Frontiers of Quantum and Mesoscopic Thermodynamics

28 July - 2 August 2008, Prague, Czech Republic

Satellite of the 22nd General Conference
of the EPS Condensed Matter Division
25 - 29 August 2008, Roma

Under the auspicies of

Prof. RNDr. Václav Pačes, DrSc.
President of the Academy of Sciences of the Czech Republic

Prof. RNDr. Václav Hampl, DrSc.
Rector of the Charles University

Supported by

- Condensed Matter Division of the European Physical Society
- Committee on Education, Science, Culture, Human Rights and Petitions of the Senate of the Parliament of the Czech Republic
- Institute of Physics, v. v. i., Academy of Sciences of the Czech Republic
- Faculty of Mathematics and Physics, Charles University
- Center for Theoretical Study, Charles University and the Academy of Sciences of the Czech Republic
- Institute for Theoretical Physics, University of Amsterdam

Topics

- Quantum, mesoscopic and classical thermodynamics
- Foundations of quantum physics
- Physics of quantum measurement
- Quantum optics
- Quantum dissipation, decoherence and noise
- Physics of quantum computing and quantum information
- Non-equilibrium quantum statistical physics
- Macroscopic quantum behavior
- Mesoscopic and nanomechanical systems
- Spin systems and their dynamics
- Brownian motion, molecular motors, ratchet systems, rectified motion
- Physics of biological systems
- Relevant experiments from the nano- to the macro-scale

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Preface

Recent progress in nanoscale technologies enables the preparation of well defined artificial structures composed of atoms (molecules) in the number range of between several and hundreds and to measure many characteristics of such systems of nanoscale sizes. At the same time, advances of measurement techniques open the possibility to investigate not only these artificial structures, but also structures of similar nanoscale size occurring in nature, as for example complex molecules, molecular motors in living cells, prions and viruses.

There is thus a growing demand for an understanding of the laws which govern the behavior of these systems. To find these laws is an challenging task, due to the complexity of these systems, their diversity, and the fact that these systems are on the borderline between different disciplines (i.e. physics, chemistry and biology) where the diverse dynamic behavior of these systems and corresponding various methods of their description (individual and statistical, microscopic and macroscopic, classical and quantum) meet.

In general, the conference will address quantum physics and non-equilibrium quantum statistical physics. The systems considered will be mainly of nanoscale size. The main task of the conference is to contribute to the uncovering of possible phenomenological ("quantum thermodynamical") laws governing the behavior of nanoscale systems, providing a better understanding and insight into the problems and interpretations of quantum physics based upon the methods of condensed matter physics and quantum optics.

FQMT'08 is a follow-up to the previous, successful Prague conference "Frontiers of Quantum and Mesoscopic Thermodynamics 2004" (FQMT'04). As in FQMT'04, the aim of FQMT'08 is to create a bridge between the fields of modern condensed matter physics, quantum optics and statistical physics and the quickly developing field of foundations of quantum physics, as have been covered by a number of recent conferences and workshops (Hot topics in Quantum Statistical Physics: q-thermodynamics, q-decoherence and q-motors, Leiden 2003; Non-equilibrium Green's Functions I-III conferences, Rostock 1999, Dresden 2002, Kiel 2005; Conferences on the Second Law of Thermodynamics and Quantum Physics, San Diego 2002, 2006; Beyond the Quantum, Leiden 2006; and Vaxjo meetings on Quantum Theory: Reconsideration of Foundations, Vaxjo 2001, 2003, 2005, 2007), which the organizers of the present meeting took an essential part in.

The conference is intended to bring together a unique combination of scientists across a disciplinary spectrum ranging from foundations of quantum physics to emerging statistical physics approaches to the study of non-equilibrium quantum systems (i.e., those who are studying various mesoscopic systems, either of artificial or biological origin, both from the theoretical and experimental point of view). The interdisciplinary character of the conference is supported by choice of key speakers who, apart from their specializations, are not only able to report specific results within their fields, but are also able to discuss the state of the art of their fields from the standpoint of broader perspective of overlap with other fields. It is intended that this arrangement of the scientific program of the conference will significantly contribute to the formulation of challenging questions and problems, as well as their related answers that are nowadays essential to improve the understanding of the foundations of quantum physics and the physics of nanoscale systems, and further will motivate new collaboration and intensive discussions between experts from different fields.

The organizers tried to this end to create a program which covers all topics of the conference. They realized it could be extremely helpful to reach ”equilibrium” between theoretically and experimentally orientated talks to stimulate the discussion between the experimentalists and the theorists as much as possible.

The conference will run from Monday morning, July 28, till Saturday noon, August 2 in the hotel Pyramida. Every morning or afternoon session will be devoted to a specific topic.

Dear colleague, we welcome you to the FQMT’08 conference and we hope you will enjoy your stay in Prague.

On behalf of the organizers

Václav Špička, Peter D. Keefe, and Theo M. Nieuwenhuizen

Contents

Abstracts are sorted according to the family names of the presenting author.

Important information

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Emergency phone numbers (free calls):

Police: 158
Ambulance: 155
Fire Department: 150
Unified Emergency Call: 112

Conference Sites

The FQMT'08 conference will take place at the following site:

Pyramida hotel
address: Bělohorská 24, Praha 6, phone: (+420) 233 102 111

Conference welcome party will take place at:
Wallenstein Palace Garden
address: Valdštejnské náměstí 4, Praha 1

One of the public lectures and classical concert will take place at:
St. Simon and Juda church
address: Dušní ulice, Praha 1 - Staré Město

The FQMT'08 conference dinner will take place at:
Břevnov monastery
address: Markétská ulice 28/1, Praha 6 - Břevnov

Entrance to and stay inside the Wallenstein Palace

There are some limitations related to the Wallenstein Palace due to the two facts:
1. the Wallenstein Palace is the seat of the Senate of the Czech Republic
2. the Wallenstein Palace is a historical building.

Please, read carefully the following text to know about these limitations:

The entrance to the Wallenstein Palace: it is a little more complicated because of the security reasons (the Palace is the seat of the Senate of the Czech Republic) - all participants need to pass the metal detection frame and their things have to be screened by x-rays similarly as at airports.
So, participants are kindly asked to come to the Wallenstein Palace not at the last moment just before the beginning of guided tours.

When entering and moving inside the Wallenstein Palace, all participants are requested to have with them their badges which they will receive during the registration; badges will also serve as the identity card for the security guards in the Wallenstein palace.

Rooms and facilities available for the participants

Hotel Pyramida

- Pyramida Congress Hall (ground floor): all lectures will be presented there.
- Lobby of Pyramida Congress Hall (ground floor): it will serve as a coffee room; tea and coffee will be available there all time.
- Lounge 1 (first floor): it will serve as a discussion room.
- Lounge 2 (first floor): it will serve as a study room (e.g. to prepare lectures); two computers with internet connection will be available there.

Posters

Poster session will be held on Tuesday (July 29). Posters can be fixed from 10:00 on Tuesday on the first floor (corridors) of the Pyramida Hotel and can be exhibited till Wednesday 14:00.

Social Events

- Tour of the Wallenstein Palace: Wallenstein Palace, Monday July 28.
- Welcome party: Wallenstein Palace Garden, Monday July 28.
- First evening lecture: St. Simon and Juda Church, Wednesday July 28.
  This evening lecture will be given by Marlan O. Scully.
- Classical music concert: St. Simon and Juda Church, Wednesday July 28.
- Second evening lecture: Cinema Hall of the Pyramida Hotel, Thursday July 29.
  This evening lecture will be given by Georgy V. Shlyapnikov.
- Jazz concert: Cinema Hall of the Pyramida Hotel, Thursday July 29.
- Conference dinner: Břevnov Monastery, Friday August 1.

Exact times of the events can be found in the conference program.

Food

Lunches:

All participants can either

- buy, during their registration on Sunday or Monday, tickets for lunches in the restaurant just in the Pyramida hotel;
  the price of one lunch will be 15 Eur (or 370 CZK)

  or

- go for lunch to restaurants which are situated in the vicinity of the Pyramida Hotel.

Dinners:

- **Monday:** Welcome party in the **Wallenstein Palace Garden**.
- **Tuesday:** Buffet during the poster session in the **Pyramida Hotel**, free evening during which participants can go for the dinner to various restaurants in the vicinity of the Hotel or in the center of Prague.
- **Wednesday:** Refreshment before the public lecture of Marlan Scully will be served in the **Kozička Bar** in the Old Town, not far from the St. Simon and Juda Church (address Praha 1, Kozí 1 - see map St. Simon and Juda Church neighborhood). It is also possible to go for dinner to numerous restaurants in the Old Town area.
- **Thursday:** There will be enough time to go for dinner before the public lecture of Georgy Shlyapnikov, either in the **Pyramida Hotel** or to various restaurants in the vicinity of the Pyramida Hotel. Small refreshment will be served before the lecture.
- **Friday:** Conference dinner in the restaurant of the **Břevnov Monastery**.
  Price: 50 Eur per person - tickets for this dinner will be available during the registration.

PROGRAM

Monday, 28 July 2008

07:00 – 13:00	Registration	
08:00 – 08:30	**Opening addresses** *Location: Pyramida Hotel Lecture Hall*	
08:30 – 10:00	**1 session: Quantum and mesoscopic thermodynamics** *Location: Pyramida Hotel Lecture Hall*	
08:30 – 09:00	Guenter Mahler:	*Quantum thermodynamic processes*
09:00 – 09:30	Udo Seifert:	*Stochastic thermodynamics: Theory and experiments*
09:30 – 10:00	Reinhard Lipowsky:	*Multiscale motility of molecular motors*
10:00 – 10:20	Coffee break	
10:20 – 12:00	**2 session: Quantum and mesoscopic thermodynamics** *Location: Pyramida Hotel Lecture Hall*	
10:20 – 10:50	Gershon Kurizki:	*Control of non-Markovian quantum thermodynamics*
10:50 – 11:20	Martin Plenio:	*Entanglement theory, thermodynamics and the 2nd law*
11:20 – 11:40	Gert-Ludwig Ingold:	*Quantum Brownian motion and the third law of thermodynamics*
11:40 – 12:00	Peter Talkner:	*Quantum fluctuation theorems*
12:00 – 13:00	Lunch	

13:00	–	14:40	**3 session: Foundations of quantum mechanics**	
			Location: Pyramida Hotel Lecture Hall	
13:00	–	13:30	Andrei Khrennikov:	*QM as approximative probabilistic model*
13:30	–	14:00	Ana Maria Cetto:	*Quantization as an emergent property of a matter-field system in permanent interaction*
14:00	–	14:20	Hans De Raedt:	*Even-by-event simulation of quantum phenomena*
14:20	–	14:40	Yuval Gefen:	*Weak values in solid state*
14:40	–	15:00	Coffee break	
15:00	–	16:40	**4 session: Quantum dissipation, decoherence and noise**	
			Location: Pyramida Hotel Lecture Hall	
15:00	–	15:30	Ulrich Weiss:	*Decoherence and relaxation of coupled qubits*
15:30	–	16:00	Amir O. Caldeira:	*Dissipative dynamics of a two-level system resonantly coupled to a harmonic mode.*
16:00	–	16:20	Sigmund Kohler:	*Dissipative Landau-Zener tunneling in circuit QED and nanomagnets*
16:20	–	16:40	Thomas Vojta:	*Effects of dissipation on quantum critical points with disorder*
16:40	–	18:00	Free time and transfer to Wallenstein Palace	
18:00	–	19:30	Guided tour through the Wallenstein Palace	
			Location: Wallenstein Palace	
19:30	–	23:00	Welcome party in the Wallenstein Palace Garden	

Tuesday, 29 July 2008

08:00	–	10:00	**1 session: Mesoscopic and nano-electromechanical systems**	
			Location: Pyramida Hotel Lecture Hall	
08:00	–	08:30	Hermann Grabert:	*Decay of metastable states driven by non-Gaussian noise*

08:30	–	09:00	Yoseph Imry:	*Effect of pair-breaking on mesoscopic persistent currents far above the superconducting Tc.*
09:00	–	09:20	Yuri Galperin:	*Decoherence in quantum devices due to low-frequency noise of environment: Role of non-Gaussian effects*
09:20	–	09:40	Irena Knezevic:	*Decoherence due to contacts in ballistic nanostructures*
09:40	–	10:00	Branislav K. Nikolic:	*Shot noise probing of spin decoherence in quantum transport through spintronic nanostructures*

10:00 – 10:20 Coffee break

10:20 – 12:00 **2 session: Mesoscopic and nano-electromechanical systems**

Location: Pyramida Hotel Lecture Hall

10:20	–	10:50	Miles Blencowe:	*Damping and decoherence dynamics of nanomechanical resonators*
10:50	–	11:20	Robert H. Blick:	*Self-excitation in nano-electromechanical systems*
11:20	–	11:40	Andrew Armour:	*Quantum dynamics of a resonator driven by a superconducting single electron transistor: A solid state analogue of the micromaser*
11:40	–	12:00	Christoph Bruder:	*Position and momentum detection in nano-electromechanical systems*

12:00 – 13:00 Lunch

13:00 – 14:40 **3 session - A parallel: Mesoscopic and nano-electromechanical systems**

Location: Pyramida Hotel Lecture Hall A

13:00	–	13:20	Jan von Delft:	*Phase-coherent transport through quantum dots*
13:20	–	13:40	Alexander Altland:	*A many particle Landau Zener problem*
13:40	–	14:00	Andreas Wacker:	*Nonequilibrium transport in quantum dot systems*
14:00	–	14:20	Igor Lerner:	*Quantum wire hybridized with a side-attached impurity*

14:20 – 14:40	Vladimir Falko:	*Percolation through electron-hole puddles: Model for transport in strongly inhomogeneous graphene*

13:00 – 14:40 **3 session - B parallel: Foundations of quantum physics**

Location: Pyramida Hotel Lecture Hall B

13:00 – 13:20	Mark Davidson:	*The quark-gluon plasma and the stochastic interpretation of quantum mechanics*
13:20 – 13:40	Luis de la Pena:	*Signs of electron diffraction obtained by numerical simulation of a diffracted zero-point radiation field*
13:40 – 14:00	Kristel Michielsen:	*Event-based computer simulation of Wheeler's delayed choice experiment with photons*
14:00 – 14:20	Bahar Mehmani:	*Work as tracer of the force that generates the geometric phase*
14:20 – 14:40	Gennaro Auletta:	*Quantum-mechanical measurement process as a general framework for information acquiring*

14:40 – 15:00 Coffee break

15:00 – 16:40 **4 session - A parallel: Quantum dissipation, decoherence and noise**

Location: Pyramida Hotel Lecture Hall A

15:00 – 15:20	Wolfgang Belzig:	*Positive operator valued measure formulation of time-resolved electron counting statistics*
15:20 – 15:40	Yaroslav M. Blanter:	*Current and noise in a single-electron transistor coupled to an oscillator*
15:40 – 16:00	Jochen Gemmer:	*Projection operator approach to transport and relaxation in closed quantum systems*
16:00 – 16:20	Tobias Brandes:	*Waiting times and noise in single particle transport*
16:20 – 16:40	Tomáš Novotný:	*Counting statistics of non-Markovian quantum stochastic processes*

15:00	–	16:40	**4 session - B parallel: Quantum optics**	
			Location: Pyramida Hotel Lecture Hall B	
15:00	–	15:20	Valentina Brosco:	*Phase diffusion in single qubit lasers*
15:20	–	15:40	Francesco Petruccione:	*Density matrice and their parametrization*
15:40	–	16:00	Norbert Kroó:	*Nonlinear and quantum plasmonics*
16:00	–	16:20	George R. Welch:	*Toward XUV Raman superradiance: breaking of adiabaticity*
16:20	–	16:40	Raymond Ooi:	*How do pulsed lasers affect photon correlation and entanglement?*
16:40	–	17:00	Free time	
17:00	–	20:00	**Poster session**	
			Location: Pyramida Hotel - first floor	

Wednesday, 30 July 2008

08:00	–	10:00	**1 session: Physics of quantum measurement**	
			Location: Pyramida Hotel Lecture Hall	
08:00	–	08:30	Nicolas Gisin:	*Towards understanding quantum correlations: New Bell tests and simulating partial entanglement with nonlocal boxes*
08:30	–	09:00	Denis Vion:	*Continuous measurement of a driven quantum electrical circuit*
09:00	–	09:20	Andrew Jordan:	*Weak values and the Leggett-Garg inequality in solid-state qubits*
09:20	–	09:40	Fritz Haake:	*Quantum measurement without Schrödinger cat states*
09:40	–	10:00	Roger Balian:	*Simultaneous measurement of non commuting observables*
10:00	–	10:20	Coffee break	
10:20	–	12:00	**2 session: Physics of quantum computing and information**	
			Location: Pyramida Hotel Lecture Hall	
10:20	–	10:50	Wolfgang Hänsel:	*Advances in ion trap quantum computation*

10:50	–	11:20	Dirk Bouwmeester:	*Solid-state cavity QED and optomechanical structures*
11:20	–	11:40	David Vitali:	*Entanglement in mesoscopic opto-mechanical systems*
11:40	–	12:00	Mark Fox:	*Coherent quantum control of excitons and spins in quantum dots*

12:00 – 13:00 Lunch

13:00 – 15:00

3 session: Physics of quantum computing and information

Location: Pyramida Hotel Lecture Hall

13:00	–	13:30	Wolfgang Tittel:	*Combining quantum memory with state manipulation*
13:30	–	14:00	Howard Brandt:	*Differential geometry of quantum computation*
14:00	–	14:30	Barry Sanders:	*Simulating Hamiltonian evolution on a quantum computer*
14:30	–	15:00	Elisabetta Paladino:	*Coherent nanodevices as detectors of structured solid-state noise sources*

15:00 – 18:00 Free time and transfer to St. Simon and Juda Church

16:15 – 17:45 Refreshment

Location: Kozička Bar - Kozí street

18:00 – 21:45

Evening session: Public lecture of Marlan Scully and concert

Location: St. Simon and Juda Church

18:00	–	18:15	Music introduction and opening address by Peter Keefe	
18:15	–	19:30	Public lecture of Marlan Scully	
18:15	–	19:15	Marlan Scully:	*The demon and the quantum: From thermodynamics to quantum mechanics and beyond*
19:15	–	19:30	Discussion after the lecture of Marlan Scully	

19:30	–	20:00	Break
20:00	–	20:50	**Concert - First part**
20:50	–	21:00	Break
21:00	–	21:45	**Concert - Second part**

Thursday, 31 July 2008

08:00 – 10:00	**1 session: Quantum optics**	
	Location: Pyramida Hotel Lecture Hall	
08:00 – 08:30	Julien Laurat:	*Quantum networking with atomic ensembles in the single excitation regime*
08:30 – 09:00	Linda Elizabeth Reichl:	*Quantum control of atomic and molecular systems*
09:00 – 09:20	H. J. Carmichael:	*Open quantum systems, entanglement, and the laser quantum state*
09:20 – 09:40	Timothy Ralph:	*Entanglement in curved space time*
09:40 – 10:00	M. Suhail Zubairy:	*Optical sub-wavelength lithography: With and without entanglement*
10:00 – 10:20	Coffee break	
10:20 – 12:00	**2 session: Physics of biological systems**	
	Location: Pyramida Hotel Lecture Hall	
10:20 – 10:50	H. Frauenfelder:	*Protein dynamics*
10:50 – 11:20	Felix Ritort:	*Mechanical manipulation of nucleic acids at 1kT energy resolution*
11:20 – 11:40	Marlan Scully:	*Using quantum mechanics to detect anthrax*
11:40 – 12:00	Allen Hermann:	*New nanoscale materials and devices*
12:00 – 13:00	Lunch	
13:00 – 14:40	**3 session - A parallel: Quantum thermodynamics, dissipation and decoherence**	
	Location: Pyramida Hotel Lecture Hall	
13:00 – 13:20	Frank Willem Hekking:	*Normal metal - superconductor tunnel junction as a Brownian refrigerator*
13:20 – 13:40	Juan Pablo Paz:	*Dynamics of the entanglement between two oscillators in the same environment*
13:40 – 14:00	Joachim Ankerhold:	*Semiclassical dynamics of non-Markovian quantum Brownian motion*
14:00 – 14:20	Jiří J. Mareš:	*Temperature transformation and Mosengeil-Ott's antinomy*

14:20	–	14:40	Peter Keefe:	*The second law of thermodynamics and quantum heat engines: Is the law strictly enforced?*

13:00	–	14:40	**3 session - B parallel: Mesoscopic and non-electromechanical systems**

Location: Pyramida Hotel Cinema Hall

13:00	–	13:20	Jerzy Luczka:	*Negative conductances in Josephson junctions*
13:20	–	13:40	Doron Cohen:	*The conductance of small mesoscopic disordered rings*
13:40	–	14:00	Andrei Zaikin:	*Zero temperature decoherence of interacting electrons: The end of the story?*
14:00	–	14:20	Gloria Platero:	*Spin transport in double quantum dots: role of hyperfine interaction*
14:20	–	14:40	Marta Prada:	*Quantum computation with silicon: ultra-long decoherence and relaxation times in quantum systems*

14:40	–	15:00	Coffee break

15:00	–	17:00	**4 session: Non-equilibrium quantum statistical physics**

Location: Pyramida Hotel Lecture Hall

15:00	–	15:30	John Barker:	*Quantum phase space distribution functions for non-equilibrium transport*
15:30	–	16:00	Pawel Danielewicz:	*Towards quantum transport for nuclear reactions*
16:00	–	16:20	Karsten Balzer:	*Quantum kinetic theory for artificial atoms*
16:20	–	16:40	Václav Špička:	*Dynamics of mesoscopic systems: Non-equilibrium Green's functions approach*
16:40	–	17:00	Bedřich Velický:	*Single molecule bridge in transient regime as a testing ground for using NGF outside of the steady current regime*

17:00	–	18:30	Free time

18:30	–	24:00	**Evening session: Public lecture of Georgy Shlyapnikov and jazz concert**	

Location: Pyramida Hotel Cinema Hall

18:30	–	18:40	Opening address by Theo Nieuwenhuizen	
18:40	–	20:00	Public lecture of Georgy Shlyapnikov	
18:40	–	19:40	Georgy Shlyapnikov:	*Novel physics with ultracold fermions*
19:40	–	20:00	Discussion after the lecture of Georgy Shlyapnikov	
20:00	–	20:30	Break	
20:30	–	24:00	**Jazz concert**	

Friday, 1 August 2008

08:00	–	10:00	**1 session: Spins systems and their dynamics**	

Location: Pyramida Hotel Lecture Hall

08:00	–	08:30	Dietrich Belitz:	*Electronic properties of helimagnets*
08:30	–	09:00	Avraham Schiller:	*Quantum impurity systems out of equilibrium: Real-time dynamics*
09:00	–	09:20	Amnon Aharony:	*Spin selection by mesoscopic systems with spin-orbit interactions*
09:20	–	09:40	Ora Entin-Wohlman:	*Spin Hall effect*
09:40	–	10:00	Pascal Simon:	*Nuclear spin ordering in interacting 2D and 1D electron liquids*
10:00	–	10:20	Coffee break	

10:20	–	12:00	**2 session: Macroscopic quantum behaviour**	

Location: Pyramida Hotel Lecture Hall

10:20	–	10:50	Stephanie M. Reimann:	*From quantum dots to cold atoms in traps - interaction blockade and vortices*
10:50	–	11:20	Iacopo Carusotto:	*The non-equilibrium Bose-Einstein condensation phase transition in microcavity polariton systems*
11:20	–	11:40	Giacomo Roati:	*An ideal Bose-Einstein condensate: from precision measurements to Anderson localization*
11:40	–	12:00	Matthias Vojta:	*Valence-bond supersolids in cuprates*

12:00	–	13:00	Lunch	

13:00	–	15:00	**3 session: Non-equilibrium quantum statistical physics**	
			Location: Pyramida Hotel Lecture Hall	
13:00	–	13:30	James Freericks:	*Nonequilibrium dynamical mean-field theory*
13:30	–	14:00	Jens Eisert:	*Looking relaxed: Apparent local equilibration in closed non-equilibrium quantum many-body dynamics*
14:00	–	14:30	Giuseppe Falci:	*Dynamics of Weyl quasiparticles in the presence of quantum noise*
14:30	–	15:00	Eugene Sukhorukov:	*Dephasing in the electronic Mach-Zehnder interferometers*

15:00	–	16:30	Free time and transfer to Břevnov Monastery

16:30	–	24:00	**Conference dinner and organ concert**
			Location: Břevnov Monastery
16:30	–	17:00	Welcome in the atrium of the Břevnov Monastery
17:00	–	18:00	Guided tour through Břevnov Monastery
18:00	–	21:00	First part of the conference dinner
21:00	–	21:50	**Organ concert**
21:50	–	24:00	Second part of the conference dinner

Saturday, 2 August 2008

08:00	–	10:00	**1 session**	
			Location: Pyramida Hotel Lecture Hall	
08:00	–	08:30	Fernando Sols:	*Nonadiabatic pumping of heat in electron systems*
08:30	–	09:00	Hans Briegel:	*Entanglement in quantum many-body systems far away from equilibrium: Are there non-trivial quantum effects in biology?*
09:00	–	09:30	Hagen Kleinert:	*Third quantization*
09:30	–	10:00	Arkady Plotnitsky:	*Physical and mathematical causality in quantum theory*

10:00 – 10:20	Cofee break	
10:20 – 11:20	**2 session** *Location: Pyramida Hotel Lecture Hall*	
10:20 – 10:50	Raymond Chiao:	*Experiments at the interface of quantum mechanics and general relativity: Transduction between electromagnetic and gravitational waves via pairs of charged superconductors*
10:50 – 11:20	Theo M. Nieuwenhuizen:	*Supermassive black holes as giant Bose-Einstein condensates*
11:20 – 11:30	Coffee break	
11:30 – 13:00	**Round table** *Location: Pyramida Hotel Lecture Hall*	
13:00 – 13:15	**Closing address** *Location: Pyramida Hotel Lecture Hall*	
13:15 – 14:15	Lunch	

Invited Lectures

Spin selection by mesoscopic systems with spin-orbit interactions

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One of the aims of spintronics is to have devices which polarize the spins of electrons, which enter unpolarized. This talk will present a simple quasi-one-dimensional quantum network (made of quantum wires or by an array of quantum dots), which can serve as such spin filters. The main idea is to combine spin-orbit interactions, whose strength can be tuned by external gate voltages, and the Aharonov-Bohm flux, which can be tuned by an external magnetic field. For broad ranges of these fields, quantum interference allows only one propagating wave function, which has a unique spin state (tunable by the fields). All the other wave functions are evanescent, i.e. they decay as the electron moves in the device.

