The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

Conference on

"Quantum Phenomena in Confined Dimensions"

(4 – 8 June 2007)

ABSTRACTS

of

SHORT TALKS

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SHORT TALK TITLES

BASKO, D.	Effect of inelastic collisions on multiphonon Raman scattering in graphene
CHUDNOVSKIY, A.	Tunneling into strongly biased Tomonaga-Lüttinger liquid
CREPIEUX, A.	Finite size effects, super- and sub-poissonian noise in a nanotube connected to leads
CSERTI, J.	Role of the trigonal warping on the minimal conductivity of bilayer graphene
GUMHALTER, B.	Ultrafast electron dynamics and decoherence in quasi-two-dimensional surface bands
HONERKAMP, C.	Long range ordered phases of electrons on the honeycomb lattice
KECHEDZHI, K.	Weak localisation magnetoresistance in graphene
KHVESHCHENO, D.V.	Composite Dirac fermions in graphene
LAVAGNA, M.	Theoretical study of the phase evolution in a Kondo quantum dot
MOLITOR, F.	Mesoscopic transport in graphene
PEREIRA, J.M.	Quantum dots in doped bilayer graphene
ROMEO, F.	Phase rigidity breaking in open Aharonov-Bohm ring coupled to a cantilever
ROMITO, A.	Charge fluctuations as dephaser of a spin qubit
RUSSELL, A.	Bistability of optically-induced nuclear orientation in quantum dots
SAVCHENKO, A.K.	Weak localisation in graphene layers
TAGLIACOZZO, A.	Tuning spin transport and magnetoconductance in a semiconductor quantum ring with Rahsba spin-orbit interaction
TEBER, S.	Attenuation of one-dimensional plasmons
VISHVESHWARA, S.	Proximity-induced effects in carbon nanotubes
WHITNEY, R.S.	Towards a dephasing diode: asymmetric and geometric dephasing

Effect of inelastic collisions on multiphonon Raman scattering in graphene

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The Raman spectrum of graphene consists of distinct narrow peaks corresponding to different optical phonon branches as well as their overtones. Raman scattering measurements represent a powerful experimental tool for studying phonon modes, as well as their interaction with electrons. Indeed, electron-phonon interaction and Raman scattering in graphene has attracted a great deal of interest, both experimental [1, 2, 3, 4] and theoretical [5, 6].

We argue that information about electron-electron interaction can be extracted from Raman spectra as well. Namely, we calculate the probabilities of two- and four-phonon Raman scattering in graphene and show how the relative intensities of the overtone peaks encode information about relative rates of different inelastic processes electrons are subject to. In particular, assuming that the most important processes are phonon emission and electron-electron collisions, one can deduce the rate of the latter from the Raman spectra. This fact is especially interesting as the question about electron-electron collisions for the Dirac spectrum is not a trivial one [7, 8].

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Tunneling into strongly biased Tomonaga-Luttinger liquid

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We consider tunneling from the Fermi-liquid reservoir into the nonequilibrium TLL through a point tunnel contact (see Fig. 1). The nonequilibrium conditions are created by a strong transport voltage applied to a TLL channel. Finite source-drain voltage $V_{\rm sd}$ applied to the channel results in the shift of the chemical potentials for the right and left movers to the quasi-Fermi energies $E_F + eV_{\rm sd}/2$ and $E_F - eV_{\rm sd}/2$ respectively. At strong enough voltages, the nonlinearity of the electronic dispersion leads to different Fermi velocities of the right- and left-movers $v_{R/L} = \sqrt{(2E_F \pm eV_{\rm sd})/m^*}$, as depicted in Fig. 1. (Here, m^* is the effective electron mass.) In turn, the tunneling densities of states (TDoS) for the left- and right-moving spectral branches differ. Furthermore, since the direction of partial tunneling currents into the left branch and out of the right branch are opposite, these two tunnel currents do not compensate any more even at zero voltage $V_{\rm pc}$ at the point contact (see Fig. 1). Therefore, a finite tunnel current flows between the nonequilibrium TLL and a point contact. We calculate the dependence $I_{\rm pc}(V_{\rm pc}, V_{\rm sd})$ analytically. To this end, we propose a method of diagonalization of TLL Hamiltonian with different Fermi velocities for the right- and left-movers. The method can be usefull for a number of problems which involve chiral asymmetry of the density of states such as a TLL wire in an external magnetic field or wires with spin-orbit interactions. The nonequilibrium TDoS ν can be best seen in the measurements of the differential conductances $\partial I_{\rm pc}/\partial V_{\rm pc,sd}$ at small voltages $V_{\rm pc}$ on the point contact (see Fig. 2). There are two power-low singularities at $V_{\rm pc} = \pm V_{\rm sd}/2$, separately for the tunneling into the right- and the left-moving spectral branch of TLL. At these voltages, the Fermi level in the Fermi liquid reservoir coincides with the quasi Fermi energy for the left- or the right-moving fermions in TLL, and the tunneling density of states in the corresponding channel is suppressed.

