The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
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IAEA
International Atomic Energy Agency

Conference on

"Quantum Phenomena in Confined Dimensions"

(4 – 8 June 2007)

ABSTRACTS

of

P O S T E R S

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METAL -INSULATOR TRANSITION IN A QUANTUM WELL SYSTEM

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Abstract

Metal-Insulator transition is investigated for a shallow donor in an isolated well of $GaAs/Ga_{1-x}Al_xAs$ superlattice system within the effective mass approximation using Thomas-Fermi screening function. Within the one-electron approximation the occurrence of Mott transition is seen when the binding energy of a donor vanishes is observed. The effects of Anderson localization and exchange & correlation in the Hubbard model are included in the model. The critical concentration is enhanced when a random distribution of impurities is considered. The relationship between the present model and the Mott criterion in terms of Hubbard model is also brought out. Hartree-Fock function yields values of critical concentration which are one order higher than when TF screening function is involved. The scaling theory of Abrahams et al., [1,2] is critically examined. The combined effects of magnetic and electric fields on MIT are studied. While the magnetic field enhances the critical concentration where MIT occurs whereas the electric field pushes down. Some of the excited states of a hydrogenic donor in a quasi quantum also discussed. The transition from the ground state to the pure $2p_z$ state which is associated with the second subband is observed. The results show that the transition line is observed near the metal-insulator transition as shown in other Ref.[3,4]. All the calculations have been carried out with finite barriers and the results are compared with the available data in the literature [5].

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Pure dephasing of two charge qubits in vertically coupled quantum dots

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Semiconductor quantum dots (QDs) are often considered as candidate devices for a solid-state implementation of quantum information processing [1,2,3]. The implementation of charge states in quantum dot (QD) systems, recently supported by an experimental demonstration [4], has driven a lot of investigations on coherence properties of these systems. Coherent oscillations in double quantum –dot qubit are observed [5].

We analyze the pure dephasing of two electrons in vertically coupled quantum dots due to the interaction with phonons. We numerically evaluated the dephasing rates due to electron coupling to both acoustic and optical phonons. Our results show that the pure dephasing rates depend on the separation between dots and the strength of electron confinement.

Keywords: decoherence, entanglement, double quantum dot

Conversion of entanglement between continuous variable and qubit systems

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Quantum information processing (QIP) has been extensively studied for a qubit system which is a quantum extension of a bit, spanning two-dimensional Hilbert space. A qubit is realized by an electronic spin, a two-level atom, the polarization of a photon and a superconductor among others. In parallel, much attentions have been paid to the QIP of quantum continuous variable (CV) system which is a quantum extension of analog information in classical information theory. CV physical systems such as a harmonic oscillator, a rotator and a light field are defined in infinitive-dimensional Hilbert space. While conversions of analog to digital (A/D) and digital to analog (D/A) are quite usual in information processing, qubit and CV systems are nearly always treated separately. Few schemes have been suggested to transfer entanglement between qubits and radiation field. The critical point in these entanglement conversions is that the usual Jaynes-Cummings interaction Hamiltonian of qubit and CV field is assumed. This usual Jaynes-Cummings interaction Hamiltonian accounts for the imperfect of the entanglement conversion.

We propose a mathematically traceable scheme of perfect entanglement transfer. The cost to realize this sheche is that a serial of non-linear interaction Hamiltonians should be used. The first Hamiltonian takes the form of $H_1 = \hbar\Omega(\sqrt{n}a^+\sigma_- + a\sqrt{n}\sigma_+)$,The $k-th$ Hamiltonian will be $H_k = \hbar\Omega[n(\frac{1}{\sqrt{n}}a^+)^{2^{k-1}}\sigma_- + (a\frac{1}{\sqrt{n}})^{2^{k-1}}n\sigma_+]$. The entanglement transfer of the two-mode squeezed vacuum state is shown in Fig.1for different value of receiving qubit pair number K. The entanglement transfer of CV Werner state is also discussed.

It is difficult to find a real physical system to realize the the nonlinear Hamiltonians. We would like to ask if it can be realized with confined dimensional quantum system?

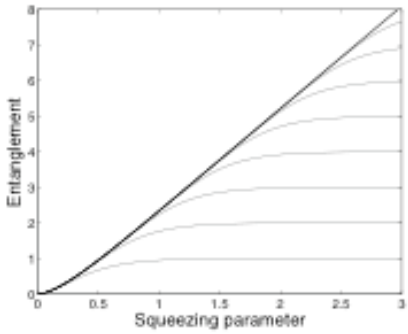

Figure 1: The thick line is for CV state, The thin lines from bottom to top are for the entanglement transferred of K=1,2,...,8 respectively.