L2

A many particle Landau Zener problem

Alexander Altland

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We will discuss the behaviour of a strongly interacting many particle system under slow external driving - a many body generalization of the Landau Zener problem. The structure of our model system is motivated by the phenomenon of BEC-BCS crossover physics in cold atom systems. By a spectrum of different methods we will show that the many body system behaves strikingly different form driven single particle systems. Notably, it is extremely difficult to stay close to the adiabatic ground state, and strong quantum fluctuations render the distributions of particle occupancies very broad. The structure of the theory suggests that these observations reflect more general phenomena in the physics of driven many particle systems.

Semiclassical dynamics of non-Markovian quantum Brownian motion

Joachim Ankerhold[1], Frank Grossmann[2], Werner Koch[2], and Jürgen Stockburger[1]

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Quantum Brownian motion can be formulated within the path integral approach or equivalently within stochastic Schrödinger equations [1]. For explicit numerical calculations the latter one is particularly suited for the challenging regime of low temperatures and weak coupling, where the reduced dynamics becomes non-Markovian. The full quantum mechanical implementation, however, is plagued by convergence problems for long times. Very recently we have shown [2] that this problem can be circumvented when the quantum propagators are represented within the time-dependent semiclassical initial value formalism. The approach allows for the first time to study the non-Markovian low temperature quantum dynamics of anharmonic systems up to times where equilibration is reached.

[1] J.T. Stockburger and H. Grabert, Phys. Rev. Lett. 88, 170407 (2002).

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L4

Quantum dynamics of a resonator driven by a superconducting single electron transistor: a solid state analogue of the micromaser

Andrew Armour

University of Nottingham, University Park, Nottingham, UK

I will discuss the dynamics of a resonator coupled to a mesoscopic conductor known as a superconducting single electron transistor (SSET), focusing on the regime where the SSET is operated in the vicinity of the Josephson quasiparticle resonance. Recent experiments have realized this system with two very different types of resonator, namely a mechanical resonator consisting of a suspended beam with a fundamental frequency of 20MHz [Naik et al., Nature 443, 193 (2006)] and a superconducting stripline resonator with a frequency of 10GHz [Astafiev et al., Nature 449, 588]. For an appropriate choice of operating point, the SSET can be used to pump the resonator, and the dynamics is similar in many ways to that found in a quantum optical systems such as the micromaser. Coupling to the SSET can drive the resonator into non-classical states of self-sustained oscillation via either continuous or discontinuous transitions. Increasing the coupling further leads to a sequence of transitions and regions of multistability. The current and epsecially the current noise of the SSET contain important signatures of the resonator's dynamics.

Quantum-mechanical measurement process as a general framework for information acquiring

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There are three general aspects or steps in any information–acquisition process.

- Firstly, a *processor* is necessary, as a source of possible variety. The processor is the component that gives the input so that information can be acquired. It is not necessary that such a processor be random. What is necessary is that the algorithm producing the input be unknown. Otherwise, the acquired information would be valueless.
- The next component is represented by a *regulator*, that is, a system able to work as the interface between the processor and the final detection event. In other words, the regulator provides the necessary coupling, without which we could not speak of information acquiring. I shall return to this point, but let me add here that we never have direct access to any source of variation, we only access its (delayed) effects. This is already true from a relativistic point of view.
- Finally, we need a *decider*, that is, a device that, given a certain coupling, is able to give rise to a decision among a given set (in the simplest case, between two alternatives). In principle, this decision event can have no relation with the initial processor. It is only the coupling (second step) that guarantees that the final event says something about the state of the processor. In this way, we say that the decider has *selected* some information from among the different possibilities to which the processor gives rise.

The three steps are represented by: preparation, premeasurement, and measurement.

[1] Auletta, G., in Auletta, G.(Ed.), Proceedings of the I Workshop onthe Relationships Between Science and Philosophy (VaticanCity, Libreria Editrice Vaticana, 2006), pp. 109-127.

[2] Auletta, G., Fortunato, M., and Parisi, G., Quantum Mechanics: A Modern Perspective Cambridge, UniversityPress (2006).

[3] Bennett, Charles H., Logical Reversibility of Computation, IBM Journal Res. Dev. 17 (1973) 525-32.

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[5] de Muynck, W. M., Stoffels, W. W., and Martens,H., Joint Measurement of Interference and Path Observables in Optics and Neutron Interferometry, Physica B175 (1991) 127-32.

[6] Landauer, Rolf, Minimal Energy Requirements in Communication, Science 272 (1996) 1914-19.

L6

Simultaneous measurement of non commuting observables

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[2] *Institut de Physique Théorique, Centre de Saclay, 91191 Gif sur Yvette Cx, France*

[3] *Institute for Theoretical Physics, University of Amsterdam, Valckenierstraat 65, 1018 XE Amsterdam, The Netherlands*

The following model of quantum measurement is considered. The $x-$ and $z-$components of a spin 1/2, the tested system S, are coupled with two apparatuses, respectively. Each apparatus simulates an Ising magnetic dot; the total magnetization is the pointer variable, and a phonon bath keeps the temperature of the dot below the Curie point. Initially in a metastable paramagnetic state, each apparatus may be switched towards either one of its two stable ferromagnetic states under the effect of its coupling with the tested spin S. The full setting thus has 4 possible outcomes. The hamiltonian dynamical equations are solved, and several time scales are exhibited. The process is not an ideal measurement, but a simultaneous unsharp measurement: if for instance S is initially polarized along $+z$, its final state is modified, and all four outcomes for the pointers may occur. However, full information about both $x-$ and $z-$components of the initial polarization of S can be gained through statistical analysis of repeated experiments. Indeed there is a one-to-one mapping of the quantum non-commuting information on S onto the counting rates of the apparatuses. Due to their necessarily large size, the pointers behave classically, so that violation of Bell's inequalities for two spins is not directly seen on the pointers of this setting.

A similar model involving only the measurement of the $z-$component of S has been introduced and solved in:

Armen E. Allahverdyan, Roger Balian and Theo M. Nieuwenhuizen, Curie-Weiss model of the quantum measurement process, Europhys. Lett. 61, (2003), pp 452.
Armen E. Allahverdyan, Roger Balian and Theo M. Nieuwenhuizen, The quantum measurement process: Lessons from an exactly solvable model, in "Beyond the Quantum", eds. Th.M. Nieuwenhuizen, V. Spicka, B. Mehmani, M. Jafar-Aghdami, and A. Yu. Khrennikov (World Scientific, 2007, pp 53).

Quantum kinetic theory for artificial atoms

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Charged particles in confinement potentials tend to resemble the electronic structure of atoms including ring/shell structures which vary with the system's dimensionality. Such "artificial atoms" have a number of interesting features missing in real atoms: the formation of weakly coupled (gas/liquid-like) as well as strongly coupled (crystal/solid-like) Wigner states [1] can be externally controlled by the confinement strength. A theoretical description of these states requires to properly take into account many-body, quantum and spin effects as well as the confinement and a possible time-dependent external excitation. To this end we develop a nonequilibrium Green's function approach [2,3] which allows us to compute the equilibrium properties (at zero and finite temperatures) and the nonequilibrium behavior of the artificial atom on the same, correlated and self-consistent footing.

After outlining some computational details and reviewing the equilibrium states [4] we, in the third part of the talk, present results for the laser induced nonequilibrium electron dynamics. In particular, we will focus on the normal, Kohn (sloshing) [5] and breathing, modes and look at the one-particle orbital occupation numbers the time-dependence of which depend on temperature, field and coupling strength. Finally, as an extension, we investigate other quantum systems such as charged bosons and electron-hole bilayers in trapping potentials. In the latter a rich variety of phases is due to the possibility to tune the pair interaction and the effective spin statistics: while at large layer separation the system consists of Coulomb interacting fermions, a transition to composite bosons with nearly dipole interaction is observed at smaller distances [6].

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L8

Quantum phase space distribution functions for non-equilibrium transport

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Very recently the practical use of self-consistent non-equilibrium Green functions (NEGF formalism computed in the double-time, double space representation $G(\mathbf{x}, \mathbf{x}', t, t')$: based on the Keldysh, Kadanoff-Baym picture) in the 3D modelling of nano-transistors has shown that quantum effects dominate the behaviour of sub-10 nm devices. In principle, the NEGF formalism should provide a rigorous basis for deriving a more phenomenological picture to provide a simpler, faster framework for device modelling. Semi-classical device modelling is underpinned by the Boltzmann transport equation coupled to Poisson's equation (usually implemented by ensemble Monte Carlo). Here, the phase-space distribution functions provide both physical insight and a route (via projection) to drift-diffusion models and hydrodynamic models that are sufficiently compact for fast numerical simulation as required by industry. At first sight the Kadanoff-Baym equations provide a similar basis through the phase space Green functions $G(\mathbf{X}, \mathbf{P}; T, E)$. However, there is a major difficulty because the phase space Green functions are basically Wigner functions and do not have compact support: the functions exist in regions of phase space where no matter is present. In essence, $\mathbf{X} = (\mathbf{x} + \mathbf{x}')/2$; $T = t + t'/2$ are centre of "mass" type variables and the momentum and energy variables $\mathbf{P}$ and E are Fourier variables derived from the Fourier transform over the relative coordinates $\mathbf{x} - \mathbf{x}', t - t'$. Mathematically this is not an issue but it is a problem for numerical calculations where very fine structure occurs in the phase space and of course it complicates considerably the derivation of simpler hydrodynamic pictures or the transition to Boltzmann transport. The work of Berry in the 1970s shows formidable structure in the Wigner function as the classical limit is approached. Many formalisms have sought to overcome these problems by coarse graining the quantum phase space (Husimi functions are an example) or by exploiting thermal broadening but they do not sustain comparison with Green function studies in the double time, double space picture. The present paper reviews these issues and then shows that it is possible to obtain real-valued quantum phase space distributions with compact support that reduce sensibly to the classical limit. The equations of motion differ from Wigner theory or Kadanoff-Baym theory. The new picture is obtained via a pseudo-spinor approach and it is discussed for simple exactly solvable examples including the harmonic oscillator and anharmonic oscillator in pure states and thermal mixtures. The extension to many-body quantum statistical mechanics and Green function theory is outlined. Finally, the classical limit is examined.

Electronic properties of helimagnets

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Helimagnets are magnetically ordered materials in which the spin-orbit interaction leads to a spiral structure of the magnetization. I will review the phenomenology of MnSi as the prototypical and best studied helimagnet, in particular various phases or suspected phases identified by neutron scattering and other techniques. The most interesting features include a tricritical point in zero magnetic field, a quantum critical point that can be reached by applying an external magnetic field, and a pronounced $T^{(3/2)}$ behavior of the resistivity in a large region of parameter space. I will then review theoretical efforts to understand the observed effects. The nature of the ordered phase is well understood, and interesting analogies with liquid crystals allow for an understanding of the structure of the phase diagram. The critical behavior at the quantum critical point has been determined exactly. The transport properties are still largely mysterious, however.

L10

Positive operator valued measure formulation of time-resolved electron counting statistics

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The core of quantum measurement theory is the projection postulate (PP). It provides a consistent description of a sequence of measurements. Quantities represented by non-commuting operators cannot be measured simultaneously. The corresponding projection operators have to be time-ordered. For continuous variables the PP should be replaced by the positive operator valued measure (POVM). The idea of the POVM is that one does not measure the exact value for a given operator but a finite accuracy is taken into account due to some interaction with the detector and its internal dynamics.

We apply these ideas to the quantum measurement of electric current in mesoscopic conductors. To this end, we propose a derivation of the full counting statistics of electronic current based on a positive operator valued measure. Our approach justifies the Levitov-Lesovik formula in the long time limit, but can be generalized to the detection of finite-frequency noise correlations. The combined action of the projection postulate and the quantum formula for current noise at high frequencies imply an additional white noise. Estimates for this additional noise are in accordance with known experiments. We propose an experimental test of our conjecture by a simultaneous measurement of high- and low-frequency noise.

Current and noise in a single-electron transistor coupled to an oscillator

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[1] *Kavli Institite of Nanoscience,, Delft University of Technology, Lorentzweg 1, Delft, The Netherlands*

[2] *CNRS Grenoble, France*

[3] *Los Alamos National Laboratory*

We investigate the effect of mechanical modes on the transport properties such as current and noise of Coulomb blockade systems. NEMS are modeled by an SET device coupled to a harmonic oscillator. We show that both at weak and strong coupling mechanical modes can have a dramatic effect, strongly modifying the current and driving the current noise well over Poisson value.

L12

Damping and decoherence dynamics of nanomechanical resonators

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Nanoscale to mesoscale mechanical resonators are finding increasing application both in fundamental investigations of the quantum-to-classical transition and in sensing applications, such as mass or spin detection. Such applications are intimately connected with the dissipation and associated quantum decoherence mechanisms of, for example, the fundamental flexural mode of the resonator. We present our recent investigations of low temperature damping and decoherence dynamics of nanobeams due to the presence of tunneling two level system defects, as well as investigations of damping at high temperatures through classical atomistic simulations of the dynamics of silicon nanoresonators, initially excited in the fundamental flexural mode.

Self-excitation in nano-electromechanical systems

Robert H. Blick, Hyun-Seok Kim I, Hyun-Seok Kim II, Chulki Kim, and Hua Qin

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In this talk I want to give an overview of mechanically mediated electron transport in nano-electromechanical systems (NEMS). One part will cover self-excitation in NEMS: self-excitation is a mechanism, which is ubiquitous for electromechanical power devices such as electrical generators. This is conventionally achieved by making use of the magnetic field component in electrical generators, where a good example are the overall visible wind farm turbines. In other words, a static force, like wind acting on the rotor blades, generates a resonant excitation at a certain mechanical frequency. This mechanical resonance is then usually transformed into electrical energy.

For nanomechanical systems such a self-excitation mechanism is highly desirable as well, since it can generate mechanical oscillations at radio frequencies by simply applying a DC bias voltage. This is of great importance for low-power signal communication devices and detectors, as well as for computing devices based on nanomechanical switches [1]. For a particular nanomechanical system – the single electron shuttle – this effect was predicted some time ago by & Gorelik et al. [2]. Here, we use a nano-electromechanical single electron transistor (NEMSET) to demonstrate first mechanical mixing and in a second step self-excitation for both the soft and hard regime, respectively [3,4]. The ability to use self-excitation in nanomechanical systems may enable the ultra-sensitive detection of radiation via rectification, the discovery of quantum mechanical backaction effects in direct tunneling, and macroscopic quantum tunneling in NEMS.

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L14

Solid-state cavity QED and optomechanical structures

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Coupling of photons to solid-state quantum systems with relatively long coherence times is essential to scalable hybrid quantum information schemes, which combine the coherence properties and ease of manipulation of photons with the robustness of local quantum systems. The spin of a single electron confined in a self-assembled semiconductor quantum dot is of particular interest since it can interact with an external photon through a mode-matched micro cavity and an intermediate trion state. The desired working point of the cavity quantum electrodynamics is just below the onset of strong coupling such that the coupling is effective but does not lead to oscillations between trion and photon occupation. I will report on the realization of such a system exploring electrically-gated quantum dots in high-quality, Q $>$ 40,000, micropillar cavities and verify its performance by cavity reflection spectroscopy.

As a second topic optical cooling of micromechanical systems will be addressed. In particular I will show how active feed back by radiation pressure can cool a micromechanical cantilever from room temperature to 135 milliKelvin. Furthermore we will discuss the possibility of investigating macroscopic quantum superpositions and environmental induced quantum decoherence using such methods.

L15

Waiting times and noise in single particle transport

Tobias Brandes

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The waiting time distribution w(τ), i.e. the probability for a delay τ between two subsequent transition ('jumps') of particles, is a statistical tool in (quantum) transport. Using generalized Master equations for systems coupled to external particle reservoirs, one can establish relations between w(τ) and other statistical transport quantities such as the noise spectrum and the Full Counting Statistics. It turns out that w(τ) usually contains additional information on system parameters and properties such as quantum coherence, the number of internal states, or the entropy of the current channels that participate in transport.

[1] arXiv:0802.2233v1

L16

Differential geometry of quantum computation

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An expository review is given of some recent developments [1], [2] in the differential geometry of quantum computation, for which the quantum evolution is described in terms of the special unitary unimodular group. Using the associated Lie algebra, detailed derivations are given of an appropriate Riemannian geometry on the group manifold, including the chosen metric, connection, and optimal geodesics for achieving minimal complexity quantum circuits.

[1] M. A. Nielsen, M. R. Dowling, M. Gu, and A. C. Doherty, Science 311, 1133-1135 (2006).

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L17

Entanglement in quantum many-body systems far away from equilibrium: Are there non-trivial quantum effects in biology?

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We show that quantum mechanical entanglement can prevail in noisy open quantum many-body systems at high temperatures and far away from thermodynamic equilibrium, despite the deteriorating effect of de-coherence. Our investigations focus on so-called spin gases in strongly decoherent environments and the possibility of quantum information processing in such systems [1][2]. From a broader perspective, these investigations also provide a new perspective on the question, whether non-trivial quantum effects such as entanglement may play a role in biology [3].

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L18

Phase diffusion in single qubit lasers

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In recent years various experimental and theoretical works pioneered the field of circuit QED [1]. Superconducting qubits, used as artificial two-level atoms, were coupled on chip to electrical resonators to study quantum optical effects. Due to the high tunability of the qubit-resonator hamiltonian, different coupling regimes were explored. In a recent set of experiments, lasing and cooling of the electromagnetic field in the resonator were observed [2]. Among the issues related to the artificial nature of the atom in single qubit lasers, we focus on the role played by qubit's noise. Specifically, we analyze the effects of qubit's decoherence on phase diffusion. In normal optical lasers the phase information contained in the lasing state is lost after a certain characteristic time, τ_d, this process is known as phase diffusion. We present a study of the phase diffusion process and we estimate τ_d for various types qubit's noise.

[1] A. Blais et al. Phys. Rev. A 69, 062320 (2004); A. Wallraff et al. , Nature 431, 162 (2004).

[2] E. Il'ichev et al., Phys. Rev. Lett. 91, 097906 (2003); O. Astafiev et al. , Nature 449, 588 (2007); J. Hauss et al. , Phys. Rev. Lett. 100, 037003 (2008).

Position and momentum detection in nano-electromechanical systems

Christoph Bruder

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In this talk, I would like to discuss position measurements of a nanomechanical oscillator by tunnel junction position detectors. Using the cross-correlated output of two such detectors, the bound on the peak-to-background ratio in a position measurement valid for a single detector can be overcome [1]. Furthermore, the double-detector setup can be exploited to drastically reduce the added displacement noise of the oscillator.

I would also like to show that the momentum p of a nanomechanical oscillator can be measured by two tunnel junctions in an Aharonov-Bohm-type setup [2]. The tunneling amplitude of one of the junctions depends linearly on the position x of the oscillator, $t(x) = t_0 + t_1 x$. The presence of two junctions can, under certain conditions, lead to an effective imaginary coupling $t(x) = t_0 + it_1 x$. By calculating the equation-of-motion for the density matrix of the coupled (oscillator+tunnel junction) system, we show that in this case the finite-frequency current noise of the detector is proportional to the momentum spectrum of the oscillator.

[1] C.B. Doiron, B. Trauzettel, and C. Bruder, Phys. Rev. B 76, 195312 (2007).

[2] C.B. Doiron, B. Trauzettel, and C. Bruder, Phys. Rev. Lett. 100, 027202 (2008).

L20

Dissipative dynamics of a two-level system resonantly coupled to a harmonic mode.

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We propose an approximation scheme to describe the dynamics of the spin-boson model when the spectral density of the environment shows a peak at a characteristic frequency Ω which is very close (or even equal) to the spin Zeeman frequency Δ. Mapping the problem onto a two-state system (TSS) coupled to a harmonic oscillator (HO) with frequency Ω - via a "σ_Z-coordinate" coupling - we show that the representation of displaced HO states provides an appropriate basis to truncate the Hilbert space of the TSS-HO system and therefore a better picture of the system dynamics.

We derive an effective Hamiltonian for the TSS-HO system, and show it furnishes a very good approximation for the system dynamics even when its two subsystems are moderately coupled. Finally, assuming the regime of weak HO-bath coupling and low temperatures, we are able to analytically evaluate the dissipative spin dynamics.

Open quantum systems, entanglement, and the laser quantum state

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Motivated by the work of Javanainen and Yoo [1] on the interference of Bose-Einstein condensates, it was suggested by Moelmer, in 1997, that intrinsic optical coherence does not exist—"optical coherences may be regarded as a convenient fiction" [2]; thus, the light of an ideal laser is not, as it is commonly believed, in a coherent state, though coherent states might provide a convenient basis for making calculations. Arguing in a similar vein, and with reference to Moelmer, Rudolf and Sanders [3] assert that genuine continuous variable quantum teleportation cannot be achieved with conventional laser sources "due to an absence of intrinsic optical coherence". In response to these and related works, in this paper we argue for a contrary point of view, namely that coherent states are not only convenient, but, according to a well-defined criterion, unique in their description of laser light—in fact any classical source of light, i.e., any source possessing a nonsingular and positive Glauber-Sudarshan P-function. We begin from the observation that a source of light is intended for illuminating a target, perhaps a single atom or qubit [4], although any target might, in principle, be considered. It then follows that asking for a quantum state of the source alone, a subsystem of the source plus target, presupposes a separation of the dynamics. Our program is to adopt the presumed separability as a criterion for assigning the laser quantum state. Specifically, we show more generally that for any classical source of light, coherent states uniquely separate the quantum dynamics of the source-plus-target when modeled as a stochastic scattering process in the Born-Markov limit—i.e., when the source-plus-target density operator satisfies a Lindblad master equation for a cascaded open system [5]. One qualification must be noted, however; a certain level of coarse graining is required in order for the separability to hold; one must discard the tracking of source-target correlations right down to the one-quantum level. The source-plus-target state is otherwise an entangled state.

[1] J. Javanainen and S. M. Yoo, "Quantum Phase of a Bose-Einstein Condensate with an Arbitrary Number of Atoms," Phys. Rev. Lett. 76, 161 (1996)

[2] K. Moelmer, "Optical coherence: A convenient fiction," Phys. Rev. A 55, 3195 (1997)

[3] T. Rudolf and B. C. Sanders, "Requirement of Optical Coherence for Continuous-Variable Quantum Teleportation," Phys. Rev. Lett. 87, 077903 (2001)

[4] H. Nha and H J. Carmichael, "Decoherence of a two-state atom driven by coherent light," Phys. Rev. A 71, 013805 (2005)

[5] H. J. Carmichael, "Quantum Trajectory Theory for Cascaded Open Systems," Phys. Rev. Lett. 70, 2273 (1993)

L22

The non-equilibrium Bose-Einstein condensation phase transition in microcavity polariton systems

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Several recent experiments have provided evidence for the appearance of macroscopic coherence in polaritonic systems with a spontaneous symmetry breaking mechanism which is the non-equilibrium analog of the Bose-Einstein condensation phase transtion.

In this seminar, we shall review the present understanding of this non-equilibrium phase transition, and we shall try to evidentiate analogies and differences from the usual Bose-Einstein condensation in equilibrium systems such as liquid He and ultracold atoms.

The principal aspects of the phase transition will be addressed, such as its order, the behaviour of the coherence functions around the critical point, the shape of the condensate in real and momentum space, the nature of the Goldstone mode, the superfluidity properties of the condensate.

Quantization as an emergent property of a matter-field system in permanent interaction

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The electromagnetic zero-point radiation field is seen to play a fundamental role in the phenomenon of quantization: further to leading to radiative corrections and other QED results, it is responsible for the quantum behaviour of matter itself. Indeed, the stationary ergodic solutions for the system composed of (otherwise classical) atomic matter immersed in the (otherwise classical) zero-point radiation, can be concisely expressed in terms of the Heisenberg formalism of quantum mechanics. The conclusion is that quantum behaviour is not intrinsic to matter, but an emergent property of it. It is the complete system, matter and field in interaction, which becomes quantum in nature.

An analysis of a system composed of two non interacting particles immersed in a common zero-point field shows the establishment of entangled states as a result of the correlations between the relevant field modes. Under the condition that the two particles are equal, the entanglement becomes maximal, meaning that the respective states are either symmetrical or antisymmetrical with respect to the interchange of particles.

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Experiments at the interface of quantum mechanics and general relativity: Transduction between electromagnetic and gravitational waves via pairs of charged superconductors

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The interaction of charged, macroscopically coherent quantum systems, such as a pair of charged superconducting spheres, with both electromagnetic (EM) and gravitational (GR) waves, will be considered. When the charge-to-mass ratio of a pair of identical superconducting spheres is adjusted so as to satisfy the "criticality" condition $Q/M = \sqrt{4\pi\epsilon_0 G}$, where ϵ_0 is the permittivity of free space, and G is Newton's gravitational constant, the gravitational force of attraction will be balanced against the electrostatic force of repulsion between the two spheres. At criticality, when these two spheres are set in simple harmonic motion relative to each other by, say, a passing GR wave, they will radiate equal amounts of quadrupolar GR and EM radiations.

The superconducting spheres possess an energy gap (the BCS gap) separating the ground state from all excited states. In the linear regime of weak incident EM and GR waves whose frequencies are well below this gap, such as microwave frequencies, the quantum adiabatic theorem implies that the spheres will remain $rigidly$ in their BCS ground state (i.e. London's "rigidity of the wavefunction"). This leads to $hard$-$wall$ boundary conditions at the surfaces of the spheres, so that both the incident EM and GR waves will undergo specular reflections at their surfaces. The scattering cross-sections for both kinds of waves will be geometric in size, i.e., on the order of $\sigma = 2\pi a^2$, when both the radius of the spheres, a, and the distance separating the two spheres are comparable to, or larger than, the microwave wavelength.