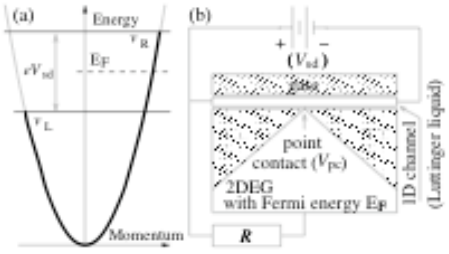

FIG. 1: (a) Occupation of the dispersional parabola in 1D channel in presence of the source–drain voltage $V_{\rm sd}$ at negligible $V_{\rm pc}$ when the Fermi energy of the 2DEG lies exactly in the middle between quasi Fermi levels of the biased TLL. (b) Schematics of the device proposed.

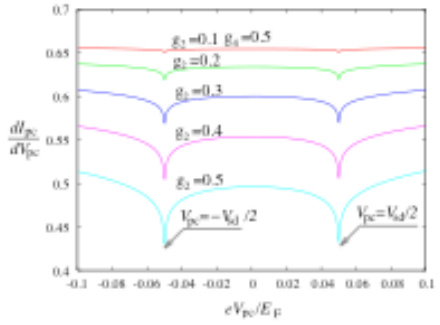

FIG. 2: Differential conductance $\partial I_{\rm pc}/\partial V_{\rm pc}$ as a function of voltage at the point contact $V_{\rm pc}$ for different values of the Luttinger liquid interaction parameter g_2 at a given g_4. The bias voltage $V_{\rm sd}$ is taken equal to $0.1E_F$, and the other parameters are relevant for typical GaAs-based electron gases. The conductance dependencies $\partial I_{\rm pc}/\partial V_{\rm pc,sd}(V_{\rm pc})$ exhibit singularities at $V_{\rm pc} = \pm V_{\rm sd}/2$.

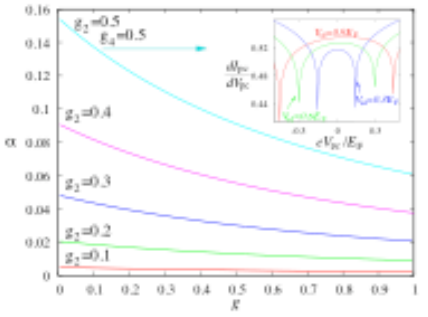

FIG. 3: The dependence of the tunneling exponent α ($\nu(\omega) \propto |\omega|^\alpha$) on the asymmetry of the Fermi velocities v_R and v_L expressed through the parameter $g = v_L/v_R$. The unbiased TLL corresponds to $g = 1$. The asymmetry increases (g diminishes) increasing the bias voltage $V_{\rm sd}$. The suppression of the tunneling density of states grows with bias voltage. Inset: Differential conductance $\partial I_{\rm pc}/\partial V_{\rm pc}$ as a function of voltage at the point contact for different values of $V_{\rm sd}$ at a given $g_2 = g_4 = 0.5$.

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Finite size effects, super- and sub-poissonian noise in a nanotube connected to leads

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The injection of electrons in the bulk of carbon nanotube which is connected to ideal Fermi liquid leads is considered. While the presence of the leads gives a cancellation of the noise cross-correlations, the auto-correlation noise has a Fano factor which deviates strongly from the Schottky behavior at voltages where finite size effects are expected. Indeed, as the voltage is increased from zero, the noise is first super-poissonian, then sub-poissonian, and eventually it reaches the Schottky limit.
These finite size effects are also tested using a diagnosis of photo-assisted transport, where a small AC modulation is superposed to the DC bias voltage between the injection tip and the nanotube. When finite size effects are at play, we obtain a stepwise behavior for the noise derivative, as expected for normal metal systems [1], whereas in the absence of finite size effects, due to the presence of Coulomb interactions, a smoothed staircase is observed. The present work [2] shows that it is possible to explore finite size effects in nanotube transport via a zero frequency noise measurement.

