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POSTER ABSTRACTS

Qualitative Perspectives on the Dynamics of a Multi-Cooper-Pair Box

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We analyze the transient entanglement of Cooper-pair boxes biased by a classical voltage and irradiated by a quantized field and find the unusual feature that the phase-damped cavity can lead to a long-lived entanglement. The results show an asymptotic value of the linear entropy (concurrence) which embodies coherence loss (entanglement survival), independent of the interaction development by dependent critically on environment. Also, we analyze a controllable generation of maximally entangled mixed states of a circuit containing two-coupled superconducting charge qubits. At sufficiently deviation between the Josephson energies of the qubits and/or strong coupling regime, maximally entangled mixed states at certain instances of time is synthesized. We show that entanglement has an interesting subsequent time evolution, including the sudden death effect. This enables us to completely characterize the phenomenon of entanglement sharing in the coupling of two charge qubits.

Keywords: Cooper pair; Entanglement; Charge Qubits

Title: **Theory of the Integer Quantum Hall Effect**

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Abstract

To describe quantitatively the Quantum Hall effect, we use our new developed self-consistent theory for a two lead mesoscopic structure in Landauer's viewpoint for transport [1], in case the magnetic field, of strong strength, is applied perpendicular to the structure. Within the edge states model for transport, supposing the existence of tunneling between those one [2], we derive a generalized longitudinal and Hall conductance's formulas within linear response theory that, for the time being, have not been derived quantitatively.

These formulas describe the region of the breakdown and lead to the integer quantum Hall effect in case the current flux is dissipation less.

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Nonlinearly driven Landau-Zener transition in a qubit with telegraph noise

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We study Landau-Zener-like dynamics of a qubit influenced by transverse random telegraph noise. The telegraph noise is characterized by its coupling strength v and switching rate γ. The qubit energy levels are driven nonlinearly in time, ~sgn(t)|t|$^{\nu}$, and we derive the transition probability in the limit of sufficiently fast noise, for arbitrary exponent ν. The level occupation after the transition depends strongly on ν, and there exists a critical ν_c with qualitative difference between $\nu<\nu_c$ and $\nu>\nu_c$. When $\nu<\nu_c$, the final state is always fully incoherent with equal population of both quantum levels, even for arbitrarily weak noise. For $\nu>\nu_c$, the system keeps some coherence depending on the strength of the noise, and in the limit of weak noise, no transition takes place. For fast noise ν_c=1/2, while for slow noise ν_c<1/2 and it depends on γ. We also discuss phase coherence, which is relevant when the qubit has a nonzero minimum energy gap. The qualitative dependency on ν is the same for the phase coherence and level occupation. The state after the transition does, in general, depend on γ. For fixed v , increasing γ decreases the final state coherence when ν<1 and increases the final state coherence when ν>1. Only the conventional linear driving is independent of γ.

Background signal of brain neurons vs quantum chaos

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The question: whether quantum coherent states can sustain decoherence, heating and dissipation over time scales comparable to the dynamical timescales of the brain neurons, is actively discussed in the last years. Positive answer on this question is crucial, in particular, for consideration of brain neurons as quantum computers. This discussion was mainly based on theoretical arguments. In present paper nonlinear statistical properties of the Ventral Tegmental Area (VTA) of genetically depressive limbic brain are studied in vivo on the Flinders Sensitive Line of rats (FSL). VTA plays a key role in generation of pleasure and in development of psychological drug addiction. We found that the FSL VTA (dopaminergic) neuron signals exhibit multifractal properties for interspike frequencies on the scales where healthy VTA dopaminergic neurons exhibit bursting activity. For high moments the observed multifractal (generalized dimensions) spectrum coincides with the generalized dimensions spectrum calculated for a spectral measure of a quantum system (so-called kicked Harper model, actively used as a model of quantum chaos). This observation can be considered as a first experimental (in vivo) indication in the favour of the quantum (at least partially) nature of the brain neurons activity.

[1] References if any

Superfluid properties of a Bose-Einstein condensate in an optical lattice confined in a cavity

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Abstract: We study the effect of a one dimensional optical lattice in a cavity field with quantum properties on the superfluid dynamics of a Bose-Einstein condensate(BEC). In the cavity the influence of atomic backaction and the external driving pump become important and modify the optical potential. Due to the coupling between the condensate wavefunction and the cavity modes, the cavity light field develops a band structure. This in turn influences the Bloch energies, effective mass, Bogoliubov excitations and the superfluid fraction of the BEC. This study reveals that the pump and the cavity now emerges as a new handle to control the coherence properties of the BEC, which offer the potential for improved interferometric technique, quantum information processing and efficient control of nonlinear excitations such as solitons.

Counting Statistics of Non-Markovian Quantum Stochastic Processes

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The concept of Full Counting Statistics (FCS) has recently attracted intensive theoretical [1] and experimental [2, 3, 4] attention in the field of electron transport. In the contest of mesoscopic transport, the FCS was introduced to determine the noise properties of nanodevices [5]. It was also demonstrated to be a sensitive diagnostic tool in the detection of quantum-mechanical coherence, entanglement, disorder, and dissipation [1].

In recent years a number of important results was obtained in the Markovian Master Equation framework. Bagrets and Nazarov have shown that the Cumulant Generating Function (CGF) is given by
the dominant eigenvalue of the Markovian master equation kernel having included the counting field factors[6]. Flindt et al. have shown that it is possible to calculate an arbitrary order of cumulants using an appropriate pertubative approach in the counting field[7]. For cases described by non-Markovian master equation with a short range memory, no power-law tails, was shown that a CGF scales linearly with time, as in Markovian processes, and can be calculated via a peculiar non-Markovian expansion[8].

