduction of the effective surface barrier.

Our results also indicated that it is possible to evidently improve the FE characteristics by only the tunable structure. It may be a new key for FE research and application, with simple processes but huge gains, far beyond exploring or amending new materials to elevate the FE characteristics.

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Influence of e-e interactions on the localization length of disordered quantum wires

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The localization length of disordered quantum wires with interaction is calculated by measuring the decay of the Friedel oscillations due to an impurity in the wire. The electron density in the system's ground state is calculated using the DMRG method with a varying number of electrons, and the Friedel oscillations data is extracted using the density difference between the case in which the wire is coupled to an impurity to the case where the impurity is absent. It is shown that the localization length decreases as a function of the interaction strength when the wire is either in the Luttinger liquid or in the charge density wave phase, in accordance with some previous predictions. In the Luttinger liquid phase, the interactions lead to a power law decay of the oscillations, while an extra exponential decay is caused by the disorder. In the charge density wave phase the exponential decay is determined by the shortest length between the localization length and the charge density wave correlation length. In both cases scaling of the average Friedel oscillations collapses the data for disordered samples on those of a clean sample.

Lateral Formation of Carbon Nanostructures in Pulsed Laser Ablation of Graphite

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Nanostructural carbon were deposited on substrates placed in adjacent to the graphite target during the pulsed Nd:YAG laser ablation in vacuum[1], in contrast to the smooth films of unhydrogenated diamond-like carbon/amorphous carbon (a-C)[2,3]. In this study, dependence of the nanostructure formation on the laser wavelength were conducted for 355nm, 532nm and 1064nm at room temperature and base pressure of 10^{-6} Torr. Analysis of these nanostructures and surface morphology from SEM and AFM revealed that their tips always pointed toward the laser ablated area; as a result of recondensation of the laser vaporized materials from the graphite target. With accumulated 6000 laser pulses at both 355nm and 532 nm, it would produce slightly elongated carbon nanostructures of 50-70 nm in size, while the longer laser wavelength at 1064 nm produced agglomerated structures of 150-200 nm (Fig. 1). These morphologies could be similar to those obtained in pulsed laser deposition but with the presence of background gases[4,5]. For longer deposition time, it increased the growth of the carbon nanostructures both laterally and vertically. Characterisation by Raman Spectroscopy for all the nanostructure materials revealed D and G peaks, thus indicating the presence of sp^2 and sp^3 hybridization, which are identical to the laser deposited amorphous carbon films.

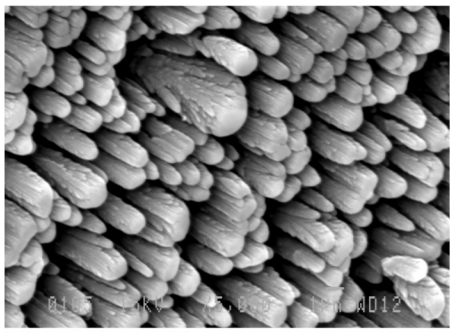

Fig. 1 SEM of carbon nanostructures deposited by 1064 nm laser

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Shot noise of charge and spin in ferromagnetic spin-valves

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Shot noise, *i. e.,* temporal fluctuations of the electrical current at low temperatures, provides valuable information about the transport process through a mesoscopic structure which are not extractable from the average current measurements.[1]. In magnetoelectronic structures, in which the spin of electrons plays an essential rule, the shot noise is expected to contain spin-resolved information, including spin-dependent correlations and spin accumulation and relaxation. In this poster presentation we extend the semiclassical Boltzmann-Langevin kinetic theory to study spin-polarized current fluctuations in ferromagnetic spin-valve structures. A spin-valve consists of two ferromagnetic (F) leads as the spin injector and detector, connected through a normal metal (N) (or ferromagnetic) spacer which serves for the spin accumulation. We explain the influence of spin polarization and spin-flip scattering on shot noise in FFF with collinear magnetization of ferromagnets and in FNF with noncollinear magnetizations. We show that in such spin-valve structures the shot noise can deviate substantially from the unpolarized values, depending on the relative orientation of the magnetizations, the degree of spin-polarization of the terminals and the strength of the spin-flip scattering in the normal conductor.