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Role of the trigonal warping on the minimal conductivity of bilayer graphene

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Using a reformulated Kubo formula we calculate the zero-energy minimal conductivity of bilayer graphene taking into account the small but finite trigonal warping. We find that the conductivity is independent of the strength of the trigonal warping and it is three times as large as that without trigonal warping, and six times larger than that in single layer graphene. Although the trigonal warping of the dispersion relation around the valleys in the Brillouin zone is effective only for low energy excitations, our result shows that its role cannot be neglected in the zero-energy minimal conductivity.

Reference: József Cserti, András Csordás, and Gyula Dávid, cond-mat/0703810.

Ultrafast electron dynamics and decoherence in quasi-twodimensional surface bands

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Abstract

We develop a many-body description of nonadiabatic dynamics of quasiparticles in surface bands appropriate to the studies of ultrafast electronic relaxation in the processes of one- and two-photon photoemission and inverse photoemission from surfaces. The approach is based on the combination of the formalisms for calculation of quasiparticle survival probabilities and selfconsistent treatment of the linear electronic response of the system. We demonstrate that the calculation of survival probabilities that carry information on the quasiparticle decoherence and decay can be conveniently mapped onto the problem of renormalization of quasiparticle propagators by the interactions with bosonized excitations constituting the system heatbath. Applying this approach to the benchmark Cu(111) surface we are able to assess the regimes of preasymptotic non-Markovian electron and hole dynamics in surface bands and locate transitions to the regime of exponential quasiparticle decay characterized by the corrected Fermi golden rule-type of transition rates. The general validity of these findings enables to establish borderlines between the various regimes of ultrafast electronic relaxation that affect the energy and time resolved measurements of surface electronic properties.

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Title:
Long range ordered phases of electrons on the honeycomb lattice

Abstract:

Motivated by the experimental realization of graphene, we investigate instabilities of electrons on the honeycomb lattice, interacting by local Hubbard and longer-ranged interactions. Using a temperature-flow functional renormalization group scheme which takes into account the wave vector-dependence of the interactions throughout the Brillouin zone, we detect the leading ordering tendencies at low temperatures. Near half band filling and for dominant onsite repulsion, critical minimal interaction strengths are required for a instabilities toward anti-ferromagnetic or charge density wave order, in support of a previous large-N work of Herbut [Phys. Rev. Lett. 97, 146401 (2006)]. Away from half filling, a triplet pairing superconducting instability occurs. Phononic coupling to the substrate can further enhance this instability.

Weak localisation magnetoresistance in graphene

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We describe the weak localization correction to conductivity in ultra-thin graphene films, taking into account disorder scattering and the influence of trigonal warping of the Fermi surface. A possible manifestation of the chiral nature of electrons in the localization properties is hampered by trigonal warping, resulting in a suppression of the weak anti-localization effect in monolayer graphene and of weak localization in bilayer graphene. Intervalley scattering due to atomically sharp scatterers in a realistic graphene sheet or by edges in a narrow wire tends to restore weak localization resulting in negative magnetoresistance in both materials.

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Title:
Composite Dirac fermions in graphene

Abstract

Generalizing the notion of composite fermions to the case of "relativistic" Quantum Hall phenomena in graphene, we discuss a possible emergence of compressible states at the filling factors 1/2 and 3/2.
This analysis is further extended to the nearby incompressible states viewed as Integer Quantum Hall Effect of composite Dirac fermions, as well as those that can result from (pseudo)spin-singlet pairing between them.

Theoretical study of the phase evolution in a Kondo quantum dot

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We study the effects of Kondo correlations on the transmission phase shift of a quantum dot (QD) in the Kondo regime. This work is motivated by the quantum interferometry experiments [1] carried out these last years at the Weizmann Institute which allow one to access the phase shift experienced by an electron passing through a quantum dot. We present our results [2] obtained for the Anderson model with 2 reservoirs using 2 types of methods: (i) Bethe ansatz and (ii) noncrossing approximation for the infinite-U Anderson model. We follow the evolution of the phase shift with the gate voltage and find quantitative agreement with experimental results in two different regimes of the coupling to the leads. Finally we extend our NCA study to the out-of-equilibrium situation and discuss how the phase shift evolves in the presence of a finite bias voltage.

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Mesoscopic transport in graphene

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We report on transport measurements on a few-layer graphene wire with a phase coherence length at low temperatures T≈2 K larger than the wire width (ca 300 nm), but comparable to the wire length (ca. 2 μm)[1]. By analyzing the weak localization peak in the one-dimensional dirty-metal regime, we find a density dependence of the quantum corrections to the conductivity. Reproducible conductance fluctuations are also analyzed as a function of density and a similar value for the phase coherence length is found. Side gates allow us to tune the Fermi energy locally and to change the disorder configuration for a fixed Fermi level.
Single layer graphene flakes are investigated by transport experiments around the charge neutrality point and for various temperature treatments.