Here we present a method which unifies extending those earlier approaches[9]. We derive a general expression for the cumulant generating function (CGF) of non-Markovian quantum stochastic transport processes[10]. The long-time limit of the CGF is determined by a single dominating pole of the resolvent of the memory kernel from which we extract the zero-frequency cumulants of the current using a recursive scheme. The finite-frequency noise is expressed not only in terms of the resolvent, but also initial system-environment correlations. As an illustrative example we consider electron transport through a dissipative double quantum dot for which we study the effects of dissipation on the zero-frequency cumulants of high orders and the finite-frequency noise[11].

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Entanglement dynamics in small rings of qubits with thermal environment

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Numerical solutions the quantum state diffusion equation for open quantum systems is used to study dynamics of nearest neighbor qubit pairs in systems of small number of qubits on rings with Heisenberg and transverse Izing interaction and under the influence of the thermal environment.

The dependence of the pair entanglement dynamics on the temperature, number of qubits, the type of coupling and the type of entanglement in the initial state was analyzed for systems of up to $N=10$ qubits.

It is concluded that the pair entanglement in rings with transverse Izing coupling and prepared in a separable initial state is the most resistant on the decoherence effects of the thermal noise.

Anisotropic conductivity of disordered 2DEGs due to spin-orbit interactions

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In the presence of both Rashba and Dresselhaus types of spin-orbit interaction (SOI), the energy spectrum of an electron gas becomes anisotropic. Using the disorder-averaging diagrammatic technique, we studied the effect of this mixed-type SOI on the conductivity tensor. The contribution from the (zero-loop) leading diagrams is isotropic; it includes Drude conductivity σ_{D} together with the small isotropic correction due to SOI[1]:

$$\delta\sigma = 2m\tau(a^2+b^2)\frac{e^2}{h}\begin{pmatrix}1 & 0\\ 0 & 1\end{pmatrix}, \tag{1}$$

where a and b are the amplitudes of Rashba and Dresselhaus SOI-types, and τ is the mean elastic scattering time of an electron in the disordered potential. The anisotropic part of the conductivity tensor is non-zero due to the contribution of the two-loop diagrams. It is non-analytic in SOI amplitudes[1]:

$$\sigma_{xx} - \sigma_{yy} = -0.011\frac{2ab}{a^2+b^2}\frac{e^2}{2\pi}\frac{1}{p_F l}, \tag{2}$$

where p_F is the Fermi momentum, and l is the elastic mean free path of an electron. A similar non-analyticity appears also in the weak antilocalization (WA) problem; however, it is not so remarkable in the WA because WA itself contains non-analytical dependence on the momentum cut-off.

Next, we considered[2] the same problem in two quasi-1D cases: (i) a wire and (ii) a ring.[1] In these cases, the effect is enhanced. The case of a ring pierced by a magnetic flux is especially interesting, since the divergent (massless) component of the diffuson propagator is uncompensated when the time-reversal symmetry is violated.[2]

In problems with spin, a summation over spin indices produces huge expressions which can not be handled manually in a reasonable time interval. We have overcome this problem by developing a symbolic-calculation program[2] that (i) generates diagrams having the requested number of loops, (ii) calculates Hikami-boxes, and finally (iii) performs the integration over the cooperon and diffuson momenta. The first two stages of the program are universal, i.e., can be readily used for other calculations in the diagrammatic technique. The program significantly facilitates the usage of the diagrammatics, especially in the spinfull case.

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[2] In the presence of time reversal symmetry, small momentum singularities (in the cooperon/diffuson momentum integrals) are mutually cancelled due to the general argument in [4].

Non-equilibrium transport at a quantum phase transition

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Abstract

We study the non-equilibrium effect at the quantum phase transition in a dissipative quantum dot. This is the first systemic and comperhensive study of this subject. The transition between the delocalized and loclaized phases is of the Kosterlitz-Thouless type.

A general and fundamental question is: Does the bias voltage play a similar role as temperature to smear out the transition? Here, we study a realistic Nano setup with a K-T phase transition. We apply a controllable nonequilibrium Renormalization Group (RG) approach allowing us to study nonequilibrium properties at a quantum phase transition. We map our problem onto a new effective Kondo model.

Solving for RG equations of the effective Kondo model out of equilibrium, taking into account decoherence effects at finite V, we find an explicit expression for G(V), which shows that V plays a similar role as T up to a logrithmic correction at the critical point (CR).

Transport and Charge Sensing of Spin Blockaded
^{12}C and ^{13}C Nanotube Double Quantum Dots

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We report measurements of gate-defined carbon nanotube double quantum dot devices with a charge sensor fabricated on the same nanotube. The methane used during growth controls the ^{13}C content of the nanotubes. ^{12}C nuclei have zero nuclear spin, and ^{13}C nuclei have spin 1/2. We tune the devices to the spin blockade regime and compare the magnetic field dependence of leakage current through the blockade for samples with natural abundance (1%) and enriched (99%) ^{13}C content. Preliminary pulsed-gate measurements of spin relaxation in a ^{13}C device will be presented. Supported by the NSF (EIA-0210736). HC acknowledges the NSF GRFP, and DM acknowledges MEC-Spain (FPU AP2005-0720).

Entanglement and density-functional theory: the case of Hooke's atom.

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Many solid state systems have merit as quantum information processors, such as quantum dots [1]. However, modelling solid state many-body systems exactly is often computationally onerous, hence approximations are used. It is therefore important to know how well these approximations model one of the key resources for quantum information processing, the entanglement. Density-functional theory is one efficient method to model many-body systems, but calculating the entanglement within this theory is not trivial as by construction it produces the system density not the many-body wave-function. We therefore present two methods of calculating the spatial entanglement of an interacting electron system within the framework of density-functional theory. For the first we define and approximate a wave-function that reproduces the density and minimises the energy of the system when approximations are used. While for the second we implement a perturbation of the Kohn Sham equations with the perturbation chosen to give the exact Hamiltonian. We test these methods on Hooke's atom--an interacting electron system which may be used to model electrons trapped in quantum dots--employing both the exact Kohn Sham equations and the local-density approximation. We then compare the results to the calculated exact spatial entanglement [2].