In a fully ferromagnetic FFF structure, in which two F terminals are contacted by tunnel barriers to a diffusive ferromagnetic metal, we show that shot noise can probe the intrinsic density of states and the extrinsic impurity scattering spin-polarization contributions in the polarization of the wire conductivity.[2] The effect is more pronounced where the terminals are perfectly polarized in the opposite directions. While in this case the shot noise has a weak dependence on the impurity scattering polarization, it is strongly affected by the polarization of the density of states. For a finite spin-flip scattering rate the shot noise increases well above the normal state value and can reach the full Poissonian value when the density of states tends to be perfectly polarized. For the parallel configuration we find that the shot noise depends on the relative sign of the intrinsic and the extrinsic polarizations.

In a noncillinear spin-valve, in which a diffusive N metal connected by tunnel contacts to two F terminals with noncollinear magnetizations, we show that for a small spin-flip strength and a substantial spin polarization of the F terminals the shot noise has a nonmonotonic variation with the angle between magnetization vectors.[3] While the shot noise is almost unchanged from the normal structure value for parallel configuration and increases well above the normal value for antiparallel configuration, it suppresses substantially at an intermediate angle depending on the ratio of the conductances of the N metal and the tunnel contacts. We also demonstrated pronounced effects of the polarization and the spin-flip scattering on the shot noise which reveals the interplay between relaxation and spatial precession of the spin accumulation vector in the N metal.

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Level-Statistics of Disordered Systems:

A Single Parametric Formulation

We present an analytical formulation for the statistics of energy levels of disordered systems, with/without e-e interactions, and, of arbitrary dimensions and boundary conditions. We find that the statistics behaves in a way similar to that of the single parametric Brownian ensembles. The latter appear during a Poisson Wigner-Dyson transition, driven by a random perturbation. The analogy provides the analytical evidence for single parameter scaling of the level-correlations in disordered systems at metal-insulator transition as well as a tool to obtain them at the critical point for a wide range of disorders. The analogy also helps us to reveal many important features of the level-statistics in interacting systems e.g. a critical point behavior different from that of non-interacting systems, the possibility of extended states even in one dimension and a universal formulation of level correlations.

Reference:

(1) RANDOM MATRICES WITH CORRELATED ELEMENTS: A MODEL FOR DISORDER WITH INTERACTIONS
PRAGYA SHUKLA, Phys. Rev. E, (71), (2005), 026266.

(2) LEVEL-STATISTICS IN DISORDERED SYSTEMS: A SINGLE PARAMETRIC SCALING AND CONNECTION TO BROWNIAN ENSEMBLES
PRAGYA SHUKLA, J. Phys.: Condens. Matter 17, (2005) 1653-1677.

Multi-Channel Transport in Disordered Medium under Generic Scattering Conditions

A variety of transport properties can be formulated in terms of the eigenvalues of transmission matrix of the region. The knowledge of the statistical behavior of transmission eigenvalues is therefore very useful in the statistical analysis of transport properties. This motivates us to study the joint probability distribution of transmission eigenvalues. Previous attempts in this direction have resulted in the well-known DMPK equation which describes the statistical evolution of transmission eigenvalues with respect to changing length of the medium. Various assumptions made in its derivation, however, restrict its applicability to quasi one dimensional systems or under specific scattering conditions. As the transport properties are also sensitive to other system parameters besides length e.g., boundary conditions, disorder strength and dimensionality, a generalization of DMPK equation for higher dimensions and under generic scattering conditions is required. The talk discusses our results obtained in this direction. Our results show that the evolution of transmission eigenvalues, due to changes in various physical parameters in a disordered region of arbitrary dimensions, is governed by a single complexity parameter; this implies a deep level of universality of transport phenomena through a wide range of disordered regions.

Reference:

(1) MULTI CHANNEL TRANSPORT IN DISORDERED MEDIUM UNDER GENERIC SCATTERING CONDITIONS

PRAGYA SHUKLA and INDER BATRA,
Phys. Rev. B. 71, 235107, (2005).

AUTHOR INDEX