At sufficiently low temperatures with respect to the BCS gap, all dissipative degrees of freedom of the spheres will be frozen out by the Boltzmann factor. Then at criticality, there will be an equipartition of both kinds of incident radiation upon scattering. By time-reversal symmetry, the scattering cross-section for the time-reverse process (EM to EM+GR waves) will be the same as for the time-forward process (GR to EM+GR waves). This implies that a Hertz-like experiment, i.e., a transmitter-receiver experiment, in which GR microwaves are generated at the emitter or transmitter by EM microwaves incident on a pair of charged superconducting spheres at criticality, and detected at the receiver or detector by another pair of charged superconducting spheres at criticality, which back-converts a portion of the GR microwaves into EM microwaves, should be experimentally feasible to perform.

The conductance of small mesoscopic disordered rings

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The calculation of the conductance of disordered rings requires a theory that goes beyond the Kubo-Drude formulation. Assuming "mesoscopic" circumstances the analysis of the electro-driven transitions show similarities with a percolation problem in energy space. We argue that the texture and the sparsity of the perturbation matrix dictate the value of the conductance, and study its dependence on the disorder strength, ranging from the ballistic to the Anderson localization regime. An improved sparse random matrix model is introduced to captures the essential ingredients of the problem, and leads to a generalized variable range hopping picture.

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L26

Towards quantum transport for nuclear reactions

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Quantum transport equations of Kadanoff and Baym are being adapted for use in describing the dynamics of central nuclear reactions. So far, equilibration for a uniform system of interpenetrating nuclear matters has been studied and has been compared to the equilibration in Boltzmann-equation description. Currently, evolution of density matrices is studied for collisions of nuclear slabs in one dimension within mean-field approximation. Adiabatic switching on of the mean field has been tested as well as the role of far off-diagonal elements in the matrix. Erasing of such elements has been found to have little impact on evolution of the elements close to the diagonal, while that erasing is important for feasibility of three-dimensional reaction simulations.

The quark-gluon plasma and the stochastic interpretation of quantum mechanics

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Extensive analysis of collision data from the Relativistic Heavy Ion Collider (RHIC) has established that a quark-gluon plasma is formed in heavy ion (Au-Au) collisions at 40 TeV center of mass energy, and that it is described remarkably well by an ideal classical fluid model with nearly zero viscosity. It is believed that a similar state of matter permeated the entire universe at about three microseconds after the big bang. Therefore, all that we observe today appears to originate from an essentially classical ideal fluid. We estimate the relativistic Reynolds number for this primordial fluid and find an extraordinarily large number on the order of 10^{19} suggesting that the early universe was extremely turbulent. This turbulence is an ideal candidate for the source of indeterminism in the stochastic interpretation of quantum mechanics. Could quantum behavior as we observe it today possibly be a stochastic manifestation of this turbulent beginning? This paper explores this question by examining a particularly simple class of ideal fluids exhibiting turbulence and chaos in numerical simulations implemented utilizing a Fourier-Galerkin spectral truncation method. This proto-fluid model ignores pressure completely and is referred to in the cosmological literature as the Lambda-CDM model or cosmic dust model. It is compatible with a flat space-time provided a cosmological constant is included in the equations of general relativity, and it can be transformed into the inviscid Burgers equation provided the fluid does not have any shocks. A new class of solitons is presented for this system. It is shown that these solitons can be combined with the known chaotic solutions, and that they then move randomly with a mean velocity which does not decay with time, exhibiting a time reversible stochastic behavior without any friction, a behavior similar to quantum particles. The turbulent fluid is statistically a Markov process, and the soliton's position can be described by a Hidden Markov model. Characteristic curves also exhibit stochastic behavior. A number of other properties of this system are exhibited. A brief discussion of some no-go theorems is also presented.

L28

Signs of electron diffraction obtained by numerical simulation of a diffracted zero-point radiation field

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We have made a rigorous numerical study of the behaviour of a stochastic electromagnetic radiation field that simulates the zero-point field in the presence of two slits pierced on an infinitely thin metallic screen of ideal conductivity. Our numerical simulations show that the field unfolds into two components, a dominant one that is disordered and contains scars, and another much more organized one that exhibits a pattern of perfectly coherent diffraction. The results confirm the existence of an effect suggested previously in the context of stochastic electrodynamics.

This behaviour of the field is considered to be of importance for a physical explanation of the quantum diffraction of matter. From first numerical experiments solving the dynamic equation for the electrons immersed in this field, we have found that the trajectories present interferences that seem to suggest a diffraction pattern.

Even-by-event simulation of quantum phenomena

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We present a computer algorithm that simulates Einstein-Podolsky-Rosen-Bohm experiments with photons [1-6]. The program produces the same kind of data as recorded in these experiments and uses the same procedure to analyze the data. We consider two types of experiments, those with a source emitting photons with opposite but otherwise unpredictable polarization and those with a source emitting photons with fixed polarization. The simulation model strictly satisfies Einstein's criteria of local causality, does not rely on any concept of quantum theory and reproduces the results of quantum theory for both types of experiments, namely the correlation of the singlet state and Malus law, respectively. A rigorous proof is given that the probabilistic description of the simulation model yields the quantum theoretical expressions for the single- and two-particle expectation values.

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L30

Looking relaxed: Apparent local equilibration in closed non-equilibrium quantum many-body dynamics

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A reasonable physical intuition in the study of interacting quantum systems says that, independent of the initial state, the system will tend to equilibrate. Yet, how and in what sense can closed quantum many-body systems apparently relax to an equilibrium state, without any thermalizing environment? In this talk, we will address this question of the local apparent relaxation of quenched quantum systems in non-equilibrium.

Emphasis will be put on a setting where relaxation to a steady state is exact and can be rigorously shown, namely for the Bose-Hubbard model where the system is quenched from a Mott quantum phase to the strong superfluid regime. We find that the evolving state locally relaxes to a steady state with maximum entropy constrained by second moments, maximizing the entanglement, to a state which is different from the thermal state of the new Hamiltonian. Remarkably, in the infinite system limit this relaxation is true for all large times, and no time average is necessary. For large but finite system size we give a time interval for which the system locally "looks relaxed" up to a prescribed error. Our argument includes a central limit theorem for harmonic systems and exploits the finite speed of sound. We also discuss implications on entropy scaling in such quenched systems and the difficulty of simulating them using matrix-product states

The final part of the talk will be concerned with numerical work on the strongly interacting case, using t-DMRG, as well as experimental implications. The idea of local relaxation has led to a joint project with an experimental group which aims at observing local relaxation using cold atoms in optical lattices. Here, the key idea is that optical superlattices allow for a period two read out of densities and correlations, such that relaxation phenomena can be studied without the need of locally addressing individual sites.

Joint work with M. Cramer, T. Osborne, A. Flesch, U. Schollwoeck

Spin Hall effect

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The spin-Hall effect in insulators is described. The Rashba and Dresselhaus spin-orbit interactions are both shown to yield the low temperature spin-Hall effect for strongly localized electrons coupled to phonons. A frequency-dependent electric field $\mathbf{E}(\omega)$ generates a spin-polarization current, normal to $\mathbf{E}$, due to interference of hopping paths. At zero temperature the corresponding spin-Hall conductivity is real and is proportional to ω^2. At non-zero temperatures the coupling to the phonons yields an imaginary term proportional to ω. The interference also yields persistent spin currents at thermal equilibrium, at $\mathbf{E} = 0$. The contributions from the Dresselhaus and Rashba interactions to the interference oppose each other.

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Dynamics of Weyl quasiparticles in the presence of quantum noise

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The recent discovery of single graphene sheets has triggered advances in two-dimensional physics [1]. Control of quasiparticle transport could led to the design of new high-performance devices. The dynamics of quasiparticle near the Fermi energy is governed by the Weyl equation, describing massless fermions with a pseudospin [2]. Chirality determines unusual effects as the total trasmission through a barrier perpendicular to the direction of motion, which is related to conservation of the pseudospin [3].

External control fields and electronic noise may strongly affect the quasiparticle dynamics. We focus on noise due to an electromagnetic environment, which is modelled by coupling a suitable set of harmonic oscillators to the particle coordinate. For free quasiparticles this model maps exactly onto a conditional spin boson model: all the effect are conveyed in the pseudospin dynamics which however reflects the state of motion of the quasiparticle.

We studied three limits of the problem, for which exact results can be derived, namely noise with arbitrary spectrum coupled parallel to the direction of motion, and for arbitrary orientation the limits of low-frequency and white noise.

Noise parallel to the direction of motion does not affect pseudospin consevation, therefore the system is insensitive except for dephasing of superpositions of spin states, which can be created by suitable AC pulses.

For coupling in arbitrary direction a Master Equation for the conditional dynamics was derived. The dynamic of quasiparticles close to the Dirac points turns out to depend crucially on non-secular terms. In particular for white noise the exact solution shows that after a transient, the pseudospin state is frozen in a direction completely determined by the geometric coupling to the noisy field. This is a manifestation of the Zeno effect, related to the continuous quantum measuremet of the particle by the noisy field. Effects on transport properties in the presence of barriers are finally discussed.

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Percolation through electron-hole puddles: Model for transport in strongly inhomogeneous graphene

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Graphene - an atomic monolayer of graphite - is a gapless semiconductor with linear electron spectrum [1]. The carrier density in a graphene-based field effect transistor (GraFET) can be varied continuously, from P-type to N-type. Experimental results are surprising: the resistance per square never exceeds several kΩ's in contrast to the pinch-off in conventional (gapfull) semiconductors [2]. The conductivity of GraFETs reaches its minima when the gate-controlled average carrier density in GraFET is zero - the so called "neutrality point". Similar observations were reported for the bilayer graphene [1]. Here, transport in undoped graphene (in GraFETs) with large inhomogenuity of carrier density is related to percolating current patterns in the networks of N- and P-type regions reflecting the strong bipolar charge density fluctuations. Transmissions of the P-N junctions, though small, are vital in establishing the macroscopic conductivity. We propose [3] a random resistor network model to analyse scaling dependencies of the conductance on the doping and disorder, the quantum magnetoresistance and the corresponding dephasing rate.

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L34

Coherent quantum control of excitons and spins in quantum dots

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In this talk I will describe the progress made in Sheffield on the coherent quantum control of excitons and spins in self-assembled InAs quantum dots. The quantum dots are grown in Schottky diode structures and are addressed with resonant picosecond laser pulses through shadow mask apertures. The coherent control experiments are performed by exciting the dots with an initialisation pulse tuned to the neutral exciton, and then probing with a control pulse tuned to the neutral exciton, the X+ charged exciton, or the biexciton.

With the control pulse tuned to the neutral exciton, it is possible to determine the coherence time of the excitons. By employing inversion recovery techniques, we have demonstrated that the coherence time is limited by the tunnelling time of the electrons [1], which depends on the electric field strength and can be $>$100ps at low fields.

With the control pulse tuned to the X+ exciton, we are able to investigate the coherence of the hole remaining in the dot following electron tunnelling. [2] The hole is initialised in the state determined by the circular polarization of the initialisation pulse. Rabi flopping is observed for a cross-polarized control pulse, with the 2π rotation equivalent to a Z gate. The final state of the hole spin is read out by measuring the photocurrent generated when the hole tunnels out of the dot.

With the pump pulse tuned to the biexciton energy, it is possible to use the four-level exciton/biexciton system as a two qubit register, with the qubits differentiated by their polarization. [3] This forms the basis of an optically gated two-qubit controlled-rotation (CROT) quantum logic gate. The fidelity of the gate is determined to be 0.87$\pm$0.04.

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Protein dynamics

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Proteins are complex systems that connect biology, biophysics, biochemistry, chemistry, physics, and even mathematics. Proteins share similarities with supercooled liquids and glasses, such as frustration, the existence of an energy landscape, and alpha and beta fluctuations. They are, however, far more complex and they can be modified and studied in much more detail. Protein research therefore has not only impact in the life sciences, but also in other fields The beautiful pictures of protein structures that appear in many publications often create the impression that proteins are rigid and function independently of their environment. Proteins are, however, surrounded by hydration water and they are embedded in a bulk solvent. We have found a model that relates the motions in the hydration shell and the bulk solvent to the motions in the protein. The model is based on an energy landscape and motivated by experiments with myoglobin that separately monitor the external and internal fluctuations over a broad temperature range. The data show that the alpha fluctuations of the bulk solvent drive the large-scale protein motions and that the beta fluctuations of the hydration water drive the internal protein motions. The model assigns clear functional roles to the bulk solvent and the hydration water and it has predictive power; the fluctuations in the hydration water forecast the internal protein fluctuations. These results hint that the protein surface is functionally as important as the interior. The data and the model suggest new experiments and prove that there is no "dynamic transition" near 200 K in proteins.

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L36

Nonequilibrium dynamical mean-field theory

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In this presentation, I will detail how dynamical mean-field theory can be extended to nonequilibrium situations corresponding to the Keldysh boundary problem: the system is initialized in equilibrium at a given temperature and then a field is turned on. We then follow the transient response until we reach the steady state.

I will use the quenching of Bloch oscillations due to many-body interactions as a specific example of the formalism. We can solve the full problem for the Falicov-Kimball model in a uniform electric field turned on a specific time. We can also solve for the many-body DOS of the Hubbard model in the steady state.

Some of the interesting phenomena we find includes the following: (i) we show how the Wannier_Stark ladder evolves in one of two ways—for small fields, the delta functions broaden, then the minibands merge, and finally the DOS starts to look like the equilibrium DOS at large U—for large fields, the delta functions broaden, but also split by U, until the minibands merge and the DOS also starts to look like the equilibrium result at large U; (ii) we show how the Bloch oscillations are quenched and develop irregular oscillations when one passes through the Mott transition; and (iii) we show how the current develops beats for large fields and small interactions.

I will also discuss remaining open issues in the field, primarily related to the steady state distribution functions and whether they can be directly found in the steady state or only in a transient-based formalism.

The original work on the quenching of Bloch oscillations can be found in Refs. [1] and [2]. Ref. [3] is a mini review.

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Decoherence in quantum devices due to low-frequency noise of environment: Role of non-Gaussian effects

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We present a review of our recent activity on theory of decoherence of a qubit in the environment consisting of two-state fluctuators, which experience transitions between their states induced by interaction with thermal bath. Due to interaction with the qubit the fluctuators produce 1/f-noise in the qubit's eigenfrequency. We calculate the results of qubit manipulations - free induction and echo signals - in such environment. The main problem is that in many important cases the relevant random process is non-Gaussian. Consequently the results in general cannot be represented by pair correlation function of the qubit eigenfrequency fluctuations. Our calculations are based on analysis of the density matrix of the qubit using methods developed for stochastic differential equations. For the case of a qubit interacting with a single fluctuator we evaluate explicitly an exact expression for the phase-memory decay in the free induction and echo experiment with a resonant ac excitation. The echo signal as a function of time shows a sequence of plateaus. The position and the height of the plateaus can be used to extract the fluctuator switching rate γ and its coupling strength v. The plateaus disappear when decoherence is induced by many fluctuators. In this case the proper generating functional is then averaged over different fluctuators using the so-called Holtsmark procedure. Hence, the echo signal depends on the distribution of the fluctuators parameters. According to our analysis, the results significantly deviate from those obtained in the Gaussian model. The analytical results are compared with simulations allowing checking accuracy of the averaging procedure and evaluating mesoscopic fluctuations.

We also propose a theoretical interpretation of the recent experiments on the T_1-relaxation rate in Josephson charge qubits. The experimentally observed reproducible nonmonotonic dependence of T_1 on the splitting E_J of the qubit levels suggests further specification of the previously proposed models of the background charge noise. From our point of view, the most promising is the "Andreev fluctuator" model of the noise. In this model the fluctuator is a Cooper pair that tunnels from a superconductor and occupies a pair of localized electronic states. Within this model one can naturally explain both the average linear $T_1(E_J)$ dependence, quadratic temperature dependence, as well the irregular fluctuations. Hence, the results allow understanding several observed features of the echo decay in Josephson qubits.

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Weak values in solid state

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The measurement of any observable in quntum mechanics is a probabilistic process described by the projection postulate [1]. Each eigenvalue of the observable happens to be an outcome of the measuremt process with a given probability, and the original state of the system collapses into the corresponding eigenstate. Weakly measuring an observable (i.e., measuring it while weakly disturbing the system), provides only partial information on the state of the system. It has been proposed [2,3] that a two-step procedure –weak measurement followed by a strong one, where the outcome of the first measurement is kept provided a second post-selected outcome occurs- leads to a weak value. The value of the latter may lie well beyond the range of projective measurements. Weak values allow us into an arena of correlations of noncomuting variables that has not been manifestly accessible before. Proposals to measure weak values within the framework of solid state physics emerged only recently [4,5].

Here we review some of the ideas associated with weak values. We will show [6] how implementing this concept vis-a-vis the physics of Mach-Zehnder interferometry allows for a full tomography of the weak values. Also we will point out how many-body facets of the the physics invovled affect the observation of weak values.

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Projection operator approach to transport and relaxation in closed quantum systems

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Projection operator methods are wellknown in the context of open quantum systems, i.e., systems coupled to infinite environments. We present an altenative application of those methods which allow for the investigation of the dynamcis of systems coupled to finite environments, as well as for the investigation of the dynamcis of certain observables in closed systems. An example for the latter is the analysis of lengthscale dependent transport in the 3-D Anderson Model. It turns out that higher oder terms in the projection expansion may play a crucial role. Eventually we would like to comment on the relation between the condition on initial states and typicality.

L40

Towards understanding quantum correlations: New Bell tests and simulating partial entanglement with nonlocal boxes

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Quantum correlations are very peculiar, especially those violating some Bell inequality. Gaining a deeper insight into such nonlocal quantum correlation is a grand challenge.

We present experimental results on tests of Bell nonlocality and its (im)possible connections to gravitionally induced collapse of the quantum state and to hypothetical universal privileged reference frames

Children gain understanding of how their toys function by dismantling them into pieces. We shall follow a similar approach. We shall decompose the quantum correlations into simpler, more elementary, nonlocal correlations. Specifically, we like to present a model simulation of von Neumann measurements on arbitrary partially entangled states of two qubits. We shall also discuss Leggett's model and understand why it is incompatible with quantum predictions. This work is part of the general research program that looks for nonlocal models compatible and incompatible with quantum predictions. The goal is to find out what is essential in quantum correlations.

Decay of metastable states driven by non-Gaussian noise

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Currently, there are experimental efforts at various laboratories to measure higher order current noise cumulants of electronic nanostructures. A promising strategy employs on-chip Josephson junctions as noise detectors [1,2]. The non-Gaussian nature of the noise generated by the electronic nanostructure modifies the switching rate of the Josephson junction out of the zero voltage state, and the noise cumulants can be extracted from this modification. The data analysis requires a detailed understanding of the escape rate from a metastable well in presence of non-Gaussian noise. In the classical limit, when the escape arises from noise activation over the barrier top, the modification of the Arrhenius law caused by non-Gaussian noise can be determined from a path integral representation based on a generalized Onsager-Machlup functional [3]. In the quantum limit, when the system escapes from the metastable well by quantum tunnelling, the rate modification can be investigated by means of an extended Caldeira Leggett approach [4]. These methods are outlined and the associated strategies to measure the third and forth noise cumulants are discussed.

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L42

Quantum measurement without Schrödinger cat states

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A quantum measurement involves an object $\mathcal{S}$ and an apparatus; the latter may be idealized to a single-freedom pointer $\mathcal{P}$ interacting with a many-body bath $\mathcal{B}$. The interactions within the three-partite system $\mathcal{S} \oplus \mathcal{P} \oplus \mathcal{B}$ must

(i) entangle $\mathcal{S}$ and $\mathcal{P}$ (associating different eigenvalues of the measured object observable with macroscopically distinct pointer displacements) and

(ii) decohere the macroscopically distinct pointer states through the action of $\mathcal{B}$.

A class of models will be presented which display the behavior just outlined. In particular, emergence and decoherence of distinct pointer displacements can be allowed to proceed simultaneously such that a mixture of macroscopically distinct states arises directly, without any intermediate macroscopic superposition.

Special models involving harmonic oscillators allow for rigorous solutions of the Schrödinger equation of $\mathcal{S} \oplus \mathcal{P} \oplus \mathcal{B}$. A much wider model class is amenable to explicit solution in the limit where the time scales for emergence and decoherence of macroscopically distinct states are small compared to the characteristic times of the free motions of $\mathcal{S}, \mathcal{P}$ or even $\mathcal{S}, \mathcal{P}, \mathcal{B}$.

Advances in ion trap quantum computation

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The idea to use a controllable quantum mechanical system as a “computer” for the simulation of another quantum mechanical system has first been formulated by Richard Feynman [1] in 1982. Since the finding of P. Shor that the factoring of large numbers could be achieved much more efficiently on a quantum mechanical computer than with any known algorithm using classical computation [2], the prospect of building such a quantum mechanical machine is fascinating a large number of people. Many research groups throughout the world are working on different implementations, ranging from nuclear spins in molecules over quantum dots and colour centres to various coupling schemes with captured ions and atoms.

Today, trapped ions are certainly one of the most advanced prototypes of such a quantum computer. In our lab, we use a string of $^{40}Ca^{+}$ ions in a Paul trap to encode and to process quantum information in the electronic and vibrational states of the ions [3].

In the past, text book experiments like deterministic teleportation of a quantum state and the entanglement of up to eight ions [4] have been achieved in this setup. This presentation will give an overview over our system and will highlight the most recent advances. On one hand, the fidelity of a two-qubit operation could be pushed above the 99% threshold [5]. On the other hand, new operations have been developed that involve more than two ions. With a new composite pulse scheme a three-qubit Toffoli gate was implemented, a gate that would require five concatenated CNOT operations. Furthermore, superpositions of Fock states were created, that can be used to efficiently generate GHZ states of four ions and possibly more.

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Normal metal - superconductor tunnel junction as a Brownian refrigerator

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Thermal noise generated by a hot resistor (resistance R) can, under proper conditions, catalyze heat removal from a cold normal metal (N) in contact with a superconductor (S) via a tunnel barrier. Such a NIS junction acts as Maxwell's demon, rectifying the heat flow. Upon reversal of the temperature gradient between the resistor and the junction the heat fluxes are reversed: this presents a regime which is not accessible in an ordinary voltage-biased NIS structure. We obtain analytical results for the cooling performance in an idealized high impedance environment, and perform numerical calculations for general R. We conclude by assessing the experimental realization of the proposed effect.

L45

New nanoscale materials and devices

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Nanoscale science and engineering (NSE) encompasses materials and processes and their utilization at the atomic, molecular or macromolecular level in the length scale of approximately 1 to 100 nm. Because of their size, nanomaterials often have novel properties and functions. The size also demands innovative fabrication methods to create structures and devices which take advantage of these new properties. Hence NSE has evolved into a realm of it own. The advent of NSE has opened up new vistas of applications from cancer prevention in health science to new devices in electronics and highly efficient solar cells. This paper discusses the some opportunities and challenges of nanoscale materials and devices. Special emphasis in the discussion of promising nanomaterials is given to the physics of the two-dimensional allotrope of carbon, graphene. Devices based on graphene and on carbon's one-dimensional allotrope, carbon nanotubes, are discussed. Some devices based on other promising nanostructured materials useful in medical science are also detailed.

L46

Effect of pair-breaking on mesoscopic persistent currents far above the superconducting Tc.

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We consider the mesoscopic normal persistent current (PC) [1,2] in a very low-temperature superconductor with a bare transition temperature much smaller than the Thouless energy. To resolve the long-standing discrepancy between the theoretical [3,4] and experimental [2] values for the magnitude of the average currents for the noble metals, we capitalize on the recent finding [5] that these metals almost always have some magnetic impurities which dominate their dephasing rates at low T. We show that in a rather broad range of pair-breaking rate, much larger than the bare transition temperature, but much smaller than the Thouless scale, the transition temperature is renormalized to zero, but the PC is hardly affected. This increases the predicted magnitudes of the PC and may provide an explanation for the values (and signs) of the average PC's in the noble metals, as well as a way to determine their "bare" transition tempertures (those that would exist without the pair-breaking magnetic impurities). This work can be found in Cond-Mat 0804.0702 and Phys. Rev. Lett., to be published.

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L47

Quantum Brownian motion and the third law of thermodynamics

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In thermodynamics, within a canonical description, the system is coupled to a heat bath to fix the temperature. Despite the necessity of this coupling, it is assumed that the coupling strength can be taken as zero. From a fundamental perspective but also in view of the advances in mesoscopic physics it is interesting to reconsider the situation in the presence of a finite coupling between system and heat bath. It turns out that in the quantum regime the definition of thermodynamic functions of the system is no longer unique [1]. This can be demonstrated explicitely by considering the damped harmonic oscillator and the free Brownian particle. The latter is particularly interesting in view of the third law of thermodynamics, because for vanishing coupling the free particle remains classical down to the lowest temperatures. This, however, implies that the specific heat keeps its classical value of $k_B/2$ and thus violates the third law. For finite coupling between the free particle and the heat bath, however, the third law is recovered. Then, a specific heat increasing linearly with temperature is obtained [1].

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L48

Weak values and the Leggett-Garg inequality in solid-state qubits

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The seminal paper of Aharonov, Albert, and Vaidman introduces the concept of a weak value as a statistical average over realizations of a weak measurement, where the system is both pre- and post-selected. By taking restricted averages, weak values can exceed the range of eigenvalues associated with the observable in question. We discuss how to implement a weak values measurement with solid-state qubits based on continuous current measurements from a quantum point contact. In parallel activity, Leggett and Garg have devised a test of quantum mechanics for a single system using different ensembles of (projective) measurements at different times and correlation functions of those outcomes. The original motivation was to test if there was a size scale where quantum mechanics would break down. Introduced as a "Bell-inequality in time", the assumptions of macrorealism that could be verified by a non-invasive detector imply that their correlation function obeys a Leggett-Garg inequality that quantum mechanics would violate, formally similar to the inequality of Bell. We demonstrate that the proper notion of a classical weak value also demands these assumptions, and that furthermore a weak value can be non-classical if and only if a Leggett-Garg inequality can also be violated. We will discuss generalized weak values, where post-selection occurs on a range of weak measurement results. Our analysis is presented in terms of kicked quantum nondemolition measurements on a quantum double-dot charge qubit.

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The second law of thermodynamics and quantum heat engines: Is the law strictly enforced?