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Coupling trapped ions via transmission lines

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An oscillating trapped ion induces oscillating image charges in the trap electrodes. If the resulting current is sent to the electrodes of a second trap, it influences the motion of an ion in the second trap, giving rise to coupling of the ion motional states. The expected motional state coupling rate is 1 kHz for traps with a characteristic size of 50 m. This inter-trap coupling may be used for scalable quantum computing, cooling ion species that are not directly accessible to laser cooling, and for coupling an ion-trap quantum computer to a solid–state quantum computer, e.g. a system of Josephson junctions. We present the feasibility of experiments towards these goals with trapped Calcium ions. The most relevant source of decoherence is heating of the ion motion due to noise in the trap electrodes (e.g. Johnson–noise). By operating ion traps at cryogenic temperatures, heating will be greatly reduced, allowing the coherent coupling of two ions. We are currently operating planar traps at room temperature, and develop methods for planar trap microfabrication. In particular, we are investigating the influence of an electrically floating coupling electrode on trap performance.

Generation of the Fock States through of the nonlinear medium

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Quantum information has been one area of great advance in physics. Examples of different protocols that develop the communication processes already are found in wide scale in literature. Many of these make use of the quantum states of the light, mainly of the superposition of the Fock's states and the coherent states. In this direction, the states of Fock that are essential for the development of certain protocols used in quantum communication, are boarded in vast literature that describes proposals for its generation. In this context we introduce new quantum states of light field, by introducing the nonlinearity. The statistical properties of this new quantum states of light are investigated and shown that this states presents several interesting quantum effects e also are one good approximation of the states of Fock.

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Quantized pumping of fractional charge.

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We propose a theoretical scenario for pumping of fractionally charged quasi-particle in the context of \nu = 1/3 fractional quantum Hall liquid. We consider quasi-particle pumping across an anti-dot level tuned close to the resonance. Fractional charge pumping is achieved by slow and periodic modulation of coupling of the anti-dot level to left and right moving edges of a Hall bar set-up. This is attained by periodically modulating the gate voltages controlling the couplings. In order to obtain quantization of pumped charge in the unit of the electronic charge fraction (\nu e) per pumping cycle in the adiabatic limit, we argue that the only possibility is to tune the quasi-particle operator to be irrelevant from being relevant in the renormalization group sense, which can be accomplished by invoking quantum Hall line junctions into the Hall bar geometry.We also comment on possibility for experimental realization of the above scenario.

A deeper insight into spin chain dynamics from an information flux viewpoint

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We use the recently introduced concept of information flux in a many-body register in order to give an alternative viewpoint on spin chain dynamics. We suggest a coupling-strength configuration which gives rise to simultaneous multiple Bell states. We also propose a novel protocol for perfect state transfer that is resilient to a broad class of realistic experimental imperfections.

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Quantum Combinatorics

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In recent years it has become clear that to fully understand certain quantum phenomena, mainly those related with quantum computation and quantum information processing, the combinatorial structures underlaying quantum mechanics will play a fundamental role. Thus a combinatorial understanding of quantum phenomena has become not only desirable but also necessary. In this poster we consider one of the mathematical structures that is more likely to play a fundamental role in the combinatorial approach towards quantum mechanics: we describe in purely categorical/combinatorial terms Moyal's star product on quantum phase space, which lies at the center of the deformation theory approach to quantization.

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Photon statistics of light in semiconductor microcavities

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Content of Abstract

We investigate the photon statistics in the light emitted by a microcavity containing a semiconductor quantum well. An analytical expression of the light emitted autocorrelation function in the weak pumping regime is derived, where the system is weakly pumped with resonant laser light taking into account the excitonic interactions. Expressions of the autocorrelation function are obtained for two coupling regimes, the weak and the strong ones. In the good-cavity limit the autocorrelation function presents a photon antibunching behavior. In the bad-cavity limit, two possible photon statistics can be manifested depending on the value of the exciton cooperativity and the ratio of the cavity and excitonic dissipation rates. We discuss photon statistical similarities with an atomic cavity.

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ELECTRONIC AND ENTANGLEMENT DYNAMICS IN BENZENOID RINGS COAXIALLY COUPLED

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We study a molecular wire that constituted of two benzenoid rings coaxially coupled, for which we consider one unique electronic localized state per ring and a torsional mode that corresponds to the relative angle between the benzenoid rings. We suppose that the direct tunneling between the two electronic states, produced by the orbital overlapping is very small and can be neglected. Considering the interaction between electrons and the torsional mode and supposing small oscillations, we solve the hamiltonian that describes the system, which has exact solution. We also solve the problem of eigenvalues and eigenvectors and calculate the evolution electronic dynamic when we have just one electron. Additionally we show how our system under certain conditions produces phonon Schrodinger cat states. Finally we study the entanglement dynamic between electrons and the phononic mode, using the concurrence to quantify the quantum correlations.

CHARACTERIZATION OF THE QUALITY OF QUANTUM MEMORIES: STATISTICAL PERSPECTIVE THROUGH ENTANGLEMENT SUDDEN DEATH

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We examine an open 2 x 2 system in which each qubit interacts with its environment. No qubit-qubit interaction is considered. As example of baths, which are considered to be identical, we present a zero-temperature RWA bath and the depolarizing channel. When concurrence is calculated from any pure initial state for both of the noises we show the appearance of the phenomenon of entanglement sudden death (ESD). We define the probability distribution function for the separation time, which turns out to be bimodal with a finite time peak and an infinite time delta contribution in the zero-temperature bath case, and unimodal in the case of the depolarizing channel.

