10-01

Evaluation of Decoherence for Quantum Control and Computing

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Different approaches in quantifying environment induced decoherence are considered. We identify a measure of decoherence, derived from the reduced density matrix of the system, that quantifies the environmentally induced error, i.e., deviation from the ideal isolated-system dynamics. This measure can be shown to have several useful features. Its behavior as a function of time has no dependence on the initial conditions, and is expected to be insensitive to the internal dynamical time scales of the system, thus only probing the decoherence-related time dependence. For a spin-boson model—a prototype of a qubit interacting with environment—we also demonstrate the property of additivity: in the regime of the onset of decoherence, the sum of the individual qubit error measures provides an estimate of the error for a several-qubit system, even if the qubits are entangled, which is important in quantum-computing applications. This makes it possible to estimate decoherence for several-qubit quantum computer gate designs.

10-02

Decoherence of a Quantum System and Dynamics of a Heat Bath

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The traditional approach to evaluate dissipation processes in a classical system interacting with an external reservoir is based on the Markov approximation. In this case evolution of a system possesses a semi-group property and is local in time. It was shown that for a quantum system this approximation is valid only on timescales larger than the thermal time, $\hbar / kT$.

In most non-markovian models for evolution of open quantum systems the bath is described by a set of non-interacting oscillators. I will consider how an internal interaction between modes of a thermal bath affects semi-group property and characteristic timescales of irreversible dynamics of a quantum system.

10-03

Efficient Wave-Induced Switching & Quantum-NOT Operation in Coupled Quantum Wires

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Coupled quantum wires have been proposed as a means to realize a scalable solid-state based qubit for quantum computing Both Gaussian-wave-packet, and plane-wave, based implementations of this approach have been explored theoretically, along with schemes for entanglement and the realization of multi-qubit networks. In spite of this interest, however, there has been little experimental progress on this problem to date. In this presentation, we present the results of a first practical step towards the implementation of this approach, providing evidence for the successful demonstration of a single qubit structure comprised of two coupled GaAs quantum wires. Our experimental results reveal extremely efficient switching of the electron wavefunction (by nearly 100%) between the two waveguides of this structure, and also show evidence for the proposed quantum-NOT operation in which an incoming electron wave is switched effectively from one waveguide to the other. This behavior is observed to temperatures as high as 35 K, suggesting the considerable potential of this approach. In our presentation we also speculate on the possibility of extending our results to achieve entanglement of coupled qubits based on this system.

10-04

Transmission Coefficient for an Electron Through a Quantum Point Contact in an Electric and Magnetic Field

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Electron transmission through a quantum point contact (QPC) in the presence of an electric and magnetic field is examined. The QPC is modeled as a saddle potential. The relevant Green function is derived using Schwinger's operator equation of motion method and used to obtain the transmission coefficient. For vanishing electric field the result reduces to Fertig and Halperin's result.

10-05

Mesoscopic and Microscopic Spin Injection, Spin Precession, Spin Diffusion and Spin Transport in Semiconductor Nanostructures

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In this talk we are going to present our theoretical investigations on spin kinetics of semiconductor nanostructures based on many-body, single particle and mesoscopic approaches under various conditions. Both transient and steady-state transports are addressed. In addition to the cases near the equilibrium, spin kinetics far away from the equilibrium such as electrons of high spin polarization and/or electrons with strong electric field (hot electrons) is also discussed in detail. Many novel effects are predicted.

10-06

Irreversible Deposition of Particles on Pre-Treated Surfaces

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We present a Monte Carlo study of irreversible, competitive deposition models, applied to single- and two-sized disks on pre-treated, patterned surfaces with short-range repulsive interactions. In particular, we study the effect of the substrate nanopatterning on coverage and particle distribution on the surface. Definition of suitable dimensionless parameters in terms of natural length scales of these systems can provide information regarding the "phase diagram" and obtain, therefore, the structure of the jamming state in several limiting cases of interest. Depending on the values of the parameters, the

presented model is capable of describing, amorphous, continuum Random Sequential Adsorption, or locally ordered regions. We also performed simulations with an initial fraction of dirt already deposited on the substrate. Our study is of interest to people working, for example, in the fields of self-assembled nanostructures, colloids, lithography, and nonequilibrium statistical physics as it provides key parameters and characterization of the evolution towards the jamming state.