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A quantum heat engine is a construct in which its working medium is cyclically processed through phase space coordinates of a pair of variables of state, involving a Bose-Einstein (B-E) condensation in which an energy input is converted into a work output. Of interest is a first specie of quantum heat engines in which the working medium is a macroscopic collective (i.e., the size scale is sufficiently large that the B-E condensation is volumetrically incoherent), where the B-E condensation involves first order phase transitions, and the variables of state have differing relaxation times. In the first specie of quantum heat engines, Carnot efficiencies are but a dream. Of particular interest is a second specie of quantum heat engines in which the working medium is a mesoscopic singularity (i.e., the size scale is sufficiently small that the B-E condensation is volumetrically coherent), where the first order phase transitions of the B-E condensation involve the variables of state having different relaxation times. In the second specie of quantum heat engines, the resulting in-process nonequilibrium condition affects the finally arrived at phase space coordinates such that Carnot efficiencies and beyond may be more than a dream. A Type I superconductor is used to real-world model the first and second species of quantum heat engines.

L50

QM as approximative probabilistic model

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We show that the mathematical formalism of quantum mechanics can be interpreted as a method for approximation of classical (measure-theoretic) averages of functionals depending of classical fields. Such functionals are classical physical variables in our model with the field-type hidden variables – Prequantum Classical Statistical Field Theory (PCSFT). We provide a simple stochastic picture of such a quantum approximation procedure. In the probabilistic terms this is nothing else than the approximative method for computation of averages for functions of random variables. The role of a classical random variable is played by a random field. In PCSFT we consider Gaussian random fields representing random fluctuations at the prequantum time scale. Quantum mechanical expression for the average (given by the von Neumann trace formula) is obtained through moving from the prequantum time scale to the quantum one (the scale at that we are able to perform measurements).

The main experimental prediction of PCSFT is that probabilistic laws of QM (based on Born's rule) are only approximations of classical probabilistic laws for random fields. Thus QM gives only an approximative probabilistic description. PCSFT provides the magnitude of deviation of QM approximation from the random field model. By approaching finer time scales one might find (if PCSFT is correct) violation of QM laws. Unfortunately, since we do not know (at the moment) the time scale of fluctuations of the prequantum field, we are not able to predict at what experimental time scale laws of QM would be violated.

Third quantization

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The description of vortex and defect ensembles requires the introduction and quantization of multivalued fields. This requires a new set of gauge fields which are superpositions of Dirac delta functions on lines, surfaces, and volumes. The properties of these ”third-quantized fields” will be discussed in my lecture which is a short survey over my new book on this subject.

L52

Decoherence due to contacts in ballistic nanostructures

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In nanoscale, quasiballistic semiconductor structures under bias, the process of relaxation towards a nonequilibrium steady state cannot be attributed to scattering within the active region, because the active region is smaller than the carrier mean free path. Rather, the active region behaves as an open quantum-mechanical system that exchanges particles and information with the contacts. In this paper, a new approach [1] for the treatment of carrier transport in nanostructures and small semiconductor devices is presented. There are two defining features of the present approach:

(1) The model interaction Hamiltonian between the active region and the contacts differs from those employed previously [2]. It is specifically constructed to conserve the current during the process of carrier injection from/into the contacts, and its matrix elements are readily calculated from the single-particle transmission problem, for structures with and without resonances alike.

(2) In the absence of scattering in the active region, it is the rapid energy relaxation due to electron-electron scattering in the contacts that is the indirect source of irreversibility in the evolution of the current-limiting active region. The contacts' energy relaxation occurs on timescales significantly shorter than those characteristic for the active region's response, so the contacts can be considered memoryless. In fact, the model of memoryless current-carrying contacts is complementary [1] to the well-known model of voltage probes [3].

A Markovian dynamical map is derived for the evolution of the statistical operator of a nanostructure's active region, coupled to memoryless contacts via the model interaction Hamiltonian. Analytical expressions are derived for the nonequilibrium steady-state distribution functions for a generic two-terminal nanostructure, and used to obtain the steady-state I-V curves for the cases of a resonant-tunneling diode and an nin diode. We also discuss the relationship between the present approach and other formalisms. Natural extensions of this work are the inclusion of scattering, a generalization to multi-terminal structures with both current-carrying and voltage probes, and lifting the Markovian approximation in order to track the full non-Markovian nature of transients. This work has been supported by the NSF, award ECCS-0547415.

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Dissipative Landau-Zener tunneling in circuit QED and nanomagnets

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The coupling of a qubit to a harmonic oscillator can induce Landau-Zener transitions of the qubit upon switching its energy splitting. The adiabatic energies of the qubit-oscillator setup are characterized by multiple exact and avoided level crossings, so that the usual two-level Landau-Zener formula is no longer applicable and needs to be generalized. Our generalization is based on selection rules for multi-level transitions and provides an exact expression for the bit-flip probability [1]. Moreover, it allows one to solve the dissipative Landau-Zener problem with both a harmonic-oscillator bath and a spin bath at zero temperature [2]. Applications range from single-photon generation in circuit-QED to the measurement of tunnel splittings in molecular nanomagnets.

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L54

Nonlinear and quantum plasmonics

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High power femtosecond lasers can be effectively used to study non-linear processes in surface plasmon (SPO) excitation. Int the present study 45nm gold films were used and the SPO-s were excited in the Kretschman geometry. The light emitted by these SPO-s is observed to be strongly directed around angles near to the surface and the mean angle depends ont he grain structure of the surface. The spectral distribution of this light is narrower than that of the exciting laser light and depends on the power density of it, getting narrower when the laser power is increased.

Near field surface plasmon STM images were also studied. Their statistical analysis shows sub-Poissonian distribution.

Both type of observations indicate some non-classical properties of SPO-s. A theoretical attempt to explain these observations is also given.

Control of non-Markovian quantum thermodynamics

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Heat flow between a large "bath" and a smaller system brings them progressively closer to thermal equilibrium while increasing their entropy. Deviations from this trend are fluctuations involving a small fraction of a statistical ensemble of systems interacting with the bath: in this respect, quantum and classical thermodynamics are in agreement. Can there be drastic differences between them? Here we address a distinctly quantum mechanical setting that displays such differences: disturbances of thermal equilibrium between two-level systems (TLS) and a bath by frequent and brief quantum (non-demolishing) measurements of the TLS energy-states. If the measurements are frequent enough to induce either the Zeno or the anti-Zeno regime, namely, the slowdown or speedup of the TLS relaxation, then the resulting entropy and temperature of both the system and the bath are found to be completely unrelated to what is expected by standard thermodynamical rules that hold for memoryless baths. The practical advantage of these anomalies is the possibility of very fast control of heat and entropy, allowing cooling and state-purification of quantum systems much sooner than their thermal equilibration time[1].

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L56

Quantum networking with atomic ensembles in the single excitation regime

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Beyond a fundamental significance, control of entanglement between material systems is an essential capability for quantum networks and scalable quantum communication architectures. In recent years, significant advances have been achieved in the control of the quantum states of atomic systems, including entanglement of trapped ions or atoms and between macroscopic quantum spins. This talk will focus on the generation of entanglement between atomic ensembles in the single excitation regime. Two different approaches will be presented.

First, by following the seminal paper of Duan, Lukin, Cirac and Zoller (DLCZ) [1], entanglement between single collective excitations stored in two remote atomic ensembles can be generated. In the DLCZ protocol, entanglement is created in a probabilistic but heralded way from quantum interference in the measurement process. The detection of a photon from one or the other atomic ensemble in an indistinguishable fashion results in an entangled state with one collective spin excitation shared coherently between the ensembles. Quantitative characterizations, for the scaling behavior of entaglement with the excitation probability and for the temporal dynamics of various correlations resulting in the decay of entanglement, will be presented [2]. Such entanglement has been used for the initial implementation of functional quantum nodes for entanglement distribution involving four atomic ensembles [3] and for the investigation of matter-matter entanglement swapping [4].

In parallel with the previous probabilistic approach, we also demonstrated a protocol where entanglement is created by reversible mapping of an entangled state of light by EIT [5]. On demand, the stored entanglement is converted back into entangled photonic modes. The degrees of entanglement for input and output states are explicitly quantified, with the transfer efficiency of entanglement approaching 20%. Unlike the previous scheme, this approach is inherently deterministic. Moreover, separating the processes for the generation and storage of entanglement, the contamination of the atomic entanglement due to multiple excitations can be arbitrarily suppressed with advances in on-demand single photon sources.

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Quantum wire hybridized with a side-attached impurity

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We consider low-temperature properties of interacting electrons in a one-dimensional quantum wire (Luttinger liquid) side-hybridized with a single-level impurity. The hybridization induces a back-scattering of electrons in the wire which strongly affects its low energy properties. Using a one-loop renormalization group approach and functional bosonization valid for a weak electron-electron interaction, we have calculated a transmission coefficient through the wire, and a local density of states at low energies. In particular, we have found that the antiresonance in the transmission coefficient has a generalized Breit-Wigner shape with the effective width which has a power-law divergence at the Fermi level.

L58

Multiscale motility of molecular motors

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The activity of molecular motors leads to several distinct motility regimes that will be addressed in this talk:

(i) The network of motor cycles arising from the chemomechanical coupling between ATP hydrolysis and mechanical work. These networks have to satisfy balance conditions that apply to chemical and/or mechanical nonequilibrum arbitrarily far from equilibrium and impose constraints on the transition rates between the different motor states. [1] When applied to conventional kinesin, a detailed comparison of theory and experiment reveals that this motor is governed by three distinct chemomechanical cycles [2];

(ii) Cooperative cargo transport by several motor molecules. This process can be modelled via a network of cargo states which differ in the number of actively pulling motors. If all motors belong to the same molecular species, the cooperative action of the motors leads to strongly increased run lengths and to a characteristic force dependence of the velocity distributions [3]. If two antagonistic species of motors pull on the cargo, they perform a tug-of-war which induces up to seven distinct patterns of bidirectional transport [4]; and

(iii) Motor traffic arising from the transport of many cargo particles or filaments. These phenomea include: build-up of traffic jams; active pattern formation leading to steady states with spatially nonuniform density and current patterns; and traffic phase transitions between different steady states far from equilibrium [5,6]. Nonequilibrium phase transitions also occur in gliding assays in which the motors are immobilized on a substrate surface and pull many filaments across this surface [7].

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Negative conductances in Josephson junctions

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One can hold a Josephson junction to be a hallmark of quantum physics. It belongs to a class of the best devices which display a quantum world at the macroscopic level. It is of a wide range of diverse applications, e.g., the Josephson junction is used for voltage standards. Devices based upon the characteristics of a Josephson junction are valuable in high speed circuits: they can be designed to switch in times of a few picoseconds. Their low power dissipation makes them useful in high-density computer circuits where resistive heating limits the applicability of conventional switches. Josephson junction devices can store single units of information (qubits) and show great promise for implementation in a future architecture of quantum information. With the Josephson qubits we are one-step closer to realization of a practical multi-qubit quantum computer.

Yet, still there are unexplored new phenomena ”hidden” in this system which can result in new applications. One of such a new phenomenon is absolute negative conductance: for small positive (negative) dc current, the voltage across the junction is negative (positive). This constitutes no contradiction to thermodynamic laws because it occurs in presence of non-equilibrium ac-driving. This novel transport phenomenon is identified in chaotic regimes. The dependence of the voltage across the junction on the dc-current exhibits other anomalous transport characteristics: the occurrence of negative differential conductance and the emergence of a negative nonlinear conductance far from zero dc-bias.

L60

Quantum thermodynamic processes

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Thermodynamics may be characterized as a control theory, combining mechanical and statistical features. It is shown that thermodynamic concepts and processes can be introduced that are essentially valid from macroscopic steam engines down to individual spins. Carnot,-Otto- and other cycle types as well as heat engines or heat pumps can be introduced. Non-equilibrium, which is generated as the cycle speed increases, eventually leads to a degradation of machine function.

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Temperature transformation and Mosengeil-Ott's antinomy

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A not satisfactorily solved problem of relativistic transformation of temperature and other thermal quantities playing the decisive role in relativistic quantum physics and cosmology is reopened. It is shown that the origin of the so called Mosengeil-Ott's antinomy [1,2] and other aligned paradoxes is related to the wrong understanding of physical meaning of temperature, Planck's Ansatz of Lorentz's invariance of entropy [3] and to the non-critical application of conceptual basis of classical thermodynamics based on Joule-Mayer's postulate of equivalence of energy and heat [4]. In the contribution there are thus anew analyzed and reintroduced the fundamental concepts of hotness manifold [5], temperature and entropy-like heat [6]. Further, the Lorentz invariance of temperature (cf. [7,8]) and relativistic transformations of the other thermal and corresponding quantum-statistical quantities are established on the basis of phenomenological arguments.

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L62

Work as tracer of the force that generates the geometric phase

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When a quantum system adiabatically evolves in a cyclic way, its wave function acquires a phase factor, the Berry phase. It is a geometric phase which can be measured via interference.

In this presentation we consider a quantum system coupled to two work sources (classical systems). The couplings to the sources vary in a cyclic way but not adiabatically slow.

For near adiabatic cycles, no work is done on the system, but a transfer of work occurs between the two work sources. We show that the Berry force (geometrical force) can be mapped out from the relatively fast parts in the still slow cycles.

For less adiabatic cycles, transitions between the energy levels occur. The work done on the system can be separated into coherent and incoherent parts, related to the geometric phase and energy level transitions, respectively. The leading part of this work can be expressed in terms of the geometrical force while the rest defines a non-adiabatic correction to it.

We discuss both the non-degenerate and the degenerate cases.

Event-based computer simulation of Wheeler's delayed choice experiment with photons

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We present a computer simulation model [1] of Wheeler's delayed choice experiment that is a one-to-one copy of an experiment reported recently (V. Jacques et al., Science 315, 966 (2007)). The model is solely based on experimental facts, satisfies Einstein's criterion of local causality and does not rely on any concept of quantum theory. Nevertheless, the simulation model reproduces the averages as obtained from the quantum theoretical description of Wheeler's delayed choice experiment. Our results prove that it is possible to give a particle-only description of Wheeler's delayed choice experiment which reproduces the averages calculated from quantum theory and which does not defy common sense.

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L64

Supermassive black holes as giant Bose-Einstein condensates

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Supermassive black hole occur in the center of probably each galaxy. The champion embodies 18 billion solar masses, has a radius of one light day and a density comparable to that of air.

The Schwarzschild metric has in the standard gauge a hitherto overlooked divergent gravitatonal energy density at the horizon, which motivates a new approach to black holes.

If matter is spread uniformly throughout the interior of a supermassive black hole, with mass $M \sim M_\star = 2.34\,10^8 M_\odot$, it may arise from a Bose-Einstein condensate of densely packed H-atoms.

Within the Relativistic Theory of Gravitation with a positive cosmological and bimetric constant, a bosonic quantum field is coupled with an adjustable strength to the curvature scalar. In the Bose-Einstein condensed groundstate an exact, selfconsistent solution for the metric is presented. It is regular everywhere with a specific shape at the origin. The redshift at the horizon is finite but large, $z \sim 10^{14} M_\star/M$.

The BH has "one hair": the binding energy remains as an additional parameter that depends on the formation history; alternatively, the mass observed at infinity can be any fraction of the rest mass of the constituent hydrogen.

If confirmed, this approach opens the door for the description of hairy black holes. The existence of a magnetic hair has been reported by Schild, Leiter and Robertson (Astronomical Journal 132 (2006) 420).

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Shot noise probing of spin decoherence in quantum transport through spintronic nanostructures

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The second generation of spintronic devices, where classical or quantum information is encoded into electron spin orientation rather than a pool of charge, will have to rely on spin coherent phenomena. In addition, building such devices around semiconductor technology, which does not couple well with ferromagnetic elements, has led recently to the emergence of the concept of all-electrical semiconductor spintronics where spin is manipulated by electrical fields through exploitation of spin-orbit (SO) couplings in solids. However, effective magnetic fields of SO couplings, being momentum dependent, are also responsible for one of the major routes for spin dephasing and decoherence.

By viewing current in the detecting lead of a spintronic device as being an ensemble of flowing spins corresponding to a mixed quantum state, where each spin itself is generally described by an improper mixture generated during the transport where it couples to other degrees of freedom, we introduce the spin-density operator associated with such current and express it in terms of the spin-resolved scattering matrix of the device [1]. This formalism, which provides a complete description of coupled spin-charge quantum transport in open finite-size systems attached to external probes, provides transparent explanation how the decay of the off-diagonal elements of the current spin-density matrix is caused by the entanglement [1] of spin to an effectively zero-temperature "environment" composed of open orbital conducting channels (decoherence). Additional decay is caused by averaging over many conducting channels (dephasing), even when spin-orbit nonequilibrium entanglement is absent [2]. By extending the same framework of the scattering approach to quantum transport in nanostructures, we treat spin-resolved zero-temperature time-dependent current fluctuations (the so-called shot noise) while including the full spin-density matrix of electrons injected from a spin filtering or ferromagnetic electrode into a quantum-coherent nanostructure governed by arbitrary spin-dependent interactions [3]. This formalism reveals that any spin flip (instantaneous or continuous precession) can lead to noise enhancement. Remarkably enough, the enhancement is in one-to-one correspondence with the magnitude of the spin-polarization vector extracted from the current spin density matrix introduced by Ref. [1]. Thus, we predict that one can probe decoherence of transported spin states with simple electrical noise measurements in a ferromagnet/SO-coupled-wire/paramagnet set up [3].

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L66

Counting statistics of non-Markovian quantum stochastic processes

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We derive a general expression for the cumulant generating function (CGF) of non-Markovian quantum stochastic transport processes. 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.

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How do pulsed lasers affect photon correlation and entanglement?

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The peculiar nature of quantum world manifests through entanglement and quantum correlation. These nonclassical concepts are are mathematically related [1] but the physical mechanisms that create quantum correlation and entanglement may be different and not well understood. Here, we study the effects of pulsed laser excitations on the nonclassical properties. Extension of photon correlation study in amplifier from continuous wave regime [2] to pulsed regime would be rewarding because it produces a new kind of light source, i.e. intense broadband correlated photon pairs.

We have developed a theoretical method (applies to any atomic scheme) to obtain the exact transient solutions of the Langevin field operators for photon pairs produced by an atom driven in a double Raman scheme [3] by arbitrary laser pulses. The method enables us to study the effects of pulsed excitations on nonclassical photon correlation, entanglement condition [4] and the role of quantum noise. We find that short laser pulses with appropriate chirping, pulse sequence, delay and detuning generate broadband photon pairs and yield very large nonclassical photon correlation. In particular, chirping of the pump and the control lasers in an opposite manner increases the correlation. The correlation further increases for partially overlapping pulses. We provide explanations on how the spectral content and large bandwidth of the laser pulses can conspire to enhance the photon correlation.

The initial condition of the atom also affects the photon correlation and entanglement. Pulse area [5] concept is invoked to explain the oscillations of the transient entanglement with pulse width and the laser field. It is found that the laser pulses tend to reduce the contribution of quantum noise to the photon number.

The results, accompanied by physical explanations, provide conceptual insights on how pulsed excitations affect nonclassical concepts (quantum correlation and entanglement) differently, and reinforce our understanding of the nature of quantum noise.

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L68

Coherent nanodevices as detectors of structured solid-state noise sources

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Coherent nanodevices are inevitably exposed to fluctuations due to the solid-state environment. Well studied examples are charged impurities and stray flux tubes which are sources of telegraphic noise in a wide class of metallic devices. Large amplitude low-frequency (mostly 1/f) noise, ubiquitous in amorphous materials, is also routinely measured in single-electron-tunneling devices. Recent experiments on Josephson qubits indicated that charged impurities may also be responsible for noise exhibiting an ohmic power spectrum at GHz-frequencies.

In this talk we will illustrate how solid state nanodevices may be used to infer characteristic features of the noise sources underlying the resulting relaxation and dephasing processes.

Typical signature of the presence of low frequency noise components is a non-exponential suppression of coherent oscillations, observed when repeated measurements are performed [1]. Single-shot measurement schemes or dynamical decoupling protocols inevitably suffer from the presence of fluctuations active during time evolution [2]. We propose a characterisation of the effects of bistable coherent impurities in solid state nanodevices and present an alternative perspective considering qubits as a measurement devices for the noise sources [3].Expected effects on complex multi-qubit architectures will be pointed out.

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Dynamics of the entanglement between two oscillators in the same environment

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We provide a complete characterization of the evolution of entanglement between two oscillators coupled to a common environment. For initial Gaussian states we identify three phases with different qualitative long time behavior: There is a phase where entanglement undergoes a sudden death (SD). Another phase (SDR) is characterized by an infinite sequence of events of sudden death and revival of entanglement. In the third phase (NSD) there is no sudden death of entanglement, which persist for long time. The phase diagram is described and analytic expressions for the boundaries between phases are obtained. These results are applicable to a large variety of non–Markovian environments.

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L70

Density matrice and their parametrization

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A new representation of density matrices on finite dimensional Hilbert spaces in terms of finitely many independent parameters is presented. For dimensions 2, 3, and 4 the parametrization is shown explicitely. A recursive scheme allows for the parametrization in higher dimensions. The suggested parametrization allows for the introduction of a class of postive maps, which might have useful applications in quantum information processing and communication.

Spin transport in double quantum dots: role of hyperfine interaction

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Spin Blockade has been recently observed in transport experiments in semiconductor double quantum dots[1-4]. It occurs as a consequence of the Pauli exclusion principle and it produces the quenching of the tunneling current. Thus, these devices could behave as externally controllable spin-Coulomb rectifiers with potential applications in spintronics. However, spin flip scattering induced by Hyperfine interaction gives rise to a finite current leakage which has been measured.

We have analyzed the electronic transport through a double quantum dot in dc magnetic fields in the regime where spin blockade occurs. Our model consists on rate equations for the electronic occupations and for the nuclei spin polarizations in the quantum dots in the presence of Hyperfine interaction. We discuss the current hysteretic behavior as a function of magnetic field, which is due to dynamical nuclear polarization induced by Hyperfine interaction [5].

Recent experiments of Electron Spin Resonance [6] show coherent spin rotations of a single electron in double quantum dots. Motivated by these experiments, we have analyzed as well the charge and spin dynamics in these systems under crossed ac and dc magnetic fields. The ac field produces coherent electron spin rotations within each quantum dot which compite with Rabi oscillations due to inter-dot tunnel, giving rise to a complicated time dependent behavior of the tunnelling current. We show that when the Zeeman splitting has the same value in both dots and spin flip is negligible, the electrons remain in the triplet subspace (dark subspace) performing coherent spin rotations and inter-dot tunnel Rabi oscillations and the current does not flow. This electronic trapping is removed either by finite spin relaxation or in the case where Zeeman splittings are different for each quantum dot [7]. Then, manipulating ac and dc magnetic fields electrons are driven to perform coherent spin rotations which can be detected by direct measurement of the tunneling current.

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L72

Entanglement theory, thermodynamics and the 2nd law

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It has long been suspected that there must be a unifying theory linking one of the oldest and most successful fields of physics (thermodynamics) with the theory of entanglement. Hints of such connections have been found in numerous places (see for example Bennett et al PRA '96, Popescu and Rohrlich, PRA '97, Horodecki et al PRL '99, Vedral and Kashefi, PRL '02, Horodecki et al PRL '02, Audenaert et al PRL '03). To date the indications of this conjectured unification have been either circumstantial or highly specific to very particular physical contexts.

Here we provide the first completely rigorous connection between these topics, in a manner which holds for any systems obeying some very basic physical laws [1,2].

The goal of entanglement theory is to develop a quantitative understanding of quantum entanglement and its manipulation under restricted class of operations. It is known that the manipulation of entanglement shares some fundamental analogies with the laws of thermodynamics. What remained as an important open question was the existence of a setting for entanglement theory fully equivalent to the second law. Guided by the concept of adiabatic processes in the context of the second law of thermodynamics, we have identified such a setting for entanglement theory and proved that it indeed leads to a remarkable simple and elegant theory for quantum entanglement. The connection we established is interesting not only on a foundational level, but also because it has important consequences: (i) it clarifies the origin of the phenomenon of bound entanglement in the manipulation of quantum information by local operations and classical communication; (ii) it constitutes an important new analysis tool in the study of entanglement, allowing the identification of several different entanglement quantifiers and a remarkable simplification in the study of entanglement shared among many parties; (iii) it opens up the possibility of considering resources theories of a thermodynamical character with new features, such as the existence of catalysis, providing important feedback from entanglement theory to the foundations of thermodynamics, (iv) the approach we suggest is capable of providing a unifying framework for all resource theories applicable to resources such as non-classicality and of the non-Gaussian character of quantum states. Other examples of resource theories where our techniques are likely to be useful are the study of super-selection rules and, even beyond quantum physics, the theory of secret correlations in classical cryptography [1,2].

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Physical and mathematical causality in quantum theory

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My point of departure in this paper is a common claim, arguably first made (in this form) by John von Neumann in his Mathematical Foundations of Quantum Mechanics, that the evolution of “a quantum state under the action of an energy operator is purely causal,” while a given state arising in the course of this evolution “undergoes in a measurement a non-casual change.” It is also at this juncture that von-Neumann considers “the principle of psycho-physical parallelism,” the subject of many philosophical discussions concerning quantum mechanics. The aim of this paper is to critically (re)examine this claim by arguing that, insofar as one can speak of the evolution in question as causal, or for that matter as ’evolution,’ it can only be seen in terms of “mathematical causality,” rather “physical causality.” In classical mechanics, by virtue of its descriptive characters, both forms of causality may be seen as coinciding. By contrast, in quantum mechanics and higher-level quantum theories, such as quantum field theory, they are essentially disconnected. It is, I shall argue, this disconnection, rather than a transition from a causal to a non-causal physical process that quantum-mechanicsqu reflects. It appears impossible to claim that quantum phenomena relate to any causal physical processes, or at least that these phenomena and quantum mechanics may be best interpreted in this irreducibly noncausal way. I shall suggest that von Neumann himself and others, in particular Dirac, who makes the same type of claims, do not necessarily disagree with this view. The problem instead is the necessity of a more careful definition of and discrimination between the key concepts involved, beginning, or perhaps ending, with the concept of quantum state, or indeed the concept of ’state’ itself, with Christopher Fuchs’s question: “Quantum States? What the Hell are They?” I shall also (re)examine the principle of psycho-physical parallelism from the perspective of this paper.