Nonlinear transport in ballistic mesoscopic systems: B field Symmetry.

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We study the conductance through ballistic mesoscopic devices beyond the linear response regime. By using non-equilibrium Green's functions we obtain a general expression for the current. This expression is manifestly gauge invariant and depends in a self-consistent way on the charge distribution in the device. To compare our findings with recent non-linear transport experimental results[1,2], our calculations are specialized to two terminal devices. The current is expanded in powers of the applied bias, which allows us to identify the nonlinear conductance terms. We study their symmetry with respect to the magnetic field and observe that they violate the Onsager relations. We identify the first correction to the linear conductance with the nonlinear conductance obtained by Büttiker and collaborators using the S-matrix formulation[3,4]. One of the advantages of our approach is that it can easily be extended beyond the first order correction. To quantitatively study the non-linear conductance we consider a simple model[5,6], namely, a single-channel quantum ring attached to two leads. In the S-matrix theory, this model allows us to compute the characteristic potentials, injectivity, and the first non-linear conductance term in a Thomas-Fermi approximation.

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0-π transition in SFS junctions with strongly spin-dependent scattering

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Abstract

A theory of the critical current and 0-π transition in a superconductor – ferromagnetic alloy – superconductor trilayers (SFS) was developed. To take strong spin dependence of electron scattering of compositional disorder in a diluted ferromagnetic alloy into account a model of ferromagnet doped by random delta-functional impurities which were implied to be both potential and magnetic was used. Employing semiclassical approximation with corresponding self-energy and applying boundary conditions at S/F interfaces we can find order parameter in ferromagnet and obtain in result the total current through the junction. We show that in such a system the critical current oscillations as the function of the thickness of the ferromagnetic layer, with the period of $v_F/2I$, v_F and I being the Fermi velocity and exchange splitting, respectively, decay exponentially with the characteristic length of the order of the mean free path.

Quantum phenomena in carbon-nanotube field emission

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The carbon nanotubes (CN) as a new kind of quasi-one-dimensional materials promise a potential application in nanotechnology. Particularly, the experimental investigations of CN field emission exhibits some excellent and novel properties, including the low turn-on field, high current density, the current-voltage characteristic deviating Fowler-Nordheim (FN) type in the high current, and the multi-peak energy distribution. These novel phenomena stimulate us a lot of theoretical thought. Is there any new field emission mechanism in CN field emission? What is the nanoscale effect in CN field emission? Using the tight-binding approach, we consider the effect of the energy band structure of CN in field emission beyond the FN theory to investigate the current-voltage characteristic and the energy distribution of CN field emission.[1] We find that the metallic and semiconducting single-wall carbon nanotubes (SWCN) exhibit different field-emission behaviors, such as the current-voltage characteristic, quantum size effect and the multi-peak energy distribution.[1,2] For the multi-wall carbon nanotubes (MWCN), the interlayer coupling induces the semiconductor-metal phase transition, which makes the quantum size effect vanish. [3] Particularly, when a magnetic field is applied along the tube axis, it modifies the energy band structures of the metallic and semiconducting SWCNs, which leads to the universal current density at the ratio of magnetic flux and flux quanta equaling to 0.21. The emission currents of the metallic and semiconducting SWCNs exhibit different responding behaviors to the magnetic field. These properties give possibilities to observe the Aharonov-Bohm phase and to generate a spin polarized electron source from the CN field emission.[4,5] These studies reveal some novel properties in the CN field emission.

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Surface plasmon guidance and control in semiconductor structures

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Abstract

This paper discusses the possible applications of semiconductor heterostructures in the propagation and control of surface plasmon polaritons (SPP). Usually, SPP are guided in the interfaces of metal and dielectric slabs. The long range surface plasmon polaritons (LRSPP) are realized in structures with a thin metal film placed in between dielectric media, where the SPP modes at the two interfaces couple to give modes with longer propagation distance [1].

The metallic character of doped semiconductor at low frequencies make it possible to excite SPPs at midinfrared, terahertz and microwave frequencies [2]. An important property of semiconductor is that their carrier density and mobility and hence the dispersion of SPP can be controlled by thermal excitation of free carriers.