10-07

Synthesis and Applications of Monofunctional Gold Nanoparticles

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In the bottom-up approach towards nanomaterial development, there are two most important aspects to be addressed: one is the synthesis of nanobuilding blocks and the other one is how to assemble the nanobuilding blocks together into materials or devices with precisely controlled structures, properties and functions. Recently our group developed a unique solid phase technique to synthesize gold nanoparticles with a single functional group attached to the surface. Using the monofunctional gold nanoparticles as *molecular nanobuilding blocks*, we further demonstrated the synthesis of covalently bonded nanoparticle/polymer hybrid materials by chemical reactions. This research provides a promising tool in the precise positioning of nanoparticles to a particular location of a substrate or scaffold material, and its applications in quantum computing and quantum devices will be discussed in the presentation.

10-08

Spins in Semiconductors for Storing and Processing Quantum Information

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Spins in semiconductors have many desirable properties for quantum information processing. Recent key experimental demonstrations by several groups have considerably improved the prospects of physical implementation of a semiconductor based processor. In this talk, I will highlight the recent progress of the UCLA group. The results of an experiment to manipulate single spin with microwave pulses and to detect its magnetic resonance and spin orientation will be reported. Effort on the fabrication and characterize long-coherent-time qubits on epitaxial SiGe heterostructures will be described. The first demonstration of trapping, storing, and detecting single photoelectrons in a controllable electrostatic quantum dot will also be presented.

10-09

Collective Decoherence of Nuclear Spin Clusters

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The problem of dipole-dipole decoherence of nuclear spins is considered for strongly entangled spin cluster. Our results show that its dynamics can be described as the decoherence due to interaction with a composite bath consisting of fully correlated and uncorrelated parts. The correlated term causes the slower decay of coherence at larger times. The decoherence rate scales up as a square root

of the number of spins giving the linear scaling of the resulting error. Our theory is consistent with recent experiment reported in decoherence of correlated spin clusters.

10-10

Transport Through a Molecular Junction: The Non-Equilibrium Small Polaron Problem

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We consider a model of a molecular switch that consists of an electronic orbital strongly interacting with a local mechanical (phonon) mode. The strong polaronic interaction prevents perturbative treatment of the problem. Instead, we find that in an adiabatic regime when the electronic dynamics is faster than the phonon frequency, it is possible to provide a fully non-perturbative treatment of the non-equilibrium properties of the system. The results show intermittent switching between bistable states of the phonon mode with an effective random telegraph noise.

10-11

Single-Photon Optical Detectors Based on Superconducting Nanostructures

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We review the current state-of-the-art in the development of superconducting single-photon detectors and demonstrate their advantages over conventional semiconductor avalanche photodiodes, in terms ultrafast and very efficient counting capabilities of both visible-light and infrared photons. Superconducting single-photon detectors (SSPDs) are quantum photon counters. Their detection mechanism is based on photon-induced generation of a picosecond voltage transient across a nanostructured, 10×10-*m*m^2-area NbN meander (4-nm-thick and ~100-nm-wide stripe). Our best devices operate at 2 K and exhibit quantum efficiency of ~30% in the visible to 1.55 ? m wavelength range, 2-GHz photon counting rate, timing jitter of <18 ps, and dark counts <0.01 per second. The SSPDs have already been applied in testers for debugging of VLSI CMOS circuits and are currently being implemented for free-space optical communications and in fiber-based quantum key distribution (cryptography) systems. Transition edge sensors (TESs) are superconducting nanobolometers and they act as super-sensitive thermometers. TES devices reach quantum efficiency of >80%, have negligible dark counts, and possess photon number resolving capability. They are excellent x-ray detectors with ~1-eV energy resolution and are expected to find applications in linear optical quantum computation.

10-12

Loss of Coherence in Gate-Controlled Qubit Systems

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Studies of decoherence for quantum computing has been based on investigation of an idling qubit system described by a time-independent Hamiltonian. We present an approach that allows

investigating the influence of essentially time-dependent gate controls on coherence of qubit system. The approximation to the reduced density matrix is obtained to the leading order in system-to-environment interaction. In the case of an adiabatic settings the approximation is shown to give decoherence behavior of the exact solution. The approach is analyzed on the example of a qubit in the rotating wave field.

10-13

Indirect Interaction of Localized Magnetic Moments in Luttinger Liquids

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Indirect interaction between localized spins in Luttinger liquid is investigated. We show that spin-spin interaction is an oscillatory function of distance between localized spins (x) with amplitude decaying asymptotically as $x^{-(1+g_C)/2}$ where $g_C > 1$ for attractive and $g_C < 1$ for repulsive interactions. We also derive effective dynamics for the system of two spins indirectly coupled via Luttinger liquid in nonequlibrium regime.