[1] D. Graf, F. Molitor, T. Ihn and K. Ensslin, condmat/0702401 (2007)

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Title:
"Quantum dots in doped bilayer graphene"

Abstract

In this work we demonstrate the possibility of confinement of electrons and holes in ,quantum dots in bilayers of graphene. A position-dependent doping breaks the equivalence between the upper and lower layer and lifts the degeneracy of the positive and negative momentum states of the dot. We present numerical results that show the simultaneous presence of electron and hole confined states for certain doping profiles and a remarkable angular momentum dependence of the quantum dot spectrum which is in sharp contrast with that for conventional semiconductor quantum dots. We predict that the optical spectrum will consist of a series of non-equidistant peaks.

Phase rigidity breaking in open Aharonov-Bohm ring coupled to a cantilever

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(Dated: May 15, 2007)

ABSTRACT

Nanoelectromechanical systems (NEMS) have been a subject of extensive research in recent years due to the possibility of combining electrical and mechanical degrees of freedom on the nanoscale. From a technological point of view the interest is largely related to the many applications that may be realized using NEMS. Among the many NEMS phenomena of considerable physical interest, we focus in this talk on the effect of quantum-coherent displacements of a molecular cantilever coupled to a one-dimensional Aharonov-Bohm (AB) ring symmetrically connected to two external leads. In such a system phase coherent charge transport through the closed loop (which can be regarded as a non-simply connected quantum dot) is perturbed as a consequence of inelastic scattering induced by electron-phonon interaction. The effect of the perturbation can be detected as a violation of the Onsager symmetry rule in the linear conductance curves as a function of the applied magnetic flux (i.e. the linear conductance is not symmetric in the AB phase). The observed asymmetry can be tuned continuously by changing the electron-phonon coupling, showing that the phase shift of the linear conductance in a two-terminal AB interferometer is not rigid when tunnelling is assisted by phonons. We will provide a characterization of such interaction effects, referred to phase-rigidity breaking in recent literature, by studying the Fourier series of the linear conductance obtained by means of a suitable scattering approach. In particular, the phase shift of the first term in Fourier expansion (which under Onsager symmetry is seen to be a dichotomic variable assuming value 0 or π) can vary continuously as a function of the electron-phonon coupling. This continuous phase variation as a function of the incident electron energy can be exploited in experiments to obtain the value of the electron-phonon coupling. The relevant structural and experimental parameters will be briefly discussed. The phase rigidity breaking can be regarded a common feature of two-terminal nanomechanical systems and thus we propose measurements of phase shifts as a way to characterize the electron-phonon coupling in NEMS.

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Title:
Charge fluctuations as dephaser of a spin qubit

Abstract:

We study the role of charge fluctuations in the decoherence of Rabi oscillations between spin states $|\uparrow\downarrow\rangle$, $|\downarrow\uparrow\rangle$ of two electrons in a double dot structure. We consider the effects of fluctuations in energy and in the quantum state of the system, both in the classical and quantum limit. The role of state fluctuations is shown to be of leading order at sufficiently high temperature, applicable to actual experiments. At low temperature the low frequency energy fluctuations are the only dominant contribution.

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Title:
"Bistability of optically-induced nuclear orientation in quantum dots"

Abstract

We demonstrate that bistability of the nuclear spin polarization in optically pumped semiconductor quantum dots is a general phenomenon possible in dots with a wide range of parameters. In experiment, this bistability manifests itself via the hysteresis behavior of the electron Zeeman splitting as a function of either pump power or external magnetic field. In addition, our theory predicts that the nuclear polarization can strongly influence the charge dynamics in the dot leading to bistability in the average dot charge."

Weak localisation in graphene layers

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We present results of the first experimental investigation of weak localisation (WL) in bilayer graphene [1]. Although the spectrum of charge carriers in bilayer graphene has a usual, parabolic character, the manifestation of WL in this system is very different from that in conventional 2D structures with such spectrum. The chiral character of charge carriers makes WL dependent not only on inelastic scattering which controls the dephasing rate, but also on different elastic scattering mechanisms.

The carrier density in the samples, fabricated by the method of mechanical exfoliation, is controlled by a gate voltage in the range up to 1.5×10^{12} cm^{-2}. The temperature dependent magnetoresistance is detected at all densities including the electroneutrality region where the type of carrier changes from electrons to holes. The analysis of the magnetoresistance using theory [2] allows us to determine the phase-breaking time, as well as the time of intervalley scattering. This scattering is essential in the manifestation of WL as it is due to this scattering that WL in graphene is not totally suppressed by topological defects or energy spectrum warping.