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Quantum computation with silicon: ultra-long decoherence and relaxation times in quantum systems

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We investigate the T_1 relaxation process of a Si quantum dot (QD) as well as singlet-triplet relaxation time, T_{ST} and decoherence time, τ_C. The main source of T_1 and T_{ST} processes is the hyperfine coupling (HC) with the nuclei of the ^{29}Si isotope, and occurs via a virtual state[1]. We note that in the presence of time reversal, the matrix elements for spin-flip due to spin-orbit coupling (SOC) are very small [2], causing, indeed, HC to be the dominant source of relaxation. Experimental results show indeed that T_{ST} is very large for Si QDs [3].

In presence of a magnetic field perpendicular to the plane of the 2DEG, $B_\perp$, relaxation process via SOC becomes important, hence shortening T_1. On the other hand, a magnetic field parallel, $B_{||}$, slows down these processes, as the energetic levels spread apart. Therefore the magnetic field effects are strongly anisotropic. Subsequent phonon emission guarantees energy conservation, making T_1 and T_{ST} a second-order process. As a result, T_1 and T_{ST} are about three orders of magnitude larger than for GaAs [4].

We then study the T_2 relaxation process of a Si double QD due to the nuclear HC. The difference of the effective magnetic field due to the anisotropy of the nuclear configuration in both QDs leads to decoherence. We consider here a prepared initial state at t=0 and calculate the time evolution, finding a coherence time, τ_C, orders of magnitude larger than the equivalent for GaAs.

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Entanglement in curved space time

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We discuss an alternative formulation of the problem of quantum optical fields in a curved space-time using localized operators. We contrast the new formulation with the standard approach and find observable differences for entangled states. We propose an experiment in which an entangled pair of optical pulses are propagated through non-uniform gravitational fields and find that the new formulation predicts de-correlation of the optical entanglement under experimentally realistic conditions.

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Quantum control of atomic and molecular systems

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When laser radiation interacts with atomic or molecular systems, it can induce chaos and new types of nonlinear dynamical structures in the phase space of the system, and thereby induce fundamental changes in the dynamics of the quantum system. We have found that it is possible to use these radiation induced dynamical structures as a basis for coherently controlling internal transitions in atomic and molecular systems.

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From quantum dots to cold atoms in traps - interaction blockade and vortices

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Many analogies exist between nanostructured quantum systems, and trapped, ultra-cold atom gases. Remarkably, phenomena such as Bose-Einstein condensation and coherent flow nowadays appear accessible for the micro- and nano-design of future quantum devices: a new road-map is presently being drawn in connection with the newly emerging research field of ”atomtronics”. We discuss how effects similar to Coulomb blockade in quantum dots will occur in small systems of ultracold, trapped atoms [1,2]. For rotating Bose-Einstein condensates, the occurrence of vortices has been much discussed. We find that, surprisingly, vortex formation is similarfor both (spinless) bosonic and fermionic particles, as for example electrons in quantum dots at strong magnetic fields [3]. Breaking the rotational invariance of the Hamiltonian of the system reveals the vortex patterns. A more general transformation from a many-fermion to a many-boson state is proposed [4]. We finally comment on vortices in multicomponent systems [5,6].

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L78

Mechanical manipulation of nucleic acids at 1kT energy resolution

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Optical tweezers use the optical gradient force generated by a focused beam of light acting on an object with index of refraction higher than that of the surrounding medium to impart sub-piconewton forces. The possibility to detect such tiny forces together with the ability of measuring extensions with sub-nanometer resolution allows to characterize the thermodynamics and kinetics of individual molecules (e.g. nucleic acids and proteins) within 1kcal/mol (or, equivalently, 1kT) energy resolution.

In this talk I will present results on the mechanical unfolding of DNA molecules and the determination of free energies of secondary structures with accuracy of 0.1kcal/mol energy resolution. I will also focus my attention on the possibility of sequencing DNA using mechanical force. Finally I will emphasize on the possibility to specifically design DNA sequences with complex free energy landscapes.

An ideal Bose-Einstein condensate: from precision measurements to Anderson localization

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We present our recent results on trapping a weakly interacting ^{39}K Bose-Einstein condensate (BEC) in optical lattices. The BEC is produced by sympathetic cooling with ^{87}Rb. The interactions between potassium atoms are sensitively tuned to almost zero by means of a broad magnetic Feshbach resonance [1]. In a first experiment, we realize an atom interferometer by loading the condensate in an optical lattice. We study Bloch oscillations of the non-interacting BEC, forced by the gravity [2]. The reduction of the scattering length between atoms strongly suppresses the interactions induced de-coherence which typically limits the performance of the interferometers based on trapped BEC, making our system the ideal candidate for measuring forces with high spatial resolution. In a second experiment, we instead study the ideal condensate loaded into a quasi-periodic optical lattice, generated by superimposing two standing waves with incommensurate wavelengths [3]. This system reproduces the Aubry-Andre' model [4] which presents a transition between extended to exponentially localized states. We clearly observe this transition by measuring the dynamics and the momentum distribution of the BEC trapped in this disordered potential [5]. Our possibility of adding the interactions in a controlled way will allow the study of the interplay between disorder and interactions which is still under debate and which is at the basis of novel quantum phases [6].

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L80

Simulating Hamiltonian evolution on a quantum computer

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Efficiently simulating arbitrary Hamiltonian evolution was the earliest motivating application for quantum computation, yet its algorithmic formulation is less advanced than those addressing search and factorization problems. Here we present an efficient quantum algorithm for simulating quantum state evolution for a sparse time-independent Hamiltonian in terms of computing its matrix elements.

For n qubits and at most a constant number of nonzero entries in each row, and a constant bound on the norm of the Hamiltonian, our algorithm cost is nearly linear in time and nearly constant in space [1]. We show how the algorithm can be adapted for efficiently simulating time-dependent Hamiltonian evolution of a state on a quantum computer with similar costs [2].

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Quantum impurity systems out of equilibrium: Real-time dynamics

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The description of strong electronic correlations far from thermal equilibrium is one of the outstanding open questions in the field of mesoscopic physics. Many of the theoretical approaches that have proven so successful in equilibrium are simply inadequate once the system is driven out of equilibrium. In this talk I will review our recent extension of Wilson's numerical renormalization-group approach to track the real-time dynamics of quantum impurities following the sudden application of a perturbation. Applications of the approach to spin and charge relaxation in ultrasmall quantum dots, decoherence of an impurity spin, and real-time dynamics in the spin-boson model will be discussed.

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The demon and the quantum: From thermodynamics to quantum mechanics and beyond

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We often hear phrases like quantum weirdness and the strange world of the quantum. A fact that is not so widely appreciated is that quantum mechanics can (and does) shed light on problems such as the Maxwell Demon Paradox of thermodynamics, the seemingly spiritual nature of information, and even, perhaps, new insights into the existence of Mind! The common denominator of all this is the fact that information is a real physical quantity. Information is more than something just in our mind, it is the essence of, and in many ways more general than the concept of entropy. By focusing on entropy, information, and observation, the authors bring a unique perspective to this subject, and offer insight into the strange ways of the quantum.

Using quantum mechanics to detect anthrax

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Counterintuitive effects such as amplification without noise and lasing without inversion are examples of quantum coherence. More recently, the study of quantum coherence effects has lead to improvements in laser spectroscopy which allow us to "instantaneously" detect anthrax type endospores.[1, 2] In the latter example, marker molecules in the endospore are put into maximal oscillation which is detected by scattering laser light off the coherently oscillating molecules. This is called coherent Raman scattering and is a type of Dicke superradiance. The preceding topics were tempered and advanced in the heat of vigorous debate.

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L84

Stochastic thermodynamics: Theory and experiments

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Stochastic thermodynamics provides a framework for describing small systems embedded in a heat bath and externally driven to non-equilibrium. Examples are colloidal particles in time-dependent optical traps, single biomolecules manipulated by optical tweezers or AFM tips, and motor proteins driven by ATP excess. A first-law like energy balance allows to identify applied work and dissipated heat on the level of a single stochastic trajectory. Total entropy production includes not only this heat but also changes in entropy associated with the state of the small system. Within such a framework, exact results like an integral fluctuation theorem for total entropy production valid for any initial state, any time-dependent driving and any length of trajectories can be proven [1]. These theoretical predictions have been illustrated and tested with experiments on a colloidal particle pushed by a periodically modulated laser towards a surface [2]. Key elements of this framework like a stochastic entropy can also be applied to athermal systems as experiments on an optically driven defect center in diamond show [3,4]. For mechanically driven non-equilibrium steady states, the violation of the fluctuation-dissipation theorem can be quantified as an additive term directly related to broken detailed balance (rather than a multiplicative effective temperature) [5]. Integrated over time, a generalized Einstein relation appears which we have recently verified experimentally [6]. Finally, optimal protocols are derived which (i) minimize the work required to switch from one equilibrium state to another in finite time [7] and (ii) maximize the power of stochastic heat engines operating between two heat baths [8].

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Novel physics with ultracold fermions

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Ultra cold Fermi gases are new interesting systems where one can discuss the formation of Cooper pairs, known from the Bardeen-Cooper-Schriefer theory of superconductivity. The composite bosons will be weakly bound molecules of fermions. One can go to the regime of strong interaction where a Bose-Einstein condensation of these bosons occurs. At short distances they ”remember” that they consist of fermions and manifest fermion statistics. This provides them with a remarkable collisional stability. After introducing these concepts, I will forecast what one can expect in mixtures of different Fermi gases.

L86

Nuclear spin ordering in interacting 2D and 1D electron liquids

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Is there some magnetic order of nuclear spins embedded in a 2D interacting electron gas ? In order to answer this question, we derive an effective magnetic Hamiltonian for the nuclear spins which is of RKKY type can be. It turns out that the interactions between the nuclear spins are strongly modified by the electron-electron interactions. The nuclear magnetic ordering at finite temperature relies on the (anomalous) behavior of the 2D static electron spin susceptibility, and thus provides a connection between low-dimensional magnetism and non-analyticities in interacting 2D electron systems. Using various perturbative and non-perturbative approximation schemes in order to establish the general shape of the electron spin susceptibility as function of its wave vector, we show that the nuclear spins locally order ferromagnetically, and that this ordering can become global in certain regimes of interest. The associated Curie temperature for the nuclear system increases with the electron-electron interactions up to the millikelvin range. We then follow similar ideas to study the magnetic order of nuclear spins in 1D interacting electron liquids such such as metallic ^{13}C carbon nanotubes where electron-electron interactions have an even stronger effect.

Nonadiabatic pumping of heat in electron systems

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We investigate a mechanism for extracting heat from metallic conductors based on the energy-selective transmission of electrons through a spatially asymmetric resonant structure subject to ac driving. This quantum refrigerator can operate at zero net electronic current as it replaces hot with cold electrons through two energetically symmetric inelastic channels. We present numerical results for a specific heterostructure and discuss general trends. We also explore the conditions under which the cooling rate may approach the ultimate limit given by the quantum of cooling power.

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Dynamics of mesoscopic systems: Non-equilibrium Green's functions approach

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Recent developments in technologies and experiments enable us to observe dynamical behaviour of very small quantum systems under conditions when it is sensitive to system parameters, internal interactions, the environment and the external time–dependent fields. This contribution deals with the status and perspectives of description of such truly non-equilibrium quantum many body systems using the non-equilibrium Green's functions (NGF) [1,2].

The basic aim of this approach is to describe time development of the many-body system out of equilibrium from its initial state over its transient dynamics to its very long time (if e.g. steady state exists), asymptotic evolution. The early stage of the transient evolution will be characterized for a broad class of the initial conditions. The gradual loss of initial correlations due to interactions and related renormalization processes in the system may, under favorable conditions, give rise to the evolution stage expressible in terms of non-equilibrium quasiparticle states [3]. This would enable us to simplify the description of the system behaviour. The consistency of such approximations for NGF may be judged by checking the non-equilibrium version of Ward identities [4]. These identities (in correspondence to the equilibrium case) follow from the gauge invariance of the 1st kind for NGF and are related to a renormalized multiplicative composion rule for NGF. To cover the whole time domain of the transient, we obtain the non-equilibrium Ward identities for NGF with initial conditions included.

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Dephasing in the electronic Mach-Zehnder interferometers

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We propose a simple physical model which describes dephasing in the electronic Mach-Zehnder interferometer [1]. This model explains very recent experimental results [2-6], such as the unusual lobe-type structure in the visibility of Aharonov-Bohm oscillations, phase rigidity, and the asymmetry of the visibility as a function of transparencies of quantum point contacts. According to our model, dephasing in the interferometer originates from strong Coulomb interaction at the edge of two-dimensional electron gas. The long-range character of the interaction leads to a separation of the spectrum of edge excitations on slow and fast mode. These modes are excited by electron tunneling and carry away the phase information. The new energy scale associated with the slow mode determines the temperature dependence of the visibility and the period of its oscillations as a function of voltage bias. Moreover, the variation of the lobe structure from one experiment to another is explained by specific charging effects, which are different in all experiments. We propose to use a strongly asymmetric Mach-Zehnder interferometer with one arm being much shorter than the other for the spectroscopy of quantum Hall edge states.

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L90

Quantum fluctuation theorems

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The characteristic function of work performed on a quantum mechanical system by an external force is expressed in terms of a correlation function of the exponentiated system's Hamiltonians at the two instants of time which mark the end and the beginning of a force protocol. This characteristic function comprises the complete information about the statistics of the work. Apart from the force protocol it depends on the state in which the system is prepared at the beginning of the protocol. For those systems which initially are in a canonical state quantum versions of the Jarzynski work theorem and the Tasaki Crooks fluctuation theorem immediately follow from the characteristic function. For a microcanonical initial state a fluctuation theorem of the Crooks type holds. As such it relates the work statistics of the original and the time reversed process to the densities of states and the entropies of microcanonical systems specified by those Hamiltonians which are realized at the beginning and the end of the protocol. A novel entropy-from-work theorem expresses the density of states and the entropy of a system exclusively in terms of the density of states of a reference system and the observable statistics of work for the original protocol without referrence to the time reversed process.

Combining quantum memory with state manipulation

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A recently proposed, photon echo related approach to quantum state storage in atomic ensembles employs controlled reversible inhomogeneous broadening (CRIB) of a single atomic absorption line [1]. Generalizing CRIB, we devise novel protocols that allow combining quantum state storage with state manipulation through coherent control. Specifically, we discuss efficient pulse compression and decompression and qubit rotations, and we present experimental investigations towards the latter based on stimulated photon echoes.

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L92

Single molecule bridge in transient regime as a testing ground for using NGF outside of the steady current regime

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The simplest mesoscopic system, the molecular bridge consisting of a single molecule with one or few electronic or vibronic levels coupled to non-interacting leads, has been widely investigated [1]. A fully consistent treatment based on the non-equilibrium Green's functions (NGF) can be cast, in this particular case, in an elegant form as represented by the original Meir-Wingreen approach for steady state [2], or its generalization for time dependent bias in [3]. In the present work, we concentrate on the behavior of the molecular bridge undergoing an abrupt change, as exemplified by connecting the molecule to or diconnecting from one of the leads. A transient process unfolds depending on the finite time initial conditions which in turn depend on the previous history of the system[4]. Our treatment is based on the so-called partitioning in time of the NGF [5] and it permits to explore several general questions, in particular the establishing of the steady state whose indicator is the fluctuation-dissipation factorization of the particle distribution function in the leads, formation of "quasiparticle" excitations and validity of the non-equilibrium Ward identities which have a direct bearing on the possibility of bringing the general NGF expressions to the quantum transport equations by means of a modified Generalized Kadanoff-Baym ansatz[6].

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Continuous measurement of a driven quantum electrical circuit

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The Cooper pair box (CPB) is a simple superconducting circuit that behaves as an artificial atom whose two lowest energy levels can be used to define a quantum bit. Modified CPBs as the quantronium [1] or the transmon [2, 3] have coherence times sufficiently long to do many atomic physics experiments with them. In the transmon case, the qubit is measured by coupling it to an electromagnetic mode of a coplanar waveguide cavity. The photons stored in the cavity progressively extract information about the quantum state of the qubit, and correspondingly dephase it [4]. This information is carried by the phase of the electromagnetic field leaking out of the cavity and being measured by homodyne detection. By continuously applying the measuring field during Rabi oscillations of the circuit, we revisit the quantum measurement problem of a mesoscopic quantum electrical circuit. By increasing the average number of photons in the cavity, we observe the transition between the weak measurement and quantum Zeno regimes, both in time and frequency domains. We discuss whether the spectral peak observed at the Rabi frequency in the noise spectrum of the detector [5] violates a modified version of the Leggett-Garg inequality [6], and is proof of the quantum behavior of the circuit.

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L94

Entanglement in mesoscopic opto-mechanical systems

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A vibrational mode of a movable cavity micro-mirror can be entangled with an intracavity mode in a robust way against temperature. Here we show that such an entanglement can be efficiently transferred at the cavity output. More precisely, by adopting a multiplexing approach, the cavity output can be divided into many independent traveling optical modes. We show that optomechanical entanglement can even increase if the output mode is appropriately filtered, and that, under appropriate conditions, one can achieve optomechanical multipartite entanglement. This scheme could be useful for continuous variable quantum communication protocols.

Valence-bond supersolids in cuprates

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Experimentally, there is growing evidence that tendencies toward charge ordering (”stripes”) are common to many high-Tc cuprates. The talk will review relevant scattering and STM experiments and discuss theoretical descriptions. In particular, bond-ordered ”d-wave” stripes coexisting with superconductivity, i.e., valence-bond supersolids, will be argued to be compatible with available data. The microscopic mechanism for d-wave bond order is outlined, and the role of disorder is discussed, the latter leading to random-field pinning and glassy behavior.

L96

Effects of dissipation on quantum critical points with disorder

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Quantum phase transitions in disordered systems are often accompanied by unconventional behavior because rare strongly-coupled spatial regions completely dominate the thermodynamics. In this talk, we investigate the effects of dissipative baths on such quantum phase transitions, and we show that dissipation further enhances the disorder effects. In some systems, it can even destroy the sharp phase transition by smearing.

The first part of the talk is devoted to transitions with a continuous-symmetry O(N) order parameter as occur, e.g., in the superconductor-metal transition in nanowires or in Hertz' theory of the itinerant antiferromagnetic quantum phase transition. By applying a strong-disorder renormalization group to the Landau-Ginzburg-Wilson field theory of the problem, we find that Ohmic dissipation results in a non-perturbative infinite-randomness critical point with exotic activated dynamical scaling while superohmic damping leads to conventional behavior.

In the second part of the talk, we discuss the case of discrete order-parameter symmetry on the example of the dissipative random quantum Ising chain. We present a comprehensive strong-disorder renormalization group theory of the quantum phase transition in this system. We find even stronger effects than for continuous symmetry: In the Ohmic case, the interplay between quantum fluctuations and dissipation destroys the quantum critical point by smearing. We also compute asymptotically exact expressions for the low-temperature behavior of observables in the vicinity of the smeared quantum phase transition.

Phase-coherent transport through quantum dots

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In a remarkable series of experiments, the Heiblum group has analyzed the complex transmission amplitude, $t_d = |t_d|e^{i\alpha}$, of a quantum dot embedded in an Aharonov-Bohm ring. In particular, by analyzing the Aharonov-Bohm oscillations of the conductance of such a ring, the dependence of both the magnitude and phase of the transmission amplitude, $|t_d|$ and α, were measured as a function of various parameters such as gate voltage Vg applied to the dot, temperature T , mean coupling strength to the leads, etc. The behavior of the transmission phase as function of gate voltage was found to change dramatically as the number of electrons in the dot is increased from 0 to being large. In the few-electron regime the phase behavior is ”mesoscopic”, in that it depends on sample details. In particular, under certain conditions it shows a plateau at $\pi/2$ that is characteristic of the Kondo effect. In the many-electron regime the phase behavior is ”universal”, independent of sample details. In my talk, I will review recent theoretical progress [1-3] in understanding these phenomena.

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Nonequilibrium transport in quantum dot systems

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Transport through nanosystems such as quantum dots and molecules is conventionally treated within one of two different approximations: (i) Rate equations for electrons entering and leaving the system, which can also take into account complex many-particle states in the central region. Here broadening effects of the levels are entirely neglected. (ii) The transmission formalism, which is usually evaluated by Green function techniques, allows for a consistent treatment of level broadening due to the coupling to the contacts. In principle, many-particle effects can be incorporated into this formalism, but the determination of the appropriate self-energies is a difficult task, where no general scheme has been found by now. Thus, many-particle effects are usually considered on a mean-field basis including exchange and correlation potentials.

Our approach for transport through finite systems based on the Liouville equation [1], is able to bridge the gap between these approaches. I.e. the approach allows to work in a many-particle basis, taking fully into account the interaction in the active region, AND recovers the correct expressions from the transmission formalism for noninteracting particles. The approach works for arbitrary bias and temperatures above the Kondo temperature. Specific results are given for the Anderson model and double-dot tunneling [2].

Furthermore we show that such a treatment of transport based on many-particle states is able to treat electron-electron scattering in a convenient way. While direct electron transmission through nanosystems is blocked if there are no states connecting the left and the right reservoir, electron-electron scattering can lift this blockade. We discuss typical signatures of this phenomenon, such as the presence of a current signal for a finite bias window.

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Decoherence and relaxation of coupled qubits

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We study the reduced dynamics of interacting spins, each coupled to its own bath of bosons. We derive the solution in analytic form in the white-noise limit and analyze the rich behaviors in diverse limits ranging from weak coupling and/or low temperature to strong coupling and/or high temperature. We also view the one spin as being coupled to a spin-boson environment and consider the regimes in which it is effectively nonlinear, and in which it can be regarded as a resonant bosonic environment.

L100

Toward XUV Raman superradiance: Breaking of adiabaticity

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A new mechanism for producing a bright source of extreme ultraviolet light is proposed and experimentally investigated. The method involves ultra-short laser pulses interacting with atoms in such a way that the atomic system cannot precisely follow the pulse envelope. In some situations, this implies that the ubiquitous rotating-wave approximation is invalid. Two different experiments exhibit the promise of this technique. The first uses two femtosecond laser pulses with wavelengths of 778 nm (two photons) and 1482 nm (one photon) to excite rubidium atoms to the 12p state and instantly release the absorbed energy in a beam of light at 308 nm. The second employs short radio frequency pulses, some containing only a few oscillations, driving transitions among magnetically-split Zeeman sublevels of the rubidium-87 ground state. The second experiment possesses features analogous to those expected for optical pulses of attosecond duration.

Zero temperature decoherence of interacting electrons: The end of the story?

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We develop a new unified theoretical approach enabling us to non-perturbatively study the effect of electron-electron interactions on weak localization in arbitrary arrays of quantum dots. Our model embraces (i) weakly disordered conductors (ii) strongly disordered conductors and (iii) metallic quantum dots. In all these cases at $T \to 0$ the electron decoherence time is determined by the universal formula $\tau_{\varphi 0} \sim g\tau_D/\ln(E_C/\delta)$, where g, τ_D, E_C and δ are respectively dimensionless conductance, dwell time, charging energy and level spacing of a single dot. In the case (i) this formula yields $\tau_{\varphi 0} \propto D^3/\ln D$ (where D is diffusion coefficient) and matches with our previous quasiclassical results [1], while in the cases (ii) and (iii) it illustrates new physics not explored earlier. A detailed comparison between our theory and numerous experiments provides overwhelming evidence that zero temperature electron decoherence in disordered conductors is universally caused by electron-electron interactions rather than by magnetic impurities.

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L102

Optical sub-wavelength lithography: With and without entanglement

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It is well known that the classical schemes for microscopy and lithography are restricted by the diffraction limit. The precision with which a pattern could be etched in interference lithography is limited by the wavelength of the light. In recent years, a number of schemes have been proposed via quantum interferometry to improve the resolution. Some of these schemes are based on quantum entanglement and multiphoton processes. In this talk we shall schemes for 'quantum' lithography using classical light. In the first scheme [1], we consider a particular multiphoton absorbing photoresist. This scheme has the same effect as using an entangled light beam but the advantage of using classical light is that the multiphoton absorption are more efficient and thus afford a practical scheme. Another advantage is that the generalization to one and two dimensional patterns is possible. In the second scheme [2], we discuss a novel approach for the generation of subwavelength structures in interferometric optical lithography is described. Our scheme relies on the preparation of the system in a position dependent trapping state via phase shifted standing wave patterns. Since this process only comprises resonant atom-field interactions, a multiphoton absorption medium is not required.

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Posters

Entanglement and separability of quantum harmonic oscillator systems at finite temperature

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We investigate the entanglement properties of thermal states of the harmonic lattice in one, two and three dimensions [1]. Several different distributions of the entanglement are considered and the corresponding critical temperatures are derived. Firstly, the value of the critical temperature for entanglement between neighbouring sites is established. We give physical reasons for why entanglement vanishes there and show that further away sites are only entangled due to boundary effects in very small lattices. Secondly, the energy is employed as an entanglement witness detecting entanglement of any partitioning (including blocks and multi-partite entanglement) and a corresponding critical temperature is found.

Thirdly, we prove the physical intuition that at sufficiently high temperatures the thermal state becomes fully separable and deduce bounds on the critical temperature at which this happens [2]. We explain why the bound becomes tight for a wide class of Hamiltonians with sufficient translation symmetry. We find that the entanglement temperature is determined by the order of the energy of the hottest (fastest) normal mode of the system and quantify the degree of entanglement below the critical temperature. We close with a comprehensive diagram showing the different phases of entanglement versus complete separability and propose techniques to swap and tune entanglement experimentally.

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P2

Spatial entanglement in a Bose gas

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We address the question of entanglement in macroscopic thermalised systems on the example of two spatial regions of a free non-interacting Bosonic gas. We firstly present an argument [1] that invokes only the Heisenberg principle to show that separable configurations of a free non-interacting Bosonic gas are macroscopically distinguishable from entangled configurations of the gas. This can be done by measuring thermodynamic quantities such as the energy. Moreover, the appearance of a Bose-Einstein condensate (BEC) is linked to the existence of entanglement in three dimensions as their critical temperatures are related.

In the second approach [2] we use two localised probes that interact locally with the two separated regions of the Bosonic gas. These probes come out entangled after the interaction implying that they must have picked up spatial entanglement from the gas. Again, entanglement appears only when the gas is below the critical temperature T_{BEC} for BEC. The existence of spatial entanglement in a Bosonic gas is therefore directly related to establishment of long-range order in the gas, which is an order concept measuring classical correlations [2].