10-14

Frequency Study of the Microwave Induced Resistance Oscillations of a High Mobility Two-Dimensional Electron Gas

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Microwave induced resistance oscillations (MIROs) detected on high mobility samples have attracted much interest recently. Under certain conditions a zero-resistance state is observed. We have investigated the evolution of MIROs on a GaAlAs/GaAs heterostructure (μ~10^7cm^2/Vs) over a very wide frequency range from ~50 GHz up to ~4 THz, from quasi-classical to the quantum Hall regime. At low frequencies regular MIROs were observed, with a periodicity determined by the ratio of microwave to cyclotron frequencies. For frequencies below 150 GHz the MIROs waveform vs magnetic field is well described by the existing theoretical models that can be used for deducing the Landau levels width.

At higher frequencies the weak MIROs were still observed on a background of relatively strong Shubnikov de Haas oscillations. The MIROs progressively vanished at higher frequencies, around 400 GHz. This sets an upper frequency limit for the observation of MIROs. However, microwave induced resistance changes are still observed at frequencies above 400 GHz in the form of sharp peaks at the cyclotron resonance and its second harmonic. The observed resistance changes in the quantum Hall regime could be qualitatively understood in terms of a bolometric-type response.

10-15

The Influence of Weak Measurement on Electron Transport in Quantum Dots Chains

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We consider the chain of semiconductor quantum dots with neighboring dots coupled by tunnel barriers with one electron coherently hopping from one dot to another. The corresponding quantum walk behavior of electron transport is strongly affected by measurement via quantum point contacts placed nearby each dot. We derive the evolution of electron density matrix and analyze the transition from coherent quantum oscillatory dynamics to diffusive classical motion.

10-16

On Quantum Walks on Graphs

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Random walk on graphs is a valuable algorithmic technique in computer science. The recent interest in quantum walks on graphs is fueled in part by the positive impact of the classical paradigm, but also in part by the possibility of exploiting natural physical processes for an implementation of a quantum model of computation. To date, there are two known models of quantum walks, discrete and continuous-time, with their respective algorithmic potential. We outline some recently proven structural properties about quantum walks on some well-known graphs, along with some preliminary work on analyzing mixing and decoherence.

10-17

Ballistic Electro Photonics

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The ballistic transport of hot electrons in semiconductors has long been a subject of interest. In this talk, I will present several exciting new results which have broad implications for the study of new semiconductor nanostructures including the transport of spin. These are:
Ballistic Electron Emission Luminescence which allows the simultaneous monitoring of electron transport and luminescence for quantum dot structures placed below the surface.
Demonstration of several new types of hot electron based devices involving the monitoring of spin transport. Examples include luminescent spin valve transistors and spin valve photodiodes.
Transport and luminescence studies of semiconductor nanowires such as ZnO.

10-18

Ab Initio Analysis of Electron-Phonon Coupling in Molecular Devices

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We report first principles analysis of electron-phonon coupling in molecular devices under external bias voltage and during current flow. Our theory and computational framework are based carrying out

density functional theory within the Keldysh nonequilibrium Green's function formalism. We analyze which molecular vibrational modes are most relevant to charge transport under nonequilibrium conditions. For a molecular tunnel junction of a 1,4-benzenedithiolate molecule contacted by two leads, the low-lying modes of the vibration are found to be most important. As a function of bias voltage, the electron-phonon coupling strength can change drastically while the vibrational spectrum changes at a few percent level.

10-19

Spin-polarized Injection and Transport in a Schottky Diode

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Using the Monte Carlo simulation model, we studied spin polarized injection and transport in an Fe(100)/GaAs(100) Schottky diode. Both intra-valley and inter-valley scatterings are considered. The model accounts for electron spin dynamics in the G and L valleys. It is found that the upper (L) valleys play an important role in spin transport close to the Schottky barrier. The simulation results are consistent with experimental data.

10-20

Decoherence and Loss of Entanglement

D. TOLKUNOV and V. Privman, Center for Quantum Device Technology, Department of Physics, Clarkson University, Potsdam, NY 13699-5721, tolkunov@clarkson.edu

We review our recent work establishing by an explicit many-body calculation for an open quantum-mechanical system of two qubits subject to independent noise modeled by bosonic baths, a new connection between two important issues in the studies of entanglement and decoherence. We demonstrate that the decay of entanglement is governed by the product of the suppression factors describing decoherence of the subsystems (qubits). This result is the first detailed model calculation proving an important and intuitively natural physical property that separated open quantum systems can evolve coherently, quantum mechanically on time scales larger than the times for which they remain entangled.

Our result also suggests avenues for future work. Specifically, for multiqubit systems, it is expected that similar arguments should apply "by induction." This will stimulate research to develop appropriate quantitative measures of entanglement, and attempts to quantify entanglement and decoherence in a unified way.