On the Classical Limit for Driven Coupled Oscillators

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The exact determination of the quantum-classical border is elusive because it depends on details like the value of Planck's constant, the quantum state of the system under consideration and the criterion employed to define classicality. Several different classical limits are found when Planck's constant is taken to zero, when the state of the system is characterized by large quantum numbers or when the system suffers decoherence. We investigate the quantum-classical border in the following context. We assume a harmonic oscillator coupled to a second, driven and damped harmonic oscillator. If the damping vanishes both oscillators will establish classical and/or quantum correlations. If, in addition the state of the second oscillator corresponds to a large number of excitations we would be in a "classical" scenario. On the other hand damping usually entails decoherence and another "classical" scenario. By examination of the dynamics of the first oscillator we find several combinations of parameters in which the second oscillator can be considered as behaving classically, and find departure with respect to the naive expected limits.

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Entanglement in Spatially Inhomogeneous Many-Fermion Systems

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We investigate entanglement of strongly interacting fermions in spatially inhomogeneous environments. To quantify entanglement in the presence of spatial inhomogeneity, we propose a local-density approximation (LDA) to the entanglement entropy, and a nested LDA scheme to evaluate the entanglement entropy on inhomogeneous density profiles. These ideas are applied to models of electrons in superlattice structures with different modulation patterns, electrons in a metallic wire in the presence of impurities, and phase-separated states in harmonically confined many-fermion systems, such as electrons in quantum dots and atoms in optical traps. We find that the entanglement entropy of inhomogeneous systems is strikingly different from that of homogeneous systems.

Bell test for the motional state of free massive particles

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We present a scheme for establishing non-classical correlations in the *motional* state of two macroscopically separated massive particles. Feshbach-induced dissociation of a diatomic molecule can generate a motional state of two counter-propagating atoms that is capable of violating a Bell inequality without resiling to entanglement in the state of some internal property, such as spin. The influence of dispersion is investigated and shown to be important, but under control. We propose an experimental setup that seems to be within the reach of present-day technology and capable of generating the non-classical correlations. It premises a BEC of Feshbach molecules as pool for a reproducable initial state that meets the required control as imposed by dispersion. A sequence of two dissociation pulses then generates an entangled motional state of two counter-propagating atoms that formally can be compared to a spin Bell state (Dissociation-time entanglement). An interferometric device providing the spin measurement analogue completes the Bell test. To this end, only single-particle interferometry is required.

Two photon source with a single ion in an optical cavity

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Abstract:

In this work we investigate the possibility of a controlled and efficient generation of two photons using single trapped ion strongly coupled to a two bimodal cavity. Physical properties of generated two photon wave packed are discussed from a possible experimental realization point of view.

Robust storage of exciton qubits in quantum dots through ultrafast multipulse control

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A major limitation in all physical implementations of quantum computing schemes is the rate at which information is lost. This is particularly crucial for solid state-based implementations, when charge degrees of freedom, such as excitons, are involved. There are two typical times which need to be considered, T1 the qubit lifetime i.e. the recombination time of an exciton qubit, and T2 the time taken for dephasing to occur due to the interaction between the qubit and the environment. Pure dephasing does not change the occupation numbers of the logical states, but modifies the relative phases in a superposition state and leads to the loss of entanglement between qubits, which is vital for quantum computation. Pure dephasing due to phonon is maybe the most serious problem when considering excitonic qubits or ancillary states.

To overcome this problem, we adapted the scheme developed in Ref[1] to an exciton qubit confined in a quantum dot. This allows for dynamical suppression of dephasing through a sequence of control pulses. The shape of the quantum dot is found to have a large effect on excitonic dephasing. It is shown that quantum dots with parameters optimized for implementing quantum computation are the most susceptible to dephasing, but at the same time dynamical suppression of dephasing through a simple series of equally spaced bit flips is most efficient for exactly that shape of dot. In addition, while the presence of an electric field (necessary for implementing some quantum computing schemes) increases natural excitonic dephasing, it also increases the efficiency of our decoupling technique. Our calculations show that dephasing can be significantly suppressed in GaAs/AlAs quantum dots suitable for quantum information processing, making our decoupling technique an ideal scheme to improve short term storage e.g. while performing quantum algorithms.

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Density Matrix Renormalization Group study of rapidly-rotating two-dimensional bosons

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Abstract:

We study a system of two-dimensional bosons with contact interactions in a rapidly-rotating anisotropic trap. The ground state phase diagram and the excitation spectra are investigated using the Density Matrix Renormalization group (DMRG) and the exact diagonalization methods.

Diagrammatic Technique for Frequency-dependent Full Counting Statistics

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Full Counting Statistics has emerged as a powerful tool to characterize correlations in quantum conductors. The theory, based on scattering matrix[1,2] or density matrix approaches[3], has been generally applied to calculate high-order cumulants of the current distribution at zero frequencies. Within the last scheme, and using Nakajima-Zwanzig projection techniques[4], we present a method to calculate N-time correlators, such that the stationary solution is the only input needed. It follows from the theory a physically-interpretable diagrammatic technique, that we have used to obtain the frequency-dependent third order cumulant (skewness) in various models.