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The quantum relativistic action-entropy connection as a measure of the amount of the computation-information in quantum field theory

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Two of the interesting questions that arise at the moment of doing computation with a quantum field are how much information can be stored and processed in a finite volume region and how it can be measured by different frames of references given that the computation is carried on a quantum/relativistic scenario.

On a computational framework the Least Action Principle (LAP) guides the computation that is carried on everywhere across the field and can be used to establish a connection between the dynamics in (d+1)-spacetime and the statistics in d-spacetime. The connection is set by relating the dynamical Action Integral with the statistical Partition Function through a Wick rotation. Through this relationship Action and Entropy can be regarded as analogous quantities (up to a proportional factor) which measure, from a computational point of view, the amount of computation and the amount of information, respectively.

This connection reflects the dual role of the field (and likely to belong to any physical system) to work as a memory (representing/storing data) and also as a computer (which process information) simultaneously. Both Action and Entropy are Lorentz Invariant quantities (thus the computation and information remain invariant as well in different reference frames) and can be used jointly to set computational complexity bounds on both space and time.

To illustrate this point we calculate the amount of computation- information in a finite volume of space time and measure it from different frames of reference. First, we enclose the space and momenta wave modes on a region using a potential and evaluate the flow of processing rules and information that are carried on inside and outside this region (minimizing the Action and maximizing the Entropy).

Then we consider two scenarios: Originally, there is a test particle lying at rest in a field that is ”moving” (translation operation) and on the other hand the field is ”at rest” and the particle is the one that is moving. An observer moving along the particle would perceive the field operating almost fully as a memory in one case and solely as processor in the other one, but in both cases performing the same computation. The specific operational configuration would be reflected back in the tradeoff between Action and Entropy.

We perform the former analysis for Klein-Gordon and Dirac fields (in order to consider the bosonic and fermionic cases). This study would reveal more about how the dynamical and the statistical features contribute in the computation that is carried on together with the information contained in a given quantum field.

P4

In search of the Darwinian foundations of quantum mechanics

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A subquantum theory is outlined in which the concept of survival of a particle or fundamental system, continuity in its trajectory in real space, plays a crucial role in order to explain quantum behaviour. A particle is defined as a dual entity formed by bare matter and a methodological probabilistic Turing machine that are coupled through information transfer. The state of the particle is defined in a quite similar way to that of the de Broglie-Bohm interpretation[1] of quantum mechanics, i.e. by means of both the trajectory of the particle and a merit or wave function, the pilot wave in the de Broglie-Bohm interpretation, that codes the information that the particle possesses about the outside world. The sketchy underlying mechanism, that determines the response of the system, is based on self-interaction. The evolution of the system is led by three regulating principles that maximize the survival expectations of the system, yielding the most convenient sequence of self-interaction events. Only the systems that follow these principles survive enough time to be detectable. The three principles read as follows. Principle I: A fundamental system maximizes the information obtained from the environment. This is made in two steps. The first step is to store the information in the most efficient way in order to maximize the resources at disposal of every system. This leads to the Hilbert space structure[2] of the space of states. The second step is to maximize the meaning of the information stored in the system. This is made extrapolating, by means of the Turing machine, the future behaviour of outside systems from present data. Probably the most efficient way of storing time evolution information is coding the information in a complex wave function. Principle II: A fundamental system minimizes the information sent to the environment. The Schrödinger equation can be obtained[3] from this principle. Principle III: The interaction between two systems is established in order to maximize the information content about the rest of the universe of both systems considered as a whole. This tentative principle could allow deducing the shape of the interaction Hamiltonian. The obtainment of the postulates of quantum mechanics from our theory is further discussed. Quantum behaviour appears as a result of Darwinian natural selection. As a consequence of this theory, reality, locality and causality are in a certain sense reconciled.

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Laser excitation of harmonically confined mesoscopic electron systems - a nonequilibrium Green

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Mesoscopic few-electron ensembles in one- and two-dimensional parabolic confinement are of relevance for quantum dots and wells in semiconductor heterostructures, metal clusters or ions in Penning or Paul traps. Laser assisted excitations in such systems generally lead to collective processes where the quantum N-particle dynamics is affected by long-range Coulomb interaction induced electron-electron correlations. Numerically, we obtain the equilibrium and dynamical properties [1,2] beyond linear response theory by solving the Keldysh/Kadanoff-Baym equations [2] for the system's (two-time) nonequilibrium Green's functions [2]. Further, initial correlations at finite temperatures are self-consistently included starting from a correlated (imaginary-time) Matsubara Green's function [3] at the second (order) Born level. The consideration of a wide range of relative interaction strengths allows us to observe the transition from almost ideal Fermi gas/liquid behavior to electron (Wigner) crystal states, which reveal different (nonlinear) response to the external field. The investigation of center-of-mass [4] and breathing motion, in particular, serves as a hot test for the numerical code.

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P6

Statistical and dynamical phases in cotunneling current

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Cotunneling current through an antidot[1,2] in the fractional quantum Hall regime is studied in order to extract information on the fractional statistics of quasi particle for the Laughlin series[3,4].

It is shown that when the energy of the antidot neutral excitations is larger than the charging energy it is possible to capture unambiguous informations about the statistical angle from the dependence of the cotunneling current on the position of the tunneling points. This peculiar geometrical effect is interpreted as the result of coherent exchange of quasiparticles. Its robustness is studied in the presence of electron-phonon coupling which could hide the above effect by introducing a disturbing dynamical phase[5].

This setup is an alternative proposal to the Mach-Zender configuration in order to directly measure the effects of fractional statistics in the current[6].

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Numerical studies of Hawking radiation from acoustic black holes in atomic Bose-Einstein condensates

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Although the existence of black-holes has been indirectly proven on astrophysical grounds, no experimental evidence of their slow but relentless evaporation into Hawking radiation has been obtained yet. In the present talk we report numerical simulations of a condensed matter system which shares many properties with gravitational black-holes, in particular the emission of a Hawking radiation: an horizon is created in a moving cloud of ultracold atoms in the nanoKelvin range where atoms behave in a coherent way as a Bose-Einstein condensate, and the presence of Hawking radiation is inferred from peculiar correlations of the quantum fluctuations of the atomic density.

P8

Sub-Poissonian phononic population in a nanoelectromechanical system

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We describe the properties of the phonon distribution of a mechanical resonator coupled to a single-electron transistor (SET) in the sequential tunneling regime. Exploiting a master equation approach. In the regime of fast vibrational motion (rotating wave approximation), we show that the electrical current flowing through the SET can induce a out-of-equilibrium distribution of phonons with sub-Poissonian statistics, which is characterized by a selective population of few phonon states [1]. In selected regimes of bias and gate voltages, the selective phonon population is reinforced by the double-occupancy of the SET, allowed when a finite electron-electron interaction is considered [2]. We conclude with some perspective on the regime of slow vibrational motion, where coherences between vibrational states may not be neglected and the rotating wave approximation is dropped in favour of the solution of a generalized master equation exploiting the fully coherent dynamics of the SET+oscillator system [2].

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Ground state and transport properties of circular dots employing the projected Hartree-Fock method

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Circular quantum dots are intriguing systems in which the interplay between spatial symmetries and Coulomb interactions gives rise to interesting phenomena, ranging from the emergence of shell structures and atomic-like Hund's rules up to the formation of Wigner molecules in the presence of strong electronic correlations. We employ a pro jected Hartree–Fock (PHF) technique [1–3] to calculate the ground state energies and wavefunctions for circular quantum dots with up to N = 12 interacting electrons in the presence of a perpendicular magnetic field. By systematically projecting spin and spatially unrestricted Hartree–Fock (UHF) [4] states onto eigenstates of the total spin and the angular momentum, we restore all the correct spin and spatial symmetries of the wavefunction. In addition, the projection technique introduces correlations beyond the mean-field level, which leads to better energy estimates than those obtained by employing the unrestricted method [2, 3]. Employing these correlated wavefunctions, transport properties in the sequential tunneling regime are studied. In both linear and nonlinear regimes signatures of Coulomb interactions are found, which lead to spin-blockade and negative differential conductance. The PHF technique is computationally efficient and represente a definite improvement over UHF at a complexity level lower than that of exact diagonalization or quantum montecarlo techniques.

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P10

Effective interaction approach to the many-boson problem

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We show that the convergence behavior of the many-body numerical diagonalization scheme for strongly interacting bosons in a trap can be significantly improved by the Lee-Suzuki method adapted from nuclear physics: One can construct an effective interaction that acts in a space much smaller than the original Hilbert space. In particular for short-ranged forces and strong correlations, the method offers a good estimate of the energy and the excitation spectrum, at a computational cost several orders of magnitude smaller than that required by the standard method.

P11

Thermodynamics of two-stroke engine based on periodically driven two-level system

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We consider a two-state system whose dynamics is controlled by the standard Pauli rate equation. We impose a periodic external driving of the energies of the both states. Each period consists of two linear isothermal branches (or strokes). Due to the driving, the transition rates in the rate equation depend on time and the system response represents a time nonhomogeneous Markov process.

Solving the rate equation, the occupation probabilities for the two states gradually settle onto a well defined limit cycle. Owing to the finite driving period, the 'engine' operates in an inherently irreversible regime. Within the limit cycle, we analyze the work done by the engine, the heat exchanged with the both reservoirs, the average power output, the efficiency of the heat-work transformation, and the entropy production. We discuss the dependence of these quantities on the parameters which describe both the external driving (the duration of the period, the allocation of the period between the two strokes, the energy span of the strokes) and the temperatures of the cold and the hot reservoir. Parameters that optimize the power output are obtained numerically. The power versus efficiency curve exhibits a well pronounced maximum for a certain apportionment of the fixed period onto the two strokes.

In the second part of our analysis, we view the work per cycle as a fluctuating quantity. We present an exact calculation of the probability density for the work. Our method is based on the probabilistic characterization of any individual sample path of the underlying Markov process. We calculate the weight of those sample paths which violate the second law of thermodynamics. In the slow driving limit, the probability density for the work collapses to a delta function localized at the reversible work. In the strongly non-equilibrium regime, the density displays a broad support and its continuous part is combined with the delta-function contributions. Our exact analytical expression for the work density is tested against the general predictions of the non-equilibrium thermodynamics of the small systems.

P12

Boltzmann conjecture on meta-equilibrium entropy, chaos and irreversibility in many body systems.

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A heuristic generalization of the Boltzmann-Gibbs microcanonical entropy is proposed, able to describe meta-equilibrium features and evolution of macroscopic systems. Despite its simple-minded derivation, such a function of collective parameters, characterizing the microscopic state of N-body systems, yields, at one time, a statistical interpretation of dynamic evolution, and dynamic insights on the basic assumption of statistical mechanics. Its natural (implicit) time dependence, entails a Second Law-like behaviour and allows moreover, to perform an elementary test of the Loschmidt reversibility objection, pointing out the crucial relevance of Chaos in setting up effective (statistico-mechanical and dynamical) arrows of time. Several concrete (analytical and numerical) applications illustrate its properties.

Quantum stirring of particles and counting statistics

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The amount (Q) of particles that are transported via a path of motion is characterized by its expectation value <Q> and by its variance Var(Q). We analyze what happens if a particle has two optional paths available to get from one site to another site, and in particular what is Var(Q) for the current which is induced in a quantum stirring device. It turns out that coherent splitting and the stirring effect are intimately related and cannot be understood within the framework of the prevailing probabilistic theory.

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P14

Shot noise in a SET nanomagnet

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A single-electron transistor (SET) based upon a II-IV semiconductor quantum dot doped with a single Mn ion behaves as a quantum nanomagnet whose total spin and magnetic anisotropy depend both on the number of carriers and their orbital nature. Thereby, the magnetic properties of the nanomagnet can be controlled electrically. Conversely, the electrical properties of the SET depend on the quantum state of the Mn spin. Interestingly, the effective exchange mechanism between the Mn and the carriers depends on whether the SET is operated in the electron or the hole region [1].

We have extended such analysis by studying the frequency-dependent shot noise (quantum correlations) in this kind of SET. The shot noise shows various regimes which, as a function of gate and bias voltages, reflect different magnetic configurations of the nanomagnet. In particular, we find super-Poissonian noise in a region of bias and gate voltages where the competing dynamics between slow and fast channels (corresponding to different orientations between a hole and the Mn atom) results in bunching. As a function of frequency, this behavior appears as a resonance around zero frequency, reflecting charge relaxation dynamics. Information about spin relaxation, which is included in the model in the form of weak transverse couplings, can be extracted from shot noise at finite frequencies.

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P15

Bipartite stationary entanglement induced by a dissipative environment

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We demonstrate theoretically that two non-interacting charge qubits (based on two double quantum-dots) become entangled due to the strong coupling with a common bosonic bath [1]. Taking into account the weak interaction of one of the qubits with two electron leads, the reduced density matrix of the qubits system is obtained by using a standard Born-Markov approximation for such coupling and a canonical polaron transformation for the coupling with the bosonic environment.

The coupling to the bath causes quantum noise (decoherence) which together with an indirect interaction between qubits, gives rise to two competing effects: entanglement generation and further charge localization. These effects are reflected in a non-monotonic behavior of the concurrence as a function of the dissipation strength with the environment. Despite the small values obtained for the concurrence ($C<0.5$), the model considered is the minimal implementation of a fully tunable pair of charge qubits coupled to a bosonic bath, and thus is an attractive system in which the interplay between quantum coherence, entanglement and decoherence can be studied.

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P16

Entanglement of qubits in dephasing environments: Exact results

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We study the evolution of quantum entanglement of a pair of non-interacting qubits, initially prepared in an entangled state, dephasingly coupled to their own independent environments. The reduced non-Markovian dynamics of two qubits is exact for arbitrary model parameters. Necessary and sufficient conditions for non-vanishing entanglement are formulated for both zero and non-zero temperatures and arbitrary time. It is also shown that the entanglement dynamics can effectively be controlled by a finite quantum system coupled to one of the qubits. The dynamical symmetry of the controlling quantum system can influence significantly entanglement of the qubits and results in its non-monotonic decay. Exact reduced dynamics for a pair of independent qubits or qutrits dephasingly coupled to a common zero-temperature super-Ohmic bosonic environment is discussed. It is shown that such a qudit-qudit subsystem initially prepared in a separable state evolves into an entangled state. This environment-induced entanglement can survive in the long time limit. The entanglement dynamics of initially maximally entangled qubit-qubit and qutrit-qutrit states is analyzed. The entangled states of a two-qutrit system are shown to be distillable (for the assumed initial state) for arbitrary environment parameters.

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Fractional revivals through Renyi uncertainty relations

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We show that the Rényi uncertainty relations give a good description of the dynamical behavior of wave packets and constitute a sound approach to revival phenomena by analyzing three model systems: the simple harmonic oscillator, the infinite square well, and the quantum bouncer. We prove the usefulness of entropic uncertainty relations as a tool for identifying fractional revivals by providing a comparison in different contexts with the with the usual Heisenberg uncertainty relation and with the common approach in terms of the autocorrelation function.

P18

Minimal set of local measurements and classical communication for continuous variable entanglement detection

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We present ou recent results [1,2] on the minimal requirements for complete entanglement quantification of an arbitrary two mode bipartite Gaussian state via local measurements and a classical communication channel. The minimal set of measurements is presented as a reconstruction protocol of local covariance matrices and no previous knowledge of the state is required but its Gaussian character. The protocol becomes very simple mostly when dealing with Gaussian states transformed to its standard form, since photocounting or intensity measurements define the whole set of entangled states.

In addition we propose a quantum tomography protocol [3] in which the whole density matrix of an arbitrary two-mode Gaussian state, entangled or not, is obtained via local operations and classical communication (LOCC) and which does not require simultaneous homodyne measurements on both modes. We also present some recent advances for the generalization of the present scheme for bipartite systems with an arbitrary Hilbert space dimension [4].

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Scaling of entanglement support for matrix product states

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The power of matrix product states to describe infinite-size translational-invariant critical spin chains is investigated. At criticality, the accuracy with which they describe ground state properties of a system is limited by the size χ of the matrices that form the approximation. This limitation is quantified in terms of the scaling of the half-chain entanglement entropy. In the case of the quantum Ising model, we find $S \sim 1/6 \log \chi$ with high precision. This result can be understood as the emergence of an effective finite correlation length ξ_χ ruling of all the scaling properties in the system. We produce five extra pieces of evidence for this finite-χ scaling, namely, the scaling of the correlation length, the scaling of magnetization, the shift of the critical point, and the scaling of the entanglement entropy for a finite block of spins. All our computations are consistent with a scaling relation of the form $\xi_\chi \sim \chi^\kappa$, with $\kappa = 2$ for the Ising model. In the case of the Heisenberg model, we find similar results with the value $\kappa \sim 1.37$. We also show how finite-χ scaling allow to extract critical exponents. These results are obtained using the infinite time evolved block decimation algorithm which works in the thermodynamical limit and are verified to agree with density matrix renormalization group results.

P20

Dynamics of hydrated starch saccharides investigated by quasielastic neutron scattering and Rayleigh scattering of Mössbauer radiation

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The role of the H-bonded network of water on structural and dynamical properties of biological macromolecules is largely well established [1]. Among bio-molecular systems, polysaccharide systems give the opportunity to change the thermodynamic parameters affecting the formation of the H-bond network in a wide range, i.e., varying hydration continuously from dry state to very diluted systems. We focused on amylose and amylopectin, the two main components of starch, which have the same primary structure (a linear polymer of glucose from 600 up to 6000 units) but different branching ratio. Quasi Elastic Neutron Scattering (QENS) and Rayleigh Scattering of Mössbauer Radiation (RSMR) have been employed by us to investigate the dynamical properties at different hydrations and temperatures (20-350 K) [2-5]. These techniques permit to explore the dynamics at atomic level in a time scale from pico to nanoseconds. The QENS and RSMR analysis on the mean square atomic displacements indicates that a dynamical glass-like transition occurs at about 200 K as observed in hydrated proteins [6]. This transition is essentially triggered and driven by the interaction of the macromolecule with the network of fluctuating H-bond of the solvent. In the case of amylose and amylopectin, a small but significant dependence of the transition temperature upon hydration is observed, reflecting the known plasticising role of water in polysaccharides. Moreover, a further dynamical transition is observed at 260 K which seems to be more directly related to the enhanced mobility of the hydrogen-bond network which enables the activation of slower backbone dynamics occurring in the 100-500 ps timescale. In this work we further investigate the dynamical properties of amylose and glucose, reporting new RSMR and QENS data analysis. The RSMR experiments were performed in Parma, while the QENS measurements were performed at ILL (IN13 and IN16 spectrometers) and at ISIS (IRIS spectrometer) using both H_2O and D_2O as solvent.

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Photon emission by an atom in a lossy cavity

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The dynamics of an initially excited two-level atom in a lossy cavity is studied by using the quantum trajectory method. Unwanted losses are included, such as photon absorption and scattering by the cavity mirrors and spontaneous emission of the atom. Based on the obtained analytical solutions, it is shown that the shape of the extracted spatiotemporal radiation mode sensitively depends on the atom-field interaction. In the case of a short-term atom-field interaction we show how different pulse shapes for the field extracted from the cavity can be controlled by the interaction time.

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Advanced control of superconducting nanocircuits

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One of the most recent and fascinating development in solid state physics is the achievement of controlled quantum dynamic in superconducting nanocircuits. This has opened the possibility to implement in such devices techniques and protocols previously typical of quantum optics but now part of a new interesting field of investigation in the solid state. A particular advantage of solid-state systems is the flexibility with respect to parameters which opens a playground to test many effects and regimes which have been only predicted in quantum optics.

As an example, stimulated Raman adiabatic passage (STIRAP), a well-known quantum optics technique for high-efficient population transfer, has been already demonstrated in a single Cooper-pair box operated as a three level atom [1]. Moreover the new branch of circuit quamtum electrodynamics (cQED) in superconducting nanocir- cuits, which provides a sytem analogous to quantum-optical cavity QED, has obtained many important results for quantum information processing.

One particularly interesting problem is the generation and detection of non-classical cavity states such as pho- ton number states (despite the fact that up to date there is no single-photon detector for these microwave photons). In a recent experiment, generation of single photons relied on spontaneous emission events has been demonstrated in a circuit QED architecture [2].

Here we propose an alternative method to trigger the emission of a single photon into the cavity by applying the stimulated Raman adiabatic passage (STIRAP) invoking a third level of the Cooper pair box. The photons are generated by an adiabatically driven stimulated Raman transition between two states of the box, with the vacuum field of the cavity stimulating one branch of the transition, and the drive deterministically driving the other branch. The method requires a leaky cavity [2], otherwise the STIRAP protocol could not generate single photons as in circuit QED the capacitive atom-cavity coupling is fixed.

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Counting statistics of non-Markovian processes

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Counting statistics has recently attracted intensive theoretical and experimental attention [1]. The interest stems from the usefulness of counting statistics as a sensitive diagnostic tool of stochastic electron transport through mesoscopic systems.

In this contribution we derive a general expression for the cumulant generating function (CGF) of non-Markovian quantum stochastic transport processes [2,3]. 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 [2]. The finite-frequency noise is given not only by the resolvent, but also initial system-environment correlations [2].

As an illustrative example we consider electron transport through a dissipative double quantum dot [2,4] for which we study the effects of dissipation on the zero-frequency cumulants of high orders and the finite-frequency noise.

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P24

A quantum dot side coupled to a Luttinger liquid out of equilibrium: Duality to resonant tunneling

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We consider a model of a single level quantum dot side-coupled to a quantum wire in a (non-chiral) Luttinger liquid phase, with both tunneling and interaction between the dot and the wire. Using both canonical transformations of the bosonized model and a Yuval-Anderson type mapping onto a classical Coulomb gas, we show that this problem is dual to that of a system consisting of a quantum dot connecting the edges of two wires with the inverse Luttinger liquid parameter g. In particular, the transport properties of the two models, both in and out of equilibrium are complementary: when one is conducting the other is insulating, and vice-versa. When g=2 the system is equivalent to a two channel Kondo model at the Emery-Kivelson line. We can then exactly solve the problem and show that both the linear and the non-linear conductance exhibit an anti-resonance behavior with a width that vanishes when the temperature and the source-drain voltage go to zero, and that the dot's density of states vanishes at the Fermi energy both on and off resonance. We complete the picture for the rest of the parameter space using Monte-Carlo simulations on the Coulomb gas model, and show that the above results apply whenever g>1, whereas for g<1 the width of the conductance anti-resonance increases with decreasing source-drain voltage and temperature.

Optimizing number squeezing in a mesoscopic condensate

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An atom interferometer can be built using Bose Einstein condensates, confined in magnetic traps, which are split by continously transforming the trapping potential [1-3]. In order to minimize phase diffusion, due to the nonlinearity originating from atom-atom interactions in the condensate, number squeezing of the atoms in the wells is required. Squeezing occurs when tunneling becomes small due to the nonlinear interaction which favors a sharp number distribution in each well.

In adiabatic scenarios, squeezing is severely limited by the timescales of the tunneling dynamics, and therefore non-adiabatic strategies are favorable. In this contribution we show that optimal control theory (OCT) [4] allows to devise control strategies which significantly outperform adiabatic schemes. We first discuss number squeezing in the framework of a generic two-mode model, and give an intuitive physical explanation for the OCT control strategy. For realistic magnetic microtraps, it becomes important to include a non-adiabatic wave function evolution beyond the generic two-mode model. In this work we describe the dynamical evolution of the two orbitals occupied by the atoms using the MCTDHB equations [5], which are based on a variational principle.

Our results cover several squeezing time scales as well as different numbers of atoms in the condensate. We compare adiabatic to non-adiabatic splitting with simple control and optimal control. By using OCT, we can handle non-adiabatic wave function evolution, and obtain number squeezed states on much shorter time scales in comparison to other strategies.

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Current noise of a superconducting single electron transistor coupled to a resonator

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When a resonator is coupled electrostatically to a mesoscopic conductor known as a superconducting single electron transistor (SSET) the coupled dynamics of the system can show a rich variety of different behaviours [1]. The SSET supports a number of current resonances which can alter the dynamics of the resonator significantly and in a way which depends very sensitively on the precise choice of operating point for the transistor. Recent experiments have realized this system with two very different types of resonator, namely a mechanical resonator consisting of a suspended beam with a fundamental frequency of 20MHz [2] and a superconducting strip-line resonator with a frequency of 10GHz [3]. Depending on the strength of the SSET-resonator coupling and the choice of SSET bias point, the resonator can be driven into thermal-like states with a low effective temperature [2], states of self-sustaining oscillation [3] or regions of bistability. Here we analyse the current noise of the SSET and show that it is very sensitive to the state of the resonator, much more so than the average current. We find that the current noise is strongly enhanced in the transition regions where the resonator's dynamical state changes, but takes a much lower value when the resonator undergoes self-sustaining oscillation.

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Superfluidity and dynamics of strongly correlated charged bosons in a 1D trap

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Systems consisting of cold bosons show interesting collective phenomena such as Bose-Einstein condensation or superfluidity and are being actively discussed in condensed matter and atomic physics. Here, we analyze a mesoscopic system of charged bosons trapped in a harmonic one-dimensional confinement. The quantum few-particle state in thermodynamic equilibrium is numerically obtained by solving the Keldysh/Kadanoff-Baym equations for the (imaginary-time) Matsubara Green's function in Hartree-Fock approximation [1,2]. The results of the simulation (total energies and densities) are compared with first principle path integral Monte Carlo methods for different relative interaction strengths and temperatures. Further, the equilibrium state is analyzed with respect to Bose-Einstein condensation and local superfluidity [3].

Finally we analyze the dynamics of the system following short-pulse laser excitation. Using the equilibrium (Matsubara) Green's function as an initial condition we compute the two-time nonequilibrium Green's functions. The excitation of collective (normal) modes, such as the breathing and center-of-mass oscillation, is of particular interest.

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P28

Enhancing natural entanglement with noise: The effect of disorder in many-body systems

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Physical systems have some degree of disorder present in them. However, most studies of entanglement concentrate on ordered systems. We consider a noisy system at finite temperature in the thermodynamic limit, and use a witness to detect this natural entanglement. To investigate noise in such a system, we must average over the disorder to calculate a quenched or an annealed witness. Each of these averages give a different region of entanglement, hence we must be clear about which we measure. Despite the expectation that disorder should destroy entanglement, we find this is not always the case. Instead, for a Heisenberg spin chain in a random magnetic field, we can actually enhance the region of entanglement detected by both witnesses. Similarly, a random coupling strength enhances the region of entanglement.