The results on WL in bilayer graphene are compared with those on single-layer graphene, which we analyse at different carrier densities (including the Dirac point) using the approaches developed in [3,4]. We study several samples of different geometry and quality, with the aim to control the characteristic times responsible for the manifestation of WL. The intensity of intervalley scattering and the scattering due to topological defects and spectrum warping are compared for different samples.

The study of WL is complemented by the analysis of the universal conductance fluctuations which are observed at all studied densities, both as a function of magnetic field and carrier density.

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[2] K. Kechedzhi, Vladimir I. Fal'ko, E. McCann, and B. L. Altshuler, Phys. Rev. Lett. **98**, 176806 (2007).

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TUNING SPIN TRANSPORT AND MAGNETOCONDUCTANCE IN A SEMICONDUCTOR QUANTUM RING WITH RAHSBA SPIN-ORBIT INTERACTION

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[b] Dip. Fisica , Universita' della Calabria and INFN, Arcavacata di Rende (CZ), Italy

Aharonov Bohm oscillations of the magnetoconductance in a ballistic quantum ring is a beautiful demonstration of the quantum interference of electrons and a probe for weak localization corrections in presence of diffusive contacts. Spin effects due to the Zeeman spin splitting and to the spin-orbit (SO) interaction can be monitored as well, together with antilocalization corrections. It has been pointed out that the transport of the electron spin around the ring affects the interference by adding an extra Berry phase. For appropriately designed heterostructures the SO is also tuned with electric gates, which is a practical realization of the Aharonov-Casher effect. Recently such effects have also been observed in a 2D GaAs hole ring structure [1]. We have analyzed in detail the interplay of the phenomena quoted above within a real time path integral approach and studied the spin polarization of the transported electron. At zero magnetic field strong SO coupling provides the flipping of the spin polarization. We will present our results which also include WL corrections and dephasing induced by non fully transparent, ideal contacts[2,3].

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[2] R.Capozza,D.Giuliano, P.Lucignano and A.Tagliacozzo, Phys. Rev. Lett. 95,226803(2005)

[3] P.Lucignano, D.Giuliano and A.Tagliacozzo, cond-mat/0703216

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Title: **"Attenuation of one-dimensional plasmons"**

Abstract:

This poster will focus on recent theoretical developments in the field of one-dimensional (1D)
plasmons in ballistic conductors. In the physics of the solid-state, plasmons correspond to quantas of the oscillation of the electronic density. Much experimental and theoretical work has been devoted to 3D (since the 50s) and 2D (in semiconductor heterostructures) plasmons.
In 1D, recent theories have motivated the need to go beyond the standard model of interacting 1D fermions, the Tomonaga-Luttinger model, in order to access the attenuation (or inverse life-time) of 1D plasmons due to electron-electron interactions. I will summarize these theoretical developments [1,2,3] and the main techniques used to tackle this problem. I will also propose the use of
electronic Raman spectroscopy, e.g. on metallic wires, in order to measure the plasmon peak and test the theoretical predictions (non-lorentzian profile [1,2] and interaction-dependent width of the peak
[2,3]).

[1] Pustilnik et al. PRL (2006)
[2] Pereira et al. PRL (2006)
[3] Teber, PRB (2007)

Proposed 15 minute talk, smr.1844, Trieste

Title: Proximity-induced effects in carbon nanotubes
Author: Smitha Vishveshwara
(in collobaration with Karyn Le Hur and Cristina Bena)

The properties of a single-walled metallic carbon nanotube placed on a superconducting substrate are discussed. Given that the nanotube possesses two bands in its excitation spectrum, a novel proximity effect is manifest which allows the existence of a ``double superconducting gap." It is shown that there is a critical experimentally-accessible interaction strength in the nanotube at which this proximity effect transitions from being suppressed to being enhanced.

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Co-authors: A. Shnirman, Y. Gefen

Title:
Towards a dephasing diode: asymmetric and geometric dephasing

Abstract

We study the effect of noise on spin and charge transport in ballistic quantum wires with strong spin-orbit coupling (Rashba coupling). We find that the wire then acts as a ``dephasing diode", inducing very different dephasing of the spins of right and left movers. We also show how geometric dephasing emerges in curved wires and find that the curvature can induce a left-right asymmetry in dephasing. We propose ways to measure these effects through spin detectors, spin-echo techniques, and Aharanov-Bohm interferometry.