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Quantum optics with quantum gases in optical lattices

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We consider a combined problem of ultracold gases in optical lattices and cavity QED, where the quantum nature of both light and matter plays a key role. Various quantum phases of atoms are shown to exhibit radically different collective light scattering. This allows to study quantum degenerate gases beyond the mean-field approximation by observing light. In contrast to standard destructive methods based on matter-wave interference, this method provides quantum nondemolition (QND) schemes for measuring different atomic variables. Moreover, using quantum properties of light, one can manipulate atomic states creating the states with some specific atom-atom and atom-light correlations.

We demonstrate a possibility to directly map the atom-number distribution function on the transmission spectrum of a high-Q cavity. This becomes possible due to the state-dependent dispersion of ultracold atoms. For example, the quantum phase transition from the superfluid to Mott insulator state is manifested by the narrowing of the multicomponent spectrum and its degeneration to a single cavity resonance, which reflects the suppression of atom-number fluctuations.

Even without high-Q cavities, some information about quantum atom statistics is accessible by angle-resolved measurements of scattered light. Simple intensity measurements provide information about local and global atom fluctuations and pair correlations even without a single-site optical access. Light statistics carries information about the higher-order atom-number moments.

The physics of different light scattering consists in the entanglement between light and many-body atomic state, which arises during the interaction. Depending on the geometry of the problem, the light detection projects the atomic wave-function to different quantum states. Thanks to this measurement back-action, one can obtain atomic quantum states with particular properties, e.g., squeezing of the atom number at some lattice region, squeezing of the difference between atom numbers at odd and even sites, Schrödinger cat states, etc.

Different light scattering from atoms trapped in an optical cavity may significantly modify many-body dynamics of ultracold atoms in optical lattices.

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Efficient characterization of mesoscopic quantum systems using the Rydberg blockade mechanism

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Abstract:
The experimental effort for the detection and characterization of quantum states of many-body quantum systems increases exponentially with the number of particles. It is therefore highly desirable to develop tools to quantitatively compare quantum states and phases, without the need to perform a complete state tomography of the quantum system of interest. One possible approach is to map the relevant global properties of a large quantum system onto a single degree of freedom, which can be accessed and characterized efficiently. Along these lines we propose to use strong dipolar interactions between Rydberg atoms in order to entangle a small ensemble of cold atoms with one "master atom" on a fast time-scale and with high fidelity. This setup can be regarded as a "mesoscopic quantum gate" for cold atoms and provides a tool to create a coherent superposition of few-body quantum states of a mesoscopic ensemble of atoms. Global information about the difference between the quantum states of the ensemble atoms undergoing distinct temporal evolutions can be gained by only measuring the state of the master atom, without the requirement of a complete quantum state tomography of the atomic ensemble. We will present a physical implementation of the scheme and discuss achievable fidelities, possible errors and limitations under realistic conditions.

Towards ultracold fermions in optical micro-potentials

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We present an experimental setup which allows us to study an ultracold fermionic quantum gas in an optical potential that can be arbitrarily controlled down to the smallest relevant length scale, i.e. that of the atomic wavefunction. The basic idea is to prepare an ultracold gas of fermionic lithium in a region of high optical access by using standard laser cooling and trapping techniques, followed by a transport and direct evaporation in an optical dipole trap. In the final position, inside a glass cell with high optical access, the gas will be sandwiched between two microscopes. One of these will focus the optical potential pattern shaped and controlled by spatial light modulators down to the length scale of about one micrometer. The other microscope objective will be used for high resolution imaging. The interaction strength of colliding atoms can be tuned by accessing a Feshbach resonance. This setup will allow us to study Josephson oscillations in the BEC-BCS crossover regime and to manipulate strongly correlated atomic samples on a local scale. First results on the cooling and trapping will be shown.

Selective parameter estimation for quantum channels

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We present a new method for quantum process tomography enabling the efficient estimation, with fixed precision, of any of the parameters characterizing a quantum channel. Here, the introduction of randomness allows avoiding the exponential overhead associated to full tomography when estimating a small set of parameters. The estimation strategy depends upon the set of χ-matrix elements one selects to estimate. Furthermore, we describe a way to efficiently gather all the information required to estimate any average survival probability of the channel (i.e. to measure any diagonal element of its χ-matrix). This information is collected in a way that large coefficients can be efficiently identified.

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Quantum parallelism as a tool for ensemble spin dynamics calculations

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Efficient calculations of quantum evolution of spin-1/2 systems are relevant for ensemble quantum computation as well as in typical NMR experiments. The usual evaluation of density matrices quickly reaches the storage limit as the number of spins increases. Alternatively, the use of a wave function representation overcomes this limitation at the expense of long computational time. This is because it requires averages over a number of realizations proportional to the Hilbert space dimension. We propose a method that reproduces the dynamics of a local observable using only one entangled pure initial state. This is built as the superposition, with random phases, of the pure elements that compose the mixture. This drastically reduces the calculation time. The power of this tool is shown for systems in two extreme interaction topologies: a spin star (cluster with random long range interactions) and a spin ladder.

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Perfect mirror transport in arbitrary dimension

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(Dated: April 6, 2008)

A fundamental issue in quantum information theory and the eventual development of a quantum computer is to transfer a quantum state through a reliable method. In general one would wish to have a method in which an input state on one particular site is then transfered to an output site with high fidelity. In general the need of local addressability of qubits is to be avoided, as it will increase the probability of errors, and implies higher experimental/technological challenges.

Spin chains [1, 2], have been introduced to perform quantum state transfer with the advantage of avoiding the local adressability of qubits. However, except for very particular examples where one pre-engineers the coupling strengths [3, 4], most spin chain transport protocols require significant resources to achieve near perfect transport fidelity [5]. More recently, a cellular automata-like scheme for perfect mirror transport was introduced [6], as an alternative. This method essentially spatially inverts a quantum state distributed along a chain via the application of homogenous single qubit pulses and Ising-like nearest neighbor interactions.