Nonequilibrium Greensfunction approach to photoionization in strong laser fields

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For many years there has been a high interest in the photoionization of electrons from atoms and solids. New radiation sources, such as femtosecond lasers or free electron lasers allow for precise time and energy-resolved measurements. From the theoretical side there are three main questions:
(i) How does the time-dependence of the photoemission signal look like ?
(ii) How does the spectrum change in dependence on laser intensity and photon energy ?
(iii) What is the effect of electron-electron correlations ?
We have recently presented results for the first two problems [1,2]. Here we concentrate on a many-body treatment of electronic correlations. To this end, we use the formalism of Non-Equilibrium Greensfunctions [3] to describe the particle interaction. First we solve the Roothaan-Hartree-Fock equations, which yield a basis to expand any space-dependent quantity in. Second we solve the Dyson equation self-consistently to determine the system's equilibrium state. Third we propagate this equilibrium state in time by solving the Keldysh/Kadanoff-Baym-equations [4] under action of an electric field.
For the description of the continuum and bound states we consider a one-dimensional model which despite of its simplicity allows for a consistent modelling of ionization processes. We compare our results to solutions of the time-dependent Schrödinger equation and analyze in detail the influence of electron-electron correlations on the short-time dynamics of photoionization in model atoms with 2..5 electrons.

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P30

Quantum mechanics and the second law of thermodynamics: Can a superconductor heat engine break the law?

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It has been shown [1-4] that the magneto-caloric effect, adiabatic phase transition of a particle dimensioned Type I superconductor specimen having a cross-section less than the Pippard range of coherence, ξ(T), is characterized by a decrease in entropy, suggesting a quantum limit to traditional formulations of the Second Law. J. Bardeen [5] proposed that such a particle dimensioned phase transition process may experience superheating of the critical magnetic field sufficient to render the process isentropic. A.B. Pippard [6] proposed an hysteresis mechanism of the critical magnetic field which yields a prediction fatally different from the prediction of J. Bardeen. In this paper, it is shown that the Bardeen and Pippard hysteresis mechanisms are mutually exclusive and hysteresis in the critical magnetic field is not an impediment to decrease in entropy during the adiabatic phase transition.

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Critical mode coupled to the heath bath and implications of ab initio thermodynamics

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First-principles theory of condensed state provides powerful tools for the description of microscopic scale properties determined by transition between classical and quantum effects. The study is based on [1] comprising amplitudes of critical mode and Born charges as the key entities for the microscopic data base. The relevant macroscopic approach is structured as sums over all elementary cells of the system each of which specified by local mode undergoing dipole-dipole, elastic and strain – local mode coupling.

Objective is unavoidable interaction of the system with thermal environment making this description probabilistic. Theoretical setup of this study is finite size system (ferroelectric dot) interacting witch thermal bath and a source of ergodicity breaking.

Technicalities [2] are based on the theory of stochastic processes and captures intrinsic spatio – temporal response of the dot as a mutual effect of temperature and electric field. A particular result is the development of polarization pattern in a dot of five atom (BaTiO3) elementary cells.

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Electron-phonon coupling in nanodevices

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In quantum dots the multiple scattering of electrons on LO phonons, included in the electronic quantum kinetic equation in the self-consistent Born approximation to the electronic self-energy, leads not only to the fast electronic energy relaxation [1,2] in these nanostructures, but also to the effect of the upconversion of electronic level occupation in quantum dots [1]. From the experimental point of view the upconversion theoretical mechanism can give an alternative explanation of the lasing of the quantum dot lasers from the higher excited electronic states. Recently the self-consistent Born approximation has also been shown to provide an explanation of the shape of the luminescence spectral line of individual quantum dots, namely of the form of a very narrow peak with a shoulder at the low-energy side.

The mechanism of the up-conversion is likely to play an important role also in the open semiconductor nanostructures like in those of a quantum dot connected to two electrodes, or in similar structures like short segments of the molecule DNA. We present some theoretical results on the electronic transport in such a zero-dimensional nanostructure, or a nanotransistor, in which we demonstrate the influence of the multiple-phonon scattering of electrons. Upon using a rather simple and well-known Toy Model of Supprio Datta, or alternatively, upon using the Meir and Wingreen formulation of the electronic transport in nanodevices, we are going to show that in an asymmetric nanodevice we can meet an effect of a spontaneous electric potential step generation between the two electric contacts of such a device. This feature will be documented numerically on a model of the active region of the nanotransistor having two electronic bound states. The presently discussed approximation uses the Toy Model for the electronic transport between the electric wires and the quantum dot, while the electron-LO-phonon interaction effect is included as a tool added to the mechanism based on the Toy Model. The electron-phonon coupling is included in the self-consistent Born approximation to the electronic self-energy. The relation of the presented theoretical results to available measurements of current-voltage characteristics of nanodevices will be shown and discussed.

The work was supported by the grant ME 866 OS of MSMT and by the institutional project AVOZ10100520 and also by the project NSC 95-2112-M-005-012-MY3 of National Science Council of the Republic of China (Taiwan).

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Interferometric distillation and determination of arbitrary unknown two-qubit entanglement

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In quantum information science, there are strong demands of distilling and quantifying entanglement[1]. We propose a scheme for both distilling and quantifying entanglement, applicable to individual copies of an arbitrary unknown two-qubit state. It is realized in a usual two-qubit interferometry with local filtering, by physically implementing the normal form[2] of the state. Proper filtering operation for the maximal distillation is achieved, by observing single-qubit interference, without tomography. Then, the concurrence of the state is determined from the visibilities of two-qubit interference. Our scheme is the first experimentally realizable approach of directly determining concurrence even for mixed states, therefore of potentially displacing the existing quantifications such as the Bell-inequality test.

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Tunable channel interference in an Aharonov-Bohm ring

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We have investigated the Aharonov-Bohm effect in a quasi one-dimensional ring on a GaAs/ $Al_{0.3}Ga_{0.7}As$ heterostructure, which is defined by two metallic arc gates coupled to each branch of the ring. Each gate can be separately biased to uniformly squeeze the channel width of electrons, thereby externally tuning the transverse modes in the interference paths. The oscillatory magnetoconductance of the device is systematically studied by varying the number of channels in each path. We have observed the evidence of phase shifts in the magnetoconductance oscillations due to the suppression of the mode numbers on the ring path. Though the periodicity is not well resolved, qualitatively our data support the random phase shifts between the successive modes.

P35

Relativistic elements of reality

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The notion of ”element of reality” was introduced in the famous Einstein, Podolsky and Rosen 1935 paper, as an attribute of a physical quantity whose value can be predicted with certainty without perturbing the system. Modern formulations have attempted to avoid the ambiguity of the phrase ”without perturbing the system”, but have otherwise kept close to the original notion.

A number of interpretations of quantum mechanics involving various kinds of elements of reality were proposed after the EPR paper, in particular Bohmian mechanics and modal interpretations. They were originally developed as nonrelativistic theories, and it has been notoriously difficult to reconcile them with the special theory of relativity. Eventually, the question was raised whether Lorentz-invariant elements of reality are inconsistent with quantum mechanics.

In this presentation, I will revisit that question, and bring a number of additional considerations to it. I will first analyze in detail Hardy’s argument, which was meant to show that Lorentz-invariant elements of reality are indeed inconsistent with quantum mechanics. I will show that this and related arguments use the EPR characterization not only as a sufficient condition for the existence of an element of reality, but also, essentially, as a necessary condition. A contradiction then immediately follows, quite independent of details of quantum mechanics. My argument will make use of constraints, whose derivation will be outlined, on elements of reality associated with a maximal set of commuting Hermitian operators. I will then investigate to what extent the light cone associated with an event can be used to define Lorentz-invariant elements of reality. It turns out to be possible, but these elements of reality won’t satisfy the so-called product rule, i.e. an element of reality associated with a product of two commuting operators will not always be equal to the product of elements of reality associated with each operator. Building on this, I will comment on a number of analyses of Hardy’s and related arguments published in the literature.

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Work in single molecule experiments: A definition that works

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In the prototypical pulling experiment, a single macromolecule is stretched by means of a device able to measure the applied force. The work performed on the system is then usually defined as the area below the resulting force-extension curve. This standard approach has a theoretical drawback: since the molecular extension is subject to thermal fluctuations, it cannot be considered a good control parameter. To address this issue we have pulled DNA hairpins using optical tweezers and measured the mechanical work. We have experimented with different settings (e.g. different values of the stiffness of the trap). We discuss under which conditions the subtleties in the definition of the work can appreciably affect the outcome of an experiment.

Quantum transport in ultracold Rydberg gases

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In the quest for signatures of coherent energy transfer we consider the trapping of excitations in frozen Rydberg gases within the continuous-time quantum walk (CTQW) framework. The dynamics takes place on a discrete network of N sites. Out of the N sites we assume $M \leq N$ sites to be traps and incorporate those phenomenologically into the CTQW formalism by a trapping operator, which leads to a new, non-hermitian Hamiltonian $\mathbf{H} = \mathbf{H}_0 + i\mathbf{\Gamma}$. The average CTQW survival probability $\Pi_M(t)$ for an excitation not to be trapped after some time t follows from the transition probabilities $\pi_{kj}(t)$ to go from site j to site k as

$$\Pi_M(t) \equiv \frac{1}{N-M} \sum_{j \notin \mathcal{M}} \sum_{k \notin \mathcal{M}} \pi_{kj}(t),$$

where $\mathcal{M}$ is the set of traps. For small M/N we show that $\Pi_M(t)$ displays different decay domains, related to distinct regions of the (imaginary part of the) spectrum of the Hamiltonian.

In the asymptotic limit, where $t \to \infty$, this leads in most cases to a simple exponential decay. However, this is not the case at intermediate, experimentally relevant times. We exemplify our analysis with a discrete linear system of N sites with traps at each end (sites 1 and N, $M = 2$). In this case the decay at intermediate times obeys a power-law, which strongly differs from the corresponding classical exponential decay found in incoherent continuous-time random walk (CTRW) situations. Moreover, we show that in this time domain $\Pi_M(t)$ scales with N and is basically independent of the coupling strength between traps and non-trap sites.

In order to investigate the intermediate time domain and to differentiate between the CTQW and CTRW mechanisms, we present an experimental protocol based on a frozen Rydberg gas structured by optical dipole traps.

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Universal behavior of quantum walks with long-range steps

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Continuous-time quantum walks with long-range steps $R^{-\gamma}$ (R being the distance between sites) on a discrete line behave in similar ways for all $\gamma \geq 2$. This is in contrast to classical random walks, which for $\gamma > 3$ belong to a different universality class than for $\gamma \leq 3$. We show that the average probabilities to be at the initial site after time t as well as the mean square displacements are of the same functional form for quantum walks with $\gamma = 2, 4$, and with nearest neighbor steps. Our findings are obtained by numerical computations as well as by analytical calculations using. We interpolate our results to arbitrary $\gamma \geq 2$.

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Entanglement in classical Brownian motion

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In texbooks and literature it is commonly stated that entanglement is a purely quantum phenomenon. Here we present a classical origin for it.

For two classical Brownian particles an analog of continuous-variable quantum entanglement is presented: The common probability distribution of the two coordinates and the corresponding coarse-grained velocities cannot always be prepared via mixing of any factorized distributions referring to the two particles separately. This is possible for particles which have interacted in the past, but do not interact at present.

Three factors are crucial for the effect: (1) separation of time scales of coordinate and momentum which motivates the definition of coarse-grained velocities; (2) the resulting uncertainty relations between the coordinate of the Brownian particle and the change of its coarse-grained velocity; (3) the fact that the coarse-grained velocity, though pertaining to a single Brownian particle, is defined on a common context of two particles.

The Brownian entanglement is a consequence of a coarse-grained description and disappears for a finer resolution of the Brownian motion. Analogies with the quantum situation are discussed, as well as possibilities of experimental realization of the effect in examples of macroscopic Brownian motion.

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Experimental challenge to the force balance at measurement of the Little-Parks oscillations

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The change of the wave function phase with magnetic field, i.e. the Aharonov-Bohm effect [1], results to shift of an interference pattern [2,3] and various phenomena in mesoscopic nanostructures [3,4]. The Aharonov-Bohm effect implies a quantum force-free momentum transfer [5] since the phase gradient is momentum according to the quantum formalism. This paradoxical feature results in some experimental challenge to the force balance. For example, the circular persistent current is observed along a ring with nonzero resistance without Faraday voltage [6] and the persistent current expelling magnetic field from the interior of a superconductor at the Meissner effect springs up against the Faraday electric field [7]. The equilibrium persistent current is a periodical function of magnetic flux inside thin-wall superconductor cylinder or ring. One of the consequences of this periodicity is the resistance oscillations observed first by W. A. Little and R. D. Parks [8]. At measurement of the Little-Parks oscillations of a ring, the measuring current and the circular persistent current have the same direction in one of the semi-rings and opposite directions in the second one [9]. The total current in the second semi-ring flows against the electric field measured at a low value of the measuring current [9]. Moreover the quantum oscillations of the dc voltage are observed on system of asymmetric superconducting rings at nonzero resistance [9]. These experimental results are most obvious challenge to the force balance connected with the absence of the Faraday electric field. The force balance can be formally restored with help of a quantum force introduced in [10].

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Critical current 0-π transition in designed Josephson quantum dot junctions

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We report on quantum dot based Josephson junctions designed specifically for measuring the supercurrent. From high-accuracy fitting of the current-voltage characteristics, we determine the full magnitude of the supercurrent (critical current). Strong gate modulation of the critical current is observed through several consecutive Coulomb blockade oscillations. The critical current crosses zero close to, but not at, resonance due to the so-called 0-π transition in agreement with a simple theoretical model.

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P42

Enhancement of photon correlation time in gain medium

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The two-level laser amplifier has been widely studied for many years using both semicalssical theory[1] and quantum theory[2]. The recent progress in quantum communication invokes interest in the photon correlation of this simple system. We have generalized the full solution in ref. 3 to a quantum version using the quantum Langevin theory and used it to study the photon correlation. We find that two-photon correlation of the amplifier in small signal regime depends on the atomic populations and the propagation length. The correlation does not show antibunching, as in resonance fluorescence[4]. We predict that inverted population associated with negative temperature[5] gives a very long correlation time even in the presence of decoherence, a useful asset for quantum communication. The correlation vanishes for very dilute atomic gas. Analytical solutions for the field operators obtained by Fourier transform and Laplace transform (with initial condition) of the time variable appear very different but yield identical numerical results except for certain parameters. Physical explanation behind the deviation is given. We also find that the presence of thermal photons tend to reduce the correlation time.

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Creating and verifying a quantum superposition in a micro-optomechanical system

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Micro-optomechanical systems have become increasingly important in the study of quantum effects in relatively massive systems. Here we review the experiment as proposed by Marshall et al. [1] which aims to demonstrate a quantum superposition of a mesoscopic cantilever. We analyze the effects of finite temperatures on the interpretation of the experiment. Although it is possible to measure the quantum decoherence time when starting from a finite temperature, an unambigious demonstration of a quantum superposition requires the mechanical resonator to be in or near the ground state. We also calculate the rate of environmentally induced decoherence and provide a rough estimate of the gravitationally induced collapse as proposed by Penrose [2].

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P44

Forms of relativity

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Einstein's theories of relativity are assumed to be based on light as a medium of transmission of signals [1]. Relativity is based on exchange of information, but it is a general physical phenomenon, and it has been shown that relativistic kinematics is a priori, not specifying the kind of physical medium for the transmission of signals involved in it [2]. It is also not a result of the regimes of velocity, as it is usually claimed in the pedagogical literature. Moreover, there are different kinds of relativity: geometrical and material. In theories made for geometrical relativity, the concept of relativity is explicitly related to movement, and both have a pure kinematical nature. The dynamical rules, as usual, represent another sector of a theory and the evolution of a relativity naturally depends on the physical nature of the interactive elements which can be involved with information and movement.

In our work, we discuss the basis of the phenomenon of observational differentiability and its forms in physics. It is based on analysis of observers, observation and their relations. We choose a suitable physical epistemology to treat the observer in such way that observation, measurement and collection of data are all treated separately [2,3]. While data and measurements are collected locally, spatiality and locality are not characteristics of observation. This is why we are able to define an observer of relativity and, consequently, discuss properly the phenomena of relativity, theories for relativity and point to certain common structures between these theories. We also show that relativistic features are not only present in the already considered theories of movement with geometrical relativity but in quantum physics as well. This discussion is a primer step on the direction of establishing an observational meaning for the quantum-relativistic phenomenon.

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Current noise in the double quantum dot

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We study the current noise through a double quantum dot coupled to two leads in the high bias limit and a phonon bath in the weak coupling limit. Our calculations are based on the solution of a Markovian generalized master equation. Zero frequency current noise calculated within the system, i.e. between the two dots, via the Quantum Regression Theorem exhibits unphysical negative values. On the other hand, current noise calculated for currents between the dots and the leads by the counting variable approach shows no anomalies and seems consistent with experiments. We inquire into the origin of the discrepancy between the two nominally equivalent approaches for the double dot systems as well as in an exactly solvable model of coupled dissipative harmonic oscillators. The purpose of the study is the development of charge-conserving approximation schemes within the GME approaches and understanding of dynamics of quantum systems coupled to multiple baths.

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The entropy of a correlated system of fermions

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The effects of beyond mean-field correlations in quantum many-body systems can be appropriately described in terms of self-consistent Green's functions theory [1]. The decomposition of the one-body propagator in terms of a non-zero width spectral function accounts for complex many-body processes that fragment the quasi-particle peak [2]. Within the context of hot correlated quantum systems, one would like to compute the thermodynamical properties from this spectral representation of the Green's functions [3]. We shall in particular discuss the computation of the entropy from the Luttinger-Ward formalism within the ladder approximation, which respects thermodynamical consistency [4]. Although applied here to nuclear systems, this formalism can be used to describe other correlated quantum many-body system [5].

This work is partially supported by the National Science Foundation, under Grant No. PHY-0555893.

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Irreversibility and dissipation in two-state systems investigated using optical tweezers

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In this work we address irreversibility and dissipation in specifically designed sequences of DNA hairpins that cooperatively fold/unfold in a two-state manner under the action of mechanical force. Based on previous analytical work in two-state systems [1,2] we have developed a general theory that expresses the dissipated work and the number of transitions executed by the molecule with an effective (adimensional) loading rate and the fragility of the molecule. We have synthesized a 21-base pairs DNA hairpin and pulled it using optical tweezers [3] at different loading rates. By repeatedly pulling single DNA hairpins we have measured the dissipated work and the number of transitions executed by the molecule along the stretching and refolding parts of the pulling cycle. The experiments are tested against the theory. Our results show that dissipation and irreversibility in two-state hairpins can be described in terms of only two parameters: the molecular fragility and the folding/unfolding critical rate.

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P48

Visualization of wave packet revivals by means of information entropy

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The phenomenon of quantum wave packet fractional revivals is a relevant feature in long time scale evolution in a wide range of physical systems including atoms, molecule and nonlinear systems. We point out that the sum of information entropies in position and momentum conjugate spaces is an indicator of fractional revivals by analyzing three different model systems (i) the infinite square well , (ii) a particle bouncing vertically against a potential wall in a gravitational field and (iii) the vibrational dynamics of hydrogen iodine molecules. This description in terms of information entropies in conjugate spaces complement the usual one in terms of the autocorrelation function.

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Conceptual foundations of von Neumann quantum measurement scheme

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A quantum measurement scheme devised by von Neumann plays a central role in all considerations relevant to the measurement problem in quantum mechanics. Despite of the fact, that the scheme ultimately did not reach the anticipated goal, a view is still maintained, that at least the very approach to the solution of the problem is correct and does not rise any doubts about its consistency. Moreover, according to some views, by including in a measurement process environment, surrounding the measurement arrangement, the scheme can be generalized in a way, that allows solution not only of the measurement problem, but also the quantum-to-classical transition and the origin of ”classicality” from quantum mechanics. However, a little critical check of a validity of the key assumptions, lying in the foundations of the scheme, casts some shadow on its seemingly unimpeachable physical status. The first objection is related with the quantization of a measurement device - a purely macroscopic physical system, which functions according to the laws of classical physics. In the result of this procedure, measurement device acquires, similarly as the Schrödinger cat, an explicitly dualistic nature: theoretically it becomes a quantum, although really it is still classical. Wherewith, theoretically, a measurement of a single quantum system turns into a measurement of interaction of two quantum systems, thus leaving us still in the realm of quantum. The second objection is related to the notion of ”ideal” (non-demolition) measurement, intensely used in the scheme. An analysis of quantum measurement reveals, that the ”ideal” measurement - two or more subsequent measurements of one and the same quantum system is impossible. The third objection is aimed against the incorrect construction and interpretation of the state vectors of composite quantum system, consisting of a measured system and a quantized measuring system. Therefore, the use of such physically bad established notions as a quantization of purely macroscopic object and an ”ideal” measurement, although embodied in the proper mathematical formalism of quantum theory, as well as an over-simplified interpretation of the theory, characterize the von Neumann measurement scheme as a purely theoretical construction, which is far away from the situation occurring in the case of real measurements.

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Entangled states in quantum mechanics

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In some circles of quantum physicists, a view is maintained that the nonseparability of quantum systems - i.e., the entanglement - is a characteristic feature of quantum mechanics. According to this view, the entanglement plays a crucial role in the solution of quantum measurement problem, the origin of "classicality" from quantum physics, the explanation of the EPR paradox by a nonlocal character of quantum world. Besides, the entanglement is regarded as a cornerstone of such modern disciplines as quantum computation, quantum cryptography, quantum information, etc. Overlooking this exceptional status, which the entanglement or more precisely - the quantum entangled states - acquired due to J.Bell, the entanglement had already been well known and widely used in various physics areas, although, under other names, such as - bounded or coupled states. In particular, this notion is widely used in nuclear, atomic, molecular, solid state physics, in scattering and decay theories as well as in other disciplines, where one has to deal with many-body quantum systems. One of the methods, how to construct a basis state of a composite quantum system out of the basis states of its forming subsystems, is the so called genealogical decomposition method, which is a recurrent by a particle number construction of many-body quantum system basis states. In the case of n-body system, consisting of two n_1- and n_2- body subsystems ($n=n_1+n_2$), the genealogical decomposition gives $I\Gamma>=\Sigma_{\Gamma_1\Gamma_2} A_{\Gamma_1\Gamma_2,\Gamma} I\Gamma_1>I\Gamma_2>$, where $I\Gamma_1>,I\Gamma_2>$ are the basis states of corresponding systems, while $A_{\Gamma_1\Gamma_2,\Gamma}$ are the decomposition coefficients, determining a weight by which a pair $I\Gamma_1>,I\Gamma_2>$ enters in the decomposition. These coupled states have a structure typical for entangled states. If a composite system is stable, the internal structure of its basis states $I\Gamma>$ does not manifest itself in measurements. However, if a composite system becomes unstable and decays to its subsystems via a particular state $BI\Gamma>$, the decay rate onto the pair of subsystems, being in the state $I\Gamma_1>I\Gamma_2>$, is $IBI^2IA_{\Gamma_I\Gamma_2,\Gamma}I^2$, where B is a factor, determined by the corresponding decay process Hamiltonian. Possible correlations between quantum numbers Γ_1, Γ_2, displayed by the decay rate values, are determined by symmetries - conservation laws of corresponding dynamical variables, and not by a quantum entanglement feature.

The dissipative quantum particle in a box

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We analyze the phase diagram of a quantum particle confined to a finite chain, subject to a dissipative environment described by an Ohmic spectral function. Analytical and numerical techniques are employed to explore the perturbative and non-perturbative regimes of the model. For small dissipation the coupling to the environment leads to a narrowing of the density distribution, and to a displacement towards the center of the array of accesible sites. For large values of the dissipation, we find a phase transition to a doubly degenerate phase which reflects the formation of an inhomogeneous effective potential within the array.

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Minimal work principle: Example and problem

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The minimal work principle states that the work done on a thermally isolated equilibrium system is minimal for adiabatically slow (reversible) realization of a given process. In the article “Minimal work principle: proof and counterexamples” [1-3], the authors have shown that if we replace thermodynamic entropy with the von Neumann entropy we can proof the minimal work principle under some particular conditions. Here we tried to calculate the work for a spin-1/2 system. To solve this specific example, some problems with unitary operator of time evolution have been emerged. The most important problem occurs when we use the temperature to define the density matrix. With this kind of definition we find that the time evolution of density matrix is not explained by the usual unitary operator of time evolution.

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Multipoint correlation and response functions for continous time random walks models of anomalous spectral diffusion: Aging phenomena in two dimesional correlation spectroscopies

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Multitime correlation functions provide useful probes for the ensembles of trajectories underlying the stochastic dynamics of complex systems. They provide information on entire stochastic paths supplementing information provided by two time correlation functions. Their modelling requires careful selection of the microscopic model of fluctuations and its detailed treatment. Reduced descriptions such as master equations are not applicable. Multipoint correlation functions are connected with higher order response function which describe measurements of the optical response to sequences of ultrashort optical pulse in experiments carried on biological, condesed matter and other mesoscopic systems.

We developed an algorithm for computing the multipoint correlation functions of a particle undergoing a biased continuous-time random walk in an external potential and an algorithm for computing nonlinear optical response functions of a two-level chromophore with stochastic frequency fluctuations described by the continuous-time random walk. Two- and three-point correlation functions are calculated for waiting-time distributions with an anomalous power-law profile. Comparison with the Brownian harmonic oscillator model illustrates how higher-order correlation functions may be used to distinguish between dynamical models that have the same two-point correlation function. We further analyze the signatures of anomalous relaxation in two-dimensional four wave mixing signals, and study the origin of algebraic decay of two-point correlation functions by two-dimensional correlation spectroscopy. Power-law spectral singularities and temporal relaxation in 2D spectra are predicted in stationary ensembles corresponding to power law exponents between (1,2).Spectroscopic signatures of aging (nonstationary) continuous time random walks are identified in time dependepents 2D lineshapes corresponding to waiting time distributions with diverging first moment (power law exponent between (0,1)). The insight into the phenomena of aging, or weak ergodicity breaking is made by comparison with aging Markovian spectral random walks which share the same two time distribution.