We have derived dispersion relations for various SPP modes, and in the present paper, these relations are used to explore theoretically the propagation in semiconductor SPP waveguides. First the usual LRSPP modes are explored with metal film replaced by a semiconductor film. This situation may also be realized in the electron gas formed at the interface between GaAs and AlGaAs. Another important situation is the metal-oxide-semiconductor structure where the coupled SPP modes at the two interfaces will give rise to long-range effects. An advantage of this structure is the possibility of controlling electron concentration by changing the gate voltage.

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One dimensional many-body dynamics in spin chains detected through multiple quantum coherence NMR experiments.

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In this work, we test the dimensionality of the quantum dynamics in a network of coupled spins using solid state nuclear magnetic resonance.
In particular, one can generate an effective double quantum Hamiltonian (flip-flip + flop-flop) that mixes subspaces with different spin projection creating many-body superposition states: the multiple quantum coherences. These states can be probed through a bidimensional technique that allows one to follow the superposition weights as they are created.
Multiple-quantum coherence intensities [1] are measured under a double-quantum Hamiltonian [2] in hydroxyapatite. This system is a quasi-one-dimensional spin chain, as the distance between hydrogen spin chains is about three times larger than the distance between adjacent protons within the chain. As a consequence of the distance dependence of the dipolar interaction and the quantum Zeno effect [3], this should lead to a separation in about three orders of magnitude between the intra and inter-chain time scales.
Analytical and numerical methods give exact expressions for the intensities of the multiple-quantum coherences in homogeneous one-dimensional linear chains of nuclear spins 1/2 coupled by nearest neighbor interactions [4]. As occurs with the XY (flip-flop) dynamics [5], the double-quantum dynamics has a simple mapping to non-interacting fermions under a Tight-Binding Hamiltonian [4]. As a consequence, only zero and second order coherences are expected in the case of a homogeneous chain. As predicted by theory, we find that all the coherences orders above two cancel out. In contrast, the dynamics of the same system under a different effective Hamiltonian shows higher orders of coherence, revealing that this is not a limitation of signal to noise ratio. Decoherence is tested through a form of Loschmidt echo experiment which reveals that in this quasi-1-d system, the double-quantum dynamics presents an exponential decay, in contrast with results in 3-d systems.

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Title:

The effect of angular dependence of magnetization on electrical transport in GaMnAs/GaAs/GaMnAs heterostructures

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Abstract: Theoretical studies on spin-dependent transport in magnetic tunnel heterostructures consisting of two diluted magnetic semiconductors (DMS) separated by a nonmagnetic semiconductor (NMS) barrier, are carried in the limit of coherent regime by including the effect of angular dependence of the magnetizations in DMS. Based on parabolic valence band effective mass approximation and spontaneous magnetization of DMS electrodes, we obtain an analytical expression of angular dependence of transmission for DMS/NMS/DMS junctions. We also examine the dependence of spin polarization and tunneling magnetoresistance (TMR) on barrier thickness, temperature, applied voltage and the relative angle between the magnetizations of two DMS layers in GaMnAs/GaAs/GaMnAs heterostructures. We discuss the theoretical interpretation of this variation. Our results show that TMR of more than 65% are obtained at zero temperature, when one GaAs monolayer is used as a tunnel barrier. It is also shown that the TMR decreases rapidly with increasing barrier width and applied voltage; however at high voltages and low thicknesses, the TMR first increases and then decreases. Our calculations explain the main features of the recent experimental observations and the application of the predicted results may prove useful in designing nano spin-valve devices.

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Spatially resolved Raman spectroscopy of Single- and Few-Layer Graphene

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We present Raman spectroscopy measurements on single- and few-layer graphene flakes. Using a scanning confocal approach we collect spectral data with spatial resolution, which allows us to directly compare Raman images with scanning force micrographs [1,2]. Single-layer graphene can be distinguished from double- and few-layer graphene by the intensity of the G-line and by the width of the 2D line. The single peak of the 2D line for single-layer graphene splits into different peaks for the double-layer. The splitting increases with increasing number of layers. These findings are explained using the double-resonant Raman model based on ab-initio calculations of the electronic structure and of the phonon dispersion. The double-resonant model explains qualitatively well the splitting of the 2D line but fails to quantitatively predict the splitting. This indicates possible limitations of the model due to the neglect of electron-electron and electron-hole interaction (excitonic effects). Moreover, we investigate the D line intensity and find no defects within the flake. A finite D line response originates only from the edges of the flakes and can be attributed to the breakdown of translational symmetry.

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