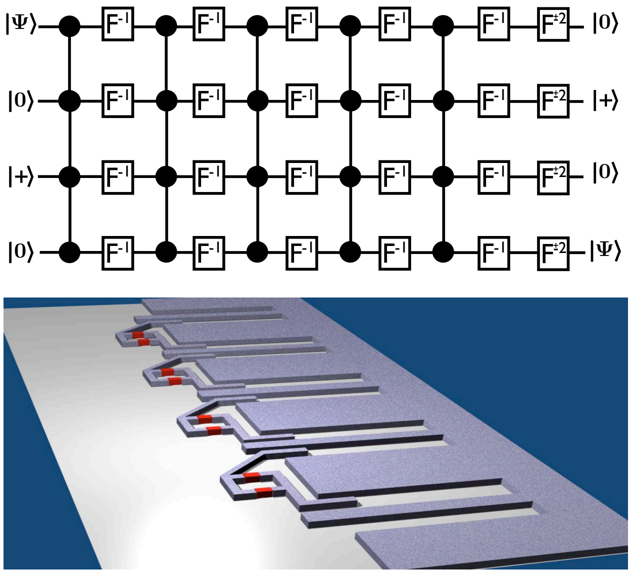

FIG. 1: (i) Perfect mirror inversion circuit for d-dimensions. In building it we use the particular input states shown above, however we prove that the circuit works independently of the input states. It is a combination of generalized Hadamard gates and generalized control-phase gates. (ii) Experimental design for continuous variables realization.

We describe a quantum cellular automata type protocol capable of spatially mirroring a quantum state. Our protocol operates on a nearest neighbor coupled 1D chain of qudits (d-level systems) or qunats (continuous variables), and requires only global pulses to be applied on the chain, and manipulation of the boundaries of the chain. It is thus a generalization of the scheme introduced in [6].

We show that the circuit depicted in Fig.1(i) is a quantum state perfect spatial mirror, which takes a qudit or qunat, N-qubit quantum state $\rho_{1,\ldots,N}$, to its mirrored version $\rho_{N,\ldots,1}$. Here we use the *Fourier gate* F, the generalization of the Hadamard gate, and the control phase gate for the qudit [7], and qunat [8], cases.

In terms of applications, in [6] it was shown that an Ising-type Hamiltonian, combined with manipulation on the boundaries of the chain, is enough to realize the mirror circuit and, even more, to perform universal computation. We focus on the continuous variable case and show that it can be implemented in circuit-QED [9]. The quantum state of $N-$CV modes is held in a chain of superconducting coplanar waveguides (CPWs) with nearest neighboring CPWs coupled by Cooper Pair Boxes (CPB). The coupling of CPWs via CPB is biased via the difference in voltages of the two CV modes held in neighboring quarter-wave CPW resonators, and the CPB operates at the charge degeneracy point. We show a procedure that can spatially mirror a quantum state of $N-$CV modes via the alternating global application of a QND gate $\exp(i\sum_j X_j \otimes X_{j+1})$, and a global Fourier gate $\mathcal{F} \sim \prod_j \exp(i\pi(x_j^2 + p_j^2)/4)$.

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2D MULTIPARTITE VALENCE BOND STATES IN QUANTUM ANTIFERROMAGNETS

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A quantum anti-ferromagnet spin-1 model is characterized on a 2D lattice with the following requirements:

i) The Hamiltonian is made out of nearest neighbor interactions.
ii) It is homogeneous, translational and rotational invariant.
iii) The ground state is a real singlet of SU(2) (non-chiral).
iv) It has a local spin-1 representation.

Along the way to characterize the system, connections with classical statistical mechanics and integrable models are explored. Finally, the relevance of the model in the physics of low dimensional anti-ferromagnetic Mott-Hubbard insulators is discussed.

[1] arXiv:0710.2349

Unambiguous preparation of non-orthogonal quantum states

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We report the experimental implementation of a protocol to unambiguously modify the inner product between two non-orthogonal polarization states, we have used two-photon states generated by spontaneous parametric down conversion (SPDC), which are selected in factorized polarization states.

One photon of the pair is used as a trigger, the other one is used for codifying two polarized initial states $|\psi_{\pm}\rangle = \cos(\alpha/2)|H\rangle \pm \sin(\alpha/2)|V\rangle$ whose inner product is conclusively modified. In the experiment, light in the two-photon state is generated by non collinear SPDC process. A 5-mm-thick BBO (β-Barium Borate) crystal, cut for type-II phase matching, is pumped by an ion-argon laser operating in a single frequency mode at $\lambda = 351{,}1$ nm, with a power of 200 mW. Signal (s) and idler (i) beams with the same wavelength around 702,2 nm are selected by inserting 10,0 nm bandwidth gaussian interference filters centered at this wavelength, which are in front of the detectors. The experimental setup is depicted in Figure 1(a).

(a) (b)

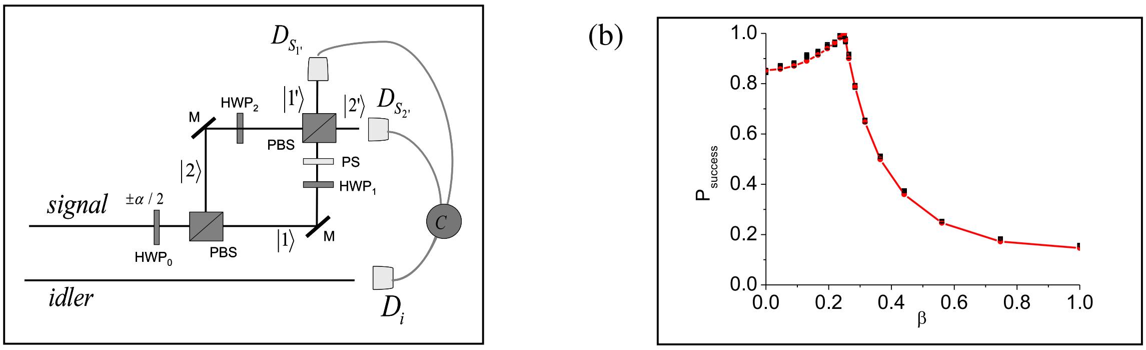

Fig. 1: (a) The experimental setup. (b) Success probability as a function of the output angle β, the initially angle $\alpha = \pi/4$.