Acknowledgements:GACR (Grant No. 202/07/P245), MSMT CR(MSM 0021620835)

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P54

Quantum control of transport behavior in low-dimensional spin systems

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We analyze transport of local magnetization and develop schemes to control transport behavior in spin-1/2 Heisenberg chains and spin-1/2 Heisenberg two-leg ladders. By adjusting parameters in the Hamiltonians, these quantum systems may show both integrable and chaotic limits. We provide evidence to refute the conjecture that chaotic systems must show diffusive transport, whereas only integrable systems exhibit ballistic transport. In addition, we propose methods of coherent quantum control to suppress the effects of the integrability-breaking terms in the chaotic systems and recover the transport behavior verified in the integrable regime.

Probabilistic approach to quantum mechanics and uncertainty relations for the probability density and probability density current

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Uncertainty relations, one of the fundamental results of quantum mechanics, have been studied in a large number of papers (see e.g. [1]). The standard approach to their derivation is based on the wave function. However, it has been shown in [3-4] that a large part of the mathematical formalism of quantum mechanics can be obtained by generalizing the statistical analysis of experimental results with the corresponding probability distribution and probability density current.

Two multi-dimensional uncertainty relations, one related to the probability density and the other one related to the probability density current, are discussed. Both relations are stronger than the usual uncertainty relations for the coordinates and momentum.

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P56

Torsion-induced persistent current in a twisted quantum ring

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We investigate the electronic eigenstates in a twisted quantum ring, and demonstrate the occurrence of a persistent current driven by geometric curvature. It is well established that when a coherent electron is bounded to a twisted quantum wire having a finite cross section, its axial motion is described by a Hamiltonian that involves an effective vector potential [1-3]. Hence, by constructing a closed loop of the twisted wire (i.e., a twisted quantum ring), a persistent current is expected to flow through the ring. To our knowledge, however, a quantitative estimation of such the persistent currents has not been carried out, and the actual experimental conditions for observing them are has not been explored thus far. To clarify the above issues, we consider a toroidal carbon nanotube with a radius of 1 μm and evaluate the persistent current induced by the helical atomic structure. We assume that an external current penetrates at the center of the twisted ring, which is required to break the time-reversal symmetry that prohibits the occurrence of a non-zero net current in the ring. The continuum approximation is employed to find that the magnitude of the torsion-induced current may be of the order of several tens nanoamperes, depending on the geometric configuration of the ring. This magnitude of the current is comparable to (or exceeds) that obtained in the measurements of isolated quantum rings [4,5], implying that it is observable in low-temperature experiments. We emphasize that the persistent current in our system is purely a consequence of the twisted atomic structure. Thus, this current differs inherently from the ordinary persistent current driven by an external magnetic field.

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Non-equilibrium transport properties and typicality for randomly interacting quantum systems

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Random matrix theory is used for wide range of different phenomena and we analyze the dynamics of some quantum models where the Hamiltonian possesses such a random part. We show them to be solvable within certain size and time scaling limit. Particularly we consider the Van-Hove limit, which is the long time-weak coupling regime, of the average of the time evolution of a macro observable. In these scaling regimes we find our systems to be described by diffusion equations or rate equations.

The deviation of such an average is then analyzed and characterized by its dependency on the ”amount” of randomness that one has in the system which in our case will be related to the size of the Hilbert space. In suitable limits we find the deviation to tend to zero. We call then the behavior typical since the average represents well the behavior of any realization.

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Nonequilibrium dephasing in an electronic Mach-Zehnder interferometer

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We study nonequilibrium dephasing in an electronic Mach-Zehnder interferometer. We demonstrate that the shot noise at the beam splitter of the interferometer generates an ensemble of nonequilibrium electron density configurations and that electron interactions induce configuration-specific phase shifts of an interfering electron. The resulting dephasing exhibits two characteristic features, a lobe pattern in the visibility and phase jumps of π, in good agreement with experimental data.[1]

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Effect of mode interactions on statistics in 1D disordered lasers

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Statistical properties of disordered lasers have been a subject of a large number of experimental studies [1,2], where the main attention has been paid to a multimode regime. In this situation nonlinear interactions between modes are important. We study this problem using lasing in active one-dimensional disordered structures open at one end, as a model. The coupling is taken into account with the help of Feshbach projection technique adapted for open optical resonators in [3], which allows to define independent quasimodes with finite radiative lifetimes. Steady-state rate equations for intensities of these quasimodes can be obtained within the framework of the standard semiclassical third-order laser theory. The solutions of these equations were found numerically as functions of the pump strength and their statistical properties were analyzed. We find that the mode interactions lead to strong nonlinear effects such as mode suppression and saturation of the average number of modes with increasing pump. These effects are related to the correlation between the resonator wavefunctions and do not arise in 2D chaotic lasers, where the wavefunctions are uncorrelated [4].

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P60

Collective electronic excitations for optical lattice cold atoms within a cavity

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We study solid-state effects, e.g. excitons and cavity-polaritons, in ultracold-atoms loaded on an optical-lattice within a cavity. In the Mott-insulator phase the system can be considered as an artificial crystal, and for the case of one atom per site, an electronic excitation can transfer among the lattice sites due to electrostatic interactions [1]. We investigate the formation of excitons in such a system, similar to Frenkel-excitons in molecular or Noble-atom crystals. Excitons can appear only if the atom excited state line-width is smaller than the exciton bandwidth. Within a cavity, the electronic excitations and the cavity-photons are coupled, and in the strong coupling regime they form cavity-polaritons. In the Mott-insulator phase with two atoms per site, an on-site single excitation forms entangled symmetric and antisymmetric states [2]. The antisymmetric states are localized, while the symmetric ones can transfer among the lattice sites, and are represented as excitons. Within a cavity the symmetric state excitations and the cavity-photons are coupled, and in the strong coupling regime they form cavity-polaritons. But, the antisymmetric states found to be dark states. For the two cases of one and two atoms per site, we calculate the transmission, reflection, and absorption spectra of an incident external filed. The linear optical spectra show resonances at the polariton frequencies. Cavity polaritons can be used as an observation tool of different kinds of defects in optical lattices [3].

[1] H. Zoubi, and H. Ritsch, Phys. Rev. A 76, 13817 (2007).

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[3] H. Zoubi, and H. Ritsch, New J. Phys. 10, 23001 (2008).

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Conference Site Buildings

Pyramida hotel

Pyramida Hotel was built in 1980 in the neo-functionalist style with an interesting star-like ground plan and pyramid-like outer shape. In 1999 a complete renovation of interiors took place. The hotel offers a wide selection of conference services.

Pyramida Hotel is situated in the residential area of Prague called Břevnov near the Prague Castle - see map 'Prague center'. It is in the same time very near the historical center of Prague and Prague international airport - about 20 minutes by car. From the Pyramida Hotel you can reach easily many historical and important places of Prague by trams 22 or 23 which have their stops nearly in front of the Pyramida Hotel: Prague Castle within 5 minutes, Lesser Town is about 10 minutes by tram, Charles Bridge area, too, Old Town and New Town centers (in the vicinity of Old Town Square and Wenceslas Square) within 20 minutes ride.

Wallenstein Palace (Valdštejnský palác)

Wallenstein Palace is situated in the very center of the Lesser Town (Malá Strana) in close vicinity of the Lesser Town Square and the Charles Bridge. The origin of the settlement in the Lesser Town is directly linked to Prague castle, which was founded around 880 AD. The oldest settlement of the future city named Prague was concentrated just to places below the castle. In this area the second town of Prague was later formed: the space between the river of Vltava and Prague Castle was fortified in the 13th century and the Lesser Town was founded in 1257 by the Czech King Přemysl Otakar II.

The Wallenstein Palace was built from 1624 to 1630 as a seat of the Imperial generalissimo, Admiral of the Atlantic Ocean and the Baltic Sea, Albrecht Eusebius of Valdstein (Wallenstein) who was one of the most important figures of the Thirty Year's War. Apart from being famous as a very influential soldier (Commander-in-Chief of the Imperial Army), Wallenstein is also known for his belief in the influence of the stars. It is a very interesting experience to read personal characterization of Wallenstein in the horoscope written for him personally by Johannes Kepler. This link is not the only one which connects Wallenstein Palace with astronomy and physics: inside the Palace there is the astronomical-astrological corridor with allegories of seven planets, the leading architect who designed the Wallenstein Palace and its Sala Terrena in the huge Baroque garden was Italian Giovanni Battisto Pieronni, a student of Galileo Galilei. When designing the huge palace complex of the Wallenstein Palace, Pieronni (together with two other Italian architects A. Spezza and N. Sebregondi) combined elements of the Late Renaissance with those of the Early Baroque. He also hired the most renowned artists to participate on the art works and decoration of the palace. This resulted in the first Baroque palace complex in Prague which became a really representative and up to date as for fashion seat of Albrecht Wallenstein. By this palace the idea of Wallenstein to express his power and glory by building a magnificent palace whose size and decoration even surpassed those of the Prague Castle, was fulfilled.

To imagine the size of the Wallenstein Palace we can remind the fact that Wallenstein purchased twenty three houses, three gardens and the municipal brick-kiln to gain the place for his palace. The palace complex has a perimeter of almost 750 meters. It is completely separated from the outside world by walls and concentrated around a landscaped garden and five courtyards. The huge garden is famous for its monumental Baroque Sala Terrena with three open arches as well as for a number of bronze statues of ancient gods by Adriano de Vries. As for the palace rooms, the most famous place there is the Main Hall. This hall reaches to the height of two floors and its dimensions are further enlarged optically by mirror windows.

The Wallenstein Palace is nowadays the seat of the Senate of the Parliament of the Czech Republic.

How to get there:
The entrance to the Wallenstein Palace is from the Wallenstein Square which you can reach within five minutes walk either from tram and underground station Malostranská or from tram station on the Lesser Town Square (Malostranské náměstí) - see map of the Wallenstein Palace neighborhood.
Special tram will depart from the Pyramida Hotel to the Malostranská stop on Monday afternoon to facilitate FQMT08 participants transfer. Exact departure time will be announced during the Conference.
Stops Malostranská or Malostranské náměstí can also be reached from the Pyramida Hotel by trams No. 22, 23 (5th or 6th stop).
Alternatively, you can get to the Wallenstein Palace directly from the Pyramida Hotel within 30-40 minutes of a nice walk - see maps 'Nearest neighborhood of the Pyramida Hotel' and 'Wallenstein Palace neighborhood'.

St. Simon and Juda Church

St. Simon and Juda church (Kostel sv. Šimona a Judy) was built by the Czech Bretheren between 1615 and 1620. After the battle of the White Mountain (1620) the Bretheren were expelled from the Czech lands, the church was given to a catholic order, the brothers of Mercy and it became part of a monastery and hospital. The first anatomy lecture hall in Prague was established here in 18th century. Rebuilt monastery complex continues to serve as a hospital.

Church Baroque facade and interior decoration are of 18th century. By its entrance there is a pieta from 16th century. The main altar of the church is the work of Josef Hager from 1773 and it contains painting of St. Simon and Juda from well known painter Václav Vavřinec Rainer. The organ is decorated with sculptures by famous Prague Baroque sculptor J. Brokoff and was played by J. Haydn and W. A. Mozart. Nowadays, St. Simon and Juda church is the concert hall of Prague Symphonic orchestra FOK.

How to get there:

Special tram will depart from the Pyramida Hotel to the Právnická fakulta tram stop on Wednesdey afternoon to facilitate FQMT08 participants transfer. Exact departure time will be announced during the Conference.

From the Právnická fakulta stop you can reach in few minutes (by streets of the Jewish Town):

1. the Kozička Bar to enjoy a refreshment before the public lecture of Marlan Scully (from Kozička Bar the way to the Church takes about 5 minutes)

or

2. directly the St. Simon and Juda Church.

For both cases - see map 'St. Simon and Juda Church neighborhood'.

For those who will use an individual transfer: The best way from the Pyramida Hotel is first to reach the Malostranská station by trams 22 or 23. From this station you can cross on foot, within 5-10 minutes, the Vltava River using the Mánesův most (Mánes Bridge). Alternatively, the River can be crossed by tram No. 18 or by underground (metro) line A (from Malostranská to Stroměstská stops). From the region of the Staroměstská Metro station you will reach either the Kozička Bar or directly the St. Simon and Juda Church by walk within 10-15 minutes. If you wish to omit the refreshment in the Kozička Bar, you can ride one stop by tram No. 17 along the right bank of the River (from Staroměstská to Právnická fakulta stops) - see the map.

Břevnov Monastery

It was founded as the first monastery in Bohemia by Prince Boleslav II and Saint Adalbert (Vojtěch) of the Slavnik dynasty, Bishop of Prague already in 993 AD. The monastery was built amidst forests, at the source of the Brusnice river and on a road leading westwards from Prague. For centuries there was only a small settlement around the monastery which was later on surrounded by farms. This Benedictine monastery, however, played the decisive role for the spreading of culture and art in Czech lands.

The original monastery has been rebuilt many times. Its oldest parts date from the 10th century. In 1964 the Pre-romanesque crypt (open nowadays to the public) of the original 10th century church was discovered below the choir of the present St. Margaret church. Neither the Romanesque nor the Gothic buildings of the monastery survived. From the 15th century on, the monastery was in a state of poverty for three centuries. During 18th century it was largely rebuilt in the Baroque style.

Most of monastery present day buildings are dated from 1708 to 1745 and were built in Baroque style by Christoph Dientzenhofer. The same architect also erected as a part of monastery complex the Church of St. Margaret, which is considered to be one of the most remarkable works of Czech Baroque architecture. The presbytery of the church was built by Christoph's son, Kilian Ignaz Dientzenhofer, architect of many important Baroque churches and palaces of Prague. The altarpieces are the work of Peter Brandl, one of the best Czech painters of high Baroque era.

The interiors of Břevnov monastery are decorated by valuable paintings, e.g. in the former ceremonial hall of the monastery, nowadays called Theresian Hall, there is a ceiling painting the Miracle of the Blessed Gunther painted by Kosmas Damian Asam of Bavaria in 1727. This is one of the best preserved ceiling paintings in Prague.

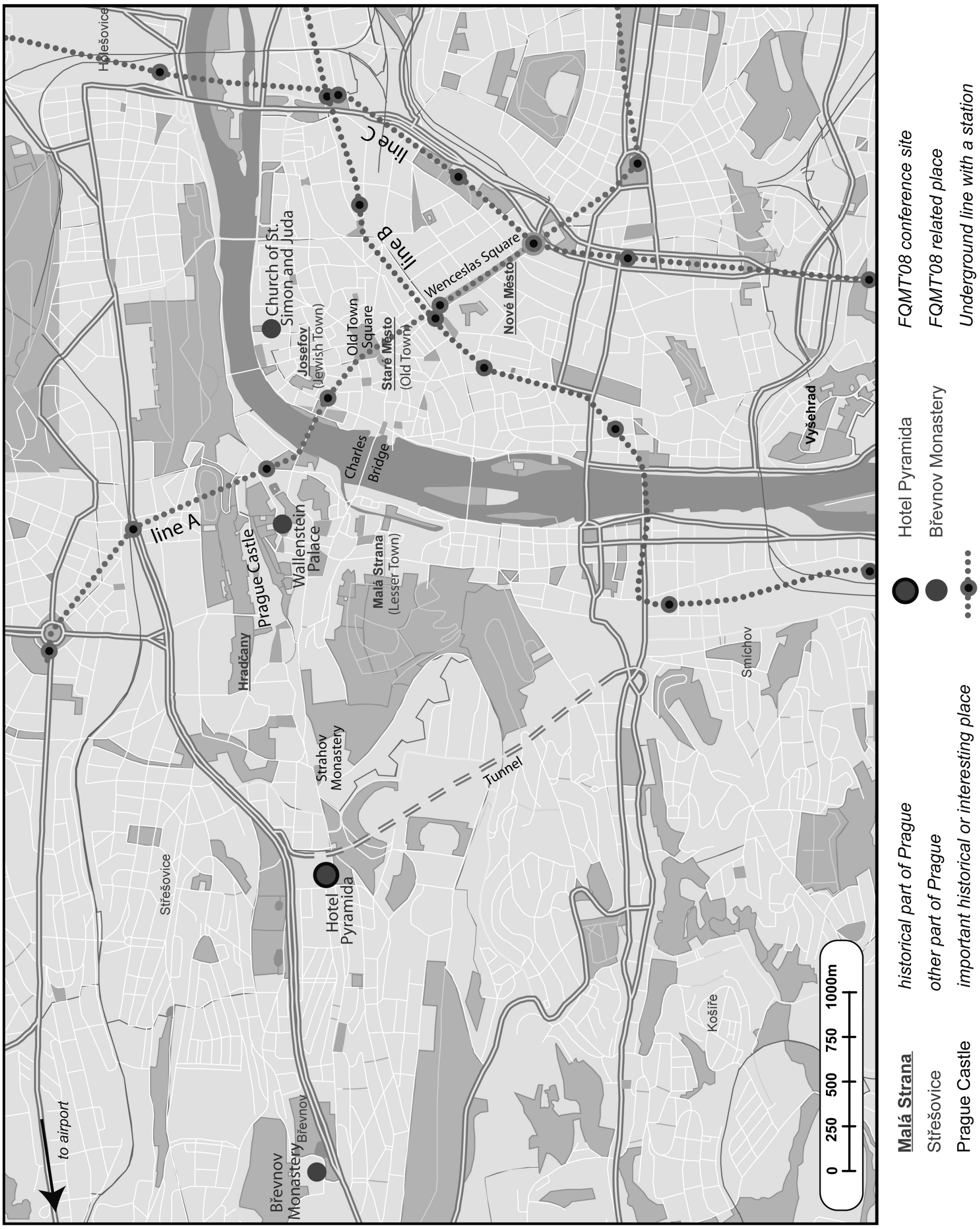
The entrance to the monastery is through the ornamented main gateway built by Kilian Ignaz Dientzenhofer in 1740 and decorated with a statue of St. Benedictine. The main building of the monastery complex can be reached then by crossing a large courtyard.

Behind the monastery is situated its large Baroque garden. At its gate is a nice Baroque pavilion called Vojtěška with a chapel above a well which marks the spot where Prince Boleslav and Bishop Vojtěch are supposed to have met and decided to built the Břevnov monastery.

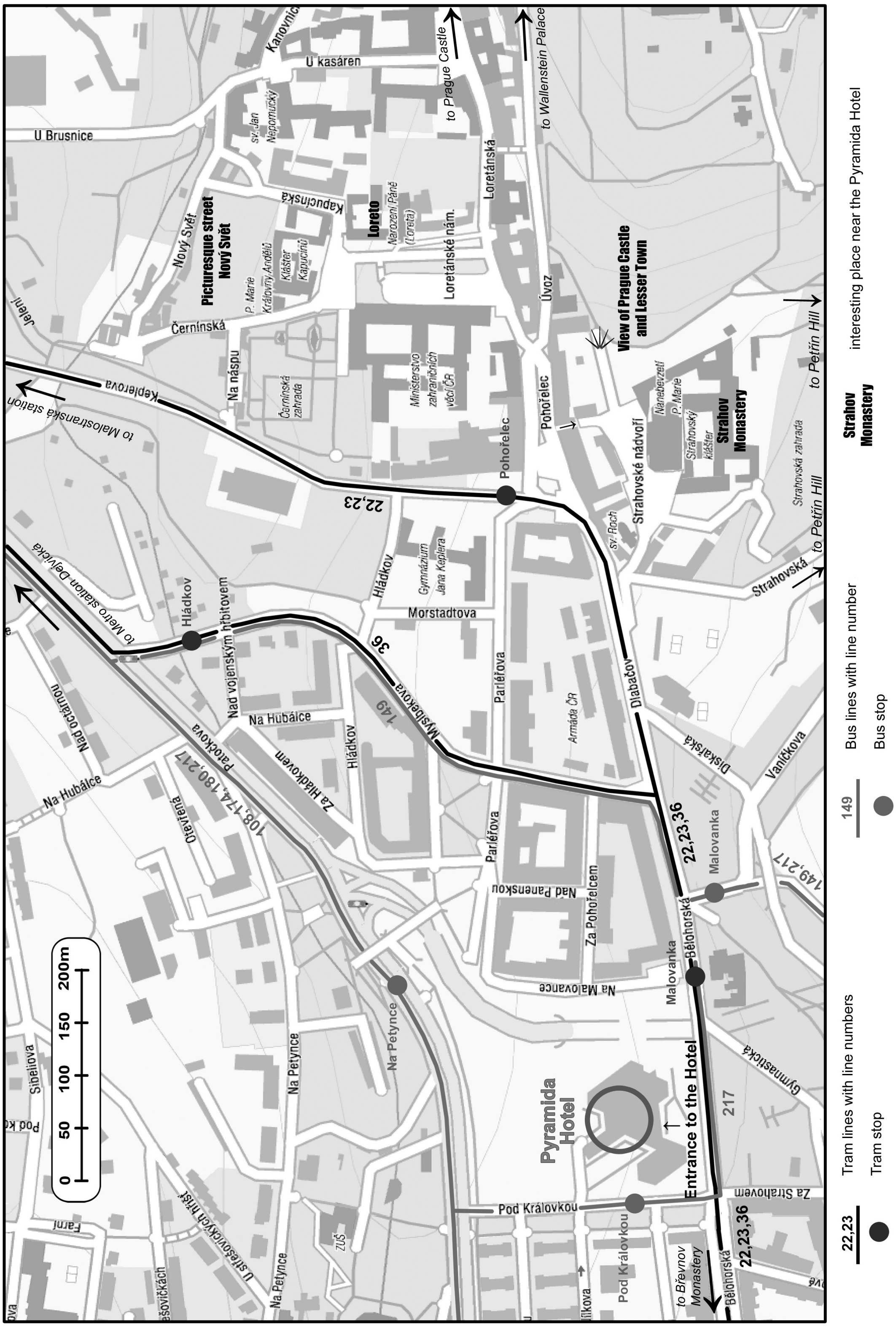
How to get there:
The Břevnov Monastery is situated in the street Patočkova not far (about 1500 m) from the Pyramida Hotel - you can reach it: 1. either by about 30 minutes walk along the Bělohorská street (the main street where the Pyramida hotel is situated) going up to its crossroad with Patočkova street, near of which you see the monastery, 2. or by going trams No. 22, 23 or 36 (4 stops, about 5 minutes) along Bělohorská street from the Malovanka station to the station Břevnovský klášter, from where you can reach the monastery within 3 minutes walk - see maps 'Prague center' and 'Nearest neighborhood of the Pyramida Hotel'.

Maps

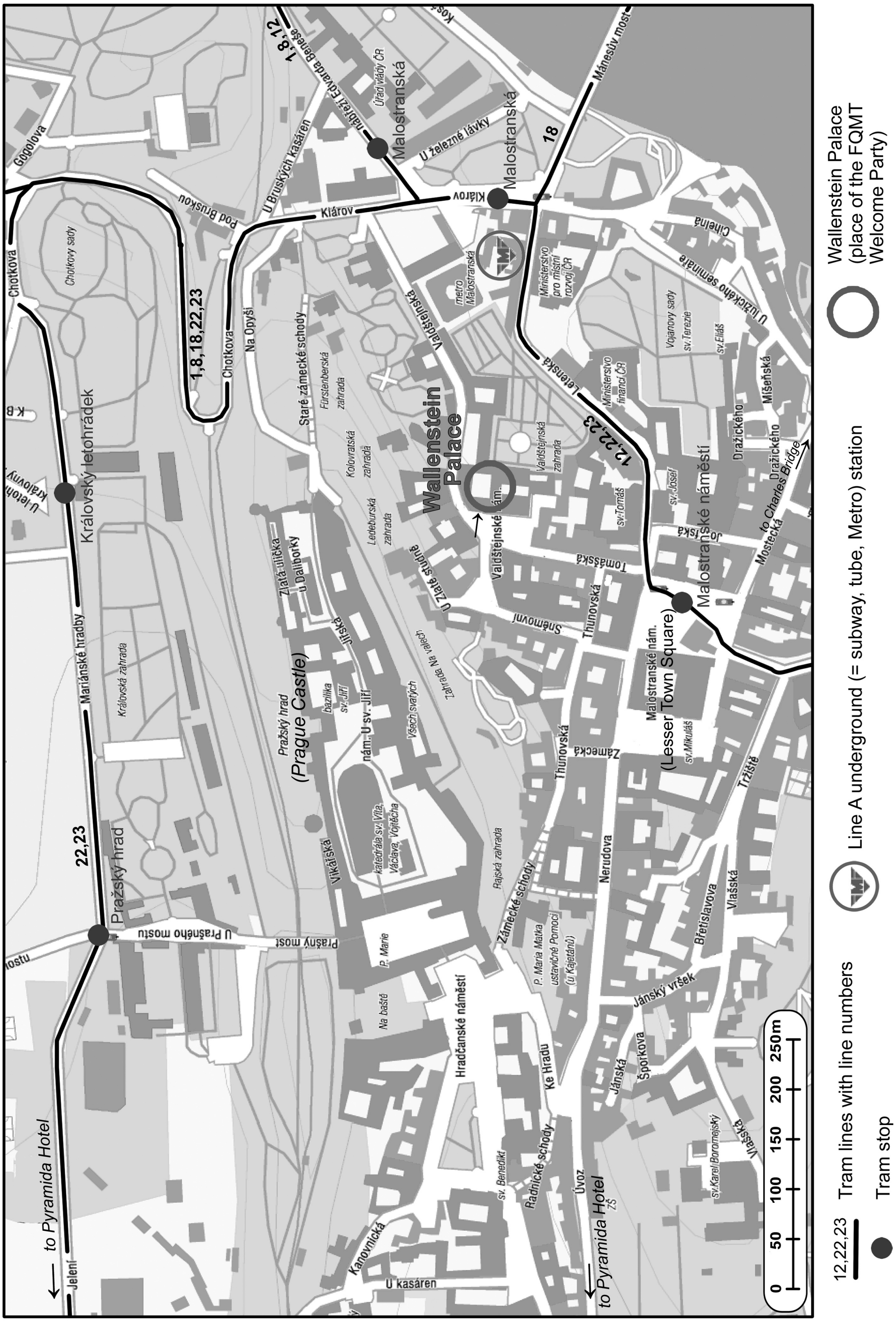
Prague center



Nearest neighborhood of the Pyramida Hotel



Wallenstein Palace neighborhood



St. Simon and Juda Church neighborhood