The operation is probabilistically performed such that the respective output states become $|\phi_{\pm}\rangle = \cos(\beta/2)|H\rangle \pm \sin(\beta/2)|V\rangle$. We chose a fixed value for the angle $\alpha = \pi/4$ of the input states and measure the success probability of generating output states with their inner product equal to cosβ. Fig. 1(b) shows the success probability as a function of β. Solid line corresponds to the theoretical prediction and boxes correspond to the experimental results.

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Quantum discrimination of N states lying in a ($N+1$)-dimensional Hilbert space

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We study the unambiguous discrimination of *3* non-orthogonal quantum states finding the optimal probability of success for certain interesting cases. We extend this study to the case of discriminating among N non-orthogonal states, specifically when a ($N+1$)-dimensional Hilbert space is required to recognize unambiguously one of them.

First of all we consider the case of three LI states, $|\alpha_i\rangle$, which are prepared with probability p_i ($i=1,2,3$). We also assume that states are lying in a *4*-dimensional Hilbert space. In this case the probability of recognizing the prepared states is

$$P_s = 1 - p_1 \frac{\langle\alpha_2|\alpha_1\rangle\langle\alpha_1|\alpha_3\rangle}{\langle\alpha_2|\alpha_3\rangle} - p_2 \frac{\langle\alpha_1|\alpha_2\rangle\langle\alpha_2|\alpha_3\rangle}{\langle\alpha_1|\alpha_3\rangle} - p_3 \frac{\langle\alpha_1|\alpha_3\rangle\langle\alpha_3|\alpha_2\rangle}{\langle\alpha_1|\alpha_2\rangle},$$

being valid for families of states which satisfy $0 \le \langle\alpha_j|\alpha_i\rangle\langle\alpha_i|\alpha_k\rangle / \langle\alpha_j|\alpha_k\rangle \le 1$ and real. We can ask: given two fixed inner product, say $\langle\alpha_1|\alpha_2\rangle$ and $\langle\alpha_1|\alpha_3\rangle$, what is the module inner product $\langle\alpha_2|\alpha_3\rangle$ which optimize the P_s probability?. That module inner product is given by

$$|\langle\alpha_2|\alpha_3\rangle| = \sqrt{p_1}|\langle\alpha_2|\alpha_1\rangle\langle\alpha_1|\alpha_3\rangle| / \sqrt{p_2|\langle\alpha_1|\alpha_2\rangle|^2 + p_3|\langle\alpha_1|\alpha_3\rangle|^2},$$

and the optimal probability becomes

$$P_{s,\max} = 1 - 2\sqrt{p_1(p_2|\langle\alpha_1|\alpha_2\rangle|^2 + p_3|\langle\alpha_1|\alpha_3\rangle|^2)}.$$

We get the Peres' formula [1] for $p_2=0$ or $p_3=0$.

We can generalized the above result for the case of N states $|\alpha_i\rangle$, each one with *a priori* probability p_i ($i=1,2,3,\ldots,N$), lying in a ($N+1$)-dimensional Hilbert space. In this case the probability is given by

$$P_s = 1 - \sum_{k=1}^{N} p_k \frac{\langle\alpha_{k-1}|\alpha_k\rangle\langle\alpha_k|\alpha_{k+1}\rangle}{\langle\alpha_{k-1}|\alpha_{k+1}\rangle},$$

understanding in the sum that $\alpha_0 \equiv \alpha_N$ and $\alpha_{N+1} \equiv \alpha_1$. This is applicable for states which satisfy the constrains $0 \le \langle\alpha_j|\alpha_i\rangle\langle\alpha_i|\alpha_k\rangle / \langle\alpha_j|\alpha_k\rangle \le 1$ and real. Same particular cases can be studied from here.

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State-Independent Optimization of a Josephson Charge Qubit

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Within the circuit model of quantum computing, the fundamental building block of a quantum computer is the qubit. As a physical realization of the qubit, we consider a superconducting Josephson charge qubit which can be controlled by an external gate voltage (V_G) and an external flux (Φ).[1]

Physical systems used to realize quantum bits are always coupled to an environment with, in general, many degrees of freedom. Such interactions result in a loss of unitary time evolution and coherence which is undesirable for quantum computing. Hence, we face the problem of minimizing the unwanted effects of such an environment on quantum gate operations. Therefore, the goal is to accomplish unitary transformations on the computational subspace as effectively as possible, irrespective of the input.[2] We try to suppress decoherence effects by proper tuning of the controls. This issue has been discussed recently, in particular, how to optimize quantum gates which are prone to decoherence.[3]

The qubit we consider is subjected to noise and leakage into non-computational states. In Josephson charge qubits the dominant dephasing mechanism is a result of 1/f noise. It is believed that background charge fluctuations are the source of this noise.[4] We assume that the effect of these fluctuations may be mapped onto a bath of harmonic oscillators which couples linearly to the qubit, *i.e.*, by a spin-boson model.

A time–optimal global optimization scheme for open quantum systems is presented. We formulate a cost functional which can be approximated by standard quantum master equation approaches in order to give a measure of robustness with respect to environmental noise and leakage. Using the theoretical principles of process tomography (see e.g. Ref. [5]), we are able to formulate such a measure. By minimizing this functional, optimal control fields which maximize the fidelity of the quantum gate may be identified. The minimization procedure is performed by a differential evolution algorithm. For the Hadamard gate we find typical gate fidelities of $F > 4 - 10^{-3}$ ($F_{\max} = 4$) and optimal gate times of ~30ps.

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Multifloquet to single channel transition in the DC response of disordered rings driven by time dependent fields

Federico Foieri , Liliana Arrachea and **María José Sánchez**

Abstract:

We investigate the dc response of a 1D disordered ring coupled to a reservoir and driven by a magnetic flux with a linear dependence on time. We identify two regimes: (i) A localized or large length **L** regime, characterized by a dc conductance whose full probability distribution is identical to the one exhibited by a 1D wire of the same length and disorder strength placed in a two terminal Landauer setup. (ii) A ``multifloquet" regime for small **L** and weak coupling to the
reservoir, which exhibits large currents and dc conductances **g_{dc}> 1** (in units of the conductance quantum), in spite of the fact that the ring contains spinless electrons and a single electronic transmission channel. The crossover length between the multifloquet to the single channel transport regime is controlled by the coupling to the reservoir.

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Dispersive optomechanics with linear and quadratic coupling

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We describe an optomechanical device in which a high finesse cavity is detuned by the motion of a micromechanical membrane placed between the cavity mirrors. This "membrane in the middle" geometry makes it possible to combine high finesse cavities with high-quality micromechanical devices. In our device the cavity finesse F = 18,000 and the mechanical quality factor Q = 1,000,000. By detuning the laser from the cavity resonance we have cooled the membrane's fundamental mode from 300 K to below 7 mK. Calculations show that the same system, cryogenically precooled to 300 mK, should optically cool to well below 7 uK and achieve the membrane's quantum-mechanical ground state. Not only does the membrane's Q increase by a factor of 10 at cryogenic temperatures, but we have also recently increased the finesse of our cavity to as high as 150,000. Other goals for this system include observing the radiation pressure shot noise, and using the quadratic relation between the cavity detuning and the membrane position to perform a QND measurment of the oscillator's phonon number.

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Title: An exponential speedup quantum searching algorithm depending on the methodology of Grover algorithm

*Authors: Elhussien Hassan Sirelkhatim *, Kasim M. Al-hity†*

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†- Laser Institute of Sudan University of Science and Technology (SUST)

Content of Abstract:

General consideration of Grover algorithm is made. Then new algorithm has exponential speedup over it is classical analogue is presented, and the needed number of iteration in this algorithm is proved to be $\ln\left(\frac{\pi}{2}\Box\vartheta\right)\Box\ln 3$

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Two-body transients in coupled atomic-molecular Bose-Einstein Condensates

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The conversion of atom pairs into molecules, using either Feshbach resonances or photoassociation can serve as a tool to probe the many-body properties of ultracold gases. In particular, photoassociation, the process of associating atoms with a resonant laser light, was recently used to observe pair correlation in a 1D Bose gas and in the BEC-BCS crossover. Conversely, it can be used to reach new collective regimes. Theories have suggested the coherent conversion of an atomic Bose-Einstein condensate into a condensate of molecules, the possibility of macroscopic superposition, and production of correlated atom pairs (or rogue dissociation) at high laser intensity. Several experiments have made the first steps in these directions.

We discuss the dynamics of an atomic Bose-Einstein condensate when pairs of atoms are converted into molecules by photoassociation. Three regimes are found and it is shown that they can be understood on the basis of time-dependent two-body theory. In particular, the rogue dissociation regime, which has a density-dependent limit on the photoassociation rate, is identified with a transient in the two-atom dynamics exhibiting universal properties. We illustrate how these regimes can be explored by photoassociating condensates of alkaline-earth atoms.

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One-Dimensional Bose Gases with N-Body Interactions

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We study the ground state properties of a one-dimensional Bose gas with N-body attractive contact interactions. By using the explicit form of the bright soliton solution of a generalized nonlinear Schroedinger equation, we compute the chemical potential and the ground state energy. For N=3, a localized soliton wave-function exists only for a critical value of the interaction strength: in this case the ground state has an infinite degeneracy that can be parameterized by the chemical potential. The stabilization of the bright soliton solution by an external harmonic trap and the comparison with higher dimensions are discussed. Preliminar results on the effects of N-body repulsive interactions are also presented, as well as a discussion of the relevance of the obtained results for the implementation of topological quantum computation schemes.

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The dynamics of developing Cooper pairing at finite temperatures

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We study the time evolution of a system of fermions with pairing interactions at a finite temperature. The dynamics is triggered by an abrupt increase of the BCS coupling constant. We show that if initially the fermions are in a normal phase, the amplitude of the BCS order parameter averaged over the Boltzman distribution of initial states exhibits damped oscillations with a relatively short decay time. The latter is determined by the temperature, the single-particle level spacing, and the ground state value of the BCS gap for the new coupling. In contrast, the decay is essentially absent when the system was in a superfluid phase before the coupling increase.

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Macroscopic tunneling, decoherence and noise-induced activation

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Herein, we describe the evolution of a Brownian quantum system coupled to a general ohmic environment, at strictly zero temperature, in terms of two main environmental induced physical phenomena: decoherence and energy-activation. We show that the latter is a post-decoherence phenomenon. In the end, we describe the evolution of a quantum particle coupled to a double well potential in terms of three main physical phenomena, namely decoherence, quantum tunneling and noise-induced activation We show that the decoherence inhibits tunneling, even though in the end, the particle may be found in the other minima of the potential well.